Table F.6 Potential Damage Value of Household Articles in the Drainage Zone B, C and F

(Unit ; million TK)

Drainage Zone	Flood/Inundation Frequency			
	1986		2000	
	1/1	1/10	1/1	1/10
B	0.6	4.4	1.3	9.2
C	0.2	3.7	0.4	7.7
F	0.5	4.0	1.0	8.4
Total	1.3	12.1	2.7	25.3

Table F.7 Potential Damage Value of Public Property

Items	Damage Value/Year (million TK)
1) Electricity Facilities	1.0
2) Telecommunication Facilities	17.7
3) Public Buildings	0
4) Road (average of the latest three years at 1986 prices)	26.8
5) Bridges	0
Total 1986	45.5
Total 2000	95.0

Table F.8 Labourer's Income Loss

(Unit : million TK)

Flood Area	Income Loss			
	Flood/Inundation Frequency			
	1/1		1/10	
	1986	2000	1986	2000
B	3.2	3.5	11.1	12.3
C	0.5	0.9	1.5	2.7
F	0.7	0.8	2.6	3.1
Total	4.4	5.2	15.2	18.1

Source; Flood/Inundation Damage Survey by the Study Team, 1987.

Table F.9 Road Traffic Demand in the Drainage Zones B, C, and F, 1986

	Traffic Volume	Vehicle-kms* (x 1000)	Passenger-kms* (x 1000)
Baby Taxi/ Motorcycle	59,792	179	215
Sedan	59,006	177	266
Bus/Truck	10,800	32	1,088
Total	-	388	1,568

Sources; Traffic Survey conducted by the Study Team.

* Trip length by each vehicle in the drainage zones B, C and F is assumed 3 km.

Table F.10 Estimated Economic Vehicle Operating Cost and Passenger Time Value

(TK/hour/head)

		Baby Taxi/ Motorcycle	Sedan	Bus/Truck
Vehicle Operation Cost	speed = 30 km/h	0.3*	2.8	6.5
	speed = 10 km/h	0.6*	5.5	13.4
Time Value	1) Vehicle	3.78	18.9	43.5
	2) Passenger	3.13	17	3.13

Source; "Feasibility Study on Meghna, Meghna-Gumti Bridge Construction Project" (March, 1985 ; JICA)

Note ; * Figures are estimated in comparison of the market price of vehicle with sedan.

Table F.11 Summary of Flood Damage Potential

(Unit : million TK)

	1986		2000	
	1/1	1/10	1/1	1/10
A. General Property				
(1) Houses	99.1	210.0	138.0	272.4
(2) Household articles	1.3	12.1	2.7	25.3
(3) Commercial building (depreciating assets and stocks)	-	-	-	-
Subtotal	100.4	222.1	140.7	297.7
B. Public Property				
(1) Electric facility	1.0	2.5	2.1	5.3
(2) Telecommunication facility	17.7	44.3	37.0	92.5
(3) Public facility	-	-	-	-
(4) Road	26.8	66.9	55.9	139.7
(5) Bridge	-	-	-	-
Subtotal	45.5	113.7	95.0	237.5
C. Agricultural Products	-	-	-	-
D. Income/Sales Loss Potential				
(1) Labour	4.4	5.2	15.2	18.1
(2) Shop	-	-	-	-
(3) Electricity sales	2.9	7.3	6.1	15.2
(4) Transport charges				
- Bus	17.7	36.9	44.2	92.3
- Rickshaw	1.7	3.5	4.2	8.8
Subtotal	26.7	52.9	69.7	134.4
E. Vehicle's Running Cost				
Operating cost	0.8	0.8	1.6	1.6
Time cost -Vehicles	5.4	5.4	10.9	10.9
-Passengers	8.6	8.6	17.5	17.5
Subtotal	14.8	14.8	30.0	30.0
Grand Total	187.4	403.5	335.4	699.6

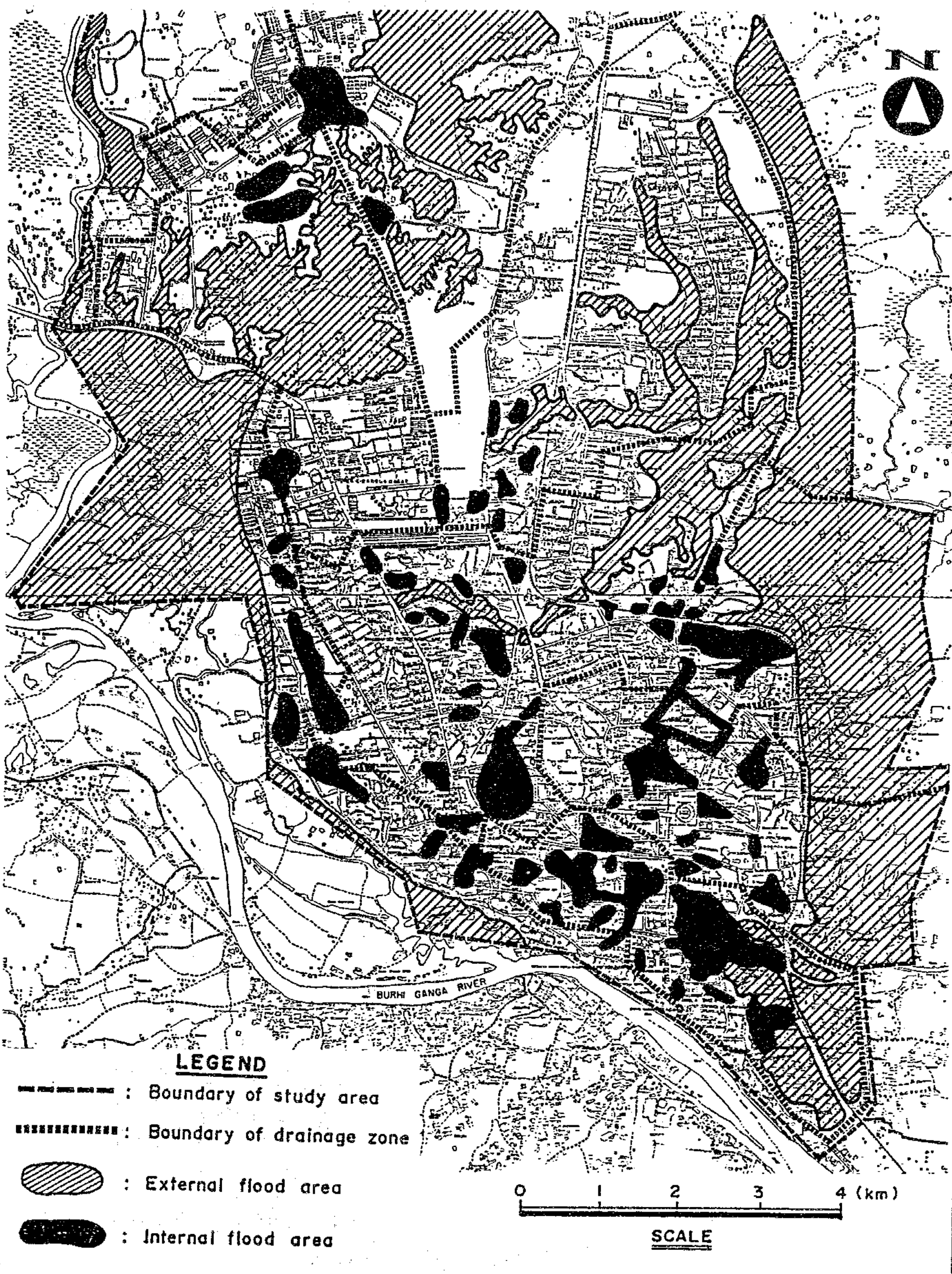

FIG. F.1 MAXIMUM FLOOD AREA IN PAST 10 YEARS

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

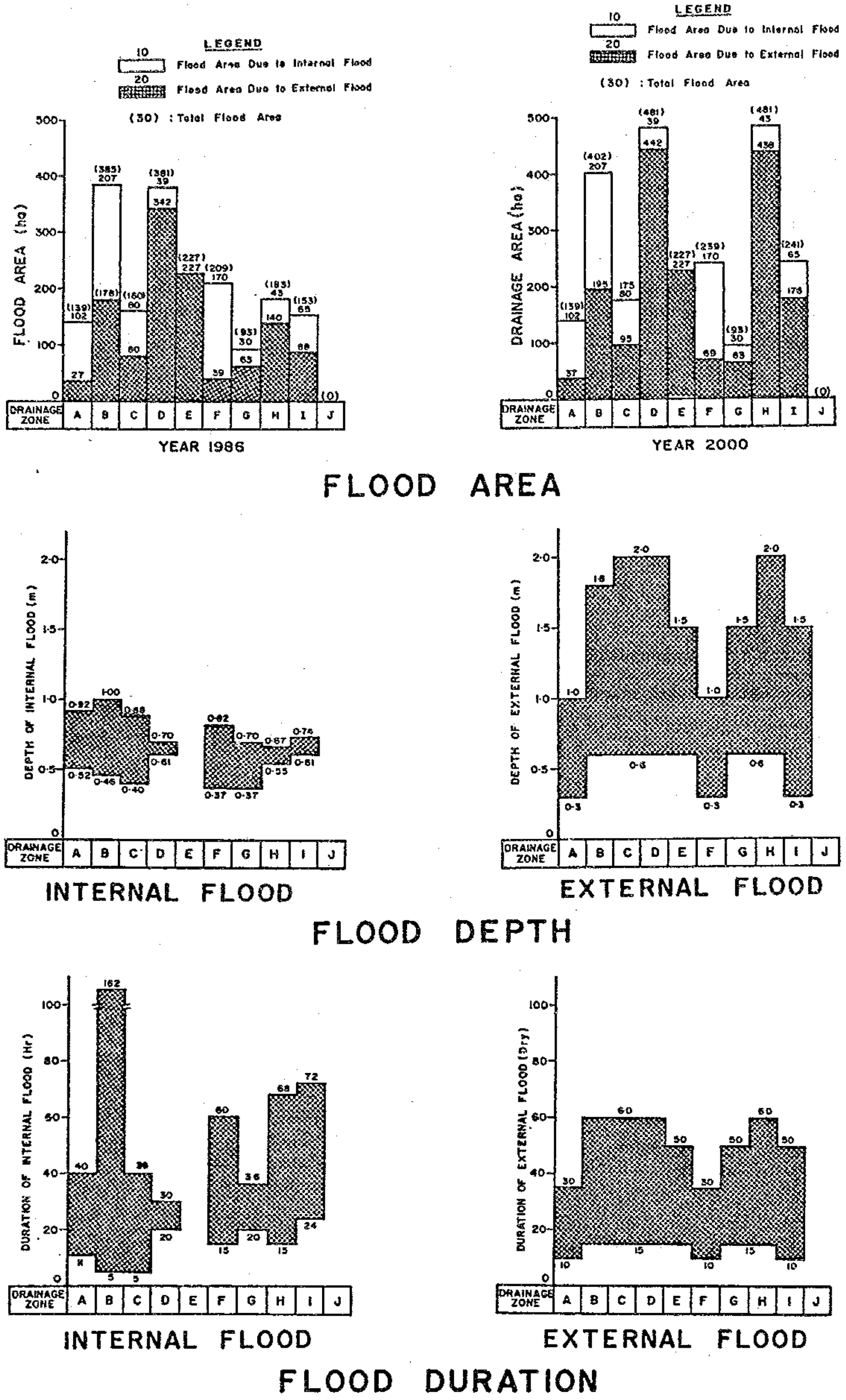

FIG. F.2	MAXIMUM FLOOD CONDITIONS IN PAST 10 YEARS

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

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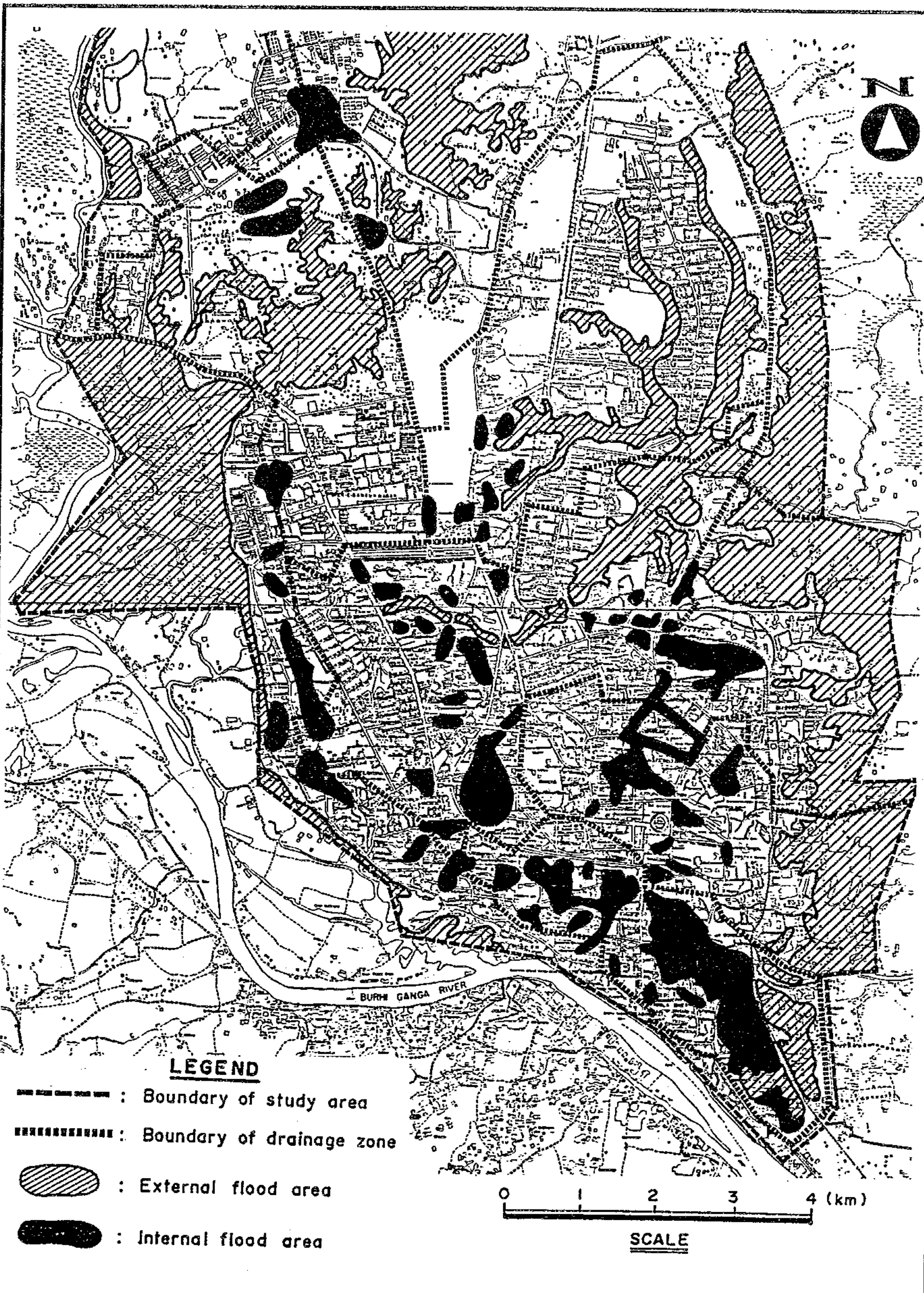

FIG. F.3	HABITUAL FLOOD AREA

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

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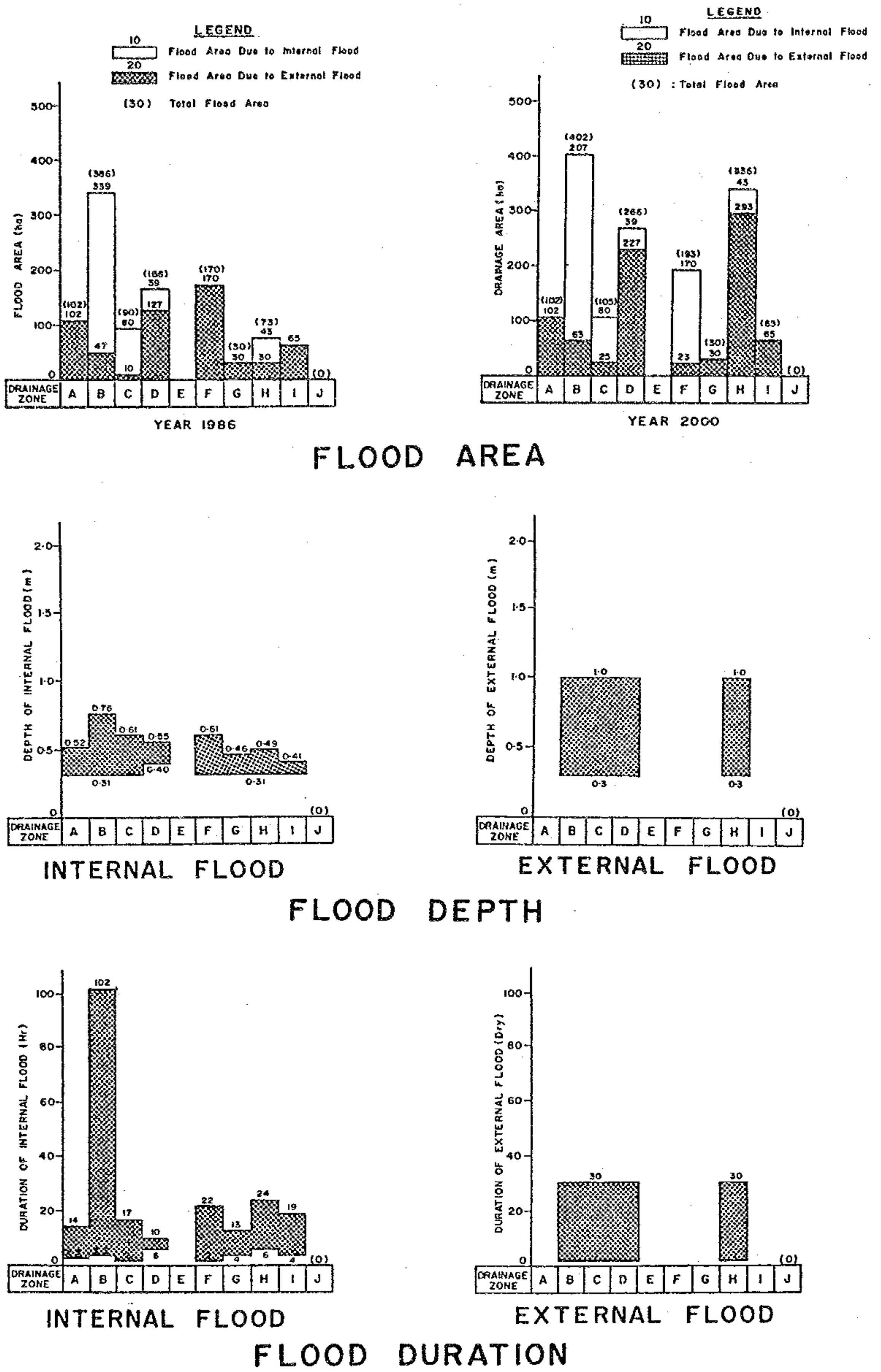

FIG. F.4 HABITUAL FLOOD CONDITIONS

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

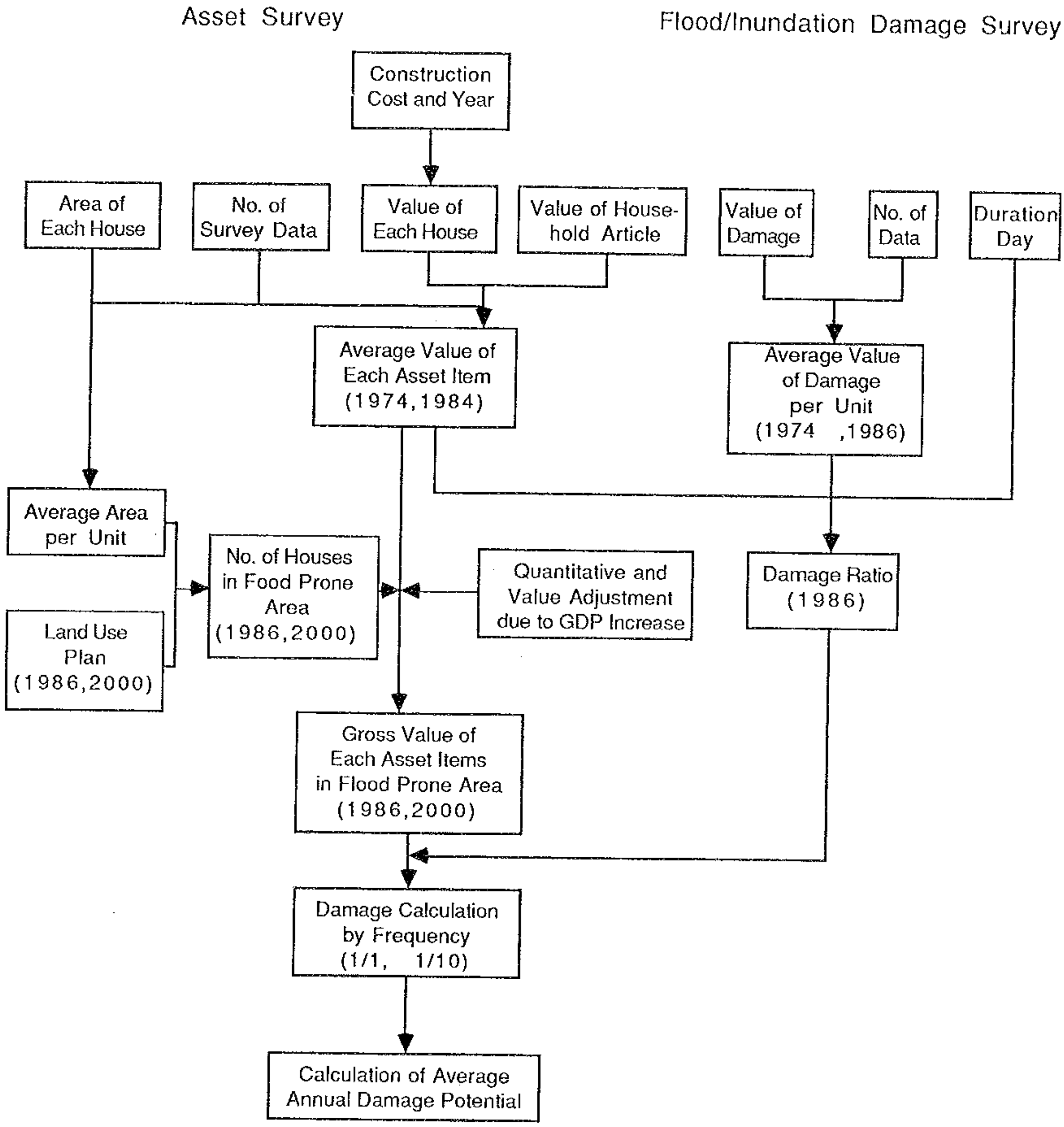

FIG. F.5 ESTIMATION PROCEDURE OF GENERAL PROPERTY DAMAGE POTENTIAL

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

SUPPORTING REPORT G

PREVIOUS DRAINAGE STUDIES AND PROJECTS

SUPPORTING REPORT G

PREVIOUS STUDIES AND PROJECTS

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SUPPORTING REPORT G
PREVIOUS STUDIES AND PROJECTS

1. History of Previous Studies and Projects

The first full-scale study on flood protection and internal drainage of Dhaka city was undertaken by DPHE in 1968 and a master plan was prepared. The master plan, covering an area of 75 km^2 included construction of embankment around the city, pump stations, and other internal drainage facilities, has a total estimated cost of 200 million Tk. The WAPDA was assigned to construct the embankment and pump stations and the DPHE was appointed to construct the internal drainage system. However, this plan did not receive final approval.

As a follow up to the above master plan, BWDB prepared a detailed plan covering an area of 144 km^2, having an estimated cost of 408.6 million Tk. DPHE also prepared a separate plan for the internal drainage system costing 130 million Tk and submitted it to the Government in 1976.

However, this large sum of money was not considered by the Government. Rather, it advised preparing a "Crash Programme for Removing Water Logging from Dhaka City". DPHE prepared a plan with an estimated cost of 66 million Tk in 1976 that was implemented up to June 1980.

In 1978, DPHE reviewed the 1968 master plan and prepared a plan of flood control and drainage works covering 144 km^2 of Dhaka city. The estimated cost was 2,880 million Tk of which 1,524 million Tk was for flood control and 1,356 million Tk was for internal drainage. However, the plan was not accepted.

In 1981, a study on "Dhaka Metropolitan Area Integrated Urban Development Project" was completed with assistance from ADB and UNDP. The study area covered 256 km^2. However, no detailed flood control and drainage plan was proposed in the study.

In 1980, following the "Crash Programme" mentioned above, another drainage plan, namely "Interim Scheme for Removing Water Logging within Dhaka Metropolis" was approved at 190 million Tk and it was completed in June 1983.

Moreover, in 1985, the "Revised Crash Programme for Construction of Storm Water Drainage in Water Logged Area of Dhaka Metropolis" was prepared by DPHE and is now ongoing.

2. Master Plan and Feasibility Study in 1968

(1) The Master Plan and Feasibility Study of Storm Drainage and Flood Control Project for Dhaka was prepared and funded in 1968 by the Government of East Pakistan with consulting services of associated consultant firms (one local and two USA).

(2) This study was intended to be the first step in a program to provide a solution to the perennial problem of flooding in Dhaka area covering 75 km^2. The report established and presented a master plan consisting of two basic concepts:

(a) Protect Dhaka from inundation when the Buriganga and other rivers are in flood stage by means of a dike which encircles the area.

(b) Provide an effective internal drainage system within the dike to convey storm water to locations where it may be discharged to natural drainage courses. Since the levels of the river waters are high during the monsoon season, the storm water would have to be discharged by means of pumping. Retention reservoirs are provided to substantially reduce pumping requirements.

(3) The proposed facilities including dike, pump station, box culvert, open channel, bridge, drain pipe, and reservoir are summarized in Table G.1 and illustrated in Fig. G.1.

(4) The project cost estimated are as follows (million Rupees):

Land and Right-of-way	Rs.	57.420
Construction Costs	Rs.	114.041
Engineering Costs (Design) 10%	Rs.	11.405
Engineering Costs - 15% (Supervision)	Rs.	17.105
Contingencies - 25%	Rs.	28.510
Interest During Construction	Rs.	19.891
TOTAL ESTIMATED CAPITAL COSTS	Rs.	248.372

(5) For scheduling of the plan, the objective area was separated into five (5) zones considering a systematic approach to the solution of the drainage problem with the economic and technical capabilities of the country. Fig. G.2 shows the suggested phases of construction on a priority basis.

TABLE G.1 FACILITIES PROPOSED IN THE MASTER PLAN

Facility	Description
(1) Dike	L = 41.4 km
(2) Pump Station	4 places, Q = 85 m^3/S
(3) Box Culvert	35 places, L = 718 m, (H = 1.5 - 2.7 m) x (W = 3.0 - 9.6 m)
(4) Open Channel	L = 4.3 km, W = 1.5 - 30.0 m
(5) Bridge	18 places, L = 897 m, W = 9 - 18 m
(6) Drain pipe	L = 20.4 km, P = 42" - 144"
(7) Reservior	A = 8.4 km^2 (a = 0.5 - 3.1 km^2)

3. Dhaka Metropolitan Area Integrated Urban Development Project

(1) The Dhaka Metropolitan Area Integrated Urban Development Project was prepared and funded jointly by the Government of Bangladesh (GOB), the Asian Devepolment Bank (ADB) and the United Nations Development Programme (UNDP). As the implementing agency, the Planning Commission was responsible for the organization of the Policy Steering Committee and the Technical Management Groups. Consulting services were provided by Shankland Cox Partnership, acting as leading consultants, in association with two (2) foreign and three (3) local consultants firms. The study was carried out between September, 1979 and March, 1981.

(2) The primary objectives of the study are as follows:

- To prepare a long term urban development strategy to guide and regulate the future growth of the Dhaka Metropolitan area and, in particular, Dhaka city.

- To set out appropriate policies designed to implement the long term objectives of the proposed Urban Development strategy and to facilitate the implementation of the priority project.

- To identify the priority project and to prepare prototype project proposals for low income group housing.

- To develop the skills and experience of local staff and provide advice for establishing an effective planning and development organization.

(3) The consultants set up the following development policies as a long term urban development strategy:

- To ensure that the city will be able to perform efficiently its essential role in national development.

- To achieve a balance between urban population and urban employment.

- To provide for the basic needs of the urban population and to secure a more equitable distribution of resources between income groups.

- To provide an urban framework capable of accommodating industrial and service requirements after the year 2000.

(4) In view of existing and future circumstances of the sectors, unban development strategy combined with two alternatives, Peripheral Growth, and Northern Expansions was proposed among three alternatives shown in Fig. G.3. Advantages of the proposed strategy could be achieved at a lower level of urban development expenditures with fewer implementation problems, and at lower risk than in the flood protection strategy.

Implementation schedule up to the year 2000 was divided into the following three stages:

1st stage (Short Term):	1980 - 1985
2nd stage (Medium Term):	1985 - 1990
3rd stage (Long Term):	1990 - 2000

Proposed projects in the integrated urban development plan consist of two project packages. One is a Site-specific Project at certain sectors; the other is a City-wide project at individual sectors. Category and location of proposed projects are shown in Fig. G.4.

(5) As mentioned above, the urban development strategy was proposed to formulate the plan expanded to northern areas, which are free from damage. Accordingly, in this project, implementation of non-structural measures for flood protection and storm water drainage works were mainly proposed. These are as follows:

- Comprehensive flood protection measures by large scale embankments for lowland areas would not be feasible.

- Small scale or partial embankments and existing road raising would be recommendable for low-lying developed areas connected with existing built-up areas.

- Reclamation and partial embankments would be also recommendable for lowland in new development areas.

- It would be proposed to develop operation and maintenance, and improvement and construction of partial embankments for the khals in existing urbanized areas.

(6) The consultants further proposed a Term of Reference for the detailed study of storm water drainage improvements in Dhaka city.

4. Ongoing Projects

"Revised Crash Programme for Construction of Storm Water Drainage in Water Logged Areas of Dhaka Metropolis" is ongoing by DPHE. Contents of the plan are described below:

(1) Objective and Target

(i) To reduce water logging problem of areas such as: Dhanmonde, Zhigatola, Lalmatia, Mohammadpur, Kallyanpur, Rayer Bazar, Sher-e-Bangla Nagar, Kathal Bagan, Elephant Road.

(ii) Diversion of existing outfall drains leading to Dhanmondi lake, to prevent it from further pollution.

(2) Implementation Period: 1984 - 1989

(3) Construction Works

The major works are construction of storm water drainage pipes.

Total length : 18.82 km
Pipe diameter: 0.3 - 2.6 m

Details of the construction works are as listed in Table G.2
The locations are as illustrated in Fig. G.5.

(4) Project Cost

Local currency	Foreign exchange	Total
77,375 x 10^3 Tk	-	77,375 x 10^3 Tk

TABLE G.2 CONSTRUCTION WORKS OF REVISED CRASH PROGRAMME

No.	Location	Pipe Dia (cm)	Pipe Length (m)	Remarks
(1)	Segunbagicha Khal	210	1	
(2)	Abdul Gani Road	60-75	350	
(3)	Inner Circular Road	75	210	
(4)	Gopibagh Khal	260	50	
(5)	Nakhalpara, Tejkunipara	75-90	225	
(6)	Banani	90	115	
(7)	Fulbaria	60	210	
(8)	Kathal Bagan	60	415	
(9)	Rayer Bazar	60	190	
(10)	Zhigatola	75	282	
(11)	Satmosjid Road	150-260	3,050	
(12)	Rayer Bazar	45-90	896	
(13)	Zhigatola	45	128	
(14)	Elephant Road	45-90	801	
(15)	Badar Road	45-60	457	
(16)	Asad Gate to Mohammadpur Bus Stand	90-120	1,067	
(17)	Mirpur Road	60-150	670	
(18)	Sher-e-Bangla Nagar	105-120	914	
(19)	Lalmatia	60-105	1,463	
(20)	Diversion from Dhanmondi Lake	45-75	3,928	
(21)	Mohammadpur Govt. School - Sarwardi Hospital	45-60	457	
(22)	Kallyanpur Area	30-60	1,431	
(23)	Other Works	-	1,510	
	Total		18,820 m	

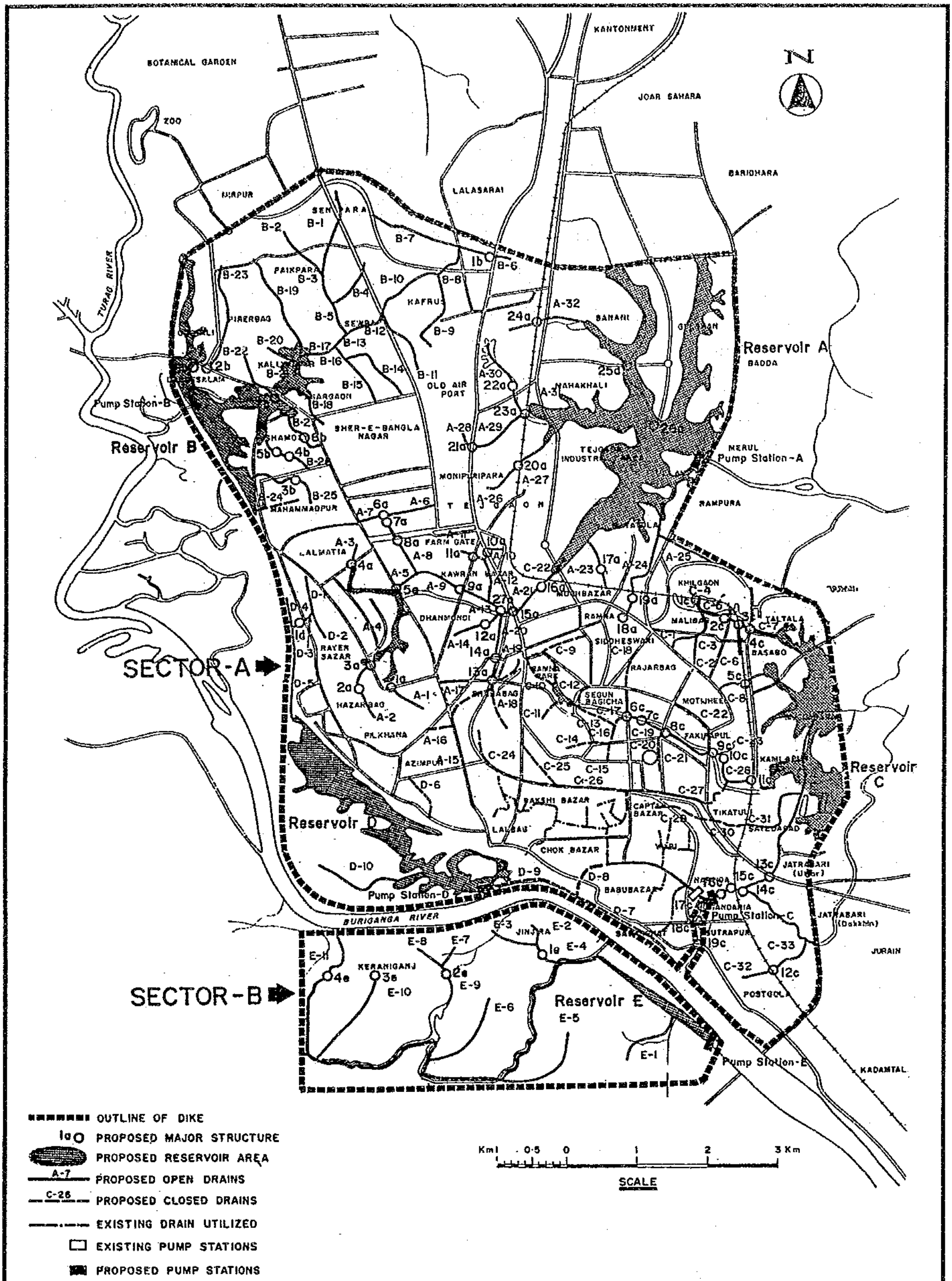

FIG. G.1 PROPOSED FACILITIES IN MASTER PLAN AND FEASIBILITY STUDY IN 1968

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

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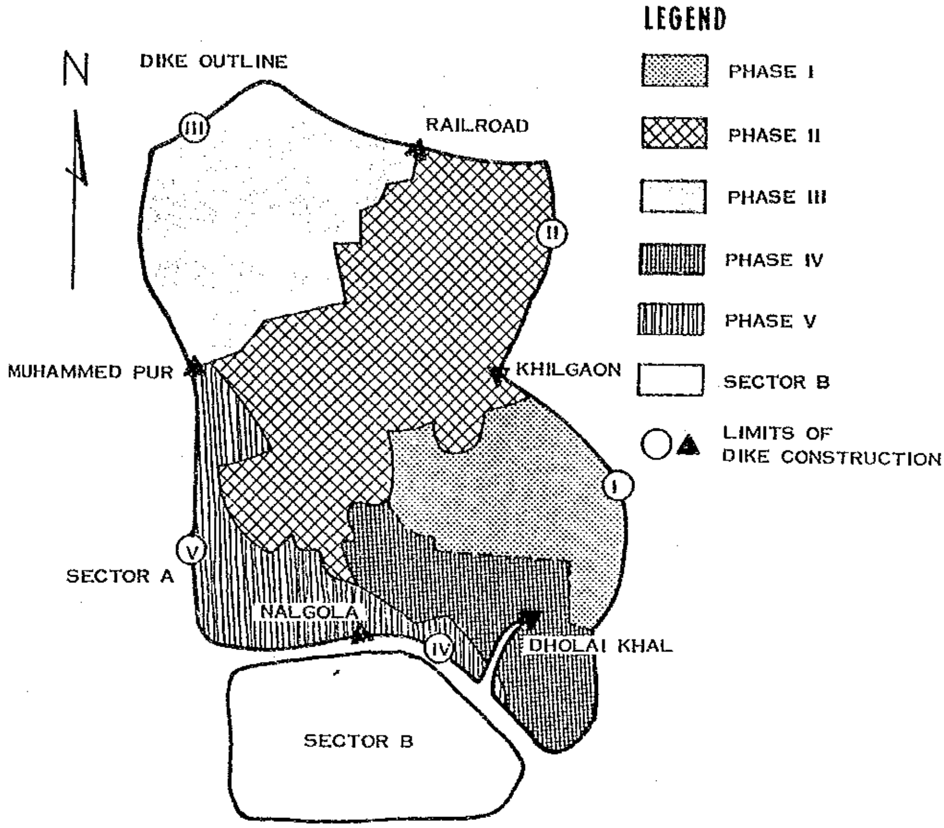
KEY TO CONSTRUCTION PHASES



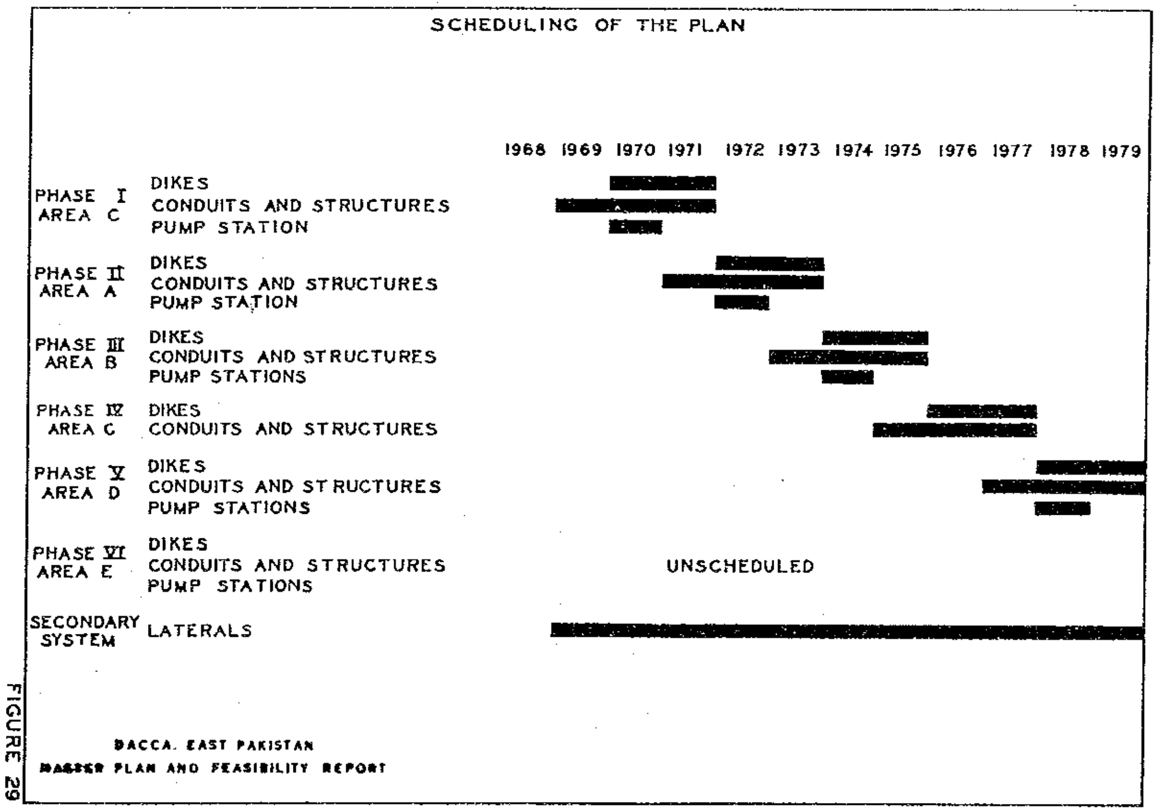
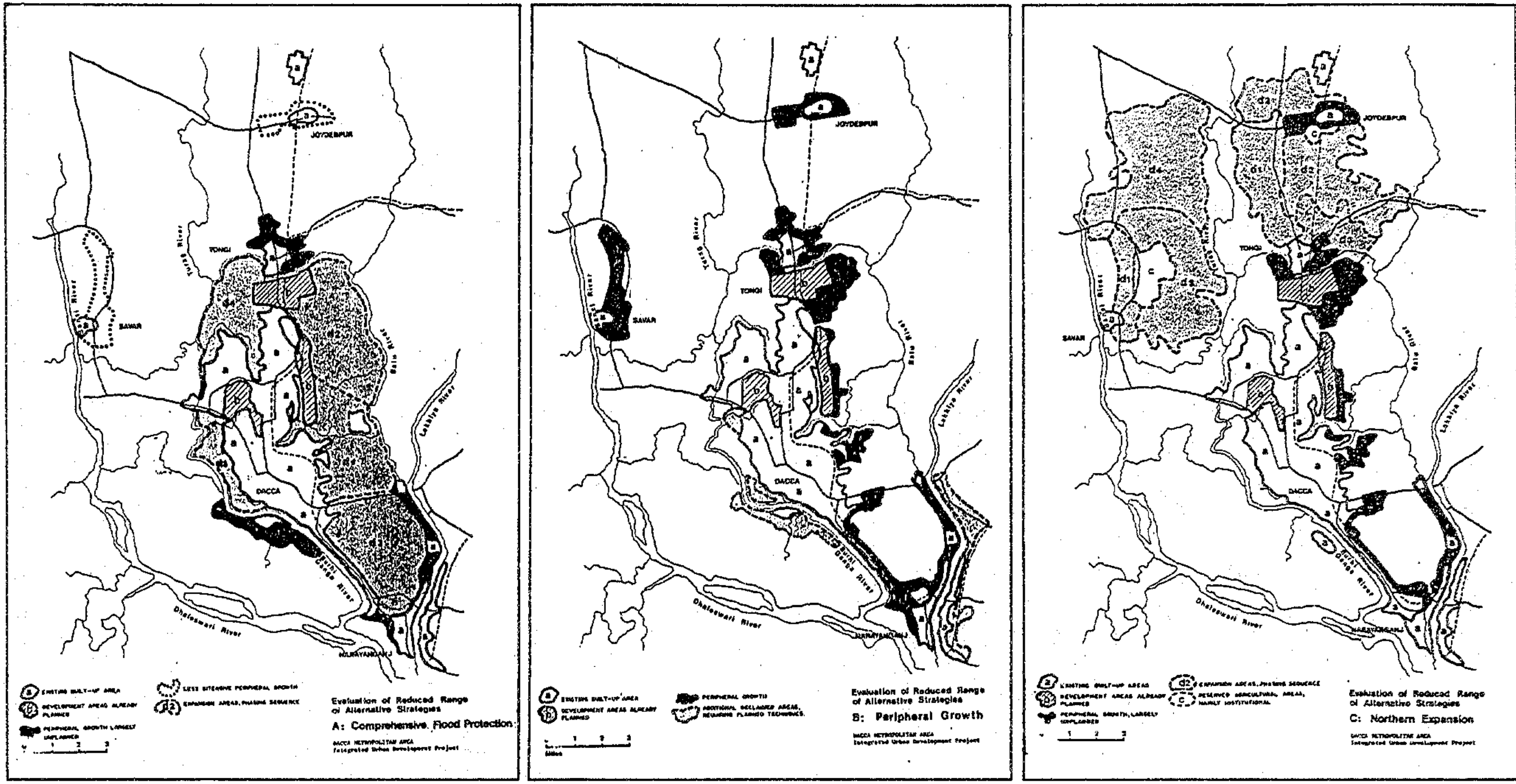


FIG. G.2 CONSTRUCTION PHASES IN MASTER PLAN AND FEASIBILITY STUDY IN 1968



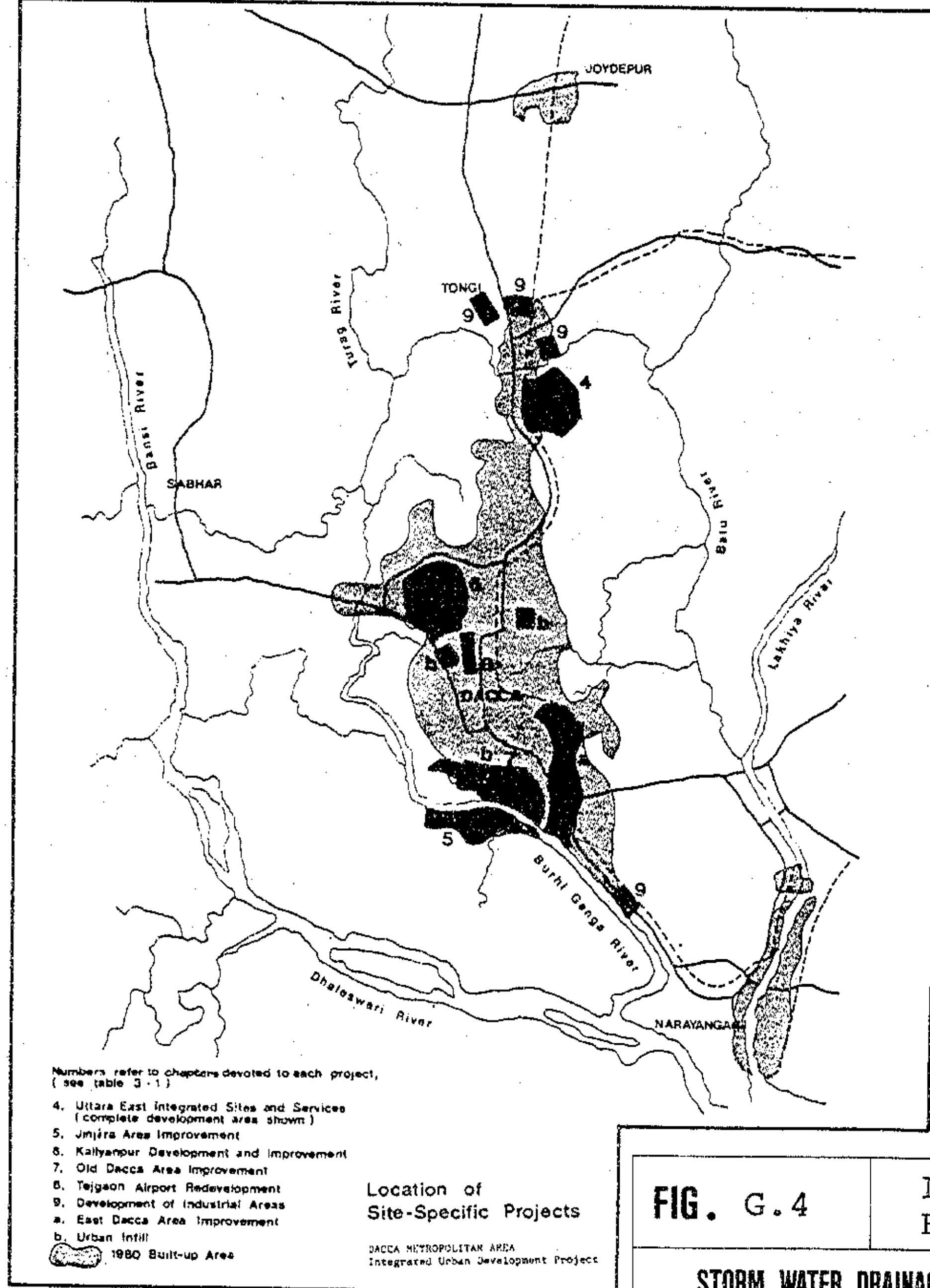
A : Comprehensive Flood Protection

B : Peripheral Growth

C : Northern Expansion

FIG. G.3 ALTERNATIVE STRATEGIES IN DMAIUD PROJECT

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



Project Listing by Categories

PROJECT TITLE	Site-Specific	City-Wide	Higher Priority	New Area Development	Improvement Of Existing Areas
Uttara East Sites and Services Housing Scheme	*		*	*	
Jinjira Area Improvement	*		*		*
Kallyanpur Development and Improvement	*			*	*
Old Dacca Area Improvement	*				*
Tejgaon Airport Redevelopment	*			*	*
Development of Industrial Areas	*		*	*	
Stormwater Drainage		*	*		
Solid Wastes Management		*	*		
Transportation Study		*	*		
Intensified Food Production in Peri-Urban Areas			*		
Aerial Photography and Mapping					
Institutional Support		*			
PROJECTS IDENTIFIED BUT NOT PRESENTED IN SEPARATE CHAPTERS :					
East Dacca Area Improvement	*				*
Urban Infill	*			*	*

FIG. G.4 LOCATION OF SITE-SPECIFIC PROJECT PROPOSED BY DMAIUD PROJECT

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

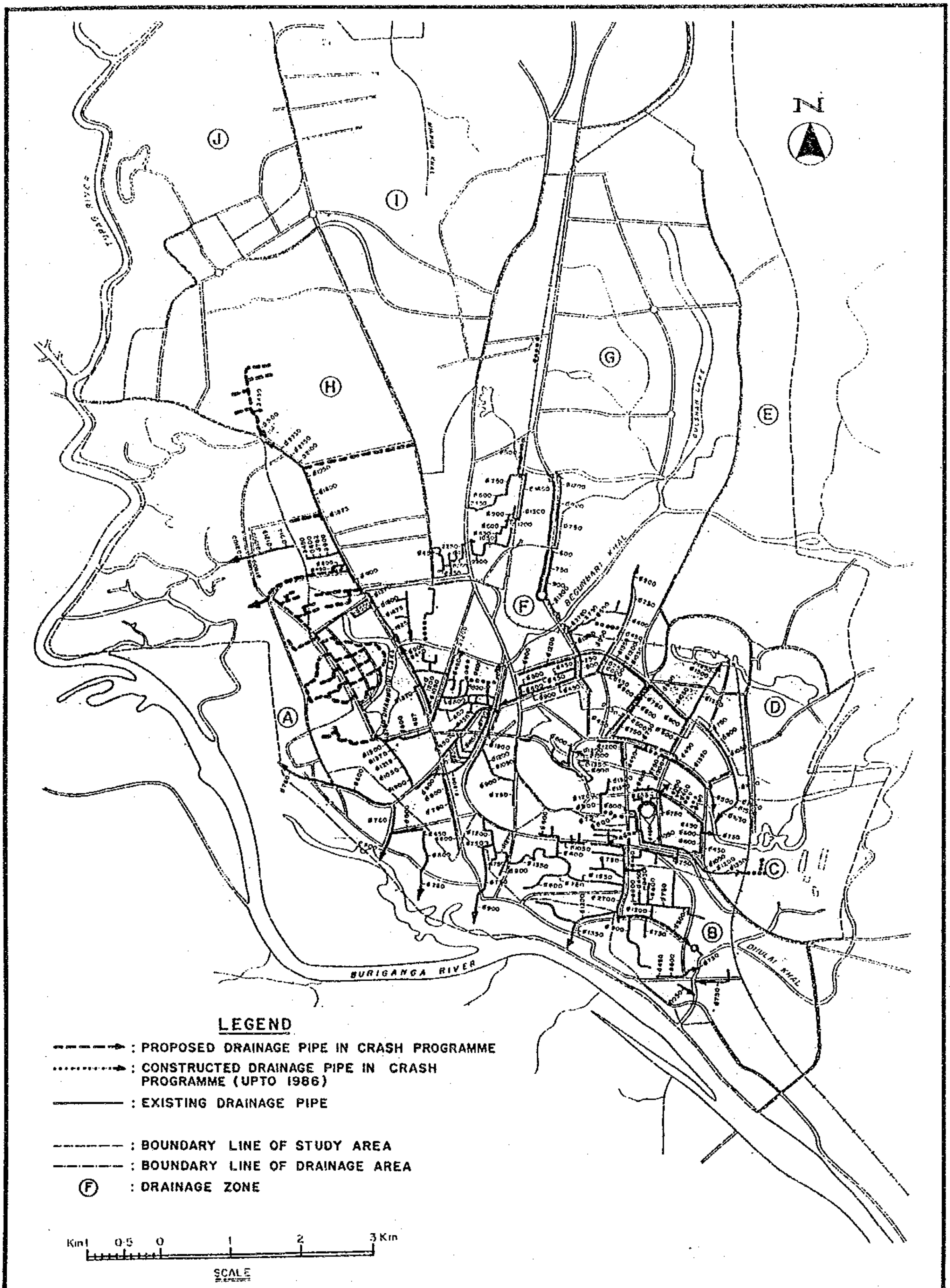


FIG. G.5 REVISED CRASH PROGRAMME BY DPHE (1984-1989)

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

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SUPPORTING REPORT H

PREPARATION OF PHASED PROGRAM

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SUPPORTING REPORT H

PREPARATION OF PHASED PROGRAM

1. Planning Policy and Design Criteria

1.1 Target Year: Year 2000

Both the structural and non-structural plans are prepared to meet the population and land use distribution in the year 2000.

1.2 Design Flood Water Level

The flood water level with a 30-year frequency is proposed as the design level based on the following facts and considerations. Two (2) design flood water levels are applied for the Study Area, considering the hydraulic gradient of the surrounding rivers:

- 6.60 m G.T.S. for the southern part including the Old Dhaka, Central Dhaka, and Gulshan-Banani areas.

- 7.30 m G.T.S. for the northern part including the Mirpur, Kallyanpur, Cantonment and Tongi areas.

(1) The maximum flood water level in the past (1945 - 1986) was 6.59 m G.T.S. at Millbarrak, having an approximate probability of 30 years.

(2) The design probability for the flood protection plan shall be balanced with that for the internal drainage improvement plan in order to attain an optimum development of flood protection and drainage. The expected design probability for the latter is 5 years. (Refer to the following section).

(3) Large-scale urban developments are underway in the Gulshan, Mirpur, Cantonment and Tongi areas along such trunk roads as DIT, Mirpur-Cantonment and New Airport Roads. The lands are filled up in conformity with the elevations of the trunk roads. The road elevations are 6.5 to 7.0 m G.T.S. in DIT Road, above 7.0 to 7.5 m G.T.S. in Mirpur-Cantonment Road and above 7.0 to 7.5 m G.T.S. in New Airport Road. The design flood water level shall be decided in due consideration of these urban developments. Otherwise, significant confusion will take place in planning of the urban development causing a delay in the development progress.

1.3 Design Rainfall

Drainage pipes and khal improvements are designed based on an estimated probability rainfall intensity. Five-year probability is applied.

The rainfall intensity with a 5-year frequency is obtained for varying durations from the following formula:

$i = 9005/(t+50)$: for 5-year frequency

where, i = rainfall intensity (mm/hr)

t = duration (min)

The pump station is designed to meet the rainfall depth with a 5-year frequency, conforming with the drainage pipe and khal improvement in design frequency. The design rainfall depth and its hourly distribution are as illustrated in Fig. H.1.

1.4 Runoff Coefficient

The following table presents runoff coefficients generally applied for planning of storm water drainage in cities of advanced countries.

Land Use	Runoff Coefficient
Commercial Area	0.7 - 0.9
Industrial Area	0.5 - 0.9
High Class Residential Area	0.3 - 0.5
Middle & Low Class Residential Area	0.5 - 0.7
Green Zone and Others	0.1 - 0.4

Source : Proposal by American Society of Civil Engineers

The runoff coefficients of the Study Area are estimated in due consideration of the following situations:

(1) There are many depression areas in the Study Area where storm water is retarded.

(2) Since priority must be given to the improvement of the trunk drains, the branches, laterals, and collectors will not be able to attain the proper level before the year 2000. As a result, small amounts of standing water will still remain in various places.

The proposed runoff coefficients are presented below:

Land Use	Runoff Coefficient
Commercial Area	0.65
Industrial Area	0.55
High Class Residential Area	0.3
Middle & Low Class Residential Area	0.5
Green Zone and Others	0.2

1.5 Scope of Structural Measures to be Proposed

The structural measures to be proposed are limited to major works required to meet a midterm range necessity of flood protection and internal drainage improvement with the limited financial resources.

The structural measures to be included are:

(1) Flood protection: all the required works

(2) Internal drainage improvement:

- All of the required pump drainage and khal improvements
- Installation of trunk drainage pipe

Lateral drains and branch drainage pipes are excluded from the phased program because:

- The existing flood conditions will be mostly solved by the above-mentioned major works.

- Beneficial effects of lateral drains and branch drainage pipes will be expected only after completion of the connected major drainage works.

Lateral drains and branch drainage pipes are to be laid after completion of this project as and when required.

2. Division of Drainage Zone

The drainage zones proposed in Paragraph 3.1 are further divided into 37 sub-divided drainage zones, taking into account topography, flooding conditions, land use, existing drainage systems and requirements of flood protection and drainage improvement.

The sub-divided zones are as illustrated in Fig. H.2. The areas of the sub-divided zones are presented in Table H.1.

3. Flood Protection Plan

3.1 Flood protection Area

A flood protection plan is prepared for all the low-lying built-up areas lower than the design flood water level. The protection area covers not only the existing developed areas but also the future development areas.

With regard to the future land development, it is assumed that:

(1) Developments in the East Gulshan, Cantonment, Tongi, and Buriganga River Bank areas will be made by filling up the grounds above the design flood water level. These development areas will require no flood protection works.

(2) Developments in the other zones will be sprawling ones and made by reclaiming the lands up to the elevation of the existing built-up areas in the neighbourhood. These zones include some low-lying areas lower than the design flood water level for which flood protection works are needed.

Based on the above policies and assumptions, the following areas are identified as flood protection area (See Fig. H.2):

(1) Gandaria and Old Dhaka areas (B_1 and B_3 areas)
(2) Segunbagicha and Bashabo zone (C_1, C_2, C_3, D_1, D_2, D_3, D_4 and D_5 areas)
(3) Kallyanpur area (H_1, H_2 and H_3 areas)
(4) Katchukhet area (I_1 area)

3.2 Proposed Flood Protection Works and Beneficial Areas

(1) Gandaria and Old Dhaka Areas

Gandaria area is protected by providing the existing Dhaka-Narayanganj Diversion Road, with control gates. One (1) control gate to prevent flood water intrusion through the existing khal is required, which is concurrently part of the pump station of internal drainage. The benefited area is 1.78 km^2. The crown elevation of the existing road and design flood water level are about 6.5 m G.T.S. and 6.60 m G.T.S. respectively.

(2) Segunbagicha and Bashabo Zones

The 9.4 km long dikes with 3 control gates are constructed to protect the area. Of the gates, one (1) gate is included in the pump station for internal drainage.

The benefited area is 14.0 km^2. The crown elevation of the dikes and design flood water level are 7.60 m G.T.S. and 6.60 m G.T.S. respectively.

(3) Kallyanpur Area

The existing Dhaka-Aricha Road is raised by about 1.5 m extending 3 km to protect the areas. Three (3) control gates are provided with the road, one (1) of which is included in the pump station for internal drainage.

The benefited area is 1.40 km^2. The crown elevation of the raised road and design flood water level are 8.30 m G.T.S. and 7.30 m G.T.S. respectively.

(4) Kachukhet Area

The existing Mirpur-Cantonment Road is raised by about 1.5 m stretching over 2 km to protect the areas covering Kachukhet, Munipur, Senpara, and Kafrul. One (1) control gate is installed in the road, which concurrently functions as a part of the pump station for internal drainage.

The benefited area is 0.88 km^2. The crown elevation of the raised road and design flood water level are 8.30 m G.T.S. and 7.30 m G.T.S. respectively.

4. Internal Drainage Plan

4.1 Design Discharge of Drainage Pipe and Khal Improvement

Peak runoffs corresponding to the 5-year probability rainfall intensity were calculated for the sub-divided drainage areas with a variety of areas, land usages, and runoff distances. Calculations were made by the Rational Formula presented below:

$$Q = 1/3.6\ f.A.R$$

where, Q: Peak run-off (m^3/S)
f: run-off coefficient
A: Drainage area (km^2)
R: Rainfall intensity during runoff time (mm/hr)

For simplification of planning, peak runoff-drainage area curves with a 5-year frequency were devised by averaging the above calculation results as illustrated in Fig. H.1.

Specific runoff - drainage area curves are also shown in the same figure.

4.2 Pump Drainage Area

The low-lying areas enclosed by the proposed dikes, or existing roads require pump stations to drain the storm waters from these areas and from the upstream areas.

These areas are the lowlands of the Old Dhaka area, Gandaria area, Segunbagicha Khal zone, Bashabo zone, Kallyanpur area, and Katchukhet area.

The covered catchment areas are:

Old Dhaka area (B_2: 3.20 km^2)*
Gandaria area (B_3: 2.72 km^2)
Segunbagicha Khal zone (C_1, C_2, C_3: 9.04 km^2)
Bashabo zone (D_1, D_2, D_3, D_4, D_5 : 8.32 km^2)
Kallyanpur area (H_1, H_2, H_3, H_4 : 12.78 km^2)
Katchukhet area (I_1 : 3.94 km^2)
Total: 40.00 km^2

*: The upstream area (B_1 = 1.03 km^2) of Old Dhaka is diverted to the Buriganga River and the downstream area (B_2 = 3.20 km^2) is covered by pump drainage.

4.3 Required Pump Discharge Capacity

Required pump discharge capacity varies inversely proportional to the storage capacity of the discharge regulating pond and pump discharge period.

Specific pump discharge capacities and specific storage capacities of regulating ponds required to meet the design rainfall under the condition of one or two day discharge periods are estimated by Fig. H.3.

The obtained specific capacities and total capacities of the Study Area are as shown below:

Required surface areas of the regulating ponds are also estimated below, assuming that the average effective depth of the regulating ponds is 2 m.

	Specific Capacity		Total Capacity of the Study Area	
	one day	two days	one day	two days
Required Discharge Capacity	1.78 $m^3/S/Km^2$,	1.14$m^3/S/km^2$	71 m^3/S,	46 m^3/S
Required Storage Capacity	123x10^3 m^3/km^2,	132x10^3 m^3/km^2	5,000x$10^3 m^3$,	5,300x$10^3 m^3$
	6.2 ha/km^2,	6.6 ha/km^2	248 ha	264 ha

As can be seen from the above table, the operation of a two day discharge period provides a more economical solution when adequate storage capacity can be accommodated. Therefore, in this study, required pump discharge capacity and storage capacity of regulating ponds are estimated under the operational a condition of a two day discharge period.

4.4 Integration of Pump Drainage Area

The pump drainage areas of Old Dhaka area (B_1), Gandaria area (B_3), Segunbagicha zone (C_1, C_2, C_3), and Bashabo zone (D_1, D_2, D_3, D_4, D_5) can be hydraulically integrated through the Dholai Khal, Segunbagicha Khal and Gerani Khal.

Four (4) alternatives are compared as follows:

Alternative I

Composed of the following four (4) sub-projects:

(1) Old Dhaka area (B_2: 3.20 km^2)
(2) Gandaria area (B_3: 2.72 km^2)
(3) Segunbagicha zone (C_1, C_2, C_3: 9.04 km^2)
(4) Bashabo zone (D_1, D_2, D_3, D_4, D_5: 8.32 km^2)

Included pump construction works:

(1) Rehabilitation of the existing Narinda P.S. (9.6 m^3/S)

(2) Installation of four (4) pump stations with a total capacity of 42.9 m^3/S

Additional Narinda P.S. (20 m^3/S)[1)]
Dholai Kahl P.S. (3.1 m^3/S)
Segunbagicha P.S. (10.3 m^3/S)
Bashabo P.S. (9.5 m^3/S)

Required regulating pond: 133 ha.

Note: 1) Pump discharge capacity to meet the peak runoff is required due to the lack of regulating pond.

Alternative II

Composed sub-projects are:

(1) Old Dhaka area + Gandaria area (B_2, B_4 : 5.92 m^3/S)

(2) Segunbagicha zone (C_1, C_2, C_3 : 9,04 km^2)

(3) Bashabo zone (D_1, D_2, D_3, D_4, D_5 : 8.32 km^2)

Included pump construction works are:

(1) Rehabilitation of the existing Narinda P.S. (9.6 m^3/S)

(2) Installation of two (2) pump stations with a total capacity of 19.8 m^3/S.

Segunbagicha P.S. (10.3 m^3/S)
Bashabo P.S. (9.5 m^3/S)

Required regulating pond: 154 ha.

Alternative III

Composed sub-projects are :

(1) Old Dhaka area + Gandaria area + Segunbagicha zone (B_2, B_4, C_1, C_2, C_3 : 14.96 km^2)

(b) Bashabo zone (D_1, D_2, D_3, D_4, D_5 : 8.32 km^2)

Included pump construction works are:

(1) Rehabilitation of the existing Narinda P.S. (9.6 m^3/S)

(2) Installation of two (2) pump stations with a total capacity of 17.0 m^3/S.

Dholai khal P.S. (7.5 m^3/S)
Bashabo P.S. (9.5 m^3/S)

Required regulating pond: 154 ha.

Alternative IV

All the areas of 23.28 km^3 are integrated.

Included pump construction works are:

(1) Rehabilitation of the existing Narinda P.S. (9.6 m^3/S)

(2) Installation of one (1) pump station with a capacity of 17.0 m^3/S (Dholai Khal P.S.)

Required regulating pond: 154 ha.

Comparison of Alternatives

	Alt. I	Alt. II	Alt. III	Alt. IV
Construction Cost	Large –	–	–	Small
O & M Cost	Large –	–	=	Small
Stage Construction	Easy	Easy	Moderate	Difficult
Water Conveyance Distance	Short	Short	Medium	Long
Security of Regulating Pond	Diffi-cult	Relatively Difficult	Easy	Eas

From the above comparisons, Altenative III is proposed.

In Kallyanpur drainage zone, the H_1 and H_2 areas are small and hydraulically independent from the H_3 and H_4 areas.

It would not be efficient to provide each of these areas with pump stations. H_1 and H_2 areas are incorporated into H_3 and H_4 areas through the proposed diversion canals to attain optimum pump drainage.

On the other hand, the Katchukhet area is drained independently to an adverse direction although it adjoins the Kallyanpur area, because integration of the two areas requires a long distance diversion work for flood water.

5. Proposed Flood Protection and Drainage Plan

5.1 Structural Plan

The proposed structural plan includes the following major flood protection and internal drainage improvement works:

(1) Construction of dikes: The dikes, with a total length of 9.4 km, are constructed to protect Segunbagicha Khal Zone and Bashabo Zone from external floods. The average dike height is 6 m.

(2) Raising of roads: The existing roads (Dhaka-Aricha Road and Mirpur-Cantonment) are raised and extended 5 km as protection against external floods of the Kallyanpur and Katchukhet areas.

(3) Installation of control gates: 8 water control gates are installed at the crossing points of the existing khals with proposed dikes and existing roads, and at the proposed pump station sites.

(4) Installation of drainage pipes: The additional trunk drainage pipes, with diameters ranging 1.5 to 3.7 m, are installed on the 14 routes to drain a total catchment area of 12.45 km^2. The total length is 18.0 km.

(5) Improvement of khals: The existing khals are widened or dredged in 25 stretches to drain a total catchment area of 85 km^2. The total improvement length reaches 39.7 km. The major works included are: dredging of $491x10^3$ m^3, reconstruction of box culverts or bridges in 69 places, construction of 1.4 km long retaining walls and brick protection 3.3 km long.

(6) Installation of pump stations: four (4) pump stations with a total discharge capacity of 36.1 m^3/S are installed in addition to the rehabilitation of the existing Narinda pump station (9.6 m^3/S). The pump stations cover a total drainage area of 40.00 km^2.

The locations of the proposed facilities are as illustrated in Fig. H.4

The proposed facilities are summarized by drainage zones as shown in Table H.2.

The details are shown in Table H.3 for drainage pipe, Table H.4 for khal improvement, and Table H.5 for pump station.

A total of 109 ha of land must be acquired in order to construct the above mentioned facilities. The construction of the dikes requires the largest land aquisition of all the works. The acquisition area includes embankment body area, the borrow pit area that will functions as a drainage canal after completion of construction work and some reserve area.

The land acquisiton areas by drainage zone and work item are shown in Table H.6.

5.2 Non-Structural Plan

(1) Swampy areas totalling 264 ha shall be reserved for the proposed pump regulating ponds. Required reserve areas of the respective pump drainage zones are as shown in Table H.5.

(2) Filling-up in the existing khal shall be under strict control in order not to block flood flows and cause adverse effects of backwater on upstream areas.

(3) Future land development in the low-lying fringe areas other than the proposed flood protection areas shall be performed by filling up the land higher than the proposed design flood levels.

- For the southern part of the Study Area, the filling-up elevation shall be higher than 6.60 m G.T.S. + allowance.

- For the northern part of the Study Area, the elevation shall be higher than 7.30 m G.T.S. + allowance.

5.3 Estimated Project Cost

The total cost of the proposed flood protection and drainage plan is roughly estimated to be 3,433.4 million TK at 1986 price. The estimated costs are broken down by drainage zone and work item as shown in Table H.7.

6. Prioritization of Drainage Zone

Priority sequences of the drainage zones are decided through comparison of the following factors:

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

The factors of beneficial population, and required project cost, and land acquisition area can be compared by the common indicators showing efficiency of financial and land resources expenditures; per capita project cost and land acquisition area.

Comparisons of per capita project cost and land acquisition area among the drainage zones are as shown in Table H.8.

From the above table, per capita project cost and land acquisition area, regarding flooding in 1986 and the maximum flooding in 2000, are taken up as priority comparison indicators to reflect the existing immediate and future potential requirements of the projects.

A comprehensive comparison viewing all the factors listed above is shown in Table H.9.

From the above table, the priority sequences of the proposed drainage zones are decided as below:

First Priority Zones : B, C, F
Second Priority Zones : A, G, H
Third Priority Zones : D, E, I, J

7. Proposed Phased Program

A program consisting of three (3) phases is tentatively proposed in conformity with the priority sequences decided in 6. above. It is as shown in Table H.10 and Fig. H.5.

Table H.1 Area of Sub-divided Drainage Zone

(A)	DURIGANGA RIVER BANK ZONE		
		A1	3.78
		A2	0.20
		A3	0.78
		A4	0.50
		A5	0.18
		A6	7.41
		SUB-TOTAL	12.85 Km²
(B)	DHOLAI KHAL ZONE		
		B1	1.03
		B2	3.20
		B3	0.81
		B4	2.72
		SUB-TOTAL	7.76 Km²
(C)	SEGUNBAGICHA KHAL ZONE		
		C1	4.95
		C2	1.13
		C3	2.96
		SUB-TOTAL	9.04 Km²
(D)	BASHABO ZONE		
		D1	0.18
		D2	1.76
		D3	1.25
		D4	1.68
		D5	3.45
		SUB-TOTAL	8.32 Km²
(E)	NORTH-EAST EDGE ZONE		
		E1	5.01
		E2	8.92
		SUB-TOTAL	13.93 Km²
(F)	BEGUNBARI KHAL ZONE		
		F1	3.36
		F2	3.41
		F3	2.73
		F4	3.77
		F5	2.75
		SUB-TOTAL	16.02 Km²
(G)	GULSHAN-BANI ZONE		
		G1	4.91
		G2	7.47
		G3	5.26
		SUB-TOTAL	17.64 Km²
(H)	KALLYANPUR ZONE		
		H1	0.60
		H2	0.90
		H3	7.71
		H4	3.57
		SUB-TOTAL	12.78 Km²
(I)	NORTH ZONE		
		I1	3.94
		I2	0.53
		I3	0.85
		I4	26.10
		SUB-TOTAL	31.42 Km²
(J)	TURAG RIVER BANK ZONE		
		J1	0.90
		J2	6.79
		SUB-TOTAL	7.69 Km²
	TOTAL DRAINAGE AREA	=	137.45 Km²

Table H.2 Proposed Facilities

DRAINAGE ZONE	AREA	FLOOD PROTECTION			INTERNAL DRAINAGE			REMARKS
		Protection Dike	Control Gate	Pump Station	Regulating Pond	Khal Improvement	Drainage Pipe	
	km2	km	places	m3/s	ha	km	km	
A	12.85	-	-	-	-	0.3	3.8	
B	7.76	-	1	9.6**	39.1	4.2	4.3	
C	9.04	2.4	1	7.5	59.7	5.1	4.8	
D	8.32	7.0	2	9.5	54.9	4.6	1.7	
E	13.93	-	-	-	-	-	-	
F	16.02	-	-	-	-	3.8	3.4	
G	17.64	-	-	-	-	2.9	-	
H	12.78	3.0*	3	14.6	84.3	11.9	-	
I	31.42	2.0*	1	4.5	26.0	6.9	-	
J	7.69	-	-	-	-	-	-	
TOTAL	137.5	14.4	8	45.7	264.0	39.7	18.0	

Note : * Raising Existing Roads
** Utilizing Existing NARINDA Pump Station

TABLE H.3 Proposed Drainage Pipes

ZONE	PIPE No.	DRAINAGE AREA km2	RUN-OFF m3/s	HYDRAULIC GRADIENT	DRAIN LENGTH km	DRAIN SIZE (Dia.) m	REMARKS
A	S1	0.69	9.40	1/2,000	1.00	3.1 (p)	
	S2	0.20	3.70	1/1,000	0.60	1.9(p)	
	S3	0.50	7.40	1/1,000	1.40	2.5(p)	
	S4	0.18	3.40	1/2,000	0.80	2.1(p)	
	Subtotal	1.57	-	-	3.80	-	
B	S5-1	2.65	26.00	1/1,000	2.30	3.1x3.1(b)	Additional
	S5-2	0.36	5.80	1/1,000	0.50	2.2(p)	
	S6	1.03	12.50	1/1,000	1.48	2.2x2.86(b)	
	Subtotal	4.04	-	-	4.28	-	
C	S7	1.43	16.20	1/1,000	2.50	2.6x3.0(b)	Additional
	S8	0.23	4.10	1/1,000	0.54	1.5(p)	Additional
	S9	0.58	8.30	1/1,000	0.72	2.7(p)	
	S10	0.83	10.80	1/1,250	1.05	2.7(p)	Additional
	Subtotal	3.07	-	-	4.81	-	
D	S11	0.81	10.50	1/2,000	1.70	3.1(p)	
E	-	-	-	-	-	-	
F	S12	0.61	8.60	1/1,000	1.10	2.8(p)	
	S13	0.18	3.50	1/1,000	0.45	1.8(p)	
	S14-1	2.17	22.00	1/1,000	1.30	3.7(p)	
	S14-2	[0.45]	6.50	1/1,000	0.56	2.2(p)	
	Subtotal	2.96	-	-	3.41	-	
G	-	-	-	-	-	-	
H	-	-	-	-	-	-	
I	-	-	-	-	-	-	
J	-	-	-	-	-	-	
	Total	12.45	-	-	18.00		

Note: (p) Brick Pipe, (b) Box Culvert

TABLE H.4 Proposed Khal Improvement

ZONE	KHAL	DRAINAGE AREA	DESIGN DISCHARGE	KHAL LENGTH	HYDRAULIC GRADIENT	SECTION B x H	BRIDGE/BOX CULVERT		RETAINING WALL	BRICK PROTECTION	DREDGING
	No.	km2	m3/s	km		m x m	places	length(m)	km	km	1,000 m3
A	K1	0.78	10.4	0.3	1/1000	4.5 X 2.0	1	5	-	-	2.7
B	K2	2.72	26.5	3.2	1/4000	8.0 X 4.0	1	25	-	0.4	25.6
	K3	7.76	59.0	1.0	1/4000	10.0 X 5.0	-	-	-	-	0.9
	Subtotal	10.48	-	4.2	-	-	1	25	-	0.4	34.6
C	K4	4.95	40.9	2.5	1/2000	8.5 x 4.0	13	210	0.6	1.2	18.2
	K5	1.25	14.8	1.0	1/2000	6.0 x 3.0	-	-	-	-	10.0
	K6	9.04	64.5	1.6	1/2000	11.0 x 5.0	-	-	-	-	16.0
	Subtotal	15.24	-	5.1	-	-	13	210	0.6	1.2	44.2
D	K7	0.94	11.6	1.5	1/2000	5.0 x 2.5	3	30	0.5	0.5	15.0
	K8	2.76	26.5	3.1	1/2000	7.0 x 3.5	6	60	-	0.5	43.4
	Subtotal	3.70	-	4.6	-	-	9	90	0.5	1.0	58.4
E	-	-	-	-	-	-	-	-	-	-	-
F	K9	3.41	31.0	1.0	1/2000	7.5 x 3.5	3	55	0.3	0.7	4.8
	K10	5.54	44.5	1.8	1/3000	9.0 x 4.5	2	30	-	-	21.9
	K11	13.27	86.0	1.0	1/5000	13.0 x 6.0	3	70	-	-	21.1
	Subtotal	22.22	-	3.8	-	-	8	155	0.3	0.7	47.8
G	K12	1.96	20.8	1.5	1/3000	7.0 x 3.5	2	50	-	-	21.0
	K13	2.95	28.3	1.4	1/3000	8.0 x 4.0	2	50	-	-	22.4
	Subtotal	4.91	-	2.9	-	-	4	100	-	-	43.4
H	K14	0.60	8.5	1.3	1/3000	5.0 x 2.5	-	-	-	-	13.0
	K15	3.81	34.0	3.6	1/3000	8.5 x 4.0	6	30	-	-	61.2
	K16	0.60	8.5	1.5	1/3000	5.0 x 2.5	1	20	-	-	15.0
	K17	0.40	6.2	0.8	1/3000	4.5 x 2.0	-	-	-	-	7.2
	K18	2.22	22.5	1.7	1/3000	7.0 x 3.5	2	40	-	-	23.8
	K19	3.53	32.0	2.3	1/3000	8.0 x 4.0	7	35	-	-	36.8
	K20	8.21	60.1	0.7	1/3000	11.0 x 5.0	-	-	-	-	15.4
	Subtotal	19.37	-	11.9	-	-	16	125	-	-	172.4
I	K21	1.10	13.1	1.0	1/3000	6.0 x 3.0	1	10	-	-	12.0
	K22	1.54	17.3	1.3	1/3000	6.5 x 3.0	1	10	-	-	16.9
	K23	3.94	34.5	1.8	1/3000	8.5 x 4.0	5	50	-	-	30.6
	K24	0.53	7.5	1.4	1/2000	4.5 x 2.0	5	95	-	-	12.6
	K25	0.85	11.3	1.4	1/2000	5.5 x 2.5	5	50	-	-	15.4
	Subtotal	7.96	-	6.9	-	-	17	215	-	-	87.5
J	-	-	-	-	-	-	-	-	-	-	-
	Total	84.66	-	39.70	-	-	69	925	1.4	3.3	491.0

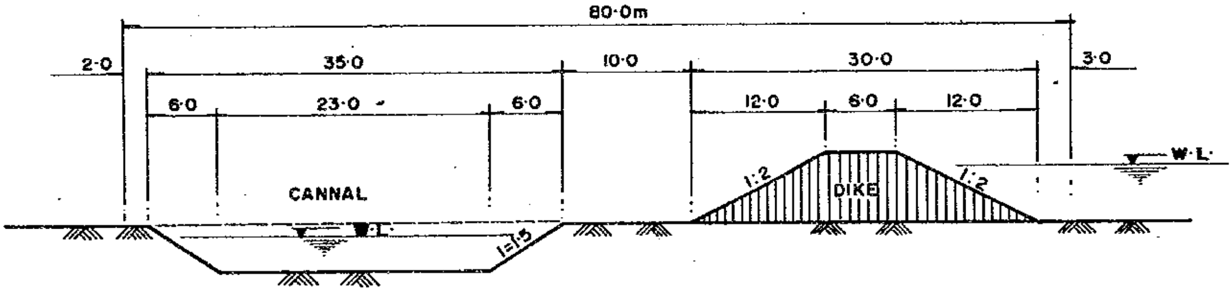
Table H.5 Proposed Pump Station

Zone	Station No.	Drainage Area	Peak Run-Off	Discharge Capacity	Regulation Pond Volume	Regulation Pond Area	Remarks
		Km^2	m^3/S	m^3/S	$x1000m^3$	ha	
(A)	-	-	-	-	-	-	
(B)		5.92	53.0	9.6	781	39.1	
(C)	P1	9.04	64.5	7.5	1,194	59.7	
	Sub-Total	14.96	98.0	17.1	1,975	98.8	
(D)	P2	8.32	60.0	9.5	1,098	54.9	
(E)	-	-	-	-	-	-	
(F)	-	-	-	-	-	-	
(G)	-	-	-	-	-	-	
(H)	P3	12.78	78.5	13.5	1,690	84.3	
(I)	P4	3.94	34.5	4.5	517	26.0	
(J)	-	-	-	-	-	-	
	Total	40.00 Km	-	45.7 m3/S	5,280 x1000m3	264.0 ha	

Table H.6 Proposed Land Acquisition

(Unit; ha)

Zone	Dike	Pump Station	Khal Improvement	Total	Remarks
A	-	-	0.1	0.1	
B	-	1.0	3.5	4.5	
C	19.2	-	4.3	23.5	
D	56.0	1.0	2.9	59.9	
E	-	-	-	0.0	
F	-	-	4.8	4.8	
G	-	-	2.2	2.2	
H	-	1.0	8.6	9.6	
I	-	0.5	4.4	4.9	
J	-	-	-	0.0	
Total	75.2	3.5	30.8	109.5	



Land Acquisition For Dike Construction

Table H.7 Project Cost

Unit : million TK, 1986 Price

DRAINAGE ZONE	FLOOD PROTECTION Protection Dike km	FLOOD PROTECTION Control Gate places	INTERNAL DRAINAGE Pump Station m3/s	INTERNAL DRAINAGE Khal Improvement km	INTERNAL DRAINAGE Drainage Pipe km	CONSTRUCTION COST	Contingency & Engineering Supervision	LAND ACQUISITION ha	TOTAL PROJECT COST
A	-	-	-	0.3 1.2	3.8 79.4	80.6	15.2	0.1 0.4	96.2
B	-	1 39.5	9.6** 97.1	4.2 38.5	4.3 178.8	353.9	66.5	4.5 9.7	430.1
C	2.4 93.1	1 30.0	7.5 183.8	5.1 151.6	4.8 125.0	583.5	109.7	23.5 35.6	728.8
D	7.0 271.6	2 60.0	9.5 232.8	4.6 108.1	1.7 35.5	708.0	133.1	59.9 80.0	921.1
E	-	-	-	-	-	-	-	-	-
F	-	-	-	3.8 96.6	3.4 71.2	167.8	31.5	4.8 14.7	214.0
G	-	-	-	2.9 27.1	-	27.1	5.1	2.2 8.8	41.0
H	3.0* 57.0	3 90.0	14.6 357.7	11.9 56.5	-	561.2	105.5	9.6 35.6	702.3
I	2.0* 38.0	1 30.0	4.5 110.3	6.9 58.8	-	237.1	44.6	4.9 18.2	299.9
J	-	-	-	-	-	-	-	-	-
TOTAL	14.4 459.7	8 249.5	45.7 981.7	39.7 538.4	18.0 489.9	2719.2	511.2	109.5 203.0	3433.4

Note : * Raising Existing Roads

** Utilizing Existing NARINDA Pump Station

Note : Upper figures indicate quantities and lower figures costs.

Table H.8 COMPARISON OF PER CAPITA PROJECT COST AND LAND ACQUISITION AREA

Item				A	B	C	D	E	F	G	H	I	J	Total
				Drainage Zone										
Beneficial Population Unit:1,000	Maximum Flood	1986	External Flood	24	71	114	232	17	18	21	71	8	-	576
			Internal Flood	45	235	33	16	-	68	8	7	24	-	436
			(U) Total	69	306	147	248	17	86	29	78	32	-	1012
		2000	External Flood	28	96	181	464	17	24	21	161	12	-	1004
			Internal Flood	63	243	36	24	-	80	11	20	40	-	517
			(V) Total	91	339	217	488	17	104	32	181	52	-	1521
	Annual Flood	1986	External Flood	-	14	15	86	-	-	-	5	-	-	120
			Internal Flood	45	265	33	16	-	68	8	7	24	-	466
			(W) Total	45	279	48	102	-	68	8	12	24	-	586
		2000	External Flood	-	57	48	238	-	8	-	108	-	-	459
			Internal Flood	63	275	36	24	-	80	11	20	40	-	549
			(X) Total	63	332	84	262	-	88	11	128	40	-	1008
(Y) Project Cost (million TK)				96.2	430.1	728.8	921.1	-	214.0	41.0	702.3	299.9	-	3433.4
(Z) Land Acquisition Area (ha)				0.1	3.2	24.0	59.9	-	5.1	2.2	9.6	4.9	-	109.0
Per Capita Project Cost (million TK)			Y/U	1.4	1.4	5.0	3.7	-	2.5	1.4	9.0	9.4	-	3.4
			Y/V	1.1	1.3	3.4	1.9	-	2.1	1.3	3.9	5.8	-	2.3
			Y/W	2.1	1.5	15.2	9.0	-	3.1	5.1	58.5	12.5	-	5.9
			Y/X	1.5	1.3	8.7	3.5	-	2.4	3.7	5.5	7.5	-	3.4
Per Capita Land Acquisition Area (m2)			Z/U	0.01	0.10	1.63	2.42	-	0.59	0.76	1.23	1.53	-	1.08
			Z/V	0.01	0.09	1.11	1.23	-	0.49	0.69	0.53	0.94	-	0.72
			Z/W	0.02	0.11	5.00	5.87	-	0.75	2.75	8.00	2.04	-	1.86
			Z/X	0.02	0.10	2.86	2.29	-	0.58	2.00	0.75	1.23	-	1.08

Table H.9 Priority Comparison

Comparison Factor		Drainage Zone A	B	C	D	E	F	G	H	I	J
[1] Per Capita Project Cost	Case 1	I	I	III	II	-	I	II	III	III	-
	Case 2	I	I	I	I	-	I	I	I	II	-
[2] Per Capita Land Acquisition Area	Case 1	I	I	II	III	-	I	II	III	II	-
	Case 2	I	I	II	II	-	I	I	I	I	-
[3] Flood Condition		II	I	I	I	-	II	II	I	II	-
[4] Damage to Commercial and Institutional Activities		III	I	I	II	III	I	II	II	III	III
[5] Hindrance to Traffic		III	I	I	II	III	I	III	II	III	III
[6] Land Use Grade		III	II	I	II	III	I	I	II	II	III

Note :
1) Case 1 : Annual flood in 1986, Case 2 : Maximum flood in 2000
2) Per capita project cost, Case 1, Y/W : 5.0 > I, 5.0 < II <10.0, III > 10.0
   Case 2, Y/V : 5.0 > I, 5.0 < II <10.0, III > 10.0
3) Per capita land acquisition area, Case 1, Z/W : 1.0 > I, 1.0 < II < 5.0, III > 5.0
   Case 2, Z/V : 1.0 > I, 1.0 < II < 5.0, III > 5.0
4) Flood condition : Very serious : I, Serious : II
5) Damage to commercial and institutional activities : Large : I, Midium : II, Small : III
6) Hindrance to traffic : Large : I, Midium : II, Small : III
7) Land use grade : High : I, Midium : II, Low : III
8) Comparison factors (3)-(6) are for present condition

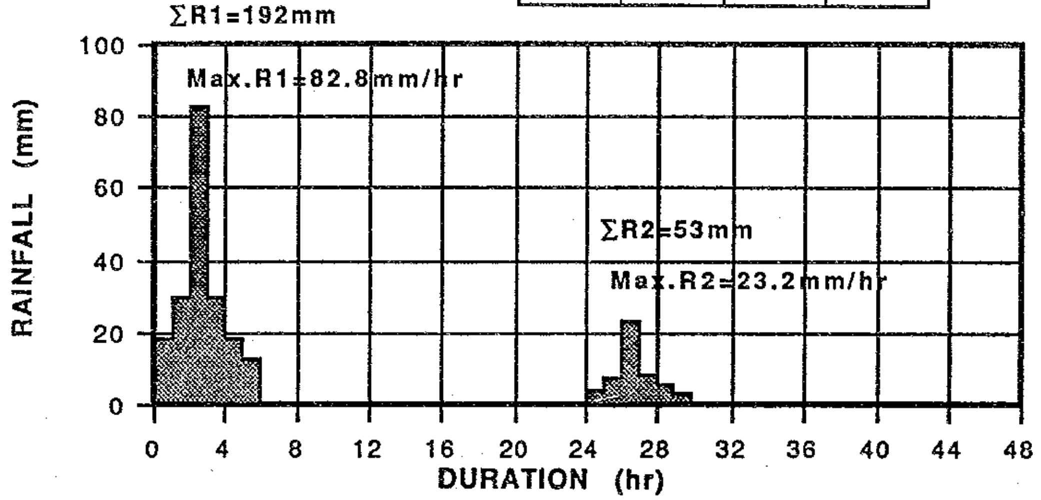
Table H.10 Proposed Phased Program

Unit : million TK, 1986 Price

Zone	Works	Phase						Remarks
		Phase-I		Phase-II		Phase-III		
A	[1] Drainage Pipe			3.8 km	79.4			
	[2] Khal Improvement			0.3 km	1.2			
	[3] Land Acquisition			0.1 ha	0.4			
B	[1] Drainage Pipe	4.3 km	178.8					
	[2] Khal Improvement	4.2 km	38.5					
	[3] Pump Station	9.6 m3/s*	97.1					*Rehabilitation
	[4] Control Gate	1 place	39.5					
	[5] Land Acquisition	4.5 ha	9.7					
C	[1] Drainage Pipe	4.8 km	125.9					
	[2] Khal Improvement	5.1 km	151.6					
	[3] Pump Station	7.5 m3/s	183.8					
	[4] Dike	2.4 km	93.1					
	[5] Control Gate	1 place	30.0					
	[6] Land Acquisition	23.5 ha	35.6					
D	[1] Drainage Pipe			1.7 km	35.5			
	[2] Khal Improvement			4.6 km	108.1			
	[3] Pump Station					9.5m3/s	232.6	
	[4] Dike					7.0 km	271.6	
	[5] Control Gate					2 places	60.0	
	[6] Land Acquisition			2.9 ha	11.6	57.0 ha	68.4	
E								
F	[1] Drainage Pipe	3.4 km	71.2					
	[2] Khal Improvement	3.8 km	96.6					
	[3] Land Acquisition	4.8 ha	14.7					
G	[1] Khal Improvement			2.9 km	27.1			
	[2] Land Acquisition			2.2 ha	8.8			
H	[1] Khal Improvement			11.9 km	56.5			
	[2] Pump Station			14.6 m3/s	357.7			
	[3] Raising of Road			3.0 km	57.0			
	[4] Control Gate			3 places	90.0			
	[5] Land Acquisition			9.6 ha	35.6			
I	[1] Khal Improvement			6.9 km	58.8			
	[2] Pump Station					4.5 m3/s	110.3	
	[3] Raising of Road					2.0 km	38.0	
	[4] Control Gate					1 place	30.0	
	[5] Land Acquisition			4.4 ha	17.6	0.5 ha	0.6	
J								
	Sub-Total		1,165.2		945.3		811.7	
	Contingency & Engineering		207.7		163.9		139.6	
	Total 3,433.4		1,372.9		1109.2		951.3	

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



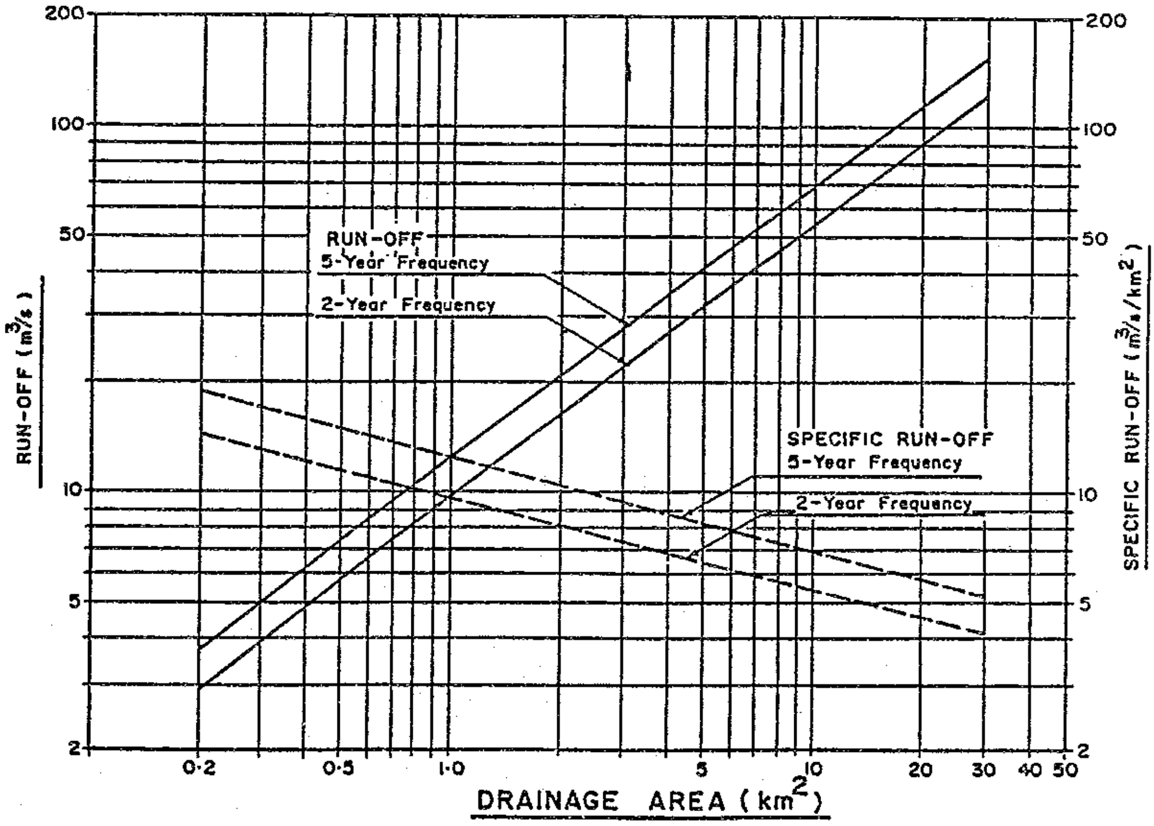


FIG. H.1 DESIGN RAINFALL DISTRIBUTION AND PEAK RUN-OFF DRAINAGE AREA CURVES

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

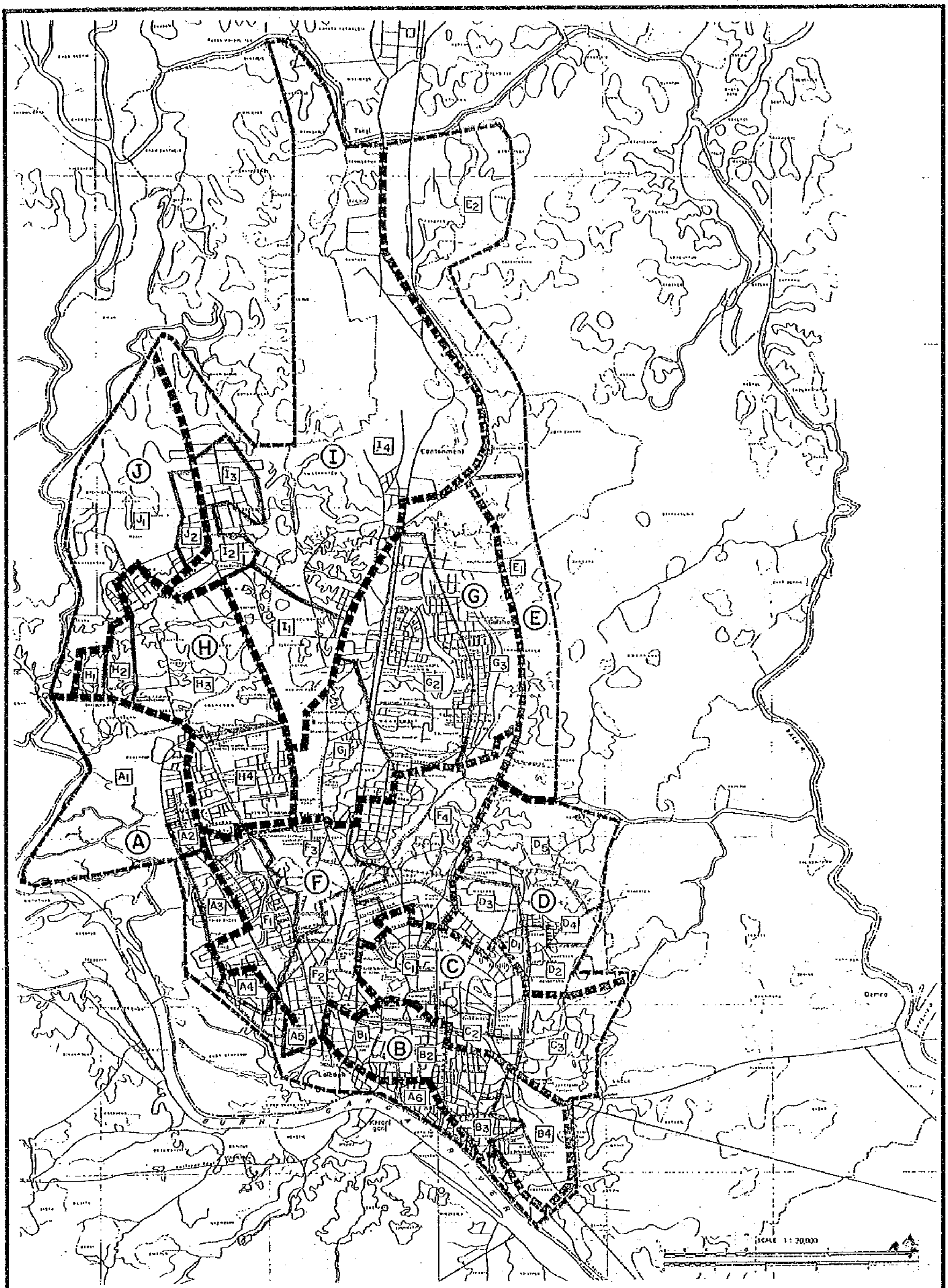


FIG. H.2 SUB-DIVIDED DRAINAGE ZONES

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

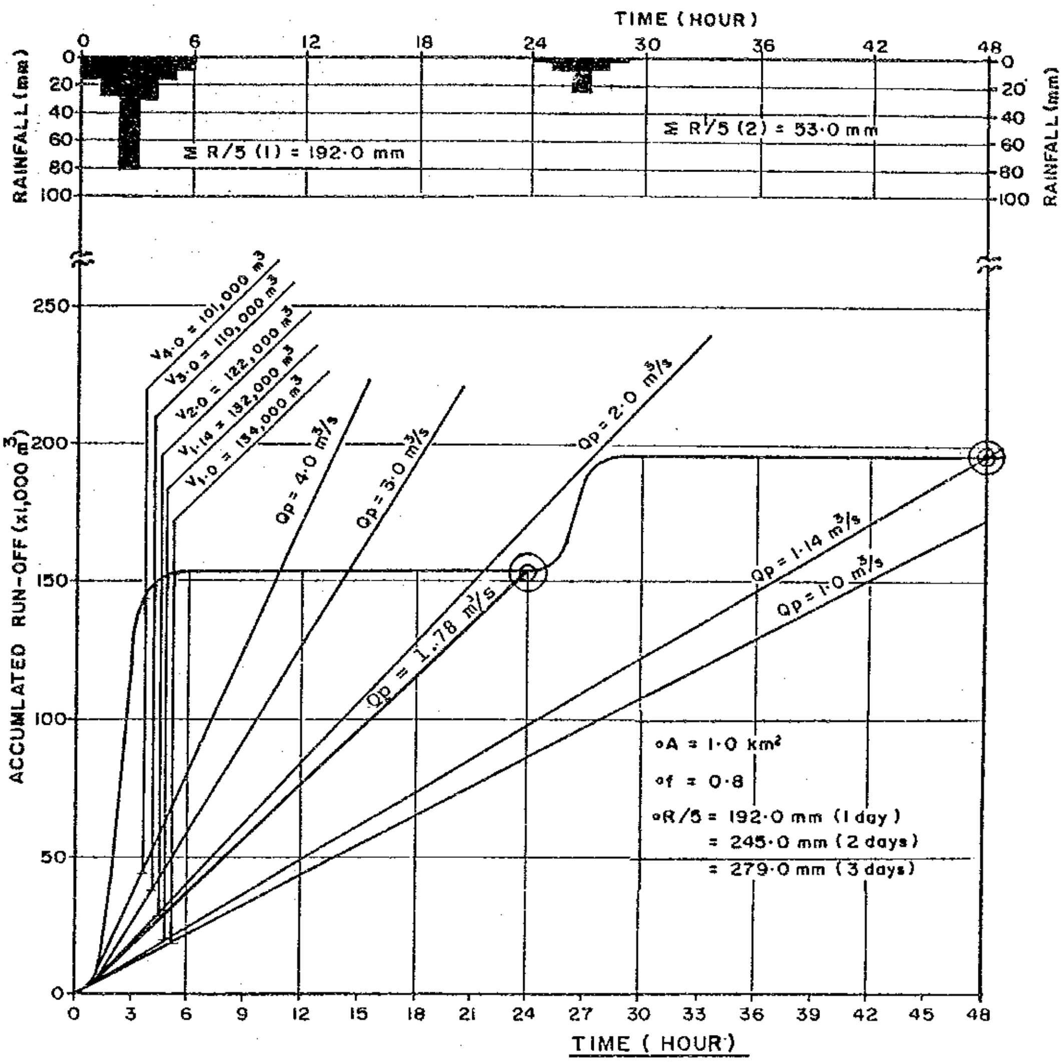


FIG. H.3 SPECIFIC RUN-OFF MASS CURVE

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

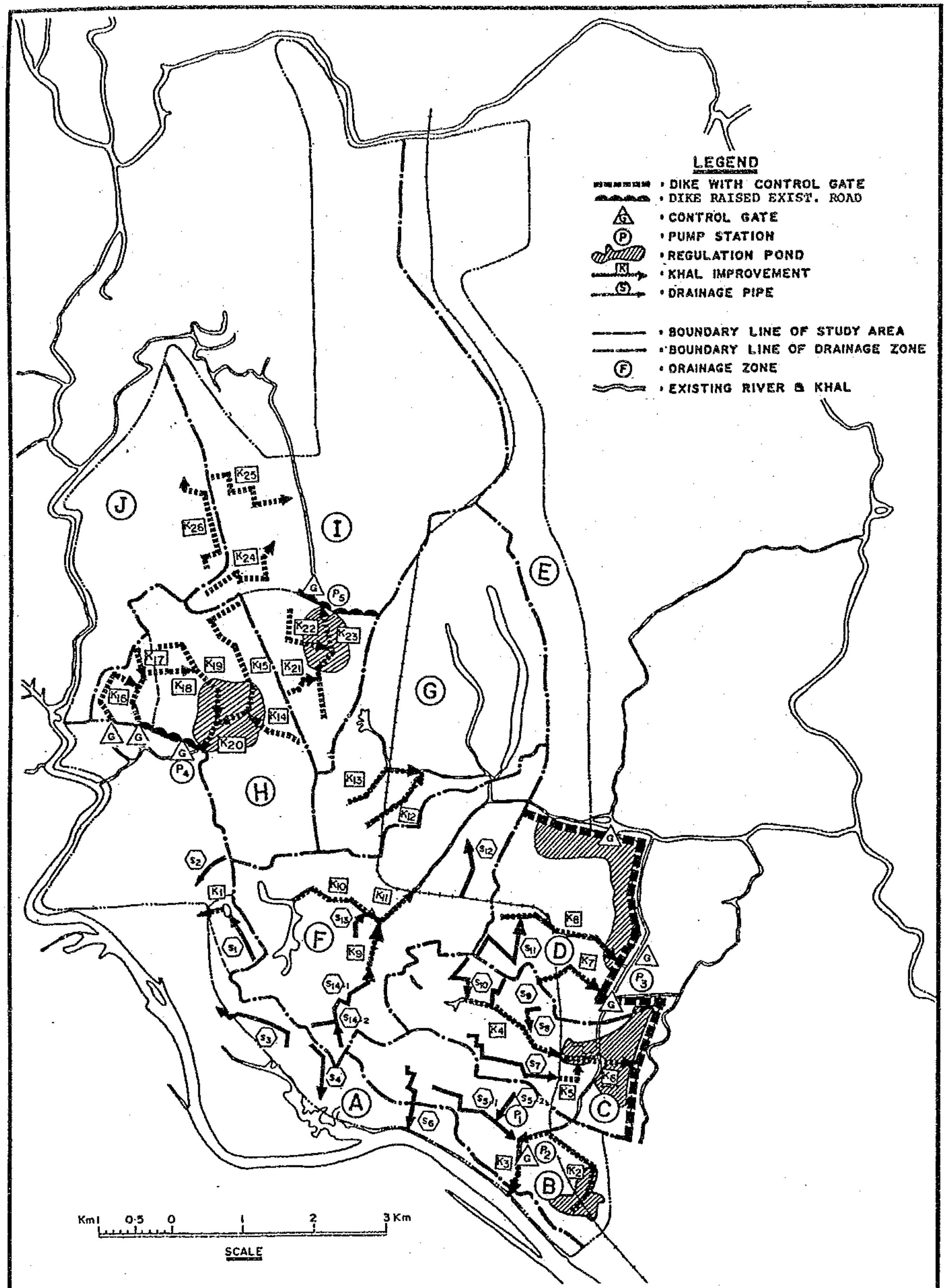


FIG. H.4 PROPOSED FACILITIES

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

DRAINAGE ZONE AREA

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

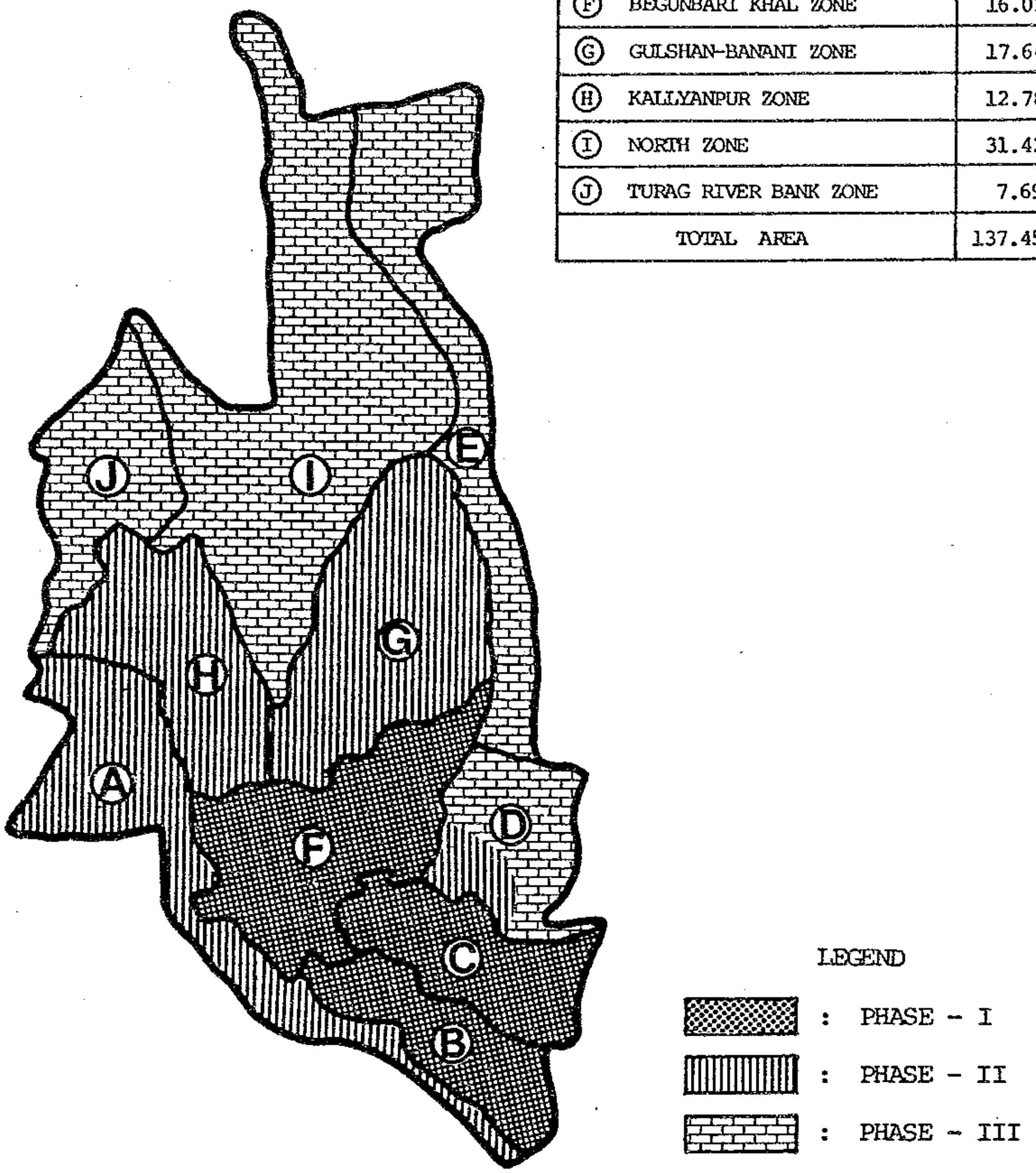


FIG. H.5 PROPOSED IMPLEMENTATION PHASES

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

SUPPORTING REPORT I

DRAINAGE IMPROVEMENT PLAN OF PRIORITY AREA

SUPPORTING REPORT I DRAINAGE IMPROVEMENT PLAN OF THE PRIORITY AREA

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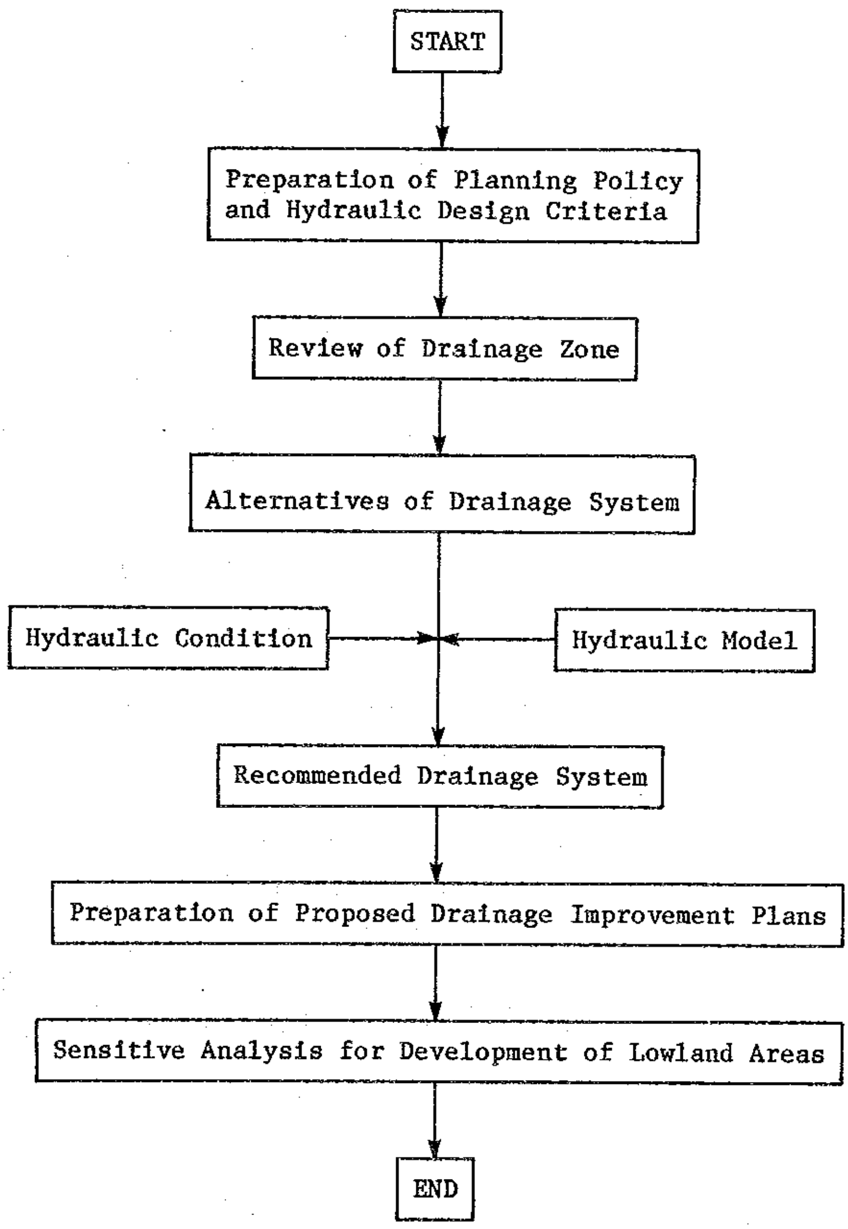
1. General

As mentioned in the Supporting Report H, three drainage zones, Dholai Khal, Segunbagicha Khal, and Begunbari Khal, were selected as the priority drainage area. In this report, detailed drainage improvement plans of the priority areas are prepared. The study was carried out in accordance with the following flow chart:

Flow Chart of The Study



2. Planning Policy and Hydraulic Design Criteria

2.1 Planning Policy

The planning policy is briefly summarized as follows;

(1) The target year is set for the year 2000. Plans are to be prepared to meet the population and land use distribution in the year 2000.

(2) The plans are to be prepared, taking into account that the investment for project implementation must be reasonable.

(3) The plans are to be prepared to mitigate flood damages to the existing external and internal flood areas where surveyed in this project.

(4) The plans are to consist of structural and non-structural measures in order to control the project cost.

(5) Structural measures are to consist of the flood protection works, Khal improvements and trunk drainage pipe works located in the existing internal flood areas. Secondary and tertiary drainage pipes are excluded in the proposal.

(6) Short duration internal flooding causing small flood damage are to be allowable.

(7) The operation of drainage pipes under full-flow conditions are to be considered in the design process.

(8) Available existing facilities are to be considered when making drainage improvement plans recommendations.

(9) Considering the insufficiency of secondary and tertiary drainage facilities, the open canals, called khal, located within the city are to remain, and are not to be enclosed either by pipe or box culverts.

2.2 Hydraulic Design Criteria

2.2.1 Design Flood Water Level

(1) For the Flood Protection Dike

The maximum flood water level, 6.6 m G.T.S., observed at Millbarak station during the 1955 flood, is almost the same value as the 30-year frequency flood water level. It is proposed to use this figure as the design level for the flood protection dike in the priority area.

(2) For the Internal Drainage Facilities

The flood water level with a two (2) year frequency at Millbarak Station, 5.36 m G.T.S., is proposed to be used as the design level for the internal drainage facilities, such as pump stations, Khal and drainage pipes.

The maximum flood water level observed and the probable flood water level at Millbarak Station are presented on Fig. B.13 and B.16 in the Supporting Report B.

2.2.2 Design Rainfall

Considering that the investment for project implementation must be reasonable, the design rainfall for drainage facilities is usually adopted from an appropriate scale of rainfall occurrence. In this study, the following criteria are proposed from a practical point of view:

(1) For Drainage Pipe and Khal Improvement

The rainfall intensity with a 5-year frequency is employed for the design of drainage pipes and khal improvements. The rainfall intensity to be applied for the Rational Formula is calculated by the following formula:

$$i = \frac{9005}{t + 50}$$

where, i : Rainfall intensity (mm/hr)
t : duration (min)

The applied rainfall intensity-duration curve is illustrated in Fig. I.1.

(2) For Pump Station and Regulating Pond

Two (2) days consecutive rainfall with a 5-year frequency is applied as the design rainfall for pump station and regulating pond. As the result of the hydrological study described in Supporting Report B, the design rainfall depth and its hourly distribution are shown in Fig. I.2.

2.2.3 Runoff Coefficient and Runoff Ratio

(1) Runoff Coefficient

Runoff coefficient (fp) is calculated as follows:

$$fp = \frac{3.6.Qp}{Ip.A}$$

where, Qp : Peak discharge (m^3/sec)

Ip : Average rainfall intensity during time of concentration (mm/hr)

A : Catchment area (km^2)

In this study, the following runoff coefficients are proposed for the calculation of design peak discharge by the Rational Formula.

Table I.1 Proposed Runoff Coefficient

Land Use	Runoff Coefficient
Commercial Area	0.65
Industrial Area	0.55
High Class Residential Area (Low Density Residential Area)	0.3
Middle & Low Class Residential Area (Middle & High Density Residential Area)	0.5
Green Zone and Others	0.2
Water Bodies	1.0

(2) Runoff Ratio

Runoff ratio (ft) is calculated as follows:

$$ft = \frac{Qt}{Rt}$$

where, Qt: Total discharge in height (mm)

Rt: Total rainfall in height (mm)

The runoff ratio (total runoff/total rainfall) of 0.8 is employed in the estimate of flood runoff volume required for the calculation of pump capacity.

2.2.4 Coefficient of Roughness

Manning's roughness coefficients applied for hydraulic calculation of drainage pipes, culverts, and khal improvements are as follows:

Drainage pipe (brick):	0.015
Concrete box culvert:	0.015
Khal improvement (smooth section):	0.025
" " (rough section):	0.035

2.2.5 Drainage Criteria

(1) Allowable Inundation

As described in design policy, short duration internal flooding with small flood damage will be allowable.

(2) Discharge Period

A two (2) day discharge period by pumps is proposed in view of economical reasons.

3. Hydraulic Model

3.1 Storage Basin Model

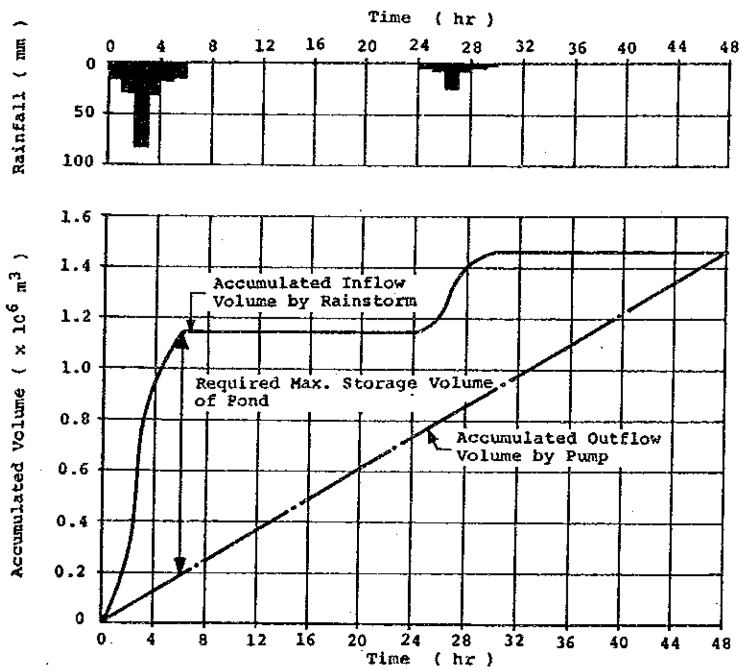
In the pump drainage area, pump capacities and storage requirements of the related regulating pond are calculated by Storage Basin Model formula as shown below:

$$I - 0 = \frac{dS}{dt} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$I = 10 \times f \times Rt \times A \quad \ldots\ldots\ldots \quad (2)$$

$$0 = Qp \times dt \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

where, I : Inflow volume due to rainfall during dt (m^3)
0 : Outflow volume due to pumping during dt (m^3)
dt: Calculation time interval
S : Storage volume of regulating pond (m^3)
f : Runoff rate (0.8)
A : Catchment area (ha)
Rt: Rainfall during dt (mm)
Qt: Pump discharge volume during dt (m^3)



3.2 Runoff Model

Design discharge for the drainage pipes and khal improvements is estimated by Rational Formula as described below;

$$Q = \frac{C \; I \; A}{360}$$

in which, Q: Peak discharge (m^3/sec)

C: run-off coefficient

I: Average rainfall intensity during time of concentration (mm/hr)

A: Drainage area (ha)

Time of concentration (Tc) expressed in minutes is:

$$Tc = Tin + \frac{L}{V}$$

where, Tin: Inflow time of rain water from the most remote point in the sub-drainage area to the drainage pipe (min.)

L: Length of drainage pipe or khal (m)

V: Average velocity in drainage pipe or khal (m/sec)

In this study, the value of Tin, V for the drainage pipe, and V for the khal are adopted 20 minutes, 1.4, and 1.0 meter per second respectively.

3.3 Uniform Flow Model

Hydraulic calculations of the drainage pipes were carried out by uniform flow model of Manning's Formula as presented below;

$$Q = \frac{1}{n} \times A \times R^{\frac{2}{3}} \times i^{\frac{1}{2}}$$

where, Q: Design discharge (m^3/sec)

n: Coefficient of roughness (0.015)

A: Flow area (m^2)

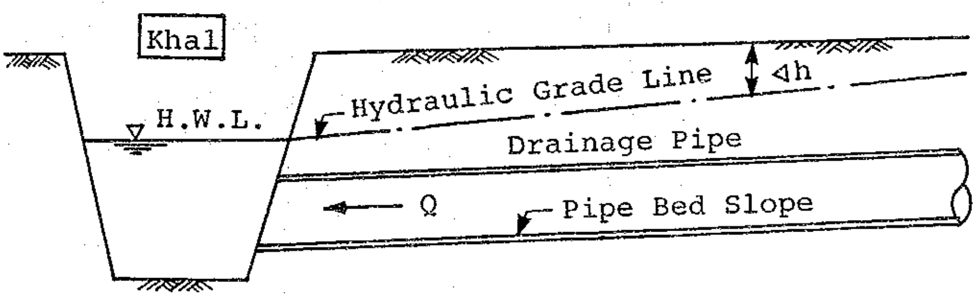
R: Hydraulic radius (m)

i: Hydraulic gradient

Since the drainage pipes were designed to allow the flow of the design discharge under full-flow water conditions, the following items were considered:

(1) In Manning's Formula, hydraulic grade line is used instead of pipe bed slope.

(2) The difference between the hydraulic grade line and the ground line is kept more than 0.5m, considering the hydraulic loss in pressure pipe.



3.4 Nonuniform Flow Model

Hydraulic calculations for the khal improvements were carried out by nonuniform flow model as presented below:

$$H_1 = H_2 + \frac{\alpha}{2g}\left(\frac{Q_2^2}{A_2^2} - \frac{Q_1^2}{A_1^2}\right) + \frac{n^2}{2}\left(\frac{Q_1^2}{R_1^{\frac{4}{3}} A_1^2} + \frac{Q_1^2}{R_2^{\frac{4}{3}} A_2^2}\right) \quad x$$

in which H_1, H_2 : Water depth at upstream and downstream sections

A_1, A_2 : Discharge area at upstream and downstream sections

R_1, R_2 : Hydraulic radius and upsteam and downstream sections

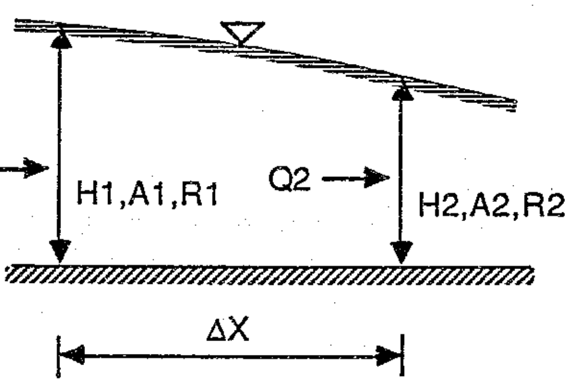
Q_1, Q_2 : Discharge at upstream and downstream sections

n : Roughness coefficient

g : Acceleration of gravity (9.8 m/sec^2)

α : Energy correction rate (nearly 1.0)

Δx : Distance between two sections



3.5 Unsteady Flow Model

Flow conditions of khal networks, including regulating ponds and a pump station, were finally checked by unsteady flow model formula as presented below:

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial X} = q(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right) + gA\frac{\partial h}{\partial x} + g\frac{n\,/Q/Q}{AR^{\frac{4}{3}}} = 0 \quad \ldots\ldots \quad (2)$$

where, t : Time

X : Direction of coordination

Q : Flow volume

A : Flow area

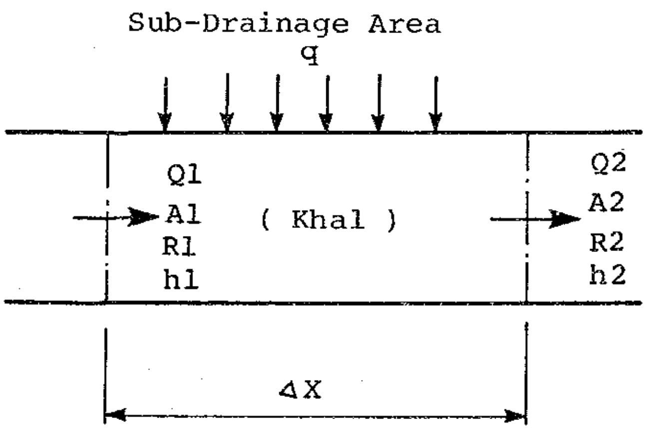
g : Acceleration of gravity

R : Hydraulic radius

n : Roughness coefficient

q : Inflow hydrograph

Inflow hydrograph from sub-drainage area to the khal is estimated by the runoff model formula mentioned in 3.2.



4. Review of Drainage Zone

4.1 Revision of Drainage Zone Boundary

The drainage zone boundaries of the priority area: B, C, and F zones are revised as illustrated in Fig. I.3, based on the detailed studies on the topographic conditions, existing drainage system, ongoing drainage program, and proposed drainage system.

(1) No. 1 revised area (Dholai Khal estuary area): 0.56 km^2

It is not necessary to cover this area by the pump drainage to be proposed for B and C zones. The area shall be incorporated into the A zone.

(2) No. 2 revised area (Dhaka Hall area): 0.52 km^2

Storm water of this area drains through the Baksi Bazar and Nazira Bazar areas to the Narinda pump station. Large scale improvement of the drainage system of the Baksi Bazar and Nazira Bazar areas is very difficult due to the congestion of the town and the narrowness of existing roads. Accordingly, the diversion of this area to C zone is recommended for the solution of the existing flood situation of the Baksi Bazar and Nazira Bazar areas.

(3) No. 3 revised area (Kamulapur area): 0.95 km^2

Construction of a dike is required between C and D zones to prevent the intrusion of floods from D zone. The villages located around the boundary of the two zones shall be included in the protected area of the Project.

(4) No. 4 revised area (Rajarbagh area): 0.26 km^2

This area can easily benefit from the C zone project, if a small extension is made to the drainage improvement work of the C zone. Therefore, the area is converted to the C zone from the D and F zones.

(5) No. 5 revised area (upstream area of Ramna Lake): 0.15 km^2

This area is shifted to the C zone from the F zone based on the detailed survey of the existing drainage condition.

(6) No. 6 revised area (east side area of DIT road): 0.25 km^2

This area is transferred to the D from the F, based on the detailed collection of the existing drainage system.

(7) No. 7 revised area (west side area of Dhanmondi Lake): 1.72 km^2

This area will be diverted to the A zone, according to the ongoing drainage improvement project of DPHE.

The revised zone areas of the B, C and F are as presented in Table I.2.

Table I.2 Revised Drainage Zone Area

Drainage Zone	Original Area (km^2)	Revised Area (km^2)
B. Dholai Khal Zone	7.76	6.68
C. Segunbagicha Khal Zone	9.04	10.92
F. Begunbari Khal Zone	16.02	13.70
Total	32.82	31.30

4.2 Demarcation of Gravity and Pump Drainage Areas

Ground elevation and area curves were made for the following sub-divided drainage areas to demarcate gravity and pump drainage areas.

B zone:	BI	(Old Dhaka upstream area: 1.03 km^2)
	BII	(Old Dhaka downstream area: 3.11 km^2)
	BIII	(Gandaria area: 2.54 km^2)
C zone:	CI	(Segunbagicha Khal upstream area: 7.03 km^2)
	CII	(Segunbagicha Khal downstream area: 3.89 km^2)
F zone:	FI	(Begunbari Khal upstream area: 9.29 km^2)
	FII	(Begunbari Khal downstream area: 4.41 km^2)

Ground elevation and area curves of the sub-divided drainage area are shown in Fig. I.4.

Flood and drainage conditions corresponding to ground elevation are as follows:

(1) The area above 6.60 m G.T.S. is free from the river floods.

(2) The area between 6.40 m G.T.S. and 6.60m G.T.S. is flood prone, but can drain storm waters by gravity, assuming that:

- outlet water level of drainage pipes is at the frequent flood water level (2-year return period) of 5.36 m G.T.S.

- head difference required for gravity drain of a 5-year frequency discharge through drainage pipes is approximately 1.0m.

(3) The area below 6.40 m G.T.S. can not be drained by gravity.

In consideration of the above conditions, the following conclusions are reached for flood protection and drainage of each area:

(1) B I area

Nearly all of the area is higher than 6.60 m G.T.S. Storm waters can be drained by gravity. No flood protection works are required.

(2) B II area

Sixty (60)% of the area is below 6.60 m G.T.S. Fifty (50)% is below 6.40 m G.T.S. Flood protection works and pump drainage are required.

(3) B III area

Almost all the area is below 6.60 m G.T.S. Ninety five (95)% is below 6.40 m G.T.S. Flood protection works and pump drainage are required.

(4) C I area

Fifty (50)% is below 6.60m G.T.S. Forty (40)% is below 6.40 m G.T.S. Flood protection works and pump drainage are required.

(5) C II area

All the area is below 6.60 m G.T.S. Flood protection works and pump drainage are inevitable.

(6) F I area

All the area except the khal area is above 6.60 m G.T.S. No flood protection works are required and gravity drainage is available.

(7) F II area

Seventy (70)% of the area is below 6.60 m G.T.S. However, this low-lying area is mostly khal area and little developed for urban use. The low-lying developed lands below 6.60 m G.T.S. are 61 ha in total but these are all situated above 5.50 m G.T.S. Gravity drainage is available even for the low-lying developed areas because the hydraulic head loss required for the drainage of these areas is small.

Proposal of structural flood protection works for these low-lying areas is not practical. These areas shall be relieved from flood damage by adequate non-structural measures.

Land areas above different ground levels are presented in Table I.3.

Table I.3 Land Areas above Different Ground Levels

	B ZONE				C ZONE			F ZONE		
G.L. (m)	I upper	II middle	III lower	I+II+III total	I upper	II lower	I+II total	I upper	II lower	I+II total
10.5	1.03			6.68						
10.0	1.02			6.67						
9.5	1.01			6.66	7.03		10.92	9.29		13.70
9.0	0.97			6.62	7.02		10.91	9.24		13.65
8.5	0.92	3.11		6.57	6.94		10.83	8.67	4.41	13.08
8.0	0.84	3.08		6.46	6.47		10.36	6.20	4.37	10.57
7.50	0.74	3.00		6.28	5.80		9.69	2.72	4.00	6.72
7.50	0.42	2.68	2.54	5.64	4.46		8.35	1.23	3.70	4.93
6.5	0.00	1.74	2.47	4.21	3.45	3.89	7.34	0.53	2.99	3.52
6.0		0.57	2.02	2.62	0.69	3.85	4.54	0.53	2.53	3.06
5.5		0.10	1.55	1.65	0.00	3.66	3.66	0.53	2.32	2.85
5.0		0.04	1.27	1.31		2.82	2.82	0.53	2.25	2.78
4.5		0.02	1.02	1.04		2.39	2.39	0.53	2.19	2.72
4.0		0.00	0.79	0.79		2.38	2.38	0.53	1.91	2.44
3.5			0.46	0.46		1.80	1.80	0.53	1.89	2.42
3.0			0.13	0.13		1.57	1.57	0.53	1.64	2.17
2.5			0.02	0.02		1.10	1.10	0.53	1.54	2.07
2.0			0.00	0.00		0.51	0.51	0.53	1.47	2.00
1.5						0.00	0.00	0.00	1.44	1.44
1.0									0.00	0.00

Unit: km^2

5. Alternative Study of Drainage Improvement Plan

5.1 Old Dhaka Drainage System

The proposed drainage area of the Old Dhaka drainage system (B_I and B_{II} areas) covers 4.14 km^2 of which 3.68 km^2 is the catchment area of the existing Narinda Pump Station and 0.46 km^2 is the residual area.

The following three (3) alternative plans are proposed for the drainage improvement of the Old Dhaka area in view of the fact that a considerable part of the drainage area is high enough to drain directly into the Buriganga River.

(1) Alternative 1

All the area (3.68 km^2) is covered by pump drainage at Narinda.

(2) Alternative 2

Composed of the following two (2) systems:

- Upstream area (1.03 km^2): diversion to the Buriganga River
- Downstream area (2.65 km^2): pump drainage at Narinda.

(3) Alternative 3

Composed of the following three (3) systems:

- Upstream area (1.03 km^2): diversion to the Buriganga River
- Middlestream area (1.05 km^2): pump drainage at the Buriganga River bank
- Downstream area (1.60 km^2): pump drainage at Narinda

The three (3) alternative drainage systems are illustrated in Fig. I.5.

The alternative plans were designed under the following conditions:

(1) Design rainfall and runoff coefficients: as given in 2.2.

(2) The capacity of the existing drainage pipes and the Narinda Pump Station are fully taken into account.

(3) The hydraulic gradient of the proposed drainage pipes: 1/1,000

(4) The required capacity of drainage pump is calculated to meet the peak runoff, due to the lack of regulating pond.

The proposed drainage facilities of each alternative plan are shown in Fig. I.6.

Cost of the alternative plans were estimated under the conditions listed below:

(1) The estimated cost items are to be follows:

Construction cost:	Proposed additional drainage pipes and pump station
OM cost:	Proposed additional pump station

(2) Construction cost adopted per meter of the drainage pipes are shown in Supporting Report L.

(3) Construction cost adopted per specific capacity of the pumping station is assumed to be 18 million Taka.

(4) Yearly OM cost of the pumping station is assumed to be almost 1.5 percent of its construction cost. Estimated period of OM cost will be 15 years.

The estimated cost of the alternative plans is as shown in Table I.4.

Alternative 2 is recommended because of the lower cost.

Table I.4 Cost Comparison of Alternatives for Old Dhaka Drainage System

(Unit : million TK)

Alternative	Construction Cost of Additional Drainage Pipe		Construction Cost of Additional Pump Station	OM Cost of Additional Pump Station	Total
	2.2 x 2.86, L=700m	42.0	Qp= 25.3 m3/s	C = 455.4 x 0.015 x 15	
1	2.6 x 2.6, L=750m	46.5		= 102.5	
	2.7 x 2.7, L=350m	22.4			
	2.7 x 2.7, L=450m	28.8	C = 25.3 x 18.0		
	3.1 x 3.1, L=650m	46.8	= 455.4 million TK		
	3.2 x 3.2, L=100m	7.5			
	Total	194.0	455.4	102.5	751.9
	2.2 x 2.86, L=700m	42.0	Qp= 23.5 m3/s	C = 423.0 x 0.015 x 15	
2	Ø 1900, L=750	12.0		= 95.2	
	Ø 2600, L=350	7.4			
	Ø 2800, L=450	10.4	C = 23.5 x 18.0		
	2.9 x 2.9, L=650m	44.2	= 423.0 million TK		
	3.1 x 3.1, L=100m	7.2			
	2.2 x 2.86, L=100m	46.8			
	Total	170.0	423.0	95.2	688.2
	2.2 x 2.86, L=700m	42.0	Qp= 27.7 m3/s	C = 498.6 x 0.015 x 15	
3	Ø 1900, L=750	12.0		= 112.2	
	Ø 2600, L=350	7.4			
	Ø 1900, L=650	10.4	C = 27.7 x 18.0		
	Ø 2500, L=100	2.0	= 498.6 million TK		
	2.2 x 2.86, L=780m	46.8			
	2.9x 2.9, L=920m	62.6			
	Total	183.2	498.6	112.2	794.0

5.2 Pump Drainage System

As concluded in 4.2 and 5.1, Old Dhaka's downstream area (B II: 3.11 km^2) consisting of Narinda P.S. area of 2.65 km^2 and the residual area of 0.46 km^2, Gandaria area (B III: 2.54 km^2), and Segunbagicha Khal zone (C: 10.92 km^2) require pump drainage. For the pump drainage system of these areas or zone, the following three (3) alternatives are proposed:

(1) Alternative 1: Each area or zone is independent.

(2) Alternative 2: B II and B III area are combined.
C zone is independent.

(3) Alternative 3: All areas and zone are integrated.

The pump drainage systems of the three alternatives are shown in Fig. I.7.

The above alternatives are mainly compared in terms of the required pump capacity and construction cost of the pump station. A required pump capacity is related, not only with the design rainfall, but to the design discharge period of the pump and the storage capacity of the regulating pond. Accordingly, the following conditions are considered in this study:

(1) Rainfall and runoff coefficient: as given in 2.2

(2) Discharge period of the pump: 2 days

(3) Design water level of the regulating ponds

H.W.L. : 4.5m G.T.S.
L.W.L. : 3.2m G.T.S.

(4) Regulating pond volume: estimated from potential reserved area in the year 2000, as shown in Fig. I.10.

B II area: None
B III area: 0.4×10^6 m^3
C zone: 1.78×10^6 m^3

As a result of the calculations by the storage basin model formula shown in Fig. I.8, the required pump capacity and construction cost of the pump station for the alternatives are shown in Table I.5.

Table I.5 Cost Comparison of Alternatives for Pump Drainage System

Alter-native	Area or Zone	Required Pump Capacity	Construction Cost of P.S.				
		m^3/sec	m^3/sec		million TK/m^3		million TK
1	B II	31.8	31.8	x	18.0	=	572.4
	B II	2.9	2.9	x	18.0	=	52.2
	C	12.4	12.4	x	18.0	=	223.2
	Total	47.1					847.8
2	B II + B III	22.0	22.0	x	18.0	=	396.0
	C	12.4	12.4	x	18.0	=	223.2
	Total	29.9					619.2
3	B II + B III + C	18.8	18.8	x	18.0	=	338.4

As shown in Table I.5, alternative 3 is recommendable.

5.3 Khal Improvement Scheme

In the priority areas, B, C, and D zone, there are a number of the trunk khals with a total length of 13.1 km. According to the Study of Preparation of Phased Program. It is concluded that these khals will be improved by widening and dredging in order to increase the discharge capacity.

Out of these khals, the name of khals and its longitudinal sections located in the completely urbanized area are as follows:

(1) Segunbagicha Khal: L = 2.1 km, Circular Rd. to DPHE Store Circle
(2) Begunbari Khal: L = 1.8 km, Airport Rd. to Dhanmondi Lake
(3) Paribagh Khal: L = 1.0 km, Begunbari Khal Junction to New Elephant Rd.

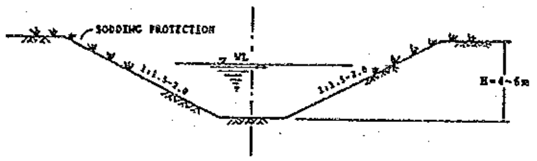
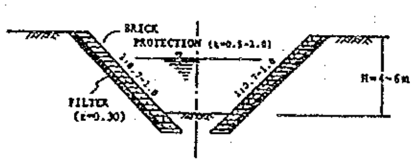
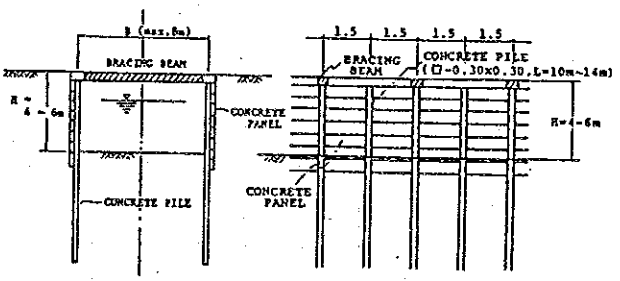
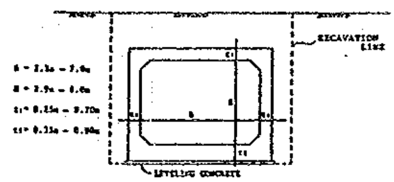
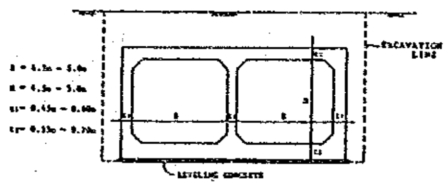
A canal type and construction cost comparison are shown in Table I.6 and I.7 respectively.

According to the comparative study results, even if the alternative 1 has some disadvantages for solution of the existing khal problems, it is recommended to adopt Alternative 1 for the khal improvement works, considering technical and economical points of view.

TABLE I.6 Canal Type Comparison of Alternatives for Khal Improvement Scheme

Problem	Open Channel Type	Covered Channel Type
(1) Collection of Stormwater	Easy to collect stormwater even before completion of secondary drainage system.	Difficult to collect stormwater before completion of secondary drainage system and causes local floods. Typical example is seem in Old Dhaka area.
(2) Maintenance	Easy	Difficult and expensive.
(3) Construction	Easier than covered channel type.	More difficult than the open channel type.
(4) Re-construction in the future	Easy. Covering of channel in the future is easy.	Difficult. Re-opening of channel in the future would be difficult.
(5) Existing bad smell due to water pollution and water disposal	Difficult to attain satisfactory solution before completion of sewerage system and collection system of waste disposal.	Bad smell due to water pollution will be solved. However, bad smell due to waste disposal will remain unresolved until completion of the collection system of water disposal.
(6) Preservation of open space	Easy. Open channel itself functions as open space.	Depends on land use pattern on covered channel.
(7) Land use on channel	Cannot be used other than for drainage.	Can be used for road or promenade.
(8) Illegal land occupation by squatter	Difficult to prevent without strong administrative control or construction of high guard fences.	Easier to prevent than for open channel type.

Table I.7 Construction Cost Comparison of Khal Improvement Plan Alternatives

Item	Alternative 1 Open Channel Type	Alternative 2 Covered Channel Type
Standard Cross Section	TYPE - 1 : TRAPEZOIDAL TYPE (1) - SODDING PROTECTION  TYPE - 2 : TRAPEZOIDAL TYPE (2) - BRICK PROTECTION  TYPE - 3 : CONCRETE PANEL WALL TYPE (1) - WITH BRACING BEAM 	TYPE - 1 SINGLE BOX CULVERT  TYPE - 2 DOUBLE BOX CULVERT 
Construction Cost		
(i) Segunbagicha Khal	47,200 TK/m x 2,100 m = 99.12 Million TK	125,000 TK/m x 2,100 m = 262.50 Million TK
(ii) Begunbari Khal	9,000 TK/m x 1,800 m = 16.20 Million TK	130,000 TK/m x 1,800 m = 234.00 Million TK
(iii) Paribagh Khal	71,400 TK/m x 1,000 m = 71.40 Million TK	116,000 TK/m x 1,000 m = 116.00 Million TK
Total	186.72 Million TK	612.50 Million TK
Note	With regard to construction cost per meter, refer to Table L.4 in the Supporting Report L.	With regard to construction cost per meter, refer to Table N.3 in the Supporting Report N.

6. Proposed Drainage Improvement Plan

6.1 Flood Protection Plan

6.1.1 Alignment of Flood Protection Dike

(1) Dholai Khal zone (B zone)

As mentioned in 4.2, B zone contains 4.2 km^2 of low-lying land lower than the design flood water level (6.60 m G.T.S.) out of the total area of 6.68 km^2. However, according to the topographic survey, the low-lying areas are protected from the river floods by the existing roads, such as the Dhaka-Narayanganji Diversion Road, and Haricharan Road, and by the Buriganga River bank. The flood water intrudes only through the Dholai Khal. Construction of a control gate is required to prevent the backwater of the Buringanga River. The gate is attached to the new Narinda pump station proposed in the Dholai Khal near the existing Narinda pump station. The gate is 6 x 6 m in size and its design high water level is 6.60 m G.T.S.

(2) Segunbagicha Khal zone (C zone)

C zone covers 7.34 km^2 of low-lying land lower than the design flood level (6.60 m G.T.S.) out of the total area of 10.92 km^2. At present, C_I area is protected from the flood water by the existing railway. However, C II area, being lower than 6.6 m G.T.S., is not free from the design flood.

Construction of dikes is proposed to prevent the floods from the Balu River. The alignment of the proposed dikes (Total length: L=4.8 km) was determined based on the following considerations:

- Existing and future land use
- Administrative division and existing community boundary
- Existing Khal networks
- Required regulation pond area for pump drainage
- Multipurpose use for road

The main features of the proposed dikes are:

- Total length: 4.8km
- Design high water level: 6.60m G.T.S.
- Free board: 1.0m
- Crown elevation: 7.60m G.T.S.

The proposed dikes are provided with control gates of 6 x 6 m in size to drain flash floods in the off-season of pump drainage. There will also be a control gate attached to the New Narinda pump station.

Location of the proposed flood protection works is illustrated in Fig. I.23.

6.2 Pump Drainage Plan

As concluded in 5.2, Old Dhaka's downstream area (B II), Gandaria area (B III) and Segunbagicha Khal zone (C) are recommended to adopt a integrated pump drainage system. In this section, the proposed pump drainage system is explained in detail.

6.2.1 Required Pump and Regulating Pond Capacities

The required pump and regulating pond capacities are calculated by storage basin model formula under the following conditions:

- Design rain storm (refer to Fig. I.2)

  o Two days consecutive rainfall in 5-year frequency
  $R = R_1 + R_2 = 192$ mm + 53 mm = 245 mm
  o Duration per one rainfall: D = 6 hours
  o Rainfall pattern: central concentration type

- Design runoff rate: f = 0.8
- Design pump discharge period: T = 48 hours
- Drainage area: A = B II + B III + C = 3.11 + 2.54 + 10.92 = 16.57 km^2

According to the calculation results shown in Fig. I.9, the required pump and regulating pond capacities are:

- Pump capacity: $Q_p = \frac{f.r.a}{3600.T} = \frac{0.8 \times 0.245 \times 16.57 \times 10^6}{3600 \times 48} = 18.8\ m^3/sec$

- Regulation pond capacity: $V = 2.14 \times 10^6\ m^3$

6.2.2 Design Water Level of Regulating Pond

(1) High Water Level (H.W.L.)

The design H.W.L. of the regulating pond is proposed to be 4.5 m G.T.S. after taking the following into consideration:

- The lowest elevation of the existing developed land in the fringe areas of B and C zone is 5.3 to 5.5 m G.T.S.

- It is recommended that future land development be made in conformity with the elevation of the neighboring built-up lands.

- A hydraulic head difference of approximately 1.0 m will be required for satisfactory drainage of the above mentioned low-lying developed land.

(2) Low Water Level (L.W.L.)

The L.W.L. of the regulating pond is related with the H.W.L. and the required storage volume of the regulating pond. Accordingly, the storage volume between H.W.L. and L.W.L. is to be same as the required regulating volume. However, it is desirable for the design L.W.L. to be more than 3.0 m G.T.S., due to the following consideration:

- Ground elevation of the proposed regulating ponds

- River flood hydrograph and required period of pump operation.

6.2.3 Proposed Regulating Pond

The proposed regulating ponds provided with a required storage capacities between H.W.L. and L.W.L. are delineated as shown in Fig. I.10 taking into account anticipated future land development.

One large pond proposed for the Jatrabari area (C II area). The proposed pond area (1.38 km^2) is approximately 58% of existing lowland area (2.39 km^2).
The other will be a small pond proposed for the Gandaria area (B III area). The area of this pond (0.47 km^2) will occupy almost 49% of the existing undeveloped lowland area (0.96 km^2).

The provided surface area and storage capacity of the regulating ponds are:

- Jatrabari pond: surface area: 1.38 km^2
  storage capacity: 1.78×10^6 m^3

- Gandaria pond: surface area: 0.47 km^2
  storage capacity: 0.40×10^6 m^3

These ponds will be effective for reducing of the requirements of the Dholai and Gandaria Khal improvements as well as the pump capacity.

A variation of water level of the Jatorabari and Gandaria ponds under the design rainstorm are estimated by the storage basin model formula and H-V curves of both ponds. The proposed pump discharge (18.8 m^3/sec) shall be distributed for each pond based on its catchment area rate as shown below:

$$\text{Jatrabari pond} = P \times \frac{\text{Area of B II and C}}{\text{Area of B II, B III and C}}$$

$$= 18.8 \times \frac{3.11 + 10.92}{3.11 + 2.54 + 10.92} = 15.9 \text{ m}^3/\text{sec}$$

$$\text{Gandaria pond} = P \times \frac{\text{Area of B III}}{\text{Area of B II, B III and C}}$$

$$= 18.8 \times \frac{2.54}{3.11 + 2.54 + 10.92} = 2.9 \text{ m}^3/\text{sec}$$

According to the calculation results presented in the Data Book, the water level at occurrence of peak runoff (H_1) and high water level (H.W.L.) of both ponds are as follows:

Jatrabari pond: H_1 = 4.03m G.T.S.
H.W.L = 4.35m G.T.S.

Gandaria pond : H1 = 4.03m G.T.S.
H.W.L. = 4.35m G.T.S.

The variation curves of the water level of both ponds are illustrated in Fig. I.11.

6.2.4 Proposed Pump Station

As mentioned in 6.2.1, the required pump capacity is proposed as 18.8 m^3/sec. It is recommended that the proposed pump stations consist of two stations, the existing Narinda pumping station, and a newly constructed pump station, due to the following consideration:

- As the technical and economical evaluation results of the existing Narinda pump station, 9.6 m^3/sec will be met by rehabilitation of this station. (Refer to Supporting Report E)

- The remaining pump capacity (18.8 - 9.6 = 9.2 m^3/sec) will be handled by the construction of an additional pump station.

Location of the new pump station is proposed near the existing Narinda pump station through comparison with the Jatrabari regulating pond site as described below:

- The Narinda site is more advantageous for saving operational and maintenance costs.

- The Narinda site is more favorable in hydraulic aspects. In the proposed integrated drainage system, the maximum flow of Dholai Khal usually takes place at the time of storm runoff peak and runs in the upstream direction, from Narinda to Jatrabari and Gandaria ponds.

If the new pump station is installed at Jatrabari, 9.2 m^3/s more discharge will flow through Dholai Khal from Narinda to Jatrabari and Gandaria ponds, compared to its being installed at Narinda. As a result, the water level of Narinda will rise higher by 0.45 m at the time of storm runoff peak and worsen the drainage situation of the Old Dhaka area.

- No significant difference is recognized between the two (2) sites in geological and construction conditions.

6.3 Khal Improvement and Drainage Pipe

6.3.1 Proposed Drainage Networks

As mentioned in 2.1 (Planning Policy), drainage improvement plans are prepared to mitigate flood damage to the existing internal flood area and also to effectively use the existing drainage system and facilities as much as possible.

The networks of the proposed khal improvements and drainage pipes are illustrated in Fig. I.12.

6.3.2 Design Discharge

(1) Division of sub-drainage area

Based on the existing and proposed drainage lines, future land use and topographic conditions of the drainage areas or zones, sub-drainage areas are divided into 55 blocks as shown in Fig. I.13.

(2) Runoff coefficient of sub-drainage area

Runoff coefficients of sub-drainage areas are estimated as shown in Table I.10 and Fig. I.14, based on the proposed standard runoff coefficient and the future land use map.

(3) Design Discharge

The design discharges with a 5-year frequency of short duration rainfall were calculated for each stretch of the proposed Segunbagicha Khal, Begunbari Khal, and drainage pipes by the Rational Formula. The design discharge of the Begunbari Khal area, however, is considered to be the effect of runoff regulation by the Dhanmondi Lake as described in 6.5.

The design discharges of the Dholai and Gundaria Khal are very difficult to estimate by the Rational Formula, because of the effect of the Narinda pump station and the Jatorabari or Gundaria regulating ponds. Accordingly, the design discharge of these khals are estimated by Unsteady Flow Model formula as mentioned in 6.4.

The calculation results are as shown in Table I.11 to I.13 and Fig. I.15.

6.3.3 Proposed Khal Improvement

The existing discharge capacities of the khals are insufficient for the design discharge. This is one of the main causes of internal flood in the project area. Improvement works of khals are required for alleviation of internal flooding.

The longitudinal and cross sections of the khals are to be designed to lower the water level to the extent that is economically possible, since the discharge capacity of drainage pipe is affected by the water level of the khal.

(1) Segunbagicha Khal

Khal improvement, with a total length of 3.0 km ,is proposed for the stretch between the railway crossing and the Ramna Lake. The proposed bed slope is designed as 1/2000, considering the improvement scale of cross sections and the existing longitudinal ground slope along the khal. The improved cross sections shown in Table I.14 are designed to be nearly sufficient under the condition of uniform flow. The design high water level of the Segunbagicha Khal is determined to envelop the following water levels:

- Nonuniform flow profile calculated under the condition that the peak of the design storm runoff appears at a time when the water stage of the Jatorabari pond reaches 4.0 m G.T.S.

- The high water levels of downstream side are affected by the design level, (4.5 m G.T.S.) of Jatrabari pond.

The proposed longitudinal or cross sections and design high water level are illustrated in Fig. I.16.

(2) Begunbari Khal

Khal improvement, with a total length of 2.8 km, is proposed for the stretch between the New Airport Road and the Dhanmondy Lake.

The proposed bed slopes are designed in 1:5,000(downstream side) and 1:3,000(upstream side) respectively. The improved cross sections shown in Table I.14 are also designed the same as for the Segunbagicha Khal. The design high water levels of the Begunbari Khal are determined to envelop the following water levels:

- Nonuniform flow profile calculated under a downstream boundary water level of 5.36 m G.T.S., which is a frequent flood water level with a 2-year return period.

- Begunbari Khal is affected by design flood water level of 6.6 m G.T.S. with a 30-year return period.

The proposed longitudinal or cross sections and design high water level are illustrated in Fig. I.17.

(3) Paribagh Khal

Khal improvement, with a total length of 1.0 km, is proposed for the stretch between the confluence with the Begunbari Khal and Elephant Road. The proposed bed slope is 1:2,000. The improved cross section shown in Table I.14 is proposed to be a rectangular type, because of the narrow land.

The design high water level is determined to envelop the following water levels:

- Nonuniform flow profile calculated under the high water level of 5.64 m G.T.S. at the confluence with the Begunbari Khal, which is the calculated high water level of the Begunbari Khal with a 2-year frequency flood.
- Paribagh Khal is also affected by design flood water level of 6.6 m G.T.S.

The proposed longitudinal or cross section and design high water level are illustrated in Fig. I.18.

(4) Dholai Khal

The khal improvement is proposed for the stretch, with a total length of 3.0 km, between the confluence with the Buriganga River and the Jatrabari regulating pond.

The stretch upstream from the proposed new Narinda pump station is improved according to the longitudinal and cross sections shown in Table I.14 and illustrated in Fig. I.19.

The khal bed gradient is designed to be flat to meet flows coming from both directions. The design high water level is 4.50 m G.T.S., equivalent to that of the regulating pond. While, for the stretch downstream from the proposed Narinda pump station, only the lowering of the khal bottom is proposed since it is wide enough.

(5) Gandaria Khal

Small scale improvement is proposed since the storm runoff of the basin will be regulated to a large extent by the Gandaria pond. The design high water level will be always affected by the design level (4.5m G.T.S.) of the Gandaria regulating pond.

The proposed longitudinal and cross sections are shown in Table I.14 and illustrated in Fig. I.18.

Location of the proposed khal improvements is illustrated in Fig. I.23.

6.3.4 Proposed Drainage Pipe

The additional drainage pipes proposed for each drainage zone are as follows:

Dholai Khal zone (B zone):	2 lines, 4.28 km
Segunbagicha Khal zone (C zone):	4 lines, 4.81 km
Begunbari Khal zone (F zone):	3 lines, 3.41 km
Total :	9 lines, 12.50 km

The cross sections of the drainage pipes are designed to permit the flow of the design discharge under surcharge water conditions. Hydraulic gradient of the drainage pipe is obtained from the difference between outlet water level of the pipe and ground elevation of the drainage area.

According to the hydraulic calculation of the khal improvements, the design outlet water levels of the drainage pipes are given as below:

- B I area of the Dholai Khal zone:
  5.36 m G.T.S. which is the 2-year frequency flood level of the Burhinganga River.

- B II and B III area of the Dholai Khal zone:
  4.00 m G.T.S., which is the water level of the Jatorabari and Gandaria pond at the time when the peak of the design storm runoff appears.

- C I area of the Segunbagicha Khal zone:
  Nonuniform flow profile of the khal corresponding to the design discharge which is calculated under the downstream boundary water level of 4.0 m G.T.S.

- C II area of the Segunbegicha Khal zone:
  4.00 m G.T.S. which is the same as for the B II and B III areas.

- F I area of the Begunbari Khal zone:
  Nonuniform flow profile of the khal corresponding to the design discharge which is calculated under the downstream boundary water level of 5.36 m G.T.S.

- F II area of the Begunbari Khal zone:
  5.36 m G.T.S. which is a 2-year frequency flood water level of the downstream side of the Begunbari Khal.

The pipe slope is proposed as 1:2,000, taking into account that the pipes are free from sedimentation problem under the free flow occurring at the outlet water level.

If the existing drainage pipes (which have an insufficient number of cross sections to handle design discharge, but are available) are located on the proposed line, these pipes will be considered in the design of drainage pipes.

Hydraulic designs of drainage pipes are shown in Table I.15 to I.16. The proposed profiles and cross sections of the drainage pipes are illustrated in Fig. I.20 to I.22.

Location of the proposed drainage pipes is illustrated in Fig. I.23.

6.4 Hydraulic Simulation by Unsteady Flow Model

In determining the design high water level of the khal and regulating ponds, the water levels of the khals were calculated by steady nonuniform flow formula and that for the regulating ponds was obtained by the storage basin model formula

However, flood flow of the khals is in complicated unsteady conditions. The flood water of Dholai Khal and Gandaria Khal flows upstream from Narinda to the Jatrabari and Gandaria ponds during the rising and peak stages of storm runoff. While it runs downstream from the Jatrabari and Gandaria ponds to Narinda during the receding stage of storm runoff. The water levels at the Jatrabari and Gandaria ponds are affected by these complicated flood flows. The water level of Seguanbagicha Khal is affected by the varying water level of the Jatrabari pond.

Hydraulic simulation by the unsteady flow model, as mentioned in 3.5, was made for checking of the proposed design high water level of the khals and regulating ponds.

6.4.1 Modeling of Drainage Networks

Based on the proposed drainage system, the drainage networks of the Segunbagicha and Dholai Khal zones are assumed to consist of the following elements:

-drainage area:	B II area	(3 areas)
	B III area	(8 areas)
	C I area	(11 areas)
	C II area	(7 areas)

- Khal:	Segunbagicha Khal	(19 blocks)
	Dholai Khal	(10 blocks)
	Gandaria Khal	(6 blocks)

- Regulating pond: Jatorabari, Gandaria, and the existing reservoir tank at the Narinda station.

- Pump stations: Proposed pump stations at the Narinda site

Khal length of one block is to be more than 100 m, taking into account of stability condition of the numerical analysis shown below:

$$dL \quad dt\ (\ \ 2gh + V\ max)$$

where;

dL:	Khal length of one block	(m)
dt:	Calculation time interval	(10 sec.)
g:	Gravity acceleration	(9.8 m/sec^2)
h:	Water depth	(4.0 m)
$V\ max$:	Maximum velocity	(1.2 m/sec)

so, $dL \quad 10 \times (\ \ 2 \times 9.8 \times 4.0 + 1.2) = 100$ m

Figure I.24 shows the khal networks and simulation model.

6.4.2 Calculation Conditions

(1) Inflow hydrograph

Inflow hydrograph from sub-drainage areas are estimated by the Rational Formula under the 5-year frequency rain storm as shown in Data Book II. Hydrological conditions of sub-drainage area are presented in Table I.8.

Table I.8 Hydrological Conditions of Sub-Drainage Areas

No. of Sub-Drainage Area	Catchment Area (ha)	Runoff Coeffi-cient	Time of Concen-tration (min)	No. of Sub-Drainage Area	Catchment Area (ha)	Runoff Coeffi-cient	Time of Concen-tration (min)
1	79	0.28	39	16	85	0.51	27
2	60	0.23	40	17	29	0.52	34
3	58	0.55	34	18	14	0.52	23
4	83	0.38	40	19	12	0.55	22
5	58	0.50	34	20	14	0.50	28
6	39	0.55	30	21	33	0.46	35
7	23	0.50	31	22	24	0.52	33
8	18	0.55	31	23	265	0.49	52
9	60	0.45	45	24	49	0.50	34
10	143	0.43	56	25	49	0.55	34
11	7	0.59	21	26	14	0.50	21
12	59	0.51	34	27	20	0.51	19
13	49	0.50	28	28	30	0.51	23
14	61	0.55	39	29	20	0.50	19
15	42	0.50	33				

(2) Cross section of khals

The proposed profiles and cross section of khal shown in Table I.14 and Fig. I.16 to I.19 are adopted.

(3) Initial water level of regulating pond

The proposed maintenance water level (L.W.L 3.2 m G.T.S.) is used as the initial water level condition.

(4) Pump station

The proposed two (2) pump stations at the Narinda site, with a total capacity of 18.8 m^3/sec, are adopted.

(5) External boundary

A 2-year frequency flood water level (5.36 m G.T.S.) is adopted.

6.4.3 Calculation Results

(1) Variation of khal discharge

Peak discharge of the Segunbagicha Khal occurs 3.5 hours after the occurrence of a design rainstorm. The values at the upstream and downstream vary approx. 10 to 63 m^3/sec, which is almost the same as or 1.2 times the value in comparison with the peak discharge calculated by the Rational Formula as described in 6.3.2., because, in this simulation, the khal discharge of downstream side is estimated by adding a discharge hydrograph from the sub-drainage area under the condition of unsteady flow.

On the other hand, the discharge and flow direction of the Dholai and Gandaria Khal always vary under the influence of the two regulating ponds and pump stations. The peak discharge of the Dholai Khal varies from approx. 15 to 29 m^3/sec (from Narinda to Jatorabari) and 16 to 19 m^3/sec (from Jatorabari to Narinda) respectively.

The peak discharge of the Gandaria Khal is very small (about 5.0 m^3/sec). It occurs when the runoff from the sub-drainage area ends; it is the effect of the Gandaria regulating pond.

The peaks and variations of khal discharge at main point are illustrated in Fig. I.25.

(2) Variation of flood water level

During a rainstorm, the water levels of the three ponds will start to rise from the L.W.L. of 3.2 m G.T.S. After almost nine hours they will reach the H.W.L. of 4.3 m G.T.S., after which they will gradually lower to the L.W.L. The water levels of 3.5 hours after a rainstorm begins (when peak discharges of khals occur) are approximately 3.8 m G.T.S. at Jatorabari, 4.0 m G.T.S. at Narinda and 3.9 m G.T.S. at Gandaria pond respectively. The H.W.L. of the Segunbagicha Khal, upstream from the cross point with the Circular Road, varies from 4.3 to 5.1 G.T.S., which is about the same as the results of a steady flow.

The H.W.L. of the Segunbagicha Khal, between the railway crossing and the Circular Rd., the Dholai and the Gandaria Khal are always affected by the H.W.L. of the regulating ponds (4.3 m G.T.S.) which are 0.20m lower than the design H.W.L. due to the storage capacity of the khals.

The H.W.L. and variation of water levels at main points are shown in Fig. I.26.

6.5 Flood regulation of Dhanmondi Lake

The Dhanmondi Lake, with a water surface area of 17.6 ha, is located at the uppermost reaches of the Begunbari Khal. Usually, the lake is used as a public recreation facility, such as for bathing in water, fishing and boating. Moreover, it also functions to regulate runoff. In this project, the runoff regulating role of the Dhanmondi Lake is proposed to be developed by constructing a small dam having multi-purpose use.

6.5.1 Proposed Small Dam

The small concrete overflow dam illustrated in Fig. I.27 is proposed to be constructed at the outlet of the Lake, which is just upstream from the junction of the Begunbari Khal and the Mirpur Rd. Runoff from the sub-drainage area in and around the Lake is temporarily stored in the Lake as a function of the dam.

6.5.2 Hydraulic Effect of Runoff Regulation

Hydraulic effect of runoff regulating of the Dhanmondi Lake is evaluated by the following formulas:

$$I - 0 = \frac{ds}{dt} \quad \text{.........................(1)}$$

$$I = C.A.R \quad \text{.........................(2)}$$

$$0 = 0.35 \times B \times dh \times \sqrt{2g \cdot dh} \quad \text{.........(3)}$$

Where,
- I: Inflow from sub-drainage area
- 0: Overflow from dam
- dS: Storage volume in the lake during dt
- dt: Calculation time interval (30 min.)
- C: Runoff ratio (late: 1.0, others: 0.8)
- A: Catchment area (lake: 17.6 ha, others: 47.4 ha)
- R: Design 2-day rainfall in 5-year return period (R=245 mm)
- B: Width of overflow section of dam (B=6.8 m)
- dh: Different water level upstream and downstream of dam
- g: Acceleration of gravity (9.8 m/sec^2)

As calculation results show in Fig. I.27, the peak discharge of 15.4 m^3/sec from the Dhanmondi catchment area is regulated to a peak outflow of 2.7 m^3/sec.

7. Sensitive Analysis for Development of Lowland Areas

7.1 Segunbagicha Khal

At the present time, both banks of the Segunbagicha Khal that stretch downstream about 1.2 km are formed into lowlands or natural ponds with widths varying from 30 to 80 meters.

The area around the circumference of this section is a well-known commercial site; its land value is extremely high. It can be expected that the lowland areas will be developed rapidly as a result of the reclamation work that will take place in the near future. Taking into consideration of the anticipated social situation, proposed cross sections of the Segunbagicha Khal were designed to be of the minimum required number.

In order to evaluate the hydraulic effect due to the reclamation of the lowlands along the khal, the following comparative studies were carried out.

- Case 1: Lowland areas will remain in the future and khal improvements will be carried out by dredging.

- Case 2: Lowland areas will be developed by reclamation, and khal improvement will be carried out in the proposed plan.

Hydraulic calculation was made based on nonuniform flow condition for the design discharge shown in Fig. I.28.

As calculation results show, the hydraulic effect due to reclamation is not affected in the downstream stretch of 1.0 km. However, the H.W.L. between the middle and upperstream stretch of about 1.5 km will be raised in the range of 10 to 25 cm due to the development of the lowlands as shown in Fig. I.28.