JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

DEPARTMENT OF PUBLIC WORKS AND TRANSPORT
MUNICIPALITY OF PHNOM PENH
THE KINGDOM OF CAMBODIA

THE STUDY ON DRAINAGE IMPROVEMENT AND FLOOD CONTROL IN THE MUNICIPALITY OF PHNOM PENH

FINAL REPORT

VOLUME 1

SUMMARY

AUGUST 1999

CTI ENGINEERING INTERNATIONAL CO., LTD.
NIPPON KOEI CO., LTD.

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ESTIMATE OF PROJECT COST

Price Level : As of July 1998
Exchange Rate : US$ 1.00 = Yen 138 = Riel 3,880

PREFACE

In response to a request from the Government of the Kingdom of Cambodia, the Government of Japan decided to conduct the Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Kingdom of Cambodia a study team headed by Mr. Keiji Sasabe, CTI Engineering International Co., Ltd. and constituted by members of CTI Engineering International Co., Ltd. and Nippon Koei Co., Ltd., four times between February 1998 and August 1999.

The team held discussions with the officials concerned of the Government of the Kingdom of Cambodia, and conducted a field study at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

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

I wish to express my sincere appreciation to the officials concerned of the Government of the Kingdom of Cambodia for their close cooperation extended to the team.

August 1999

Kimio Fujita
President
Japan International Cooperation Agency

August, 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

We are pleased to submit to you the final report on the Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh in the Kingdom of Cambodia.

This study was conducted by CTI Engineering International Co., Ltd. and Nippon Koei Co., Ltd., under contracts to JICA, during the period February 1998 to August 1999. In conducting the study, we have paid much attention to formulate a realistic master plan with the target year 2010 with due consideration to the present situation of Cambodia and to formulate the most appropriate plan in the feasibility study.

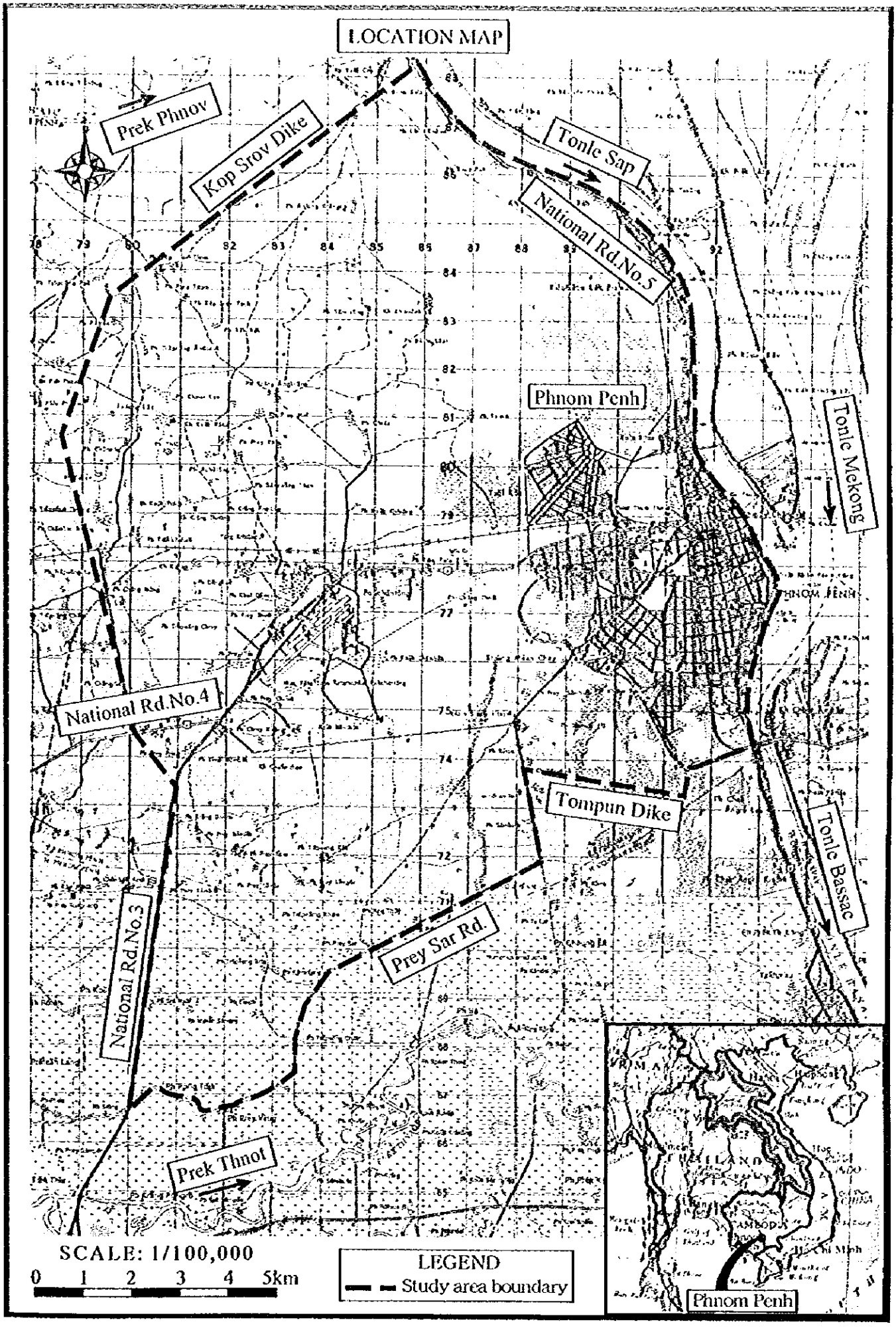
We wish to take this opportunity to express our sincere gratitude to the officials concerned of JICA, the Ministry of Foreign Affairs, and the Ministry of Construction. We would also like to express our gratitude to the officials concerned of the Department of Public Works and Transport of the Municipality of Phnom Penh, the JICA Cambodia Office, the Embassy of Japan in Cambodia for their cooperation and assistance throughout our field survey.

Finally, we hope that this report will contribute to drainage improvement and flood control in the Municipality of Phnom Penh.

Very truly yours,

Keiji Sasabe

Keiji Sasabe
Team Leader
Study Team on
Drainage Improvement and Flood Control
in the Municipality of Phnom Penh
CTI Engineering International Co., Ltd.


LOCATION MAP
Prek Phnov
Kop Srov Dike
Tonle Sap
National Rd.No.5
Phnom Penh
Tonle Mekong
National Rd.No.4
Tompun Dike
Tonle Bassac
National Rd.No.3
Prey Sar Rd.
Prek Thnot
SCALE: 1/100,000
0 1 2 3 4 5km
LEGEND
Study area boundary
Phnom Penh

LIST OF REPORTS

ABBREVIATIONS

1. ORGANIZATIONS

ADB	:	Asian Development Bank
APUR	:	Atelier Parisien d'urbanisme (Town Planning Agency for Paris)
BAU	:	Bureau des Affaires Urbaines
CATUC	:	Comité de l'Aménagement du Territoire, d'Urbanisme et de Construction (Committee for Planning, Urbanization and Construction)
CDC	:	Council for the Development of Cambodia
CNATUC	:	Comité National de l'Aménagement du Territoire, d'Urbanisme et de Construction (National Committee for Country Planning, Urbanization and Construction)
COM	:	Council of Ministers
CRDB	:	Cambodian Rehabilitation and Development Board
CTA	:	Cambodian Telecommunications Authority
DPWT	:	Department of Public Works and Transport
DSD	:	Drainage and Sewerage Division
EdC	:	Electricité du Cambodge
EU	:	European Union
GDIMH	:	General Directorate of Irrigation, Meteorology and Hydrology of MAFF
GOJ	:	Government of Japan
JICA	:	Japan International Cooperation Agency
MAFF	:	Ministry of Agriculture, Forestry and Fisheries
MEF	:	Ministry of Economy and Finance
MFAIC	:	Ministry of Foreign Affairs and International Cooperation
MOE	:	Ministry of Environment
MOP	:	Ministry of Planning
MPP	:	Municipality of Phnom Penh
MPWT	:	Ministry of Public Works and Transport
MWRM	:	Ministry of Water Resources and Meteorology
NORAD	:	Norwegian Agency for Development Cooperation
PMU	:	Project Management Unit
PPWSA	:	Phnom Penh Water Supply Authority
TdC	:	Telecommunication du Cambodge
UNDP	:	United Nations Development Program
UNESCO	:	United Nations Educational, Scientific, and Cultural Organization
UNICEF	:	United Nations Children's Fund
UNTAC	:	United Nations Transitional Authority in Cambodia
USAID	:	United States Agency for International Development
WB	:	World Bank
WHO	:	World Health Organization

2. OTHER TERMS

BOD	:	Biochemical Oxygen Demand
BOT	:	Built, Operation and Transfer
COD	:	Chemical Oxygen Demand
CUDSS	:	Cambodian Urban Development Strategy Study

CUEIP	:	Cambodian Urban Environmental Improvement Project
DO	:	Oxygen Demand
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
GRDP	:	Gross Regional Domestic Product
EPNRM	:	Law on Environmental Protection and Natural Resources Management
NR	:	National Road
PAP	:	Project Affected Persons
PIP	:	Public Investment Plan
SEDP	:	Socio-Economic Development Plan
SS	:	Suspended Solid
TA	:	Technical Assistance

3. UNITS OF MEASUREMENT

(Length)

mm	:	millimeter(s)
cm	:	centimeter(s)
m	:	meter(s)
km	:	kilometer(s)

(Weight)

mg	:	milligram(s)
g, gr	:	gram(s)
kg	:	kilogram(s)
ton	:	tonne(s)

(Area)

mm^2	:	square millimeter(s)
cm^2	:	square centimeter(s)
m^2	:	square meter(s)
km^2	:	square kilometer(s)
ha	:	hectare(s)

(Time)

s, sec	:	second(s)
min	:	minute(s)
h(hrs)	:	hour(s)
d(dys)	:	day(s)
y, yr(yrs)	:	year(s)

(Volume)

cm^3	:	cubic centimeter(s)
m^3	:	cubic meter(s)
ℓ	:	liter(s)

(Concentration)

mg/ℓ	:	milligram per liter

(Speed/Velocity)

cm/sec, cm/s	:	centimeter per second
m/sec, m/s	:	meter per second
km/hr, km/h	:	kilometer per hour

(Stress)

kg/cm^2	:	kilogram per square centimeter
ton/m^2	:	ton per square meter

(Flow/Discharge)

ℓ/sec, ℓ/s	:	liter per second
m^3/sec, m^3/s	:	cubic meter per second
m^3/yr, m^3/y	:	cubic meter per year

(Electrical Units)

W	:	watt(s)
kW	:	kilowatt(s)
MW	:	megawatt(s)
kWh	:	kilowatt-hour
MWh	:	megawatt-hour
GWh	:	gigawatt-hour
V	:	volt(s)
kV	:	kilovolt(s)

(Note: Other combined units may be constructed similarly as above)

4. MONETARY TERMS

¥	:	Japanese Yen
US$	:	United States Dollar
Riel	:	Cambodian Riels

5. CAMBODIAN TERMS

Boeng	:	Lake
Prek	:	River/Stream
Stoeng	:	River (medium)
Tonle	:	River (large)

OUTLINE OF THE STUDY

1. Background of the Study

After the Paris Peace Agreement in 1991, the Government of the Kingdom of Cambodia has been promoting reconstruction and rehabilitation of the country. Phnom Penh, the capital city of the Kingdom of Cambodia, is located on the right bank of the Tonle Mekong River and is the political, economic, traffic and cultural center of the country.

Outer ring dikes of Phnom Penh City having a function of protecting flooding from neighboring rivers, lakes and swamps had developed by 1960s. Urban drainage facilities also developed gradually according to the expansion of the city have a function to drain stormwater and domestic wastewater outside of the city. All these facilities, however, are not functioning well due to the superannuated facilities constructed from the beginning of the 1900s as well poor maintenance in the 1970s. As a result, the city suffers from habitual flooding and inundation and from poor environmental condition with stagnant wastewater in lower areas, which are serious constraints to the citizen's living environment and social and economic development not only of Phnom Penh City but the whole country in general.

The Government of Cambodia accordingly made a request for technical cooperation from the Government of Japan. In response to the request, the Government of Japan dispatched a preparatory study team through Japan International Cooperation Agency (JICA) in March 1997, and the Scope of Work has been agreed between Municipality of Phnom Penh and JICA.

2. Objectives of the Study

The objectives of the Study are:

a. To formulate a master plan of drainage improvement and flood control in the Municipality of Phnom Penh with the target year 2010;

b. To conduct a feasibility study on drainage improvement and flood control for the priority project identified in the master plan study; and

c. To transfer knowledge on method and management of drainage improvement and flood control to counterpart personnel in the course of the study.

3. Study Area

Of the total area of 290.06 km^2 of Phnom Penh City, the Study Area covers an area of 195.71 km^2. Population in the Study Area is estimated at 817,000 as of 1998 including those non-registered; thus about 81.7% of the Phnom Penh's population lives within the Study Area.

4. Present Condition on Flood Protection/Drainage Facilities and Measures

1) There currently exists no official master plan for the Phnom Penh City development, though proposals and projects have been developed by the various concerned services, with little co-ordination between them. The Study Team prepared a future land use map for the target year 2010 referring to these proposals and projects.

2) The Tonle Mekong River system causes flood problems in the Study Area. Water level records of the Tonle Mekong River at Chaktomuk Station are available from 1960, except between January 1975 and June 1980. The historical highest water level at Chaktomuk since 1960 was EL 9.96 in 1961. The highest water level at Chaktomuk in 1996 when there was a risk of flooding was EL 9.92 m. The probable water levels at the same station are calculated at EL 10.0 m for a 30-year return period and EL 10.1 m for a 50-year return period.

Local rainfall causes inundation in the study area. The probable hourly and daily rainfalls at Pochentong Meteorological Station have been calculated at 44.8 mm/hr and 87.8 mm/day for a 2-year return period, and 63.2 mm/hr and 112.3 mm/day for a 5-year return period.

3) Kop Srov Dike connects NR 4 to NR 5 as the northern border of the Study Area. The crest width ranges between 10 m and 12 m. The crest elevation varies from 14.4 to 10.2 m. The dike is eroded in many places by rainfall and seepage, and overall condition is quite bad. Tompun Dike has a crest width of about 15 to 20 m, and the crest elevation varies from 9.5 m to 9.7 m. The crest surface is heavily undulated, but erosion is less than Kop Srov Dike. National roads along the Tonle Sap and Tonle Bassac rivers are asphalt paved and are relatively well maintained. Revetment along the river has been destroyed at some portions.

4) There are a total of nine drainage pumping stations. Of these, Tompun pumping station has the largest capacity at 6.1 m^3/s. It drains storm and sewerage water collected from a basin of 17.47 km^2 including the west part of the city core to outside of the ring dike. Major drainage open channels are the Trabek, Toul Sen and Salang channels in the City Core and the Meanchey channel, aligned along the southwest perimeter of the Inner Ring Dike outside of the City Core. These channels are in many parts clogged with debris and sediments. As a result, the flow capacities are remarkably restricted. A sewer network had been under construction until the end of 1960s with city development. A greater part of the sewer pipes are now choked with sediment and solid waste generated mainly by neighboring inhabitants. The choke rate is reported at 50 to 90 % of original pipe flow capacity.

5) As non-physical measures for flood protection in the Municipality of Phnom Penh, flood forecasting/warning and flood defense activity is presently conducted. When the water level of the Tonle Mekong River rises to the warning level, a committee and sub-committees to protect against flooding are called for and organized. These committees conduct necessary action to protect against flood. Lack of budget, however, has constrained this activity.

6) Drainage improvement and flood control in Phnom Penh are under the jurisdiction of the Municipal Government. The Department of Public Works and Transport (DPWT) is the implementing agency for drainage improvement and flood protection. In DPWT, the Drainage and Sewage Division has direct responsibility for drainage improvement. There is no division responsible for flood protection in the Municipality.

7) There is no law on water, its use and its management in Cambodia. At present, no law regulates domestic or industrial wastewater disposal to rivers or to sewerage systems. In the Municipality of Phnom Penh, a sewerage fee equivalent to 10% of the water bill has been collected from water users from 1997. The collected sewerage fee is paid from PPWSA to the account of MPP. "Law on the Country Planning, Urbanization and Construction" on May 24, 1994 (referred to as the CNATUC Law) stipulates regarding country planning, urbanization, and construction.

5. Master Plan

5.1 Outline of the Master Plan

1) The Master Plan of drainage improvement and flood control in the Municipality of Phnom Penh with the target year 2010 has been formulated. In due consideration of preceding practices in the similar projects in Southeast Asian capitals, protection levels have been decided as a 30-year return period for flood protection facilities, a 5-year return period for major drainage facilities and a 2-year return period for minor drainage facilities.

2) Physical measures of the Master Plan consist of the following eight components:

- Component 1: Riverfront Protection in Sap Downstream Middle Section
- Component 2: Reinforcement of Kop Srov and Tompun Dikes
- Component 3: Tompun Watershed Drainage Improvement
- Component 4: Trabek Basin Drainage Improvement
- Component 5: City Core North Drainage Improvement
- Component 6: Pochentong East Drainage Improvement
- Component 7: Northeast and Northwest Areas Drainage Improvement
- Component 8: Environmental Enhancement

3) The land use control and flood defense activities are judged most applicable and effective among the non-physical measures in the Study Area. For land use control, water zone conservation in the Northeast Area and agricultural land conservation in the Northwest and South areas are recommended.

4) The total project cost required for the implementation of the Master Plan is estimated US$261.6 million.

5) Economic Internal Rate of Return (EIRR) of the proposed Master Plan has been calculated at 12.9%. An implementation schedule has been prepared limiting the annual amount of expenditure to US$ 10 to 15 million. This amount is considered reasonable provided some form of foreign assistance is provided for project implementation. Operation and maintenance cost of envisioned facilities has been estimated at US$ 0.77 million, and this amount can be covered by Cambodian budget if sewerage surcharge is considered. The proposed project impacts are largely beneficial. Negative impact on the natural environment is minimal, and without the proposed physical and non-physical measures, flooding in Phnom Penh would continue to cause considerable economic disruption and social hardship to a very large proportion of the population. There are no serious technical difficulties.

6) The Executing Agency for the implementation of the Master Plan will be the Municipality of Phnom Penh and the Department of Public Works and Transport (DPWT) will be the Implementing Body. No organization is appointed specifically for flood protection at present, so that creation of a Flood Protection Division under the DPWT is recommended.

7) Various laws and regulations should be developed as soon as possible. Of these, first priority should be given to a regulation pertinent to flood protection and drainage which must include clauses defining a charge collection system for operating and maintaining the relevant facilities. Second priority should be given to a regulation related to the land use master plan in Phnom Penh City.

Implementation Schedule for the Master Plan

Project Component	Cost in US$ mil	Year 2000	01	02	03	04	2005	06	07	08	09	2010	11	12	13	14	2015	16	17	18	19	2020
Component 1: Riverfront Protection in Sap Downstream Middle Section (1.0km)	2.3																					
Component 2: Reinforcement of Kop Srov and Tompun Dike	17.8																					
a. Reinforcement of Kop Srov Dike (9.0km)	16.2																					
b. Reinforcement of Tompun Dike (4.4km)	1.6																					
Component 3: Tompun Watershed Drainage Improvement	88.6									53.7												34.9
a. Tompun Pumping Station (15m³/s) and Regulation Pond	15.7																					
b. Meanchey Drainage Main, Downstream Stretch (2.76km long)	5.0																					
c. Meanchey Drainage Main, Upstream Stretch (2.335km long)	3.9																					
d. Tum Nup Tock Drainage Sluiceway (2mx2mx1 lane)	0.4																					
e. Samdachi Mooireth Drainage Main (2.36km long)	24.8																					
f. Jawaharlal Nehru Drainage Main (1.16km long)	3.6																					
g. Salang Drainage Main (1.89km long)	2.3																					
h. Sewer Rehabilitation excluding Tum Nup Tock Basin (931ha)	32.8																					
i. Sewer Construction, Tum Nup Tock Basin (68ha)	2.1																					
Component 4: Trabek Basin Drainage Improvement	94.5								42.0													52.5
a. Trabek Pumping Station (8m³/s) and Regulation Pond	18.2																					
b. Trabek Drainage Main (1.604km long)	13.7																					
c. Toul Sen Drainage Main (2.05km long)	4.0																					
d. Norodom Drainage Main (1.768km long)	6.1																					
e. Sewer Rehabilitation (1,083ha)	52.5																					
Component 5: City Core North Area Drainage Improvement	32.0									12.5												19.5
a. C1: Wat Phnom Basin, Sewer Rehabilitation (89ha)	4.3																					
b. C2: Kak Lakeshore Basin, Sewer Rehabilitation (51ha)	0.4																					
c. C3: Boeng Kak Basin, Kak Drainage Sluiceway	0.4																					
d. C4: Tuol Kork Basin, Major Drainage Facilities	11.5																					
e. C4: Tuol Kork Basin, Sewer Rehabilitation (332ha)	14.8																					
f. C5: University Basin, Drainage Sluiceways (2 locations)	0.7																					
Component 6: Pochentong East Basin Drainage Improvement	11.9																					
Component 7: Northeast and Northwest Areas Drainage Improvement	12.1																					
a. Poungpeay Drainage Main (11.92km)	10.4																					
b. Svay Pak Drainage Sluiceway (2mx2mx2 lanes)	0.7																					
c. Drainage Sluiceways in Poungpeay East Basin (12 locations)	1.1																					
Component 8: Environmental Enhancement	1.9																					
a. Environmental Canal (1.75km long)	1.7																					
b. Kak Interceptor (0.85km long)	0.2																					
Total	261.1	154.2											106.9									

5.2 Priority Projects

The priority projects to be examined in the subsequent feasibility studies are identified as follows:

- Project A: Reinforcement of Kop Srov and Tompun Dikes
  (including reconstruction of Svay Pak Drainage Sluiceway)
- Project B: Tompun Watershed Drainage Improvement
  (excluding sewer rehabilitation)

6. Feasibility Study on Priority Projects

6.1 F/S on Project A: Reinforcement of Kop Srov and Tompun Dikes

1) Project A: Reinforcement of Kop Srov and Tompun Dikes (correspondent to Component 2 and a part of Component 7 in the Master Plan), aims at flood protection for a major part of Phnom Penh City against floodwater level with a 30-year probability in the Tonle Mekong river system. The Project consists of the following four sub-components:

- Sub-component A1: Reinforcement of Kop Srov Dike with a length of 7.65 km
- Sub-component A2: Reinforcement of Tompun Dike with a length of 4.44 km
- Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway with a 3-lane box culvert 1.5 m wide and 2.0 m high per each lane
- Sub-component A4: Preparation of Relocation Site and Spoil Area with a total area of 25 ha

2) The project cost for the Reinforcement of Kop Srov and Tompun Dikes amounts to approximately US$ 20.8 million, whose breakdown by sub-component is presented below:

Project Cost for the Reinforcement of Kop Srov and Tompun Dikes

Sub-component	Project Cost (US$ million)
A1: Reinforcement of Kop Srov Dike	15.9
A2: Reinforcement of Tompun Dike	3.2
A3: Reconstruction of Svay Pak Drainage Sluiceway	1.0
A4: Relocation Site and Spoil Area	0.7
Total	20.8

3) The implementation schedule has been prepared on the premises that the actual construction will initiate in 2001 and terminate in 2003 with a construction period of 3 years. The year 2000 will be allocated for the basic and detailed designs of the structures/facilities and land acquisition and house evacuation necessary for securing right-of-way for construction.

4) The results of the economic evaluation for the Project are tabulated below, from which this Project is judged to have sufficiently high economic return with an EIRR higher than the opportunity cost of capital of 10 %.

Economic Indices for the Reinforcement of Kop Srov and Tompun Dikes

Indices	Reinforcement of Kop Srov and Tompun Dikes	Including Tompun Watershed Drainage Improvement
EIRR (%)	25.2	16.7
B/C	2.76	1.69
NPV (US$ thousand)	29,475	35,384

Note: B/C and NPV with a discount rate of 10%

5) As of 2008 when the facilities start operation, the DSD's revenue (including those of the proposed Flood Protection Division) from government budget reaches the level slightly above the operation and maintenance cost. The Project is thus financially affordable from the O/M cost recovery viewpoint.

6) An adverse impact by the implementation of the project is improvement of living environment through reduction of flooding risks, the objective of the project. Negative impacts on natural environment e.g. turbid water flow and dust during construction and on social environment aspect e.g. relocation of 54 houses can be minimized through introduction of proper environmental management and monitoring plans.

6.2 F/S on Project B: Tompun Watershed Drainage Improvement

1) Project B: Tompun Watershed Drainage Improvement comprises the following 13 sub-components:

- Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel with a capacity of 15 m^3/sec
- Sub-component B2: Construction of Tompun Regulation Pond with a total area of 47.5 ha
- Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch, from Tompun Regulation Pond to Meanchey Bridge with a length of 2.635 km
- Sub-component B4: Improvement of Meanchey Drainage Main, Middle Stretch, from Meanchey Bridge to the junction with a branch with a length of 1.285 km
- Sub-component B5: Improvement of Meanchey Drainage Main, Upstream Stretch, upstream from the junction with a length of 0.535 km
- Sub-component B6: Construction of Tum Nup Toek Drainage Sluiceway with a capacity of 10 m^3/sec
- Sub-component B7: Construction of Samdach Monireth Drainage Main, Downstream Stretch, between the junctions with Meanchey and Jawaharlal Nehru drainage mains with a length of 1.676 km
- Sub-component B8: Construction of Samdach Monireth Drainage Main, Upstream Stretch, upstream from the junction with Jawaharlal Nehru Drainage Main with a length of 0.714 km
- Sub-component B9: Construction of Jawaharlal Nehru Drainage Main with a length of 1.152 km
- Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch, from the junction with Meanchey Drainage Main to a bridge with a length of 0.887 km
- Sub-component B11: Improvement of Salang Drainage Main, Upstream Stretch, upstream from the bridge with a length of 0.488 km

- Sub-component B12: Conservation of the north lake of Boeng Salang with dredging (5.1 ha) and providing a walkway around the lake
- Sub-component B13: Preparation of Relocation Site and Spoil Area with a total area of 26 ha

2) The total project cost for the Tompun Watershed Drainage Improvement amounts to approximately US$ 50.8 million, the breakdown of which by sub-component is as follows:

Project Cost for the Tompun Watershed Drainage Improvement

Sub-component	Project Cost (US$ million)
B1: Tompun New Pumping Station and Inlet Channel	11.5
B2: Tompun Regulation Pond	3.6
B3: Meanchey Drainage Main, Downstream Stretch	3.8
B4: Meanchey Drainage Main, Middle Stretch	0.5
B5: Meanchey Drainage Main, Upstream Stretch	0.5
B6: Tum Nup Toek Drainage Sluiceway	0.7
B7: Samdach Monireth Drainage Main, Downstream Stretch	16.3
B8: Samdach Monireth Drainage Main, Upstream Stretch	3.7
B9: Jawaharlal Nehru Drainage Main	4.1
B10: Salang Drainage Main, Downstream Stretch	1.3
B11: Salang Drainage Main, Upstream Stretch	0.6
B12: North Lake of Boeng Salang	0.7
B13: Relocation Site and Spoil Area	3.5
Total	50.8

3) The implementation schedule has been prepared on the premises that the actual construction will initiate in 2001 and end in 2007 with a construction period of 7 years. Both the basic and detailed designs of structures/facilities in the Project, as well as the land acquisition and house evacuation would be carried out in 2000.

4) The results of the economic evaluation for the Project are tabulated below, from which this Project is judged to have sufficiently high economic return with an EIRR higher than the opportunity cost of capital of 10 %.

Economic Indices for Tompun Watershed Drainage Improvement

Indices	Tompun Watershed Drainage Improvement	Including Reinforcement of Kop Srov and Tompun Dikes
EIRR (%)	11.7	16.7
B/C	1.17	1.69
NPV (US$ thousand)	5,909	35,384

5) As of 2008 when the facilities start operation, the DSD's revenue (including those of the proposed Flood Protection Division) from government budget reaches the level slightly above the operation and maintenance cost. The Project is thus financially affordable from the O/M cost recovery viewpoint.

Implementation Schedule for the Reinforcement of Kop Srov and Tompun Dikes and for the Tompun Watershed Drainage Improvement

Project Component	Cost (US$ mil.)	Year 2000	2001	2002	2003	2004	2005	2006	2007
Project A: Reinforcement of Kop Srov and Tompun Dikes	20.8								
-Sub-component A1: Reinforcement of kop Srov Dike (7.65 km)	15.9								
-Sub-component A2: Reinforcement of Tompun Dike (4.44 km)	3.2								
-Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway	1.0								
-Sub-component A4: Preparation of Relocation Site /Spoil Area (25 ha)	0.7								
Project B: Tompun Watershed Drainage Improvement	50.8								
-Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel (15 m^3/sec)	11.5								
-Sub-component B2: Construction of Tompun Regulation Pond (47.5 ha)	3.6								
-Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch (2.635 km)	3.8								
-Sub-component B4: Improvement of Meanchey Drainage Main, Middle Stretch (1.285 km)	0.5								
-Sub-component B5: Improvement of Meanchey Drainage Main, Upstream Stretch (0.535 km)	0.5								
-Sub-component B6: Construction of Tum Nup Took Drainage Sluiceway (10 m^3/sec)	0.7								
-Sub-component B7: Construction of Samdach Monireth Drainage Main, Downstream Stretch (1.676 km)	16.3								
-Sub-component B8: Construction of Samdach Monireth Drainage Main, Upstream Stretch (0.714 km)	3.7								
-Sub-component B9: Construction of Jawaharlal Nehru Drainage Main (1.152 km)	4.1								
-Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch (0.887 km)	1.3								
-Sub-component B11: Improvement of Salang Drainage Main, Upstream Stretch (0.488 km)	0.6								
-Sub-component B12: Conservation of North Lake of Boeng Salang (5.1 ha)	0.7								
-Sub-component B13: Preparation of Relocation Site / Spoil Area (26 ha)	3.5								
Total	71.6	1.05	13.10	14.00	13.45	7.20	7.20	7.55	8.05

6) An adverse impact by the implementation of the project is improvement of living environment through drainage improvement and resulting water quality improvement, the objective of the project. Negative impacts on natural environment e.g. turbid water flow and dust during construction and on social environment aspect e.g. relocation of 480 houses can be minimized through introduction of proper environmental management and monitoring plans.

6.3 Possible Urgent Projects

1) The feasibility study on each of the two projects, A: Reinforcement of Kop Srov and Tompun Dikes, and B: Tompun Watershed Drainage Improvement, has been carried out as presented above. The study sets out a cost estimation which is $ 20.8 million for the former and $ 50.8 million for the latter, totaling a massive $ 71.6 million. In such case, it would be natural to schedule a stepwise implementation of the entire package of projects.

2) Suggested as sub-components that should be realized in the earlier stage of the two projects are the following:

(1) In Project A: Reinforcement of Kop Srov and Tompun Dikes
- (a) Sub-component A1: Reinforcement of Kop Srov Dike
- (b) Sub-component A2: Reinforcement of Tompun Dike
- (c) Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway
- (d) Sub-component A4: Preparation of Relocation Site/Spoil Area

(2) In Project B: Tompun Watershed Drainage Improvement
- (a) Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel
- (b) Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch
- (c) Sub-component B6: Construction of Tum Nup Took Drainage Sluiceway
- (d) Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch
- (e) Sub-component B13: Preparation of Relocation Site/Spoil Area

7. Recommendations

1) Of the component projects of the master plan for the drainage improvement and flood control in the Municipality of Phnom Penh included under the present study, the following two component projects are given high priority for implementation.

- Component 2: Reinforcement of Kop Srov and Tompun Dikes (including reconstruction of Svay Pak Drainage Sluiceway)
- Component 3: Tompun Watershed Drainage Improvement (excluding sewer rehabilitation)

2) Proposed non-physical measures under the master plan for drainage improvement and flood control in the Municipality of Phnom Penh is the introduction of land use control and the continuous application of flood defense activity. An official development plan for the Municipality of Phnom Penh is recommended to be established as soon as possible

considering the requirements of flood protection and drainage improvement, namely, water zone conservation in the Northeast Area and agricultural land conservation in the Northwest and South areas

3) The implementing body for the projects proposed in the master plan is the Department of Public Works and Transport of the Municipality of Phnom Penh. The Drainage and Sewage Division will be in charge of drainage improvement projects. It is recommended to establish a Flood Protection Division that will be responsible for implementation, operation and maintenance for flood protection projects.

4) The results of the feasibility study conducted for Reinforcement of Kop Srov and Tompun Dikes and Tompun Watershed Drainage Improvement, the priority projects selected from the master plan components, revealed high economic viability, financial affordability, environmental justifiability, and technical soundness. Early implementation of these projects is recommended. However, a massive project cost of US$ 71.6 million and a long period of seven years are required for the implementation of all the component projects of these two projects. Accordingly, it is recommended to implement the following sub-component projects prior to the other sub-component projects.

(1) Project A: Reinforcement of Kop Srov and Tompun Dike
   - (a) Sub-component A1: Reinforcement of Kop Srov Dike
   - (b) Sub-component A2: Reinforcement of Tompun Dike
   - (c) Sub-component A3: Re-construction of Svay Pak Drainage Sluiceway
   - (d) Sub-component A4: Preparation of Relocation Site/Spoil Area

(2) Project B: Tompun Watershed Drainage Improvement
   - (a) Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel
   - (b) Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch
   - (c) Sub-component B6: Construction of Tum Nup Toek Drainage Sluiceway
   - (d) Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch
   - (e) Sub-component B13: Preparation of Relocation Site/Spoil Area

5) It is recommended to start as early as practical the land acquisition and house relocation required for the above sub-components.

6) There exist no sufficient water level data for the Study Area and environs. The Study Team hence established water level gaging stations for Kop Srov Dike, Tompun Dike, etc. and observation has been conducted by the Department of Public Works and Transport. Although the results were used for the feasibility study, higher water records are not sufficient due to the low water level of the last flood season. It is recommended to continue this observation, since these data will be important in the basic design and detailed design stages.

7) An adverse impact by the implementation of the project is improvement of living environment through reduction of flooding risks and improvement of drainage condition. The negative impacts identified in the Environmental Impact Assessment include affect in

water and atmospheric quality during construction works and of necessary relocation of houses, etc. These negative impacts should be minimized through implementation of Environmental Management Program and Environmental Monitoring Program. Attention should be paid to prevent uncontrolled development according to the betterment of Kop Srov and Tompun dikes, and resulting negative impact including water pollution in the Prek Phnov and Prek Thnot basins. Management and monitoring for relocation of the residents are also important to minimize negative socioeconomic impact.

Part I

Master Plan for Drainage Improvement and Flood Control in the Municipality of Phnom Penh

THE STUDY ON
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

SUMMARY - PART I

MASTER PLAN FOR
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

TABLE OF CONTENTS

I1. INTRODUCTION

1.1 Background of the Study

After the Paris Peace Agreement in 1991, the Government of the Kingdom of Cambodia has been promoting reconstruction and rehabilitation of the country. Phnom Penh, the capital city of the Kingdom of Cambodia, is located on the right bank of the Tonle Mekong and is the political, economic, traffic and cultural center of the country.

Outer ring dikes of Phnom Penh City having a function of protecting flooding from neighboring rivers, lakes and swamps had developed by 1960s. Urban drainage facilities also developed gradually according to the expansion of the city have a function to drain stormwater and domestic wastewater outside of the city. All these facilities, however, are not functioning well due to the superannuated facilities constructed from the beginning of the 1900s as well poor maintenance in the 1970s. As a result, the city suffers from habitual flooding and inundation and from poor environmental condition with stagnant wastewater in lower areas, which are serious constraints to the citizen's living environment and social and economic development not only of Phnom Penh City but the whole country in general.

The Government of Cambodia had accordingly conducted various measures for drainage improvement of the city through assistance from the City of Paris, ADB, etc. However, it has become recognized that the preparation of a master plan for drainage improvement and flood control covering the whole area of the city is needed for the expected future urban expansion. The Government of Cambodia accordingly made a request for technical cooperation from the Government of Japan. In response to the request, the Government of Japan dispatched a preparatory study team through Japan International Cooperation Agency (JICA) in March 1997, and the Scope of Work has been agreed between Municipality of Phnom Penh and JICA.

1.2 Objectives of the Study

The objectives of the Study are:

a. to formulate a master plan of drainage improvement and flood control in the Municipality of Phnom Penh with the target year 2010;

b. to conduct a feasibility study on drainage improvement and flood control for the priority project identified in the master plan study; and

c. to transfer knowledge on method and management of drainage improvement and flood control to counterpart personnel in the course of the study.

1.3 Study Area

The study area principally covers the urban center of the Municipality of Phnom Penh (approximately 28 km^2). In addition, the surrounding areas and rivers that may influence inundation in the urban center shall also be covered. The study area, a total of 195.71 km^2, is shown in the location map.

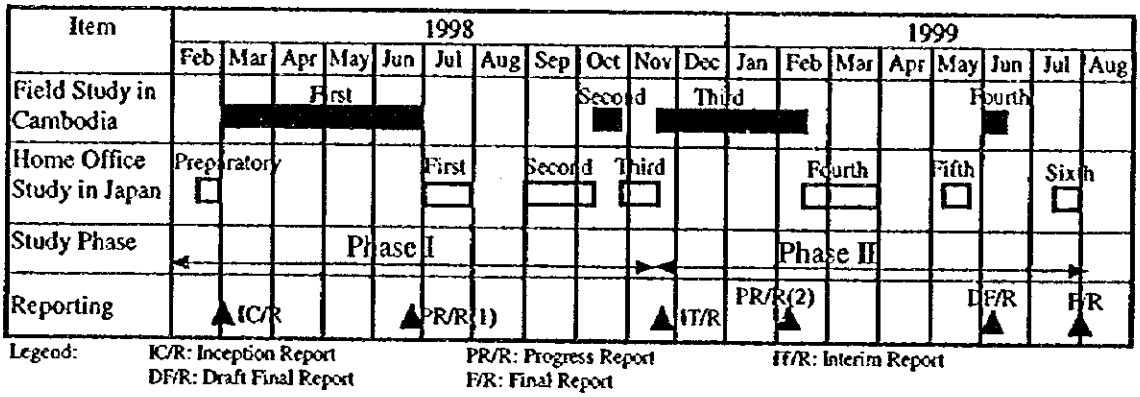
1.4 Implementation Organization of the Study

The Study has been conducted by a Study Team organized by JICA and consisting of nine experts. An Advisory Committee has also been organized to give technical advice to JICA. On the Cambodian side, Municipality of Phnom Penh was the counterpart agency for the Study. Municipality of Phnom Penh established a Steering Committee to assist the Study and to discuss various issues related to the Study.

1.5 Study Flow

The Study has been conducted dividing it into two phases. In Phase I, from February to November 1998, a master plan study for drainage improvement and flood control in the Municipality of Phnom Penh with the target year 2010 has been conducted. In Phase II, from November 1998 to July 1999, a feasibility study on priority project(s) has been conducted. Reports were presented at the times indicated as below.

Overall Study Flow



I2. PRESENT CONDITIONS AND RESULTS OF BASIC STUDIES

2.1 Related Studies and Projects

Various studies and projects are related to the present study. Of these, "Phnom Penh Water Supply and Drainage Project, Part B: Drainage" (ADB Trabek Project) is presently under the stage of detailed design and implementation with ADB loan. This project includes "Institutional Capacity Building Component and the Neighborhood Improvement Program" financed by NORAD (Norwegian Agency for Development Cooperation).

The ADB Trabek Project includes: (i) rehabilitation and upgrading of the Trabek and Toul Sen canals and associated secondary drainage works, (ii) reconstruction of the Boeng Trabek Pumping Station and Spillway, with a maximum pumping discharge of 8 m^3/s. The Institutional Capacity Building Component is to improve the proficiency and technical skills of the professional staff in DPWT (Department of Public Works and Transport) of the MPP (Municipality of Phnom Penh), and to enhance the overall management capability of DPWT. The Neighborhood Improvement Program is conducted to establish workable systems for community based solid waste collection services, and to establish community organizations that will enable people to participate actively in the improvement and maintenance of sanitation/drainage systems in their own community.

2.2 Socioeconomy

Cambodia has a population of about 10 million, about double of Laos, and 14% and 17% each of those of Vietnam and Thailand. Gross national product (GNP) per capita of Cambodia at US$ 270 (World Bank, 1997) is comparable to Laos and Vietnam with US$ 350 and US$ 240, respectively. Following the economic reforms launched since 1989, the Cambodian economy showed a recovery at a fairly high pace. GDP growth rates maintained the level of around 7% per year until 1996. In 1997, however, the economic growth downed to about 2.0% as a result of the political crisis in July. The prospect for 1998 is not very bright. The economic crisis started in the second half of 1997 in neighboring Asian countries will inevitably affect the Cambodian economy.

Socioeconomic characteristics of *Phnom Penh* are presented below:

Socioeconomic Characteristics of Phnom Penh

Item	Values
Land area	290.06 km^2
Population (registered as of March 1998)	872,000
Population (total)	1,000,000
Sex composition of population	
- Male	47 %
- Female	53 %
Population density	3,006 persons/km^2 (registered population)
Population growth (1986-1996)	3.2 %/year
Household size	5.7 persons/household
Population under 20 years of age	54 %
Migrants	43 % of total population
Unemployment	6.5 %
Labor force structure	
- Agriculture	13 %
- Industry	14 %
- Service	74 %
Average household expenditure	781 thousand Riel (1993-1994)

Note: Values are from 1996 Census unless otherwise noted in the table
Ratios may not add up to 100% due to rounding

Of the total area of 290.06 km^2 of Phnom Penh City, the ***Study Area*** covers an area of 195.71 km^2. Population in the Study Area is estimated at 817,000 as of 1998 including those non-registered, thus about 81.7% of the Phnom Penh's population lives within the Study Area.

Reflecting the overall good economic performance until 1996, economic development targets and prospect are assumed based on an optimistic view and with the characteristics as a base target for policy formulation. The following are the assumed ***economic growth targets and prospects***, and these targets are the basis for establishing a socioeconomic framework for the present study.

- SEDP (Socio-Economic Development Plan) : 7.5 % per year between 1996 and 2000
- PIP (Public Investment Plan) 1998-2000 : 7.0 % per year between 1998 and 2000
- WB report : 7.1 % per year for 1999 - 2001
  7.6 % per year for 2002 - 2006

2.3 Land Use and City Planning

The Team has developed present land use map with close cooperation of BAU (Bureau des Affaires Urbaines). There currently exists no official master plan for the Phnom Penh City development, though proposals and projects have been developed by the different interested services, with little co-ordination between them. Hence choices had to be made in order to predict what are the directions of development that will most likely be followed in the next ten years and the Team prepared ***future land use map*** for the target year 2010 as presented in Figure I2-1.

Present Land Use as of 1998 and Future Land Use in 2010

Category		Area in 1998 (ha)	Areal growth (%)	Area in 2010 (ha)	Ratio to total (%)
A	Dense urban center	603	10	663	3.4
B	Dense residential	1,124	20	1,349	6.9
C	Loose residential	3,012	85	5,572	28.5
D-1	Dense activities	287	50	431	2.2
D-2	Loose activities	793	100	1,586	8.1
E	Agricultural land	11,919	-32	8,130	41.5
F	Fish ponds	70	10	77	0.4
G	Green spaces	209	0	209	1.1
H	Lakes and ponds	1,554	0	1,554	7.9
Total of Study Area		19,571	-	19,571	100.0

2.4 Meteorology and Hydrology

The Study Area is within longitude105°45'E to 105°55'E and latitude 12°27'N to 12°40'N, and is in the delta plain of the Tonle Mekong river system with low altitudes ranging from elevations of 4 to 14 m above sea level. The east side of the study area, enclosing central Phnom Penh city, is located on the right bank of the confluence of three rivers, the Tonle Mekong, Tonle Sap and Tonle Bassac. It also lies between two rivers, Prek Phnov in the north and Prek Thnot in the south both flow generally from west to east. The dimensions of the above mentioned ***rivers*** are as follows:

Dimensions of the Rivers

River Name	Catchment Area (km^2)	Length (km)	Average Flow (m^3/s at Phnom Penh)
Tonle Mekong	660,000*	4,500*	11,830**
Tonle Sap	84,400*	400*	1,570**
Tonle Bassac		300***	
Prek Phnov	640	49	
Prek Thnot	5,200	108	

Note: *: Upseream of Phnom Pneh, **: at Phnom Penh, ***: from Phnom Penh to the sea

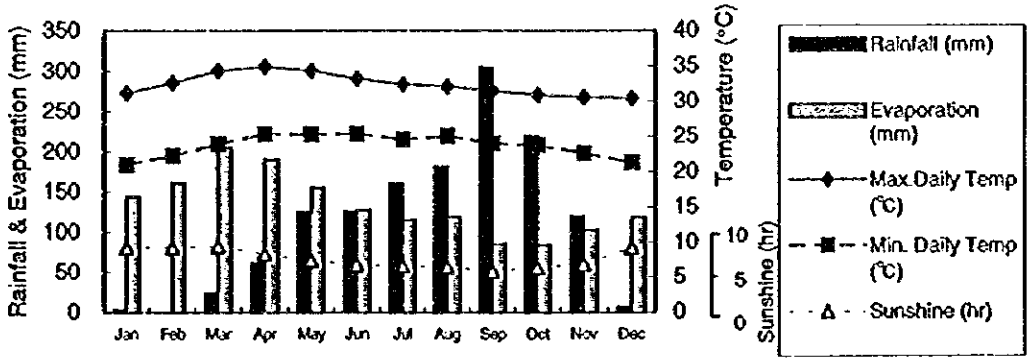
In view of the topography, hydraulic characteristics and land use, the Study Area can be divided into the following five ***watersheds***.

- City Core : C1 to C10 Basins (25.29 km^2)
- Northeast Area : E1 to E4 Basins (40.23 km^2)
- Northwest Area : No subdivision (50.79 km^2)

- Middle Area : M1 to M4 Basins (38.80 km^2)
- South Area : S1 and S2 basins (40.60 km^2)

Ministry of Water Resources and Meteorology, former General Directorate of Irrigation Meteorology and Hydrology (GDIMH) of Ministry Agriculture, Forestry and Fisheries (MAFF) controls meteorological and hydrological observation. The Study Area is in Tropical Monsoon Area. ***General meteorological data*** are illustrated below:

General Meteorology at Pochentong Station



Average annual ***rainfall*** is 1,327 mm (1981-97). About 93% of the annual rainfall occur in the rainy season from May to November, and 57% of the same concentrates in three months from August to October. Two types of rainfall are identified. One is typical tropical shower and the other is the long spell of rain by the influence of a typhoon, etc. going to the north. Cause of inundation is mainly rainfall of tropical shower.

Water level record of the Tonle Mekong river at Chaktomuk Station is available since 1960, except between January 1975 and June 1980. Figure I2-2 depicts seasonal variation of the water level at Chaktomuk Station since 1960. The highest water level at Chaktomuk in 1996 was EL 9.92 m. The historical highest water level at Chaktomuk since 1960 was EL 9.96 in 1961.

No overtopping happened along the Outer Ring Dike in both flood years thanks to the flood defense activity by governmental agencies concerned. Figure I2-3 shows ***inundation map.***

Automatic rainfall gaging data from 15 minutes up to 24 hours duration at Pochentong Station were available. From the data, the ***probable hourly and daily rainfall*** of each return period are calculated as follows:

Probable Rainfall at Pochentong Meteorological Station

Return Period (year)	Hourly Rainfall (mm/hr)	Daily Rainfall (mm/day)
2	44.8	87.8
5	63.2	112.3
10	75.4	128.4

As a ***rainfall intensity curve***, Horner Type equation has been adopted after comparison with other equations:

$I = 2{,}566.07 \times (T+25.48)^{-0.93}$ (constants are the case of 2 year return period and used for sewer design)

$I = 5{,}009.12 \times (T+31.38)^{-0.98}$ (constants are the case of 5 year return period and used for major facilities' design)

The rainfall intensity-duration curves are developed for the study area based on the above equations. ***Model hyetograph*** has been applied for probable rainfall after reviewing the actual rainfall pattern.

To decide the design high water level of the area along Tonle Mekong, the ***probable high water level*** is calculated as shown below:

Probable Maximum Water Level at Chaktomuk Station

Return Period (year)	Water Level (EL. m in NGK)
2	8.9
5	9.4
10	9.7
20	9.9
30	10.0
50	10.1

Two-dimensional Unsteady Flow Model has been applied for ***runoff and inundation analysis model.*** In the model, Suburban Area is divided into 117 blocks with areas of 20 to 460 ha, while the City Core into 77 blocks with areas of 6 to 156 ha in view of the location of major channels, roads, dikes, embankments and other facilities controlling flood. Flow rates and flow directions through every block boundary, and hydrographs at the pumping station sites are estimated through the model. Figure I2-4 presents flow directions and peak discharges in Suburban Area, with-project and 5-year return period rainfall condition, and Figure I2-5 is the same in City Core with the same condition. Figure I2-6 is the design hydrographs at the inlets of Tompun, Trabek and Pochentong pumping stations under with-project and 5-year return period rainfall condition.

2.5 Topography and Geology

The ***topography*** of the Study Area, as a whole, slopes down moderately from west to east and from north to south. The difference between the lowest and highest elevations is approximately 10 m. There is a high terrain zone measuring a maximum elevation of 14 m between Prey Key Village and the western part of Pochentong Airport, however no terrain is higher than EL. 14 m within the Study Area. The Boeng Poungpeay area has low elevations of 5 to 6 m, and the Tompun area of 4 m at the lowest point. The remaining area representing most of the Study Area, in general terms, ranges between 7 m and 10 m in elevation.

Topographic mapping has been conducted in 1/2,000 scale for the lacking part of the existing maps, and accordingly, the project area of approximately 196 km^2 has been covered with 1/2,000 scale maps together with the maps developed by French cooperation. Contour line (50 cm interval) maps have been prepared for the entire study area.

The ***geological structure*** of the Mekong Delta region, where the Study Area is situated, was formed from Precambrian to Holocene ages. During Plio-Pleistocene Age, the Old Alluvium was deposited by the Mekong River and its tributaries in a vast deltaic fill, and succeedingly Holocene deltaic alluvium was deposited. The Holocene Alluvium, consisting largely of unconsolidated silt and clay with some lenses of sand, blankets virtually the entire delta. The Holocene Alluvium in and around the Study Area has generally a thickness of less than 25 m and thickens. The Holocene Alluvium differs from the Old Alluvium in having a generally finer texture, almost no laterite, and a relative abundance of shell and lignite layers.

2.6 Flood Protection/Drainage Facilities and Measures

Condition of dikes is as follows: Kop Srov Dike connects NR 4 to NR 5 as the northern border of the Study Area. The crest width ranges between 10 m and 12 m. The crest elevation varies from 14.4 to 10.2 m. Dike is eroded in many places by rainfall and seepage and the condition is quite bad. Tompun Dike has the crest width of about 15 to 20 m and the crest elevation varies from 9.5 m to 9.7 m. Crest surface is heavily undulated, but erosion is less than Kop Srov Dike. National roads along the Tonle Sap and Tonle Bassac rivers are asphalt paved and are relatively well maintained. Revetment along the river is destroyed in some portion.

There are a total of nine ***drainage pumping stations***. Of these, Tompun pumping station has the largest capacity at 6.1 m^3/s (present) and drains storm and sewerage water collected from its own catchment and those pumped by Tum Nup Toek, Salang and Toek Laak pumping stations. All runoff from the total drainage area of 17.47 km^2 is collected through Meanchey Channel and is stored in Boeng Tompun before discharged by the pumping station. The second largest is Trabek pumping station with a present capacity of 5.2 m^3/s and drains runoff from the area of 10.63 km^2. These two pumping stations drain storm and sewerage water outside of the ring dike. Other pumping stations drain water intermediately or locally and they have small capacities.

Major ***drainage open channels*** in the City Core are Trabek, Toul Sen and Salang channels. These channels are in many parts clogged with debris and sediments. As a result, the flow capacities are remarkably restricted. The channels have been, from time to time, cleaned up by DPWT using their own equipment and by subcontracting with local firms, however the problems have not greatly been solved. It is reported that the clogging ratio is 70 to 80 % of the original flow areas. Outside the City Core, Meanchey Channel, aligned along the southwest perimeter of the Inner Ring Dike, has a great role to drain storm water in the Tompun catchment.

Sewer network had been constructed until the end of 1960s with city development. The sewers are mainly circle-shaped concrete pipes ranging 300 to 1,500 mm in diameter and the longitudinal gradients range from 1/500 to 1/2,000. The pipes are buried, with coverings of 0.5 to 3 m, on one side in narrow to medium streets and on both sides in wide streets. The present sewerage network system in the City Core is in Figure I2-7. A greater part of sewer pipes are choked with sediment and solid waste generated mainly by inhabitants neighboring. The choke rate is reported as 50 to 90 % of their original flow capacities. Along the riverfront of the Sap and Bassac rivers, sewer outfalls are found at 17 locations. Some are completely broken and the others are clogged with sediment and wastes.

Organization in charge of the maintenance of the dike is Road and Bridge Division of DPWT. Periodical maintenance work has not been conducted though rainfall and seepage have heavily damaged dikes, especially Kop Srov Dike. Drainage and Sewage Division of DPWT is in charge of the ***operation and maintenance*** of sewer system and pumping stations. Operation and maintenance manuals do not exist. Periodical dredging is conducted in the rainy season using excavators and trucks of DPWT. Cleaning of sewer pipe is also conducted not periodically according to the availability of budget for purchasing fuel. Weekly Report and Monthly Report for operation and maintenance work are submitted from the Director of DSD to the DPWT and MPP.

As ***non-physical measures*** for flood protection in the Municipality of Phnom Penh, flood forecasting/warning and flood defense activity is presently conducted. When the water level of the Tonle Mekong River come up to the warning level, committee and sub-committee to protect flood are declared and organized. These committees conduct necessary action to protect flood. Lack of budget was the problem for the activity.

2.7 Organization and Institution

Drainage improvement and flood control in Phnom Penh are under the jurisdiction of the Municipal Government. MPP is presently conducting a similar project, ADB Trabek Project, as the Executing Agency responsible for project implementation and coordination, and gaining experiences. ***Department of Public Works and Transport*** (DPWT) is the implementing agency for drainage improvement and flood protection. There is a total of 1,308 staffs (626 of full-time and 682 of part-time staffs, 1998). The DPWT is under the dual supervision of Ministry of Public Works and Transport (MPWT) and of the Vice Governor of the MPP in charge of infrastructure.

Drainage and Sewerage Division of DPWT has direct responsibility for drainage improvement. There is a total of 257 staffs. Of these, 118 are full-time and 137 are part-time.

CNATUC-CATUC-BAU (Bureau des Affaires Urbaines) is related to urban planning in the Municipality of Phnom Penh. CATUC (Committee for Country Planning, Urbanization and Construction), not yet organized in reality and BAU is acting as the implementing body of CNATUC (National Committee for Country Planning, Urbanization and Construction), is responsible to establish land use master plans. The land use master plan shall be firstly approved by CATUC for the municipality and subsequently by the CNATUC.

There is ***no law on water***, its use and its management in Cambodia. At present, no law regulates domestic or industrial wastewater disposal to rivers or to sewerage systems. In the Municipality of Phnom Penh, sewerage fee of 10% of water bill is collected from water users from 1997. The collected sewerage fee is paid from PPWSA to the account of MPP. "Law on the Country Planning, Urbanization and Construction" on May 24, 1994 (called as CNATUC Law) declares about country planning, urbanization, and construction.

2.8 Environment

Natural environment is as follows: Situated in a low flood plain is the most dominant topographical features of the area. All lakes and drainage channels have very poor quality due to direct discharge of sewage and garbage into them. The rivers also seem polluted by

untreated sewage to a lesser degree. The study area consists of the central urbanized areas and the peri-urban rural suburbs where paddy cultivation is common, hence aquatic faunal species especially different kinds of fish are common in various water bodies and the rivers. Existence of valuable floral species is not reported in the Study Area.

Land tenure condition is the following: There is presently a defined land registration procedure with roles of concerned governmental institutions defined. Cadastral mapping is also in progress. Land Law (1992) is the base law for land ownership. The Land Titles Department in the MPP has made a start in registering properties of the central district of Phnom Penh, but the progress is less due to complicated procedures.

Questionnaire survey on *resettlement issue* has been conducted in the Study. These areas are typically encroached areas or illegal squatter settlements. Average household size is 4.25 persons. The average household annual income is US$ 1,309. The average commuting distance for employed persons is about 3.3 km. The average residential area is 365m^2/household. About 61% of respondents have some sort of land ownership certificate. More than half the respondents (56%) showed their cooperation to relocate while 19.4% disagreed and 24.7% gave no opinion.

I3. MASTER PLAN STUDY

3.1 Premises for Study

In accordance with the Scope of Work, the *target year* for the Master Plan is defined as year 2010. The year 2010 is only 12 years ahead of the present, and the Mater Plan must therefore be formulated in strictly realistic considerations, especially on the future change in land use, growth of the socioeconomic frame, possible investments, and availability of land acquisition and house evacuation for the construction.

In due consideration of preceding practices in the similar projects in Southeast Asian capitals (Bangkok, Hanoi, Vientiane, Jakarta, Manila and Dhaka), the *protection levels* have been decided as follows:

Kind of Facilities	Protection Level
Flood protection facilities such as dikes, river walls, road heightening, etc.	30-year return period of water level (EL. 10 m) a little higher than the maximum water level since 1960 at Chaktomuk Station (EL. 9.96 m in 1961)
Major drainage facilities such as pumping stations, floodgates/sluiceways, regulation ponds, drainage mains (catchment area > approx. 1 km^2)	5-year return period of rainfall
Minor drainage facilities, meaning sewer systems (catchment area < approx. 1 km^2)	2-year return period of rainfall

3.2 Planning Conditions

Prior to the study for the Master Plan, planning conditions therefor have been established as stipulated below:

a. To save the initial investments as well as the operation and maintenance cost for structures/facilities, the non-physical measures will be incorporated as a major factor of the Master Plan.

b. Land acquisition and house evacuation must cause social conflicts in this area, so that the Master Plan should refrain from these as much as possible.

c. Taking into account deteriorated environmental condition in the city of Phnom Penh, alternatives in this study will include not only those for flood protection and drainage improvement but for the environmental enhancement.

d. Most area of the City Core has been furnished with sewer networks of the combined system to collect both storm water and wastewater. The present Master Plan includes improvement of drainage situation in the Study Area, but excludes sewerage problem from its scope of work.

3.3 Alternative Studies on Flood Protection

The most essential issues on the flood protection for the Study Area are:

- The protection line, meaning on which line the Study Area should be protected from floods brought about by the Mekong river system; and
- Basic measures for the flood protection.

<u>Protection Line along Sap Upstream and Bassac Sections</u>

These sections are short in height against the design high water level. In this case, two alternatives on the protection line are looked into: i. e. Alternative 1: Construction of dikes on the riverbanks; and Alternative 2: Promotion of flood defense activity in lower portions of the trunk roads (refer to Figure I3-1). The Alternative 1 requires cost as high as US$ 11,100/household and US$ 4,000/household for Sap Upstream and Bassac sections, respectively, compared with US$ 900/household in case of Tompun Watershed Drainage Improvement Project. This result indicates that the construction of dikes along the riverbanks can be a quite costly and ineffective exercise. In conclusion, most economical and reasonable measures for the flood protection in the two sections is to promote flood defense activity along NR-5 for Sap Upstream Section and along Samdach Sothearos/Norodom blvds. for Bassac Section.

<u>Riverfront Protection in Sap Downstream Section</u>

The bank of this section is higher than the design high water level, and rather stable except in its middle stretch from Street 108 to Street 184 with a length of approximately 1.0 km where revetments are damaged in places (refer to Figure I3-1). For the reconstruction of such revetments, the following two alternatives are suggested: i. e. Alternative 1: Stone pitching; and Alternative 2: Concrete facing. Taking into account the following points, it is recommended that Alternative 1 be applied to the slope protection for the stretch:

- The cost of Alternative 1 is a little lower than that of Alternative 2;
- Alternative 1 is, environmentally, superior to Alternative 2; and
- Maintenance of stone pitching is in wide meaning easier than the concrete facing.

Reinforcement of Kop Srov and Tompun Dikes

The height of the existing ***Kop Srov Dike*** is insufficient, by 1.1 m at maximum, safely to confine the design high water level plus a wave setup, and further the dike itself is judged to be structurally week to prevent piping through the dike body or its foundation (refer to Figure I3-1). In this connection, two alternatives are worked out: i.e. Alternative 1: Triple section, and Alternative 2: Single section. The cost comparison clarifies that Alternative 1 can achieve an about 10 % cost reduction compared with Alternative 2. Taking into account the relative easiness of construction as well, Alternative 1 is selected as the optimal reinforcement method.

The existing ***Tompun Dike***, on the other hand, has crest elevations enough to be free from overtopping, while the dike body, likewise in Kop Srov Dike, is in problem. As for Tompun Dike, the application of the land side berm method is recommended similar to Kop Srov Dike in view of economy and precedents in other countries.

Protection of South Area

With respect to the flood protection line, in other words whether the South Area will be protected or not, two alternatives are suggested: i. e. Alternative 1: On Prey Sar Road to protect the whole South Area, and Alternative 2: On the planned Tompun Extension Road in future and on BOT Road for the time being principally not to protect the South Area (refer to Figure I3-1). Naturally, Alternative 1 entails the heightening of Prey Sar Road, and provision of a pumping station at the Prey Sar Bridge site, a regulation pond near the pumping station and three floodgates across the existing outlets. The economic efficiency of this flood protection work can be assessed using the cost per number of beneficiary. It is as high as around US$ 4,900/household. Comparing with US$ 900/household in case of Tompun Watershed Drainage Improvement Project, this project is very costly and can be said unfeasible. The selection of Alternative 2 should be reasonable.

3.4 Studies on Drainage Improvement

The most important matters on the drainage improvement study are:

- Drainage direction of each basin; and
- Basic measures for drainage in each basin.

The drainage direction and basic measures in each basin are examined as presented in Figure I3-2. Most of the directions are naturally determined by the topography, land use and layout of existing drainage facilities except Pochentong East Basin. As for the drainage direction of Pochentong East Basin, the following three alternatives are examined, and Alternative 1 has finally been selected considering its easiness in land acquisition and so on:

- Alternative 1: To the south over BOT Road;
- Alternative 2: To Tompun Basin through Meanchey Channel; and
- Alternative 3: To the north up to Boeng Poungpeay.

Tompun Watershed

There exists a pumping station at the downmost of the watershed (17.47 km^2) on the immediate land side of Tompun Dike, whose capacity is rated at 5.9 m^3/sec on official base. In view of pump engineering, however, the pump capacity can be assessed nearly nil considering large volume of water leakage and deterioration of efficiency of pumps, motors and engines. It is technically difficult and even economically unreasonable not merely to repair such mechanical and electrical facilities but to rehabilitate the civil and architectural structure so aged and damaged. In this case, a new pumping station, called ***Tompun New Pumping Station***, shall be constructed for sure and entire drainage of the watershed. The location will be on the west side of the existing station where less compensation is expected. The existing station will then be left intact just for emergency.

The pumping station is the key element of drainage in the watershed, however it is uneconomical to cope with all the peak discharge solely by pumps. Assistance of a regulation pond is essential. Fortunately, a large lake, Boeng Tompun, is located just upstream of the pumping station (refer to Figure I3-2). This can function as a regulation pond with only a certain excavation of the lake bottom, which is named ***Tompun Regulation Pond.***

The following table shows the study results to seek an economically optimal ***combination of pump capacity and regulation pond volume*** based on the design hydrograph of Tompun Watershed with a return period of 5 years. Alternative 2 is the most economical, and hence selected as the optimal combination. The pump capacity is 15 m^3/sec and the necessary regulation pond volume is 560,000 m^3.

Dimensions and Construction Costs of Alternatives on the Combination of Pump Capacity and Regulation Pond Volume

Alternative	Pump Capacity (m^3/sec)	Regulation Pond (47.5 ha) *			Construction Cost (US$ million)
		Necessary Volume (m^3)	Regulation Water Depth (m)	Low Water Level (EL. m)	
1	9	750,000	1.6	2.9	12.6
2	15	560,000	1.2	3.3	12.3
3	21	450,000	1.0	3.5	13.0
4	27	370,000	0.8	3.7	14.3
5	33	290,000	0.7	3.8	14.5

* The design surcharge water level is set at EL. 4.5 m.

Meanchey Drainage Main is an open channel running along outside of the Inner Ring Dike and conveys all storm water from the watershed finally to discharge to the Tompun Pumping Station site (refer to Figure I3-2). The channel improvement is as follows:

Features of Meanchey Drainage Main

Description	Downstream Section	Upstream Section
Improvement Length (km)	Approx. 2.8	Approx. 2.1
Design Discharge (m^3/sec)	75	15 & 11
Longitudinal Profile	To be dug as deep as possible to ease drainage in the City Core area. 1/2,500.	To keep the existing profile not to affect riverine houses. 1/2,000 & 1/1,000.
Cross-section	Earth channel	Earth and revetted channels

In the City Core portion of Tompun Watershed with a catchment area of 6.31 km^2, there are no open drains. This is very exceptional compared with other cases, e.g. in Hanoi City are open drains with densities of 1 km or more per km^2. Such lack of open drains is a main reason why the area suffers from repeated inundation even in small rains when the total rainfall becomes over approximately 50 mm. However, this area is completely congested with buildings, apartments and ordinary housing. No space is found for newly excavating open drains at all. Only the solution to be conceived in this case is establishment of a drainage system mainly comprising ***underground drainage mains*** as follows:

a. Construction of Samdach Monireth Drainage Main, of box culvert type with design discharges of 44 and 20 m^3/sec, and Jawaharlal Nehru Drainage Main (box culvert, 8 m^3/sec) beneath the respective streets with the same names, connecting to Meanchey Drainage Main near Meanchey Bridge;

b. Construction of Salang Drainage Main digging the existing Boeng Salang south lake (21 m^3/sec), while Boeng Salang north lake being left intact; and

c. Provision of a sluiceway across the Inner Ring Dike to lead storm water in Tum Nup Toek Basin to Meanchey Drainage Main (10 m^3/sec).

The existing ***sewer network***, of the combined system, will be rehabilitated by means of furnishing new pipeline networks because most existing pipes are largely short in capacity. The coverage area is 631 ha.

Trabek Basin

For the Trabek Basin (10.83 km^2), on the same philosophy as applied to Tompun Watershed, a new pumping station will be provided on the west side of the existing one, and Boeng Trabek will be dug for regulation (refer to Figure I3-2). The capacity of ***Trabek New Pumping Station*** has been set at 8 m^3/sec according to the ADB project, and the official capacity (4.2 m^3/sec) of the existing station is ignored. ***Trabek Regulation Pond*** (28.7 ha) should hence store a volume remaining after subtracting the new pump capacity of 8 m^3/sec constantly from the hydrograph, i.e. 350,000 m^3 .

The following three ***drainage mains*** are conceived in Trabek Basin on the basis of the same strategy as applied to Tompun Watershed:

a. Trabek Drainage Main, of the box culvert type, along the existing Trabek channel;

b. Toul Sen Drainage Main along the existing channel, of the box culvert type in the downstream stretch while of the open channel type in the upstream stretch; and

c. Norodom Drainage Main, of the box culvert type, on a new route under Street 360 and Norodom Blvd.

The existing ***sewer network***, of the combined system, will be rehabilitated in the same way as in Tompun Watershed. The coverage area is 1,083 ha.

City Core North Area

Toul Kork Basin in the City Core North Area (6.57 km^2) has a comparatively large catchment (3.32 km^2), hence requiring construction of ***drainage mains***. Two underground drainage mains are proposed along Streets 289 and 315. Both drainage mains discharge to the Northeast Area by gravity. Refer to Figure I3-2.

One ***drainage sluiceway*** will be installed at the discharge point of Boeng Kak to ensure drainage and to control water stage of the lake. In addition, similar sluiceways will be constructed in Toul Kork Basin (3 locations) and University Basin (2 locations).

In the same line as in Tompun Watershed, the existing ***sewer networks*** will be rehabilitated. The total coverage area is 472 ha.

Pochentong East Basin

For this basin (15.35 km^2), one ***pumping station*** will be constructed near the existing pipe culvert across BOT Road (refer to Figure I3-2). On the east side of the station, there were two slender lakes: north and south lakes. However, the south lake has been reclaimed, so that the north lake (6.0 ha) can only be used as the ***regulation pond***. Its regulation volume is limited to 60,000 m^3, which can achieve a peak cut of 5 m^3/sec, giving the pumping station a design capacity of 5 m^3/sec.

Major part of Pochentong East Basin has been prepared for future developments furnished with a canal network. This network can be used as ***drainage mains*** in the Master Plan with only providing some revetment works.

There exists a ***closing gate*** at the outlet of the North Lake (regulation pond) to control the discharge to Tompun Watershed and water level of the lake. This gate is an important structure to protect Tompun Watershed from excess water generated in Pochentong East Basin, etc. The structure will be rehabilitated in the scope of the Master Plan.

Northeast and Northwest Areas

In the Northeast and Northwest areas (100.09 km^2), storm water from the catchment is drained through ***Svay Pak Drainage Sluiceway*** to the Tonle Sap River when the river water stage is low, while in the reverse case it is stored in the swampy area (refer to Figure I3-2). The sluiceway is a crucial structure for the flood protection in the Study Area. Once that were broken down, the northern half of the Study Area should go under water. The existing sluiceway, partially damaged, will be rehabilitated under the Master Plan.

The major purpose of ***Poungpeay Drainage Main*** is to convey to Boeng Poungpeay storm water in M3, Pochentong West Basin presently intruding into Pochentong Airport and even inflicting damage over Pochentong East Basin.

Poungpeay East Basin is partitioned by several embankments for roads and railways. Some are furnished with pipe culverts, whose sizes are however insufficient to drain storm water. This condition causes not merely inundation in the rainy season but deterioration of water quality in the dry season. Construction of twelve ***sluiceways*** is hence proposed.

3.5 Studies on Environmental Enhancement

The Master Plan examines on environmental enhancement over the Study Area, although it is limited within the scope of flood protection and drainage improvement. The measures comprise river front conservation, lake conservation and "Green Channel" plan.

3.6 Formulation of Master Plan

According to the alternative studies on flood control, drainage improvement and environmental enhancement, preliminary designs for ***physical measures*** have been made. The results are depicted in a figure by component as follows (refer to Figure I3-3):

- Component 1: Riverfront Protection in Sap Downstream Middle Section (refer to Figure I3-6);
- Component 2: Reinforcement of Kop Srov and Tompun Dikes (refer to Figure I3-4);
- Component 3: Tompun Watershed Drainage Improvement (refer to Figure I3-5);
- Component 4: Trabek Basin Drainage Improvement (refer to Figure I3-6);
- Component 5: City Core North Drainage Improvement (refer to Figure I3-7);
- Component 6: Pochentong East Drainage Improvement (refer to Figure I3-8);
- Component 7: Northeast and Northwest Areas Drainage Improvement (refer to Figure I3-9); and
- Component 8: Environmental Enhancement (refer to Figures I3-5 and 7)

Comprehensive flood protection and drainage improvement cannot be materialized solely by the physical measures, but should incorporate the ***non-physical measures***. The land use control and flood defense activity are most applicable and effective among the non-physical measures in the Study Area:

a. Land Use Control (comprising zoning control and development and building control): Municipality of Phnom Penh has not yet established an authorized city development plan for its territory. This causes uncontrolled developments in many locations, not only destroying environments of the city but jeopardizing the function of flood protection and drainage facilities. Early establishment of the city development plan is strongly anticipated to control such condition. From the viewpoint of flood protection and drainage improvement, the following should be included in the plan:

   - Water zone conservation in the Northeast Area; and
   - Agricultural land conservation in the Northwest and South areas.

b. Flood Defense Activity: This is another important factor in the non-physical measures. Municipality of Phnom Penh, under coordination with Ministry of Public Works and Transport and other ministries concerned, forms an ad hoc committee for flood defense during high water stage of the Mekong river system (refer to Figure I3-10), and makes great effort to protect Phnom Penh City from being flooded. The

Master Plan considers such effort still essential to reinforce and ensure the function of facilities to be provided under the plan.

The ***project cost*** required for the implementation of the Master Plan is estimated as follows:

Project Costs of Eight Components in the Master Plan

Component	Project Cost (US$ million)
1: Riverfront Protection in Sap Downstream Middle Section	2.3
2: Reinforcement of Kop Srov and Tompun Dikes	17.8
3: Tompun Watershed Drainage Improvement	88.6
4. Trabek Basin Drainage Improvement	94.5
5: City Core North Area Drainage Improvement	32.0
6. Pochentong East Basin Drainage Improvement	11.9
7. Northeast and Northwest Areas Drainage Improvement	12.1
8: Environmental Enhancement	1.9
Total	261.6

Table I3-1 is an ***implementation schedule*** for the Master Plan worked out in the following considerations:

a. Components with higher economy should be implemented earlier than others. The individual EIRR of each component is as follows:

Individual EIRR and the Rank of Each Component

Component	EIRR (%)	Rank
1: Riverfront Protection in Sap Downstream Middle Section	- 0.5	6
2: Reinforcement of Kop Srov and Tompun Dikes	24.8	1
3: Tompun Watershed Drainage Improvement	11.0	2
4: Trabek Basin Drainage Improvement *	9.1	3
5: City Core North Area Drainage Improvement	5.3	4
6: Pochentong East Basin Drainage Improvement	4.8	5
7: Northeast and Northwest Areas Drainage Improvement	- 2.1	7
8: Environmental Enhancement	No tangible benefit	8
Total	12.9	-

* The construction of major facilities, Trabek pumping station and Trabek and Toul Sen drainage mains, will start in 1999 under the loan from ADB.

b. Disbursement amounts in each year are assumed to be around US$ 10 to 15 million considering possible implementation by Japan's Grant.

c. In Components 3, 4 and 5, the major drainage works such as construction of pumping stations, regulation ponds and drainage mains with high cost performance should be followed by the sewer rehabilitation of lower cost performance. In this context, it is premised that the major drainage works be completed by year 2010 while the sewer rehabilitation by year 2020.

Table I3-1 Implementation Schedule for the Master Plan

Project Component	Cost in US$ mil	Year 2000	01	02	03	04	2005	06	07	08	09	2010	11	12	13	14	2015	16	17	18	19	2020
Component 1: Riverfront Protection in Sap Downstream Middle Section (1.0km)	2.3																					
Component 2: Reinforcement of Kop Srov and Tompun Dike	17.8																					
a. Reinforcement of Kop Srov Dike (9.0km)	16.2																					
b. Reinforcement of Tompun Dike (4.4km)	1.6																					
Component 3: Tompun Watershed Drainage Improvement	88.6									53.7												34.9
a. Tompun Pumping Station (15m³/s) and Regulation Pond	15.7																					
b. Meanchey Drainage Main, Downstream Stretch (2.76km long)	5.0																					
c. Meanchey Drainage Main, Upstream Stretch (2.135km long)	1.9																					
d. Tum Nup Toek Drainage Sluiceway (2mx2mx1 lane)	0.4																					
e. Samdachi Monireth Drainage Main (2.36km long)	24.8																					
f. Jawaharlal Nehru Drainage Main (1.16km long)	3.6																					
g. Salang Drainage Main (1.89km long)	2.3																					
h. Sewer Rehabilitation excluding Tum Nup Toek Basin (931ha)	32.8																					
i. Sewer Construction, Tum Nup Toek Basin (68ha)	2.1																					
Component 4: Trabek Basin Drainage Improvement	94.5								42.0													52.5
a. Trabek Pumping Station (8m³/s) and Regulation Pond	18.2																					
b. Trabek Drainage Main (1.604km long)	13.7																					
c. Toul Sen Drainage Main (2.05km long)	4.0																					
d. Norodom Drainage Main (1.768km long)	6.1																					
e. Sewer Rehabilitation (1,083ha)	52.5																					
Component 5: City Core North Area Drainage Improvement	32.0										12.5											19.5
a. C1: Wat Phnom Basin, Sewer Rehabilitation (89ha)	4.3																					
b. C2: Kak Lakeshore Basin, Sewer Rehabilitation (51ha)	0.4																					
c. C3: Boeng Kak Basin, Kak Drainage Sluiceway	0.4																					
d. C4: Tool Kork Basin, Major Drainage Facilities	11.5																					
e. C4: Tool Kork Basin, Sewer Rehabilitation (332ha)	14.8																					
f. C5: University Basin, Drainage Sluiceways (2 locations)	0.7																					
Component 6: Pochentong East Basin Drainage Improvement	11.9																					
Component 7: Northeast and Northwest Areas Drainage Improvement	12.1																					
a. Poungpeay Drainage Main (11.92km)	10.4																					
b. Svay Pak Drainage Sluiceway (2mx2mx2 lanes)	0.7																					
c. Drainage Sluiceways in Poungpeay East Basin (12 locations)	1.1																					
Component 8: Environmental Enhancement	1.9																					
a. Environmental Canal (1.75km long)	1.7																					
b. Kak Interceptor (0.85km long)	0.2																					
Total	261.1	154.2											106.9									

3.7 Recommendation for Organization and Institution

The ***Executing Agency*** for the implementation of the Master Plan will be the Municipality of Phnom Penh, and the DPWT, MPP will be the ***Implementing Body***. In the DPWT, Drainage and Sewage Division (DSD) is the agency specifically responsible for the management and operation of drainage facilities. However, any organization is not appointed specifically for flood protection at present, so that creation of Flood Protection Division (FPD) under the DPWT is strongly recommended (refer to Figure I3-11).

Capacity building for DPWT staffs especially pertinent to basic knowledge is presently conducted through "Institutional Capacity Building Component and the Neighborhood Improvement Program". After the creation of a division responsible for flood protection, capacity building regarding river engineering must be incorporated in the program.

Various ***laws and regulations*** should be developed as soon as possible. Of these, first priority should be given to a regulation pertinent to flood protection and drainage which must include clauses defining charge collection system for operating and maintaining the relevant facilities. Second priority should be given to one related to the land use master plan in Phnom Penh City.

I4. PROJECT EVALUATION

4.1 Economic Evaluation

Based on the socioeconomic framework and land use in year 2010, the amounts of direct damage by flooding and inundation have been estimated for building properties/assets and agricultural products. Indirect damage, say inconvenience in transportation and water supply and health problems, is assumed at 30 % of the direct damage. ***Economic benefit*** is calculated as a difference in damages between with- and without-project conditions.

Economic evaluation for the established Master Plan has been conducted, the results of which are tabulated below. In the evaluation, the opportunity cost of capital is assumed at 10 % and the evaluation period is 50 years.

- Economic Internal Rate of Return (EIRR) : 12.9 %
- Benefit Cost Ratio (B/C) : 1.25
- Net Present Value (NPV or B-C) : US$ 32.1 million

It is clarified that the Master Plan shows sufficiently high economic return, compared with the opportunity cost of capital at 10 %.

4.2 Financial Affordability

The implementing body is the DPWT of MPP, and Drainage and Sewerage Division will directly be in charge. Accordingly, the DSD's revenue and the master plan's fund requirement are compared to judge financial affordability of the project as follows:

(Unit: $ million)

Item		2010	2020
Revenue	Budget (Standard Scenario)	0.39	0.76
	Wastewater Surcharge (10% of water sale)	1.51	2.06
	Total	1.90	2.82
Fund Requirement	Depreciation (total cost)	3.08	5.22
	Operation and Maintenance Costs	0.77	1.31

As presented in the table, it is difficult to cover the depreciation cost of the capital investment by the DSD's budget. The annual investment amount of around US$ 10 to 15 million is considered reasonable if implementation is conducted using some form of foreign assistance. Operation and maintenance costs can be covered by the increased budgetary revenue for DSD with wastewater surcharge.

4.3 Initial Environmental Examination

An adverse impact by the implementation of the project is improvement of living environment through reduction of flooding risks and drainage improvement, the objective of the project. Negative impacts on natural environment e.g. turbid water flow and dust during construction will be minimized through introduction of proper environmental management and monitoring plans. Negative impacts of relocation are anticipated as social environment aspect, but they can be controlled by the formulation of appropriate mitigation measures.

4.4 Technical Evaluation

Cambodia has experienced construction of dikes, revetments, pumping stations, open channels and sewers by himself or under foreign assistance. No difficulty would thus be encountered in the actual construction of Master Plan projects, except for (a) the electrical and mechanical works in pumping stations and sluiceways, (b) temporary works such as earth retaining in underground drainage mains, and (c) PC pipe fabrication in sewers. Pumps, gates and the appurtenance in Item (a) above shall be imported from a developed country, and the installation, operation and maintenance shall be conducted by Cambodian engineers under the supervision and technical training by engineers from such a country. Moreover, there might not be practices to date in earth retaining, with high sheet pile walls and H-beam struts, in Item (b), and fabrication of PC pipe in Item (c). Advanced technology therefor shall be introduced from neighboring countries.

I5. IDENTIFICATION OF PRIORITY PROJECTS

The total Master Plan, either physical or non-physical measures, has been confirmed to be economically viable, financially affordable, environmentally sound and technically possible. This Section, as the final stage of the Master Plan study, attempts to identify one or some priority project(s) to be subject to the succeeding feasibility study. The logic for the identification is as follows:

a. Three components, Reinforcement of Kop Srov and Tompun Dikes, Tompun Watershed Drainage Improvement, and Trabek Basin Drainage Improvement, are of higher economic viability, namely 24.8 %, 11.0 % and 9.1 % of EIRR, respectively.

The others are rather low in EIRR, say less than 6 %, which can naturally be out of the priority projects.

b. As for Trabek Basin Drainage Improvement among the three, the construction of a new pumping station and drainage mains is on schedule starting in mid-1999 under the loan from ADB. This is also omitted from the priority projects.

c. On the other hand, Kop Srov and Tompun dikes play an important role in protecting the Municipality of Phnom Penh from floods of the Mekong River system. Once these should breach, most part of the city would go under floodwater. Taking into account its high economy as well, Reinforcement of Kop Srov and Tompun Dikes must be a component of the priority projects. Moreover, Svay Pak Drainage Sluiceway with the same nature as the dikes shall be reconstructed under this component although it was included in Component 7 in the Master Plan.

d. The eastern half of the urbanized area of Phnom Penh is being safe from inundation through the Trabek Project financed by ADB, however the western half will yet suffer from repeated inundation. To solve this, Tompun Watershed Drainage Improvement targeting said area shall be promoted as another component of the priority projects. However, sewer rehabilitation in the drainage improvement is excluded from this component.

Summarizing the above, the priority projects to be examined in the succeeding feasibility studies are identified as follows:

- Project A: Reinforcement of Kop Srov and Tompun Dikes
  (including reconstruction of Svay Pak Drainage Sluiceway)
  Component 2 and a part of Component 7

- Project B: Tompun Watershed Drainage Improvement
  (excluding sewer rehabilitation)
  A part of Component 3

Part II

Feasibility Studies on Reinforcement of Kop Srov and Tompun Dikes and Tompun Watershed Drainage Improvement

THE STUDY ON
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

SUMMARY - PART II

FEASIBILITY STUDIES ON
REINFORCEMENT OF KOP SROV AND TOMPUN DIKES AND
TOMPUN WATERSHED DRAINAGE IMPROVEMENT

TABLE OF CONTENTS

II1. INTRODUCTION

In the Master Plan of drainage improvement and flood control in the Municipality of Phnom Penh formulated in Part I of this report, the proposed facilities have been packaged into eight components. Priority for the implementation of these component projects has been determined in the last part of Part I Master Plan Study, and the following two projects have been selected as priority projects:

- Project A: Reinforcement of Kop Srov and Tompun Dikes
- Project B: Tompun Watershed Drainage Improvement

This part of the report compiles the results of the feasibility study on the above two priority projects. All the planning conditions applied to the Master Plan are also applied for this feasibility study.

II2. PRESENT CONDITIONS AND RESULTS OF BASIC STUDY

2.1 Socioeconomy

Population in the areas for feasibility study is estimated based on the population by sub-districts. The following are the derived population in 1998:

- Northeast, Northwest and Middle Areas (protected by Reinforcement of Kop Srov and Tompun dikes) : 227,000
- Tompun Watershed (bettered by Tompun Watershed Drainage Improvement) : 269,000

2.2 Land Use and City Planning

Along the ***Kop Srov Dike***, human occupation on the dike is continuously growing, mostly as a precarious, squatter-like kind of habitations. The dike road is presently used for servicing these housings. If left uncontrolled this trend would lead to its destruction in the short term. After the rehabilitation of this dike, it will then naturally become a major way of transit, bringing along different kinds of activities. Proper management forbidding what could lead to an alteration of the dike, such as too close settlement, should be introduced.

The dike occupation along the ***Tompun Dike*** is recent and already almost continuous. It plays a major role for the servicing of the newly developing urban zone, which gives it a mid-term vocation as an urban boulevard. Most proposals for a close ring road include a section along this dike, and suggest that the dike road should naturally be extended eastwards, up to the NR-2.

The ***Boeng Salang area*** is the second big catchment of the city core. The road network and urbanization is almost complete in this area, mainly with a dense residential urban type of occupation. The current natural trend is the completion of the ongoing urbanization process, mainly in the southwestern zone, and densification in other areas with often illicit and precarious habitations, especially around the boeng. For this status, following the CNATUC law for urban planning, a sub-decree has been adopted by the Government in 1997, which takes over the full urban planning and restructuring of the Boeng Salang sector and its retention basin. No concrete action, however, has been taken so far.

On the contrary, in the ***Boeng Tompun area*** occupation really started only 4 or 5 years ago. It has risen rapidly to more than 40,000 people. No coherent planning has been used to guide this development, and little infrastructure exists apart from the main drain and natural retention basin. In the near future this fast and unregulated development is likely to carry on. It seems more wishful that the Municipality would take the opportunity of the current drainage improvement Project, to develop an urban master plan for this area.

2.3 Meteorology and Hydrology

The ***hydrological study*** in this feasibility study stage focuses on the City Core including Tompun Basin, where the Tompun Watershed Drainage Improvement selected as a priority project is situated, and targets to give more detailed baseline for facility design in the feasibility study. All the study results, together with necessary data, on meteorology and hydrology for the feasibility studies have been reflected in the Master Plan Study and already been compiled in Part I.

2.4 Topography and Geology

The ***topographic survey*** has been conducted for the feasibility study. Cross-sectioning and profiling total 28.68 km, sounding 11.74 km with 20-line, and topographic mapping 13.4 ha with a 1/1,000 scale.

Soil mechanics investigation comprises 11 borings, 19 test pittings and laboratory tests for samples taken from the above. Major findings are:

The bearing layer for the ***Kop Srov Dike*** slopes down constantly from west to east. It appears on EL. 4.5 m (4 m deep from the ground) near the western edge of the Dike, while EL. -16.6 m (26.5 m deep from the ground) at Tonle Sap River (near the ***Svay Pak Drainage Sluiceway*** site). The bearing layer is unchangingly composed of sandy clay. Proposed to be constructed in the area are, a drainage sluiceway comprising 3 cells of box culverts (1.5 m wide and 2 m high), and Kop Srov Dike with heights of 3 to 4 m. The Svay Pak sluiceway will be safely supported by foundation piles reaching the bearing layer with an approximate length of 20 m. No special treatment is needed for the foundation of the Kop Srov dike.

A clay layer, sometimes intruded by sand and clayey sand layers, uniformly covers the bearing layer. The clay is commonly firm, over 10 of N-value in general, and of low to medium plasticity. This nature of the clay will allow shallow excavations without difficulties such as slope failure and hazardous seepage. However, this clay, almost pure clay, cannot apply to embankment material for Kop Srov Dike.

In stead, soils procured from the ***Udon and Basset borrow areas*** are considered for that purpose. The former borrow is approximately 30 km away from Kop Srov Dike through NR-5 (well paved in most stretch), and has supplied good quality of laterite for various projects. On the other hand, the latter borrow is within an about 15 km distance from the construction site, however the access roads are quite poor and the soil is too coarse for dike material. In this case, it is recommended that the embankment material for Kop Srov Dike be transported from the Udon borrow area.

The three boreholes dug in the *City Core* area are EL. 7.1 to 10.2 m in ground level, EL. 4.8 to 5.6 m in groundwater level, and EL. - 5.4 to - 3.2 m in bearing layer (say, 12 to 15 m deep from the ground surface). By location, there exists less difference in each item. The soil of the bearing layer is sandy clay and clayey sand, which composition is similar to along Kop Srov Dike. Most remarkable structures proposed in the City Core is the construction of box culverts, Samdach Monireth and Jawaharlal Nehru drainage mains, both underneath streets of the same name. The box culverts will be laid on the formation approximately between EL. 1 m and EL. 3 m (about 6 to 7 m deep under the street surfaces). To support the structure safely, piles shall be driven down to the bearing layer, however the lengths are expected to be not more than 8 m.

The bearing layer is overlain by a cohesive soil layer composed of clay, sandy silt and backfills of 12 to 15 m thick. The upper 3 to 4 m portion of the layer is relatively soft with N-values of 0 to 6, whilst the lower portion is firm with over 10 of N-value. This soil condition may pose no serious issues for shallow excavation and dredging anticipated along Salang Drainage Main and at the Tum Nup Toek Drainage Sluiceway site. However, the construction of box culverts beneath Samdach Monireth and Jawaharlal Nehru streets, with 6 to 7 m excavation, should incorporate temporary retaining walls of steel sheet piles in view of the considerably high groundwater level and low plasticity of the soil

The results of two borings at Tompun Dike show ground levels of EL. 4.7 m and EL. 5.0 m, groundwater levels of EL. 2.5 m and EL. 3.2 m, and bearing layers (sandy clay) of EL. - 10.8 m and EL. -9.5 m, respectively. ***Tompun Pumping Station*** is proposed at this site. To ensure the stability of the station, bearing piles shall be driven under the structure with an approximate length of 10 m.

On top of the bearing layer, there lies a relatively soft subsoil of approximately 15 m thick or more. Its N-values are 10 to 20 as a whole. Different from the areas along Kop Srov and in City Core, the subsoil in the Tompun area is characterized by its alternating stratification comprising cohesive layers, such as clay, silty clay and sandy clay layers, and sand layers such as clayey sand and silty sand layers. The cohesive layers are comparatively firm, but of low plasticity likewise in the City Core area. Despite such alternation of cohesive and sand layers, the upper 5 m subsoil is supposed to be cohesive and slightly firm, in most places, taking into account the test pit results as well. Shallow excavation planned in the project may thus not encounter serious problems. However, the excavated material is recommended to be hauled to adequate spoil banks, not to be used for backfilling or embankment.

II3. REINFORCEMENT OF KOP SROV AND TOMPUN DIKES

3.1 General

Project A: Reinforcement of Kop Srov and Tompun Dikes (correspondent to Component 2 and a part of Component 7 in the Master Plan), aims at flood protection for a major part of Phnom Penh City against a 30-year probability of floodwater level in the Tonle Mekong river system. All the ***premises and major conditions*** established in the Master Plan are still valid in this feasibility study. The Project consists of the following four ***sub-components*** (refer to Figure II3-1):

(a) Sub-component A1: Reinforcement of Kop Srov Dike with a length of 7.65 km

(b) Sub-component A2: Reinforcement of Tompun Dike with a length of 4.44 km

(c) Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway with a 3-lane box culvert of 1.5 m wide and 2.0 m high per each lane

(d) Sub-component A4: Preparation of Relocation Site and Spoil Area with a total area of 25 ha

3.2 Preliminary Design

Kop Srov Dike

In-depth survey in the feasibility study stage revealed detailed topography, elevations and conditions of the existing Kop Srov Dike. As a result, the ***reinforcement measures by stretch*** is decided as shown in the following table (refer to Figure II3-2):

Measures Applicable by Stretch

Section	Crest Height of Existing Dike	Possibility of Wave Setup (Necessity of Freeboard)	Condition of Existing Dike Body	Measures	
				For Dike	For Road
0+000 to 0+900 (900 m long)	EL. 10.5 to 10.7 m (higher than the design HWL EL. 10.4 m)	Not possible (another road in front of the stretch with a lot of houses and trees), then no freeboard required.	Few damaged portions exist.	Not to be constructed.	To be paved to connect the following section with NR-5.
0+900 to 7+650 (6,750 m long)	EL. 10.1 to 10.9 m (partly lower than the design HWL 10.4 m)	Possible (directly facing on a swamp area along the Prek Phnov), then a freeboard necessary.	Serious damage, such as piping holes, gullies, etc. found in many places.	To be constructed with a crest elevation of 11.2 m.	To be paved.
South from 7+650 (9,350 m long)	Above EL. 10.5 (higher than the design HWL EL. 10.4 m)	Not possible (new embankments for a temple and factories, in addition to old villages, located in front), requiring no freeboard.	No damage observed along the stretch.	Not to be constructed.	To be paved to connect the above section with NR-4.

The construction method of ***Kop Srov Dike*** shown in Figure II3-3 can achieve an about 10 % of cost reduction compared with full-width heightening of the existing dike road and moreover has the following advantages:

- To ensure seepage prevention by filling non-permeable soil on the riverside;
- To secure space for dike construction outside the existing roadway; and
- To minimize evacuation of houses that are much more built on the inner side.

The dike is 3 m wide on its crest, and slopes down at 1:2 on both sides with sod facing. The material of diking will be of laterite, which is suitable to control seepage so that a land side berm proposed in the Master Plan can be left out.

The existing ***road*** surface will be paved with high quality asphalt between the junctions with NR-5 and NR-4 (17,000 m in length). The pavement is for the following purpose:

- Easy operation of flood defense and maintenance of the dike;
- Prevention of piping holes made by seepage of rainfall on the dike crest; and
- Protection of the dike body from heavy traffic.

Considering that the road may constitute in future a part of the proposed Outer Ring Road, cross-sectional design of the road follows Cambodian National Road Standard, specifically a carriageway of 7.0 m with 1.5 m shoulders (refer to Figure II3-3).

Tompun Dike

Field reconnaissance in the feasibility study stage has identified in detail the existing conditions of ***Tompun Dike*** with a length of 4.44 km and damage incurred by the 1996 flood. The results lead the conclusion that (refer to Figure II3-4):

a. Provision of a land side berm proposed in the Master Plan is not so effective, and moreover this should bring about a huge number of house evacuation (more than 260 houses); and

b. Instead, pavement on the dike crest is recommended to prevent seepage from the crest to both slope surfaces and for easy maintenance of the dike.

Likewise with Kop Srov Dike road, considering that Tompun Dike ***road*** may constitute in future a part of the proposed Outer Ring Road, cross-sectional design of the road follows Cambodian National Road Standard, specifically a 7.0 m carriageway of the high quality asphalt with 1.5 m shoulders.

Svay Pak Drainage Sluiceway

There exists a sluiceway passing under NR-5 about 2 km southward from the intersection to Kop Srov Dike, which will be re-constructed under the Project. The proposed sluiceway is of the general type of RC gate structure with manually-operated steel slide gates (1.5 m wide, 2.0 m high and 3 sets).

Relocation Site and Spoil Area

No ***land acquisition*** is necessary for the construction of Sub-components 1 to 3, while ***house evacuation*** of 54 houses in the section from 0+900 to 7+650 of Kop Srov Dike. Suggested as one of the relocation sites for them is the narrow housing zone (25 ha) along a part of Kop Srov Dike which was once constructed under the assistance of UNBRO (refer to Figure II3-2).

On the other hand, the construction of Kop Srov Dike will produce approximately 200,000 m^3 of excess soil. That soil can be used for raising the formation of the UNBRO area by about 1 m, then making the area free from inundation. The UNBRO area is hence recommended as the ***spoil area*** for construction. Moreover, the raised UNBRO area can serve as the ***relocation site*** for the 54 households. The relocation site will be furnished with necessary infrastructures, such as roads, electricity, wells and sanitary facilities.

3.3 Cost and Schedule

The ***project cost*** for the Reinforcement of Kop Srov and Tompun Dikes amounts at approximately US$ 20.8 million, whose breakdown by sub-component is presented below:

Project Cost for the Reinforcement of Kop Srov and Tompun Dikes

Sub-component	Project Cost (US$ million)
A1: Reinforcement of Kop Srov Dike	15.9
A2: Reinforcement of Tompun Dike	3.2
A3: Reconstruction of Svay Pak Drainage Sluiceway	1.0
A4: Relocation Site and Spoil Area	0.7
Total	20.8

Table II3-1 shows the ***implementation schedule*** for the Project. The actual construction will initiate in 2001 and terminate in 2003 with a construction period of 3 years. The year 2000 will be allocated for the basic and detailed designs of the structures/facilities by a proper consulting firm, and land acquisition and house evacuation necessary for securing right-of-way for the construction.

3.4 Project Evaluation

The results of the ***economic evaluation*** for the Project are tabulated below, from which this Project is judged to have sufficiently high economic return with an EIRR higher than the opportunity cost of capital of 10 %. The Project is proved to be worth being promoted to the implementation stage.

Economic Indices for the Reinforcement of Kop Srov and Tompun Dikes

Indices	Reinforcement of Kop Srov and Tompun Dikes	Including Tompun Watershed Drainage Improvement
EIRR (%)	25.2	16.7
B/C	2.76	1.69
NPV (US$ thousand)	29,475	35,384

Note: B/C and NPV with the discount rate of 10%

As of 2008 when the facilities start operation, the DSD's revenue from government budget reaches the level slightly above the operation and maintenance cost (refer to the following table). The Project is ***financially affordable*** from the O/M cost recovery viewpoint.

Comparison of DSD's Revenue and O/M Cost

Item	Amount (US$ million)
Revenue by Government Budget in 2008	0.34
Wastewater Surcharge Revenue in 2008	1.41
Total Revenue in 2008	1.76
Total O/M Cost Required since 2008	0.32
Balance	1.40

Table II3-1 Implementation Schedule for the Reinforcement of Kop Srov and Tompun Dikes and for the Tompun Watershed Drainage Improvement

Project Component	Cost (US$ mil.)	Year 2000	2001	2002	2003	2004	2005	2006	2007
Project A: Reinforcement of Kop Srov and Tompun Dikes	20.8								
-Sub-component A1: Reinforcement of kop Srov Dike (7.65 km)	15.9								
-Sub-component A2: Reinforcement of Tompun Dike (4.44 km)	3.2								
-Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway	1.0								
-Sub-component A4: Preparation of Relocation Site /Spoil Area (25 ha)	0.7								
Project B: Tompun Watershed Drainage Improvement	50.8								
-Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel (15 m^3/sec)	11.5								
-Sub-component B2: Construction of Tompun Regulation Pond (47.5 ha)	3.6								
-Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch (2.635 km)	3.8								
-Sub-component B4: Improvement of Meanchey Drainage Main, Middle Stretch (1.285 km)	0.5								
-Sub-component B5: Improvement of Meanchey Drainage Main, Upstream Stretch (0.535 km)	0.5								
-Sub-component B6: Construction of Tum Nup Toek Drainage Sluiceway (10 m^3/sec)	0.7								
-Sub-component B7: Construction of Samdach Monireth Drainage Main, Downstream Stretch (1.676 km)	16.3								
-Sub-component B8: Construction of Samdach Monireth Drainage Main, Upstream Stretch (0.714 km)	3.7								
-Sub-component B9: Construction of Jawaharlal Nehru Drainage Main (1.152 km)	4.1								
-Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch (0.887 km)	1.3								
-Sub-component B11: Improvement of Salang Drainage Main, Upstream Stretch (0.488 km)	0.6								
-Sub-component B12: Conservation of North Lake of Boeng Salang (5.1 ha)	0.7								
-Sub-component B13: Preparation of Relocation Site / Spoil Area (26 ha)	3.5								
Total	71.6	1.05	13.10	14.00	13.45	7.20	7.20	7.55	8.05

An adverse impact by the implementation of the project is improvement of living environment through reduction of flooding risks. As a result of the ***Environmental Impact Assessment***, some negative impact that includes turbid water flow, dust and noise during construction, and replacement of a total of 54 houses. All these negative impact can be minimized and solved if appropriate environmental management and monitoring plans are introduced.

Structures required for the Project are so simple that ***no technical difficulty*** can be encountered in designing, construction and even operation and maintenance. Noted here are only the following items:

(a) Soil for diking shall be transported from an adequate borrow area which can supply low permeability and high strength soil, e.g. Udon borrow area;

(b) Cofferdams and detouring of NR-5 for the construction of Svay Pak Drainage Sluiceway shall carefully be planned and operated; and

(c) Steel slide gates for the sluiceway shall be ones made in an advanced country in view of their importance.

II4. TOMPUN WATERSHED DRAINAGE IMPROVEMENT

4.1 General

Project B: Tompun Watershed Drainage Improvement (corresponding to Component 3 in the Master Plan), is for the drainage improvement of Tompun Watershed (17.47 km^2), the western half of the populated area of Phnom Penh City, with a scale of a 5-year return period rainfall. All the ***premises and major conditions*** set forth in the Master Plan can hold for the feasibility study. The Project comprises the following 13 ***sub-components*** (refer to Figure II4-1):

(a) Sub-component B1 : Construction of Tompun New Pumping Station and Inlet Channel with a capacity of 15 m^3/sec
(b) Sub-component B2 : Construction of Tompun Regulation Pond with a total area of 47.5 ha
(c) Sub-component B3 : Improvement of Meanchey Drainage Main, Downstream Stretch, from Tompun Regulation Pond to Meanchey Bridge with a length of 2.635 km
(d) Sub-component B4 : Improvement of Meanchey Drainage Main, Middle Stretch, from Meanchey Bridge to the junction with a branch with a length of 1.285 km
(e) Sub-component B5 : Improvement of Meanchey Drainage Main, Upstream Stretch, upstream from the junction with a length of 0.535 km
(f) Sub-component B6 : Construction of Tum Nup Toek Drainage Sluiceway with a capacity of 10 m^3/sec
(g) Sub-component B7 : Construction of Samdach Monireth Drainage Main, Downstream Stretch, between the junctions with Meanchey and Jawaharlal Nehru drainage mains with a length of 1.676 km

(h) Sub-component B8 : Construction of Samdach Monireth Drainage Main, Upstream Stretch, upstream from the junction with Jawaharlal Nehru Drainage Main with a length of 0.714 km
(i) Sub-component B9 : Construction of Jawaharlal Nehru Drainage Main with a length of 1.152 km
(j) Sub-component B10 : Improvement of Salang Drainage Main, Downstream Stretch, from the junction with Meanchey Drainage Main to a bridge with a length of 0.887 km
(k) Sub-component B11 : Improvement of Salang Drainage Main, Upstream Stretch, upstream from the bridge with a length of 0.488 km
(l) Sub-component B12 : Conservation of the north lake of Boeng Salang with dredging (5.1 ha) and providing a walkway around the lake
(m) Sub-component B13 : Preparation of Relocation Site and Spoil Area with a total area of 26 ha

4.2 Preliminary Design

Tompun Pumping Station, Inlet Channel and Regulation Pond

The ***design discharge*** with a 5-year probability of rainfall at the downstream end of Tompun Watershed is 75 m^3/sec. The combination of the capacity of Tompun Pumping Station and the volume of Tompun Regulation Pond is as follows:

- Pump capacity : 15 m^3/sec
- Regulation pond volume : 560,000 m^3

The ***design water levels*** necessary for designing the Tompun new pumping station, inlet channel, regulation pond are listed in the following table:

Water Levels Concerning Tompun Pumping Station and Related Structures

Water Level	Elevation (m)	Reasons
(1) Outer Side (a) Design High Water Level (HWL)	9.00	Derived from the 30-year return period floodwater level at Chaktomuk Station, EL. 10 m, deducting the water level difference of 1 m between Chaktomuk and Tompun Dike in the 1996 flood.
(b) Normal Water Level (NWL) in the Dry Season	4.00 to 4.50	According to water level surveys.
(2) Inner Side (a) Design Surcharge Water Level (SWL)	4.50	On account of ground elevations in vicinity.
(b) Design High Water Level (HWL)	3.70	On account of ground elevations along Meanchey Drainage Main
(c) Design Low Water Level (LWL)	3.30	To be Maintained in the rainy season
(d) Normal Water Level (NWL) in the Dry Season	About 3.30 in future (4.00 at present)	Considering the convenience for water body utilization.

Determination of the ***pump type*** is an essential issue on designing a pumping station. The following three pump types are examined, and finally the submersible type of pump is recommended for Tompun New Pumping Station as it is economical and easy for maintenance and further construction thereof is relatively simple and quick:

- Axial flow vertical-shaft motor driven traditional type;
- Axial flow horizontal-shaft motor driven traditional type; and
- Submersible type.

The ***structural features of Tompun New Pumping Station*** are shown in Figures II4-2 and II4-3. Main points of the structure of the station are as follows:

a. Tompun New Pumping Station will be constructed on the west side of the existing one with a total capacity of 15 m^3/sec (5 units of 3 m^3/sec submergible pumps).

b. The main civil work of the station is designed without superstructure because submersible pumps can be installed outdoor. The main structure is about 24.6 m wide and 16.9 m long.

c. An operation building yard is planned to be constructed beside the main structure, having a dimension of 12.3 m wide and 39.1 m long, to house an operating room, electric room, backup generator room, substation yard and store room.

The ***inlet channel*** connecting to Tompun New Pumping Station is designed with the same capacity of 15 m^3/sec as the pumping station. The channel is 1,020 m long and 1/10,000 in bed gradient (refer to Figure II4-4). Other main features of the channel are as follows:

Major Features of Inlet Channel

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Inlet Channel	Earth channel	15	3.8	0.3	29.2

Tompun Regulation Pond is located on the existing Boeng Tompun just upstream of the new pumping station. The area is 47.5 ha, consisting of the east and west lakes sandwiching the inlet channel (refer to Figure II4-4). The bed elevation is 3.0 m with small dikes and earth banks on which sodding will be made.

<u>Meanchey Drainage Main</u>

The alignment of ***Meanchey Drainage Main*** generally follows the existing Meanchey stream. The total length of the channel is 4,455 m, which is composed of the following three stretches (refer to Figure II4-5):

- Downstream Stretch : 0+000 to 2+635 (75 m^3/sec, 1/2,500, 2,635 m long)
- Middle Stretch : 2+635 to 3+920 (15 m^3/sec, 1/2,000, 1,285 m long)
- Upstream Stretch : 3+920 to 4+455 (11 m^3/sec, 1/1,000, 535 m long)

Major features of the drainage main are as follows (refer to Figure II4-6):

Major Features of Meanchey Drainage Main

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Downstream	Earth channel with side slopes of 1:2	75 (at DHWL) 15 (at DSWL)	3.8	0	32.4
Middle	- ditto -	15	2.5	0	13.2
Upstream	Masonry-reveted channel with side slopes of 1:0.3	11	2.0	0	4.4

Note: DHWL and DSWL mean the design high water level (EL. 3.7 m) and design surcharge water level (EL. 4.5 m) of Tompun Regulation Pond, respectively.

Tum Nup Toek Drainage Sluiceway is the facility provided beneath the Inner Ring Dike to drain storm water in the subject drainage basin to Meanchey Drainage Main.

Samdach Monireth and Jawaharlal Nehru Drainage Mains

The alignments of the designed drainage mains follow Samdach Monireth and Jawaharlal Nehru streets. Most part of the drainage mains is of the underground box culvert except an open channel portion joining Meanchey Drainage Main about 50 m downstream of Meanchey Bridge. The drainage mains comprise the following stretches:

- Samdach Monireth Downstream: 0+000 to 1+676 (44 m^3/sec, 1/2,000, 1,676 m)
- Samdach Monireth Upstream : 1+676 to 2+390 (20 m^3/sec, 1/2,000, 714 m)
- Jawaharlal Nehru : 0+000 to 1+152 (8 m^3/sec, 1/2,000, 1,152 m)

Major features of the drainage mains are shown in Figure II4-7, and summarized as below:

Major Features of Samdach Monireth and Jawaharlal Nehru Drainage Mains

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Samdach Monireth, Outlet	Earth channel	44	3.0	0.0	20.2
Samdach Monireth, Downstream	Underground box culvert	44	3.0	0.6	4.25 (2-lane)
Samdach Monireth, Upstream	Underground box culvert	20	3.0	0.6	4.00 (1-lane)
Jawaharlal Nehru	Underground box culvert	8	2.5	0.6	2.50 (1-lane)

Salang Drainage Main

Boeng Salang plays an important role in the retention of storm water gathering from the City Core portion of the Tompun Watershed. However, the south lake of Boeng Salang has been reclaimed in most area and encroached on by housing, resulting in diminution of its retention function although the north lake comparatively remains as it was. To compensate and control such deterioration in terms of drainage, Salang Drainage Main will be provided along the centerline of the south lake, and moreover some conservation measures are recommended to be taken in the north lake (5.1 ha). The measures comprise

dredging on the lake bottom and building a walkway along the perimeter of the lake to control house encroachment into the lake area.

The alignment of ***Salang Drainage Main*** generally follows the existing Boeng Salang south lake, and joins Meanchey Drainage Main about 50 m upstream of Meanchey Bridge. The total length of the channel is 1,375 m composed of the downstream stretch of 887 m and upstream stretch of 488 m (refer to Figure II4-8). The bed gradient is constantly 1/3,000 and other major features are as follows (refer to Figure II4-9):

Major Features of Salang Drainage Main

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Downstream Stretch	Earth channel with side slopes of 1:2	21	3.0	0	15.7
Upstream Stretch	Masonry-reveted channel with side slopes of 1:0.3	21	3.0	0	7.0

Relocation Site and Spoil Area

The total land acquisition and house evacuation for Sub-components 1 to 12 are 58,400 m^2 and 460 houses. As for the relocation site, one suggested is the proposed spoil area (26 ha) near Tompun New Pumping Station (refer to Figure II4-4). The proposed spoil area will be provided in two stages with the following respective dimensions:

Dimensions of Proposed Spoil Area

Stage	Corresponding Sub-components	Excess Soil Volume Approximate (m^3)	Area (ha)	Formation Height (EL. m)	Embankment Height (m)
I	B1, B3, B6 and B10	250,000	10.5	6.0	2.5
II	B2, B4, B5, B7, B8, B9, B11 and B12	550,000	15.5	7.0	3.5
Total	-	800,000	26.0	-	-

A part of the spoil area, Stage I, will be used for the relocation site of the evacuated peoples, 480 households. The relocation site will require 48,000 m^2 of land complete with necessary infrastructures, such as roads, electricity, wells and sanitary facilities.

4.3 Cost and Schedule

The ***project cost*** for the Tompun Watershed Drainage Improvement amounts at approximately US$ 50.8 million, whose breakdown by sub-component is as follows:

Project Cost for the Tompun Watershed Drainage Improvement

Sub-component	Project Cost (US$ million)
B1: Tompun New Pumping Station and Inlet Channel	11.5
B2: Tompun Regulation Pond	3.6
B3: Meanchey Drainage Main, Downstream Stretch	3.8
B4: Meanchey Drainage Main, Middle Stretch	0.5
B5: Meanchey Drainage Main, Upstream Stretch	0.5
B6: Tum Nup Toek Drainage Sluiceway	0.7
B7: Samdach Monireth Drainage Main, Downstream Stretch	16.3
B8: Samdach Monireth Drainage Main, Upstream Stretch	3.7
B9: Jawaharlal Nehru Drainage Main	4.1
B10: Salang Drainage Main, Downstream Stretch	1.3
B11: Salang Drainage Main, Upstream Stretch	0.6
B12: North Lake of Boeng Salang	0.7
B13: Relocation Site and Spoil Area	3.5
Total	50.8

The ***implementation schedule*** for the Project is shown in Table II3-1. The actual construction will initiate in 2001 and end in 2007 with a construction period of 7 years. The year of 2000 will be shared for the basic and detailed designs of structures/facilities in the Project and the land acquisition and house evacuation.

4.4 Project Evaluation

The results of the ***economic evaluation*** for the Project are tabulated below, from which this Project is judged to have sufficiently high economic return with an EIRR higher than the opportunity cost of capital of 10 %. The Project is proved to be worth being promoted to the implementation stage.

Economic Indices for Tompun Watershed Drainage Improvement

Indices	Tompun Watershed Drainage Improvement	Including Reinforcement of Kop Srov and Tompun Dikes
EIRR (%)	11.7	16.7
B/C	1.17	1.69
NPV (US$ thousand)	5,909	35,384

As of 2008 when the facilities start operation, the DSD's revenue from government budget reaches the level slightly above the operation and maintenance cost (refer to the following table). The Project is ***financially affordable*** from the O/M cost recovery viewpoint.

Comparison of DSD's Revenue and O/M Cost

Item	Amount (US$ million)
Revenue by Government Budget in 2008	0.34
Wastewater Surcharge Revenue in 2008	1.41
Total Revenue in 2008	1.76
Total O/M Cost Required since 2008	0.32
Balance	1.40

An adverse impact by the implementation of the project is improvement of living environment through reduction of stormwater inundation and realization of a better water environment. As a result of the ***Environmental Impact Assessment***, some negative impact that includes turbid water flow, dust and noise during construction, and replacement of a total of 480 houses. All these negative impact can be minimized and solved if appropriate environmental management and monitoring plans including establishment of a proper relocation program are introduced.

The construction of a pumping station might be rather complicated, and necessitate some advanced technology. In particular, submergible pumps, valves and the appurtenance shall be imported from a developed country, and the installation, operation and maintenance of them shall be conducted by Cambodian engineers under supervision and with technical training by engineers from such a country. Moreover, since there are no practices in Cambodia pertaining to earth retaining in a part of the temporary works for construction of box culverts, advanced technology therefor shall be introduced from neighboring countries. However, as a whole, the construction of the Project can go well with ***no definite technical problems***.

II5. POSSIBLE URGENT PROJECTS

The feasibility study on each of the two projects, A: Reinforcement of Kop Srov and Tompun Dikes, and B: Tompun Watershed Drainage Improvement, has been achieved and completed as presented in Chapters II3 and II4. The study gives a cost estimation: that is $ 20.8 million for the former and $ 50.8 million for the latter, totaling as huge as $ 71.6 million. If an implementation by using Japan's Grant is considered, a stepwise implementation of the entire projects is needed. The next table shows the evaluation results of the urgency of each sub-component using "High", "Medium" and "Low", along with its construction cost and compensation required, under the following considerations:

- Project A has an economic return as high as 25.2 % of EIRR, and each sub-component therein is indispensable to protect the major part of Phnom Penh from flooding caused by the Mekong river system. All four sub-components in Project A are hence ranked "High" in urgency.
- As for Project B, sub-components located downstream should be implemented ahead in general consideration. Sub-components B1 and B3 are hence assessed "High", while Sub-component B2, also situated downstream, "Medium" since the existing Boeng Tompun has about 70 % of regulation capacity compared with the proposed regulation pond.

- The preparation of a relocation site/spoil area (Sub-component B13) must be "High" to secure the succeeding construction works.
- Sub-components B6 and B10 are indispensable for drainage in the City Core portion of Tompun Watershed and are with high cost performance, so that the two sub-components are evaluated also "High".
- Sub-components B7 to B9 will play an important role in the drainage of the City Core portion, however they have low cost performance and the function of existing facilities can be taken into consideration to a certain extent and are classified "Medium".
- The other sub-components located in upstream reaches with less beneficiary, Sub-components B4, B5, B11 and B12, are rated "Low" in urgency.

Urgency of Each Sub-component in Project A: Reinforcement of Kop Srov and Tompun Dikes, and Project B: Tompun Watershed Drainage Improvement

Sub-component	Rank of Urgency	Construc-tion Cost ($ mill.)	Compensation Required	
			Land Acquisition (m^2)	House Evacuation (house)
Project A: Reinforcement of Kop Srov and Tompun Dikes (EIRR = 25.2 %)				
A1: Kop Srov Dike	High	15.9	0	54
A2: Tompun Dike	High	3.2	0	0
A3: Svay Pak Drainage Sluiceway	High	1.0	0	0
A4: Relocation Site/Spoil Area	High	0.7	250,000	0
Total	-	20.8	250,000	54
Project B: Tompun Watershed Drainage Improvement (EIRR = 11.7 %)				
B1: Tompun New Pumping Station and Inlet/Outlet Channels	High	11.5	5,000	30
B2: Tompun Regulation Pond	Medium	3.6	20,000	20
B3: Meanchey Downstream	High	3.8	28,000	90
B4: Meanchey Middle	Low	0.5	0	120
B5: Meanchey Upstream	Low	0.5	0	10
B6: Tum Nup Toek Drainage Sluiceway	High	0.7	3,000	10
B7: Samdach Monireth Downstream	Medium	16.3	2,400	30
B8: Samdach Monireth Upstream	Medium	3.7	0	0
B9: Jawaharlal Nehru	Medium	4.1	0	0
B10: Salang Downstream	High	1.3	0	60
B11: Salang Upstream	Low	0.6	0	90
B12: Boeng Salang	Low	0.7	0	0
B13: Relocation Site/Spoil Area	High	3.5	260,000	20
Total	-	50.8	318,400	480

Note: The overall EIRR is 16.7 %.

From the table above, suggested as sub-components that should be realized in the earlier stage of the two projects are the following:

(1) In Project A: Reinforcement of Kop Srov and Tompun Dikes

(a) Sub-component A1: Reinforcement of Kop Srov Dike;
(b) Sub-component A2: Reinforcement of Tompun Dike;

(c) Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway; and
(d) Sub-component A4: Preparation of Relocation Site/Spoil Area.

(2) In Project B: Tompun Watershed Drainage Improvement

(a) Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel;
(b) Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch;
(c) Sub-component B6: Construction of Tum Nup Took Drainage Sluiceway;
(d) Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch; and
(e) Sub-component B13: Preparation of Relocation Site/Spoil Area.

II6. RECOMMENDATIONS

1. Of the component projects of the master plan for the drainage improvement and flood control in the Municipality of Phnom Penh established in the present study, the following two component projects have high priority for implementation. It is recommended to give high priority for implementation to these two component projects.

   - Component 2: Reinforcement of Kop Srov and Tompun Dikes (including reconstruction of Svay Pak Drainage Sluiceway)

   - Component 3: Tompun Watershed Drainage Improvement (excluding sewer rehabilitation)

2. Proposed non-physical measure in the master plan for the drainage improvement and flood control in the Municipality of Phnom Penh is the introduction of land use control and continuous application of flood defense activity. An official development plan for the Municipality of Phnom Penh is recommended to be established as soon as possible considering the recommendation from the view point of flood protection and drainage improvement, namely, water zone conservation in the Northeast Area and agricultural land conservation in the Northwest and South areas

3. The implementing body of the projects proposed in the master plan is Department of Public Works and Transport of Municipality of Phnom Penh. Drainage and Sewage Division will be in charge drainage improvement projects. It is recommended to establish Flood Protection Division that will be responsible for implementation, operation and maintenance for flood protection projects.

4. The results of the feasibility study conducted for Reinforcement of Kop Srov and Tompun Dikes and Tompun Watershed Drainage Improvement, the priority projects selected from the master plan components, revealed high economic feasibility, financial affordability, environmental justifiability, and technical soundness. Early implementation of these projects is recommended. However, a huge project cost of US$ 71.6 million and a long period of seven years are required for the implementation of all the component projects of these two projects. Accordingly, it is recommended to implement the following sub-component projects prior to the other sub-component projects.

(1) Project A: Reinforcement of Kop Srov and Tompun Dike

(a) Sub-component A1: Reinforcement of Kop Srov Dike
(b) Sub-component A2: Reinforcement of Tompun Dike
(c) Sub-component A3: Re-construction of Svay Pak Drainage Sluiceway
(d) Sub-component A4: Preparation of Relocation Site/Spoil Area

(2) Project B: Tompun Watershed Drainage Improvement

(a) Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel
(b) Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch
(c) Sub-component B6: Construction of Tum Nup Toek Drainage Sluiceway
(d) Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch
(e) Sub-component B13: Preparation of Relocation Site/Spoil Area

5. Land acquisition and house relocation are needed for project implementation. It is recommended to start land acquisition and house relocation for the above sub-components.

6. There exist no sufficient water level data in and around the Study Area. The Study Team hence established water level gaging stations for Kop Srov Dike, Tompun Dike, etc. and observation has been conducted by the Department of Public Works and Transport. Although the results were used for the feasibility study, higher water records are not sufficient due to the low water level of the last flooding season. It is recommended to continue the observation, since these data will be important in the basic design and detailed design stages.

7. An adverse impact by the implementation of the project is improvement of living environment through reduction of flooding risks and improvement of drainage condition. The negative impacts identified in the Environmental Impact Assessment include affect in water and atmospheric quality during construction works and of necessary relocation of houses, etc. These negative impacts should be minimized through implementation of Environmental Management Program and Environmental Monitoring Program. Attention should be paid to prevent uncontrolled development according to the betterment of Kop Srov and Tompun dikes, and resulting negative impact including water pollution in the Prek Phnov and Prek Thnot basins. Management and monitoring for relocation of the residents are also important to minimize negative socioeconomic impact.