MAIN REPORT

TABLE OF CONTENTS

APPENDICES

(Contained in Vol. II)

LIST OF FIGURES

Chater 12

Chapter 13

Chapter 14

LIST OF TABLES

ABBREVIATIONS

AIT	Asian Institute of Technology
฿	Baht (Thai Currency) ; US$ = approximately ฿ 23.00
BFCD	Bangkok Flood Control and Drainage Project (City Core Project)
BM	Bench Mark
BMA	Bangkok Metropolitan Administration
CDM	Camp Dresser & McKee
cm	centimeters
CMD	cubic meters per day
DDS	Department of Drainage and Sewerage, BMA
Fig.	Figure
GDP	Gross Domestic Product
GRP	Gross Regional Product
DTCP	Department of Town and Country Planning
ha	hectares (10,000 m^2)
HD	Highways Department
hp	horse power
hr	hours
HHWL	Highest high water level
HWL	High water level
JICA	Japan International Cooperation Agency
klong	A term commonly used in Thailand for "canal".
km	kilometers
m	meters
m^2	square meters
m^3	cubic meters
m^3/s	cubic meters per second
mm	millimeters
MCMD	million cubic meters per day
MOI	Ministry of Interior
MSL	Mean Sea Level
MWL	Mean Water Level
MWWA	Metropolitan Water Works Authority
NEB	National Environmental Board
NEDECO	Netherlands Engineering Consultants
NESDB	National Economic and Social Development Board
NSO	National Statistical Office
PAT	Port Authority of Thailand
PCI	Pacific Consultants International
Polder	A community surrounded by a dike to protect it from floods
PWD	Public Works Department
RID	Royal Irrigation Department

RTSD	Royal Thai Survey Department
SRT	State Railway of Thailand
TEC	Tokyo Engineering Consultants
¥	Yen (Japanese Currency); US$ = approximately ¥230.0

Chapter 1 INTRODUCTION

1.1 GENERAL

In accordance with the scope of work for the Preliminary and Master Plan on Flood Protection/Drainage Project in the Eastern Suburban-Bangkok in the Kingdom of Thailand agreed upon between the Bangkok Metropolitan Administration (BMA) and Japan International Cooperation Agency (JICA) in November 5, 1982, the JICA Study Team commenced the Site Office Work in Thailand on May 16, 1983.

After the completion of the site work in Bangkok, the JICA Study Team carried out the preliminary study on the Flood Protection/Drainage Project in Eastern Suburban Bangiok in their home office.

Main work of the Preliminary Study is as follows:

1. Data collection and analysis related to the study
2. Review of previous study
3. Development of the criteria to formulate the drainage zone.
4. Development of the criteria to set the priority of the drainage zone.
5. Analysis for selecting master plan area
6. Definition of survey area for master plan
7. Rough study of flood protection and drainage method.
8. Studies of organization, operation and management plan

The main objective of this Preliminary Study is the selection/definition of master plan area. The preliminary study was focussed on this objective.

A rough study of flood protection/drainage methods, and studies of organization, operation and management plans were also made. These established the guide lines for the preparation of the master plan to be executed in the next stage of the Study.

Brief contents of each chapter of the Report are as follows:

For Chapter 2 to 5, the necessary data for the basic conditions of the Study were collected and studied. Chapter 2 deals with the general characteristics of the Study Area, Chapter 3 deals with the historical flood, Chapter 4 with the information of the 1983 flood, and Chapter 5 deals with the existing klong networks and flood control system.

In Chapter 6, based on these studies, the major causes of flood damage are investigated.

Chapter 7 reviews previous studies and relevant plans.

In Chapter 8, the study on the future urbanizaed area is explained and Chapter 9, the study on the land subsidence is described.

In Chapter 10, using the causes of flood damage investigated in Chapter 6, the general concept of a flood protection/drainage system is proposed.

In Chapter 11, the methodology of the flood protection study is explained.

In Chapter 12, a hydrological and hydraulic model is established, and in Chapter 13, the hydrological design criteria is explained.

In Chapter 14, the result of the hydrological and hydraulic study is explained. At this point a basic idea on the flood protection/drainage system is established.

In Chapter 15, the selection/definition of a Master Plan area is explained.

Chapter 16 describes the studies on the organization, operation and management plans. Chapter 17 describes the study on the finance as reference. It is to be noted that the indicated construction cost is obtained from assumptions and not obtained from the result of study estimates.

In Chapter 18, the conclusions of the Preliminary Study and suggestions for the Master Plan Study are given.

1.2 BACKGROUND OF THE STUDY

Bangkok, the capital of Thailand, is located on the flat deltaic plain of the Chao Phraya River. The existing ground level of Bangkok is about 0.0–2.0 meters above Mean Sea Level, the flood level of the River frequently exceeds 1.5 meters above Mean Sea Level.

Bangkok's population reached approximately 5,480,000 as of January 1983, whereas it was only about three million in the early 1970s. The construction of infrastructure, including flood protection/drainage has not been kept pace with such rapid urbanization.

In addition to the low ground elevation, land subsidence, the maximum rate of which has been 10 cm/year, has been taking place due to the excessive pumping-up of groundwater. In the flood of 1980, some parts of Bangkok was inundated for a period of about two months.

In order to solve this problem, a Master Plan which covers 370 km^2 in the central area of Bangkok was already prepared and proposed in 1968 by engineering consultants, Camp Dresser & Mckee (CDM). The proposed system consisted of three parts: a flood protection system, a drainage system and a sewerage system.

In order to protect the area against flooding, it was proposed to construct embankments all around the area and install floodgates and locks.

Pumping stations and drains were also proposed so that stormwater could be pumped from the protected areas into external klongs and the river, whenever the water level of the latter is higher than the level of the internal klongs.

The required facilities proposed in the CDM Master Plan were not constructed with some exception. Instead, provisional measures such as installation of portable pumps, sandbags and cofferdams were provided to protect the central parts of Bangkok while other areas were left unprotected.

The Government of Thailand has now decided to solve the flood problem in the core area of Bangkok as part of the fifth national development plan (with financial assistance from the World Bank).

The flood protection project in the eastern suburban area is planned to be implemented during the sixth plan starting in 1986. A request was made by the Government of Thailand to the Government of Japan for the Preliminary Study and a preparation of Master Plan for Eastern Suburban-Bangkok.

In response to a request from the Government of Thailand, the Government of Japan has decided to conduct a Preliminary Study and Master Plan for the Flood Protection/Drainage Project in Eastern Suburban-Bangiok (hereinafter referred to as the Study), within the general framework of technical cooperation between Thailand and Japan which is set forth in the Agreement on Technical Cooperation between the Government of the Kingdom of Thailand and the Government of Japan signed on 5 November 1981.

Based on this agreement, the JICA, an official agency responsible for the implementation of technical cooperation programs of the Government of Japan, was assigned to carry out this Study.

In November 1982, the scope of work to be performed by JICA was agreed upon between Bangkok Metropolitan Administration (BMA) and JICA.

1.3 OBJECTIVE OF THE STUDY

The objective of the Study is to carry out a Preliminary Study of the Flood Protection/Drainage Project in Eastern Suburban-Bangkok, and to undertake a Master Plan Study in the high priority area (to be identified) based on the results of the Preliminary Study. This Report presents the result of the Preliminary Study, and the Master Plan study is planned to be commenced in May, 1984.

The Study aims at a planning of the adequate facilities so as to play a role for providing the city with pleasant and healthy environment. The project should match the socio-economic situation of the country in view of long range operation of the facilities and also have consistency with other related projects.

Target year for the Master Plan Study is adopted as the year 2000 under the consideration of consistency with other related plans or projects; e.g., "Draft of the Structural Plan for Bangkok Metropolis and its Vicinity" prepared by DTCP, "Master Plan on Flood Protection/Drainage Project in Bangkok Metropolis" prepared in 1968 by Camp Dresser and Mckee (CDM Plan).

1.4 STUDY AREA

1.4.1 Preliminary Study

The Preliminary Study area covers the eastern suburbs of 501 square kilometers located between the Viphavadee Rangsit Highway and the Green Belt Zone as shown in Fig. 2.1.

1.4.2 Master Plan

The Master Plan Study area was selected as shown in Fig. 15.1, based on the results of the Preliminary Study.

1.5 EXECUTION OF THE STUDY

The Study was carried out by the Study Team which was composed of the Japanese Consultant Staff retained by JICA and Counterpart Staff of Department of Drainage and Sewerage (DDS), BMA.

The Advisory Committe of DDS and JICA acted as advisors to the Study Team. All the technical matters on the Study were resolved by the DDS advisory committee.

1) Members of JICA Advisory Committee

Chairman

1. Mr. Tsunekazu Fukui	:	Ministry of Construction

Committee Member

2. Mr. Akira Kato	:	Ministry of Construction
3. Mr. Isao Dohdoh	:	Japan Sewage Works Agency
4. Mr. Tadao Ishikawa	:	Ministry of Construction
5. Dr. Katsuhide Yoshikawa	:	Ministry of Construction
6. Mr. Kenichi Ohsako	:	Tokyo Metropolitan Government
7. Mr. Yoichi Seki	:	Japan International Cooperation Agency (as Coordinator)

2) Member of JICA Study Team

1. Mr. Saburo Fukagawa	:	Team Leader (PCI)
2. Mr. Kazufumi Momose	:	Drainage System Planning (1) (TEC)
3. Mr. Hikoroku Ohtsuka	:	Drainage System Planning (2) (PCI)
4. Mr. Toshiaki Tokumasu	:	Hydrologic Analysis (PCI)
5. Mr. Masami Kondo	:	Drainage Network Planning (PCI)
6. Mr. Shigehiko Homma	:	Drainage Facility Planning (TEC)
7. Mr. Daijiro Sezaki	:	Facility Maintenance Planning (TEC)
8. Mr. Toshinori Ohshita	:	Runoff Observations and Analysis for Model Area (PCI)
9. Mr. Jyudo Hagiwara	:	Flood Damage Survey (TEC)
10. Mr. Sachio Okutsu	:	Land Survey (TEC)
11. Mr. Kohki Fujii	:	Land Use Planning (TEC)
12. Mr. Hidekazu Tanaka	:	Administration/Management Planning (PCI)

3) DDS Advisory Committee

1.	Mr. Anuchit	: Project Director
2.	Mr. Somchit	: Assistant Director
3.	Mr. Mana	: Committee Member
4.	Mr. Nikom	: Committee Member
5.	Mr. Piroon	: Committee Member
6.	Mr. Pitool	: Committee Member
7.	Mr. Thongchai	: Committee Member
8.	Dr. Ksemsan	: Secretary
9.	Mr. Thammanat	: Assistant Secretary

4) DDS Counterpart Staff

1.	Dr. Ksemsan	: Leader of the Staff
2.	Mr. Teeradej	: Counterpart
3.	Mr. Thongchai	: Counterpart
4.	Mr. Thammanat	: Counterpart
5.	Mr. Changtong	: Counterpart
6.	Mr. Prasert	: Counterpart
7.	Mr. Vichai	: Counterpart
8.	Miss Angsana	: Counterpart
9.	Mr. Praving	: Counterpart
10.	Mr. Sompop	: Counterpart
11.	Mr. Atorn	: Counterpart

Chapter 2 DESCRIPTION OF THE STUDY AREA

The characteristics of the Study Area gives a decisive influence on the planning of the flood protection/drainage system. So, the geneal characteristics of the Area are studied in this Chapter.

2.1 TOPOGRAPHY

The Study Area (Fig. 2.1) is located in part of the "central plain" which is an extensive and rather flat area formed by the sediments of the Chao Phraya and its tributaries over a long period of time. The width of the lowland in the central plain ranges from 200 km in the southern part, to 150 km in the middle and 60 km in the north.

The topographic map (Fig. 2.2), surveyed in 1969, indicates that 70 percent of the low-lying flat part of the central plain is lower than 2.5 meters above mean sea level (MSL).

Pumping of groundwater, however, since the 1970s has changed the topographic features. A large part of the plain has already subsided and this area becomes a large lake during a flood period. Figs. 2.3 – 2.5 show the ground surface elevation and profiles respectively in the Study Area, which are based on the recent survey conducted by the Study Team. The lowest parts of the Study Area are Lat Phrao, Hua Mark, Bang Kapi and Phra Khanong. The ground elevations in these areas are lower than 1.0 meter above MSL and the lowest is about 0.2 meter, while the highest water level of the Chao Phraya river exceeds 2.0 meters above MSL.

2.2 GEOLOGY

The central plain was evidently formed on a fault/flexure depression filled with plastic sediments. The depression is underlain by various types of bedrock at depths of 400 to 3,500 meters. The alluvium is composed of alternating sands and clays as shown in Fig. 2.6.

2.3 CLIMATE

2.3.1 Rainfall

Bangkok has three seasons, cold, hot and wet. The "Cold Season", is from November to January, the "Hot Season", from February to May, and the "Wet Season" the remaining five months from June to October. The weather is relatively dry from November to April with almost no rain in December and January.

During the wet season, regular rainfall becomes more intense from June to August due to southwest monsoon starting in mid-May, and subsides in mid-November.

The heaviest rainfall occurs in September when the typhoon passes through the country on a wide front. Fig. 2.7 indicates the mean monthly rainfall and number of rainy days which occurred in Bangkok during the period from 1951 to 1982.

2.3.2 Evaporation, Evapotranspiration and Humidity

Evaporation has a definite negative correlation with rainfall. Measurements in Bangkok reported by AIT indicate the figures of 150 mm per month during the low-rainfall season between December and April, dropping to about 120 mm per month in September.

The actual evapotranspiration figures vary with the rainfall, temperature, soil moisture and other factors. According to the report of NEB in 1982, the highest, mean and lowest evapotranspiration figures are 113 mm/month, 81 mm/month and 39 mm/month respectively for the Lower Chao Phraya Basin.

The humidity in Bangkok is relatively high. It averages 78 percent annually. Evaporation and humidity in Bangkok and evapotranspiration in the Lower Chao Phraya Basin are also shown in Fig. 2.7.

2.3.3 Temperature

The average annual temperature in Bangkok is 27.7°C, while the average monthly figures range from 25.5°C in December to 29.6°C in April. Mean monthly maxima range from 31.3°C to 34.9°C, and the minima, from 20.6°C to 25.7°C.

2.4 CHAO PHRAYA RIVER

The Chao Phraya river so called the mother of the Thailand has a drainage area of 162,600 km^2 (it occupies 32 percent of the total area of the Thailand) and a total length of river course of 980 km. Average annual rainfall in the drainage area is 1,500 milimeters. It is said that rainfall in the upper reaches of the river will not reach the river mouth until several months after falling.

Flood discharge at the entrance of the Chao Phraya delta and at the river mouth for the flood of 10-year return period are estimated as about 5,400 m^3/sec. and 3,300 m^3/sec. respectively. The reduction in the downstream of the river is caused by the effect of flood water retention in the area between Chainat and Ayutthaya. (Ref. to section 7.3)

The water level of the Chao Phraya river usually rises first in May or June to about 2 – 3 m above the lowest river level within a period of only 1 – 3 weeks, after which there is a fall of 1 – 2 m during July. The second rise follows gradually and reaches its maximum in October in the upper reaches and November in the lower reaches. Fig. 2.8 shows the daily flow and water level which was observed in 1980 at Nakon Sawan on the Chao Phraya river and at Ban Muang Na on the Pa Sak river.

The water level at Bangkok Port as shown in Fig. 2.9, however, is affected strongly by the tide in the Gulf of Thailand as well as the upstream discharge.

2.5 IRRIGATION

During the reign of King Rama V (1868–1910) in Thailand the cultivated area of the Chao Phraya river delta expanded considerably, and rice export also increased sharply from the mid-1870s. In the 1870s, the State began to adopt policies for the reclamation of recefields that depended upon the excavation of canals. In the Study Area, large areas of arable land were also cultivated for rice.

Most of the central plain had already been fully developed as paddy field by the Greater Chao Phraya Project (Fig. 2.10). In the area south of Ayutthaya, the irrigation is done by storage of water since gravity irrigation is difficult. The location of head works and water regulating gates or navigation locks is shown in Fig. 2.10. The water level has been controlled to be at about the same level as the land. The water level starts rising in August and lowers in November as shown in Fig. 2.10.

In planning the Greater Chao Phraya Project, which was started in 1952, the net water requirement for a rice growing period of 180 days was estimated as 1,800 mm (10 mm per day), and the average effective rainfall for the same period was 1,050 mm. The difference of 750 mm is considered as the net irrigation water requirement. Allowing for losses in conveyance and distribution of about 800 mm, the estimated gross irrigation water required was calculated to be 1,550 mm (8.8 mm per day). In a survey of the water demand in the year 1968 in the northern region of the Greater Chao Phraya Project, it was found that the approximate irrigation water supply was 950 ± 270 mm for broadcast wet season rice.

2.6 ECONOMY

2.6.1 National Level

Thailand has enjoyed high economic growth during the past two decades. The national income has increased by approximately eight per cent per year and the real GDP has quadrupled and the GDP per capita has more than doubled in twenty years. (GDP per capita in 1981 = US$770)

The most striking feature of Thailand's growth pattern over the past two decades has been the sustained growth of the agricultural sector. Agricultural output, the highest source of income (25% of total production in 1981), has expanded at the rather high rate of five per cent per annum. Thailand has enjoyed not only agricultural self-sufficiency but also a position as a continuous food exporter. Most of the growth of agricultural production can be explained by the expansion of land under cultivation along with relatively stable average yields.

Recent growth in the industrial sector, (approximately 11% per annum), has been sustained by the dynamic private sector. While the government is providing infrastructure and exerting a relatively limited control over private industry, a free enterprise system has emerged which has allowed development to take place at a rapid rate consistent with the needs and resources available. The portion of manufacturing in GDP reached 21% in 1981.

The rapid economic growth, however, has created many problems affecting social and environmental conditions, and increased urban congestion leading to deterioration in cultural, social values, mental well-being, and the safety of lives and property. Furthermore, it is also widely observed that benefits from past development efforts and economic progress have not been distributed equally throughout the country.

Recent world economic changes, particularly due to high energy prices, high interest rates, and stagnant economic growth, have greatly affected the Thai economy as is the case for any country which imports raw materials for energy, capital and many other resources related to production.

In order to overcome these difficulties in development, the Thai Government established a new national economic discipline, the Fifth National Development Plan 1982–1986. It has the following major goals:

(1) The adjustment of economic structure through economic growth.

(2) Equity in distribution of national economic and social development effort.

(3) Alleviation of poverty for people in backward rural areas.

(4) Closer coordination between economic and social development and national security management.

(5) The implementation of the Plan into operational plans.

(6) Emphasis on the role and cooperation of the private sector.

The Plan, drafted by the National Economic and Social Development Board, has its major focus on the economic development of the provincial area.

2.6.2 Municipal Level

The economic activities of Bangkok Metropolis are significant for the entire economy of the Kingdom. Due to the highly centralized nature of the Thai bureaucracy and also the geographical advantages, all the major central government facilities, industrial firms, trading companies, multinational corporations and international organizations are located in this area. These establishments are supported with seaport, airport, other transportation facilities, and also with various commercial and service activities, resulting in a high concentration of people and their economic activities in the city. The population in Bangkok Metropolis of 5 million was 60% of the urban population and 10% of the total population in the Kingdom in 1980. Although the area comprises only 0.6% of the country, 30% of the GDP is generated in the Metropolis. Table 2.1 indicates a comparison of GDP and GRP of Bangkok by sectors. It indicates that the higher production for manufacturing, construction, transportation and communication, banking and other services are generated in Bangkok.

In 1979, the GRP per capita of Bangkok was 2.4 times of that of the whole Kingdom. The difference in income level induces an influx of migrants from outer areas, which brings rapid growth of the urban population which was estimated to be 5% per year in 1979. Various problems related to the rapid urbanization are evident in inadequate infrastructure such as transportation facilities, water supply, sewerage, waste disposal, flood protection, drainage and other public facilities. The phenomenon of flooding deteriorates the local conditions further, bringing about another burden for the municipality of Bangkok.

Table 2.1 GROSS DOMESTIC PRODUCT AND BANGKOK'S GROSS REGIONAL PRODUCT (1979)

	GDP of whole Kingdom		GRP of Bangkok	
	million Baht	%	million Baht	%
Agriculture	145,616	25.8	1,005	0.7
Mining	13,798	2.4	-	-
Manufacturing	108,865	19.3	40,422	26.8
Construction	31,471	5.6	11,626	7.7
Electricity and Water Supply	5,730	1.0	1,488	1.0
Transportation & Communication	35,312	6.3	13,436	8.9
Trade	112,964	20.0	25,578	17.0
Banking, Insurance & Real Estate	31,372	5.6	22,046	14.6
Ownership of Dwellings	6,875	1.2	3,646	2.4
Public Administration	21,292	3.8	9,880	6.5
Services	51,136	9.0	21,664	14.4
Total:	564,431		150,791	
Per capita:	12,459 ($593)		30,161 ($1,436)	

[Source : Statistical Yearbook, Thailand No. 32]

2.7 POPULATION AND LAND USE

The population of the Bangkok Metropolis and the Study Area in 1980 was estimated to be 5,070,000 and 1,160,000 respectively. The annual population growth rate in the Study Area during the period from 1970 to 1980 was 5.2 percent, which was larger than the annual growth rate of 4.0 percent for the Bangkok Metropolis. The past trend of the population of the Bangkok Metropolis and the Study Area are shown in Fig. 2.11.

The present land use in the Study Area is of ribbon development pattern as is shown in Fig. 2.12.

2.8 TRANSPORTATION

Bangkok is the starting point of three of four national long-distance highways; Route 1 to the North: Route 3 to the Southeast; and Route 4 to the West and peninsular Thailand. National Highway Route 31 and 34 were constructed as by-passes to relieve the traffic on Routes 1 and 3, respectively. Other National Highways are Route 304 (called Ram Indra Road), No. 336 and No. 3202. (Fig. 2.1)

Except for these national highways, the roads are administered mostly by BMA.

Figs. 2.13 and 2.14 indicate the main road network and the road elevation (details are shown in Figs. 4.3 to 4) which were usually raised to about two meters above sea level. These levels are now below two meters due to land subsidence, however, are higher than the ground levels in the adjacent areas.

The elevations of north-bound and east-bound-railway line are also higher than the ground levels in the adjacent areas. Therefore, both railway lines and most of roads will be used as natural boundaries for flood protection and/or drainage zone.

2.9 CONCLUSION

The Study Area of 501 km^2, located in the eastern suburban-Bangkok is characterized by the extremely low and flat, as it is located in deltaic alluvial plain of the Chao Phraya basin.

Even now, the high water level of the Chao Phraya River exceeds the ground surface in the Study Area during high tide and flood season. The Study Area will be submerged by water from the Chao Phraya River if no measures is taken.

In rainy season, a large amount of water flows into the Study Area from outer area besides the rainfall within the Study Area. Urbanization has been remarkably accelerated toward eastern suburban area (Study Area) during two decades, thus increased property. Roads and railways are served as dykes since they are of mounding structural type.

Chapter 3 HISTORICAL FLOOD

The historical flood is one of the important basic data for the study of a flood protection/drainage system. The Study Team investigated the historical flood. Floods in 1983, which occurred during the Study is described in the following chapter.

3.1 HISTORICAL FLOOD

From the beginning of the history of Bangkok, the reign of King Rama I, floods have been one of the big problems in the capital.

The largest flood in recent years occurred in November 1942, when flood-water overflowed the banks of the Chao Phraya River from Nakhon Sawan southward through Chainat, Ayutthaya, Pathum Thani, Nonthaburi and into Bangkok over a two month period. The highest water level of 2.27 meters above mean sea level ever recorded at Memorial Bridge occurred at that time, while the discharge of the river at Nakhon Sawan was over twice the capacity of the channel and reached 6,500 cubic meters per second (CMS).

Since dams and a water diversion system of the Greater Chao Phraya Project, were constructed by RID in 1960s, a large flood was prevented for a while.

Since the mid-70s, however, flooding began to occur again. The flood of 1975 had a discharge of 4,350 CMS at Nakhon Sawan, which was still lower than that of 1942. The population of Bangkok had grown to more than 4 million by 1975, and the social and economic effects of the 1975 flood were much greater than the flood of 1942.

In 1978, 1980 and 1982 severe floods also occurred. The highest water levels at Memorial Bridge, as shown in Fig. 3.1, were over two meters above mean sea level when the flooding occurred.

Since the 1970s, the recorded highest water level (Ref. to Fig. 3.1) has been rising. One of the reasons for this phenomenon is the land subsidence which has occurred due to excessive removal of groundwater which has been practiced in the area since the 1970s.

3.2 RECENT FLOOD

Flood areas, depth and duration in the central area of Bangkok are relatively cleared since flooding has been experienced frequently.

No such an information outside the central area, however, are obtainable since flooding there has only recently become a problem. Urbanization has now taken place in the Study Area where only paddy field used to be cultivated.

In the flood of 1980, some parts of the eastern suburbs were covered with flood water for more than two months. The flooding occurred in the Study Area again in 1982. Fig. 3.2 shows the flooded area in 1982 which was provided by DDS.

Based on this figure, and in order to grasp a more precise situation regarding the flood, the Study Team surveyed the flooded area, depth and duration of the 1982 flood. According to the survey results, the entire Study Area except some parts near the Airport were submerged under flood waters as shown in Fig. 3.3. The depth of water was generally more in the northern and eastern parts of the Study Area, however, these areas are mainly used as paddy fields. The water depth in the middle part was around 20 cm, shallower than the north and east, however the social impact here was much more extensive. The floods lasted from a few days to three months as shown in Fig. 3.4. Fig. 3.5 shows the observed flood mark in 1980 flood.

Fig. 2.9 indicates the average 10-days rainfall in the Study Area and the daily highest, mean and lowest water levels in the Chao Phraya river at Bangkok Port. These figures show that large floods which occur from September to November are influenced mostly by the low and mean water levels which make gravity flow difficult in the low-lying Study Area.

3.3 FLOOD DAMAGE INVESTIGATION IN PAST

Several attempts by different organizations were made to estimate the cost of flood damage in the central Bangkok area.

These estimates vary from 133 million Baht to 1,100 million Baht as shown in Table 3.1.

Table 3.1 FLOOD DAMAGE IN CENTRAL BANGKOK

No.	Year	Estimated Cost of Damage (million Baht)	Investigated Item	Source of Estimate
1	1975 flood	1,100	Direct damage, indirect damage and utility losses	Water Resource Committee, NESDB
2.1	1975 flood	133	Health benefit	World Bank
2.2	1975 flood	1,000	Annual increment of land value	World Bank
3	1981 flood	450	Direct damage, indirect damage and flood prevention cost	Burkhard*

* Burkhard Teichgraber, Karlsruhe University, West Germany

3.3.1 Estimate by the Water Resources Committee, NESDB for 1975 flood

Damage from the flooding in 1975 was estimated as follows by the Committee for Planning of Water Resources Committee:

1) Direct damage : 1,000 ฿ per affected households = 400 million Baht
   (2/3 of all 600,000 households were affected.)

2) Indirect damage : 1,000 ฿ for each household = 600 million Baht
   (in the period 3 months)

3) Utility losses (Damage to streets)
   The damaged road surfaces comprised more than 500,000 sq. meters of main road

   Repair cost for main roads = 60 million Baht

   Repair cost for branch roads = 40 million Baht

4) Total Damage 1,100 million Baht

3.3.2 Estimate of World Bank

An appendix to the World Bank report /1/ contains a brief economic analysis for the 1975 flood. The category "benefits" was used to appraise the City Core project. To evauate them, the following methods were utilized.

1. Helath : Assume costs of medical goods and services were estimated at 200 Baht per person per year for one third of the population : (March 1980 prices) 133 million Baht

2. All marketable land values are said to be enhanced by 5 per cent owing to the execution of the project. This benefit will be : 4,940 million Baht

Estimation basis is as follows:

(a) Value of property

Downtown dense	:	฿ 3,000 – 4,000 per square meter
Moderate dense	:	฿ 2,000 per square meter
Uninhabited	:	฿ 1,000 per square meter

(b) Size of area: 82 square kilometers

(c) Assume 30 per cent is downtown dense
30 per cent is moderate dense
40 per cent is uninhabited

(d) Assume 50 per cent of downtown is marketable (Balance is roads and public land)
60 per cent of moderate dense is marketable
80 per cent of uninhabited is marketable

(e) Assume all marketable land values are enhanced by 5 percent because of the flood protection project.

(f) Then, downtown value increase = ฿ 2,152 million
Moderate dense value increase = ฿ 1,476 million
Uninhabited value increase = ฿ 1,312 million
Total increase = ฿ 4,940 million

/1/ World Bank : Bangkok Flood Protection and Drainage Project, Staff Appraisal Report Thailand, November 1979, World Bank Report No. 2002

Assuming these increased values accrue over a five year period, annual values are 1,000 million Baht.

3.3.3 Burkhard Estimation

Damage from the flooding in 1981 was estimated by Burkhard Teichgraber, Karlsruhe University of West Germany. The estimates were done for residential houses and for commercial stores, for three categories as indicated below.

(1) Direct Material Damage

Damage on private buildings and loss of production and services.

(2) Indirect Damage

Non-material damage such as time loss in the traffic and environmental damage expressed in terms of willingness-to-pay.

(3) Flood Prevention Investment

These costs for raising land, construction of flood walls and other preventive measures as an investment by residents or by shop owners.

The results of this estimate are indicated in the table below.

Means of Damage

(Baht/m^2)

		Direct Damage	Indirect Damage	Prevention
Residential	Large dwelling and terrace-houses	12.8	5.5	62.0
	Small dwelling houses	34.5	13.6	41.1
	Flats	4.45	3.78	74.1
Trade	Street shops	1960	499	3590
	Shops	3470	526	3610
	Supermarket & Department Stores	2840	673	2340

The Burkhard Estimate was based on 65 questionnaires distributed over an area of 5.4 km^2. The figures were extrapolated linearly to 450 million Baht as the estimated damage for an area of 82 km^2 in the central area.

3.4 Flood Damage Survey in 1982 Flood

There has been no flood damage estimate made within the Study Area, although there are some records on flood damage in the central Bangkok area. The Study Team surveyed the damage of the 1982 flood within the Study Area. The survey was done in the form of a direct interview method from June 29, 1983 to July 13, 1982, with the assistance of 11 staff members of DDS. The number of collected samples was approximately 400. The area surveyed was mainly in the middle of the Study Area, where the flooding was considered to be severe.

Flood damage is classified into five categories; direct damage, indirect damage, secondary damage, intangible damage and uncertain damage.

1) Direct Damage

This damage is costs for repairs of replacement for goods spoiled by water.

2) Indirect Damage

This damage includes the value of lost business and services, the cost of alleviating hardship, safeguarding health, rerouting traffic, delays and related phenomena.

3) Secondary Damage

Secondary damage may occur when people who are not living or not working in the flooded area suffer economic losses caused by the flooding, e.g. those who depend on the output from a damaged property or on services which are affected, suffer a substantial reduction in income. Secondary damage, however, is normally smaller than secondary benefits and can be excluded from the evaluation.

4) Intangible Damage

The value of damage to environmental quality, social well-being etc. cannot be expressed in monetary units and is, therefore, designated as intangible damage.

5) Uncertain Damage

The inhabitants of a flood-prone area suffer continuous uncertainty as to when the next flood will occur and how serious it will be. The cost for flood prevention works belongs into this category.

Among the five categories, three items; direct, indirect and uncertain damage were estimated by the Study Team as follows:

Damage from the 1982 Flood

Direct Damage	:	260 million Baht
Indirect Damage	:	41 million Baht (only for traffic delays)
Uncertain Damage	:	82 million Baht
Total Damage	=	384 million Baht

(Details are explained in Appendix B)

3.5 Conclusion

Floods, forced to be admitted by Bangkokians for a long time, have become more and more serious since the late 1970s. Severe floods occurred in 1978, 1980 and 1982. Especially, the 1980 flood caused much havoc. The flood damage investigations for the flood in central Bangkok exist, however, no flood damage investigation was made for the Study Area. Hence, as a case study of flood damage in the Study Area it was estimated as about 400 million Baht for 1982 flood by the Study Team.

Chapter 4 FLOOD IN 1983

During the Preliminary Study in 1983, Bangkok was incidentally assaulted by an extraordinary rainfall and flood. The opportunity was taken to get as much information about the flood as possible, which is described in this chapter.

4.1 FLOOD SITUATION

1983's flood in the Bangkok Metropolis caused by heavy rainfall started in the Bang Na area at the end of August. It extended to some parts of northern and eastern suburbs in the Bangkok Metropolis from the middle of September and continued until the end of November. Fig. 4.1 shows the view of the inundation area in the Bangkok Metropolis between the middle of September and the end of October. The depth of the flood water along the main road is indicated in Fig. 4.2. The stretches of main roads over which floodwater flows are clearly found from Figs. 4.3 to 4.7.

Most serious flood areas are Bang Na, Hua Mark, Bang Kapi and Lat Phrao. These areas were flooded for more than two months and the depth of floodwater reached about one meter at some places in these areas. Schools in the flood areas were closed, especially Ramkhamhaeng University in Hua Mark and Japanese school in Soon Vijai.

Almost all the Study Area suffered from flooding, especially areas along the main klongs suffered severely. The heavy rainfall especially in August of about 460 mm rainfall was recorded, whilst in the 1980 flood, only about 190 mm was recorded. Furthermore, much water equivalent to 12 mm to 15 mm per day rainfall came from the outer areas into the Study Area. The volume of 12 to 15 mm per day (totaled 1,080 mm to 1,350 mm for three-month) is almost the same as the rainfall (1,078 mm) in the Study Area.

However, existing capacity of main pumps and main klongs were only 9 mm per day. Consequently, inflowed and precipitated water accumulated in the low-lying area in the Study Area, thus flood lasted for a long period.

4.2 RAINFALL

Monthly area rainfall in the Study Area in August, September and October in 1983 amounted to 461.5 mm, 331.8 mm and 284.8 mm respectively. Three-month rainfall totalled to 1,078.1 mm. Table 4.1 shows the comparison of monthly rainfalls in recent flood years.

It is very clear from Table 4.1 that the amount of the rainfall in August 1983 is more than twice that of other years, and the total rainfall in the three months in 1983 is more than 1.5 times that of other years. The rainfall in three months from August to October 1983 is of a 25-year return period.

Table 4.1 MONTHLY AREA RAINFALL IN AUGUST, SEPTEMBER AND OCTOBER IN THE STUDY AREA

(Unti: mm)

Month Year	1978	1980	1982	1983
August	90.0	191.5	168.9	461.5
September	321.4	318.9	237.5	331.8
October	119.2	274.3	238.8	284.8
Total	530.6	784.7	645.2	1,078.1

Monthly and weekly rainfall at Don Muang, Bangkok and other stations are shown in Fig. 4.8 and the daily area rainfall in the Study Area and the variation of water level at Bangkok Port in the Chao Phraya River are shown in Fig. 4.9.

4.3 WATER LEVEL OF KLONGS AND INFLOW FROM THE OUTSIDE OF STUDY AREA

The water level at 12 water gauging stations in the existing klongs were observed in the 1983's rainy season by the Study Team in cooperation with DDS counterparts.

The detail of the observation result is shown in Appendix F.

Fig. 4.10 shows the locations of the water level gauging stations. The daily area rainfall in the Study Area and typical water level at the observation stations between August and November are shown in Figs. 4.11 and 4.12.

Fig. 4.12 shows that the water levels of two stations G and H were 1.2 m above MSL in the middle of October being caused by heavy rainfall and floodwater from the northern and eastern parts of the Study Area.

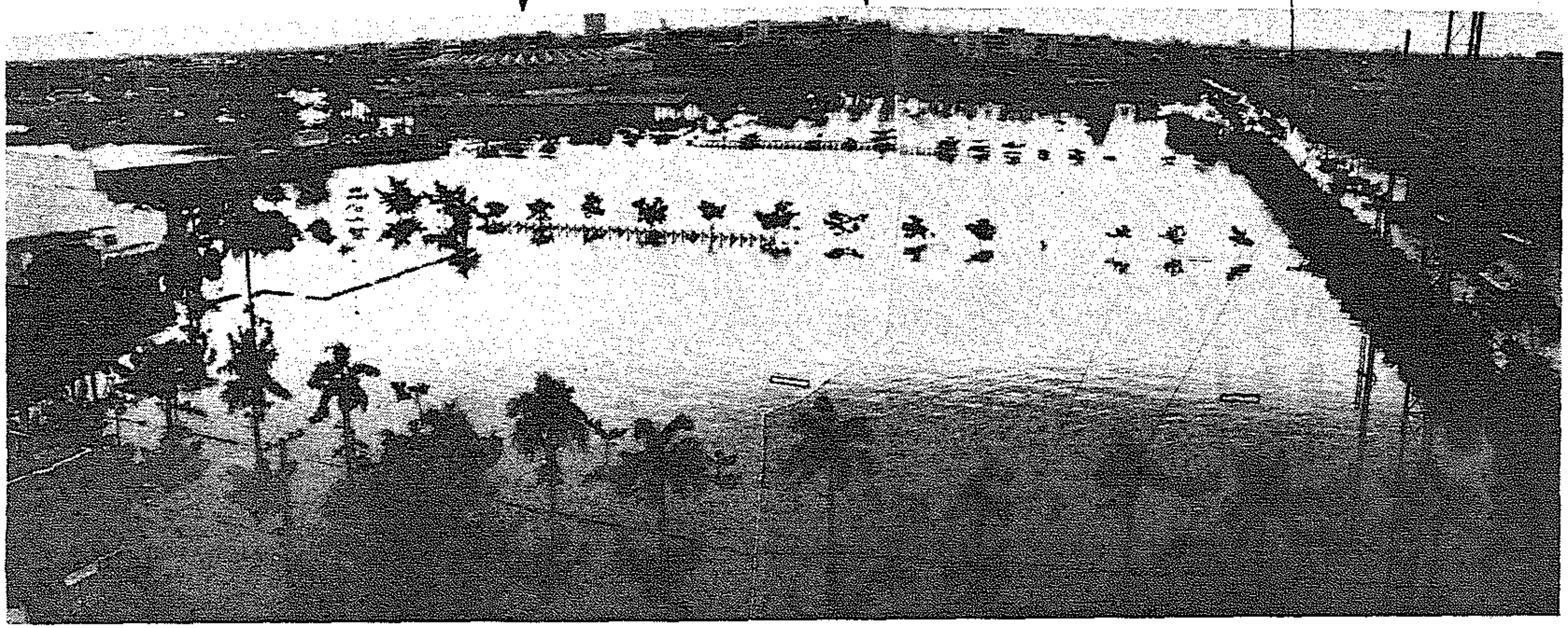
The amount of water inflow from the outside of the Study Area was observed at essential points as shown in Figs. 4.13 and 4.14. The total inflow into the Study Area was estimated between 70 m^3/sec and 90 m^3/sec. at the time of the observation period which were equivalent to 12 mm/day rainfall to 15 mm/day for the Study Area of 501 km^2.

4.4 CONCLUSION

The 1983 Flood was in extraordinary which is the biggest for these 40 years.

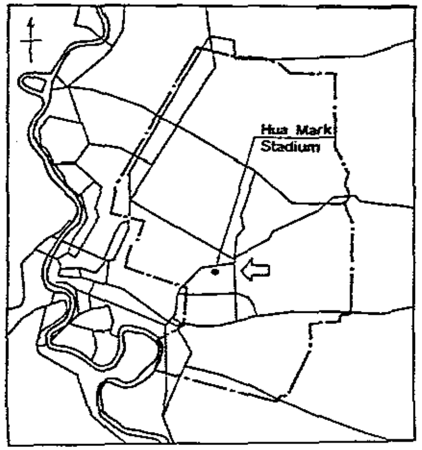
The probability of the rainfall in three months from August to October in 1983 flood has been estimated as 25-year return period, while the probability of 1980 flood was only a 3.4-year return period. Further, water amount inflowed from the outer areas into the Study Area was almost the same as the rainfall in the Study Area.

Invaluable data such as flood level, flooded area and the amount of inflow from the outside of the Study Area were obtained, which are not only used in the hydrological study but also give a guideline for establishment of flood protection/drainage system and selection of Master Plan Area.

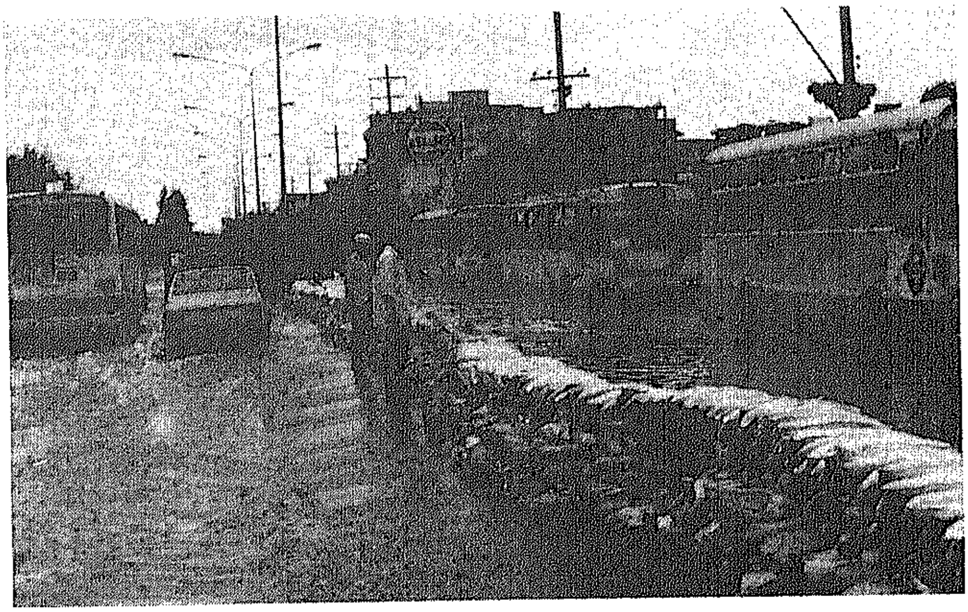


From Oct. 17 Until The Middle of Dec. 1983

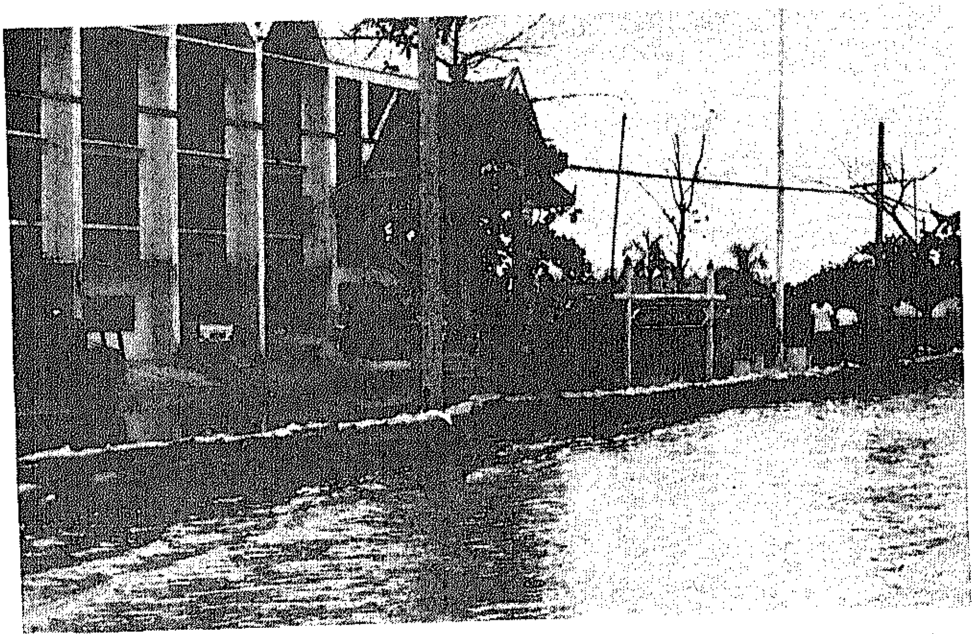
Key Map



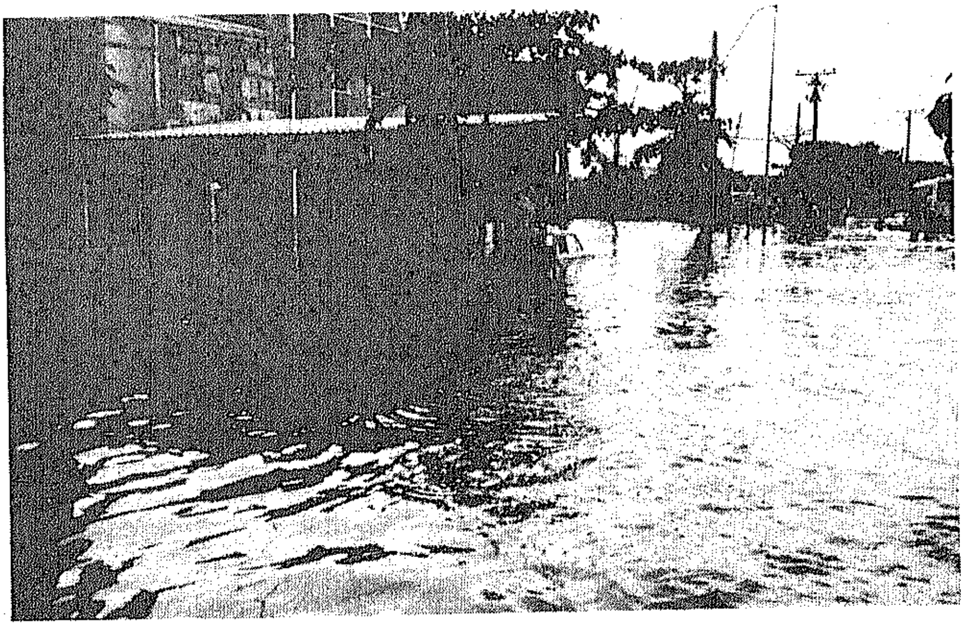
Hua Mark Stadium Under The Flood Water



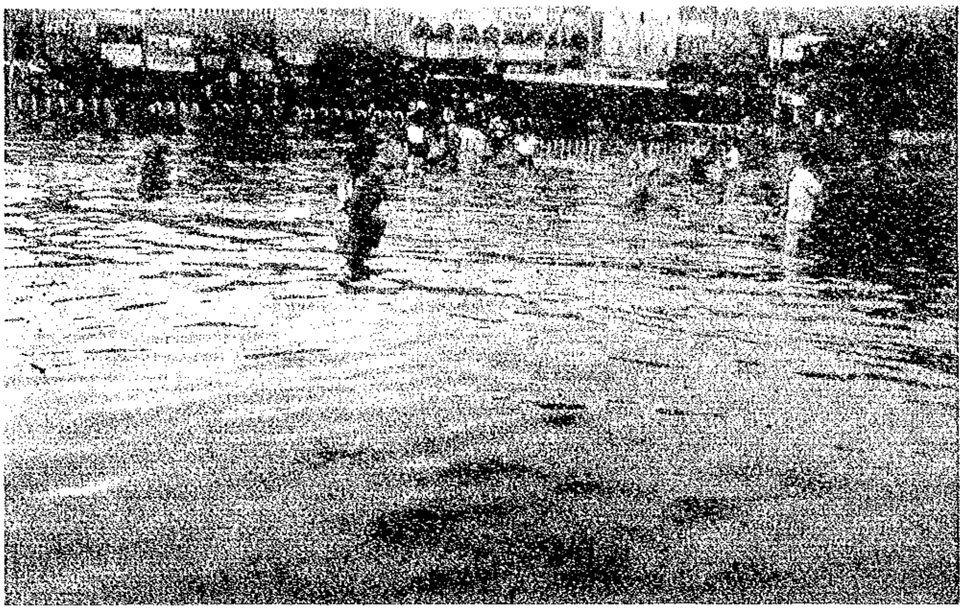
Temporary dyke in the middle of the Rangkhamheng Road.



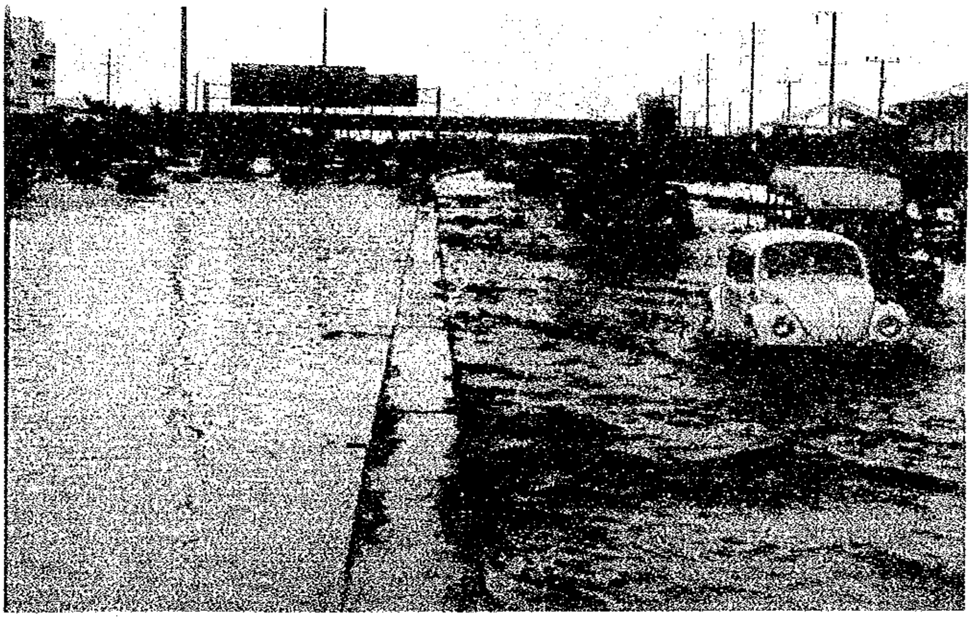
Sand bags protect the Hua Mark Police Office from flooding
on Oct. 14, 1983.



The Hua Mark Police Office inundated with flood water
on Oct. 17, 1983.



Floodwater was the waist depth in front of
Rang Khamheng Univ. on Oct. 17, 1983.



Floodwater flowed through the Wiphawade Rangsit Rd.

The shops prevent the floodwater by sand bags.

Chapter 5 EXISTING KLONG NETWORKS AND FLOOD CONTROL SYSTEM

Existing klong networks and flood control system are the basic physical conditions in planning the flood protection/drainage system. So, they are explained in this Chapter.

5.1 ACTIVITY OF DEPARTMENT OF DRAINAGE AND SEWERAGE

The flood in 1975 caused severe havoc throughout the city core, because it was thought that a big flood such as the one which occurred in 1942 would not happen again because the large dams had been constructed in the upper reach of the Chao Phraya River. As a result of the 1975 flood, the Bureau of Drainage and Sewerage (now called "the Department of Drainage and Sewerage") was established in 1977.

In 1978, DDS devised emergency flood protection schemes or short-term measures to alleviate the problem aiming at the protection of the 100 square kilometers area in the center of the city. Seven polders were devised in which five polders (No.1 to 5) are in the central area and two polders (No. 6 located in Bang Na and No. 7 in Hua Mark) are located within the Study Area as shown in Fig. 5.1. These areas are enclosed by dykes which utilized existing roads and railways and cofferdams to block outside water from flowing into the areas. Rainfall occurring within these protected areas is to be pumped out.

Since 1980, not only the central area but the eastern suburbs (Study Area) as well, suffered from flooding. Flooding in the Study Area lasted longer than that in the central area due to inadequate outflow capacity and abundant inflow from the outer areas. Provisional measures such as many cofferdams, pumps and gates were constructed. In addition, many main klongs were cleared out so that water could easily run off to the south.

Apart from the emergency schemes, a long-term program for central Bangkok, called the "Bangkok Flood Control and Drainage Project (BFCD)" covering an inner core area of 86 km^2 began in June 1983, and detailed designs and draft tender documents are expected to be completed by February 1985. This program is explained in section 2 of Chapter 7.

In addition, a considerable area is protected from water coming from outer areas under the administration of DDS as shown in Fig. 5.2.

5.2 EXISTING KLONG NETWORK

The extensive network of canals, known as klongs, that traverse the Area serve as a drainage system, while pipe drains have been installed in some urban areas. Originally, the klongs were excavated for navigation, irrigation and drainage.

The klongs have long served as an irrigation and drainage system. After World War II, the Study Area was covered by the irrigation network project, the Greater Chao Phraya Project". Irrigation water carried from the Rama VI dam on the Pasak River is to be stored at a high elevation with regulators.

The density of distribution of the klongs is more than one kilometer per one square kilometer. Fig. 5.3 shows the main existing klong network. Channel widths vary from a few to 40 meters. The main klongs which are more than 20 meters wide are Phra Khanon, Saen Saep, Tan and Lat Phrao. Typical cross sections are shown in Figs. 5.4 and 5.5.

According to the result of the topographic survey, average longitudinal grades of Klongs Phra Khanong, Saen Saep, Tan and Lat Phrao as shown in Figs. 5.6, 5.7, 5.8 and 5.9 are estimated to be about 1:15,000 to 1:20,000.

The existing discharge capacities estimated by the uniform flow method are shown in Figs. 5.7, 5.8 and 5.9, while the capacities estimated by the non-uniform flow method are shown in Fig. 5.10 under the condition of keeping the water surface below ground elevation.

The discharge capacity of Klong Phra Khanong is estimated to be 50 m^3/s to 80 m^3/s downstream of the confluence of Klong Tan, with 10 m^3/s to 20 m^3/s upstream. These results are by the calculation of both the uniform flow method and the non-uniform flow method.

Similarly, the discharge capacities of Klongs Tan, Saen Saep and Lat Phrao are estimated as about 25 m^3/s, 15 to 25 m^3/s and 10 to 20 m^3/s respectively.

This means that main Klongs can carry such stormwater in one day as being equivalent to 9 mm a day precipitation in the whole Study Area of 501 km^2, or 18 mm precipitation even if the drainage area is reduced to the half. A discharge capacity of the Area is governed mainly by the existing downstream capacity of Klong Phra Khanong. Consequently, flooding occurs frequently because rainfall exceeds 10 mm per day.

5.3 FLOOD CONTROL SYSTEM

Seven areas have been protected by a polder system from stormwater flooding as shown in Fig. 5.1. About 180 pump units with a total capacity of about 100 m^3/sec are installed at 86 locations mostly within the areas covering 100 km^2 which are shown in Fig. 5.11.

At present, stormwater within these protected areas causes inundation for a short period which is then pumped out.

The larger areas, outside these protected areas have temporary flood protection facilities, most of which are cofferdams. The locations of these facilities are shown in Fig. 5.2.

5.4 CONCLUSION

Various flood protection measures have been executed in the central area of Bangkok. Recently, they have been expanded towards the Study Area.

However, the capacities of these measures – pumps, klongs, etc. – are insufficient, and most of the measures are of a temporary nature or remedey works, for flood damage.

Hence it is necessary that the permanent measures as well as improvement of drainage capacity will be taken for alleviating flood damage.

Chapter 6 CAUSES OF FLOOD AND FLOOD DAMAGE

Based on the site investigation for past flood damage and the existing flood protection system, the major causes of flood and flood damage in the Study Area were investigated. This chapter describes the findings.

6.1 GENERAL

In order to establish a suitable and effective flood protection and drainage system, the causes of flood and flood damage were studied by:

1. Evaluation of the general mechanism of flood damage occurrence. (refer to Fig. 6.1)

2. Review of the present status of the flood protection plan arranged by NESDB. (refer to Fig. 6.2)

6.2 MAJOR CAUSES OF FLOOD

The major causes of flood in the Study Area were found to be as the following: (refer to Fig. 6.3)

1) Rainfall

The rainy season usually extends from mid-May to mid-October as the southwest monsoon brings moist air from Indian Ocean. Besides the monsoon, heavy tropical storms due to tropical depressions are experienced in Bangkok several times between August and October. The highest rainfall usually occurs in September.

2) Low Flat Plain and High Water Level of the Chao Phraya River

The ground surface elevation in the Study Area is very low while the water level of the Chao Phraya River rises between September and November due to high tides and floodwaters flowing from the North. Thus, the amount of discharge from the Study Area to the Chao Phraya River is reduced.

3) Inflow from Outer Areas

The amount of floodwater due to inflow from outside of the Study Area is very large.

4) Progression of Land Subsidence

Land subsidence which is caused by excessive pumping-up of groundwater, reduces the gravity discharge from the Study Area to the Chao Phraya River.

5) *Insufficient Drainage Capacity*

Besides the major causes of flood described above, the insufficient drainage capacity of *klongs*, pumps, gates and drainage pipes are the other causes. Main drainage gates to the Chao Phraya River are limited in number. There are only four stations, Bang Khen, Bang Sue, Phra Khanong and Bang Na in the Study Area.

6) Change in Land Use Condition

Flood water retention capacity in the Study Area has decreased considerably becuase housing construction and reclamation of swamp areas has taken place to meet land use demand for urbanization, causing an increased runoff discharge.

6.3 MAJOR CAUSES OF FLOOD DAMAGE

Flood has occurred in the Study Area since a long time ago due mainly to natural conditions mentioned in the preceding section. However, it is relatively recent years that flood became a serious problem. This was caused by unplanned urbanization, which increased flood damage potential and subsequently flood damage. In other words, flood damage was created by human activity.

6.4 GENERAL FLOOD DAMAGE MODEL

Flood damage will occur when a heavy rainfall occurs in a flood-prone area which has damage potential. In general, the flood damage potential can be measured by the relationship between ground surface and expected flood water level.

Fig. 6.4 shows an example of flood damage models.

6.5 CONCLUSION

The following six factors are considered as the causes of flood.

1) Rainfall

2) Low Flat Plain and High Water Level of the Chao Phraya River

3) Inflow from Outer Areas

4) Progression of Land Subsidence

5) Insufficient Drainage Capacity

6) Change in Land Use Condition

The rapid increase of flood damage in recent years was caused by an increase of damage potential due to unplanned urbanization. Therefore, flood plain management will play an important role for alleviating the flood damage.

Chapter 7 PREVIOUS STUDIES AND RELEVANT PLANS

In this chapter, the previous flood control studies and relevant plans related to this Study are investigated to provide the fundamental imformation for the Study.

7.1 CAMP DRESSER & MCKEE (CDM) PLAN

Since 1960, numerous studies related to flood protection and drainage have been made for Bangkok. In 1969, a Master Plan prepared by Camp, Dresser and Mckee (CDM) was approved by the Government as the official plan. The study area covers 370 square kilometers of central parts of Bangkok.

The proposed Master Plan includes establishment of 11 polders as shown in Fig. 7.1, whose area varies from 11 to 100 square kilometers each. Each polder was planned to be protected from external flood waters by a flood protection barrier consisting of a combination of embankments, highways and concrete walls. Each polder is surrounded either by rivers or large klongs. The crest elevations of the flood protection barrier are 2.2 meters above MSL at Memorial Bridge (47 km upstream from the river mouth) and 1.9 meters at Bangkok Port (28 km). These are planned based on the 100-year frequency flood levels and a freeboard of 0.37 meters.

Drainage within each polder is affected by a system of interconnected internal drainage klongs. Stormwater runoff is pumped from the internal drainage klongs into the external klongs such as Klongs Phra Khanon, Saen Saep and Lat Phrao, or directly into the Chao Phraya River. Each polder requires from one to eight pumping stations. Fig. 7.2 indicates the principal components of the proposed system consisting of the flood barriers, the internal drainage klongs and the stormwater pumping stations.

According to the results of the computer study by CDM, the planned pumping capacity varies between 15 and 27.5 CMS (0.6 to 1.4 CMS/km^2) while the average peak run-off ranges from 4 to 7 CMS/km^2. This difference is created by temporary stormwater storage within the areas.

According to the CDM plan, stormwater drainage in the residential area was designed to carry away the run-off expected from a storm occurring only once every two years. In other developed parts of the study area, the drainage was designed for a storm with an expected frequency of once in five years.

Implementation of the CDM plan was proposed to take about 30 years to complete up to the year 2000. The budget for this project estimated in 1968 excluding the sewerage system were 7,400 million baht.

The most significant portion of the construction cost, which was to be completed within 14 years or by the year 1980, was 1,150 million baht in terms of 1968 costs.

The construction, however, did not proceed except for two pumping stations: the Rama IV and the Padung Krung Kasem and some other facilities.

7.2 FLOOD CONTROL AND DRAINAGE PROJECT IN CENTRAL (CITY CORE) AREA

NEDECO in joint venture with NECCO and LAND MARINE/SPAN is now carrying out the Feasibility Study and Detail Design on "Bangkok Flood Control and Drainage Project (City Core)" covering an area of 86 km^2, which is shown in Fig. 7.3. The NEDECO's study began in June 1983, and the detail design is scheduled to be completed by February 1985. The main work items are summarized as follows:

A. Review of the Project Status
B. General Studies for all Polder Areas
C. Specific Studies for each Polder Unit
D. Preparation of Detail Designs and Draft Tender Documents
E. Procurement Assistance

The draft of general study report covering the items A and B was presented on 30 September 1983. Other items are now under study. It is understood that this report is the interim report that shows a guide line for the detail design.

According to the report a flood protection barrier, consisting of retaining walls or (raised) embankments is proposed to prevent flooding of the central area. The flood protection barrier is classified into three classes; main protection barrier, secondary protection barrier and temporary protection barrier.

Main protection barrier will be located along the Chao Phraya River and the major boundary klongs, viz. Klong Bang Sue, Klong Tan and Klong Phra Khanong. This barrier will be designed for high water levels with a return period of 100 years and with expected land subsidence in 10 years.

Secondary protection barrier will be located on the inland boundaries, viz, Viphavadi Rangsit Highway, northern side of the east bound railway line and north of New Petchburi Road. This barrier is designed for high water levels with a return period of 10 years and with expected land subsidence in 5 years. Temporary barrier will be located inside the project area to protect the first phase area (western part of the project area, while the second phase (eastern part) is not completed. For the design of temporary barrier a return period of high water levels of 10 years and with expected land subsidence in 3 years is adopted.

It is designed that klong water level within the main barrier is to be 1.5 m or more lower than the land level of the protected area. Assuming that a land level is between 1.00 m and 1.50 m above MSL (Mean Sea Level), the average klong water level should be around MSL −0.25 m.

The polder units are proposed to have an independent water management for each unit, which are shown on Fig. 7.3. Some of the units will be combined to larger units.

Provisionally, the design of the drainage system is based on a combination of rainfall with a 2 years return period outside water levels of 0.70 m and 1.35 m above MSL. The frequency of occurrence of this condition is once per 10 years. However, the future drainage system in eastern parts of the Core Project area will be based on the use of pumped discharge only, because the possibility of discharge by gravity will decrease with land subsidence.

Local short flooding caused by torrential rainfall, for example with a 10 years return period, seems to be allowed because of the difficulty of increasing storage capacity and the high cost of the installation of additional pumps. For example, installing additional pump with relatively high capacity at some places can reduce the duration of flooding to only a few hours.

Table 7.1 gives a summary of the peak runoff values for the distinguished polder areas expressed in m^3/sec per km^2 at the selected return periods for the present and future land use conditions from the result of the model simulations for storm-durations of 3 hours.

The pumped-out water from the Core Area to main klongs, Klong Tan, Klong Phra Khanong and Klong Bang Sue, brings the greatest impact on flood protection/drainage system in the Study Area. Therefore, improvement of these main klongs and installing pumps in their lower reach are essential for the drainage system.

Table 7.1 PEAK RUNOFF IN M^3/S PER KM^2 IN POLDER AREAS DUE TO RAIN-STORMS OF SELECTED RETURN PERIODS (CITY CORE PROJECT)

Polder	Size of Polder (km^2)	present land use			Future land use		
		T2	T5	T10	T2	T5	T10
1	19.8	10.5	12.5	14.0	12.0	14.2	16.0
1A	11.2	11.5	13.7	15.4	12.0	14.3	16.1
1B	8.6	10.1	11.9	13.4	12.9	15.3	17.2
2	11.2	12.5	14.9	16.7	12.5	14.9	16.7
3	17.4	8.3	10.0	11.2	8.8	10.6	11.9
3A	12.0	8.6	10.2	11.5	9.7	11.6	13.0
3B	3.2	10.3	12.2	13.7	10.3	12.2	13.7
3C	2.2	9.0	10.8	12.1	9.5	11.3	12.7
4	7.6	8.6	10.3	11.6	12.7	15.2	17.2
5	15.0	8.3	9.8	11.0	10.7	12.5	14.0
6A	12.1	8.1	9.7	10.8	9.5	11.3	12.7
6B	0.8	12.6	15.0	16.9	15.9	18.9	21.3
6C	2.7	10.0	11.7	13.1	10.2	12.0	13.3

The recommended pump capacity for present and future situation by NEDECO is shown on Table 7.2.

The total cost of the project is provisionallly estimated at:

Flood protection barrier	฿ 792,860,000
Pumping stations	฿ 900,900,000
Sluices	฿ 6,350,000
Klong improvement, etc.	฿ 436,670,000
Land acquisition	฿ 416,000,000
Total	฿ 2,552,780,000

Table 7.2 EXISTING PERMANENT AND PROPOSED NEW PUMPING STATIONS (CITY CORE PROJECT)

Polder	Size of Polder (km2)	capacity of pumping station existing [m3/s]	proposed [m3/s]		Total [m3/s]
1 A/B	19.8	6			
			10		36
		20			
2	11.2	25	-		25
3	17.4	-	10		
			10		40
			15		
			5		
4	7.6	-	15	(35)*	15 (35)*
5	15.0	2.2			
		2.2			29.4 (69.4)*
			15	(25)*	
			10	(15)*	
6	15.6	-	25	(35)*	
			5		35 (70)*
			5		
Total	86.6	55.4	125	(45)*	180.4 (225.4)*

* : These capacities will be required in the future, taking into account of land subsidence.

7.3 CHAO PHRAYA RIVER WATER LEVEL LOWERING PLAN

The water level of Chao Phraya River usually experiences the first rise in May or June within a period of 1–3 weeks. The second rise occurs gradually and reaches its maximum in October in the upper reaches and in November in the lower reaches.

When the water level rises, a considerable quantity of water escapes into tributaries and branches. This water overflows the banks of tributaries and spreads out into the low-lying areas on both banks of the Chao Phraya. The lower plain of the Chao Phraya River, between Nakhon Sawan and Bangkok, looks like a large lake during a high flood season.

The major existing storage dams in the Chao Phraya river, the Bhumipol dam (effective storage volume, 8,600 million cubic meter) and the Sirikit dam (ditto, 8,800 million cubic meter) have a flood regulating capacity of 500 m^3/sec of the Chao Phraya River. These dams, which have been in operation respectively since 1962 and 1971, have had a remarkable effect on lowering water levels in the Chao Phraya River for small to medium size floods. However, for large floods, these are not so effective.

Besides these dams' capacity, "conservation areas" between Chainat to Ayutthaya play an important role in alleviating the flood damage in the Chao Phraya River basin. About one-third of the discharge of the Chao Phraya River is retained in the "conservation areas".

The followings are brief outline of the calculated distribution of discharge in the middle reach of the Chao Phraya River.

1) Total discharge flow into the Chao Phraya delta is 5,365 m^3/sec for the flood in a 10-year return period.

From the Chao Phraya River at Chainat	4,160 m^3/sec
From the Pasak River at Tha Rua	520
From western terrace	85
From eastern terrace	100
From others (Rainfall etc.)	500
Total	5,365

2) A flow of 3,515 m^3/sec is discharged through the two rivers, while the remaining flow of 1,850 m^3/sec is distributed over or naturally conserved as follows:

Conserved amount	1,850 m^3/sec
Chao Phraya River	3,315
Suphamburi River	200
Total	5,365

About one-third of the discharge of the Chao Phraya River is retained in the "conservation areas" between Chainat to Ayutthaya. If these areas do not retain the water, then the water level in the lower reach becomes very high. If the retaining capacity loses a flow of 600 m^3/sec out of total of 1,850 m^3/sec, then the water level in Bangkok is estimated to be increased by 0.4 to 0.5 meters according to the NEDECO study.

AIT is now undertaking an 18-month long study which is called the "Flood Routing and Control Alternatives for the Chao Phraya River for Bangkok" for NESDB. The study began in early 1983. The following flood control schemes are being considered in this study.

a. Construction of diversion dams and flood bypass channels to divert flood flows to Bangkok.

b. Dredging or widening of the shallow or narrow reaches of the Chao Phraya River to increase flood conveyance capacity.

c. Construction of cutoff channels at meanders below Bangsai, which is located between Bangkok and Ayutthaya.

The above-mentioned study will be studied under the condition that no any adverse effect will be made on the irrigated area. It will also not consider such "headwater" schemes as reforestation or reservoir construction.

The natural storage capacity of the Chao Phraya plain has protected Bangkok from severe flooding. Accordingly the conservation of the areas which are contributing to storage of potential flood water should be maintained in their present land condition.

7.4 GREEN BELT PROJECT

The Master Plan of the Royally-Initiated Flood Prevention Scheme, the so-called "Green Belt Project" was worked out in 1981 after the serious flooding which occurred in 1980. The plan covers the area of the eastern cultivated fields as shown in Fig. 7.4. The area between Klong Sam Wa and Klang Lan Pla Tew has been declared as a green belt area, which clearly separates the unbanized area and the surrounding agricultural land. The project aims at the drainage of the water quickly into the South, directly into the Gulf of Thailand. For this purpose, the construction of embankments, regulators and cofferdams, and dredging and widening of klongs are being planned as described in the following paragraphs:

1) Embankment

An embankment along the city's eastern outskirts parallel to the western side of Rom Klao Road is to be built from Klong Rangsit to Bang Phli district in Samut Prakan Province. This embankment will be 77.08 kilometers long. The Rom Klao Road and other roads, forming dykes, are to be raised in elevation in order to construct an effective barrier.

2) Regulator and Cofferdam

Forty-three regulators and cofferdams are to be installed along the dykes and the main klongs to control the flow of water, preventing from flowing westward into inhabited areas.

3) Klong (Canal)

Dredging of 19 canals, 173.5 kilometers in total length, are expected to improve the flow of water into larger canals such as Klongs Rangsit, Bang Khen, Lat Phrao and into the Chao Phraya River via Klongs Bang Na, Saen Saep and Phra Khanong. The planned discharge capacities are shown in Fig. 7.5.

During the first year of this King's project in 1981, the Royal Irrigation Department (RID) completed the dredging program for the large canals of Rangsit, Nong Ngu Hao, Bang Plara and Lam Pla Tew. These will be linked to several small klongs which the BMA have excavated in Bang Khen, Lat Krabang and Phra Khanong districts.

The Green Belt Project, which will cost 375.39 million baht, is expected to be completed by 1985. The project is the joint responsibility of NESDB, RID, BMA, the Highways Department and the State Railway of Thailand (SRT).

7.5 SAMUT PRAKAN SEA WALL PROJECT

Samut Prakan Province, covering an area of 934 km² which had a population of 536,000 in 1980 is located adjacent to the south of the Study Area. Some parts of Samut Prakan have been changed substantially from a rural area consisting of farmers, fruit growers and fishermen into an industrial area which is located near Bangkok Port along the Chao Phraya River.

The problem of drainage and flooding in Samut Prakan has become similar to Bangkok since the 1960s. The excessive withdrawal of groundwater due to the increase of factories and population has caused land subsidence. For the prevention of land subsidence, the Metropolitan Water Works Authority (MWWA) is planning to supply surface water as a substitute for groundwater.

A flood protection Master Plan on "Samut Prakan Sea Wall Project" was completed in September 1983 by the Thailand Institute of Scientific and Technological Research. As the project name denotes, the embankments along the Chao Phraya River, the Gulf of Thailand and the Green Belt area are planned to prevent inflow from outer areas. Pumps and gates will be constructed for drainage. In this scheme, floodwater flowing into the area from eastern Bangkok (Study Area) is not considered.

7.6 URGENT FLOOD CONTROL MEASURES DUE TO 1983 FLOOD

In 1983, Bangkok was assaulted by the extraordinary rainfall and flood. The flood was the worst for about 40 years. The total rainfall from August to November amounted to about twice the usual mean rainfall. The damage due to floods are expected to be extraordinary.

In these situation, the Government of Thailand set up the "Committee of Flood Protection and Solution in BMA and the Circumference" on October 10, 1983 in order to take urgent measures for flood control.

It is reported that at the Committee held on October 25, 1983, the following three plans were decided to be executed using the budget of central government.

These plans are scheduled to be completed by the middle of 1984 & 1985 flood season.

Table 7.3 THREE URGENT PLANS

(Unit: million Baht)

Plan	Organization	Budget 1984	1985	Total
1. Raise of Elevation of Rom Klao Road	RID SRT HD	194.5	181.5	376
2. Dike at Samut Prakan	PWD Samut Prakan Province			122
3. Improvement of Klong Samrong	Samut Prakan Province			81
Total				579

Besides the three plans, additional 11 plans were also authorized. (Fig. 7.6) Navigation locks and pumps will be improved at the mouth of Klong Bang Khen, Klong Bang Sue, Klong Sam Saen, Klong Phra Khanong, Klong Jek, Klong Bang Oa, Klong Bang Na and Klong Sam Rong. Two flood protection barriers along both sides of Klong Saen Saep (from Patumwan Gate to Klong Bang Kapi intersection) and along western side of Klong Phra Khanong (from Phara Khanong Gate to Klong Tan intersection) will be constructed. Four klongs in Samut Prakan Province; namely, Klong Bang Ping, Klong Preksa, Klong Mahavong and Klong Tup Nang will be dredged.

Table 7.4 ADDITIONAL 11-URGENT PLANS

(Unit: million Baht)

Plan	Cost of Improvement of Navigation lock and Dredging klong	Installing Pumps		Cost of Pumps	Cost of Installation	Total Cost
		Number	Total Capacity			
1. Improvement of Klong Bang Khen Project (RID)	11.0	$7x3m^3/sec$	$=21m^3/sec$	15.4	5.6	32.0
2. Improvement of Klong Bang Sue Project (BMA)	27.0	8x3	=24	17.6	6.4	51.0
3. Improvement of Klong Sam Saen Project (BMA)	-	6x3	=18	13.2	4.8	18.0
4. Improvement of Klong Phra Khanong Project (RID)	15.0	15x3	=45	33.0	12.0	60.0
5. Improvement of Klong Jek Project (BMA)	4.0	2x3	=6	4.4	1.6	10.0
6. Improvement of Klong Bang Oa Project (BMA)	15.0	6x3	=18	13.2	4.8	33.0
7. Improvement of Klong Bang Na Project (BMA)	5.0	5x3	=15	11.0	4.0	20.0
8. Improvement of Klong Sam Rong Project (RID)	18.0	10x3	=30	22.0	8.0	48.0
9. Construction of Klong Phra Khanong Embankment Project (BMA)	10.0	--	--	--	--	10.0
10. Construction of Klong Saen Saep Embankment Project (BMA)	45.0	--	--	--	--	45.0
11. Dredging Klongs in Samut Prakan Province (Samut Prakan Province)	14.0	--	--	--	--	14.0
Total	164.0	59x3	$=177m^3/sec$	129.8	47.2	341.0

[Source: Sub-Committee of Flood Protection and Solution in BMA and Circumferrence.]

Note : Refer to Fig. 7.6

Total 59 units of portable pumps having a capacity 3 CMS each will be installed at 11 locations in the left bankside of the Chao Phraya River. These pumps are scheduled to be completed by the middle of 1984 to cope with 1984 flood.

The three urgent plans and the additional 11 plans have direct or indirect linkage with the proposed flood protection system in the Study Area. Basically, the 14 plans seem to be consistent with the proposed flood protection system.

Among the three urgent plans, raising the level of Rom Klao Road (as one of the Green Belt Projects) has been proved to be effective, as will be shown in Chapter 14. More than half the stormwater in the 1980 and 1983 flood would have been reduced if the Green Belt Project had been completed. Other two urgent plans will contribute to relieve the flood conditions in Samut Prakan Province, however, they will only indirectly mitigate flood conditions in the Study Area, because stormwater from the Study Area will become more easily to be drained southward.

Among the additional 11 plans, eight plans are intended to prevent backwater from the Chao Phraya River and to pump out stormwater from the Eastern Suburban Area to the Chao Phraya River. Six plans (Klong Bang Khen Project, Klong Bang Sue, Klong Phra Khanong, Klong Jek, Klong Bang Oa and Klong Bang Na Project) are included in the Study Area except Klong Sam Saen Project (Inner Core Project) and Klong Sam Rong Project (Samut Prakan Seawall Project). As these six klongs will become the main outlets from the Study Area, these plans can be considered as the first step for temporary measures against floods in the Study Area. The proposed flood protection system by the Study Team may be two-stage pump system of a more permanent nature, considering that the flood-prone area is located along the main klongs. The main pumps will be installed at the main outlet and auxiliary pumps will be installed at the inner polders which will be planned for the very low-lying area where main pumps cannot solve flood problems.

The temporary pumps in the urgent plan can be used in other places when designed pumps are installed by this project.

7.7 CONCLUSION

In this Chapter, the following 6 Plans/Projects were investigated:

1) Camp Dresser & McKee (CDM) Plan
2) Flood Control and Drainage Project in City Core Area (review and revise of CDM Plan)

3) Chap Phraya River Water Level Lowering Plan

4) Green Belt Project

5) Samut Prakan Sea Wall Project

6) Urgent Flood Control Measures due to 1983 Flood.

Among the six plans, plans 1), 2) and 6) are aiming mainly at improvement of storm-water discharge, while plans 3), 4) and 5) are aiming mainly at prevention of inflow from outer area and from the Chao Phraya River. These Plans/Projects have great influence on the flood condition of the Study Area, especially plans 2), 4) and 6) which are closely related. They are basically consistant with this Study and are recognized as effective Plans/Projects.