社会開発協力部報告書

No. 207

THE KINGDOM OF THAILAND
BANGKOK METROPOLITAN ADMINISTRATION

# MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

## MAIN REPORT

MARCH, 1985

JAPAN INTERNATIONAL COOPERATION AGENCY

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THE KINGDOM OF THAILAND
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# PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the Flood Protection/Drainage Project in Eastern Suburban-Bangkok, comprising two stages, Preliminary Study and Master Plan. The study was entrusted to the Japan International Cooperation Agency (JICA) who sent to Thailand a study team headed by Mr. Saburo Fukagawa.

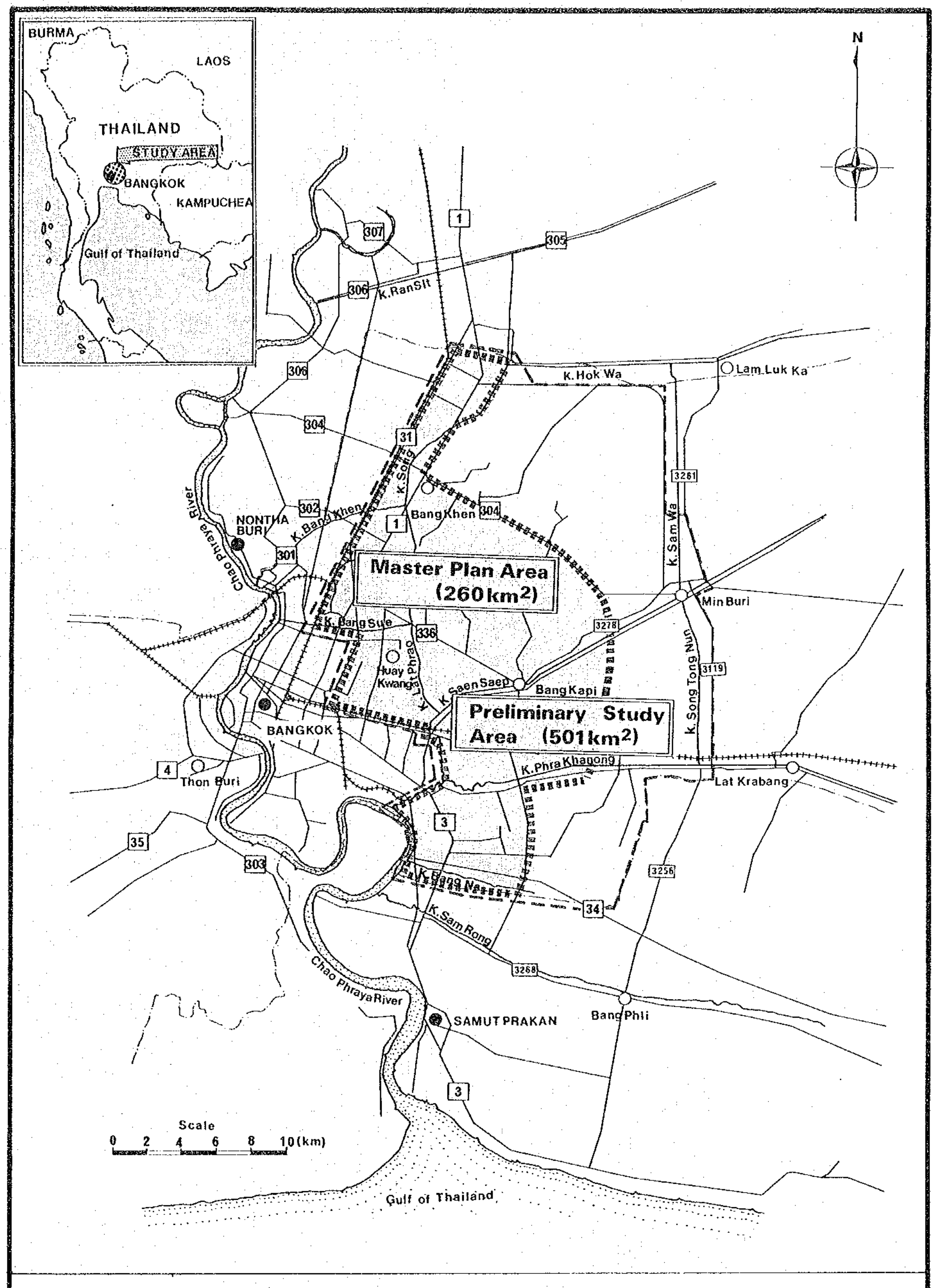
Based on the Preliminary Study completed in early 1984, the preparation of the Master Plan was carried out between May 1984 and March 1985. The team exchanged views on the Project with the officials concerned of the Government of Thailand and conducted a field survey in the eastern suburbs of Bangkok. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve to assist the development of the Project and contribute to the promotion of friendly relations between our two countries.

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

March, 1985

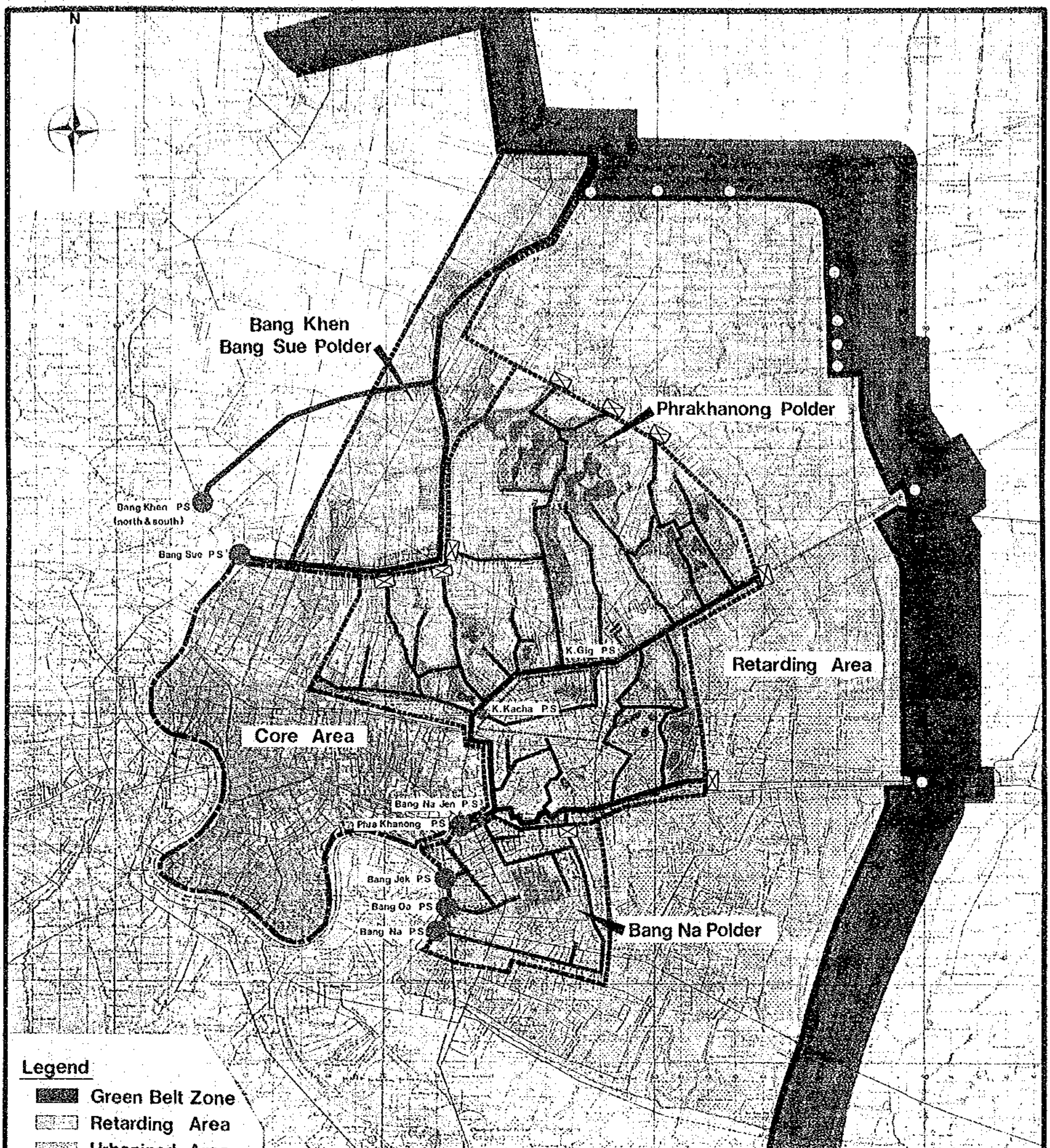
Keisuke Arita
President
Japan International Cooperation Agency




MASTER PLAN AREA

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D




## CONCEPT FOR FLOOD PROTECTION/DRAINAGE SYSTEM

# MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

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1985A.D

# SUMMARY

## SUMMARY

### 1. Introduction

Bangkok, the capital of Thailand, is located on the flat deltaic plain of the Chao Phraya River, and founded on low marshland where flooding has been a seasonal phenomenon. The floods used to bring no substantial damages for the residents living in stilt-elevated houses and relying on boat transportation. But modernization of life-style and rapid urbanization has changed the susceptibility to damage by seasonal floods as indicated by the rising cost of the severe floods which have hit Bangkok since the 1950s. The eastern part of Bangkok is particularly vulnerable to flood due to the continuing land subsidence and rapid urbanization.

The Government of Thailand has been planning and implementing various flood control projects in the Bangkok area. The JICA Study Team initiated the Preliminary Study on Flood Protection/Drainage Project in Eastern Suburban-Bangkok in 1983, which studied an overall flood damage mitigation plan for 501 $km^2$ of the eastern part of Bangkok, and concluded that the selected 260 $km^2$ is to be covered with a flood protection/drainage facilities as the Master Plan Area targeted for the year 2000.

In the rainy season of 1983, a severe flood enveloped the Bangkok area. The estimated flood damage in the Master Plan Area was 3,500 million Baht, the highest in the whole Bangkok. For an immediate mitigation of the flood condition, the Government of Thailand executed urgent projects which are estimated to reduce future flood damage to one-third of the 1983 flood. However, it is anticipated that the flood damage potential of the area is increasing each year, because the population will increase by more than twice (Fig. 1) and the ground elevations will be further lowered to below mean sea level by the year 2000 (Fig. 2). As a result, if the same rainfall as 1983 occurs in the year 2000, the flood damage would be 7,000 million Baht at 1984 prices even with the existence of urgent facilities.

In order to bring a permanent solution which is effective for the expected topographical change and urbanization by 2000, this Master Plan incorporates comprehensive flood protection/drainage systems for the Eastern Suburban-Bangkok.

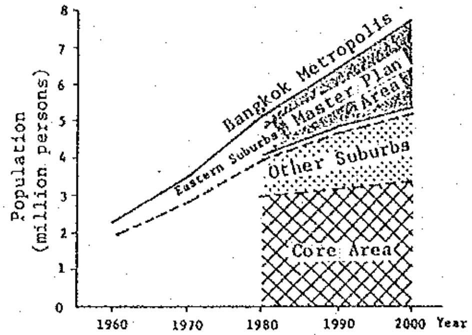


Fig. 1 Population Increase

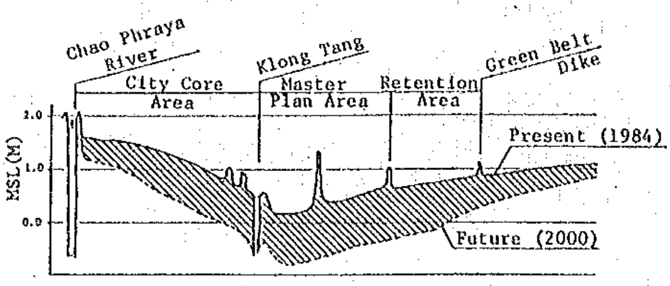


Fig. 2 Progression of Land Subsidence

## 2. Comprehensive Flood Damage Mitigation Plan

Numerous examples of floods, which have occured in cities of other countries indicate that the drainage capacities of the conventional structural measures have not been able to catch up with rapid urbanization and sprawling of urbanization in flood-prone areas. It has become increasingly evident that in order to minimize losses to future development and reduce losses to existing development, a combination of structural and non-structural measures must be employed (Fig. 3). This combination is common for all neighboring areas such as the Core Area, Thonburi Area, Samut Prakan Province in the Lower Central Plain.

For the eastern suburbs of Bangkok, since the area is on the verge of urbanization, it is particularly effective to employ a comprehensive approach, consisting of both structural and non-structural measures, as shown in Fig. 4.

### 2.1 Proposed Structural Measures

The basic idea behind the structural measures is the establishment of a polder system. The inside of the polder is to be protected against inflow from outer areas and the Chao Phraya River by polder embankments and gates. Rainfall inside the polder is to be discharged by the drainage facilities installed inside the polder.

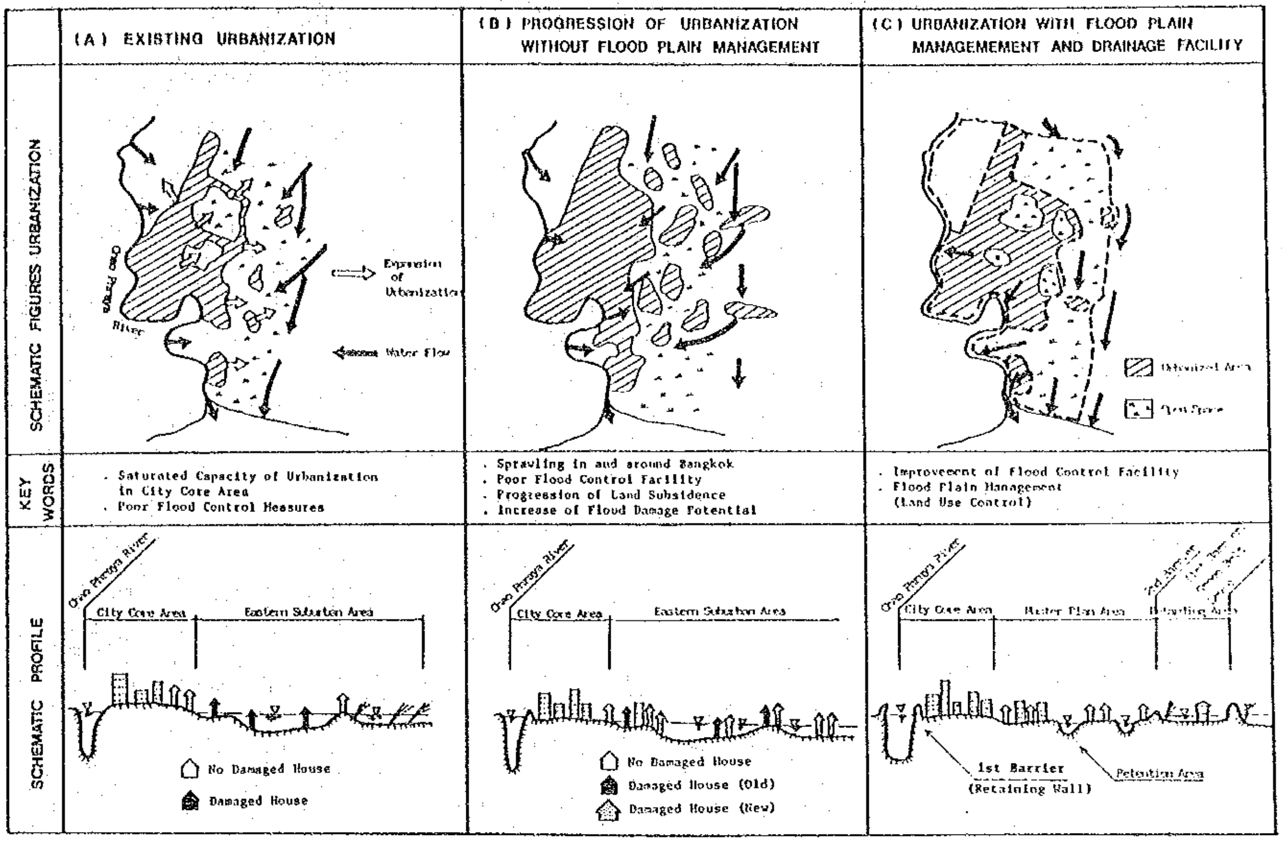


**Fig. 3 Concept of Comprehensive Flood Damage Mitigation Plan**

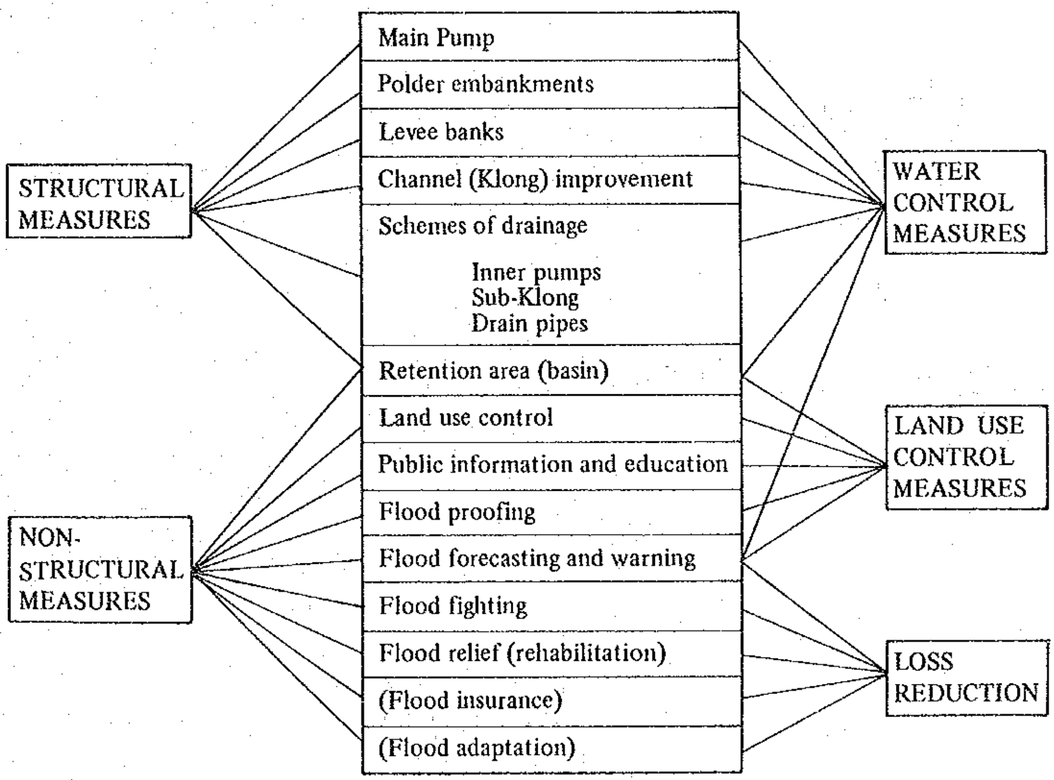


**Fig. 4 Comprehensive Flood Damage Mitigation Measures**

The Eastern Suburbs (501 $km^2$) covered by the Preliminary Study has been protected already by the Green Belt embankment. Further, since about half (230 $km^2$) of the Eastern Suburbs (501 $km^2$) is estimated to be urbanized, the Master Plan Area (260 $km^2$) is proposed for protection by the construction of polder embankments and gates surrounding the Master Plan Area.

The Master Plan Area should be subdivided into three polders i.e., Bang Khen – Bang Sue, Phra Khanong and Bang Na, using topography and the road network acting as natural boundaries and the klong network (Fig. 5).

Once the outer water is blocked off, the inner storm water will be discharged by drainage facilities. Installation of outlet pumping stations discharging storm water into the Chao Phraya River and imrpovement of main klongs leading to the pumping stations will alleviate overall flooding. On the other hand, heavy local flooding will be relieved by improvements to a large number of sub-klongs and main drain pipes, and the installation of inner pumps (Fig. 6).

The structural-measures proposed are shown in Table 1 and Fig. 5.

**Table 1 Proposed Structural Measures**

| | |
|---|---|
| Embankment | 6.2 km |
| Gates | 55 places |
| Pumping Station with Gate | |
| Outlet | 7 stations (200 $m^3$/sec) |
| Inner | 3 stations (18 $m^3$/sec) |
| Klong Improvement | |
| Main Klong (Phra Khanong, Tan and Saen Saep) | 25.5 km |
| Sub-Klong | 107.5 km |
| Main Drain Pipe | 110 km (80 $km^2$) |

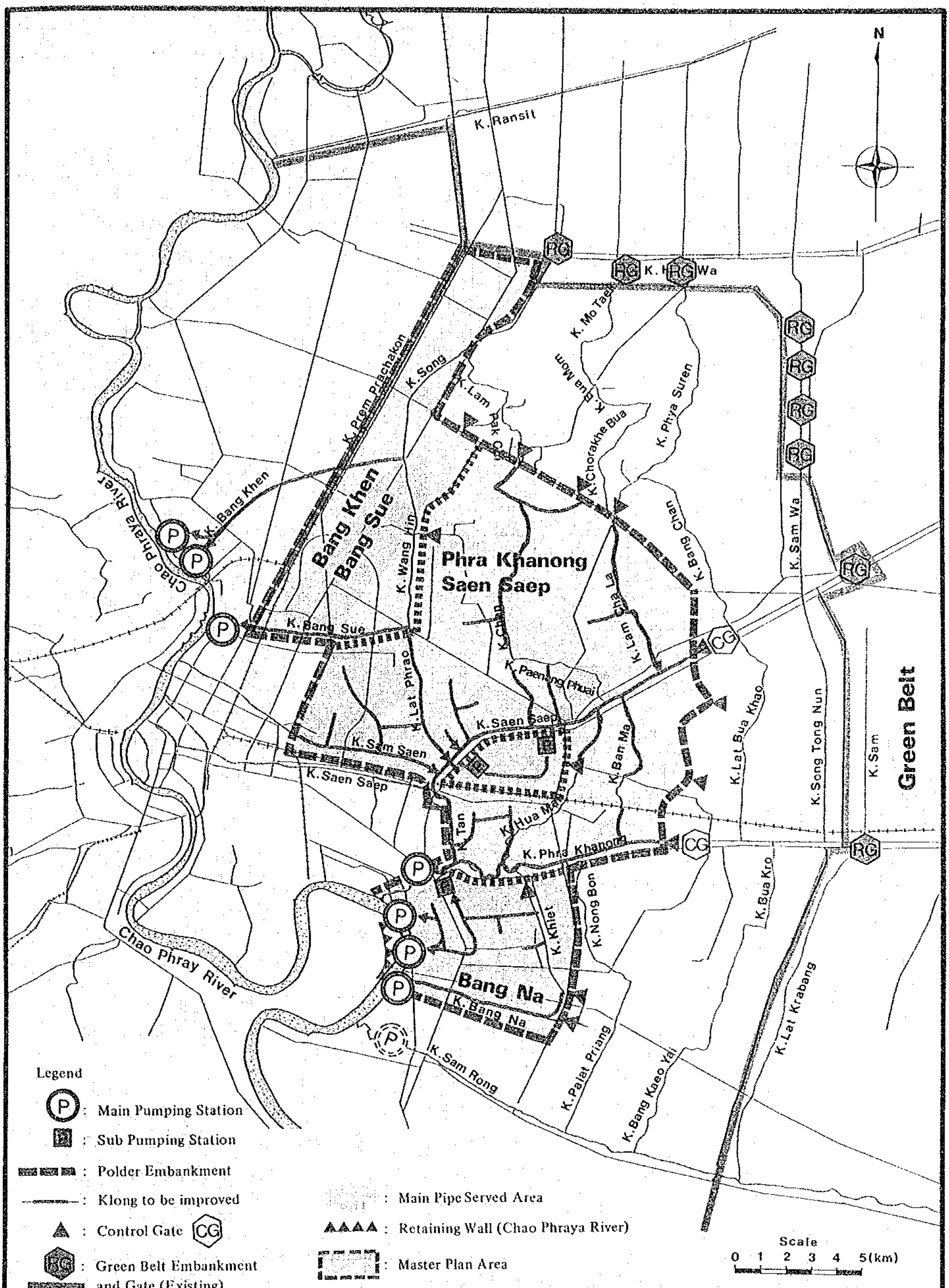


Fig. 5 . PROPOSED FLOOD PROTECTION/DRAINAGE FACILITIES

**MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK**



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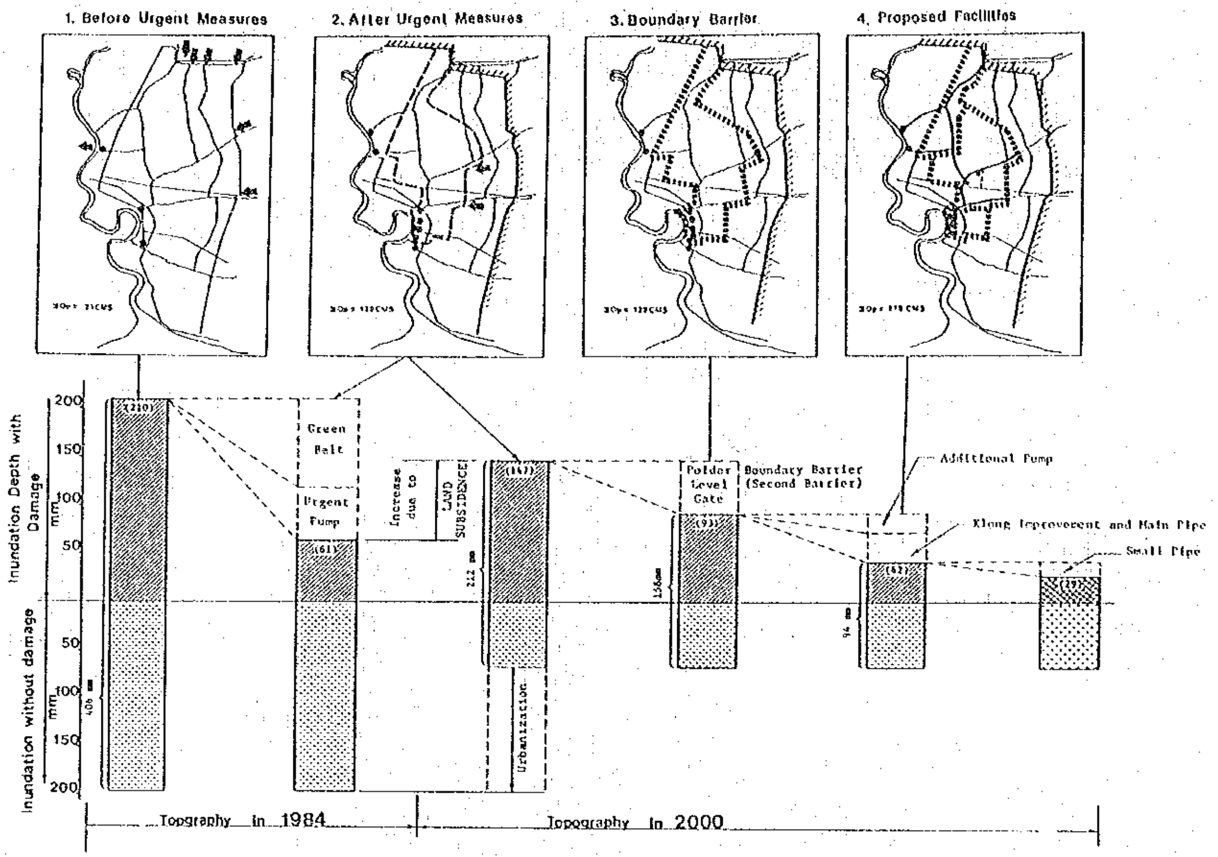



Fig. 6 Hydrological Effect of the Proposed Project

## 2.2 Proposed Non-Structural Measures

The basic idea for non-structural measures is to modify the susceptibility to damage from flooding of property and activities in the flood-prone areas.

The future urbanized area of 82 $km^2$, which will be required between 1980 and 2000, should be allocated to flood-free areas (Fig. 7). Publication of the observed extent and depth of the 1983 flooding should be first made for the education of residents. Then proper guidance of land use and application of building codes should be taken according to the flood risk.

The remaining non-urbanized area (44 $km^2$) in the year 2000 will have the natural function of storm water retention (11 million $m^3$). This will reduce the requirements placed on the klongs and capacities of the pumps and hence reduces the investment in structural facilities, and brings a higher efficiency in the invested funds.

Additionally individual self-help community programmes should be prepared, particularly for the existing urbanized, flood-prone areas.

These will be greatly assisted by the institution of a flood forecasting and warning system which should provide for the proper operation of the sturctural facilities and flood fighting control.

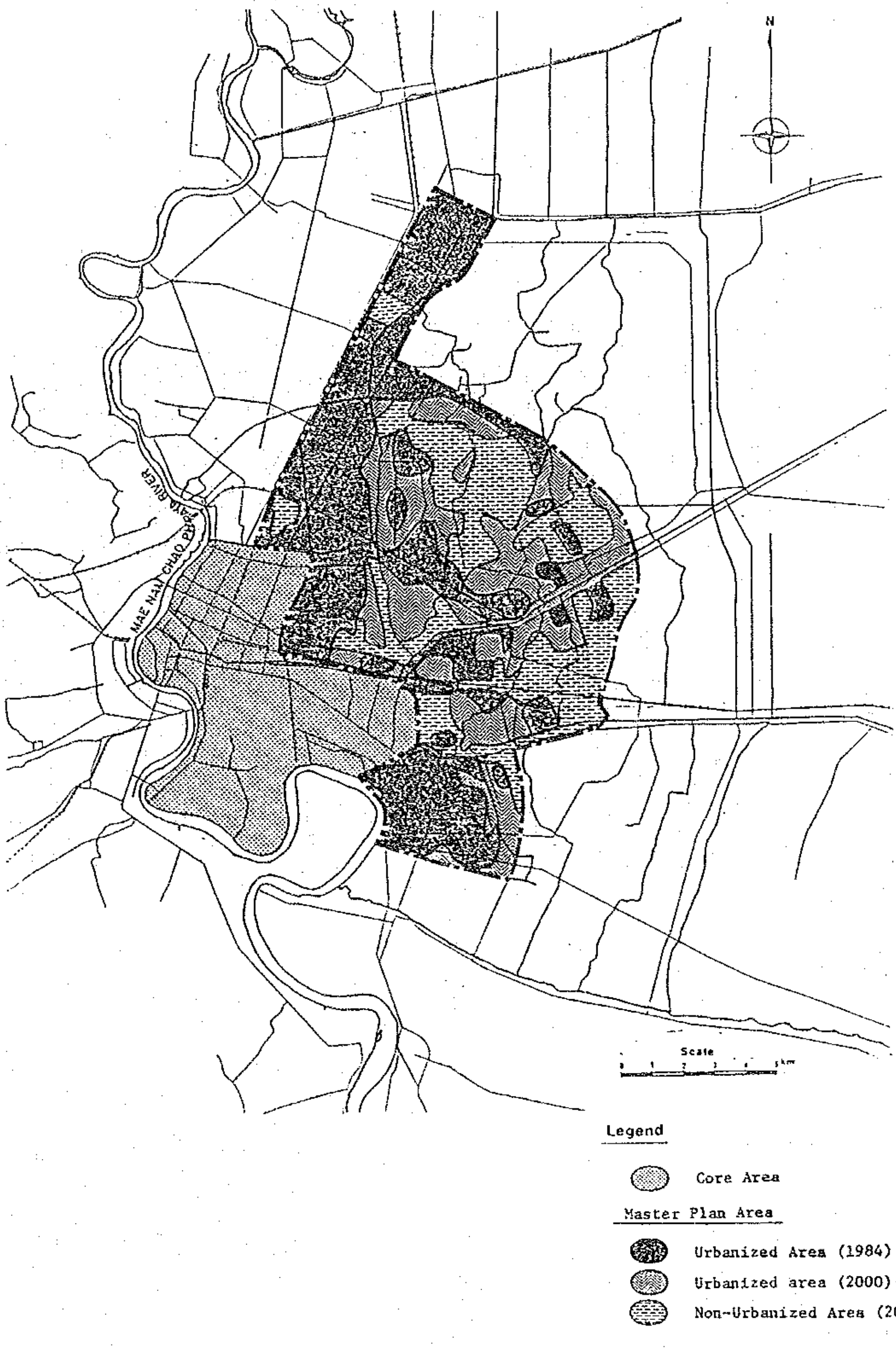



**Fig. 7 Urbanized Area and Retention Area According to Flood Risk**

## 3. Cost and Benefit of Project

6,280 million Baht is to be invested by the target year of 2000. When not only the proposed structural-measures but also non-structural measures are concurrently executed, the annual average flood damage will decrease from 2,716 million Baht to 147 million Baht in 2000. This indicates a high economic viability for the project. Other economic evaluation is shown below.

| | |
|---|---|
| Benefit/Cost | 1.5 |
| Internal Rate of Return | 26.5% |

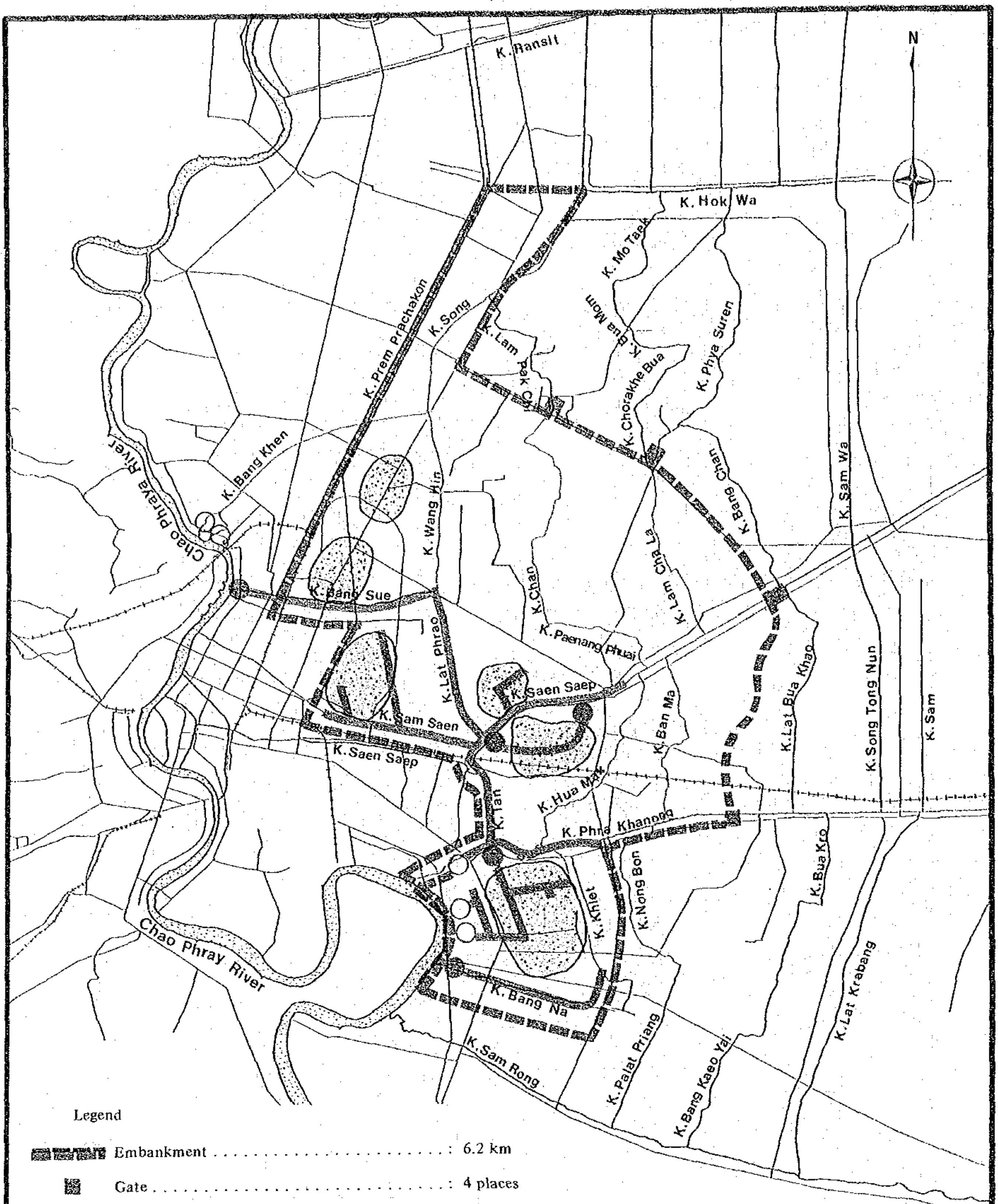
## 4. Implementation Schedule

Staged construction will enable capital expenditure to be distributed over a period of years and will facilitate implementation. After two-years of preparatory work for feasibility study, detailed design and financial procurement, construction can start in 1987 when the Sixth National Economic and Social Development Plan (Oct. 1986 to Sept. 1991) starts. Each stage is planned to correspond to the 5-year Development Plan.

Since the overall facilities such as polder embankment, gates, pumping stations and main klongs are effective in reducing overall flooding (Fig. 6), these facilities should be constructed at any early stage. On the other hand, facilities such as sub-klongs and main drain pipes which contribute to the alleviation of local flooding are proposed for implementation according to the area priority. As a result, the implementation schedules proposed are shown in Fig. 8, and the works included in the first stage (2,560 million Baht) are shown in Fig. 9.

| Item | Total | First (1987 – 1991) | Second (1992 – 1996) | Third (1997 – 2000) |
|---|---|---|---|---|
| Cost (million Baht) | 6,280 | 2,560  | 1,830  | 1,890  |
| Facilities | | | | |
| Embankment | 6.2 km | 6.2 km | – | – |
| Pumping Station with Gate | 10 stations (218 m³/sec) | Kacha (6 m³/sec)<br>Gig (3 m³/sec)<br>Bang Na Chine (9 m³/sec)<br>Bang Sue (14 m³/sec)<br>Bang Na (6 m³/sec) | Replacement of Urgent Pumps<br>Phra Khanong (90 m³/sec) | Bang Khen North & Sourh (15 m³/sec)<br>Bang Sue (36 m³/sec)<br>Jek (6 m³/sec)<br>Bang Oa (18 m³/sec)<br>Bang Na (15 m³/sec) |
| Gate | 55 places | 4 | 26 | 25 |
| Main Klong | 25.5 km | 16.5 km | (Phra Khanong, Tan & Saen Saep)<br>9.0 km | |
| Sub Klong | 107.5 km | 52.3 km | 26.9 km | 28.3 km |
| Main Pipe | 351 km | 30 km | 40 km | 40 km |
| Flood Forecasting and Warning System | | 1 set | – | – |

Fig. 8 Implementation Schedule




Legend

| | | |
|---|---|---|
| ▬▬ | Embankment | 6.2 km |
| ■ | Gate | 4 places |
| ● | Pumping station with Gate (newly installed or increased) | 5 stations |
| ○ | Pumping station (already available) | 5 stations |
| ▬ | Klong Improvement | 75 km |
| ⬭ | Main pipe served area | 21 km² (30 km) |

Fig. 9 . PROPOSED FACILITIES AT FIRST STAGE

MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



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## 5. Financial Plan

The construction cost of 6,280 million Baht by the year 2000 is to be financed by foreign loans (40%), government subsidy (30%) and the Bangkok Metropolitan Administration (30%), while the debt service of the loan and the operation and maintenance cost is covered by the BMA. In order to finance the BMA's financial requirement, three kinds of finnancial resources are recommended for each implementation stage (Fig. 10).

(a) Increasing local taxes (stage I)

(b) Collecting surcharge from developers (stage II)

(c) Imposing "Urban Development Tax" (stage III)

## 6. Organization

In order to realize a comprehensive flood protection and drainage system, it is recommended that a permanent flood protection organization at national-level is established incorporating similar functions at the current Urgent Committee.

It is recommended that the current Urgent Sub-Committee, mainly in charge of structural measures, be made permanent, and an equivalent organization for flood plain management established.

## 7. Recommendation for Feasibility Study

A feasibility study for the implementation of stage I should be conducted. The works to be included in the first stage are flood protection barriers and main drainage facilities to prevent overall flooding, and drainage facilities for high priority areas within the polders. Thus, it is expected that the first stage package will yield a highly efficient return on investment. It should be emphasized that the realization of the planned functions are contingent upon the administrators' efforts in controlling land-use, and in strengthening financial resources and other administrative measures taken by the Government and BMA.

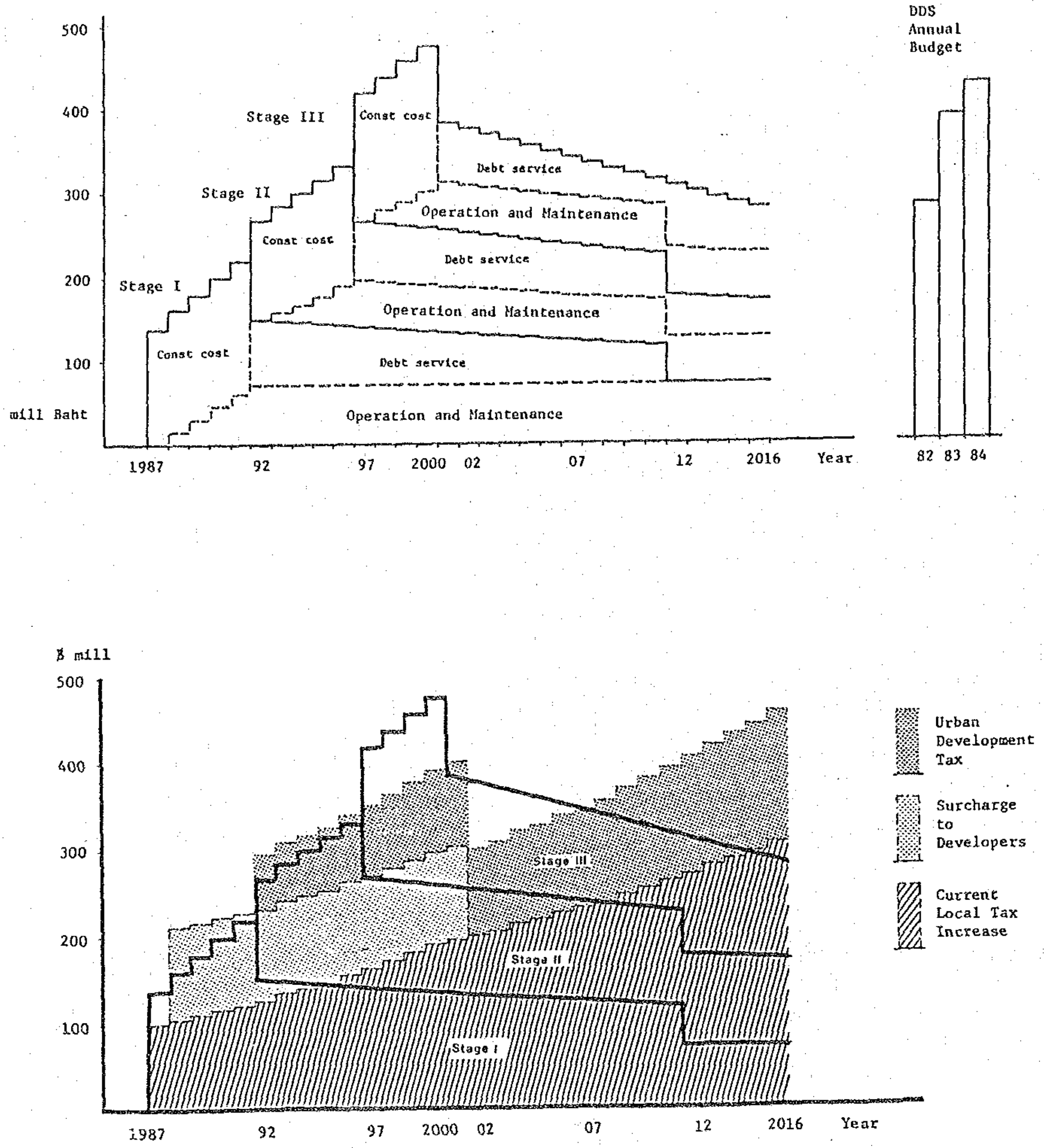


Fig. 10 Cash Flow Schedule of BMA for Stage I, II & III

# MAIN REPORT

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## 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 |
| CMS | cubic meters per second |
| 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 |
| SP | Samut Prakan Province |
| SRT | State Railway of Thailand |
| TEC | Tokyo Engineering Consultants |
| TISTR | Thailand Institute of Scientific and Technical Research |
| ¥ | Yen (Japanese Currency); US$ = approximately ¥230.0 |

# Chapter 1. INTRODUCTION

## 1.1 Background and Necessity of the Study

Bangkok, the capital of Thailand, is located on the flat deltaic plain of the Chao Phraya River which has a drainage area of about 160,000 km$^2$ – about one-third of the total area of Thailand.

As Bangkok was founded on marshland near the mouth of the Chao Phraya River, floods have occurred regularly from its beginnings. The style of houses, traditionally built on stilts, has been steadily changing since the 1950s due to economic development accompanied by modernization in life-style, and flood waters have brought increasing amounts of damage.

As early as in the 1960s, various plans for flood protection were proposed, from which a 370 km$^2$ master plan in the central area of Bangkok was prepared by the engineering consultant firm, Camp Dresser & McKee (CDM) in 1968 (CDM Plan). This plan which covers not only the central area but also large parts of this Master Plan Area was officially approved.

At that time, the Bhumipol Dam and Sirikit Dam encompassing flood control functions were constructed upstream of the Chao Phraya River. It was believed that these projects would protect Bangkok from severe flood damage. However, severe floods hit Bangkok frequently during the 1970s. Because of rapid urbanization, the construction of infrastructure could not keep pace, and large amounts of groundwater were extracted, causing land subsidence which further aggravated flood conditions in the Master Plan Area. The 1980 flood, for example, lasted for more than two months.

Under these circumstances, many flood protection plans were/are being prepared by the Government of Thailand to solve the flood problem in Bangkok; construction of dams and diversion channels on the Chao Phraya River, prohibition of groundwater withdrawal, extension of surface water served area and improvement of drainage facilities are some of the plans.

Among these plans, the Government of Thailand requested the Government of Japan to undertake a study, the results of which would be implemented during the Sixth National Development plan (October 1986 to September 1991). In response to the request, the Government of Japan decided to undertake the preliminary and master plan studies, the scope of which was agreed upon between the Bangkok

Metropolitan Administration (BMA) and Japan international Cooperation Agency (JICA) in November 1982.

The Preliminary Study was conducted from May 1983 to March 1984 which established the general concept for the flood protection/drainage system, consisting of structural measures and flood plain management, in Eastern Suburban-Bangkok (501 $km^2$). A Master Plan Area of 260 $km^2$ (Fig. 2.1) was selected as a high priority area for provision of adequate flood protection and drainage facilities, targeting the year 2000. The Master Plan Study was subsequently conducted from May 1984 to March 1985.

## 1.2 Objective of Study

The Study aims at a plan to provide adequate flood control and drainage facilities for the selected areas (260 $km^2$) which would provide the city with a plesant and healthy environment. The project should match the socio-economic situation of the country in terms of long-range operations of the facilities and should also have consistency with other related projects.

The year 2000, the target year for the Master Plan Study is adopted as for 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).

## 1.3 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 the Department of Drainage and Sewerage (DDS), BMA.

The Advisory Committee 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

| | | |
|---|---|---|
| Mr. Tsunekazu Fukui (Chairman) | : | Ministry of Construction, Japan |
| Mr. Akira Kato | : | Ministry of Construction, Japan |
| Mr. Isao Dohdoh | : | Japan Sewage Works Agency |

| | | |
|---|---|---|
| Mr. Tadao Ishikawa | : | Okayama Prefectural Government, Japan |
| Dr. Katsuhide Yoshikawa | : | Ministry of Construction, Japan |
| Mr. Kenichi Ohsako | : | Tokyo Metropolitan Government, Japan |
| Mr. Yoichi Seki (Coordinator) | : | Japan International Cooperation Agency |

2) DDS Advisory Committee

| | | |
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| Mr. Anuchit | : | Project Director |
| Mr. Somchit | : | Assistant Director |
| Mr. Mana | : | Committee Member |
| Mr. Nikom | : | Committee Member |
| Mr. Piroon | : | Committee Member |
| Mr. Pitool | : | Committee Member |
| Mr. Thongchai | : | Committee Member |
| Dr. Ksemsan | : | Secretary |
| Mr. Thammanat | : | Assistant Secretary |

3) Members of the JICA Study Team

| | | |
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| Mr. Hikoroku Ohtsuka | : | Drainage System Planning (PCI) |
| Mr. Toshiaki Tokumasu | : | Hydrologic Analysis (PCI) |
| Mr. Shigehiko Homma | : | Drainage Facility Planning (TEC) |
| Mr. Toshinori Ohshita | : | Drainage Facility Planning (PCI) |
| Mr. Daijiro Sezaki | : | Facility Maintenance Planning (TEC) |
| Mr. Jyudo Hagiwara | : | Flood Damage Survey (TEC) |
| Mr. Sachio Okutsu | : | Land Survey (TEC) |
| Mr. Kohki Fujii | : | Land Use Planning (TEC) |
| Mr. Takao Yamane | : | Economic/Financial Analysis (TEC) |
| Mr. Hidekazu Tanaka | : | Administration/Management Planning (PCI) |

4) DDS Counterpart Staff

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| Dr. Ksemsan | : | Leader of the Staff |
| Mr. Teeradej | : | Counterpart |
| Mr. Thongchai | : | Counterpart |
| Mr. Thammanat | : | Counterpart |
| Mr. Changton | : | Counterpart |
| Mr. Prasert | : | Counterpart |
| Mr. Vichai | : | Counterpart |
| Miss Angsana | : | Counterpart |
| Mr. Praving | : | Counterpart |
| Mr. Sompop | : | Counterpart |
| Mr. Atorn | : | Counterpart |

## 1.4 Composition of Report

This report consists of the following two volumes:

MAIN REPORT
APPENDIX

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

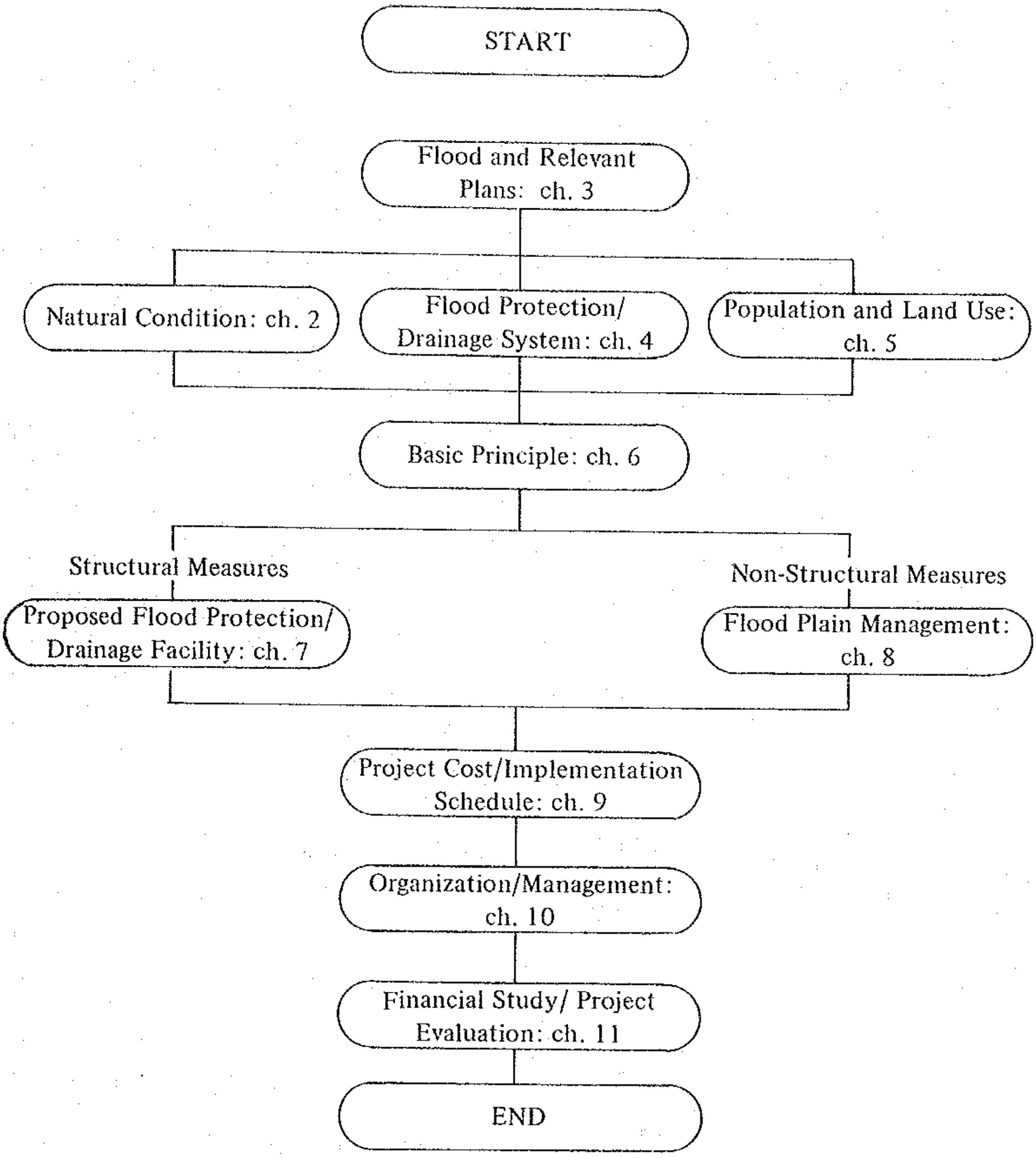
For Chapter 2 to 5, the necessary data for the basic conditions of the Study are collected and studied. Chapter 2 (Appendix A and D) deals with the general characteristics of the Master Plan Area, Chapter 3 (Appendix B and P) explains flood and the related plans, and Chapter 4 (Appendix C) deals with the existing flood protection and drainage system including urgent measures and their evaluation.

In Chapter 5 (Appendix E) the future population and required urbanized area are estimated.

In Chapter 6, considering the foregoing, the basic principle for comprehensive flood damage mitigation plan is proposed. Under this principle, structural measures and non-structural measures are proposed in Chapter 7 (Appendix F, G and H) and 8 (Appendix I ) respectively.

The proposed project cost and implementation schedule are explained in Chapter 9 (Appendix J, K and L).

Chapter 10 (Appendix M and N) describes the studies of organization and management. Chapter 11 (Appendix O and Q) describes financial study and project evaluation.




FLOW CHART OF STUDY

# Chapter 2. DESCRIPTION OF THE MASTER PLAN AREA

The characteristics of the Master Plan Area exert a decisive influence on the planning of the flood protection/drainage system. Consequently, the general characteristics of the Area are described first in this Chapter.

## 2.1 Natural Conditions

### 2.1.1 Topography and Land Subsidence

The Master Plan Area of 260 $km^2$ (Fig. 2.1), located in eastern suburban Bangkok is characterized by extremely low and flat land (Fig. 2.2). It is located in the 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 Master Plan Area during high tide and flood season. Furthermore, owing to severe land subsidence (the maximum rate of which is over 10 cm/year) caused by excessive withdrawal of groundwater, the ground surface has been lowered and is expected to become further lower from the originally low-lying ground level (Figs. 2.3 to 2.4).

### 2.1.2 Geology

The alluvial and marine deposits extend to an indeterminate depth of not less than 300 meters. The upper 15 to 20 meters of clays have formed a homogeneous and level plain.

### 2.1.3 Climate

Bangkok has three seasons – cool, hot and wet. 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 as shown in Fig. 2.5.

During the wet season, rainfall becomes more intense from June to August and subsides in mid-November. The heaviest rainfall occurs in September and October when the monsoon passes through the country on a wide front as shown in Table 2.1. The actual evaporation is 113 mm/month (highest), 81 mm (mean) and 39 mm (lowest).

Table 2.1 Monthly Rainfall between 1951 and 1982

( Unit : mm/month )

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Don Muang | 6.9 | 19.2 | 31.6 | 62.3 | 162.3 | 154.3 | 164.4 | 205.8 | 287.1 | 212.8 | 37.5 | 14.2 | 1359 |
| Bangkhen | 8.7 | 10.5 | 22.3 | 85.6 | 186.5 | 164.4 | 188.6 | 190.4 | 280.2 | 257.1 | 50.3 | 17.3 | 1362 |
| Bangkok | 9.7 | 29.7 | 28.3 | 71.3 | 194.1 | 158.8 | 171.1 | 197.2 | 334.0 | 223.3 | 47.5 | 9.0 | 1474 |
| Bang Na | 10.8 | 30.0 | 19.3 | 70.3 | 195.4 | 135.5 | 134.3 | 160.0 | 275.5 | 174.9 | 65.2 | 12.2 | 1283 |
| Bang Kapi | 13.1 | 26.2 | 18.6 | 75.5 | 163.5 | 150.0 | 161.8 | 191.4 | 295.1 | 193.6 | 32.5 | 12.7 | 1334 |
| Minburi | 10.9 | 23.1 | 13.5 | 84.4 | 194.3 | 155.6 | 157.7 | 185.5 | 288.9 | 190.1 | 36.4 | 13.1 | 1354 |
| Average | 9.7 | 23.2 | 20.9 | 75.0 | 184.0 | 153.3 | 163.4 | 192.4 | 293.5 | 192.2 | 43.8 | 13.3 | 1365 |

### 2.1.4 Hydrology

1) Rainfall

The maximum daily and 3-day rainfall were 209 mm at Bang Khen and 349 mm at Bang Kapi (Table 2.2). Probable daily and 3-day rainfall in the Master Plan Area is shown in Table 2.3. Probable rainfall intensity for 2 and 5-year return period, which is used in run-off analysis inside the sub-drainage area, is summarized in Table 2.4.

Table 2.2 Maximum Daily and 3-Day Rainfall in the Master Plan Area

(Unit: mm)

| Station / Rainfall | DonMuang | BangKhen | Bangkok | BangNa | BangKapi | MinBari | Average |
|---|---|---|---|---|---|---|---|
| Daily | 148 | 209 | 167 | 131 | 162 | 163 | 147 |
| 3-Day | 255 | 342 | 290 | 260 | 349 | 203 | 285 |

Table 2.3 Probable Daily and 3-Day Rainfall in the Master Plan Area

(Unit: mm)

| Year / Rainfall | 2 | 5 | 7 | 10 | 20 | 30 | 50 | 100 |
|---|---|---|---|---|---|---|---|---|
| Daily | 60.1 | 80.8 | 87.4 | 94.2 | 107.0 | 114.3 | 123.5 | 135.9 |
| 3-Day | 105.9 | 150.9 | 165.2 | 180.6 | 210.1 | 227.3 | 249.0 | 279.0 |

Table 2.4 Probable Rainfall Intensity – Duration

(Unit: mm/hr)

| Return Period \ Duration (min) | 5 | 10 | 15 | 30 | 60 | 120 | 360 | 720 | 1440 |
|---|---|---|---|---|---|---|---|---|---|
| 2 | 135.5 | 121.1 | 99.8 | 84.9 | 58.7 | 36.2 | 14.3 | 7.5 | 3.9 |
| 5 | 168.9 | 152.0 | 126.7 | 108.6 | 76.0 | 47.5 | 19.0 | 10.0 | 5.1 |

2) Tide

The tidal information at Fort Phrachul, located at the mouth of Chao Phraya River is shown in Table 2.5.

Table 2.5 Tidal Information at Fort Phrachul

| H.H.W.L. | M.H.W.L. | M.S.L. | M.L.W.L. | L.L.W.L. |
|---|---|---|---|---|
| +2.22 (1970.12) | +0.94 | ±0.00 | -0.63 | -1.79 (1956.7) |

(Note) H.H.W.L : Highest High Water Level
M.H.W.L : Mean High Water Level
M.S.L. : Mean Sea Level
M.L.W.L : Mean Lowest Water Level
L.L.W.L : Lowest Low Water Level

3) Chao Phraya River

Bangkok is located on both sides of the Chao Phraya River about 40 km from the river mouth. The river, so-called the mother of Thailand, has a drainage area of 162,600 km² (about 32 percent of the total area of the Thailand) and a total length of 980 km.

About 85 percent of the annual precipitation (1,500 millimeters) falls from May through September. During the months of September to October flooding caused by discharge from the Chao Phraya River occurs in the vicinity of Lop Buri, Ang Thong, Ayutthaya and Bang Sai.

In the reach of the river from Bang Sai to the river mouth, flooding mainly extends from mid-October to the beginning of December. Due to its physiography, the high water discharge from the north, e.g., about 2,500 CMS at Bang Sai in 1975, overflows the river reach to Bangkok City.

The more important factor which promotes flooding in the Master Plan Area is the high tide in the Gulf of Thailand (Fig. 2.6). As the slope of the Chao Phraya River downstream from Bang Sai is roughly 5 to 6 cm per km but with only a width 200 to 500 m, the lower stretch of the river is strongly affected by ocean tides. As a result, the fresh water of the Master Plan Area to be discharged to the river is substantially retarded, causing a large volume of water to inundate the Area.

## 2.2 Social Conditions

### 2.2.1 Economy

Thailand has enjoyed high economic growth during the past two decades. The national income has increased by approximately eight percent 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 rapid economic growth, however, has created many problems affecting social and environmental conditions, and increased urban congestion leading to deterioration in cultural and social values, mental well-being and the safety of lives and property. These problems are especially acute in Bangkok.

Due to the highly centralized nature of the Thail bureaucracy and also the geographycal advantages, all the major central government facilities, industrial firms, trading companies, multinational corporations and international organizations are located in Bangkok, resulting in a high concentration of people and their economic activities in the city.

In 1979, the Gross Regional Product (GRP) per capita of Bangkok was 2.4 times of that of the whole Kingdom, which induced an influx of migrants from outer areas. Various problems related to the rapid urbanization are evident in inadequate infrastructures including flood protection and drainage facilities. The phenomenon of flooding deteriorates the local conditions further, bringing about another burden for the BMA.

As the Bangkok Metropolis expanded, the Master Plan Area became a major residential area of the city. Unlike the city core area, the investment for urban infrastructure including drainage facilities is not yet complete. Along with future economic development, the Master Plan Area will become a more important residential area which will include some commercial and industrial areas.

### 2.2.2 Population and Land Use

In 1985, the population of Bangkok Metropolis was concentrated in central Bangkok area of about 96 $km^2$. Rapid urbanization has since continued, and the total

Table 2.6 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] urban area has increased to about 350 $km^2$ in 1980 along the main roads (which caused a ribbon style development pattern). As a result, the population of the Bangkok Metropolis and the Master Plan Area reached 5,070,000 and 1,060,000 respectively in 1980.

In the year 2000, the population of Bangkok Metropolis is estimated to be 7.7 million persons while that of the Master Plan Area is 2.5 million persons. Consequently, about 80 percent of the Master Plan Area will be urbanized (Refer to Chapter 5).

### 2.2.3 Transportation

Formerly, housing or residential areas were concentrated near the klongs which provided transportation and communication routes. The introduction of a road system in the region of King Rama V (1868 – 1910) affected the pattern of the city growth. As roads were introduced, people began to move from water to land routes.

From Bangkok, three of the four national long-distance highway start: 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.

These roads run through the western and the southern part of the Master Plan Area and are grid-pattern with low-density. All the roads, which were raised usually to about two metres above Mean Sea Level, are now below two due to land subsidence. However, they are acting as man-made hydrological boundaries. The north-bound and east-bound railway lines also act as boundaries.

## 2.3 Water Use

### 2.3.1 Water for Domestic, Industry and Commerce

Over 2 million cubic meters per day (CMD) of water is consumed currently in Bangkok and its vicinity. The Metropolitan Water Works Authority (MWWA) supplies water of about 1.75 million CMD for about 3 million people, of which 0.5 million CMD is obtained from groundwater. An additional 0.9 million CMD of groundwater is used in the private sector. The MWWA, aiming at phasing out groundwater use both in the MWWA and in the private sector, is expanding the water supply system (Fig. 3.5).

### 2.3.2 Irrigation

Most of the lower Central Plain has already been fully developed as paddy field with the aid of extensive canal networks by the Greater Chao Phraya Project (Fig. 2.7). In the area south of Ayutthaya, irrigation is made by storage of water since gravity irrigation is difficult, and the water level has been controlled to be at about the same level as that of the land. The controlled water level starts rising in August and lowers in November as shown in Fig. 2.7. If there is much rainfall in the northern part of Thailand, some flood water is distributed through the extensive canal network, and if there is much rainfall in the lower Central Plain, excess water floods into the Plain.

### 2.3.2 Water Quality

According to the NEB survey the present situation of water quality of the Chao Phraya River in Bangkok is heavily polluted by industrial wastewater and domestic wastewater. Water pollution of the river has been mainly caused by the development of industries along the river and concentration of population in the Bangkok Metropolis. Meanwhile, according to the DDS survey result, the surface water quality in the central Bangkok area is very poor, due to the discharge of sewer, domestic wastewater and industrial wastewater. Although data is inadequate, the rate of water pollution in the Master Plan Area is only somewhat better than that in the central area.

# Chapter 3. FLOOD AND RELEVANT PLANS

Bangkok lies in a topographically very flat area. The stormwater drainage system in existence relying only on gravity, worked well a few decades ago, when Bangkok had low-density population and an extensive network of canals. This system can still be seen today in the rural areas of Bangkok; however, it is no longer applicable in the urbanized area of Bangkok.

Recent rapid urbanization coupled with land subsidence caused by pumping of groundwater has induced severe flood damage almost every year since 1980.

## 3.1 Flood Damage

In the flood of 1980, some parts of the eastern suburbs were covered with flood water for more than two months. Flooding occurred in the Master Plan Area again in 1982. In 1983, the lower Central Plain suffered the largest flood damage (6,597 million Baht) since 1942 as shown in Fig. 3.1. Particularly, flood damage in the Eastern Suburban-Bangkok was severest and reached about 3,500 million Baht (For details, see Appendix P). If no flood mitigation measures are taken and the same degree of flooding occurs again, flood damage will become very high.

## 3.2 Hydrological Status of 1983 Flood

Rainfall in August 1983 amounted to 461.5 mm, more than twice that of other usual years; e.g, 191.5 mm in 1980. Much rainwater also flowed into the Eastern Suburban-Bangkok area. Further, as heavy rainfall continued to fall during September to October, the water level of the Chao Phraya River continued to rise. The discharge amount of water from theArea was restricted and as a result, the flood area expanded month by month as shown in Fig. 3.2. The floods lasted one to four months and the maximum flood depth was 80 cm.

## 3.3 Causes of Flood and Flood Damage

The lower Chao Phraya deltaic plain is flat with low elevation. The entire metropolis is approximately 1.5 meters above mean sea level. Consequently, during flood stages, heavy overflow from the upstream along the Chao Phraya River banks, causes severe flooding.

Another factor which generates flooding in Bangkok is the high tide in the Gulf of Thailand. The rainwater discharged from inland to the sea is substantially retarded by the high tide, causing a large volume of water to inundate the inland area. Inundation in the inland area, particularly in the Master Plan Area has been aggravated by land subsidence caused by excessive pumping of groundwater.

The causes of flood are listed below.

(1) Heavy rainfall

(2) High water levels and high tides in the Chao Phraya River

(3) Inflow from the north and east

(4) Progression of land subsidence

(5) Insufficient drainage capacity

(6) Run-off discharge increased due to urbanization

Floods have occurred since early times due to the natural conditions mentioned above. However, it is only recently that floods have become a serious problem. This has been caused by unplanned urbanization which increased flood damage potential and subsequently the actual flood damage. In other words, flood damage is partly the result of human activity.

## 3.4 Relevant Plans and Projects

As early as in the 1960s, various plans for flood protection in Bangkok were studied/proposed, among which a master plan on flood protection/drainage in the then Bangkok Metropolis (370 $km^2$) was prepared in 1968 by the engineering consultant firm, Camp Dresser & McKee (CDM plan). In the master plan a polder system was proposed.

CDM plan had long served as flood protection and drainage system in Bangkok, however, only some facilities were constructed due to financial constraint. In view of increased flood damage during the 1970s, the following plans and projects have been/are being studied or executed in order to alleviate flood damage in and around Bangkok.

- City Core Project (NEDECO, BMA)
- Eastern Suburban Project (JICA, BMA)
- Green Belt Project (including Channel Improvement Project)
- Samut Prakan Project (TISTR, Samut Prakan Province)
- Flood By-Pass (East Bank) Project (AIT, NESDB)
- Surface Water Supply Project (MWWA)

On the occasion of 1983 flood, various plans and projects have been or will be commenced. These plans and projects including the foregoing are classified as follows:

1) Drainage System Improvements in Specific Areas

2) Chao Phraya River

3) Prevention of Land Subsidence

4) Others

### 3.4.1 Drainage System Improvement

The following six plans or projects are shown in Fig. 3.3.

1) City Core Project

This project, covering the city core area of 92 $km^2$, is the first phase of the large-scale flood protection scheme undertaken by DDS. The proposed polder system, based on a review and revision of the CDM Plan to meet the existing situation, will be implemented from 1986 at a cost of 2,050 million Baht. About 1,200 million Baht will be loaned from the World Bank.

2) Eastern Suburban Bangkok

This project is the flood protection/drainage project in Eastern Suburban-Bangkok. Following the Preliminary Study (501 $km^2$), the Master Plan study covering 260 $km^2$ area was conducted.

3) Samut Prakan Sea Wall Project

Samut Prakan Province, located to the south of Bangkok, has also a flood problem, As the project name denotes, the main elements of the project is to construct embankments along the Chao Phraya River, Gulf of Thailand and Green Belt Area.

4) Thonburi Project

Reportedly, a reconnaissance study in the Thonburi Area are under execution by the grant of the Netherland Goverment, followed by a master plan study.

5) Green Belt Project

As a result of the 1980 flooding, this project was initiated by the order of the King, aiming at the prevention of flow into Bangkok, by diverting flow southward to the Gulf of Thailand. Some parts of this project were completed in 1984 as one of the major components of the urgent flood protection measures (Refer to section 4.3).

6) West Bank (Thawee Wattana) Project (AIT)

Many klongs predominantly run east-west although the topography is high in the north and low in the south. The capacity of the existing klongs from the north to the south is limited, causing inundation in most of Thonburi area. This project aims at improving the existing klongs in order to drain the water rapidly southward to the Gulf of Thailand. Connection of Klong Thawee Wattana (running north-south in the middle of the west bank) to Kong Khun Radpinidjai (running north-south from the Chao Phraya River to the Gulf of Thailand) is expected to be effective.

3.4.2 Chao Phraya River

1) By-Pass Channel (East Bank)

Construction of a diversion channel through the Green Belt Area (Fig. 3.4) and a short-cut channel of the Chao Phraya River are being studied by AIT for NESDB. According to the AIT interim report, no appreciable lowering of the water level near Bang Na area is expected due to tidal influence.

2) By-Pass Channel (West Bank)

This project is aimed at lowering the water level of Chao Phraya River (Fig. 3.4). The By-Pass Plan on the East Bank studied by AIT indicated that the diversion canals would not be economic. Hence, the west bank project by Austria Consultant has been under study incorporating the land use development aspects as a major item of the studies.

3) Flood Protection Works upstream from Bangkok

Beisdes the Bhumipol Dam and Sirkit Dam constructed upsteream, there are no appropriate dam sites upstream. Further, the constructed embankments (as shown in Fig. 2.7) from Chai Nat to Bang Sai in the Central Plain inrcrease the flood potential in and around Bangkok. Consequently, flood protection measures in the Chao Phraya River itself is necessary to be studied from the viewpoint of Bangkok flood protection.

### 3.4.3 Prevention of Land Subsidence

Water supply expansion plan (Fig. 3.5) which is being implemented by MWWA in order to prevent land from subsiding, is closely related with the flood protection in Eastern suburban-Bangkok and Samut Prakan Province. Despite these efforts, it is estimated that land will continue to subisde by 0.7 to 1.0 m in the Master Plan Area by the year 2000. As a result, ground elevations in the Master Plan Area will become below mean sea level.

### 3.4.4 Others

1) Study on Bangkok Flood Control Management

The Study on Bangkok Flood Control Management are under execution by ADB for NESDA. This study concentrates on long-term organizational framework and financial system for whole Bangkok.

2) USA Assistance for Urgent Flood Protection Committee

Reportedly, USA assistance to the Urgent Flood Protection Committee and BMA will be given by the dispatch of some experts.

3) Sewerage Master Plan

A study and master plan for the Bangkok Sewerage System Project covering an area of approximately 400 $km^2$ was completed by JICA in 1981. The treated water in 10 divided zones will be discharged into nearby kongs which were considered as external klongs connecting with the Chao Phraya River in the officially approved CDM plan. However, since these klongs are to be internal klongs in the Master Plan for flood protection and drainage, the water quality of these klongs is expected to deteriorate.

# Chapter 4. EXISTING FLOOD PROTECTION AND DRAINAGE SYSTEM

The existing flood protection and drainage systems are the basic physical conditions used in planning the flood protection and drainage system. The urgent flood protection measures executed at a cost of about 1,000 million Bhat after the 1983 flooding laid the cornerstone of the long-term plan for the Master Plan Area.

## 4.1 Flood Protection and Drainage System before the 1983 Flood

Following the 1980 flooding, an area of about 800 $km^2$ including the Master Plan Area (260 $km^2$) was enclosed by many cofferdams in order to prevent inflow from the north and east areas of the city and overflow from the Chao Phraya River, making the area one large outer polder with inner polders provided to protect the high priority areas.

Five inner polders existed in central Bangkok and two inner polders existed in the Master Plan Area. Two inner polders located in Hua Mark (No.7 of Fig. 4.1) and Bang Na (No. 6 of Fig. 4.1) were enclosed by dikes which utilized existing roads and railway and cofferdams to block outside water from flowing into the polder areas. Pumps of 4 $m^3$/sec and 4.5 $m^3$/sec capacity were installed in Hua Mark polder and Bang Na polder respectively to pump out rainwater. However, as the existing facilities were inadequate and of a temporary nature, severe water inflow occured in 1983 from the north and east area of the city, by overflowing cofferdams and roads, and also from the Chao Phraya River.

## 4.2 Existing Klongs

An extensive network of canals known as klongs, extending for 200 km, has been used for drainage in the Master Plan Area. The width of these klongs is generally 5 to 15 m with 1 to 2 m depth, except such main klongs as Saen Saep, Phra Khanong and Tan, where the width is more than 20 m.

Reflecting the flat grade (1:20,000) and small size, the discharge capacity is small, at most 5 $m^3$/sec, except that of the main klongs, which have a discharge capacity of 10 to 80 $m^3$/sec (Fig. 4.2).

## 4.3 Urgent Flood Protection Measures

### 4.3.1 1984 Plans

As the 1983 flood was so severe, the previous system described in section 4.1 was not so effective. Hence, the Prime Minister ordered the setting up of a Committee of Flood Protection and Solution in Bangkok and the Vicicnity" in October, 1983. The Committee proposed an urgent programme, consisting of 22 plans in three stages at a budget of 1,021 million Baht. The execution of these plans as shown in Table 4.1 and Fig. 4.3 and were almost completed by August, 1984. The facilities constructed as urgent measures are classified permanent type (embankments and gates), semi-permanent type (pumps) and temporary type (cofferdam).

The objectives of the urgent measures are as follows:

1) To prevent inflow from the eastern and northern areas (Part of the Green Belt Project)

2) To prevent inflow from the Chao Phraya River (10 tide gates)

3) To increase drainage capacity (dredging of many klongs and constructing pumping stations totalling 354 $m^3/s$).

Pumping Capacity:

129 $m^3/s$ for the Eastern Suburbs (Nos. 1-3 and 5-9 of Fig. 4.3)

30 $m^3/s$ for Samut Prakan Province and part of the Eastern Suburbs (No. 10 of Fig. 4.3)

18 $m^3/s$ for the City Core Area (No. 4 of Fig. 4.3)

177 $m^3/s$ for Green Belt Area and Nonthaburi Province (Nos. A-1 to A-10 of Fig. 4.3)

These objectives are basically consistent with the JICA Study Team proposal which was presented in the Preliminary Study Report.

### 4.3.2 1985/1 Plan

Following the 1984 urgent measures executed, additional urgent measures (1985/1 plan) which consist of 17 plans at a cost of 505 million Baht, have been planned by the Committee. Among the 17 plans, 7 plans as shown below are directly related to the Eastern Suburbs.

## Table 4.1 Urgent Flood Protection Programme (1984)

| Stage | Plan | Purpose | Construction Item | Organization | Budget (Million Baht) 1984 | 1985 | Total |
|---|---|---|---|---|---|---|---|
| 1984/1 | Green Belt Project | Control the inflow from outer area, Discharge the flood water into the Gulf of Thailand | Embankment, dredging, Control Gate, Expansion of Bridge, Retainig wall and Bridges | RID, BMA<br>SRT, HD | 194.5 | 181.5 | 376.0 |
| | Samut Prakarn Project | Prevention of overflow from Chao Phraya River | Embankment along the Chao Phraya River | PWD | 62.7 | 59.4 | 122.1 |
| | Improvement of K.Samrong | Increase the discharge capacity of klongs | Dredging of 16 canals | Samut Prakarn Province | 80.8 | 0 | 80.8 |
| | Stage 1. Total (3 Plans) | | | | 338.0 | 240.9 | 578.9 |
| 1984/2 | Improvement of Klong Phra Khanong etc. (3 plan) | Increase the puming capacity | K. Bangkhen Pumping Station<br>K. Phra Khanong "<br>K. Sam Rong " | RID | 140.0 | 0 | 140.0 |
| | Improvement of Klong Bang Sue, etc. (7 plan) | Increase the pumping capacity | K. Bang Sue Pumping Station<br>K. Sam Sen "<br>K. Jek "<br>K. Bang Oa "<br>K. Bang Na "<br>Improvement of K. Phra Khanong<br>K. Sam Sen | BMA | 187.0 | 0 | 187.0 |
| | Improvement of Klongs (1 plan) | Increase the drainage capacity of klongs | Dredging | Samut Prakarn Province | 14.0 | 0 | 14.0 |
| | Stage 2. Total (11 Plans) | | | | 341.0 | 0 | 341.0 |
| 1984/3 | Green Belt Project (2 plan) | Reserve budget for BMA and SRT activity | Embankment, Coffer Dam | BMA<br>SRT | 48.7 | 0 | 48.7 |
| | Samut Prakarn Project (1 plan) | Increase the drainage capacity of klongs | Dredging | Samut Prakarn Province | 10.4 | 0 | 10.4 |
| | West Bank Project (4 plan) | Alleviation measure of flood in Thonburi Area | Dredging, Water Gare, Pumping Station | BMA<br>HD<br>RID | 34.9 | 0 | 34.9 |
| | Nonthaburi Project (1 plan) | Alleviation measure of flood in Nonthaburi Area | | RID | 7.2 | 0 | 7.2 |
| Stage 3. Total (8 Plans) | | | | | 101.2 | 0 | 101.2 |
| Grand Toatl (22 Plans) | | | | | 780.2 | 240.9 | 1,021.1 |

Note: The budget of improvement of K. Phra Khanong, K. Bang Sue and etc. (10 plans) in 2nd Stage Programme include the budget of the installation of 59 units pumps granted by Japan.

1) Increase of pumps at Phra Khanong pumping station (60 $m^3$/sec)
RID, 51 million Baht

2) Improvement of pumps at Bang Sue pumping station (12 $m^3$/sec),
RID, 30 million Baht

3) Flood protection barrier (embankment) in the Master Plan Area,
RID, 1 million Baht

4) Flood protection barrier (7 gates) in the Master Plan Area,
BMA, 4 million Baht

5) Construction of flood wall at Klongs Phra Khanong (1,223 m),
Bang Oa (69 m) and Jek (55 m), BMA, 44 million Baht

6) Expansion of east-bound railway bridge at Kong Saen Saep,
BMA, 3 million Baht

7) Canal dredging in Bangkok
BMA, 24 million Baht

## 4.4 Evaluation of the 1984 Urgent Flood Protection Measures

The implemented urgent measures could change long-period, large-area flooding to short duration, small-area flooding for design rainfall. The constructed embankment and the control gates to prevent inflow from the outer area can reduce maximum flood depth by about half to 40 cm–70 cm and that flood duration in total will be shortened by one third. The pumps to drain out the inner water can much reduce flooding as is seen in Fgis. 4.1 to 4.6, and the significant effect is one the flood duration which is reduced to a few days.

It can be said that even after the execution of urgent measures there still remain flood-prone areas especially in Hua Mark, Huay Kwang, Bang Kapi, Bang Na (Fig. 8.2 and Fig. 4.7 for Bang Na) etc., Therefore, further improvement measures are necessary to solve short duration but frequent flooding. Besides as land subsidence is expected, it can be said that the additional measures should be executed to alleviate future flooding, otherwise, hydrologically, the flood situation may return to "before urgent measures" status.

As for the life of the submerged pumps installed by the urgent measures, it is difficult to be precise because of the few past experiences with this pump type. However, it may be assumed that 10,000 to 15,000 hours in operation is to be expected provided that normal maintenance is done. If the annual operation hours is assumed 1,500 hours, based on the record of the 1984 rainy season for the installed pumps in urgent measures, the operational life of the pump is estimated as a range of 7 to 10 years.

The pumping stations constructed as urgent measures have operational problems owing to future land subsidence, therefore, these are considered as semi-permanent structure. For pumping stations of this project, it is recommended to adopt the permanent pump type such as the mixed and/or axial flow type because of high reliability and durability.

# Chapter 5. FUTURE POPULATION AND LAND USE

The future population and required urbanized area are estimated and explained in this Chapter.

## 5.1 Existing Conditions

### 5.1.1 Unplanned Urbanization

From 1900 A.D. onwards, the urbanized area of Bangkok Metropolis has increased as follows:

| | |
|---|---|
| 1900 | 13 $km^2$ |
| 1936 | 43 $km^2$ |
| 1953 | 66 $km^2$ |
| 1958 | 96 $km^2$ |
| 1971 | 183 $km^2$ |
| 1980 | 345 $km^2$ |

This rapid increase in recent urbanization has taken place along the existing main roads for easy access (Fig. 5.1) resulting in an irregular, ribbon style development causing the following problems:

- Heavy road traffic
- Floods
- Inadequate public utilities
- Land subsidence
- Environmental pollution
- Crime
- Uncontrolled urbanization

### 5.1.2 Population and Land Use

The population and urbanized area in the Master Plan Area was 1,060,000 persons and 134 $km^2$ in 1980 whilst those of Bangkok Metropolis were 5,070,000 persons and 345 $km^2$. The urbanized area within the Master Plan Area is mainly for residential use with some industries and commerce. The commercial areas are located along the existing main streets.

The classification of land use in 1980 A.D. is shown in Table 5.1.

Table 5.1 Land Use in the Master Plan Area, 1980

| Land Use Classification | Area ($km^2$) | Percentage (%) |
|---|---|---|
| Residential | 97 | 37.3 |
| Commercial | 6 | 2.3 |
| Industrial | 3 | 1.1 |
| Institutional | 22 | 8.5 |
| Park, Sport Ground, etc. | 6 | 2.3 |
| Agricultural and Open Space | 126 | 48.5 |
| Total | 260 | 100.0 |

5.1.3 Related Development Plans and Projects

There are two related land -use development plans.

1) The Fifth Five-Year National Development Plan

This plan, covering the period from October 1981 to September 1986, focuses on a strategy to stimulate economic activities in regions outside the capital, emphasizing the problem of excessive concentration of economic activities and population in Bangkok.

2) The Structural Plan for Bangkok Metropolis and its Vicinity

The Department of Town and Country Planning (DTCP) prepared a structural plan for Bangkok Metropolis and its Vicinity and has held public hearings since 1976 several times without success. Thus, there is no authorized city plan at this time. Nevertheless, the concepts are used more or less in conformity with the policy of the Fifth 5-Year National Development Plan. The plan divides the whole region into three parts; viz.:

- Inner Area
- Green Belt Area
- Outer Area

The inner area is surrounded by the outer ring road within a radius of 20 to 25 km from the center and is'designated as an urban area. The Master Plan Area is located in the inner area. The outer area will be designed for agricultural land

and for location of residential and industrial complexes. The Green Belt Area is to be conserved as agricultural land or open spaces.

## 5.2 Future Land Use

### 5.2.1 Population Projection

The population of Bangkok Metropolis in 2000 is estimated at 7.7 million persons as a result of studies by several methods as shown in Fig. 5.2. An estimated 2.5 million persons will reside in the Preliminary Study Area (501 $km^2$) – Eastern Suburban-Bangkok. Among them, 2.35 million persons are assumed to be alloted to live in the Master Plan Area for the orderly development of Bangkok based on the precepts of urban development and reserving the retarding areas.

### 5.2.2 Future Land Demand

The future urbanized area for the Master Plan Area is estimated at 216 $km^2$ with a population density of about 100 persons per hectare, thus reserved agricultural and open space area of 44 $km^2$ is considered to exist until 2000.

**Table 5.2 Land Use in the Master Plan Area, 2000**

| Land Use Classification | Area ($km^2$) | Percentage (%) |
|---|---|---|
| Residential | 185 | 71.2 |
| Commercial | 14 | 5.4 |
| Industrial | 3 | 1.1 |
| Park, Sport Ground, etc. | 14 | 5.4 |
| Agricultural and Open Space | 44 | 16.9 |
| Total | 260 | 100.0 |

### 5.2.3 Land Use Plan

The following factors are taken into consideration for land use planning (Fig. 5.3):

1) Past Trend of Urbanization

Urbanization will expand along the main roads from the center of Bangkok to the surrounding areas in the same pattern as in the past.

2) Road Plan

Urbanization has taken place by the private sector mainly along the existing roads. Hence, future road construction is a key item for future land use pattern.

3) Flood-Prone Area

Areas which are severely flood-prone will be excluded from future urban areas where possible. In order to reduce an increase in flood damage potential, it is proposed to reserve some open spaces for storm water retention. This is described in Chapter 6. Nevertheless, Huay Kwang area located adjacent to the central area is planned as an urbanized area due to the importance of the area although this area has large capacity for rainwater retention.

## Chapter 6. BASIC PRINCIPLE FOR PROPOSED FLOOD PROTECTION/DRAINAGE SYSTEM

This chapter describes the basic principle of the flood protection/drainage measures, consisting of non-structural, so-called flood plain management, and structural measures.

Firstly, an explanation is made for the comprehensive flood damage mitigation approach which is indispensable for the Master Plan Area.

Then, the basic idea for structural measures by the establishment of a polder system is explained. Various alternatives to the system and the idea of the discharge to outer areas other than the Chao Phraya River are also considered.

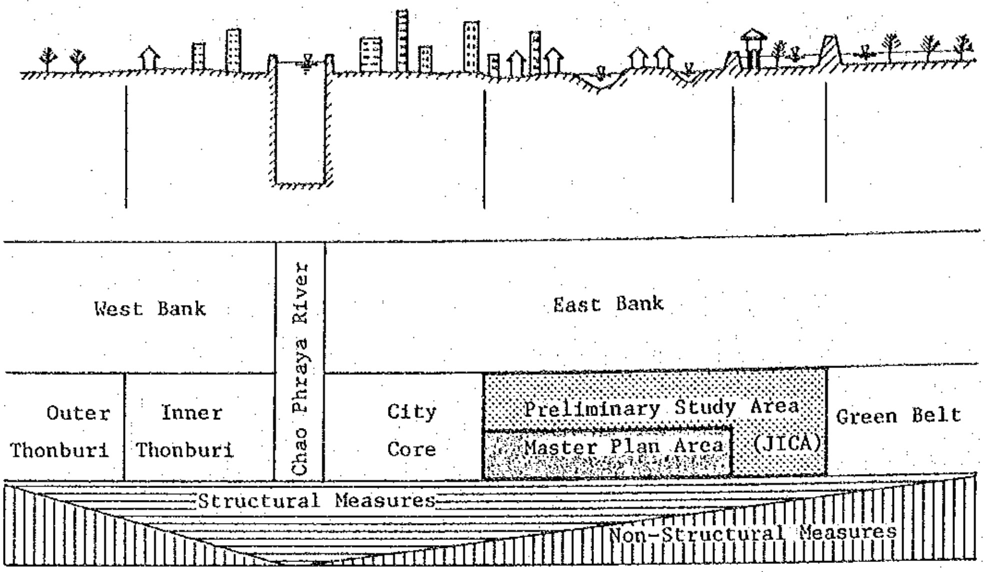
Finally, the necessity of flood plain management is explained. The establishment of a rainwater retention area inside the polder is also explained as the essential solution of the drainage problem.

### 6.1 General Concept

Recently, it has been proved that structural measures should be combined with non-structural measures as the most effective and efficient method of flood damage prevention. Numerous examples of floods, which have occurred in cities of other countries indicate that the drainage capacity of the conventional structural measures have not been able to catch up with rapid urbanization and the urbanized area spraw in flood-prone areas.

This is especially true in the Master Plan Area, because population in 2000 will increase twice as much as that in 1980 and because the ground elevations will sink further below mean sea level in 2000. If current trend of urbanization continues (B of Fig. 6.1), flood damage will inevitably increase. Therefore, a combination of structural and non-structural measures must be applied in the Master Plan Area in order to mitigate flood damage both at present and in future (C of Fig. 6.1).

Adoption of the combination of structural measures and non-structural measures is common for all neighbouring areas like Core Area, Thonburi Area, Samut Prakan Province in the Lower Central Plain. The difference is in degree; namely, structural measures are emphasized in urbanized areas while non-structural measures in the rural area as shown below.




**Schematic Concept for Application of Structural and Non-Structural Measures in Bangkok**

Among the many measures as shown in Fig. 6.2, some structural measures have already been adopted in Bangkok. However, from now on particularly non-structural measures must be employed.

## 6.2 Structural Measures

The basic idea for structural measures is the establishment of a polder system. The inside of the polder is protected against inflow from the outer areas and the Chao Phraya River by flood protection embankments and gates, and rainfall inside the polder will be discharged by the drainage facilities installed inside the polder.

As the Green Belt embankment has been constructed as an urgent measure, the Preliminary Study Area (501 $km^2$) has become a polder system as proposed in the Preliminary Study. In order to protect the Master Plan Area (260 $km^2$), a higher economic area, the Master Plan Area is proposed to be separated from the Preliminary Study Area by the construction of embankments and gates surrounding the Master Plan Area.

### 6.2.1 Alternatives of Polder System

There are two basic polder systems. One is the construction of large area polders. (Alternative I of Fig. 6.3). The other is to create smaller multipolders (Alternative II).

The main characteristics difference between these systems are in the location of main pumps and high water level in the main klongs. In the former type, main pumps are located near the Chao Phraya River and high water level in main klongs is lowered by the operation of main pumps. In the latter type, main pumps are located at the lowest point of each polder, and high water level in the main klongs is governed by the water level of the Chao Phraya River.

Because of the existing restricted flow capacity of the main klongs, it does not seem practical to adopt the latter system in which large improvement works for the main klongs are needed and, therefore, land acquisition is required.

Incidentally, to cope with the severe floods in 1983, in addition to the Green Belt embankment, large scale pumps have been already installed as urgent measures near the Chao Phraya River. This is based on the drainage system of the former type. Therefore, the large area polder system is proposed for the Master Plan Area.

### 6.2.2 Three Polders in the Master Plan Area

Considering the topography, klong network and land subsidence, the Master Plan Area is divided into 3-polders (modification of Alternative I) that is Bang Khen-Bang Sue Polder, Phra Khanong Polder and Bang Na Polder as shown in Fig. 6.4.

1) Topography

Topographically the Master Plan Area is divided into two areas i.e. rather high land of Bang Khen, Bang Sue Area and the low land area of the remaining area, which consists of the rainwater catchment area of Klongs Saen Saep, Tan, Phra Khanong and Bang Na Area.

The ground elevations of three polders are shown in Table 6.1.

**Table 6.1 Ground Elevation in Polders**

(Unit: meter MSL)

| | Present (1984) | Future (2000) |
|---|---|---|
| Bang Khen–Bang Sue | +1.0 to +1.8 | +0.3 to +1.1 |
| Phra Khanong | +0.6 to +1.2 | −0.4 to +0.2 |
| Bang Na | +0.4 to +0.7 | −0.6 to −0.3 |

2) Klong Network

Main outlet klongs in the Master Plan Area are Klongs Bang Khen, Bang Sue located in Bang Khen and Bang Sue Area, and Klong Phra Khanong which is the largest outlet in the Master Plan Area. There are also small klongs in the Bang Na Area (Fig. 6.4.).

3) Past Flooding

Klong Sean Saep is blocked at the east of the Master Plan Area and rainwater in the Klong Saen Saep flows into Klong Phra Khanong through Klong Tan. Further, some rainwater in the Bang Sue Area flows into Klong Phra Khanong through Klongs Lat Phrao and Tan. Nevertheless, these klongs especially Klong Tan are very narrow and constitute a bottle neck to flow. Therefore, the rainwater catchment area of Klong Phra Khanong is very large and the downstream area has been suffering frequently from floods.

The Phra Khanong Polder is so large and flat that the inner polder plan results from the hydraulic study.

6.2.3 Discharge to Outer Area

At present, storm water in the Master Plan Area is discharged directly into the Chao Phraya River. Incorporating the existing klong network into the proposed drainage system is the most economic method (Alternative A of Fig. 6.5). Since this is achieved through existing klong improvements basically within the right-of-way as is explained in Chapter 7, other diversions as shown in Fig. 6.5. need not necessary be considered. These alternatives, however, may become possible after the year 2000 when more urbanization will progress and amount of storm water will increase. The following are some comments:

1) Discharge into Green Belt Area (Alternative D of Fig. 6.5)

The big problem of this alternative is that the site belongs to the Samut Prakan Province. Therefore, it is deemed that a long time is necessary for negotiations with other authorities and with land owners for land acquisition for the required new klong construction or improvements. The flood protection/drainage of eastern-suburban Bangkok is very urgent and should be executed as soon as possible. Moreover, the required klongs are long. Therefore, the construction cost seems to be very large.

NESDB has studied the flood routing and control of Chao Phraya River in which a diversion along the Green Belt Area has been considered. If the discharge of rainwater in the Master Plan Area into the Green Belt Area is planned simultaneoulsy with the diversion works of the Chao Phraya River, this alternative then may be feasible.

2) Discharge into Eastern Agricultural Area between the Master Plan Area and the Green Belt Zone (Alternative C of Fig. 6.5)

Rainwater in the eastern agricultural area flows into the Samut Prakan Province through several klongs due to topographic conditions. The Samut Prakan Province has suffered the same severe flooding as eastern-suburban Bangkok and is undertaking independent flood protection measures. Administratively, this area can not be controlled by BMA, therefore, the same problem as that described in the discharge into the Green Belt Area is anticipated. There is sufficient capacity within Klongs Phra Khanong and Tan, and thus this alternative does not require consideration.

3) Discharge through Core Area into the Chao Phraya River (Alternative B of Fig. 6.5).

Some storm water in the Master Plan Area used to be discharged through Klongs Sam Sen, Saen Saep, Padung Krung Kasem, located in the City Core Area until the inception of the polder system for the City Core Area in 1970s. As a result, outflow from the Master Plan Area has been blocked. Since the capacity of these klongs is limited, as studied in the City Core Project, reopening these klongs for the Master Plan Area requires an extensive amount of widening or tunnel construction with large cost implications.

## 6.3 Non-Structural Measures

### 6.3.1 Land Use Guidance

Since the flooding of non-used land implies almost no damage, controlling urban development in a flood-prone area is the most efficient method of flood damage prevention. Consequently, the reserved flood-prone areas can be used as rainfall retention areas which have a capacity to absorb storm water caused by intensive rainfall, leading to a considerable reduction in costs of facilities and the achievement a sound economic effect.

From the study, for the target year of 2000, about half (235 $km^2$) of the Preliminary Study Area (501 $km^2$) is estimated to be urbanized and a Master Plan Area (260 $km^2$) and Retarding Area (241 $km^2$) were proposed.

It is planned that the Master Plan Area should be protected by flood protection barriers. For the Master Plan Area, improvement of drainage facilities is to be implemented as part of this project. For the remaining Retarding Area, the drainage facilities will be required in future to keep pace with urban development.

### 6.3.2 Rainwater Retention in the Master Plan Area

It has been determined that about 20 percent of the Master Plan Area can be utilized for temporary storage. The urbanized area in 2000 is estimated by the Study Team to increase to 216 $km^2$ from 134 $km^2$ in 1980. This urbanized area, which can accommodate 2.5 million persons out of the anticipated 7.7 million persons in Bangkok Metropolis is proposed to be allocated to flood-free or light flood-prone areas rather than heavy flood-prone areas. Consequently, the remaining open space of 44 $km^2$ can be utilized for water retention purposes (Fig. 6.6).

### 6.3.3 Landfill and Retention in the Estate

The greater part of the lower Chao Phraya Plain is well suited to rice production under the conditions of yearly flooding. Farmers in the plain have used houses on stilts along the klongs. On the contrary in the urbanized area, landfill has been cope with flooding. Therefore, the future urbanized areas are proposed to be elevated in the same way, to the same level as the existing urbanized area (see Fig. 7.1). The difference between the elevated level and the existing level of the urbanized area is 0.4 to 1.0 meter. Hence, landfill elevation should be 0.4 to 1.0 meter varying from area to area.

# Cahpter 7. PROPOSED FLOOD PROTECTION/DRAINAGE FACILITY

In this chapter, structural measures for flood protection are proposed based on the year 2000.

These measures consist of a system to block water inflow from outer areas and a drainage system for the discharge of storm water to the outer area.

## 7.1 Planning Criteria

### 7.1.1 Physical Conditions

1) Land-Use

The proposed land-use pattern in 2000 as shown in Fig. 5.3, aimed at controlling increase of flood damage potential, is the base for facility planning.

2) Land Subsidence

Land subsidence by the year 2000 of 0.7 meter (in Bang Khen and Bang Sue drainage areas, see Fig. 7.2) and 1.0 meter (in the other six drainage areas) are considered.

3) Landfill

The ground elevations in the year 2000 are estimated by using the combination of future land subsidence and future landfill for newly urbanized areas (see section 6.2). Fig. 7.1 shows the estimated ground elevation in 2000.

4) Polder

Three polder areas (Bank Khen-Bang Sue, Phra Khanong and Bang Na) as shown in Fig. 7.2 topographically affect facility planning.

5) Retention Area

For planning run-off control, the retention areas as shown in Fig. 6.6 are considered.

6) Klongs

Existing klong networks are to be fully utilized for planning purposes.

a) Improvement of klongs is considered principally within the right-of-way without land acquisiton. After comparative study (See section 4.2 of Appendix J), rectangular-shape klongs with retaining walls are adopted for the urbanization area while the trapezoidal-shape klong is adopted for the non-urbanized area.

However, the latter type will undoubtedly require land acquisition, due to private ownership of most real estate in this area.

b) Klong depth is limited to 4 – 5 m due to poor subsoil strength.

7.1.2 Hydrological Design Criteria

1) High Water Level

The influence of water level on the flood protection barriers to be constructed and on the storm water discharge from the Master Plan Area, determines the basis for hydrological design, as follows:

a) Chao Phraya River

The 100-year frequency flood level
+1.90 meters above MSL in Bang Na and Phra Khanong areas
+2.20 meters above MSL in Bang Khen and Bang Sue Areas

b) East border area of the Master Plan Area

+1.10 meters above MSL based on present elevations in the northern area (+0.10 meters above MSL in 2000 due to land subsidence)

+0.80 meters above MSL at present in the southern area (–0.20 meters above MSL in 2000 due to land subsidence)

For the planning of barrier along the Chao Phraya River, a freeboard of 30 cm is required.

2) Rainfall

Two-year frequency rainfall (91 mm/day) is adopted for designing the inland drainage facilities, while a 5-year frequency rainfall (120 mm/day) is used for the trunk drainage facilities due to their importance. The trunk drainage facilities are the Phra Khanong Pumping Station, Klong Phra Khanong, Klong Saen Saep and Klong Tan.

3) Run-off Coefficient

Table 7.1 Run-Off Coefficients for Various Land-Use Types

| Land-use Type | Run-Off Coefficient |
|---|---|
| 1. Residential (medium density) | 0.50 |
| 2. Residential (low density) | 0.40 |
| 3. Commercial | 0.75 |
| 4. Industrial | 0.75 |
| 5. Institutional | 0.70 |
| 6. Park/Agricultural | 0.15 |
| 7. Pond | (1.00) |

4) Maintenance Water Level in Klongs

Maintenance water levels in klongs are planned as shown in Table 7.2. These levels are defined as the level to be maintained just upstream of the pumping stations under normal dry weather flow conditions. Under design rainfall, water levels in the klongs would rise some 1.5 m above normal polder water levels, reaching land level elevations.

The maintenance water level is decided under the consideration of 1) utilizing effective ranwater storage of the klongs, 2) stability of retaning wall against earth pressure, 3) required pump operation time for restoration of water level to maintenance water level as a provision against the next rainfall, 4) covenience of water use for navigation and 5) environmental effect.

Table 7.2 Maintenance Water Level in Klong

| Polder Area | Maintenance Water Level | |
|---|---|---|
| | Present | Future (in 2000)* |
| Bang Khen – Bang Sue | -0.50 MSL | -1.50 MSL |
| Phra Khanong | -0.80 MSL | -1.80 MSL |
| Bang Na | -0.80 MSL | -1.80 MSL |
| North Hua Mark (Within Phra Khanong Polder) | -0.80 MSL | -1.80 MSL |

* considering land subsidence

5) Inflow from the City Core Area

Some stretches of Klongs Bang Sue, Phra Khanong and Tan are located at the boundaries between the Master Plan Area and the City Core Area. These klongs are connected to the Chao Phraya River for the discharge from the Master Plan Area. After discussions with DDS, the following discharges are planned from the City Core Area into the following two klongs:

| | |
|---|---|
| Klong Bang Sue | 12 $m^3$/sec |
| Klong Tan | 14 $m^3$/sec |

However, these inflows should be waited until the proposed facilities of this Master Plan will be constructed otherwise these will bring adverse effect on the Master Plan Area.

6) Degree of Drainage

The proposed flood protection and drainage facilities is planned under conditions of almost no inundation in the urbanized area from the design rainfall. However, short periods of local flooding may occur in some limited low places considering topographical conditions, difficulties in klong improvement works, etc.

## 7.2 Flood Protection Barrier

The outer flood protection barrier is proposed to be constructed along the boundary of the Master Plan Area. Within the Master Plan Area, inner barriers along the boundaries of designated polders are also proposed, consisting of embankments and gates.

### 7.2.1 Embankment

The flood protection barrier is divided into 8 sections as shown in Fig. 7.3. Section 1 is the stretch along the Chao Phraya River, section 2 along the City Core project, section3 along northern Bangkok, sections 4 and 5 along the eastern outer area and Samut Prakan Province, section 6 for the border between Polder Bang Sue and Phra Khanong, section 7 for the border between Polder Phra Khanong and Bang Na and section 8 for the border of North Hua Mark Polder.

Almost all sections running on the existing embanked roads and railways have sufficient elevation at present and for the future. The only required sections to be constructed are sections I and V. (See Appendix H).

For section I, a retaining wal of average height of 2 m is required, while for part of section V, an earth embankment of 0.7 m height on average is necessary. However, the latter is moved eastward in order to utilize existing roads as shown in Fig. 7.3.

Table 7.3 Proposed Embankment

| Section | Length (m) | Type | Remarks |
|---|---|---|---|
| 1 | 2,000 | Retaining Wall | Along Klong Phra Khanong (Phra Khanong pumping station to Chao Phraya River) |
| 1 | 4,200 | Retaining Wall | along Chao Phraya River |
| Total | 6,200 | | |

### 7.2.2 Gates

Fifty five gates in the inland area are required to be oeprated, mostly in the closed mode during the rainy season and open in the dry season for flushing, cleaning the klongs and irrigation.

In addition, ten gates at the proposed pumping stations are required to operate in conjunction with the water level of the river or outer klong by opening in case of low water level and closing in the case of high water level.

In addition to the gates, a navigation lock in the Klong Phra Khanong, one of the large navigable klongs in the Master Plan Area, is necessary with the capacity of handling river barges and boats.

Table 7.4 Proposed Gates at Pumping Stations

| Name of Pumping Station | Gate | | Number of Locations | Klong Width (m) | Remarks |
|---|---|---|---|---|---|
| | Width(m) | Nos. | | | |
| Bang Khen (North) | 4 | 3 | 1 | 15 | Bang Khen Drainage Area |
| Bang Khen (South) | 4 | 2 | 1 | 10 | Bang Khen Drainage Area |
| Bang Sue | 6 | 4 | 1 | 25 | Bang Sue Drainage Area |
| Kacha | 4 | 2 | 1 | 12 | Hua Mark Drainage Area |
| Gig | 4 | 2 | 1 | 12 | Hua Mark Drainage Area |
| Bang Na Chine | 4 | 2 | 1 | 13 | Bang Na Drainage Area |
| Jek | 4 | 2 | 1 | 12 | Bang Na Drainage Area |
| Bang Oa | 4 | 2 | 1 | 11 | Bang Na Drainage Area |
| Bang Na | 6 | 3 | 1 | 20 | Bang Na Drainage Area |
| Phra Khanong | 6 | 6 | 1 | 35 | Trunk Drain |
| Total | | | 10 | | |

Table 7.5 Proposed Gates in Inland Area

| Barrier Section | Gate | | Number of Locations | Klong Width (m) | Remarks |
|---|---|---|---|---|---|
| | Width(m) | No. | | | |
| III | 4 | 1 | 3 | 10 | |
| IV | 4 | 1 | 12 | 10 | |
| IV | 6 | 1 | 1 | 35 | Klong Saen Saep |
| V | 4 | 1 | 12 | 10 | |
| V | 6 | 1 | 1 | 35 | Klong Phra Khanong |
| Vi | 4 | 1 | 10 | 10 | |
| VII | 4 | 1 | 9 | 10 | |
| VIII | 4 | 1 | 7 | 10 | |
| Total | | | 55 | | |

## 7.3 Drainage Facility

### 7.3.1 Drainage Area

The Master Plan Area is divided into three polders. Three polders are further subdivided into eight drainage areas as shown in Table 7.6 and Fig. 7.2 for the convenience of operation and management of the facility. The borderline of respective drainage area is determined, taking into account land use, past flood damage and location of highways and railways. Especially, highways and railways were usually built about 1 to 2 meters high from adjacent ground level, constituting natural barriers.

Table 7.6 Drainage Area

| Polder | Drainage Area | |
|---|---|---|
| Bang Khen -- Bang Sue | Bang Khen | 29 km² |
| | Bang Sue | 35 |
| | Sub-Total | 64 |
| Phra Khanong | Klong Chan | 24 |
| | Lat Phrao | 59 |
| | Huay Kwang | 35 |
| | Patterna Karn | 24 |
| | Hua Mark | 23 |
| | Sub-Total | 165 |
| Bang Na | Bang Na | 31 |
| Total | | 260 |

### 7.3.2 Procedure of Hydraulic-Hydrological Analysis

Hydraulic-hydrological analyses are carried out respectively for each polder.

1) Phra Khanong Polder

The following four steps were carried out.

In Step – I, an approximate flooding status for several different capacities of trunk drainage facilities are investigated by means of storage basin model (9 basins model).

In Step – II, the poor drainage areas are identified by means of storage basin model (19 basins model) (see section 5 of Appendix H).

In Step – III, for the divided five drainage areas, main drainage facilities such as pumping stations, main klongs and sub-klongs are studied and determined by means of unsteady flow model. (See section 6.1 of Appendix H)

In Step – IV, trunk drainage facilities consisting of Phra Khanong Pumping Station, Klongs Phra Khanong, Saen Saep and Tan are studied and finally, total drainage facilities including drainage facilities in designated drainage areas are checked and confirmed by unsteady flow model (See section 6.2 of Appendix H).

2) Bang Khen – Bang Sue Polder and Bang Na Polder

Hydraulic-Hydrological analysis for Bang Khen – Bang Sue Polder and Bang Na Polder are performed by the process described in Step III owing to a rather small area of the polder.

For Bang Khen – Bang Sue Polder, alternative studies on combination and separation of Bang Khen and Bang Sue drainage areas are made, then, the combination of both areas is adopted.

### 7.3.3 Results of Hydraulic-Hydrological Analysis

The main factors influencing the scale of drainage facilities are ground surface storage, storage in retention area, storage in klongs, flow capacity of klongs and discharge capacity of pumps. Relationships between storage and pump discharge in the respective polder is shown in Fig. 7.4 from the results of the study. The retention areas play a large role in the decrease of peak flows in the kongs. Fig. 7.5 shows the maximum discharge in each section of klong for the proposed drainage facilities shown in Fig. 7.6 – Fig. 7.9.

The storage capacities of klongs and retention areas are the storage volume between lowest residential land level and maintenance water level in klongs. The storage capacities of each polder are determined based on the physical conditions (future land use plan, future ground elevation, improved klong sections), maintenance water level and hydraulic study in conjunction with pump capacity. The determined storage capacities are shown in Table 7.7.

Table 7.7 Storage Capacity of Klongs and Retention Area

(Unit: $10^6 m^3$)

| Polder | Polder Area | Retention Area | Storage Capacity | | |
|---|---|---|---|---|---|
| | | | Klong | Retention Area | Total |
| Bang Khen – Bang Sue | 93 km² | 2.5 km² | 1.79 (19 mm) | 0.38 (4 mm) | 2.17 (23 mm) |
| Phra Khanong | 165 km² | 39.8 km² | 2.74 (23 mm) | 4.19 (25 mm) | 7.93 (48 mm) |
| Bang Na | 31 km² | 1.7 km² | 0.95 (31 mm) | 0.09 (4 mm) | 1.04 (34 mm) |
| Total | 289 km² | 44 km² | 6.48 (22 mm) | 4.66 (16 mm) | 11.14 (38 mm) |

Note: 1. ( ) shows equivalent storage height in millimeter.
* Additional area between Chao Phraya River and Super Highway of 29 km² is added.

### 7.3.4 Planned Drainage Facilities

#### 1) Pumping Station

Seven outlet pumping stations are proposed in order to pump storm water out into the Chao Phraya River as shown in Fig. 7.6. In addition, three inner pumping stations are proposed within Phra Khanong polder and Bang Na polder to discharge storm water into Klongs Saen Saep or Phra Khanong. Capacities of the pumps are shown in Table 7.8.

**Table 7.8 Proposed Pumping Station**

| Polder | Name | Capacity ($m^3/sec$) |
|---|---|---|
| A. Outlet Pump | | |
| Bang Khen – Bang Sue | Bang Khen (North)<br>Bang Khen (South) | 15 |
| | Bang Sue | 50 |
| Phra Khanong | Phra Khanong | 90 |
| Bang Na | Jek | 6 |
| | Bang Oa | 18 |
| | Bang Na | 21 |
| Sub-Total | 7 stations | 200 |
| B. Inner Pump | | |
| Phra Khanong | Gig | 3 |
| | Kacha | 6 |
| Bang Na | Bang Na Chine | 9 |
| Sub-Total | 3 stations | 18 |
| Total | 10 stations | 218 |

2) Klongs

Among the 172 kms of klong, 133 km, as shown in Fig. 7.7 require improvement works. (Refer to 5 of Appendix J).

The works are categorized as follows:

Total 133 km
Widening 50 km (Categories I, II and V)
Deepening 133 km (Categories I, II, III, IV-1 and V)
Construction of Retaining Wall 80 km (Categories I, II and III)

Table 7.9 Summary of Proposed Klong Improvement

(unit: km)

| | Polder | Drainage Area | Category * I | II | III | IV-1 | V | Total | No improvement (IV-2) |
|---|---|---|---|---|---|---|---|---|---|
| Main Klong ** | | | – | – | 10.5 | 15.0 | – | 25.5 | – |
| Sub Klong | Bang Khen and Bang Sue | Bang Khen | – | – | – | 3.9 | 6.5 | 10.4 | 10.0 |
| Sub Klong | Bang Khen and Bang Sue | Bang Sue | – | 2.0 | 6.0 | – | – | 8.0 | 12.7 |
| Sub Klong | Bang Khen and Bang Sue | Sub-Total | – | 2.0 | 6.0 | 3.9 | 6.5 | 18.4 | 22.7 |
| Sub Klong | Phra Khanog | Klong Chan | – | – | 1.3 | – | 5.8 | 7.1 | 3.9 |
| Sub Klong | Phra Khanog | Lat Phrao | – | 4.9 | 8.1 | – | 2.7 | 15.7 | 4.2 |
| Sub Klong | Phra Khanog | Huay Kwang | 1.0 | – | 15.1 | – | 12.8 | 28.9 | – |
| Sub Klong | Phra Khanog | Patterna Karn | – | – | – | – | 5.5 | 5.5 | 3.0 |
| Sub Klong | Phra Khanog | Hua Mark | – | – | 9.3 | – | 0.5 | 9.8 | – |
| Sub Klong | Phra Khanog | Sub-Total | 1.0 | 4.9 | 33.8 | – | 27.3 | 67.0 | 11.1 |
| Sub Klong | Bang Na | Bang Na | 5.8 | 2.1 | 13.2 | 1.0 | – | 22.1 | 5.0 |
| Total | | | 6.8 | 9.0 | 63.5 | 19.9 | 33.3 | 133.0 | 38.8 |

*Note: Category I : new drain with retaining wall
Category II : widening + deepening + construction of retaining wall
Category III : deepening + construction of retaining wall
Category IV : deepening (IV-1), no improvement (IV-2)
Category V : widening + deepening

**Note: Klong Phra Khanong, Tan and Saen Saep

3) Tertiary Drainage Facilities

Generally, tertiary drainage facilities, consisting of main pipes, branch pipes and ditches etc., is required in addition to pumping stations and improvement of klongs, to eliminate flooding. In this Master Plan, however, plans for tertiary drainage systems are not made, although the main pipe length is to be 351 km in total (Refer to Appendix K).

## 7.4 Proposed Facilities

The planned facilities in the preceeding sections are based on the planning criteria set out in section 7.1; namely, aiming at alleviation of overall areal flooding as well as local flooding in the urbanized areas. This has an estimated cost of 11,000 million Baht. However examination of the cost effectiveness of the planned facilities indicates that substantial savings can be made in reducing the length of main drain pipes to be installed. (Cost is discussed in detail in Chapter 9.)

This will result in local flooding for short periods. If this can be restricted to areas outside the high-priority urbanized area (80 km² described in Section 9.4.2) a substantial cost saving is obtained.

The reduced requirements are termed Proposed Facilities or Priority Facilities, and are compared with the Planned Facilities or Total Facilities in Table 7.10.

**Table 7.10 Summary of Proposed Facilities**

| Item | Total Facilities | Priority Facilities |
|---|---|---|
| Embankment | 6.2 km | |
| Gate | 55 places | |
| Pumping Station with Gate | 10 stations (218 m³/s) | |
| Klong Improvement<br>Main klong<br>Sub klong | <br>25.5 km<br>107.5 km | |
| Main Drain Pipe | 351 km (260 km²) | 100 km (80km²) |
| Flood Forecasting and Warning System | 1 set | |
| Total Cost * | 11,000 million Baht | 6,280 million Bhat |

* : Refer to Chapter 9

### 7.4.1 Hydrological Effect of the Facilities

1) Effect of the Urgent Measures

According to the hydrological analysis, if the urgent measures are not executed, the average inundation depth (for 5-year frequency rainfall) would be 210 mm in the Master Plan area. This has been reduced to 61 mm by blocking inflow of outer water by the dykes of the Green Belt project, and by increasing the drainage capacity due to the installed pumps. This indicates the very large effect of the urgent measures. These are based on the topographic and urbanizing conditions as of 1984, which allows the average storage volume of 196 mm being provided by unurbanized low-swampy areas within the Master Plan area (Fig. 7.11).

However, by the year 2000, because of change in topographic and urbanizing conditions, the average inundation depth would increase to 147 mm, if the area is left only with urgent facilities. In order to protect the area from flooding, it is evident that additional drainage facilities are required by their order of effectiveness.

2) Effect of the Proposed Project

As it is indicated on Fig. 7.11 under the estimated topographic and urbanized conditions as of 2000, construction of a boundary barrier surrounding the Master Plan area will lower the average inundation depth from 147 mm to 93 mm by assuming 65 mm can be stored in the unurbanized areas reserved through flood plain management. The inundation depth can be further lowered to 42 mm by installing additional pumps and implementing klong improvements and main pipes at severely-flooded areas. The construction of small pipes further reduce the inundation to 29 mm. However, this latter effect costs as much as ten times that of the boundary barrier, additional pumps, klong and main pipes. Therefore, the construction of small pipes are excluded from this master plan.

### 7.4.2 Priority of Areas for Main Drain Pipe

The high priority areas are selected by ranking the flood damage potential of 4 $km^2$-meshes considering the topography, hydraulic conditions and population density. As a result, meshes near Central Bangkok are ranked generally with high potential as shown in Fig. 9.1. These meshes are about 80 $km^2$ in total. These meshes include observed flood area of about 21 $km^2$ as shown in Fig. 8.2 on September 21 and October 7, 1984 when nearly design rainfall of 91 mm occurred.

# Chapter 8. FLOOD PLAIN MANAGEMENT

## 8.1 General

Flood damage potential in the Master Plan Area has been increasing and is expected to increase significantly due to increasing unplanned urbanization and land subsidence, in addition to the heavy rainfall and water inflow from the outer area. Therefore, modifying the susceptibility of property and activities in the flood-prone area to damages from flooding is crucial. This can be accomplished by flood plain management. Experience has shown that it can be highly effective, and that is generally costs much less than structural measures alone. Most importantly, it tends to pass the burden of costs from the public at large to those who reap the advantages of flood plain location, and as a consequence it promotes increased awareness of the need for efficient flood adjustments.

Main items for the flood plain management are:

1) Identification and Publicizing of Flood-prone Areas

2) Land Use Guidance

3) Encouragement of Individual Flood-Proofing Measures

4) Flood Forecasting and Warning System

5) Emergency Flood Fighting Organizations

6) Flood Protection Committee

## 8.2 Identification and Publicizing of Flood-prone Area

Flood inundation maps are an essential tool for the dissemination of information on floods. They serve as a guide for stabilizing living conditions for the people, preparation against sudden heavy rainfall and future urban development, resulting in mitigation of flood damage. The following maps have been prepared by the Study Team.

- Observed flood area in 1983 flooding (Fig. 8.1)
- Observed flood area in 1984 flooding (Fig. 8.2)
- Map showing the estimated extent and depth of flooding for a 5-year frequency rainfal after execution of the urgent measures (Fig. 8.3)

– Map showing the estimated extent and depth of flooding in the year 2000 after execution of urgent measures, considering land subsidence (Fig. 8.4).

In Fig. 6.4, the planned areas for temporary storage of water are shown. These maps are proposed for distribution to government agencies, the public directly and indirectly, such as through mass media and bulletin boards.

## 8.3 Land Use Guidance According to Flood Risk

Land use guideance seeks to minimize loss by discouraging those activities which have a high flood-damage potential in flood-prone areas. The entire Master Plan Area located in the lower Central Plain can be considered as flood-prone area. However, susceptibility of property and activities to damages from flooding differs in each part of the Area. Experience shows that areas with low ground elevation such as Bang Na, Huay Kwang and Hua Mark suffer from long-term flooding. Consequently, these areas should not be developed until structural measures have been provided, to the extent that demand and supply of land for urbanization will allow. The other alternative is to reserve some areas as retention areas. Some parts of Lat Phrao drainage area can be used until the year 2000. Fig. 5.3 shows a proposed land use taking into account the foregoing. The following proposed measures should be accomplished concurrently:

1) Limitation of urban development in Eastern Suburban-Bangkok to only within the Master Plan Area until the year 2000.

2) New estates in future urbanized areas (216 $km^2$ out of the Master Plan Area of 260 $km^2$) to be elevated to the same level of the existing urbanized area or to be built in stilt-type construction.

   The required volume of landfill will be roughly 56 million cubic meters (Newly urbanized area = future urbanized area in 2000 minus existing urbanized area in 1984 i.e. 216 $km^2$ – 134 $km^2$ = 82 $km^2$. Assuming an average landfill height of 70 cm, then the volume becomes 56 million cubic metres). If this volume is brought from outside, e.g., Green Belt Area, it will cost about 6,700 million Baht assuming a unit cost of landfill (including transportation of earth of 10 km) of 123 Baht/$m^3$: Thus it will cost about 5,000 Baht per person (6,700 million Baht for 1.4 million persons).

   A housing estate will not necessarily be elevated. If all the estate except the buildings and the paths leading to public roads are not elevated, these estates will act as retention areas. This will considerably reduce not only the public expenditure for drainage systems but also private expenditures. It is preferable for the required fill material to be taken from within the estate and this borrow-pit is then used as a retention site. The cost of landfill is then considerably reduced to about 2,000 million Baht or 1,500 Baht per person.

3) Retention basin within future estates should be encouraged in order to preserve potential storm water storage capacity.

4) All roads, existing and planned, to be elevated at 1 m MSL (at present) in order to maintain traffic flow even during flood.

5) Limit service of such public facilities as drainage, water supply and electricity basically to only urbanized areas (both existing and planned).

Although the 1975 Town and Country Planning Act has not yet had any discernible effect on residential development, its enforcement is crucial. Besides, the BMA building code which has been effective on housing developments in Green Belt Area, can be utilized for the proposed land use guidance. The other opportunity to impose planning standards is the Land Subdivision Control Act (1972). Under the Act, any development of more than 10 plots requires a permit from the Committee whose members are from government agencies concerned with land, local administration, urban planning, housing, utilities and legal affairs.

## 8.4 Encouragement of Individual Flood-proofing Measures

Houses will continue to suffer from flooding until structural measures are completed. Further, even after the structural measures are completed, flooding will still occur for heavy rainfall which exceeds a 2-year frequency rainfall. Hence, individual flood-proofing measures such as landfill, flood-proof walls, etc. should be encouraged as in the past.

## 8.5 Flood Forecasting and Warning System

Effective flood forecasting can enable the community to prepare against a possible flood, thereby, leading to reduction of flood damage. Necessary data such as rainfall, water levels of klongs and the Chao Phraya River should be collected by the control center of the DDS.

A communication system, such as shown in Fig. 8.5, is of vital importance and should be established.

## 8.6 Flood Fighting

Flood fighting can be defined as the execution of emergency measures against disaster at times of flood. A combination of sufficient trained manpower, adequate stocks of material, telecommunication equipment, construction machinery and vehicles for transport are necessary for an effective flood fighting operation.

## 8.7 Flood Protection Committee

An organization has to be formed to be able to undertake both structural and non-structural measures for flood protection. Therefore, firm policies and a suitable organization are needed.

## Chapter 9. PROJECT COST AND IMPLEMENTATION SCHEDULE

The project cost, consisting of the construction cost of the proposed flood protection and drainage facilities, engineering/supervision fees, contingencies and land acquisition costs, is first explained. Then, an implementation schedule is proposed, considering the project cost and degree of alleviation of flood damage.

### 9.1 Basis of Project Cost Estimates

Labour cost is presented in Table 9.1. Unit basic construction cost including contractor's profit, overhead, relevant customs tax, surtax and sales tax, are presented in Table 9.2 Based on these data, unit costs of drainage facilities are developed.

**Table 9.1 Labour Cost**

| Type of Labour | | Labour Cost per Day (฿) |
|---|---|---|
| Unskilled Labour | | 64 |
| Mason | | 80 – 85 |
| Bar Bender | | 85 – 120 |
| Concretor | | 100 – 140 |
| Asphalter | | 100 – 130 |
| Carpenter | | 100 – 180 |
| Painter | | 120 – 150 |
| Welder | | 130 – 150 |
| Foreman | | 180 – 200 |
| Chief Foremen | | 350 – 600 |
| Car Driver | | 100 – 150 |
| Crane Operator | | 150 – 180 |
| Boat Crew | (low) | 90 – 290 |
| " | (middle) | 120 – 430 |
| " | (high) | 400 |

Table 9.2 Basic Cost

| Item | Description | Unit | Price (฿) |
|---|---|---|---|
| Backfilling | Local soil | $m^3$ | 130 |
| Excavation | Manual | $m^3$ | 600 |
| Excavation | Backhoe | $m^3$ | 180 |
| Excavation | Clamshell | $m^3$ | 700 |
| Concrete | 1 : 2 : 4 | $m^3$ | 1300 |
| Concrete | 1 : 3 : 5 | $m^3$ | 1000 |
| Formwork | Wood | $m^2$ | 200 |
| Dredging | on Bank | $m^3$ | 53 |
| Dredging | on Barge | $m^3$ | 176 |
| Steel Sheet Work | SP II $\ell = 8.0$ m | m | 2600 |
| Steel Sheet Work | SP III $\ell = 15.0$ m | m | 5800 |
| Driving & Extracting of Steel Sheet Pile | H-shape | t | 2600 |
| Rental Cost | H-shape | t/day | 120 |
| Rental Cost | SP | t/day | 10 |
| Maintenance Cost for Steel | H-shape | t/day | 90 |
| Maintenance Cost for Steel | SP | t/day | 80 |

## 9.2 Construction Cost

The estimated project cost of the "total facilities" amounts to 11,000 million Baht whilst the cost of the proposed "priority facilities" is 6,280 million Baht as shown in Table 9.3. For the estimate of project cost, engineering and supervision fees (10% of construction cost) and contingency fees (17% of construction cost and engineering/ supervision fee) are included (See Appendix K).

Table 9.3 Estimated Project Cost

(Unit: million Baht at 1984 price)

| Name of Facility | Total | Priority |
|---|---|---|
| 1) Embankment | 70 | 70 |
| 2) Gate | 298 | 298 |
| 3) Pumping Station | 1,479 | 1,479 |
| 4) Improvement of Main Klong | 357 | 357 |
| 5) Improvement of Sub Kong | 1,914 | 1,914 |
| 6) Main Pipe | 6,692 | 2,033 |
| 7) Flood Forecasting/Warning System | 129 | 129 |
| Total | 10,939 | 6,280 |

## 9.3 Operation and Maintenance Cost

Annual operation and maintenance cost is estimated at 3% of construction cost; that is, 248 million Baht per year.

## 9.4 Implementation Schedule

### 9.4.1 Factors for Determination of Implementation Schedule

A higher implementation priority should be given to those works that will alleviate the heavier flood damage. High priority is given to the works that will alleviate overall, large-area and long-term flooding. These works are for flood protection facilities, such as embankments and gates, and trunk drainage facilities such as main klong improvements and the Phra Khanong pumping station. Lower priority works include sub-klong improvements, remaining pumping stations and main drain pipes for the existing urbanized area.

Since the pumps installed under the urgent measures, have sufficient capacity to meet the hydraulic requirement studied by the Master Plan and the life of which are estimated as 7 to 8 years, replacement with permanent ones is planned for the second and third stages. The 55 gates include large scale gates, such as those up-stream of Klongs Phra Khanong and Saen Saep, and small one. Those which have a major effect on the prevention of inflow from outer areas, will be constructed at an early stage and the smaller gates constructed at second or third stages until when cofferdams can be temporarily used .

Improvement of sub-klongs, construction or replacement of pumpting stations and construction of main drain pipes are implemented so as to keep pace with the progress of urbanization. This will avoid excessive initial investment with due consideration to financial constraints as well. As described in Chapter 7, flood damage potential by means of 4 $km^2$-meshes are estimated by considering the topography, hydraulic conditions and population density etc. As a result, meshes near Central Bangkok indicate high priority as shown in Fig. 9.1. The high priority area is about 80 $km^2$ in total. These meshes include the September 21 and October 7, 1984 observed flood area of about 21 $km^2$ as shown in Fig. 8.2 when nearly the 91 mm design rainfall occurred. The Bang Na, Hua Mark, Huay Kwang and Bang Sue drainage areas also have high priority. Based on these results, the implementation schedule has been prepared.

### 9.4.2 Implementation Schedule

The preparatory work for a feasibility study, detailed design and financial procurement could be carried out in 1985 and 1986. Hence, construction can be started in 1987 in the Sixth National Development Plan. The proposed facilities with a cost of 6,280 million Baht at 1984 prices will be constructed in the following three stages;

The First Stage (1987 – 1991)

The Second Stage (1992 – 1996)

The Third Stage (1997 – 2000)

The works in each stage are shown in Table 9.4 and Fig. 9.2 whilst Table 9.5 shows the breakdown .

First Stage Works

The First Stage (Fig. 9.3) aims at the prevention of areal overall flooding and heavy local floodingof 21 $km^2$ belonging to high priority areas. For that purpose, the expenditure of 2,300 million Baht will be required.

Table 9.4 Implementation Schedule

| Item | Total | 1st Stage (1987 – 1991) | 2nd Stage (1992 – 1996) | 3rd Stage (1997 – 2000) |
|---|---|---|---|---|
| Project Cost (million Baht) | 6,280 | 2,560 | 1,830 | 1,890 |
| Facilities | | | | |
| Embankment | 6.2 km | 6.2 km | – | – |
| Pumping Station with Gate | 10 stations ($218\ m^3/s$) | Kacha ($6\ m^3/s$)<br>Gig ($3\ m^3/s$)<br>Bang Na Chine ($9\ m^3/s$)<br>Bang Sue (14)<br>Bang Na (6) | Phra Khanong ($90\ m^3/s$) | Bang Khen North & South ($15\ m^3/s$)<br>Bang Sue ($36\ m^3/s$)<br>Jek ($6\ m^3/s$)<br>Bang Oa ($18\ m^3/s$)<br>Bang Na ($15\ m^3/s$) |
| Gate | 55 places | 4 places | 26 paces | 25 places |
| Main Klong* | 25.5 km | 16.5 km | 9.0 km | – |
| Sub Klong | 107.5 km | 52.3 km | 26.9 km | 28.3 km |
| Main Drain Pipe | 110 km | 30 km | 40 km | 40 km |
| Flood Fore-casting and Warning System | 1 set | 1 set | – | – |

* Klongs Phra Khanong, Tan and Saen Saep

**Table 9.5 (1) Works at Each Stage**

(A) Embankment

| First Stage | Second State | Third Stage |
|---|---|---|
| 6.2 km | – | – |

(B) Gate

| Name \ Stage | First Stage | Second Stage | Third Stage |
|---|---|---|---|
| Gate at Pumping Station | Bang Sue<br>Bang Na<br>Bang Na Chine<br>Gig<br>Kacha | Phra Khanong | Bang Khen north,<br>Bang Khen south,<br>Bang Oa<br>Jek |
| Gate | | | |
| Phra Khanong | 1 | – | – |
| Saen Saep | 1 | – | – |
| Other 53 gates | 2 | 26 | 25 |

(C) Pumping Station

(Unit: $m^3$/sec)

| Name \ Stage | First Stage | Second Stage | Third Stage |
|---|---|---|---|
| Outlet Pump | | | |
| Phra Khanong | – | 90* | – |
| Bang Khen (North & South) | – | – | 15* |
| Bang Sue | 14 | – | 36* |
| Jek | – | – | 6* |
| Bang Oa | – | – | 18* |
| Bang Na | 6 | – | 15* |
| Inner Pump | | | |
| Kacha | 6 | – | – |
| Gig | 3 | – | – |
| Bang Na Chine | 9 | – | – |

Note: * replacement of urgent pump

Table 9.5 (2) Works at Each Stage

(D) Klong

(Unit: km)

| Drainage Area | First Stage | | Second Stage | | Third Stage | |
|---|---|---|---|---|---|---|
| | Length | Section | Length | Section | Length | Section |
| Main Koong (Phra Khanong, Tan and Saen Saep) | 16.5 | 1 to 7, 11 to 19 | 9.0 | 8, 9, 10, 20 to 26 | – | – |
| Sub Klong | | | | | | |
| Bang Khen | – | – | 10.4 | 14 to 18 | – | – |
| Bang Sue | 8.0 | 9 to 12 | – | – | – | – |
| Klong Chan | – | – | – | – | 7.1 | 1 to 3, 7, 8 |
| Lat Phrao | – | – | – | – | 15.7 | 1 to 11, 15 |
| Patterna Karn | – | – | – | – | 5.5 | 1 to 4 |
| Hua Mark | 3.9 | 1 to 3 (north) | 5.9 | 1 to 6 (south) | – | – |
| Huay Kwang (East) | 4.2 | 2, 3, 5, 6 | 1.8 | 1 | – | – |
| (West) | 14.1 | 6, 7, 10, 11, 12, 13, 14 | 8.8 | 8, 9 | – | – |
| Bang Na | 22.1 | 1 to 3, 5 to 7, 9 to 14, 19, 20 to 25 | – | – | – | – |
| Sub-Total | 52.3 | | 26.9 | | 28.3 | |
| Total | 68.8 | | 35.9 | | 28.3 | |

Note: Sections are shown in Appendix J.

## Chapter 10. ORGANIZATION AND MANAGEMENT

In this chapter, the organizational and managerial aspects of implementing and operating the project are studied and some recommendations are presented.

### 10.1 Bangkok Metropolitan Administration (BMA) and Department of Drainage and Sewerage (DDS)

BMA is the regional administrative body governing the 24 districts of Bangkok Metropolis, which covers an area of 1,589 $km^2$. The Governor and four Deputy Governors are appointed by the Cabinet and the Undersecretary by the Minister of Interior while Bangkok Metropolitan Assembly is the formal body which governs BMA (Fig. 10.1).

Various municipal services – police, medical, health, education, sanitation, social welfare, roads, canals and drainage – are provided by BMA through 11 departments and 24 district offices. The public services such as water supply, mass transportation, expressway, housing and electricity are provided by "Authorities" which are public enterprises under the central government.

The Bureau of Drainage and Sewerage (BDS) was established in 1977 as a body separate from the Bureau of Sanitation. Because of increasing problems of flooding and waste water in canals, BDS was established, charged with the direct responsibility for storm drainage, flood protection and sewage disposal. BDS changed its name to the Department of Drainage and Sewerage (DDS) in 1981 and established a policy reinforcing its administrative powers. The number of officials at DDS is about 450, and it currently employs about 1,400 regular workers. The DDS consists of four divisions: Drainage Control, Canal Maintenance, Technical, and Waste Water Treatment divisions (Fig. 10.1).

### 10.2 Coordination with Other Government Authorities

Although drainage facilities under DDS play a major role in flood protection, coordination with central government authorities such as RID, NEB, NESDB,finance offices, relevant BMA offices and research institutions is required. The functions covered by these organizations can be divided into structural and non-structural measures which are shown on Table 10.1. The Master Plan Area covers parts of four administrative districts: Huay Kwang, Phra Khanong, Bang Khen and Bang Kapi (Fig. 10.2). These district offices also take care of construction of drainage facilities, especially for small klongs and other local facilities.

Table 10.1 Structural and Non-structural Measures Required at National and Executing Agency Level

| | National Level | Executing Agency Level |
|---|---|---|
| Structural | Construction, operation and maintenance of physical facilities under control of RID, Highway, Railway Dept., Public works and surrounding provinces. | Construction, operation and maintenance of physical drainage facilities and emergency relief activities |
| Non-Structural | Land use control, establishing building code, weather and land subsidence information covered by City Planning Division, TCPD, NEB and Meteorological Dept. | Flood plain management, publicizing, forecasting and warning of flood. |

"The Committee of Flood Protection and Solution in Bangkok and the Vicinity", the Urgent Committee, was formed in October 1983 as a committee for implementing urgent flood protection measures with coordinating function with various organizations. Two subcommittees have been established, one for project allocation which deals with implementation of urgent projects, and the other for coordinating, evaluating and publicizing activities. An additional subcommittee for non-structural measures is under consideration (Fig. 10.3).

## 10.3 Recommendations for Organizational Aspect

At present, the Urgent Committee is acting as a flood protection committee at the national level. However, since this organization is of a temporary nature, it will be dissolved when large flood damage is relieved through the urgent measures. As has been explained in the previous chapters, the flood damage potential will increase annually due to land subsidence and urbanization. In order that Bangkok shall be provided with permanent flood protection measures, it is essential to have a permanent national-level flood protection organization within a committee or an independent government agency, incorporating similar functions as the Urgent Committee. Under the national flood protection organization, structural and non-structural measures, especially flood plain management,should be strengthened (Fig. 10.4). The following measures are recommended for flood plain management and implementation for this project.

### 10.3.1 Flood Plain Management

1) Strengthening Planning Function for Non-structural Measures:

Under a committee in charge of non-structural measures at the national level, an agency-level organization is recommended to analyze data and advise the authorities concerned. For example, under the proposed Flood Protection Organization at national level, a center for planning non-structural measures can be set up at the same level as the technical center. This planning center should have specialists to cover the following subjects:

i) Land use planning with respect to drainage control.

ii) Study for reserving areas for rainwater retention.

iii) Building Codes for anti-flood construction.

iv) Effective and administrative guidelines for flood plain management.

The planning center is desirable to be headed by an authority on city planning, for example, from the City Planning Division of BMA or DTCP. The staff should come from DDS, City Planning Division, Policy and Planning Division, Institutions and other relevant offices.

2) Setting up a Central Flood Control Information Center:

The present system for flood control and flood fighting teams within DDS should be strengthened with automatic water level gauging system and radio and telephone information network. In case of flooding, this center should possess information on the water level at key locations and with the estimated precipitation information, should instruct the operation of gates and pumps in order to minimize the flood damage over the whole area.

3) Setting up (Public Relations) Information Office:

Educating residents of Bangkok concerning the causes, conditions and countermeasures against floods is important to enable effective measures to be implemented. The office should inform the public through the media and District Offices about previous flood conditions and the estimate of flooding and its severity, how the government is planning and conducting flood protection measures, and what each resident should prepare. It was found that during the interview with residents for flood damage survey, some assumed BMA held total responsibility for flooding, without realizing that land subsidence and urbanization are the major causes of flooding. If a proper understanding by residents of the causes of flooding is obtained, tax and other financial impositions might be accepted more readily.

### 10.3.2 Project Implementation

At present, a team to study and plan this project has been set up under the Technical Division of DDS. For the implementation stage, this project team should be expanded into an organization at the same level as divisions, basically with the following functions:

i) Administration and programming

ii) Design

iii) Construction supervision

The use of foreign and local consultants will be necessary to employ the expertise necessary for efficient implementation. This team should be put under direct coordination with sub-committees for structural and non-structural measures at the national level.

## 10.4 Operation and Management Plan

In order to operate drainage facilities in the 260 $km^2$ area,which includes 55 gates, 10 pumping stations and 172 km of klongs, a separate office under DDS to take care of the drainage of Eastern Suburban-Bangkok should be established within the area; for example, at Phra Khanong (although the facilities belong to RID at present).

The Koto Area Drainage Office of Tokyo Municipality is referred here as an example. in southeastern Tokyo, there is a low land delta area called "Koto zero-meter area". The area is about 40 $km^2$ accommodating 700,000 residents, and its elevation is from -1.5 m to +2.0 m. The area used to suffer severe flooding caused by heavy rain and high tide. It is protected now with dykes, canals, 7 gates, two pumping stations, one navigation lock and one flushing gate. The Koto Area Drainage Office, which is under the Construction Bureau of Tokyo Municipality, controls all these facilities and other drainage facilities in the neighbouring flood-prone areas. For the effective management of the operation and management of the drainage facilities in Eastern Suburban-Bangkok, the establishment of an "Eastern Suburbs Drainage Office" is proposed (Fig. 10.5).

The proposed "Eastern Suburbs Drainage Office" will consists of:

(1) Secretary (3 sections)

(2) Design Division (3 sections)

(3) Operation and Mainteancne Division (8 sections & 10 pumping stations)

(4) Construction

A special unit for emergency flood fighting will be attached, similar to that in DDS. The total number of officials attached to this office would be 118, by assuming four or five officials are to be assigned to each of 29 sections (Table 10.2).

**Table 10.2 Number of Officials at Eastern Suburbs Drainage Office**

| Divisions | Number of Sections | Number of Officials |
|---|---|---|
| Secretary | 3 | 12 |
| Design Division | 3 | 15 |
| Operation and Maintenance Division | 8 | 40 |
| (Pumping Stations) | 10 | 30 |
| Construction Division | 4 | 16 |
| Emergency Flood Fighting Unit | 1 | 5 |
| Total | 29 | 118 |

# Chapter 11. FINANCIAL STUDY AND PROJECT EVALUATION

In this chapter, financial and economic aspects of the Master Plan are studied. The financial plans to follow the implementation schedule are presented. An economic cost and benefit analysis has been done to evaluate the project.

## 11.1 Financial Study

### 11.1.1 Revenue and Expenditure of BMA and DDS

Revenue of BMA consists of taxes, fees, property and business revenue, subsidy from the central government and other miscellaneous revenue (Table 11.1). The largest portion is the tax revenue (68% in 1984) which consists of local taxes (13%) and taxes collected by the central government and transferred to BMA, or shared tax (55%). The central government subsidy is provided for education and several projects, sharing 24% of the BMA budget in 1984. Thus, funds from the central government, shared tax and subsidy, amounts to nearly 80%, indicating the limited financial autonomy of BMA itself.

On the expenditure side, the allocation for Drainage and Sewerage has been increasing from 277 million Baht in 1982 to 387 million Baht in 1983 and 752 million Baht in 1984. In 1985 (Oct. 1984 to Sept. 1985), 895 million Baht has been allocated, sharing 15% of 6,006 million Baht of the BMA budget. Within the budget for drainage and sewerage, majority of the portion is allocated to DDS while the rest is allocated to the district offices for their own flood protection measures. Table 11.2 shows breakdown of DDS budget, indicating the sharp increase in flood protection-related expenses. From the budget figures, it can be said that BMA pays keen attention to flood protection and drainage activities, which are being handled at DDS level and also at the district office level.

### 11.1.2 Financial Plan

The construction cost of 6,280 million Baht for the proposed "priority facilities" has been estimated for Master Plan. The three stages in the implementation schedule are also given in order to seek a realistic and financially sound execution of the project under financial constraint.

## Table 11.1 BMA Annual Budget (1982 – 1984)

| Revenue | 1982 (2525) ฿ mill | % | 1983 (2526) ฿ mill | % | 1984 (2527) ฿ mill | % |
|---|---|---|---|---|---|---|
| 1. Tax Revenue | 3,224.87 | 68.3 | 3,266.00 | 69.8 | 3,732.00 | 68.3 |
| (BMA Local Taxes) | (616.13) | (13.1) | (656.50) | (14.0) | (721.50) | (13.2) |
| (Shared Taxes) | (2,608.74) | (55.2) | (2,609.50) | (59.8) | (3,010.50) | (55.1) |
| 2. Fee for Licensing & Permits | 49.94 | 1.0 | 100.17 | 2.1 | 105.93 | 1.9 |
| 3. BMA Property Revenue | 252.01 | 5.3 | 183.30 | 3.9 | 224.68 | 0.4 |
| 4. Business Revenue | 8.90 | 0.2 | 8.90 | 0.2 | 10.30 | 0.2 |
| 5. Others | 78.55 | 1.7 | 197.24 | 4.2 | 84.42 | 0.8 |
| Sub Total | 3,660.28 | 77.6 | 3,755.62 | 80.3 | 4,157.33 | 76.1 |
| 6. Central Government Subsidy | 1,059.62 | 22.4 | 921.20 | 19.7 | 1,306.40 | 23.9 |
| Total | 4,719.91 | 100.0 | 4,676.82 | 100.0 | 5,463.73 | 100.0 |

| Expenditure | 1982 (2525) ฿ mill | % | 1983 (2526) ฿ mill | % | 1984 (2527) ฿ mill | % |
|---|---|---|---|---|---|---|
| 1. Public Work | 952.15 | 22.2 | 909.98 | 19.0 | 1,216.13 | 21.5 |
| 2. Education | 912.26 | 21.3 | 887.03 | 18.5 | 936.12 | 16.6 |
| 3. Project Expenditure | 738.11 | 17.3 | 624.38 | 13.0 | 598.16 | 10.6 |
| 4. General Administration | 519.48 | 12.1 | 636.23 | 13.3 | 611.22 | 10.8 |
| 5. Medical & Sanitation | 394.29 | 9.2 | 487.09 | 10.2 | 611.09 | 10.8 |
| 6. Cleaning | 308.19 | 7.2 | 618.44 | 12.9 | 569.67 | 10.1 |
| 7. Drainage & Sewerage* | 277.21 | 6.5 | 387.49 | 8.1 | 752.04 | 13.3 |
| 8. Social Welfare | 116.60 | 2.7 | 122.55 | 2.6 | 167.13 | 2.9 |
| 9. Loan Repayment | 7.32 | 0.2 | 3.63 | 0.1 | 2.17 | 0.04 |
| 10. Commerce | 55.46 | 1.3 | 114.97 | 2.4 | 183.82 | 3.3 |
| Total | 4,281.07 | 100.0 | 4,791.79 | 100.0 | 5,647.55 | 100.0 |

* This includs budget for DDS and drainage budget for District offices

Source: BMA Document

## Table 11.2 DDS Annual Budget (1982 – 1984)

(฿ 1,000)

| | 1982 (2525) | 1983 (2526) | 1984 (2527) |
|---|---|---|---|
| A. General Administration | | | |
| 1. Secretary | 3,372 | 4,099 | 4,536 |
| 2. Technical Administration | 3,282 | 3,982 | 4,605 |
| B. Drainage and Sewerage | | | |
| 1. Drainage Control | | 134,826 | 165,866 |
| 2. Sewer Cleaning | 166,665 | 18,000 | 18,000 |
| 3. Klong Maintenance | | 62,201 | 100,995 |
| 4. Klong Improvement | 54,017 | 4,843 | 7,402 |
| 5. Project Study for Thombri | – | – | 1,500 |
| 6. Project for Reserving Temples | – | 8,300 | 20,000 |
| 7. Survey of Klong Network | – | 469 | – |
| 8. Waste Water Treatment | 8,449 | 7,908 | 5,051 |
| 9. City Core Flood Protection Project | | | 31,622 |
| 10. Suburban Flood Protection Project | 41,420 | 136,673 | 61,000 |
| DDS Total Budget | 277,205 | 381,297 | 420,578 |

Source : BMA Document

**Construction Cost by Stages**

| Stages | I | II | III | Total |
|---|---|---|---|---|
| Year | 1987<br>1991 | 1992<br>1996 | 1997<br>2000 | |
| Cost (Million Baht) | 2,560 | 1,830 | 1,890 | 6,280 |

The following conditions are assumed for the financial plan.

Expenditure (cash-outflow) side:

(1) Construction cost is spread evenly for each year during the construction period.

(2) Operation and Maintenance (O/M) cost is assumed as 3% of the cumulative construction cost.

(3) Loan repayment starts after the construction and its period is for 20 years, with the same amount due every year.

(4) Interest of the loan is 3.5% per year.

Revenue (cash-inflow) side:

(1) 40% of the constructioncost is foreign currency, covered by foreign loan during the construction period.

(2) 30% of the construction cost (1/2 of local currency portion) is covered by subsidy by the central government.

(3) The remaining 30% of the construction cost is covered by BMA budget.

The cash-flow schedule for 30 years (project life) from 1987 until 2016 is shown on Table 11.3.

In the first stage, BMA has to finance ฿154 million to ฿244 million during the construction period (5 years), after which the cost for loan repayment, interest and O/M costs from 164 to 130 million Baht. At year 2012, after the loan repayment, BMA pays for O/M cost of 77 million Baht every year. The stage II starts from 1992 with smaller yearly construction cost than that of stage I. For stage III,

## Table 11.3 Cash Flow Table

CONSTRUCTION STAGE 1 COST 2560 — INTEREST RATE 3.5 %

| YEAR | | 1987 – | 1991 | 1992 – | 1996 | 1997 – | 2000 | 2001 – | 2006 | 2007 – | 2011 | 2012 – | 2016 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CASH IN | BMA | 154 – | 244 | 164 – | 157 | 155 – | 150 | 148 – | 139 | 137 – | 130 | 77 – | 77 | 4314 |
| | SUB | 154 – | 154 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 768 |
| | LOAN | 205 – | 205 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 1024 |
| | TOTAL | 512 – | 602 | 164 – | 157 | 155 – | 150 | 148 – | 139 | 137 – | 130 | 77 – | 77 | 6106 |
| CASH OUT | CON | 512 – | 512 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 2560 |
| | O/M | 0 – | 61 | 77 – | 77 | 77 – | 77 | 77 – | 77 | 77 – | 77 | 77 – | 77 | 2074 |
| | LOAN | 0 – | 0 | 51 – | 51 | 51 – | 51 | 51 – | 51 | 51 – | 51 | 0 – | 0 | 1024 |
| | INT | 0 – | 29 | 36 – | 29 | 27 – | 22 | 20 – | 11 | 9 – | 2 | -0 – | -0 | 448 |
| | TOTAL | 512 – | 602 | 164 – | 157 | 155 – | 150 | 148 – | 139 | 137 – | 130 | 77 – | 77 | 6106 |

CONSTRUCTION STAGE 2 COST 1830 — INTEREST RATE 3.5 %

| YEAR | | 1987 – | 1991 | 1992 – | 1996 | 1997 – | 2000 | 2001 – | 2006 | 2007 – | 2011 | 2012 – | 2016 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CASH IN | BMA | 0 – | 0 | 110 – | 174 | 117 – | 113 | 112 – | 106 | 104 – | 99 | 98 – | 93 | 2009 |
| | SUB | 0 – | 0 | 110 – | 110 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 549 |
| | LOAN | 0 – | 0 | 146 – | 146 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 732 |
| | TOTAL | 0 – | 0 | 366 – | 430 | 117 – | 113 | 112 – | 106 | 104 – | 99 | 98 – | 93 | 4090 |
| CASH OUT | CON | 0 – | 0 | 366 – | 366 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 1830 |
| | O/M | 0 – | 0 | 0 – | 44 | 55 – | 55 | 55 – | 55 | 55 – | 55 | 55 – | 55 | 1208 |
| | LOAN | 0 – | 0 | 0 – | 0 | 37 – | 37 | 37 – | 37 | 37 – | 37 | 37 – | 37 | 732 |
| | INT | 0 – | 0 | 0 – | 20 | 26 – | 22 | 20 – | 14 | 13 – | 8 | 6 – | 1 | 320 |
| | TOTAL | 0 – | 0 | 366 – | 430 | 117 – | 113 | 112 – | 106 | 104 – | 99 | 98 – | 93 | 4090 |

CONSTRUCTION STAGE 3 COST 1890 — INTEREST RATE 3.5 %

| YEAR | | 1987 – | 1991 | 1992 – | 1996 | 1997 – | 2000 | 2001 – | 2006 | 2007 – | 2011 | 2012 – | 2016 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CASH IN | BMA | 0 – | 0 | 0 – | 0 | 142 – | 284 | 121 – | 114 | 113 – | 108 | 106 – | 101 | 2468 |
| | SUB | 0 – | 0 | 0 – | 0 | 142 – | 142 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 567 |
| | LOAN | 0 – | 0 | 0 – | 0 | 189 – | 189 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 756 |
| | TOTAL | 0 – | 0 | 0 – | 0 | 473 – | 535 | 121 – | 114 | 113 – | 108 | 106 – | 101 | 3791 |
| CASH OUT | CON | 0 – | 0 | 0 – | 0 | 473 – | 473 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 1890 |
| | O/M | 0 – | 0 | 0 – | 0 | 0 – | 43 | 57 – | 57 | 57 – | 57 | 57 – | 57 | 992 |
| | LOAN | 0 – | 0 | 0 – | 0 | 0 – | 0 | 38 – | 38 | 38 – | 38 | 38 – | 38 | 605 |
| | INT | 0 – | 0 | 0 – | 0 | 0 – | 20 | 26 – | 20 | 19 – | 13 | 12 – | 7 | 304 |
| | TOTAL | 0 – | 0 | 0 – | 0 | 473 – | 535 | 121 – | 114 | 113 – | 108 | 106 – | 101 | 3791 |

TOTAL COST 6200 — INTEREST RATE 3.5 %

| YEAR | | 1987 – | 1991 | 1992 – | 1996 | 1997 – | 2000 | 2001 – | 2006 | 2007 – | 2011 | 2012 – | 2016 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CASH IN | BMA | 154 – | 244 | 274 – | 331 | 414 – | 467 | 381 – | 359 | 354 – | 337 | 281 – | 271 | 9591 |
| | SUB | 154 – | 154 | 110 – | 110 | 142 – | 142 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 1884 |
| | LOAN | 205 – | 205 | 146 – | 146 | 189 – | 189 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 2512 |
| | TOTAL | 512 – | 602 | 530 – | 587 | 745 – | 798 | 381 – | 359 | 354 – | 337 | 281 – | 271 | 13987 |
| CASH OUT | CON | 512 – | 512 | 366 – | 366 | 473 – | 473 | 0 – | 0 | 0 – | 0 | 0 – | 0 | 6200 |
| | O/M | 0 – | 61 | 77 – | 121 | 132 – | 174 | 188 – | 188 | 188 – | 188 | 188 – | 188 | 4274 |
| | LOAN | 0 – | 0 | 51 – | 51 | 88 – | 88 | 126 – | 126 | 126 – | 126 | 74 – | 74 | 2341 |
| | INT | 0 – | 29 | 36 – | 49 | 53 – | 63 | 67 – | 45 | 40 – | 23 | 18 – | 8 | 1173 |
| | TOTAL | 512 – | 602 | 530 – | 587 | 745 – | 798 | 381 – | 359 | 354 – | 337 | 281 – | 271 | 13987 |

although the cost is the same as stage II, since the construction period is four years, its yearly cost outlay is slightly more than that of stage II.

The total financial burden of BMA for these three stages starts from ฿154 million in 1987 to its peak of ฿67 million, then gradually decreases from ฿381 million in 2001 to ฿271 million in 2016 while it takes five more years to completely pay back the borrowing (Fig. 11.2).

A difference in interest rate of foreign borrowing alters financial burden for BMA, the ratio of total interest amount to the total BMA payments in 30 years are:

| Interest rate | Ratio of interest cost to total BMA payment |
|---|---|
| 3.5% | 11% |
| 6.0% | 18% |
| 10.0% | 27% |

### 11.1.3 Increasing Financial Resources of BMA

Although the budget for drainage in BMA has been increased greatly, allocation of extra funds for this project might be difficult under the current ordinary financial resources of BMA. Finding a new financial source for this project is therefore necessary, and the possibilities for this are given below.

1) Increasing the Current Tax

"House and Land" tax and "Land Development" tax are local taxes based on property valuation. The owners of land and property are beneficiaries of the flood protection project in Bangkok, both directly and indirectly. If the current tax revenue is increased from 10% to 20% by adjusting property valuation and increasing collection efficiency, 100 to 200 million Baht per year will be available on the assumption that 25% of this increase is to be allocated for this project.

2) Surcharge to developers in the Master Plan Area

Since the Master Plan Area includes vacant areas to be developed in the future, resulting in run-off discharge increase collecting a surcharge from developers of residential construction can be an effective tool. In Japan, a similar system is being adopted in Yokohama city to collect funds from residential developers.

If ฿1,000 per new resident can be collected from developers, a total of 1,500 million Baht will be available for 1.5 million new entrants are expected by year 2,000.

3) Urban Development Tax

Urban Development Tax excised in Japan is used for the construction of various urban infrastructure, including roads and drainage facilities. This tax is levied in the urban and suburban areas. The land owners are tax payers, since land value increases as urban infrastructure develops. If 2.5 – 5% tax on property is imposed, 100 million Baht/year will be available.

4) Formation of Residents' Cooperative

For the construction of main drain pipes, a cooperative can be formed by residents in an unit district where they share the drainage facility. The government authority is to announce that if residents in one district agree to pay a certain cost for tertiary drain construction, a subsidy will be available at some rate (e.g. 50%). In this way the budgetary burden on the government will become less. According to the damage survey, residents in the flood-prone area are willing to pay around ฿1,000 per house for flood prevention. This means part of the cost can be covered directly by beneficiaries if they are convinced that flood conditions will be mitigated by this program. (Since main drain pipe construction is mostly beyond stage III, this idea is not incorporated in the financial plan for stage I, II and III.

In developing those financial resources, the following adverse impacts are anticipated, and it requires further study for an effective rate to be imposed.

(a) Inflationary effect

An increase in tax rate and new tax on real estate would increase the rent of houses and buildings which makes the living cost in Bangkok higher.

(b) Uneven development

If the developers' surcharge is too high compared with locational advantage of the Master Plan Area, urbanization speed will become slower than other areas.

c) Cooperative Formation

Since formation of residents' cooperative is based on "willingness" of residents, some areas might be left without drainage pipes because the residents are unable to form cooperatives for various reasons. Some other measures have to be considered in this case.

### 11.1.4 Schedule of Financial Resources Allocation

Table 11.4 indicates revenue and expenditure flow of BMA under assumptions that the proposed financial resources in the previous section are available. There are three sources, tax increase, developers' surcharge and Urban Development Tax.

The tax increase is assumed that 100 million Baht, available for this project in 1987 will increase at 5% until year 2,000. This can be further increased if main drain pipe construction are expanded. For this calculation, however 2.5% increase is assumed after the construction period.

The Development Surcharge is imposed for developers during the implementation period. 107 million Baht per year is available from 1988 to 2001.

The Urban Development Tax might be realized after 5 years of Tax Increase. Its amount is about 1/2 of the local tax increase.

The project can be financed with these resources as is shown on the Table 11.4 and Fig. 11.2. In the year 2014, all the deficit is cleared out.

These figures further indicate that construction stages beyond year 2,000 can be financed by directing more funds to the project, thus the total cost of 11,000 million Baht can be financed if foreign loans and government subsidies are also available.

Although the above analysis takes a rather conservative approach, it also presents a "menu" that considering the difficulty in establishing new collection system, the administrators can alter the construction stages to be implemented. However, since the serious flood damage potential increases annually, the efforts to allocate these financial resources should be taken immediately.

### 11.1.5 Conclusion

How to finance flood protection projects under the tight budget of BMA has been in debate. After the 1983 flood, when an idea of "flood tax" to be levied on residents in flood-prone areas was proposed, the idea was strongly opposed by the residents.

Table 11.4 Revenue and Expenditure Flow for BMA

(million Baht)

| Year | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 |
|---|---|---|---|---|---|---|---|---|---|---|
| Revenue | | | | | | | | | | |
| (1) Tax Increase | 100 | 105 | 110 | 115 | 121 | 127 | 134 | 140 | 147 | 155 |
| (2) Dev. Surcharge | - | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 |
| (3) Urb. Dev. Tax | - | - | - | - | - | 64 | 67 | 70 | 74 | 78 |
| Total Revenue | 100 | 212 | 217 | 222 | 228 | 298 | 308 | 317 | 328 | 340 |
| Expenditure for BMA | 154 | 176 | 199 | 221 | 244 | 274 | 288 | 302 | 317 | 331 |
| Balance | -54 | 36 | 18 | 1 | -16 | 24 | 20 | 15 | 9 | 9 |
| Cum. Balance | -54 | -18 | 0 | 1 | -15 | 9 | 29 | 44 | 53 | 62 |
| Year | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
| Revenue | | | | | | | | | | |
| (1) Tax Increase | 162 | 171 | 179 | 188 | 194 | 199 | 205 | 212 | 218 | 224 |
| (2) Dev. Surcharge | 107 | 107 | 107 | 107 | 107 | - | - | - | - | - |
| (3) Urb. Dev. Tax | 81 | 86 | 90 | 94 | 97 | 100 | 103 | 106 | 109 | 112 |
| Total Revenue | 350 | 364 | 376 | 389 | 398 | 299 | 308 | 318 | 327 | 336 |
| Expenditure for BMA | 414 | 431 | 449 | 467 | 381 | 376 | 372 | 367 | 363 | 359 |
| Balance | -64 | -7 | -73 | -78 | 17 | -77 | -64 | -49 | -36 | -23 |
| Cum. Balance | -2 | -9 | -82 | -160 | -143 | -220 | -284 | -333 | -369 | -392 |
| Year | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
| Revenue | | | | | | | | | | |
| (1) Tax Increase | 231 | 238 | 245 | 253 | 260 | 268 | 276 | 284 | 293 | 302 |
| (2) Dev. Surcharge | - | - | - | - | - | - | - | - | - | - |
| (3) Urb. Dev. Tax | 116 | 119 | 123 | 127 | 130 | 134 | 138 | 142 | 147 | 151 |
| Total Revenue | 347 | 357 | 368 | 380 | 390 | 402 | 414 | 426 | 440 | 453 |
| Expenditure for BMA | 354 | 350 | 346 | 341 | 337 | 281 | 279 | 276 | 273 | 271 |
| Balance | -7 | 7 | 22 | 39 | 53 | 121 | 135 | 150 | 167 | 182 |
| Cum. Balance | -399 | -392 | -380 | -331 | -278 | -157 | -22 | 128 | 295 | 477 |

However, it is necessary to educate the public that the cost is an investment to maintain and increase the value of land and property, by preventing more serious damage which is anticipated in the future. The administrators have to find ways to collect funds from beneficiaries. This is not limited to flood protection facilities, but is common for any urban infrastructure development. In the Preliminary Study, it was indicated that the tax burden for Bangkok residents is comparatively low in comparison with that of other foreign countries.

It is recommended for BMA to increase its own financial autonomy, which will give strength to breaking through the financial constrains facing this project,

## 11.2 Project Evaluation

This section gives an evaluation of the economic viability for flood protection/ drainage project through the study of benefit cost analysis.

### 11.2.1 Economic Cost Estimates

The financial project cost explained in Chapter 9 was converted into economic cost by the following modification:

1) Import duties and domestic taxes are assumed to be 10 percent for the foreign portion and 5 percent for the local portion of the project cost.

2) Shadow exchange rate of 1.06 was applied to the foreign currency component and a shadow wage rate of 0.88 was applied to the wage of the unskilled labourer of the local currency component.

### 11.2.2 Projection of Flood Damages in 2000

Future damages in the year 2000 were estimated by the following methodology;

1) Private Sector

Damage was estimated under the concept of "Annual Average Flood Damage". The definition is as follows;

$$\overline{D} = \int_{Fo}^{\infty} Pr(F) \cdot D(F, Fo, S, Ls) \cdot dF$$

where,

$\bar{D}$ : Average annual flood damage

D : Flood damage

F : Rainfall

$F_0$ : Capacity of flood control facilities

S : Damage potential

Ls : Land subsidence

Pr(F) : Probability density function of F

2) Public Sector

1 Public Expenditure for Flood

The public expenditure for flood such as direct damage to the buildings and extra medical expenditure was assumed to be 10 percent of total flood damages according to past flood surveys.

2 Public Corporation

The amount of this damage is estimated according to the BFCD Project (City Core Project).

### 11.2.3 Calculation of Benefit

Since the benfit from the proposed project can be calculated as the difference between the amount of flood damage "without project" and that of "with project", the benefits for the following projects are estimated considering rainfall probability based on Fig. 11.3, that is,

1) Benefit from Green Belt Project
1,914 million Baht

2) Benefit from Green Belt + the Proposed Project
4,483 million Baht

3) Benefit from the Proposed Project
2,569 million Baht

### 11.2.4 Economic Analysis

The economic justification of the project is attempted by comparing the economic cost with economic benefit. The economic analysis was performed for three cases i.e. Green Belt Project, Green Belt + the Proposed Project, and the Proposed Project.

The results of the economic analysis is shown in Table 11.5.

Table 11.5 The Results of Economic Evaluation

| Project | N.P.V.* (฿ million) | B/C* | IRR (%) |
|---|---|---|---|
| Green Belt | 4,253 | 11.2 | 136.6 |
| Green Belt + Proposed Project | 5,261 | 3.3 | 105.5 |
| Proposed Project | 1,009 | 1.5 | 26.5 |

* N.P.V. (Net Present Value) and B/C (Benefit Cost Ratio) are calculated under the condition of opportunity cost of Capital at 16%.

Judging from the results, IRR of Green Belt Project is 137 percent and B/C is 11.2, which means that the most crucial facilities for flood protection were initially constructed at relatively low cost. Nevertheless, it is found that even after the completion of this project, a considerable amount of benefit exists by the proposed project, since IRR of the proposed project shows 26.5 percent. If the implemented Green Belt Project and the proposed project could be considered as one system, the IRR shows 105.5 percent (See Appendix Q).

### 11.2.5 Justification

In evaluating the feasibility for the project, it is necessary to evaluate the project not merely from the economic aspects based on the results of economic analysis, but also comprehensively from the technical, social, environmental, political, and financial aspects. There will be no doubt that the proposed project will produce high social and economic benefits such as upgrading daily life and also contribute towards a betterment in community standards. With the rising level of living standards, what once seemed tolerable has come to be recognized as being intolerable. If the flood protection project is not implemented, flooding will become more and more serious due to the anticipated land subsidence and population inflow into the Master Plan Area, the flood damage is expected to exceed the estimated damage in this study. It can be judged from this evidence that the project is a worthy investment.

### 11.2.6 Recommendation for Feasibility Study

A feasibility study for the implementation of stage I whould be conducted. The works to be included in the stage I are flood protection barriers and main drainage facilities to prevent overall flooding, and drainage facilities for high priority areas within the polders. Thus, it is expected that the first stage package will yield a highly efficient return on investment. It should be emphasized that the realization of the planned functions are contingent upon the administrators' efforts in controlling land-use, and in strengthening financial resources and other administrative measures taken by the Government and BMA.