THE KINGDOM OF THAILAND
BANGKOK METROPOLITAN ADMINISTRATION

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

MAIN REPORT

FEBRUARY, 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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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 feasibility Study on the Flood Protection/Drainage Project in Eastern Suburban-Bangkok. The study was entrusted to the Japan International Cooperation Agency (JICA).

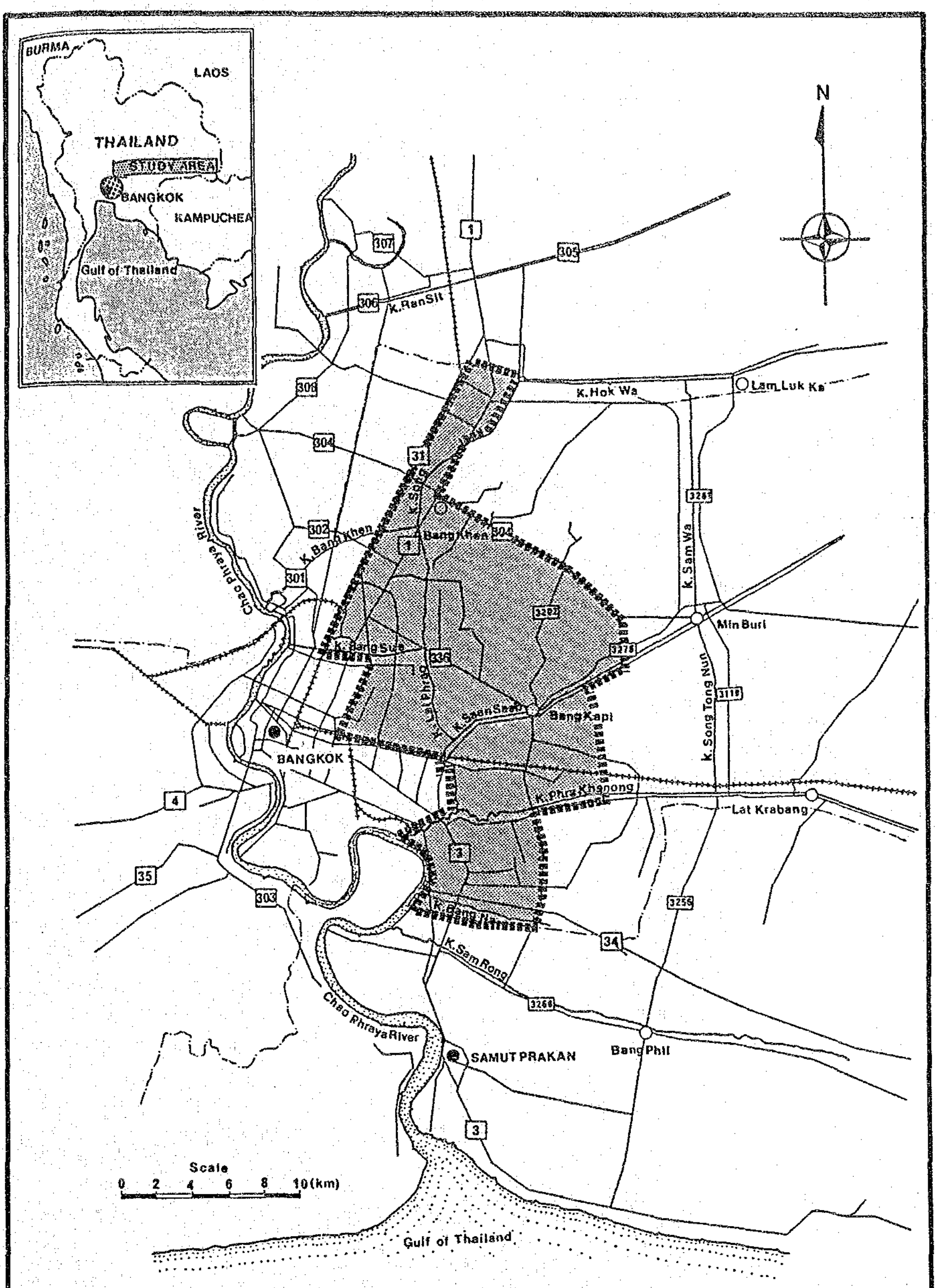
Based on the Master Plan Study completed in early 1985, the Feasibility Study was carried out by a study team headed by Mr. Fukagawa, Director of Pacific Consultants International, which was sent to Thailand from June 1985 to February 1986. The team exchanged views on the Project with the officials concerned 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.

February, 1986

Keisuke Arita
President
Japan International Cooperation Agency



STUDY AREA OF THE EASTERN SUBURBS
FLOOD PROTECTION AND DRAINAGE PROJECT

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2529B.E
1986A.D

SUMMARY

SUMMARY

1. Introduction

In response to the request, Japan International Cooperation Agency (JICA) undertook the preliminary and master plan studies for the flood protection/drainage project in eastern suburban Bangkok (1983 – 1985). In the preliminary study, the general concept for a comprehensive flood damage mitigation plan for an area of 501 km^2 in eastern suburban Bangkok was studied. In the master plan, structural and non-structural measures were established as the comprehensive permanent measures, targeting the year 2000, for the western half of the area (260 km^2).

Following the master plan study, a feasibility study has been carried out since June, 1985 on the first stage programme, as defined in the Master Plan, which has high priority in mitigating the effects of serious flooding. This study also presents the action plan for non-structural measures (Flood Plain Management).

2. Outline of Comprehensive Flood Damage Mitigation Plan

Past flood damage in Bangkok has been caused by natural physical conditions (heavy rainfall, tide, low flat plain) and also by the progress of urbanization and land subsidence.

Flood damage in an urbanizing area can not be mitigated only by structural measures which have very high construction costs. The introduction of flood plain management will reduce construction costs and the resulting financial burden. Thus, a comprehensive flood loss mitigation plan including non-structural measures is needed (See Fig. S.1).

On the occasion of the 1983 floods, urgent structural measures complying with the general concept recommended by the JICA preliminary study were carried out. Nevertheless, residual flooding problems will still remain for a large segment of the community. The progress of urbanization and land subsidence is aggravating the flooding situation. It is estimated that almost the same damage as the 1983 flood will occur in 2000 if no measures are undertaken. Therefore, the execution of a comprehensive flood damage mitigation plan is needed.

2.1 Structural Measures

The basic idea of the structural measures is to establish a polder system. The area is to be protected by polder dykes and gates against water inflow from outside and from the Chao Phraya River. Rainfall collected in the polder is to be discharged by drainage facilities installed inside the polder (See Fig. S.2).

The Eastern Suburbs covered by the Preliminary Study has been protected since 1984 by the Green Belt dyke. The western half of the study area is to be surrounded also by polder dykes and gates. Installation of pumping stations discharging storm water into the Chao Phraya River and the improvement of the main klongs leading to the pumping stations is necessary to alleviate overall flooding. On the other hand, heavy local flooding will be relieved by improvements to a large number of sub-klongs and main drains, and the installation of inner area pumps.

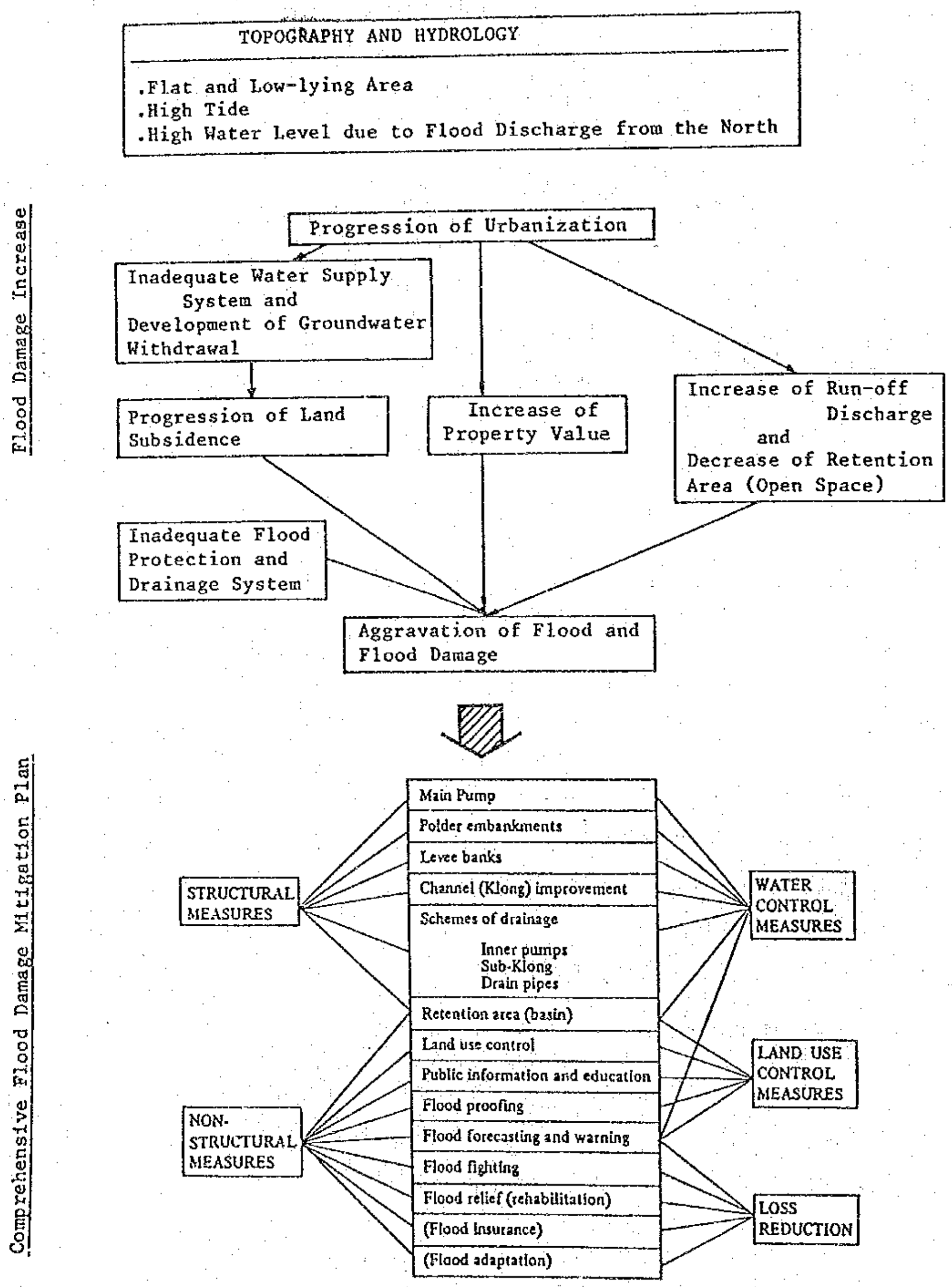


Fig. S.1 Comprehensive Flood Damage Mitigation Plan (1)

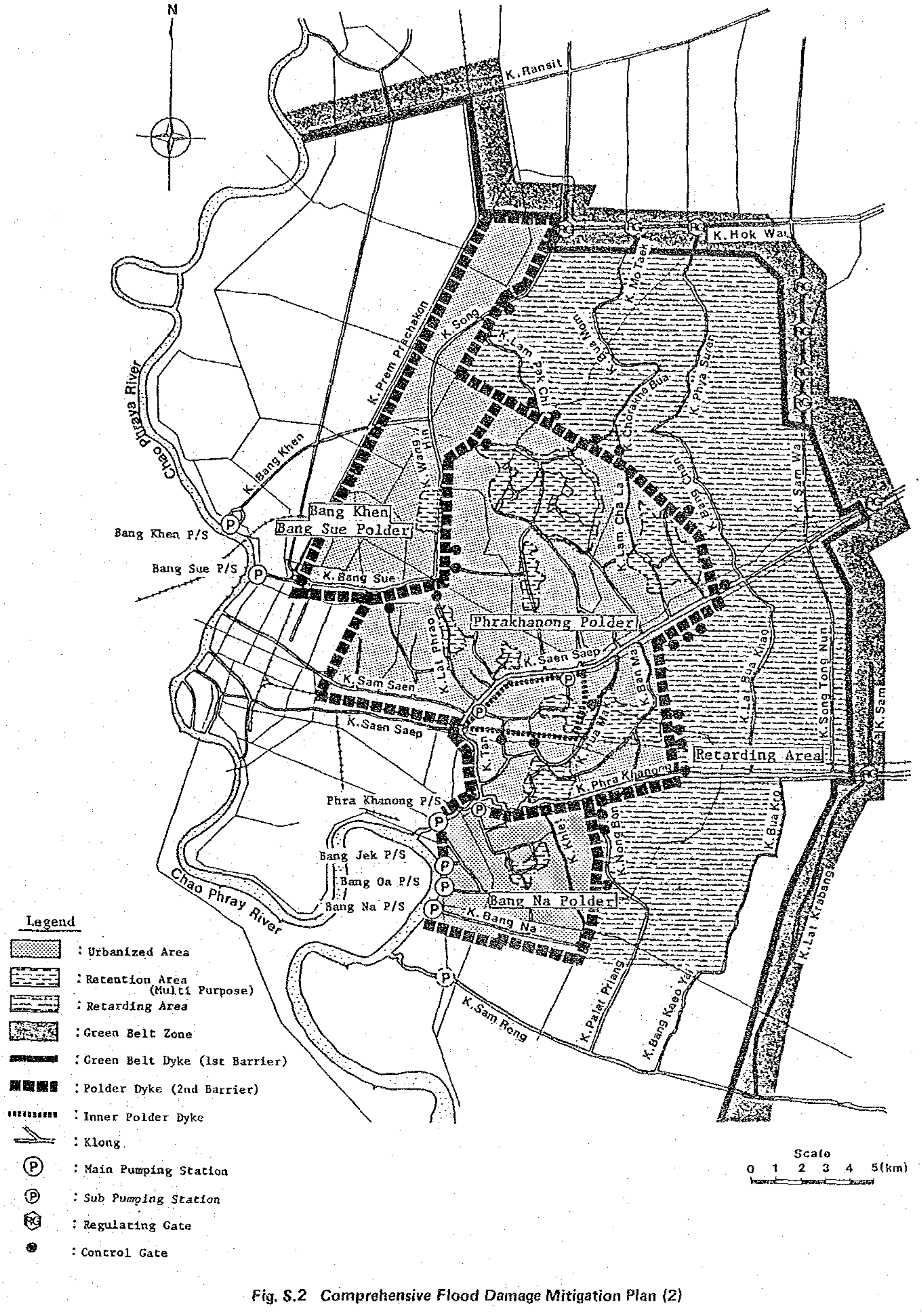


Fig. S.2 Comprehensive Flood Damage Mitigation Plan (2)

2.2 Non-Structural Measures

The basic idea of non-structural measures is to modify the susceptibility of damage to property and activity in the flood-prone area and to maintain the natural rainwater storage function in the area in order to lessen peak discharge into the klongs.

The Green Belt Area has already been designated as an agricultural conservation area in order not to increase future flood damage. Similarly, the eastern half of the preliminary study area enclosed by the Green Belt and some parts of the master plan areas are also designated as rainwater retarding areas.

The master plan area is in principle designated as a flood protection area. However, the increasing urbanized area (82 km^2) between 1980 and 2000 should be allocated to low risk flood-prone areas. Then, the remaining non-urbanized areas (44 km^2) in the year 2000 can be utilized as the natural storm-water retention areas, reducing the investment in structural measures.

2.3 Hydraulic and Environmental Impact

Flood damage is reduced to a great extent by the proposed structural measures. However, it will raise the flood level in neighboring areas and the Chao Phraya River, and will deteriorate water quality in the Project Area. Control of the discharge to the Chao Phraya River and introduction of fresh water from the outer areas will improve the flooding condition in the outer areas to some extent. The proper operation of facilities is a prerequisite condition for maintaining environmental conditions.

3. Results of the Feasibility Study

Examination is made of the feasibility of the selected facilities to alleviate overall flooding in the entire Study Area and also local flooding in high priority areas. An action plan for the implementation of the non-structural measures is also proposed.

3.1 Facilities, Project Cost and Implementation Schedule

Based on the first stage program of the Master Plan, field investigations and comparative studies on alternatives were made and final plan is formulated as shown in Fig. S.3.
The proposed facilities, costing Baht 2,655 million at 1985 prices are shown in Table S.1.

Table S.1 Proposed Facilities

Facility	Quantity
Dyke (Barrier)	5.1 km
Gate	4 places
Pumping Station with Gate	5 stations (36 m^3/s)
Klong Improvement	93 km
Main Drain Improvement	4 km
Flood Control Operation Centre	1 set

The project is to be scheduled for execution during the 6th five-year national plan period (1987–1991). The facilities to alleviate overall flooding such as dykes, gates, pumping stations, main klongs and flood control operation centre are to be constructed in 1988 and 1989 following detailed design in 1987. Sub-klongs and drains are improved in 1990 and 1991.

3.2 Flood Plain Management

The effective measures are to establish a zoning system (see Fig. S.4) according to flood risk of each area through city planning. Considering the difficulty in enforcing city planning now under preparation and the increasing flood damage each year during the preparation, the necessary measures to be initiated are shown in Table S.2. These measures are classified into three stages; short-term, intermediate-term and long-term action plans. To begin with, the sub-committee for non-structural measures is to be mobilized, because flood plain management needs strong leadership and public support. Then, the publication of observed flooding, construction of retention ponds etc. are to be made.

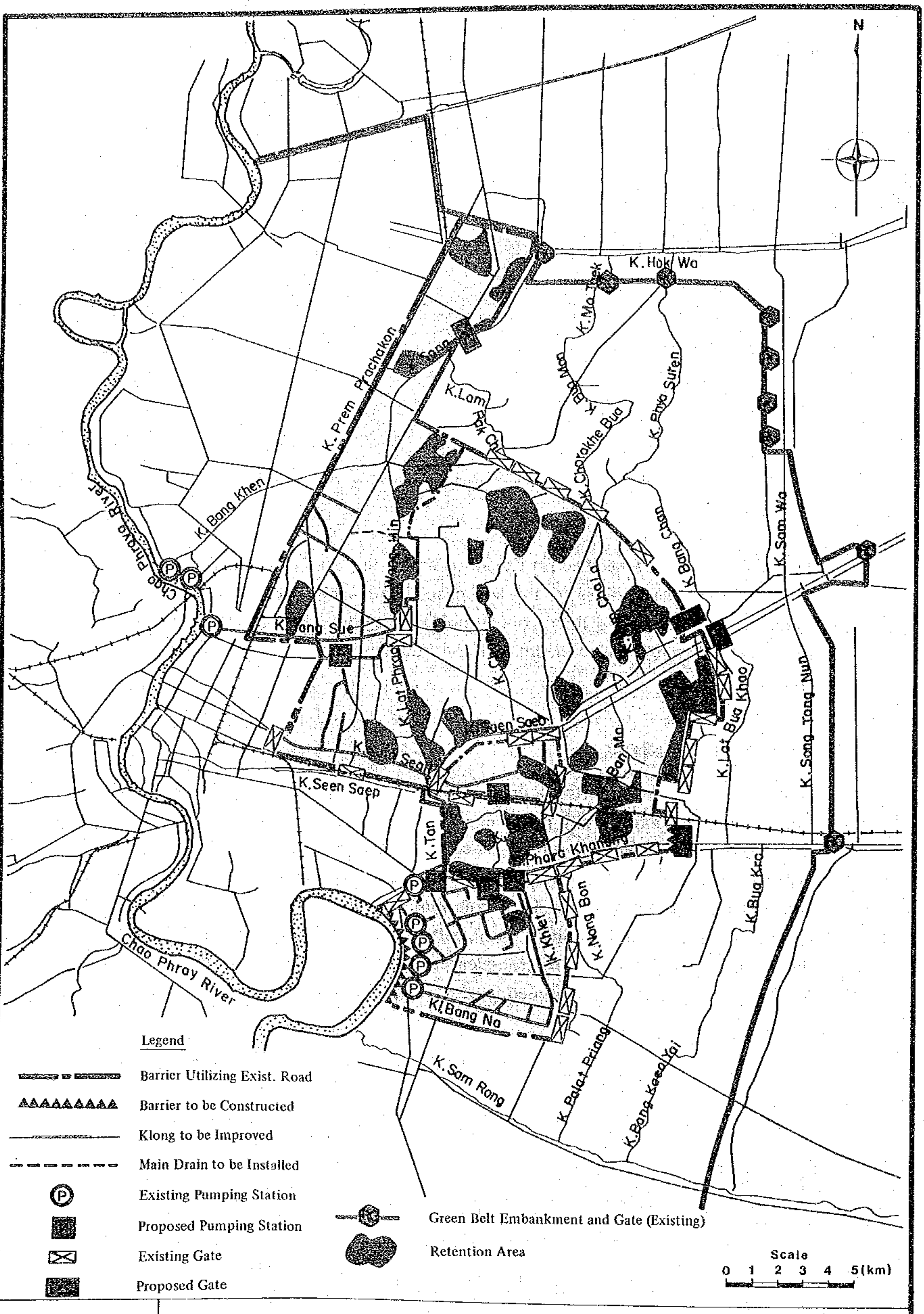


Fig. S.3 . PROPOSED FACILITIES IN THE FEASIBILITY STUDY

FEASIBILITY STUDY ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

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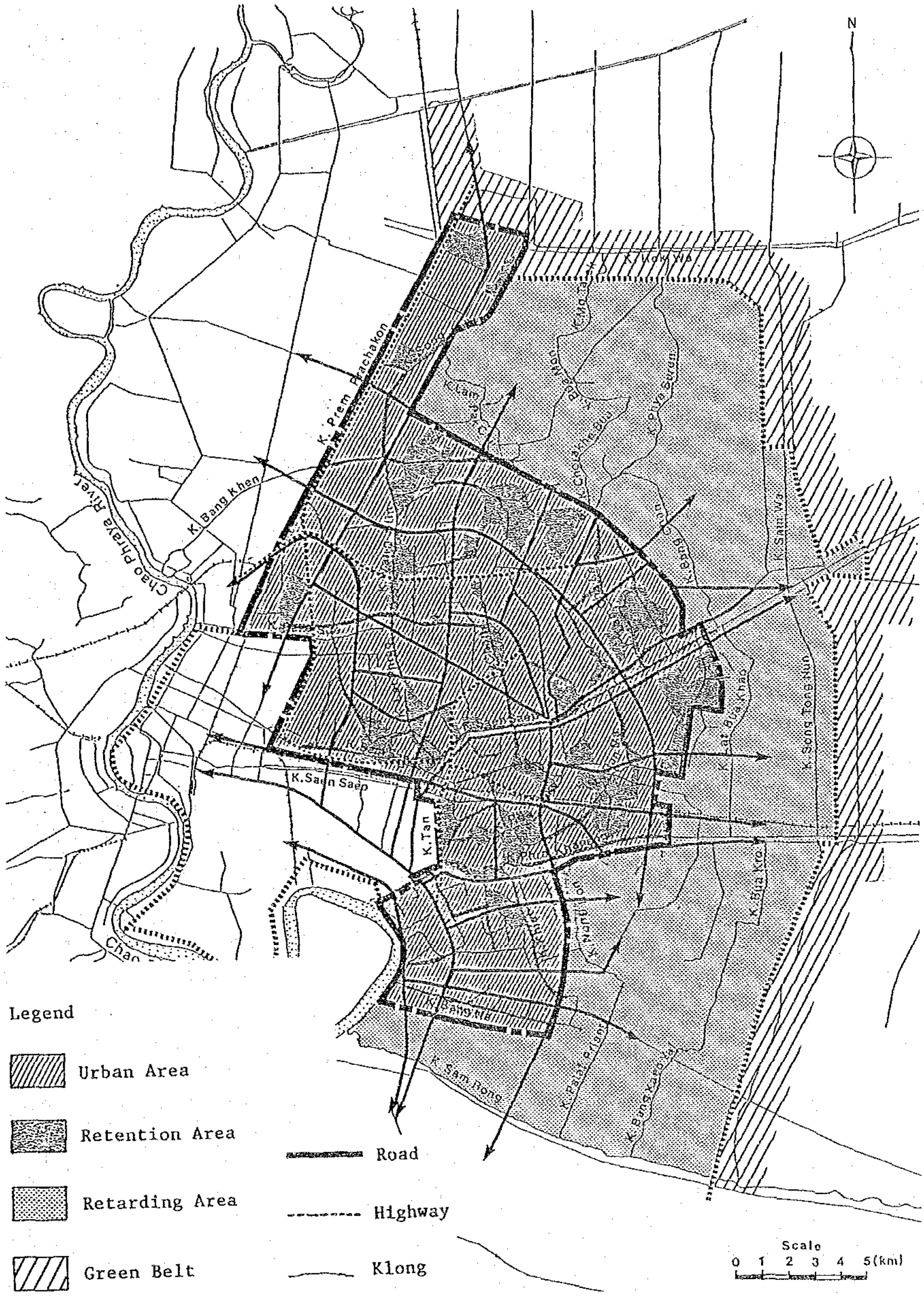

Fig. S.4 Proposed Zoning

Table S.2 Action Plan for Non-Structural Measures

Authority in Charge	Flood Protection Committee (Overall Flood Control)	Flood Control & Operation Authorities	Regional City Planning Authorities
Current Situation	* Sub-Committee	* Construction of Green Belt Dyke	* Green Belt area as open space (retarding area)
Short Term Action Plan	* Mobilization of sub-committee * Recognition of importance of flood plain management between relating agencies * Public education of flood plain management	* Publicizing observed flood area * Establishment of flood control operation system	* Projection of population and urbanized area
Inter-mediate Term Action Plan	* Inter-governmental recognition of zoning system in accordance with flood risk * Publicizing flood risk map	* Collection of flood data * Preparation of flood risk map * Improvement of flood control operation system	* Approval or dis-approval of development applications based on building codes * Construction of roads and water supply, compatible with zoning system * Guidance for prohibition of land reclamation in retarding area * Multi-purpose retention pond in the park
Long Term Action Plan	* Zoning regulation * Property tax adjust-ment, reflecting zoning * Surcharge to developers		* Approval or dis-approval of development applica-tions based on zoning regulation

3.3 Flood Control Operation Centre

The proposed facilities rely on rainwater storage in the klongs and retention areas. Further, the proposed facilities contribute not only to flood alleviation in the eastern paddy and Green Belt areas but will also raise the water level of the Chao Phraya river if facilities are operated. Besides, klong flushing will become necessary for improvement of klong water quality. For these operations, a flood control operation centre which supervises the hydrological conditions in the entire study areas and neighboring areas, are proposed.

Fifteen monitoring stations are proposed as a first step of the control centre organization.

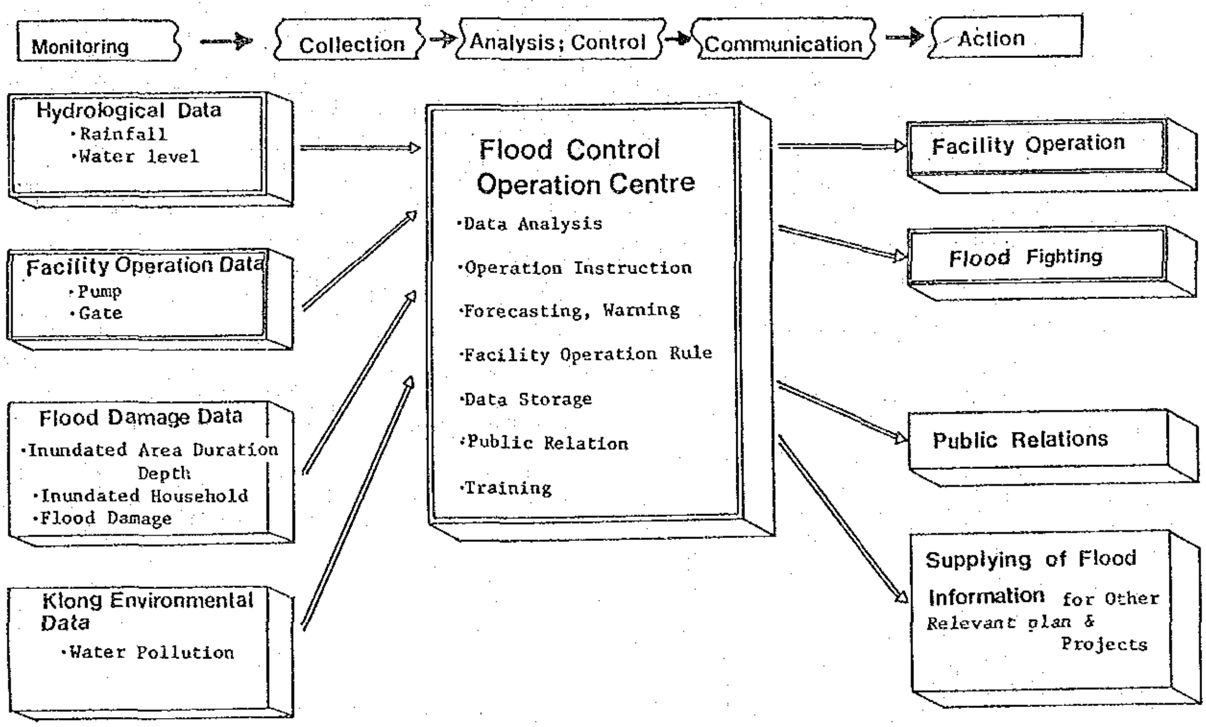

Fig. S.5 Concept of Flood Control Operation System

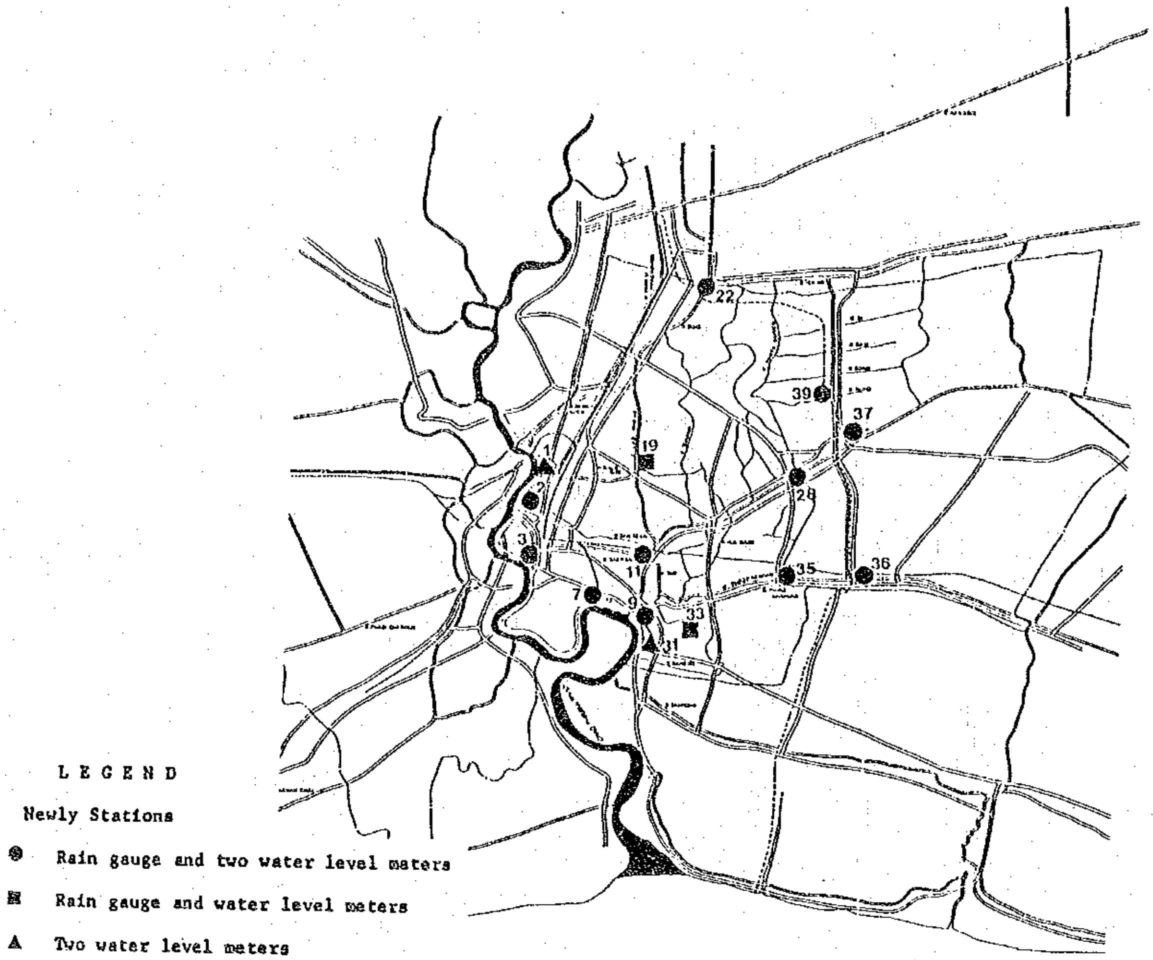

Fig. S.6 Proposed 15 Monitoring Stations

3.4 Organization

The organization is examined within the current framework where the present Flood Protection Committee is the co-ordinating body and the DDS is the executing body. For the execution of the project, three items must be set up/strengthened (Fig. S.7),

(1) Strengthening of the DDS for the construction, supervision, and operation/maintenance of the facilities;

(2) The mobilization of a "sub-committee on supporting activities" for flood plain management;

(3) The establishment of a flood control operation centre.

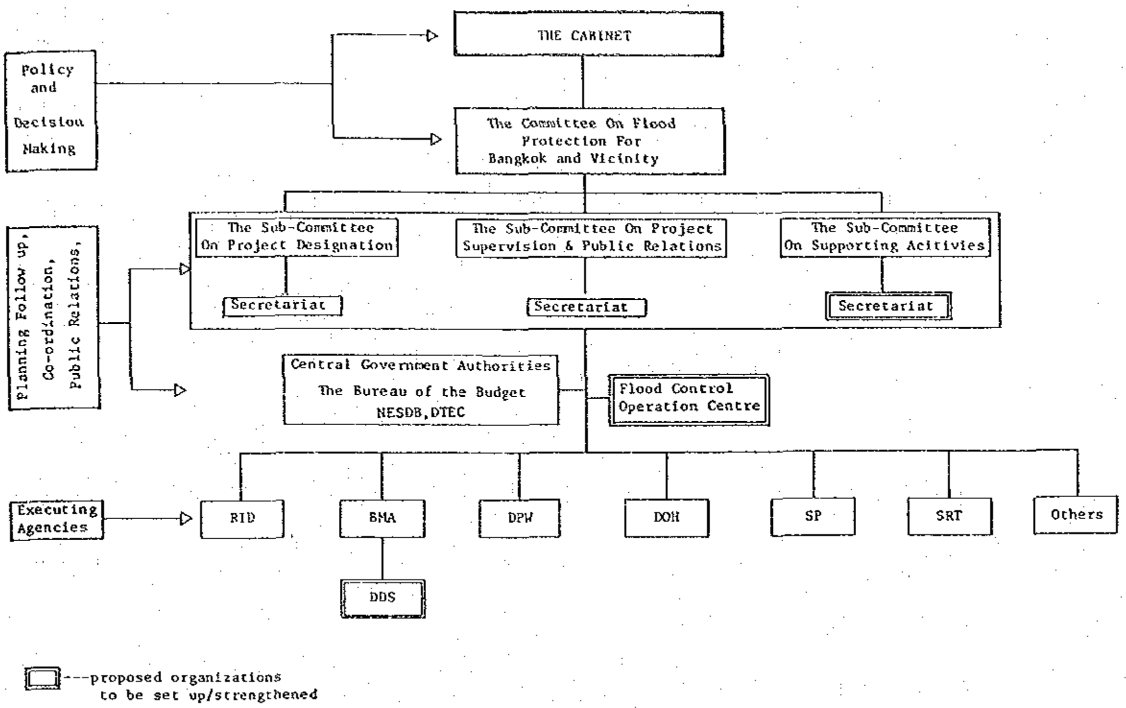

Fig. S.7 Proposed Organizations

3.5 Financial Aspect

The project cost is estimated at Baht 2,655 million at 1985 prices. Out of it, the foreign currency component of Baht 1,261 million (47.5%) is to be financed by foreign loans and the local currency component of Baht 1,394 million is proposed to be equally split between the BMA and the Central Government, while the debt service of the loan and the operation and maintenance cost is covered by the BMA.

BMA's financial requirement of about Baht 200 million per year during 1988 – 1991, will be covered by one fourth of the revenues to be generated by the natural increase in tax base and the appropriation of existing local taxes.

To recover repayment and O/M and replacement costs from 1992 onwards, between one sixth and one ninth of the revenue of existing local taxes will be allotted to the Project. These are shown graphically in Figure S.8.

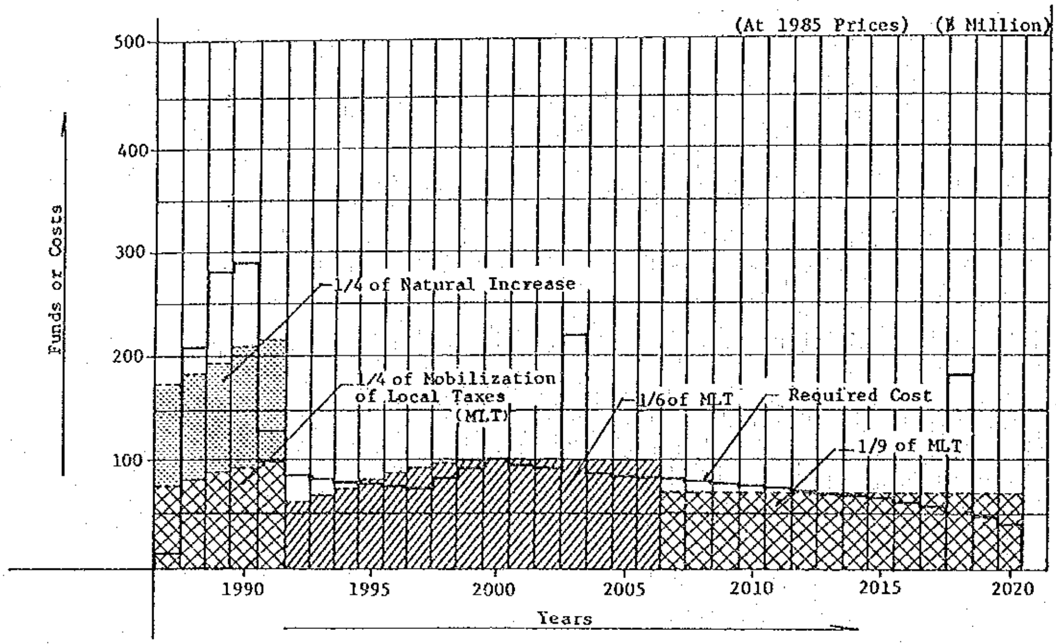

Fig. S.8 Project Cost and Financial Source

Annual damage and loss per capita are estimated at Baht 495 and project cost per capta is calculated at Baht 54.5 at the 1985 price.

3.6 Economic Evaluation

From the result of the economic analysis, economic internal rate of return, net present worth, benefit cost ratio are:

Economic rate of return	20.2%
Net present worth	Baht 425 million
Benefit cost ratio	1.24

Annual benefit and economic cost per capita are calculated at Baht 24 and 19 respectively. (discounted at the rate of 16%).

4. Conclusion and Recommendations

There are various standpoints from which to judge the feasibility of the Project.

It is proved that the Project is economically feasible; the Project, from the standpoint of national economy is estimated to generate a benefit greater than the cost of the project implementation and operation/maintenance during the project life of 40 years.

Technically speaking, there is no problem or difficulty in implementing the Project.

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ABBREVIATIONS

AIT	Asian Institute of Technology
฿	Baht (Thai Currency); US$ = approximately/฿ 26.50
BFCD	Bangkok Flood Control and Drainage Project (City Core Project)
BM	Bench Mark
BMA	Bangkok Metropolitan Administration
CDM	Camp Dresser & McKee
cm	centimetres
CMD	cubic metres per day
CMS	cubic metres per second
DDS	Department of Drainage and Sewerage, BMA
DIV	Division
DOH	Department of Highway
Fig.	Figure
GDP	Gross Domestic Product
GRP	Gross Regional Product
DTCP	Department of Town and Country Planning
DTEC	Department of Technical and Economic Cooperation
EGAT	Electricity Generating Authority of Thailand
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	kilometres
m	metres
m^2	square metres
m^3	cubic metres
m^3/s	cubic metres per second
mm	millimetres
MCMD	million cubic metres 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
OECF	Overseas Economic Cooperation Fund (of Japan)
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
TOT	Telephone Organization of Thailand
¥	Yen (Japanese Currency); US$ = approximately ¥200.0

MAIN REPORT

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, 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 JICA Study Team initiated the Preliminary Study on Flood Protection/Drainage Project in Eastern Suburban Bangkok (501 km^2) in early 1983 which conceptualised a comprehensive flood damage mitigation plan, consisting of structural and non-structural measures. The entire area is enclosed by polder dykes and is, further, divided into two areas. The eastern part (241 km^2) is to be a retarding area in order not to increase future flood damage while the western part (260 km^2) is to be covered with drainage facilities in order to alleviate current and future flood damage. The western part is selected as the Master Plan Area.

The Master Plan Study was subsequently conducted from May 1984 to March 1985 which established a comprehensive flood damage mitigation plan targeting the year 2000. Retention areas are proposed in high risk flood-prone areas to retain excess rainwater and, based on this, drainage facilities are proposed, costing Baht 6,280 million (1984 prices). Their construction is planned in three stages to be completed by the year 2000. The first stage program covers facilities to reduce overall areal flood damage and heavy local damage in high priority areas and is selected as the objective work for the Feasibility Study.

The Feasibility Study, conducted from June 1985 to February 1986, is the subject of this report.

1.2 Objective of the Study

The Feasibility Study examines the feasibility of the first stage programme from engineering, financial, institutional and economic aspects. Non-structural measures (flood plain management) and flood control operation system are also studied.

1.3 Composition of Report

This report consists of two volumes; Main Report and Appendix. Brief contents of the Main Report are:

Chapters 2 to 3 describe the basic information for the Study, i.e., description of the study area, and current flood control activities. In Chapter 4, the flood protection/drainage system is proposed. Based on this system, Chapter 5 presents the proposed facilities, estimated project cost and implementation schedule. In Chapters 6 and 7, the procedure of flood plain management and the flood control operation system are explained. Chapter 8 deals with organization and management aspect and Chapters 9 and 10 describe the financial study and economic evaluation respectively.

The Appendix contains the supporting data for the main report. Each appendix corresponds as follows;

Appendix	A	Topographical Survey	Chapter 2
	B	Existing Facility	Chapter 3
	C	Flood Protection/Drainage System	Chapter 4
	D	Facility Planning	Chapter 5
	E	Project Cost	Chapter 5
	F	Flood Plain Management	Chapter 6
	G	Flood Control Operation System	Chapter 7
	H	Institutional/Organizational Aspect	Chapter 8
	I	Financial Plan and Evaluation	Chapter 9
	J	Economic Evaluation	Chapter 10
	K	Environmental Impact Pertaining Water Quality	Chapter 4
	L	Evaluation of Hydraulic Impact to Surroundings	Chapter 4

1.4 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.

1) Members of JICA Advisory Committee

Mr. Tsunekazu Fukui (Chairman)	:	Ministry of Construction, Japan
Mr. Hideaki Oda	:	Ministry of Construction, Japan
Mr. Tadao Ishikawa	:	Okayama Prefectural Government, Japan
Dr. Katsuhide Yoshikawa	:	Ministry of Consctruction, Japan
Mr. Ken-ichi Ohsako	:	Tokyo Metropolitan Government, Japan
Mr. Yoichi Seki (Coordinator)	:	Japan International Cooperation Agency

2) DDS Advisory Committee

Mr. Anuchit	(Project Director)	: Deputy Director of DDS
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Dr. Ksemsan	(Secretary)	: Sanitary Engineering Specialist
Mr. Thammanat (Assistant Secretary)		: Section Chief, Waste Water Treatment Division

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Mr. Naomichi Ishibashi	(PCI)	: Economic/Financial Analysis
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CHAPTER 2 DESCRIPTION OF THE STUDY AREA

The characteristics of the Feasibility Study Area exert a decisive influence on the planning of the flood protection/drainage system. The general characteristics of the Area are described in this Chapter.

2.1 Economy

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

Due to the highly centralized nature of the Thai bureaucracy and also the geographical advantages, all the major central government facilities, industrial firms, trading companies, multinational corporations and international organizations are located in Bangkok. The Gross Regional Product (GRP) per capita in Bangkok was 2.4 times of that of the whole Kingdom in 1979. These socio-economic situations induced an influx of migrants from outer areas, resulting in a concentration of people and their economic activities in the city.

2.2 Urbanization

The urban area of Bangkok which was concentrated in a central Bangkok area of about 96 km^2 in 1958 had increased to about 350 km^2 in 1980 along the main roads causing the ribbon style development pattern as shown in Fig. 2.1. The main thrust of this expansion was in the eastern suburban Bangkok due to the growing network of main roads there. The population of the Bangkok Metropolis and the Study 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 Study Area is 2.5 million persons. And about 80 percent of the Study Area is expected to be urbanized.

Various problems related to the rapid urbanization are evident in inadequate infrastructures including flood protection and drainage facilities.

2.3 Natural Conditions

During the progress of urbanization, many paddy fields were reclaimed and converted into residential areas, resulting in an increase of the runoff discharge due to the decrease in the rain water retention function. Large amounts of ground water was extracted in the Study Area because a piped water supply could not keep pace with rapid urbanization. As a result, the land has been subsiding and lowering (See Fig. 2.3). Even now, the high water level of the Chao Phraya River is above ground surface in the Study Area during high tides and the flood season.

In the Bangkok area, the alluvial and marine deposits usually extend to an indeterminate depth of not less than 300 metres. The upper 15 to 20 meters are impervious clay. It is reported that land subsidence has occurred mainly in the alluvial and marine deposits.

Most of the lower Central Plain has already been fully developed as paddy fields with the aid of extensive canal networks by the Greater Chao Phraya Project (Fig. 2.4). In the area south of Ayutthaya, irrigation is by the natural storage of water and gravity drainage is difficult. If there is rainfall in the northern part of Thailand, much flood water is distributed through the extensive canal network, and if there is rainfall in the lower Central Plain, excess water floods in the Plain.

The high water discharge of the Chao Phraya river at Bang Sai located about 100 km upstream from the river mouth was reported as about 2,500 CMS in case of 1975 flood when much rain water overflowed at the lower stream.

During the wet season, from June to August rainfall becomes more intense but subsides in mid-November (See Fig. 2.5). The heaviest rainfall occurs in September and October when the monsoon passes through the country on a wide front.

The other important factor which generates flooding in the Study Area is the high tide in the Gulf of Thailand (Fig. 2.6). As the Chao Phraya River downstream from Bang Sai is flat in slope and only a 200 to 500 m wide, the lower stretch of the river is strongly affected by ocean tides. As a result, the rainwater in the Study Area to be discharged to the river is substantially retarded, causing a large volume of water to inundate the Area.

2.4 Recent Floods and Their Causes

Floods have occurred since early times due to the physical conditions of the site. However, the recent rapid urbanization coupled with land subsidence has induced severe flood damage almost every year since 1980.

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.

The causes of flood and flood damage in the Study Area are summarized below (see Fig. 4.2).

(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) Unsystematic character of the drainage system
(6) Run-off discharge increase due to urbanization

CHAPTER 3 CURRENT FLOOD CONTROL ACTIVITIES

Provision of infrastructure could not catch up to the rapid increase of population and progress of urbanization. In this chapter, existing flood control/drainage facilities and activities, relevant plans and projects are described

3.1 Past Flood

After the 1980 flooding, an area of about 800 km² including the Study Area (260 km²) was enclosed by a flood barrier including many cofferdams, in order to prevent inflow from the north and east areas of the city and the overflow from the Chao Phraya River, making the area one large outer polder. The inner polders were also provided to protect the high priority areas.

However, as these facilities were inadequate and of a temporary nature, severe water inflow occured in 1983, by overflowing the cofferdams and roads, and also from the Chao Phrays River. The 1983 flooding was recorded as the largest flood damage, Baht 6,597 million, since 1942. Particularly, flood damage in the Study Area was the severest, reaching about Baht 3,500 million.

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 from outer areas. Heavy rainfall continued to fall duing September to October, and the water level of the Chao Phraya River continued to rise. The discharge amount of water from the Area was restricted. As a result, the flood area expanded month by month, lasting from one to four months with a maximum flood depth in the urban area of 80 cm (See Figs. 3.1 to 3.2).

3.2 Existing Facilities

On the occasion of the 1983 floods, a "Committee of Flood Protection and Solution in Bangkok and its Vicinity" was set up in October, 1983. The Committee proposed and executed an urgent programme (See Fig. 3.3), based on the concept proposed in the Preliminary Study although the sizes of facilities have been determined arbitrarily rather than hydraulicly and hydrologically.

A permanent flood protection barrier, consisting of dykes and gates, now forms an outer polder and currently protects against in-flow flooding. Inside the outer polder some inner polders have been planned in the urban areas. These polders are the south, north and east polders (located in the Core Area) and Bang Na, Phra Khanong and Bang Khen-Bang Sue polders (in the Study Area). In addition, north Hua Mark (Ramkhambaeng) polder is constructed within Phra Khanong polder. Pump capacities in these polders have been increased by more than 6 times to 202 m³/s.

Existing drainage facilities are classified into primary, secondary and tertiary ones. This classification is related to their functions and not their size.

1) Primary drainage facilities generally consists of main klongs and main pumping stations, which are intended to transport and pump out rain water into the outer area.

2) Secondary drainage facilities consists of small pumping stations and small klongs which provide major feeders to the primaries; or which provide connections between primaries.

3) Tertiary drainage facilities; which lead to secondaries.

The primary, secondary and tertiary drainage facilities included in the Feasibility Study Area are shown in Table 3.1 and in Fig. 3.4.

Klongs 253 km long in total are gentle in slope and shallow. Further, their cross-sectional areas are small that runoff discharge is limited.

Table 3.1 Existing Drainage Facilities

Polder / Facility	Bang Khen - Bang Sue	Phra Khanong	Bang Na	Total
Pumping Station (Number, m^3/s)				
Primary	3 (57.0)	1 (105.0)	2 (33.0)	6 (195)
Secondary	4 (5.0)	7 (9.75)	3 (7.8)	14 (23)
Tertiary	3 (6.5)	5 (2.47)	6 (3.9)	14 (13)
Total	10 (68.5)	13 (117.22)	11 (44.7)	34 (231)
Klong (km)				
Primary (*)	31.0	32.0	9.5	72.5
Secondary	16.3	59.8	15.8	91.9
Tertiary	8.0	61.9	18.7	88.6
Total	55.3	153.7	44.0	253.0
Drain (km)				
Primary	-	-	-	-
Secondary	8.0	-	5.6	13.6
Tertiary	8.0	8.0	7.0	23.0
Total	16.0	8.0	12.6	36.6

Note: * Primary klongs in Phra Khanong polder i.e., Klongs Phra Khanong, Tan and Saen Saep are called trunk klongs in the Master Plan.

3.3 Necessity of Additional Measures

The implemented urgent measures could mitigate a serious flood i.e., long-duration, large-area flooding to short duration, small-area flooding (See Fig. 3.6).

However even after the execution of urgent measures there will still remain flood-prone areas especially in Hua Mark, Huay Kwang, Bang Kapi, Bang Na etc. (refer to Fig. 7.4). Besides, if the additional measures are not constructed, and as land subsidence and urganization are expected to continue, the flood situation may return hydrologically, to "before the urgent measures" status.

3.4 Relevant Plans and Projects

Coping with recent increased flood damage, the following plans and projects have been/are being studied (See Fig. 3.7);

1. City Core project
2. Eastern Suburban project
3. Samut Prakan project
4. Green Belt project

On the occation of 1983 flooding, various plans were initiated and are planned as follows;

5. Flood Routing and Control Alternative of Chao Phraya River
6. Improvement of Canals connecting Klong Tawee Wattana and Klong Khum Ratpinidjai
7. Integrated Flood Relief plan of the West Bank
8. Thonburi and Samut Prakan West project
9. Bangkok Flood Control Management project : ADB
10. Bangkok Flood Alleviation study : CIDA
11. Flood Control Management planning : USAID

Among the above-mentioned projects/plans, the following two projects are particularly related to the Eastern Suburban project and they are explained here (The others are explained in Master Plan);

(1) City Core Project

The city Core Project, covering the City Core area of 94 kg^2 is studied as the large scale permanent flood protection/drainage project. The construction cost is estimated in the order of Baht 3,400 million and the priority package of Baht 2,050 million is scheduled to be implemented in four years (1985 – 1988).

(2) Bangkok Flood Control Management Project

Bangkok Flood Control Management Project was studied based on the above-mentioned plans and projects by NESDB and ADB from Nomember, 1984 to May,

1985. Its objective is to provide advice to the Government on 1) formulation of a flood control strategy and a cordinated long-term plan for Bangkok and vicinity, including integrating the various technical proposals then being studied and 2) defining the most appropriate institutional and financial arrangements for effective implementation.

In this study, it was proposed that the flood control plan should be based on a larger area of comprehensive impact rather than the existing piecemeal approach and the illustrative example which would protect an area of 1,400 km^2 of Bangkok and its vicinity (See Fig. 3.8) and the construction cost is estimated as Baht 32,300 million (in January 1985 prices). Around 80% of the costs (Baht 25,800 million) is projected to fall within the BMA area. Of these costs, Baht 17,410 million is assumed to be implemented in the first 15 years including about Baht 7,000 million of Eastern Suburbs project proposed by the Master Plan.

The Sources of finance is assumed in such a way that 60% comes from loans (20% each from ADB, OECF and commercial banks) and the rest of 40% derives from the central/local government (BMA) grant/donation. The cost recovery mechanism is proposed as follows; 1) an annual charge on each property, to be introduced in line with the phased execution of flood control works, ranging Baht 1,000 to 1,770, and 2) the mobilization of local property tax, including removal of the exemption for owner occupiers.

Benefit in monetary terms is quantified to be around Baht 6,400 million annually and economic rate of return is estimated to be 20.5%.
Regarding institutional/organizational aspect, the ADB report proposes the new organization as the alternative to the present urgent committee/executing organizations. The urgent committee is to be redesignated as the National Flood Protection Board (NFPB), and Bangkok Flood Control Fund (BFCF) is an executive arm of the Board. The Board takes responsibility for objective, policies, strategies, priorities and target setting.

BFCF is responsible for ensuring flood protection achieved by the existing executive agencies and has overall responsible for planning, finance, project implementation and supervision, flood plain management etc. However, the operation and maintenance of flood control works are the responsibility of the present executive agencies.

CHAPTER 4 PROPOSED FLOOD PROTECTION AND DRAINAGE SYSTEM

Flood protection and drainage system is reviewed in the Feasibility Study, focusing on the facilities proposed by the Master Plan. As a result, the finalized flood protection and drainage system is proposed in sections 4.3 and 4.4. Prior to its presentation, the basic idea behind the proposed system and the proposed system of the Master Plan are presented in sections 4.1 and 4.2 respectively. Section 4.5 deals with the hydraulic and environmental assessments of the proposed system.

4.1 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 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 (See Table 4.1).

It is particularly effective for eastern suburban Bangkok since the area is on the verge of urbanization. The eastern suburbs are divided into two parts, i.e., western part (Master Plan and Feasibility Study Areas) and eastern part (Retarding Area) as shown in Fig. 4.1. The structural measures are to be executed in the former area and the non-structural measures in both areas. The various measures are indicated in Fig. 4.2.

Table 4.1 Concept of Comprehansive Flood Damage Mitigation Plan

Reason	Difficulty in Provision of Drainage Facilities	
	Structural Measures	Non-Structural Measures
	REDUCTION OF FLOOD	REDUCTION OF FLOOD DAMAGE
Objective	. To block inflow from outer areas	. To prohibit flood-prone area from urban development
	. To increase drainage capacity	. To guide urban development to flood-free area
Measures	. Polder dyke and gate	. Land use guidance according to flood risk
	. Pumping station	. Flood proofing
	. Klong and drain improvement	
	. Retention basin	. Retention area

4.2 System Proposed by Master Plan

4.2.1 Structural Measures

The essence of 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 dykes and gates. Rainfall inside the polder is to be discharged by the drainage facilities installed inside the polder.

The Eastern Suburbs (501 km^2) covered by the Preliminary Study has been protected already by the Green Belt dyke. 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 dykes and gates around the Master Plan Area.

The Master Plan Area is subdivided into three polders i.e., Bang Khen-Bang Sue, Phra Khanong and Bang Na, using topography, the road network acting as natural boundaries and the klong network (Fig. 4.3).

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 improvement 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 drains, and the installation of inner pumps (Fig. 4.4). The structural-measures proposed are shown in Table 4.2 and Fig. 4.3.

Table 4.2 Proposed Structural Measures (Master Plan)

Items	1st - 3rd Stages (1987 - 2000)	1st Stage (1987 - 1991)
Dyke	6.2 km	6.2 km
Gates	55 places	4 places
Pumping Station with Gate		
Outlet	7 stations ($200\ m^3/s$)	2 stations ($20\ m^3/s$)
Inner	3 stations ($18\ m^3/s$)	3 stations ($18\ m^3/s$)
Klong Improvement		
Main Klong (Phra Khanong, Tan and Saen Saep)	25.5 km	16.5 km
Sub-Klong	107.5 km	52.3 km
Main Drain Improvement	110 km	30 km
Flood Forecast and Warning system	1 set	1 set
Project cost (million Baht)	6,280	2,560

4.2.2 Non-Structural Measures

The basic idea for non-structural measures is to modify the susceptibility of damage by 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. Publication of the observed extent and depth of the 1983 flooding should be firstly 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 requirement placed on the klongs and capacities of the pump and hence reduces the investment in structural facilities, and brings a higher efficiency in the invested funds.

4.2.3 Facilities for Feasibility Study

The proposed structural measures are scheduled to be implemented in three stages by the year 2000. Since the overall facilities such as polder dyke, gates, pumping stations and primary klongs are effective in reducing overall flooding (Fig. 4.4), these facilities are proposed to be constructed at an early stage. On the other hand, facilities such as secondary/tertiary klongs and main drains which contribute to the alleviation of local flooding are proposed for implementation according to the area priority. As a result, the works as shown in Fig. 4.5. are included in the first stage program which is planned to be constructed during the period of the Sixth National Economic and Social Development Plan (Oct. 1986 to Sept. 1991).

4.3 Proposed Flood Protection and Drainage System

4.3.1 Review of Master Plan

A part of dyke section 1 is excluded in the Feasibility Study (see Fig. 4.6) because the 1.6 km dyke along the Klong Phra Khanong (from the pumping station to the outlet) was constructed in 1984 or is scheduled to be constructed in 1985 and because the existing 1.8 km quay walls supported by foundation piles of the Port Authority can be used as a dyke. As a result, the remaining 3.4 km dyke along the Chao Phraya River is included in the Feasibility Study.

A part (1.7 km) of section 5 was supposed to be completed but is incomplete. Therefore, it is included.

The drainage facilities for the Feasibility Study are located mainly in Bang Na polder, Ramkhamhaeng polder, west Huay Kwang drainage area and Bang Sue drainage area. So the system in these polders are reviewed based on the results of field reconnaisance, survey of klongs and roads, etc. Further primary drainage system in Phra Khanong polder which includes Ramkhamhaeng polder and west Huay Kwang drainage area is reviewed. As a result, the facilities are modified as shown in Table 4.3 and Fig. 4.6.

Table 4.3 Modified Works

Items	Proposed by Master Plan	Modified by Feasibility Study
Dyke	6.2 km	5.1 km
Gate	4 places	4 places
Pumping station with Gate	5 stations ° Bang Sue ° Kacha ° Gig ° Bang Nang Chine ° Bang Na	5 stations ° Huay Kwang ° Lao ° Bang Na Chine ° Bang Lai ° Klet
Klong Improvement	70 km	93 km
Main Drain Improvement	30 km	4 km
Flood Control Operation Centre	1 set	1 set

4.3.2 Planning Criteria

The planning criteria is as follows:

- Target year – 2000 A.D. (2543 B.E.)
- Land use as shown in Fig. 6.1
- Landfill, the planned urbanized areas as shown in Fig. 6.1 are elevated to the same level as neighboring, existing urbanized areas.
- Land subsidence, 0.7 m in Bang Khen – Bang Sue polder and 1.0 m in Phra Khanong and Bang Na polders.
- Inflow from the City Core Area

  - o Klong Bang Sue 12 m^3/s
  - o Klong Tan 15 m^3/s

The drainage system is designed for 6 hour areal rainfall with a 2 and 5 year return period in combination with a 100-year return period Chao Phraya river level (+1.9 m in Bang Na and Phra Khanong polders, and +2.1 m in Bang Khen-Bang Sue polder). The 5-year return period rainfall is applied only to primary drainage facilities in Phra Khanong polder. The areal rainfall is determined by applying reduction factors to point rainfall. For transformation from rainfall to runoff the Rational Method is used.

Rainwater retention function of the non-urbanized areas is planned to be utilized fully. For the design of klong improvement, in order to use the water storage function of the klongs as much as possible, the maintenance water level of klong is decided (Table 4.4). The maintenance water levels are defined as the level to be maintained just upstream of the pumping stations during the rainy season. Under the design rainfall, water level in the klongs would rise to the neighboring land elevations.

Table 4.4 Maintenance Water Level in Klong

[Unit: metre MSL]

Polder Area	Maintenance Water Level	
	Present	Future (in 2000)*
Bang Khen - Bang Sue	-0.80	-1.50
Phra Khanong	-0.80	-1.80
Bang Na	-0.80	-1.80

*considering land subsidence:

0.7 m in Bang Khen - Bang Sue

1.0 m in Phra Khanong and Bang Na

It is stressed that the effectiveness of proposed facilities will change corresponding to the change of the above mentioned conditions in future. Therefore, periodical monitoring of the following is indispensable.

(1) Land Subsidence Control

The land subsidence control programme to take place in a few years time must be on schedule, because land subsidence will take place for several years after the ceasing of all ground water pumping.

(2) Land Reclamation and Retention Area

Landfill accompanied with urban development is recommended to be continued in future to protect developed land. However landfill will cause a loss in the natural water retention function, resulting in an increasing flood risk. Hence, measures for recovery of the retention function, harmonizing with urban development are needed in addition to structural measures.

(3) Land Use Control

The absence of effective controls on land use and urban development is causing difficulties in maintaining the existing capacity of drainage and flood control facilities and is increasing the risk of flooding. Accordingly land use control should take place as early as possible.

4.3.3 Proposed Flood Protection System

1) Barrier (Dyke)

Almost all sections of the flood protection barrier surrounding the Study Area are on the existing elevated roads, and some will be constructed by the City Core Project. Therefore, the required sections to be constructed in this project are parts of section 1 and section 5 as shown in Fig. 4.6.

For the part of section 1, there exist quay walls (of the Port Authority and the Petroleum Authority) and retaining walls (of private company and the Navy) along the river. For these sections except for the Port Authority, new barriers need to be constructed because the exiting wall crest levels of +2.1 to +1.2 m is inadequate.

Two alternatives to the barrier alignments of section 1 are studied i.e., along the Chao Phraya river bank (alternative 1) and the Na Krom road (alternative 2) as shown in Fig. 5.2. Alternative 1 is recommended for protecting the entire riverine area.

The recommended barrier alignment of part of section 5 (from the eastbound railway to Klong Phra Khanong, 1.7 km) is along the alignment proposed by DDS.

2) Gates

Along the flood protection barrier, 4 gates are planned. Those are in Klongs Phra Khanong, Saen Saeb, Song and Lolae as shown in Fig. 4.6

4.3.4 Proposed Drainage System

Proposed drainage works result from the comparative study on drainage alternatives in terms of location and capacity of pump, drainage area and shape/size of klongs. The unsteady flow method is used.

Capacities and locations of the proposed drainage facilities are schematically indicated in Fig. 4.9 while runoff discharges are shown in Fig. 4.8. Those are planned for a design rainfall of 2-year frequency except for Phra Khanong polder where primary facilities are designed for 5-year frequency with secondary/tertiary facilities of 2-year frequency.

At the start of rainfall, rainwater is partly pumped out and is also simultaneously temporarily stored within klongs and retention areas, the storage volume constitutes more than half of the rainfall volume at peak times. With time the stored water is also pumped out. As large retention areas are planned in Phra Khanong polder, the planned pump capacity is small at 0.5 $m^3/s/km^2$ and it will take 36 hours to pump out the rainwater. Other planned pump capacities are also small i.e., 0.8 $m^3/s/km^2$ (Bang Khen – Bang Sue polder) and 1.7 $m^3/s/km^2$ (Bang Na polder).

1) Bang Na Polder (31 km^2)

Bank Na polder is divided into four sub-drainage areas as shown in Fig. 4.10. Three alternatives (See Fig. 4.10 and Table 4.5) are compared. Alternative BN-1 separates four areas while alternatives BN-2 and BN-3 combines two areas. The latter two alternatives need the widening of connecting klongs, resulting in higher costs and land acquisition.

In addition, the increase of discharge into Klong Phra Khanong in BN-1 is found to need no increase of klong improvement works or in capacity of Phra Khanong Pumping Station. Therefore, alternative BN-1 is recommended.

Table 4.5 Sub-Drainage Areas and Their Primary Klongs and Pumping Stations in Alternative of Bang Na polder

(Unit: m^3/s)

Sub-drainage Area / Alternative	A	B	C	D
BN-1	Jek (3) Bang Oa (12)	Bank Nang Chine(9) Bang Lai (6)	Klet(9)	Bang Na (15)
BN-2	Jek (3) Bang Oa (18)		Klet(9)	Bang Na (15)
BN-3	Jek (6) Bang Oa (12)	Bang Nang Chine(12)	Bang Na (24)	

2) Ramkhamhaeng (North Hua Mark) Polder (9 km^2)

Ramkhamhaeng area forms an inner polder within Phra Khanong polder. Klong Kacha runs in an east-west direction in the middle of the area, branching off Klongs Gig, Lao and Sakae.

Storm water is planned to be pumped out into Klong Saen Saeb through Klongs Kacha and Gig in alternative R-1 of Fig. 4.11. Besides, storm water in the Ramkhamaeng Campus and the area between Ramkhamhaeng road and Klong Saen Saeb is planned also to be pumped into Klong Saen Saeb since they are lower topographically.

Alternative R-2 is considered to relieve overloaded Klong Tan, downstream of Klong Saen Saeb. i.e., storm water is to be pumped out southward through Klong Lao connecting Klong Phra Khanong. Although both alternatives have the same drainage facilities except pumping stations and cause no flooding downstream, alternative R-2 is adopted to reduce the overloaded Klong Tan discharge capacity.

3) West Huay Kwang Drainage Area (24 km^2)

Some storm water in this area used to be discharged westward into the Chao Phraya river through Klong Sam Sen until the construction of the polder for the City Core Area in the late 1970s. Resuming discharge westward (alternative HK-3 of Fig. 4.12) is not practical because of the extensive amount of widening or tunnel constuction required in the congested City Core Area and the limited capacity of Klong Sam Sen as studied in the City Core Project. Further it is pointed out that ground elevation in the east will become lower than in the west due to land subsidence.

Therefore, the possible ways of discharging storm water are 1) through Klong Sam Sen eastward then Klongs Saen Saeb, Tan and Phra Khanong (alternative HK-1) and 2) in addition of Klong Sam Sen, through Klong Bang Sue westward partly (alternative HK-2).

Comparison of both alternatives reveal that 1) drainage facilities are the same except in alternative HK-2 Huay Kwang pumping station (3 m^3/s) is needed for discharging into Klong Bang Sue, and that 2) drainage condition of HK-2 is far better.

Some discharge into Klong Bang Sue is found to have no adverse effects. Therefore, alternative HK-2 is recommended despite a slightly higher cost. The Makkasan pond now under construction as well as highway side drain is incorporated in this drainage system.

4) Bang Sue Drainage Area (35 km^2)

Flooding in this area has not been of long-duration caused by overland flow, as was observed in other eastern suburbs, but is a short-duration one as experienced in the City Core Area. Flooding is presumably caused by inadequate drainage facilities, particularly as the Klong network is small and the lack of a retention area.

The recommended drainage system as shown in Fig. 4.11, therefore, intends to increase drainage capacity and to increase retention capacity. For that purpose not only existing Klong Prem Prachakorn (which just runs outside of this area) and super-highway side drain but also new Klongs along Middle Rind road and Ngam Wong Wang road near Kasetsart university are planned. As a result, the size of Bang Sue pumping station proposed in the Master Plan is reduced from 50 m^3/s to 36 m^3/s.

Inflows to Klong Bang Sue from the City Core Area (12 m^3/s) and West Huay Kwang drainage area (3 m^3/s) are taken into account in Bang Sue drainage system.

4.4 Proposed Works

As a result of the comparative study, the works are proposed in the following Tables 4.6 to 4.10.

Table 4.6 Proposed Dyke

Section 1	along Chao Phraya River	3,400 metre
Section 5	along Klong Tub Chang Bon	1,700 metre
	Total	5,100 metre

Table 4.7 Proposed Gate

Klong Phra Khanong	6 metre width, 1 set
Klong Saen Saep	6 metre width, 1 set
Klong Lolae	6 metre width, 1 set
Klong Song	6 metre width, 1 set

Table 4.8 Proposed Pumping Station with Gate

Pumping Station	Pump Capacity	Proposed Pump Capacity (m^3/s)	Existing Works	New Works
Bang Khen and Bang Sue Polder	1. Bang Khen New		9	-
	2. Bang Khen Old	15	12	-
	3. Bang Sue	36	36	-
	Sub Total	51	57	-
Phra Khanong Polder	1. Phra Khanong	90	105	-
	2. Lao	9	0	9
	3. Huay Kwang	3	-	3
(*)	Sub Total	102	105	12
Bang Na Polder	1. Jek	3	6	-
	2. Bang Oa	12	18	-
	3. Bang Na	15	15	-
	4. Bang Nang Chine	9	-	9
	5. Bang Lai	6	-	6
	6. Klet	9	-	9
	Sub Total	54	39	24
Total		207	201	36

Note; Proposed pump capacities are not always the same as the existing.
* including Ramkhamhaeng polder and west Huay Kwang drainage area.

Table 4.9 Proposed Klong

[Unit: klong metre]

Polder or Drainage Area	Retaining Wall		Dredging
	Construction	Existing	
Phra Khanong*	9,895	3,005	18,600
Ramkhamhaeng	3,770	100	7,240
Huay Kwang	900	200	15,870
Bang Sue	12,950	1,750	18,540
Bang Na	23,240	1,720	32,710
Total	50,755	6,775	92,960

* Klongs Phra Khanong, Tan and Saen Saep

Table 4.10 Proposed Drain

Name	Length (m)
Phra Khanong Polder	-
Ramkhamhaeng Polder	200
Huay Kwang Drainage Area	900
Bang Sue Drainage Area	2,170
Bang Na Polder	1,060
Total	4,330

4.5 Hydraulic and Environmental Impact

The proposed system will undoubtedly alleviate flooding to a great extent. However, as the system blocks inflow from the outer area and, instead, pumps out a large amount of water into the Chao Phraya river at a short period, it will bring various effects. Therefore, the following hydraulic and environmental impacts are studied;

(1) Impact on high water levels of the Chao Phraya River,

(2) Hydraulic impact on the eastern paddy area located between Green Belt Area and Master Plan Area, and

(3) Water quality deterioration in the Study Area.

4.5.1 Hydraulic Impact on the Chao Phraya River

After implementation of the projects in the Study Area as well as the City Core Area discharge of about 420 m^3/s in total will be pumped out into the Chao Phraya River while the river discharge during high tide season is 200 to 1,500 m^3/s at present. Hence an increase in the water level of the Chao Phraya River is expected.

For estimating the rise in water level, an unsteady flow model is used from the river mouth (Fort Phrachul) to Rama VI bridge (58 km from the river mouth). At present, there is almost no reliable data of the discharge near Bangkok, therefore, discharges at Ram VI Bridge are calculated by the analysis for the assumed tide at River Mouth (2-cases) and high water level of 100 year return period at Rama VI Bridge. The two tides adopted are (Case I) spring tide (Oct. 26, 1980) and (Case II) tide of 100 year return period.

As the result, the discharge at Rama VI Bridge in Case I, 1500 m^3/s in Case II, 200m^3/s. Water stage rise by the pump discharge is about 10 cm for Case I and about 20 cm in Case II.

In future, Thonburi side will be protected by a polder system and stormwater will be pumped out into the Chao Phraya River, resulting in further rise of water level. These will necessiate some measures in future to prevent overspill from the river to the areas. These measures will include a diversion channel for the river, rise in crest level of polder dyke etc. For the time being, when water level of the river is high or is expected to become high, pumping is necessary aiming at minimizing the adverse effects on both the river and inside the Area. This operation requires a hydrological understanding of the river and the Klongs.

4.5.2 Hydraulic Impact to Eastern Paddy Area

Before the construction of the Green Belt dyke, the eastern paddy area used to be flooded by large inflows from the outer areas during the flood season. According to the study analysis the maximum flood depth above average paddy field land levels are estimated as 1 to 1.4 m for a 5-year return period rainfall, and the flooding period is estimated as about 4 months as shown in case A of Fig. 4.14.

The flooding status has been greatly improved by the execution of the Urgent Measures, especially by the construction of Green Belt dyke and Sam Rong Pumping Station. It can be seen from the Fig. 4.14 that the maximum flood depth has decreased by 50 to 80 cm to 20 – 40 cm above average land level.

The flooding status is generally little influenced by the proposed barrier located on the westside border as shown in Fig. 4.14. However, water levels in the retarding area may rise for a short period when heavy rainfall occurs because the gates along the western border are closed in order to protect the Feasibility Study Area. Excess water will be necessaily be diverted into the Study Area when water levels in the Study Area are low enough. This operation requires hydrological understanding both in the Study Area and in the eastern paddy area.

4.5.3 Environmental Impact in the Study Area

Water quality of the Klongs in the Study Area is not good, for example, BOD is 10 to 40 ppm due to discharge of domestic, commercial and industrial wastewater and is shown in Fig. 4.15. Water quality is expected to deteriorate because the inflow of fresher water from the outer areas. Further, as water is maintained at a lower level, the water quality will be aggravated.

In order to improve water quality, Flushing is required, by bringing fresh water from the outer areas. However, this operation should be carried out only when flooding is not expected. The amount of inflow varies greatly, depending on the dry season and the rainy season.

As shown in Fig. 4.1.6, for example, BOD is considerably improved by flushing but is still not good for removing odour of 10 – 20 ppm.
Therefore, eventually a study and execution of fundamental measures like a sewerage project will become necessary and dredging of silts will become necessary.

CHAPTER 5 PROPOSED FACILITY, PROJECT COST AND IMPLEMENTATION SCHEDULE

Based upon the proposed flood protection and drainage system in the previous chapter, this chapter describes the design of facilities to be constructed, project cost estimation and implementation schedule.

5.1 Facility Planning

Locations of the proposed facilities are shown in Fig. 5.1.

5.1.1 Flood Protection Barrier

The following types are adopted as a result of the alternative studies (See Fig. 5.2);

1) Section 1 (3.4 km long along the Chao Phraya River)

A concrete wall on a concrete sheet pile support type is adopted. The wall height is 1.5 m and the sheet pile length to be driven is 7.0 m for protection against seepage.

2) Section 5 (1.7 km long along Klong Tub Chang Bon)

An earth embankment type is adopted. The embankment height is 1.3 m and the top width is 5.0 m.

The dimensions of the proposed barriers are shown in Table 5.1

Table 5.1 Proposed Barrier (Dyke) Works

Location	Structural type	Length (km)	Height of Barrier (m)	Crest Elevation (m MSL)	Existing Ground Level (m MSL)
1) Chao Phraya River	Conc. wall with Conc. Sheet Pile Support	3.4	1.5	+2.20	+1.20
2) Klong Tub Chang Bon	Earth Embankment	1.7	1.3	+1.50	+0.20

5.1.2 Gate

A sluice gate of 6 metre width is adopted which is of steel supported on foundation piles.

Table 5.2 Proposed Gate Works

Name of Gate	Width, Height of Gate (m)	No.	Gate Type	Klong width (m)
K. Song	6 x 5	1	Sluice	32.0
K. Lolae	6 x 6	1	Sluice	15.0
K. Saen Saep	6 x 6	1	Sluice	42.0
K. Phra Khanong	6 x 6	1	Sluice	35.0

5.1.3 Pump

Submersible axial flow pumps as shown in Fig. 5.3 is adopted, i.e., same type as constructed by the urgent project because of the following reasons:

1) To cope with land subsidence
2) To meet the site conditions (difficulty of land acquisition)
3) Construction cost is low although the durable life of submersible type is expected as 7 – 10 years.
4) To harmonize with existing pumping stations constructed by urgent project.

Table 5.3 Proposed Pumping Station Works

Name	Capacity per set (m^3/s)	No.	Total Capacity (m^3/s)	Pump type
K. Bang Nang Chine	3.0	3	9.0	axial flow submersible
K. Ban Lai	3.0	2	6.0	"
K. Klet	3.0	3	9.0	"
K. Lao	3.0	3	9.0	"
K. Huay Kwang	1.5	2	3.0	"

5.1.4 Klong Improvement

Klong improvement is confined, as much as possible, into the existing right-of-way to avoid land acquisition, and Klong cross sections are planned to be of rectangular shape with retaining wall or a trapezoidal shape with 1:2 side slope.
Four types of structural retaining walls, are adopted (See Fig. 5.4);

(Type A) Concrete panel wall with bracing beam
(Type B) Concrete panel wall with anchor pile
(Type C) Concrete panel wall with anchor pile
(Type D) Concrete sheet pile wall with anchor pile

Type A is used in klongs with less than 6 to 8 m width while types B and C are for medium-sized klongs. Type D is used when the height of the retaining wall is more than 3.5 m due to wall stability (See Fig. 5.5). Examples of profiles and cross sections are shown in Fig. 5.4.

Table 5.4 Proposed Klong Improvement Works

Name of polder or Drainage Area	Phra Khanong (*)	Kankham-haeng	Bang Na	West Huay Kwang	Bang Sue	Total
Klong Length Improved (m)	18,600	7,240	32,710	15,870	18,540	92,960
Dredging (m)	18,600	7,240	32,710	15,870	18,540	92,960
earth volume ($1,000M^3$)	353	41	337	169	184	1,084
Construction of Retaining Wall (m)						
Type A	-	5,470	29,680	-	21,700	56,850
Type B	-	-	-	1,300	-	1,300
Type C	4,440	-	12,700	-	2,400	19,540
Type D	4,940	-	-	-	600	5,540
Sub-Total	9,380	5,470	42,380	1,300	24,700	83,230
Reconstruction of Retaining Wall (m)						
Type A	-	2,070	1,400	-	-	3,470
Type B	-	-	-	500	-	500
Type C	2,850	-	2,700	-	800	6,350
Type D	7,560	-	-	-	400	7,960
Sub-Total	10,410	2,070	4,100	500	1,200	18,280
Utilizing Existing Retaining Wall (m)	6,010	200	3,440	400	3,500	13,550
Trapezoidal Shape Embankment	5,700	3,370	7,750	14,770	3,840	24,860
Land Acquisition (m^2)	12,800	-	400	9,220	5,200	27,620

(*) primry klongs only, i.e., Klongs Phra Khanong, Saen Saep and Tan

5.1.5 Drain

Table 5.5 indicates the proposed drains. To be noted is that unequal settlement has occured in many pipes in Bangkok. Therefore, the construction of a wooden ladder type of foundation is adopted. For large box culverts, the pile foundation is also recommended.

Horizontal jacking method for installation of pipes is proposed under busy highways, particularly where open-cut method is difficult.

Table 5.5 Proposed Drain Works

Name	Length (m)
Phra Khanong Polder	-
Ramkhambaeng Polder	200
Bang Na Polder	1,060
West Huay Kwang Drainage Area	900
Bang Sue Drainage Area	2,170
Total	4,330

5.2 Project Cost

5.2.1 Basis of Cost Estimation

Based on facility plans, the project costs are estimated in accordance with the following conditions:

1) The estimates are made on the condition that all construction works will be contracted to general contractors by international tender.

2) The costs are computed under the economic conditions prevailing in Aug., 1985.

3) The costs are classified into foreign and local currency portions.

The foreign currency portions consist of the costs of;

- Imported equipment, materials and supplies;
- Domestic materials of which the country is an importer;
- Wages of expatriate personnel; and
- Overhead and profit of foreign firms.

The local currency portions include the cost of:

- Domestic materials and supplies
- Wages of local personnel;
- Overhead and profit of local firms; and
- Taxes.

The unit prices are based on the list of labour, equipment redemption and material prices obtained from the Ministry of the Interior, constructors, lease firms etc.

4) Land acquisition cost of 3,000 Baht/m^2 is adopted using current data obtained by the real estate study report published by TISCO.

5) For all unit construction costs a constant allowance of 30% for overhead and profit are added to the direct unit prices.

6) Contingency allowance are made of 9% of the construction cost.

7) The engineering design and supervision fees etc. are assumed to be 4% of the construction cost.

8) Annual price escalation of 5% is considered for both foreign and local currency portion. Based on the implementation schedule as described in section 5.3, total price escalation was taken 22.1% against 1985 construction costs.

5.2.2 Construction Cost

The construction cost by work items is calculated in principle from the material cost, labour cost, equipment redemption cost, etc. analyzing the data on the construction cost of recent similar projects such as the Urgent Project and the City Core Project as well as taking into consideration the local conditions in Bangkok. The construction costs amount to Baht 2,655 million at 1985 price. Out of it the foreign currency component is Baht 1,261 million while the local currency component is Baht 1,394 million (see Table 5.6).

Table 5.6 Summary of Construction Cost

(Baht Million at 1985 price level)

Facility	Construction Cost			Land Acquision	Total
	F/C	L/C	Total		
A. Dyke	19.6	20.7	40.3	-	40.3
B. Gate	31.3	16.9	48.2	-	48.2
C. Pumping Station	86.3	37.0	123.3	6.7	130.0
D. Klong Improvement	834.5	1,005.7	1,843.2	82.9	1,926.1
E. Drain	73.8	73.8	147.6	-	147.6
F. Flood Control Operation System	68.0	-	68.0	-	68.0
Sub-Total (A-F)	1,116.5	1,154.1	2,270.6	89.6	2,360.2
G. Physical Contingency	100.4	103.8	204.2	-	204.2
H. Engineering /Supervision	44.6	46.2	90.8	-	90.8
Total (A-H)	1,261.5	1,304.1	2,565.6	89.6	2,655.2

5.2.3 Operation and Maintenance Cost

The operation and maintencne costs, comprising the cost of yearly operation and maintenance of klongs, pumping stations, gates, drains, dykes and flood control operation centre are estimated at Baht 42 million per year.

5.3 Implementation Schedule

The degree of flood protection should be upgraded stage by stage. The high priority measures are the exclusion of river overspill and the overland flow from outside areas. This suggests the early construction of dykes and gates, which would protect the area from outside flooding, and inland drainage facilities later or in parallel, depending on usefulness of the work.

The facilities for the Feasibility Study are ranked as shown in Fig. 5.6. The dykes and gates are ranked as high priority. Then primary drainage facilities, which contribute to the alleviation of overall flooding are ranked as next priority generally, followed by secondary and tertiary drainage facilities. Effects of these facilities are shown in Fig. 4.4 from which the implementation order is determined.

Considering the time for preparation of detailed design and particularly financial procurement, construction can be started in 1988, one year later than the Master Plan proposal, and completed in 1991. The dykes, gates, pumping stations and control centre are planned to be implemented in 1988.
Construction of primary facilities are scheduled in 1988 and 1989, followed by secondary and tertiary facilities as shown in Table 5.7.

Table 5.7 Implementation Schedule

Item / Year	Unit	Total	1987	1988	1989	1990	1991
Dyke	km	5.1	-	5.1	-	-	-
Gate (place)	No.	4	-	4	-	-	-
Pumping Station (station)	No.	5	-	5	-	-	-
Klong Improvement	km						
Primary Klongs		26.0	-	18.6	7.4	-	-
Secondary/Tertiary Klongs		66.9	-	-	14.5	33.6	18.8
Drain Improvement	km	4.3	-	-	-	3.2	1.1
Flood Control Operation Centre (set)	No.	1	-	1	-	-	-
Detailed Design	Item	1	1	-	-	-	-
Project Cost (million Baht at 1985 price)		2,655	46	825	825	805	154
Foreign Portion		1,261	23	450	353	372	63
Local Portion		1,394	23	375	472	433	91

CHAPTER 6 FLOOD PLAIN MANAGEMENT

"Food plain management" or "non-structural measures" is required for mitigating flood damage in Lower Chao Phraya Plain, including eastern suburban Bangkok, in addition to the proposed structural measures.

6.1 Necessity of Flood Plain Management

Modernization of life-style and rapid urbanization has changed the susceptibility to damage by seasonal floods, resulting in loss of natural retention area/capacity and increase in run-off discharge. In addition, groundwater abstraction increased particularly in the eastern suburbs and Samut Prakan Province, where these is no piped water service, resulting in severe land subsidence. This land subsidence has greatly aggravated the flood problem.

On the occation of the 1983 flooding, urgent (structural) measures have been provided which improved drainage conditions to a great extent as shown in Fig. 3.6. Furthermore, if the proposed structural measures are provided in the eastern suburbs, although they will take a long time and cost much, flooding problems will be greatly resolved. Nevertheless, residual flooding problems will still remain for smaller segments of the community because of drainage difficultles in the very flat eastern suburbs. Consequently, a comprehensive flood damage mitigation plan, consisting of both structural and non-structural measures, is proposed to solve such flood problems.

Since few non-structural measures have been introduced as urgent measures much effort will be required for their introduction.
The objectives are to:

- ensure, through appropriate zoning, the rainwater retention function of flood prone land which is compatible with the degree of the flood hazard;

- implement a management plan aimed at:
  - resolving the problem by development and building controls;
  - reducing the extent and severity of the hazard by removal of development from the flood plain;
  - ensuring adequate flood warning procedures.

Particularly, as demand of land in eastern suburbs is growing at a high rate (discussed in section 6.2), non-structural measures are considered effective not to increase flood damage.

More importantly, they tend to pass the burden of cost from the public-at-large to those who reap the advantages of flood plain location because flood protection responsibility is shared between the governments (on structural measures) and the beneficiaries (on non-structural measures). However, it is stressed that the application of non-structural measures requires strong leadership and public support. This matter is discussed in seccion 6.3.

6.2 Zoning Regulation

6.2.1 General

By the Master Plan Study, the eastern suburbs are divided into two zones (see Fig. 6.1), one is flood protection area and the other is retarding area.

Urban development which accompanies a property value increase, is guided to take place in the flood protection area while no urban development is allowed in the retarding area (see Table 6.1). Similarly no urban development is allowed in flood-prone areas (which are designated as retention areas) which the flood protection area. These divisions are determined by the flood risk evaluation and urbanization trend. It is noted that stormwater is temporarily stored in the designated retention areas as well as klongs and is gradually pumped out.

6.2.2 Flood Risk Evaluation

The following approaches are used for flood risk evaluation;

1) Histrical Approach (See Fig. 3.2)
2) Geomorphological Approach (See Fig. 6.2)
3) Hydrological-Hydraulic Approach (See Figs. F11 to F12 in Appendix)

Table 6.1 Concept of Zoning Regulations

Classification	Urban Development	Scope of Area	Measures
Protection Area	. Urbanized Area . Urbanization Area Promotion	Master Plan and Feasibility Study Area	1) To form a polder 2) To improve drainage capacity 3) To make retention pond, compensating retention area lost with urban development 4) Prohibition of ground water withdrawal 5) Improved piped water supply system 6) Provision of Infrastructure
	. Retention Area	Master Plan and Feasibility Study Area	1) Prohibition of landfill 2) Prohibition of Infrastructure provision (1) Roads (2) Water Supply (3) Others 3) To encourage flood-proofing
Retarding Area	. Urbanization Area Prohibited	East half of eastern suburban Bangkok between Green Belt and Master Plan Area	1) To adjust drainage condition for agriculture and open space 2) To encourage flood-proofing 3) Prohibition of infrastructure provision (1) Roads (2) Water Supply (3) Others

Observed flood area, depth and duration in the serious 1983 floods (see Figs. 3.1 to 3.2) is at present the most reliable data for evaluation because other approaches have started only recently. According to Figs. 3.1 to 3.2 the southern part of the Study Area suffered most from severe flooding.

The southern part is situated in and near the mouth of Klong Phra Khanong (downstream of which was not a man-made canal but a river) and it also has an extensive man-made klong network (see Fig. 6.2) and its ground elevation is relatively lower (see Fig. 6.3). On the other hand, the western part of the Study Area has a smaller klong network and its ground elevation is relatively higher. From these facts, it is clear that the southern part is apt to suffer from flooding than the north. Land subsidence has increased this tendency.

6.2.3 Urbanization

The important factor for a sound land-use pattern is to delineate the required future urbanized areas, in addition to a flood risk map. To begin with, the urbanization trend is explained.

The city's population increase has been extremely rapid since the 1950s. Although increases in residential use occured in all directions, the main thrust of expansion was in the direction of Bang Kapi, Bang Khen, and Min Buri in the north, Muang Samut Prakan and Phra Khanong to the south and east. The development pattern has been virtually unplanned although the construction of roads has been the most important determinate of the spatial orientation of development and induced an unintended ribbon development and vacant areas remain among the thin ribbons along the major roads (see Fig. 2.1).

In order for an effective drainage system as well as city planning, the future urbanized area of 216 km^2 in 2000, which will accommodate 2.5 million persons, is obtained by filling in the large vacant areas, instead of sprawling along the main roads (see Fig. 6.1).

6.2.4 Present Stage of the Greater Bangkok Plan

The Department of Town and Country Planning (DTCP) has been in charge of updating and revising the Greater Bangkok Plan, the most important tool for zoning regulations, since 1960. However, the Plan was never officially adopted.

The present version of general plan for BMA still stays in the initial phase of the "Planning Advisory Board", although legal procedures began in 1982.

On the other hand, the Metropolitan Area Structure Plan, which is not bound by legal procedures, was drafted in conjunction with the Fifth National Plan (1982 – 1986). The conceptual framework intended a multinuclear structure. The plan included a comprehensive metropolitan open space system, including flood protection zones in the eastern suburbs.

As the flood protection system had got much attention, a set of new bye laws under the Building Control Act was enacted by BMA to restrict concomitant development.

6.3 Action Plan for Non-Structural Measures

Zoning regulations are the effective measures but their immediate enforcement is considered difficult owing to the social and economic consequences to affected property owners. A good and sound relationship needs to be established between governmental authorities and the local communities. Fortunately, as inter-governmental coordination and cooperation for flood protection has become easy through the recently set up national-committee, preparatory work for zoning regulations as well can be started immediately.

Nevertheless while consuming the time for preparation of zoning regulations, the flood risk will continue to worsen. Therefore, in order not to increase flooding risk and problems, the following measures are recommended to be applied step by step by the government (see Table 6.2).

6.3.1 Short Term Action Plan

(1) Mobilization of Non-Structural Measures Committee

The national foood protection committee for Bangkok and Vicinity formed in 1983, has implemented urgent flood protection measures by a coordinating function with various organizations. The sub-committee for project designation has played a key role in planning and implementing urgent structural measures. The sub-committee for supporting activities, designated in planning and implementing non-structural measures is also necessary to be mobilized.

(2) Recognition of Flood Plain Management

Such recognization is firstly required to be made between the committee and related agencies that land use and development controls are major and fundamental measures of preventing the growth of the existing flood risk and damage problem and that there is a high flood risk area.

(3) Publicizing Flood Risk

Observed flood data, including flooded area, depth and duration and estimated flood data are to be publicized. Understanding the real facts about flooding by residents will ease the implementation of non-structural measures.

(4) Improvement of Observed Flood Data

The "Flood Authority" needs continue to collect flood data for improving the flood risk maps which will become the fundamental base for zoning. At the same time, "Planning Aurhority" needs to estimate future population and the required urbanized area from time to time, reflecting the actual progress of urbanization.

(5) Flood Control Operation Centre

For implementation of flood plain management a flood control operation centre is recommended to be established.

Table 6.2 Action Plan for Non-Structural Measures

Authority in Charge	Flood Protection Committee (Overall Flood Control)	Flood Control & Operation Authorities	Regional City Planning Authorities
Current Situation	* Sub-Committee	* Construction of Green Belt Dyke	* Green Belt area as open space (retarding area)
Short Term Action Plan	* Mobilization of sub-committee * Recognition of importance of flood plain management between relating agencies * Public education of flood plain management	* Publicizing observed flood area * Establishment of flood control operation system	* Projection of population and urbanized area
Inter-mediate Term Action Plan	* Inter-governmental recognition of zoning system in accordance with flood risk * Publicizing flood risk map	* Collection of flood data * Preparation of flood risk map * Improvement of flood control operation system	* Approval or dis-approval of development applications based on building codes * Construction of roads and water supply, compatible with zoning system * Guidance for prohibition of land reclamation in retarding area * Multi-purpose retention pond in the park
Long Term Action Plan	* Zoning regulation * Property tax adjust-ment, reflecting zoning * Surcharge to developers		* Approval or dis-approval of development applica-tions based on zoning regulation

6.3.2 Intermediate Term Action Plan

(1) Inter-governmental recognition and agreement of zoning system:

For example, proposed zoning as shown in Fig. 6.1 should be recognized/agreed between related organizations.

(2) Road planning and construction in accordance with the city plan:

The construction of roads has been the important determinant of the spatial orientation of urbanization. Therefore, planning and construction of roads are proposed to comply with future city plan (zoning system). Such development can lead more efficient use of both land and infrastructure.

(3) Prohibition of infrastructure provision in retention area:

Prohibition of infrastructure provision in retention area is very effective for proper land use guidance. The first priority is given to the construction of road and then water supply, electricity and telephone are given next priorities.

(4) Prohibition of land reclamation in retention area:

Land reclamation naturally reduces the natural water retention capacity. Hence, land reclamation is proposed to be prohibited in the designated retention area where low level property tax is recommended to be imposed for compensation.

(5) Flood Proofing:

Flood proofing is defined as those actions taken to avoid flood losses or damage to buildings or structures. Some measures to be taken are as follows:

- Raising structure; houses are built on poles, piles or stilts
- Raising land; houses are built on reclaimed land only in promoting an urbanization area.

(6) Retention Pond:

Multi-purpose retention ponds in the parks and grounds of government agencies are encouraged to be constructed (See Table 6.3).

(7) Building Codes:

The important legal base for planning and control by BMA is the Building control Act 1961. The 24 district offices of BMA play a key role in issuing the required building permits, whereas all applications for larger projects are controlled by the central BMA office. The requirements of structural safety, sanitation, drainage and car parking are controlled by the building regulations. Building in the Green Belt Area is also controlled by the regulations because the Building Control Act enables the BMA to establish local bye laws, which represent an important planning instrument. Therefore bye laws can facilitate, to some extent, the zoning regulations.

6.3.3 Long Term Action Plan

(1) Zoning Regulation

Flood plain management will be made effective when public participation is obtained. The restrictive regulations should be applied to the retention areas. No big houses and vital buildings such as hospitals, police stations, schools, telephone or telecommunication exchanges or electrical distribution centres should be located in any retention area. Existing buildings in retention areas must be flood proofed.

(2) Development Control

In the case where new houses are allotted in flood-prone areas, houses must be of flood-proofed. In such cases, houses may be constructed on the reclaimed land. However, land reclamation will reduce the natural retention capacity, causing an adverse effect on the urbanized area. In order to compensate for the lost capacity, retention ponds are necessary as shown in Table 6.3 when houses are built in promoting an urbanization area.

(3) Property Tax Adjustment

Flood protection and drainage facilities themselves will increase the effective supply of land, because the supply of developable land has been constrained by the infrastructure, especially roads. It is recommended that the construction of infrastructure should be accompanied by an increased property tax assessment. The increased property tax could become the important financial resource of infrastructure including drainage facilities.

Table 6.3 (1) Measures for Establishment of Retention Area

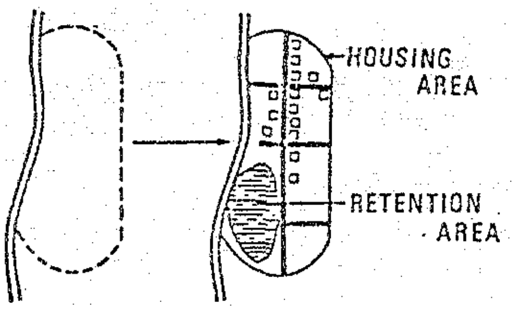
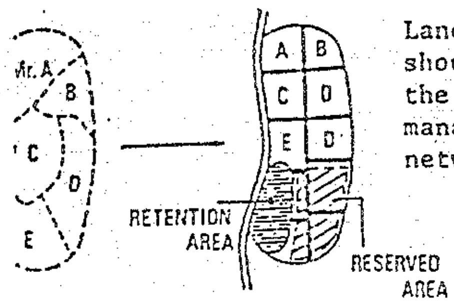
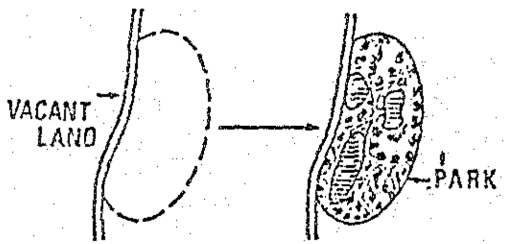
Measures	Proposal	Relevant Laws	Examples	Current Situation	Note
1. Urban Development Control 1) Development Permission	Each residential estate set out some percent of the land area as the retention area. 	(Subdivision Law)	-	According to the sub-division Law, 4-5 percent of the land area must be planned as the park in each residential estate.	If 10 percent of each residential estate is set out as the retention area, 8km^2 will be reserved as retention areas in 2000. For this purpose, some amend-ment of the Sub-division Law is necessary.
2) Land Readjust-ment Project	As a kind of public facility retention areas are kept under the Land Readjustment Project.	(Land Consolida-tion Act)	(Some agri-cultural lands) 		Land Readjustment Project should be executed from the viewpoints of flood management and road-network arrangement.

Table 6.3 (2) Measures for Establishment of Retention Area

Measures	Proposal	Relevant Laws	Examples	Current Situation	Note
2. Building Control	Each building lot installs a retention pond or sunk garden.	(Building Code)	-	According to the Building Code, 30 percent of the land area must be kept as an open space, paved or unpaved, in each dwelling house plot.	If 10 percent of each dwelling lot is kept as the retention pond or sunk garden without landfill, only 5km² will be reserved as retention areas in 2000. To keep 10 percent of the land area as the retention area, some amendment of the Building Code is necessary.
3. Land Acquisition	Public sectors should acquire vacant lands for parks or green areas. 	Land Acquisition Law	Makkasan Park (15 ha) Nonborn Park (80 ha)	For the long-range objective of parks in BMA, green areas of 6.4m² per person is planned.	According to this [illegible] plan, 14km² will be kept in eastern suburbs as retention areas.