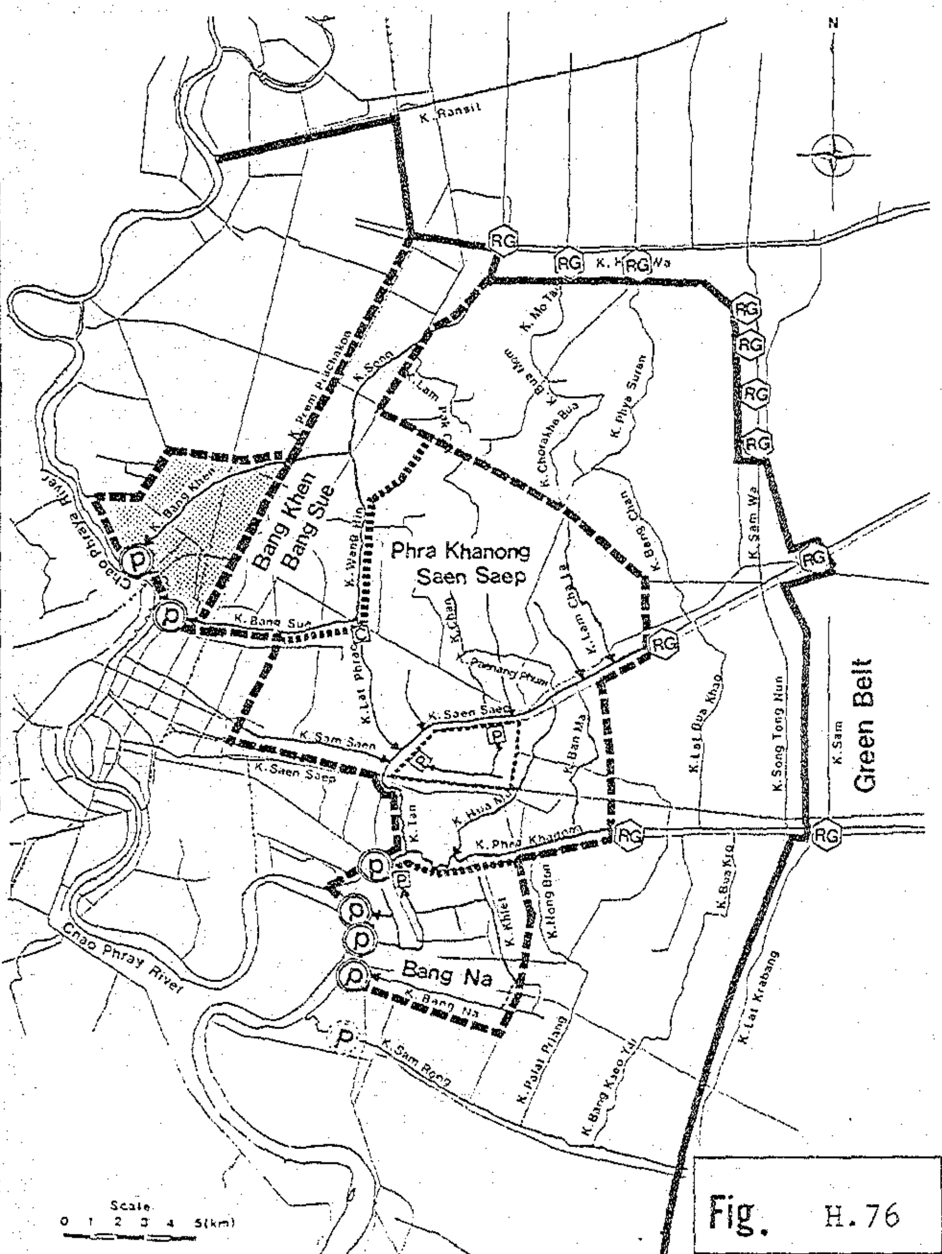

PUMPING STATION

	Polder	Area (km²)	Name of Pumping Station	PUMP Capacity (m^3/sec)	PUMP Maintenance Water Level above (M.S.L)	PUMP Specific Discharge ($m^3/s/km^2$)
MAIN POLDER	BANG KHEN & BANG SUE	64+29* = 93	Bang Khen	15	-1.50	
			Bang Sue	50	-1.50	
			Sub-Total	65		0.70
	PHRAKHANONG	165	Phra Khanong	90	-1.80	0.55
	BANG NA	31	Bang Jek	6	-1.80	
			Bang Oa	18	-1.80	
			Bang Na	21	-1.80	
			Bang Na-Chin	9	-1.80	
			Sub-Total	54		1.74
	Total	260+29 = 289		209		0.72
INNER POLDER	NORTH HUA MARK	9	Cig	3	-2.00	
			Kucha	6	-2.00	
			Sub-Total	9		1.00

Legend

- (P) : Main Pumping Station
- [P] : Sub Pumping Station
- (P) : Pumping Station for vicinity of Master Plan Area (by others)
- : Barrier utilizing existing embankment
- : Barrier to be newly constructed
- : Main Polder Boundary
- : Inner Polder Boundary
- : Dike of Green Belt
- : Klong to be improved
- CG : Control Gate
- RG : Existing Dike/Regulator Gate along Green Belt
- : Additional Drainage Area for Bang Khen - Bang Sue Polder (A' = 29km²)

Fig. H.76 PROPOSED DRAINAGE FACILITIES IN THE MASTER PLAN AREA

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

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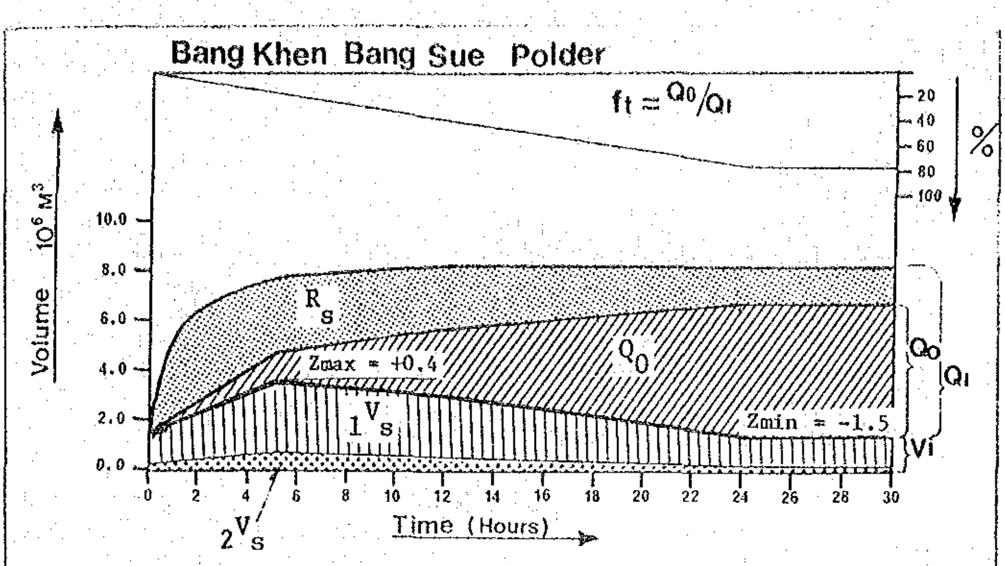
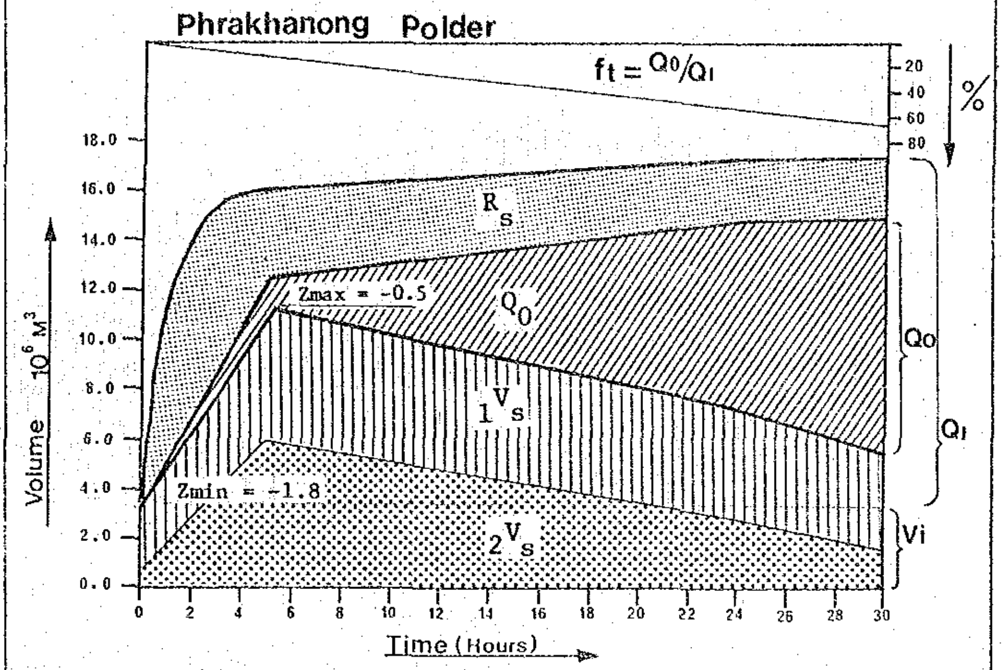


Polder Area=64+29*=93km^2

Design Rainfall
2year Freq.
R^2_{24}=91mm/day
A.R.F=0.78

Pump Capacity
Bangkhen P/S=15CMS
Bang Sue P/S=50CMS
Total =65CMS

* Additional area between Chao Phraya R. and Supper Highway.

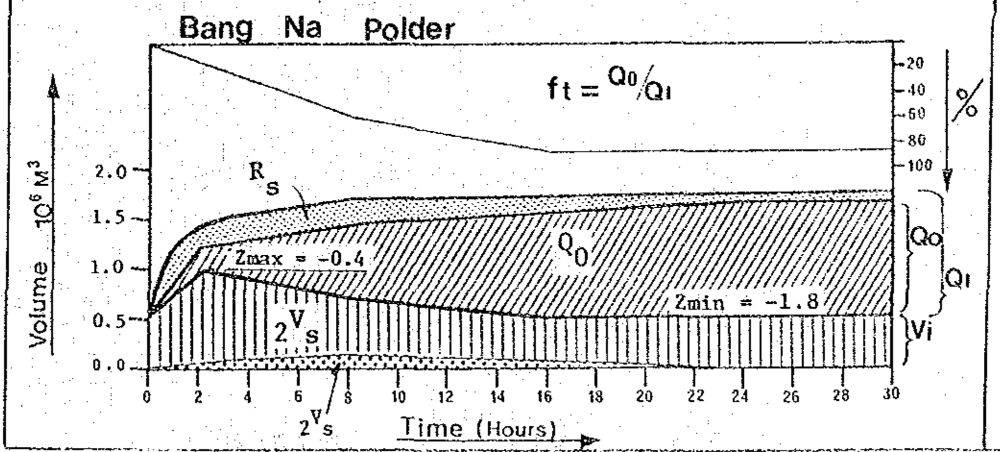


Polder Area=165km^2

Design Rainfall
5year Freq.
R^5_{24}=120mm/day
A.R.F=0.68

Pump Capacity
Phra Khanong P/S=90CMS

(Inner Polder Pump Capacity)
North Hua Mark
K.Gig P/S=3CMS
K.Kacha P/S=6CMS



Polder Area=31km^2

Design Rainfall
2year Freq.
R^2_{24}=91mm/day
A.R.F=0.84

Pump Capacity
Bang Jek P/S =6CMS
Bang Oa P/S =18CMS
Bang Na P/S =21CMS
Bang Na Chin P/S=9CMS
Total=54CMS

Legend
Q_i : Accumulated Rainfall
Q_0 : Accumulated Discharge
V_i : Initial Storage Volume
R_s : Ground Surface Storage
$_1V_s$: Storage in klongs
$_2V_s$: Storage in Detention Pond
Z_{max}: Average Maximum Water Level
Z_{min}: Maintenance Water Level

Fig. H.77 EFFECT OF STORAGE FOR DRAINAGE AREA (RELATIONSHIP BETWEEN STORAGE AND PUMP DISCHARGE)

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

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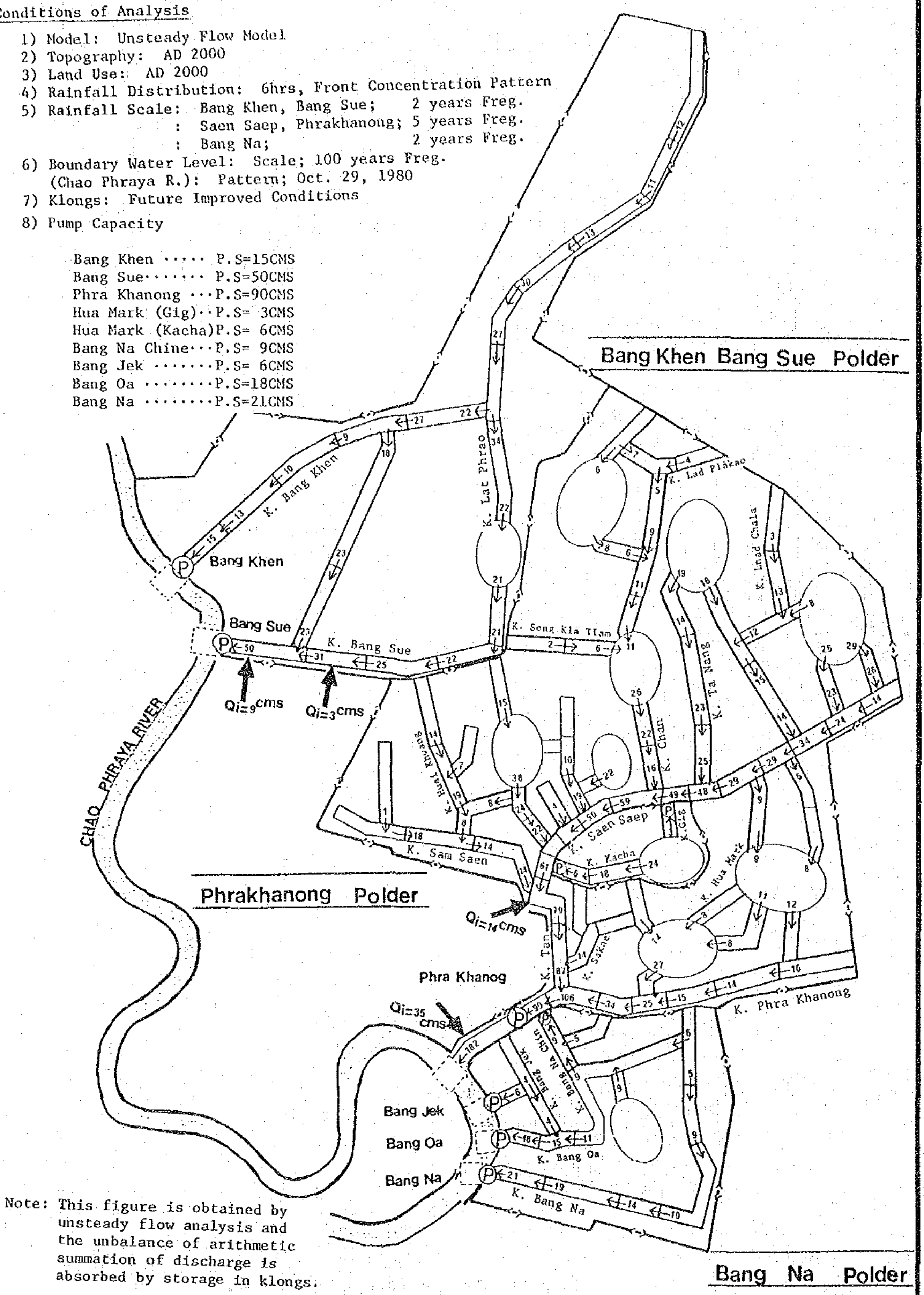
Conditions of Analysis

1) Model: Unsteady Flow Model
2) Topography: AD 2000
3) Land Use: AD 2000
4) Rainfall Distribution: 6hrs, Front Concentration Pattern
5) Rainfall Scale: Bang Khen, Bang Sue; 2 years Freg.
   : Saen Saep, Phrakhanong; 5 years Freg.
   : Bang Na; 2 years Freg.
6) Boundary Water Level: Scale; 100 years Freg.
   (Chao Phraya R.): Pattern; Oct. 29, 1980
7) Klongs: Future Improved Conditions
8) Pump Capacity

Bang Khen ····· P.S=15CMS
Bang Sue······· P.S=50CMS
Phra Khanong ···P.S=90CMS
Hua Mark (Gig)··P.S= 3CMS
Hua Mark (Kacha)P.S= 6CMS
Bang Na Chine···P.S= 9CMS
Bang Jek ·······P.S= 6CMS
Bang Oa ········P.S=18CMS
Bang Na ········P.S=21CMS



Note: This figure is obtained by unsteady flow analysis and the unbalance of arithmetic summation of discharge is absorbed by storage in klongs.

Fig. H.78 SIMULATED MAXIMUM DISCHARGE IN KLONGS (FINAL CONFIRMATION OF STEP IV ANALYSIS)

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

APPENDIX I

FLOOD PLAIN MANAGEMENT

APPENDIX I FLOOD PLAIN MANAGEMENT

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Appendix I FLOOD PLAIN MANAGEMENT

Bangkok lies in an area of very flat topography with a high water table in the klongs. The existing stormwater drainage system operates only by gravity through an extensive network of canals which worked well a few decades ago, when Bangkok had low density population. However, this no longer applies today, due to the great increase in population.

In the past, works undertaken for alleviation of flood damage consisted of structural measures provided on an ad hoc basis in response to specific problems as they arose. The same mode was applied in Bangkok, consisting of channel dredging, pump installation and embankment construction.

However, the initial heavy reliance on such structural measures in Australia, Canada, Japan and the United States have been recently replaced by a mix of structural measures and non-structural measures which was found to be more effective.

1. Objective of Flood Plain Management

Non-structural measures, i.e., flood plain management which comprises all means other than the construction of such flood protection and drainage facilities as improvement of klongs, installation of pumps and construction of embankments. Main items for flood plain management are:

(1) Identification and publicizing of flood-prone areas
(2) Land use control
(3) Encouragement of individual flood-proofing measures
(4) Flood forecasting and warning system
(5) Emergency flood fighting
(6) Flood protection committee

These items of flood plain management aim at:

(1) Alleviating both the existing and future hazard and damage potential of the properties in flood risk areas.
(2) Ensuring against increase in future hazard and damage potential as a result of new property developments in unsuitable locations.

In other words, they supplement the structural measures by providing the required degree of protection.

2. Recent Trend in Other Countries

2.1 United States of America

The passage of the Federal Flood Control Act of 1936 issued in a new era of greater and more coordinated federal involvement. However, the emphasis was still on structural measures of control. By 1960, it was becoming increasingly apparent that structural measures, in themselves, were ineffective in limiting and/or reducing the annual flood loss in the United States.

A mix of structural and non-structural measures was found to be more successful than structural measures alone. Non-structural measures that were recommended included land use development controls and flood insurance.

These findings culminated in the establishment of the National Flood Insurance Programme (NFIP) in 1968. This programme provides subsidized insurance for existing properties at risk and was used as an instrument to enforce the adoption by state and local governments of land use development controls and regulations for flood prone areas. The NFIP is but one tool for flood plain management. In recent years, the emphasis has been toward having communities adopt a broader range of non-structural controls.

The municipal government is responsible for day-to-day implementation with control exercised through zoning ordinances, sub-division regulations and building codes.

2.2 Canada

Canada recently adopted a co-ordinated and comprehensive approach to reducing flood damage. The National Flood Damage Reduction Programme in 1975 employed strategies to inhibit new flood plain development based on the identification of hazards through mapping while at the same time incorporating other programmes, such as flood forecasting/warning, protective works, and land acquisition to minimize damage to existing flood plain development.

The cornerstone of the programme was a series of flood hazard maps. Once an area had been mapped and the flood hazard area designated jontly by the federal and provincial governments, the information on flood hazard was communicated to the public, industries and government agencies and all investment of public funds for flood-vulnerable undertakings in the flood-hazard area was ceased.

Other steps taken were the refusal of Federal housing loans and other grants for development in flood-prone areas, or the making of such financial assistance conditional upon adequate flood proofing or other damage reduction measures.

To restrict private development, the flood-hazard information was incorporated into official plans and in municipal laws and provincial regulations.

2.3 Japan

In Japan, the Building Standards Act (1974) grants wide powers to provincial governors for designating disaster areas and for controlling new building in these and adjacent areas.

The city of Nagoya has applied this act by restricting new housing and building on the basis of risks associated with a particular typhoon. The area vulnerable to flooding is classified in five zones as follows:

1st zone:	Reclaimed land developed for industry, vulnerable to storm
2nd zone:	Low-lying land currently being developed for housing and industry, vulnerable to flood
3rd zone:	Developed low-lying city area, vulnerable to flood
4th zone:	Lower-level city area, vulnerable to flood
5th zone:	Lower-level rural area, vulnerable to flood.

No residential housing or buildings are permitted within 50 metres from the seashore or a river in the first zone. Ground level of buildings in the first zone must be at least 4 m above mean low tide Nagoya Port (NP), 2 m in the second and fifth zones, and 1 m in the third and fourth zones. No wooden buildings may be constructed in the first zone and the floor height of residential buildings in the second, third and fifth zones must be more than 3.5 m above NP. All public buildings such as schools, hospitals, government offices, etc., and public facilities such as power stations and pumping stations must be waterproofed structures of concrete or steel. Except in the first zone, these public buildings should have a ground level of more than 2 m higher than NP.

3. Land Use Control

A laissez-faire approach for land use or urban development has resulted in such socio-economic problems as hampered economic activities, flood losses, congested road traffic and inconvenience of city life, etc. As early as 1974, one expert had made the following comments:

> Planning for the provision of public utilities and services are complicated by the fact that it is very difficult to anticipate future land use patterns. Electricity, water, telephone, drainage and sewerage authorities are all facing this problem and each would make his own estimates in his own way. This results in duplication and lack of co-ordination of work programmes of the various agencies and a lot of inconvenience and cost to the general public. It also results in spending most of the effort to solve the problems already created and very little in planning for the future. When various master plans are implemented individually by each agency, conflicts are unavoidable. This has resulted in an almost continuing process of master plan revisions which in turn lead to wastages and inconsistencies in the use of scarce financial and manpower resources of the country as a whole. The lack of a powerful and effective coordinating body is an important cause for such failures.

To solve such problems, the Department of Town and Country Planning (DTCP) of the Ministry of Interior made a long-ranged structural plan of Bangkok Metropolis and its Vicinity under the City Planning Act (1975), and held a public hearing from 1976 several times, aiming for its authorization. However, the DTCP was unable to get public consent up to now, faced by resistance from th people. The only successful application of land use control is for the Green Belt Area through building codes.

On the other hand, future flood damage will definitely not be alleviated, even if structural measures are provided. Retaining storm water in the Area must be included in the flood protection system in a very flat, high density area.

In the past, when the Master Plan Area was used as paddy fields with elevated, low-density residences, storm water was safely stored in the paddy fields, resulting in small discharge of the klongs. However, as urbanization progressed in the eastern suburbs, paddy fields were converted into residential, industrial and commercial lots by reclamation, causing high discharge (Fig. I.1).

As water supply system could not keep pace with urbanization, land subsidence took pace in the urbanized area. As a result, the elevated land which had become flood-free before land subsidence, became again vulnerable to flooding. Further, owing to urbanization, flood damage potential increased largely. It can be said that landfill is effective to some degree and that landfills cause adverse effect. To utilize landfill for alleviation of flood damage, it must be planned in one total system. The practical approach is enforcement of land use control. Without land use control, the proposed structural measures will not work well because they are based on the proposed land use plan and retaining storm water is inevitable in the low-lying Master Plan Area, and land use plan is combined with the proposed structural measures.

For the Preliminary Study Area (including the Master Plan Area), the following land use control is recommended:

(1) Urban development is allowed only within the Master Plan Area and not in the urban control area until the year 2000 (Refer to Appendix E).

(2) Such public facilities as drainage, water supply and electricity are proposed to be covered basically in the Master Plan Area, not in the urban control area.

(3) Urbanized area (220 km^2 out of the Master Plan Area of 260 km^2) is proposed to be elevated to the same level of the existing urbanized areas or to be built in stilt-type houses.

(4) Retention basin within future estates should be encouraged in order to provide storm water storage capacity.

(5) New estates in the retention area will be permitted provided existing water storage capacity is maintained in such ways as housing on stilts or provision of retention basin. Retention basin with a capacity of 1,000 m^3 per ha (160 m^3 per rai) is recommended in the Area, the value of which is derived under the condition that it has storage capacity of 3-day rainfall in 2-year return period (about 100 mm depth). These retention areas will be used for other purposes as park, sports ground, etc., during dry season as shown in Figs. I.2 to I.4.

(6) All roads, existing and new, are proposed to be elevated at about 1 metre MSL (as of 1984) in order to maintain smooth traffic flow during floods.

4. Indentification and Publcizing of Flood-prone Area

The flood-prone area map is an essential tool for the dissemination of public information on floods and enforcement of land use plan for mitigation of flood damage. The 1984 flood-prone area map or flood risk map (Fig. I.5) is depicted for a 5-year frequency rainfall under urgent implementation measures, considered to be useful until the proposed structural measures are completed. The observed flood areas in september 29, 1984 and October 7, 1984 as shown in Fig. I.6 is also useful.

If there is no increase in pump capacity or improvement of klongs, land subsidence is expected to continue, followed by increase in flooding with the passage of time. Fig. I.7 shows the flood-prone areas in the year 2000, with land subsidence taken into consideration.

The natural low areas (Fig. I.8) which are intended to store flood water, are planned not to be urbanized; instead, they are to be used as paddy field, open space, park, fish pond, etc.

There are many methods for dissemination of flood-prone area maps as follows.

(1) Direct distribution to the government agency
(2) Direct distribution to developers
(3) Mass media such as newspaper, TV and radio
(4) Bulletin board on sites, including information on flood marks (Fig. I.9)
(5) Others

5. Encouragement of Individual Flood-Proofing Measures

Houses will continue to be damaged by flooding until structural measures are completed Further, even after structural measures are completed, flooding will still occur from heavy rainfalls exceeding estimated 2-year planned rainfall frequency. Consequently, individual flood-proofing measures now being taken extensively, continue to be encouraged.

Examples of flood-proofing measures follow (Fig. I.10):

(1) Permanent Type

- Landfill
- Construction of houses on stilts
- Construction of Pilottie-style houses
- Construction of flood-proof walls and entrance

(2) Temporary Type

- Blockage of water by building dikes of bricks, sandbags, etc.
- Installation of pump

6. 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.

6.1 Existing Activities

1) Water Level of the Chao Phraya River

The Flood Forecasting Center (FFC), established in 1979 has a permanent center at the Electricity Generating Authority of Thailand (EGAT). FFC reports weekly 7-day forecasts on the Chao Phraya River and its tributaries consisting of;

- Inflows into the multi-purpose reservoirs
- Discharge at the fork of tributaries (Nakhon Sawan Province), and
- Maximum water level at the Memorial Bridge in Bangkok

Also, the Chao Phraya River water levels at and near the Master Plan Area are recorded every day at the following stations of the relevant agencies:

- . Bangkok Port (27 km from the river mouth; Port Authority)
- . Memorial Bridge (47 km); RID
- . Near Memorial Bridge (48 km); Hydrological Department, Royal Navy
- . Sam Saen (55 km); RID
- . Rama VI Bridge (58 km); RID
- . Pak Kret (72 km); RID

2) Water Level of the Klongs

DDS has the control center, where water levels of various klongs, mainly in the central area (and hourly rainfall data in 25 places) have been collected by walkie-talkie, telephone and facsimile. RID has also collected water level records at control gates for long periods. In addition, 11 self-recorded water level gauges and two rainfall gauges were installed in 1983 in Eastern Suburban-Bangkok by the Study Team.

3) Meteorological Information

The Meteorological Department is mainly in charge of meteorological and hydrometeorological observations, weather forecasting and weather warning including flood forecasting. At present, the basic observation network for weather forecast consists of 66 surface observational stations, two 10-cm and five 5-cm weather radars, and the systems for Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT), Satellite Imaginary Receiving Equipment, etc. All weather observation data in the national network come into Bangkok through Single Side Band (SSB). The meteorological service relies mainly on the telephone and daily weather map printout to issue warnings to the mass media and relevant agencies.

4) Flood Warning

The Civil Defence Division of the Local Administration Department (LAD) is responsible for planning of the disaster prevention, disseminating warnings to the local government and other organizations and informing the general public.

6.2 Establishment of Forecasting and Warning System

1) Necessary Data

Relevant information should be collected at the control center of DDS. The required information consists of:

. Rainfall
  - Surface observation stations (25 stations) ----- DDS
  - Surface observation stations in Bangkok and its vicinities ----- Meteorological Department
  - Water radars ----- Meteorological Department

. Water level of Klong in Bangkok and its vicinities
  - DDS
  - RID

. Water level of the Chao Phraya River

- Flood Control Center at EGAT
- RID
- Port Authority
- Royal Navy

2) Communication System

Communication system is of vital importance. Establishment and proper operation and maintenance of such communication system constitutes an essential component of the flood protection plan. Fig. I.11 is an example of a communication system. The telecommunication facilities used for this purpose should be capable of withstanding heavy rains or floods.

As for the mode of communication, landline circuits are commonly used. It is obviously economical to use existing landline circuits, provided they are well maintained. However, experience shows that landline circuits are not always sufficiently reliable and difficult maintenance are involved practically. In some countries, the warning system is linked by direct telephone lines which are more reliable and have proved to be very useful in an emergency. Today, radio communication systems (HF, VHF, UHF) are being widely adopted for reliable communication and present fewer difficulties in maintenance. Japan, for example, has already established an exclusive UHF communication system in the Ministry of Construction which links all provincial offices. The UHF system is supplemented by hundreds of mobiles and portable VHF communication sets.

3) Data Process and Analysis

Upon receiving necessary information, flood will be forecast of then forecast of flood status, depth, etc. is relayed to the public and relevant agencies. Development of method of flood forecasting is necessary, such as one or both of the following:

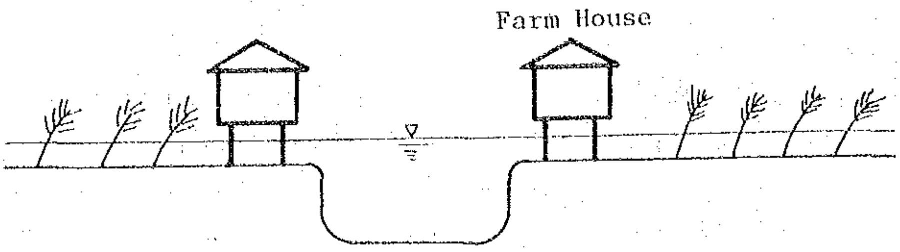
- Hydrological simulation
- Correlation between historical flooding and existing hydrological data

7. Flood Fighting

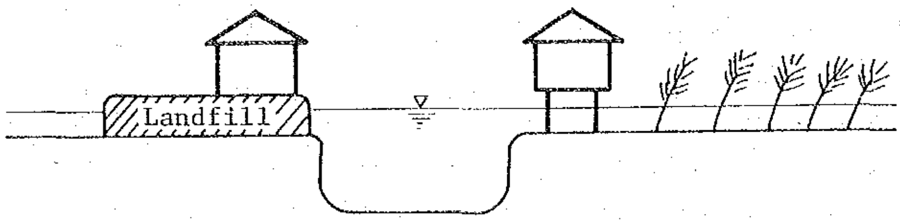
Flood fighting can be defined as the execution of emergency measures against disaster at times of flood. The Civil Defence Division of the Local Administration Department (LAD) is the representative of the Civil Defence Secretariat according to the Civil Defence Act (1979). Secretariat must make two principle plans; 1) public disaster prevention and relief plan of the people and of government facilities. The civil defence volunteers have been also set up to assist the authorities. At present volunteers (over 600,000 persons) are well trained to support civil defence officers.

A combination of sufficient trained manpower, adequate stocks of material, telecommunication equipment, construction machinery and vehicles for transport are necessary for effective flood fighting operations. The volunteers should be equipped with walkie-talkies for ease of communication. Warehouses or depots should be constructed along the river embankment so that tools such as pickaxes, shovels, sandbags, lumber, ropes and wire are readily available for emergency use.

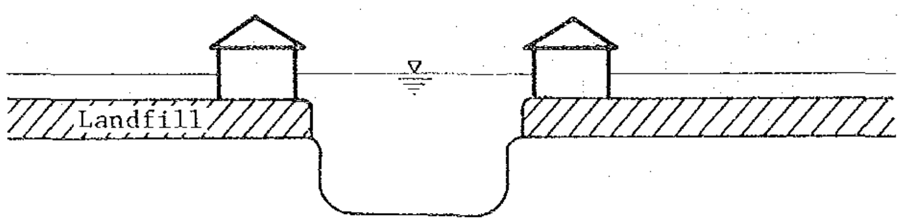
1. Past Period (~ 1960)



2. Beginning of Urbanization (1960 ~ 1970)



3. Urbanization progress (1970 ~ Now) With Flooding



4. Urbanization With Flood Protection Measures (From now)

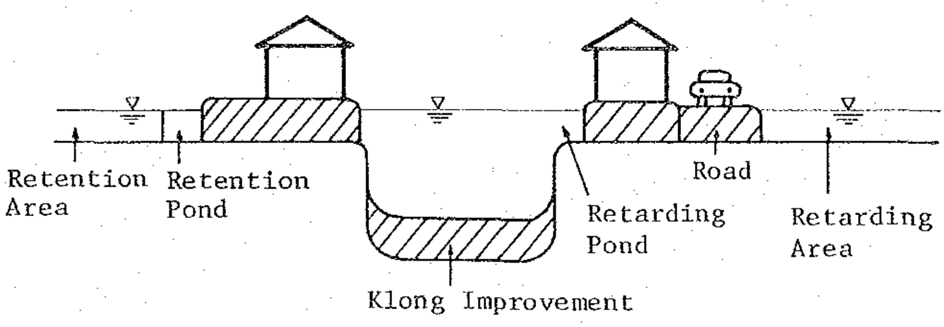


Fig. I.1	PROGRESS IN FLOOD PROTECTION MEASURES WITH URBAN DEVELOPMENT

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

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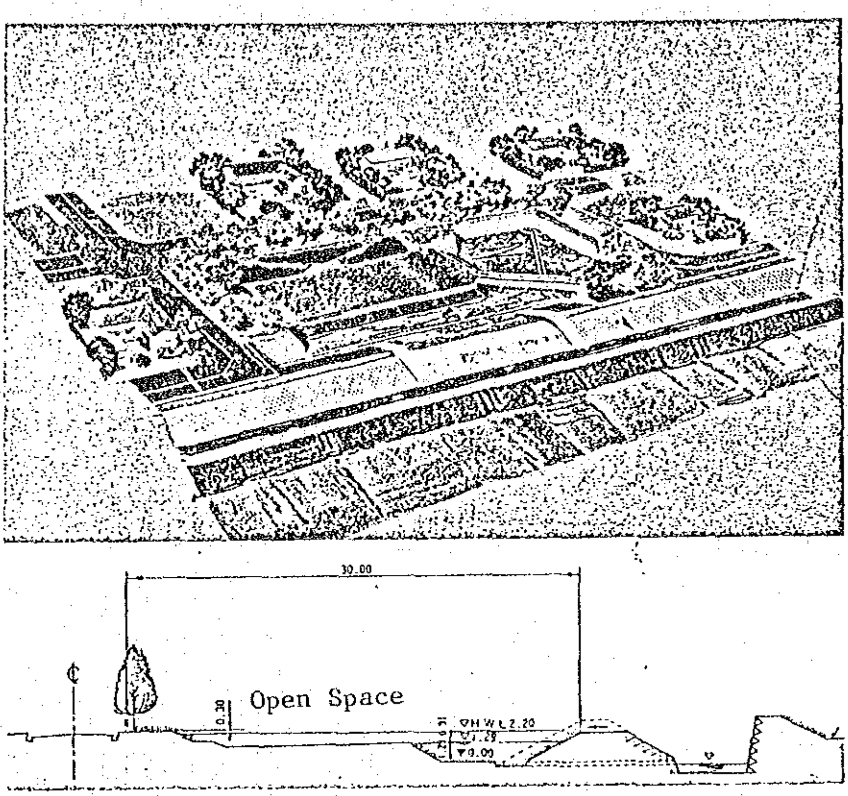
Park



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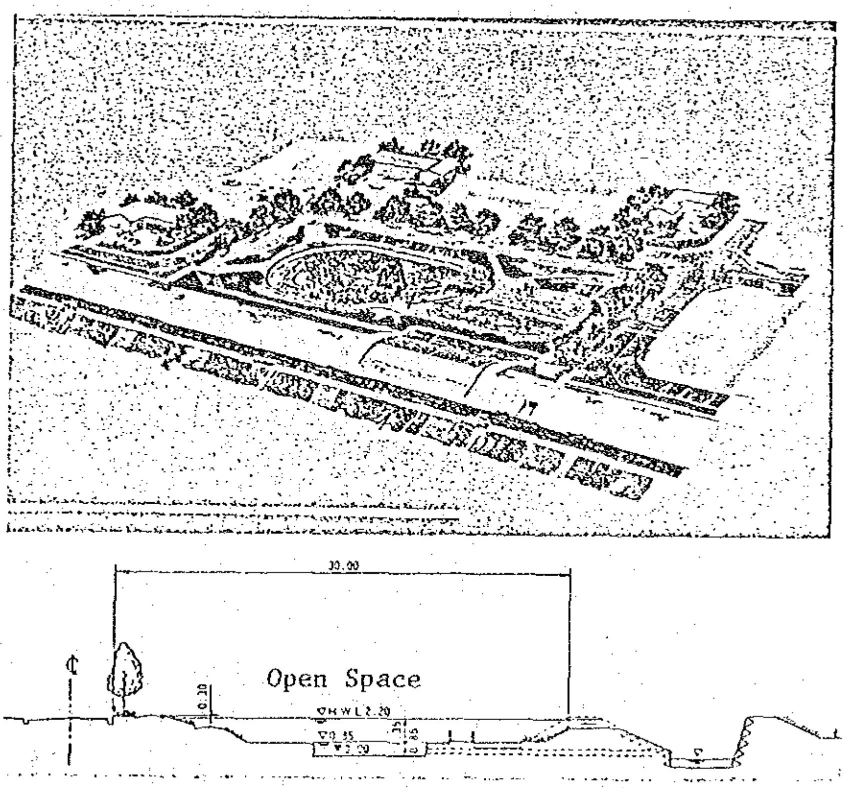
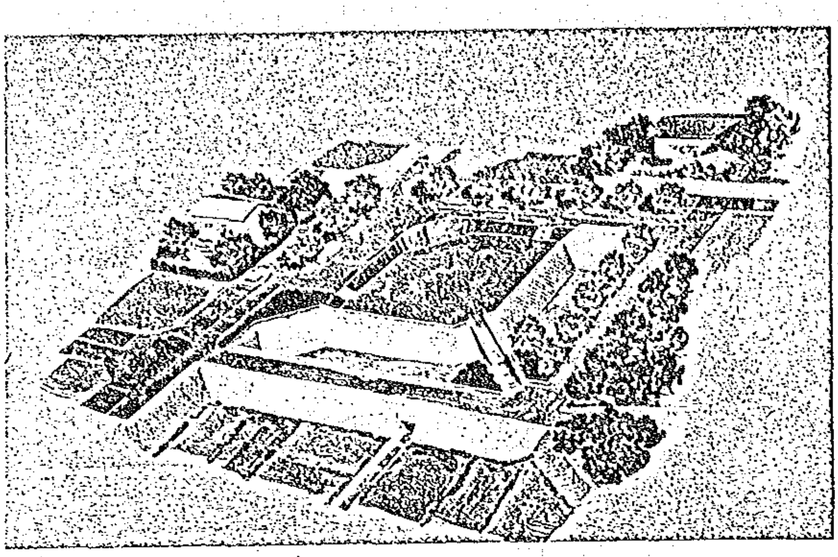
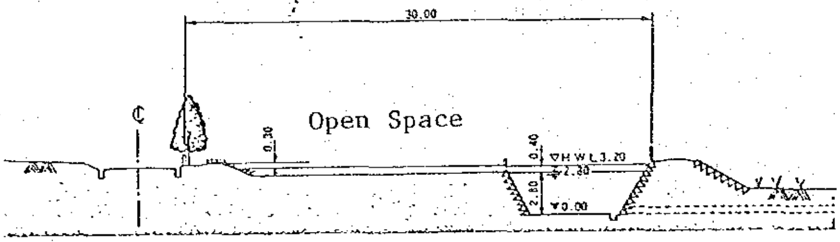


Fig. I.2 EXAMPLE OF MULTI-PURPOSE RETENTION AREA (1)

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

Park





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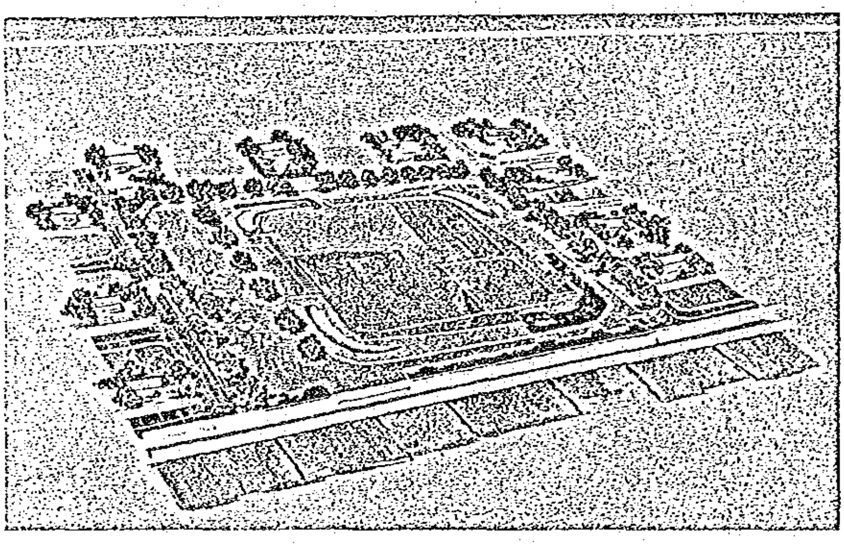


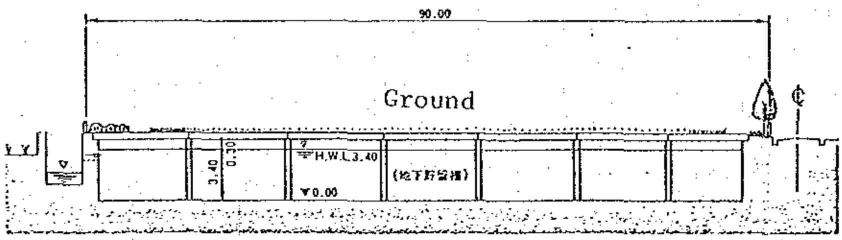
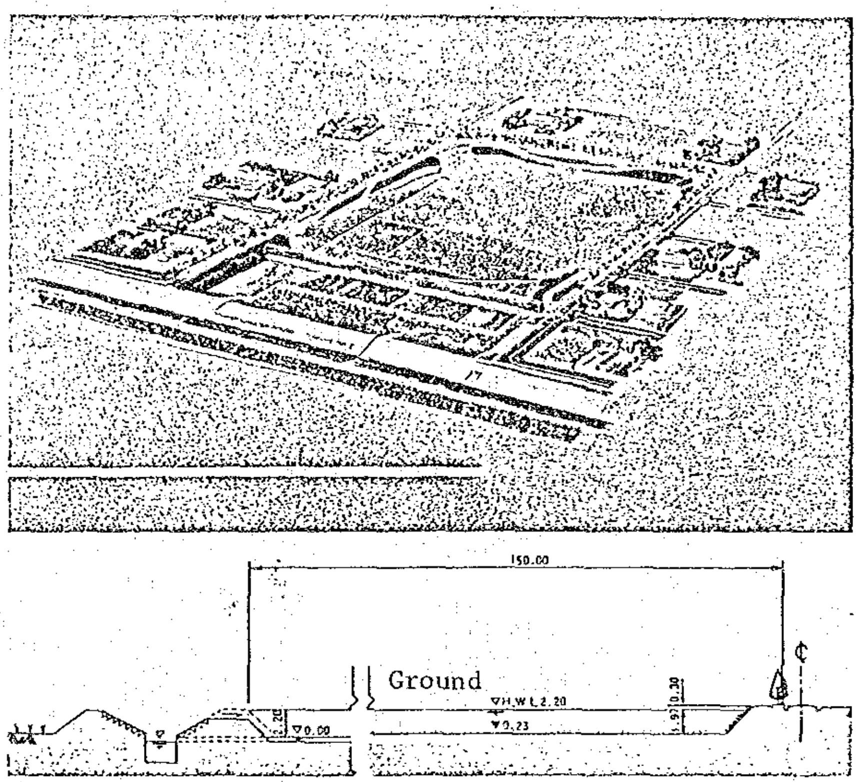


Fig. I.3	EXAMPLE OF MULTI-PURPOSE RETENTION AREA (2)

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

Park



Sport Center

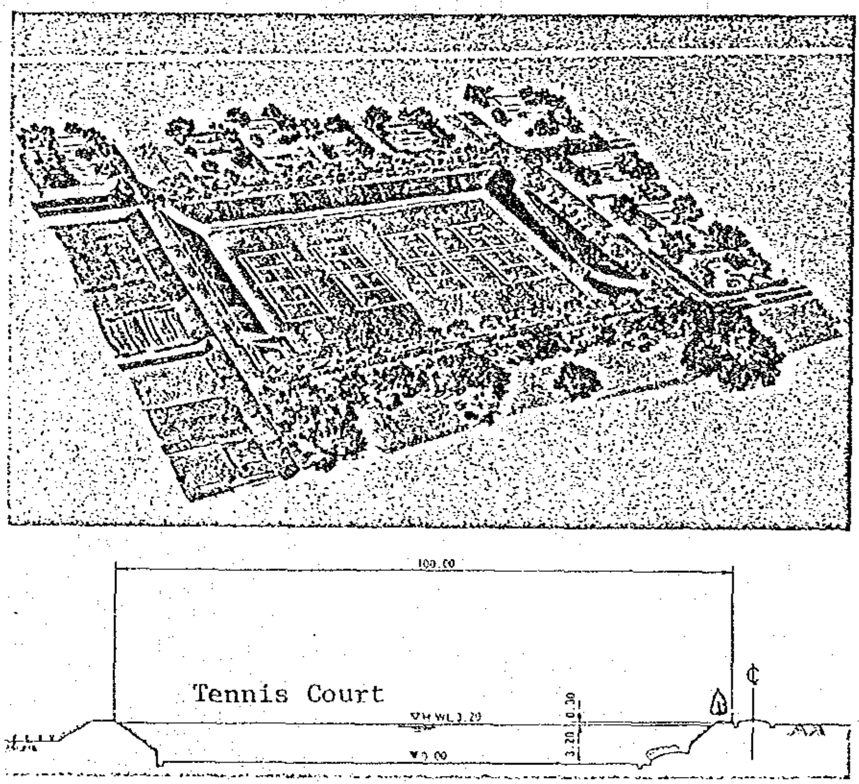


Fig. I.4	EXAMPLE OF MULTI-PURPOSE RETENTION AREA (3)

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

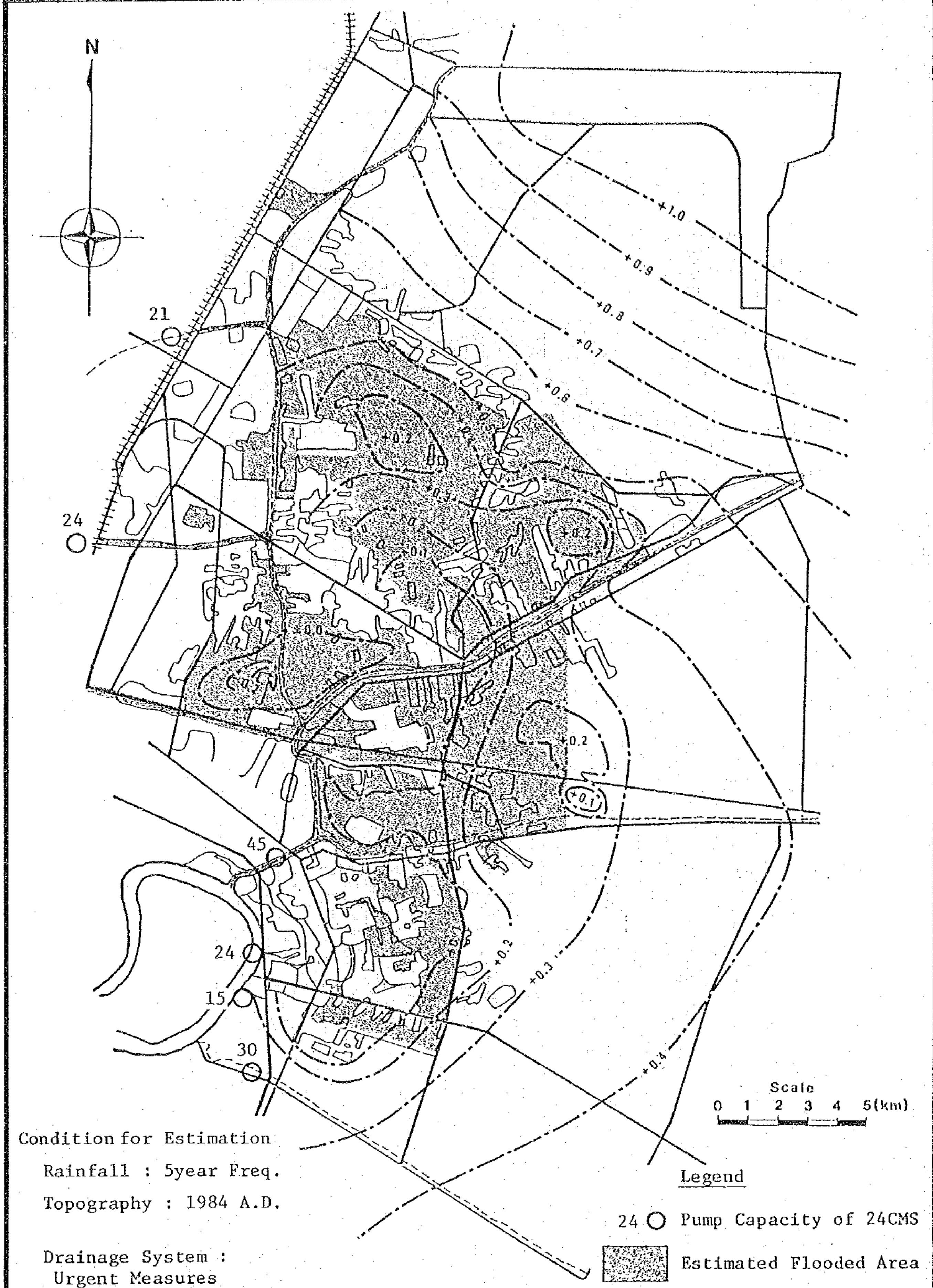


Fig. I.5 FLOOD RISK MAP (IN 1984, 5 YEAR FREQUENCY RAINFALL)

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

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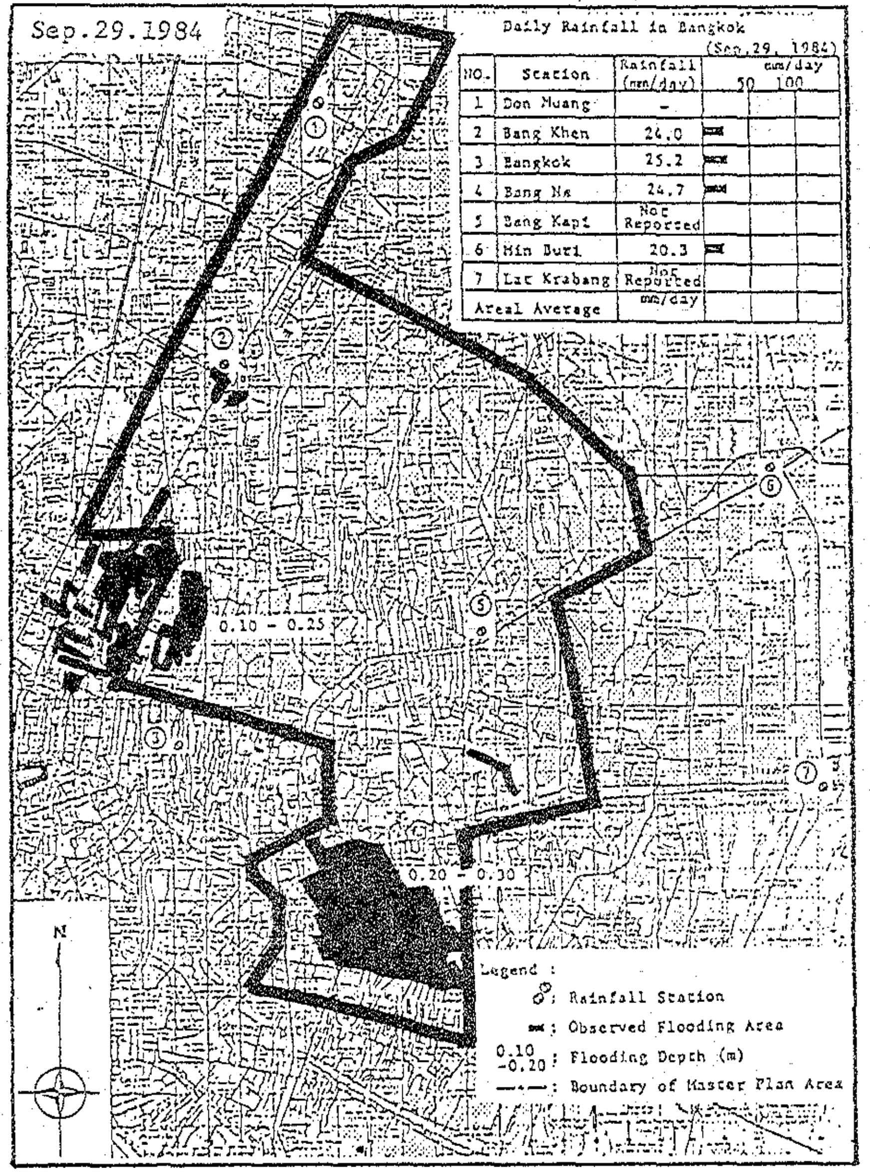

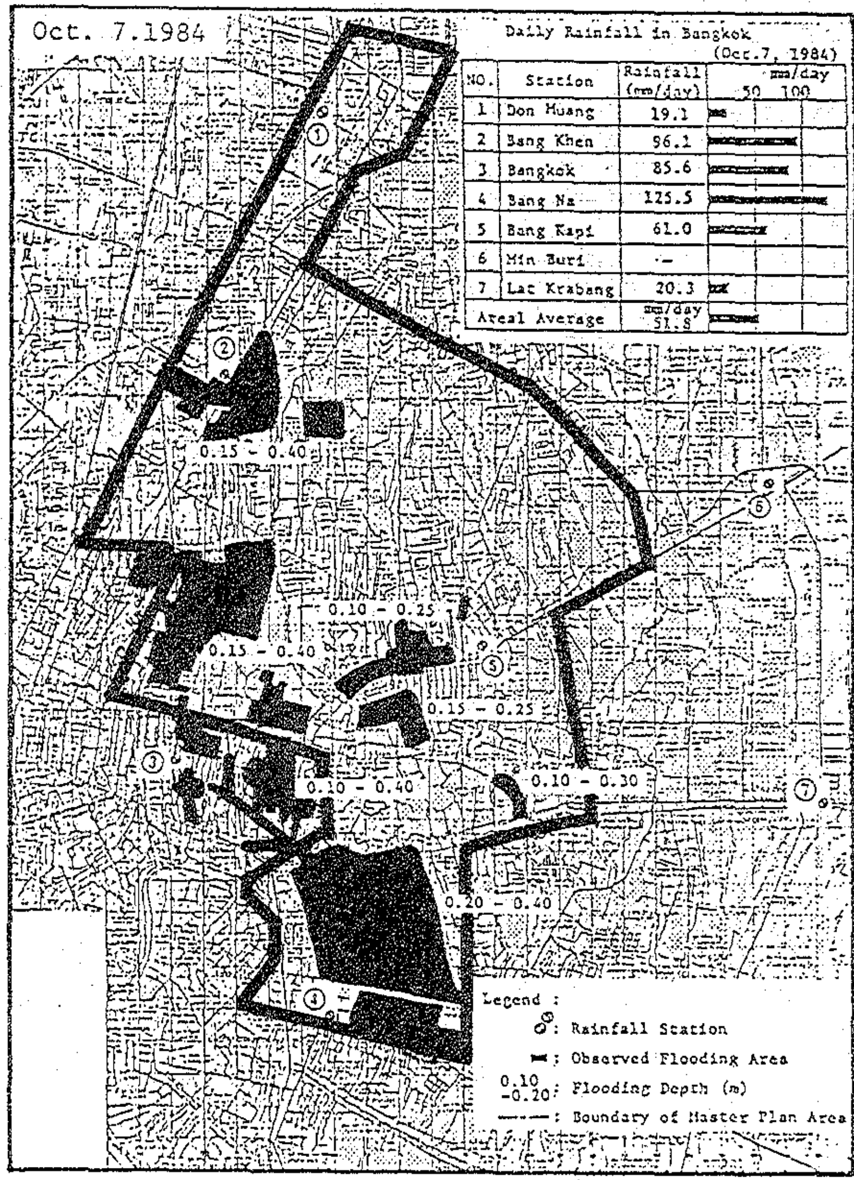

Fig. I.6 FLOOD RISK MAP (OBSERVED FLOOD AREA IN 1984)

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

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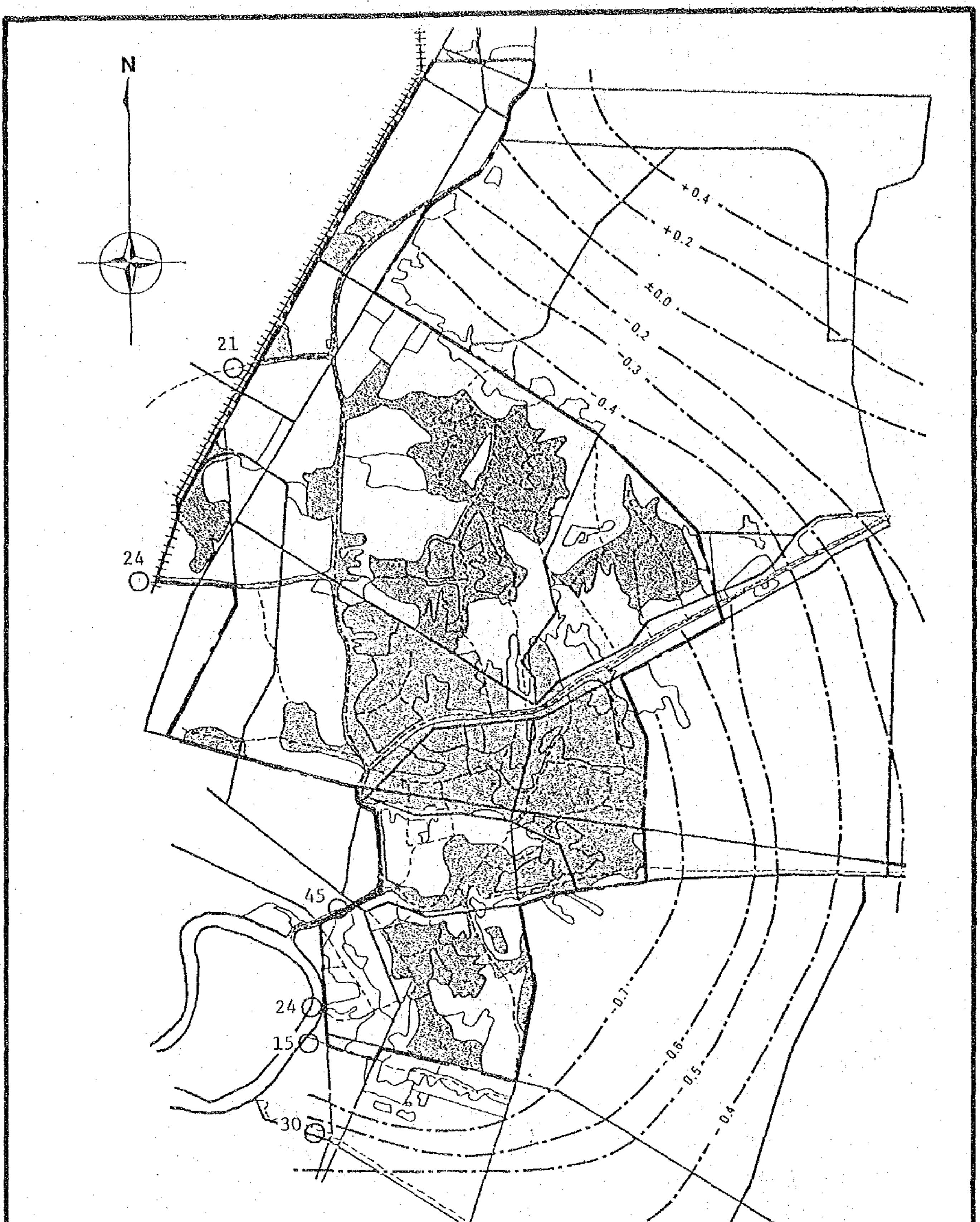


Fig. I.7 FLOOD RISK MAP (IN 2000, 5-YEAR FREQUENCY RAINFALL)

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

Proposed Scale of Retarding Pond

Polder	No.	A	V	Zmax.a	Z_i	Remarks
Bang Khen Bang Sue	1	2.8	1,038	+0.30	-1.50	
Phra Khanong –	2	7.0	2,203	+0.20	-1.80	
	3	8.0	2.420	+0.10	-2.80	
Saen Saep	4	9.6	2.166	+0.00	-1.80	
	5	2.3	0.920	-0.20	-1.80	
	6	1.3	0.406	-0.20	-1.80	
	7	2.0	0.625	-0.20	-1.80	
	8	8.8	2.194	-0.30	-1.80	
	9	2.5	0.490	-0.30	-1.80	
	10	3.7	0.737	-0.30	-1.80	
Bang Na	11	2.0	0.418	-0.60	-1.80	
Total		50.0	13.617			

Note ; No. : Number of Retarding Pond
A : Capacaity Area (km^2)
V : Storage Capacity
Zmax.a: Allowable Maximum Water Level (unit above M.S.L in meter)
Z_i : Initial Water Level (unit above M.S.L in meter)

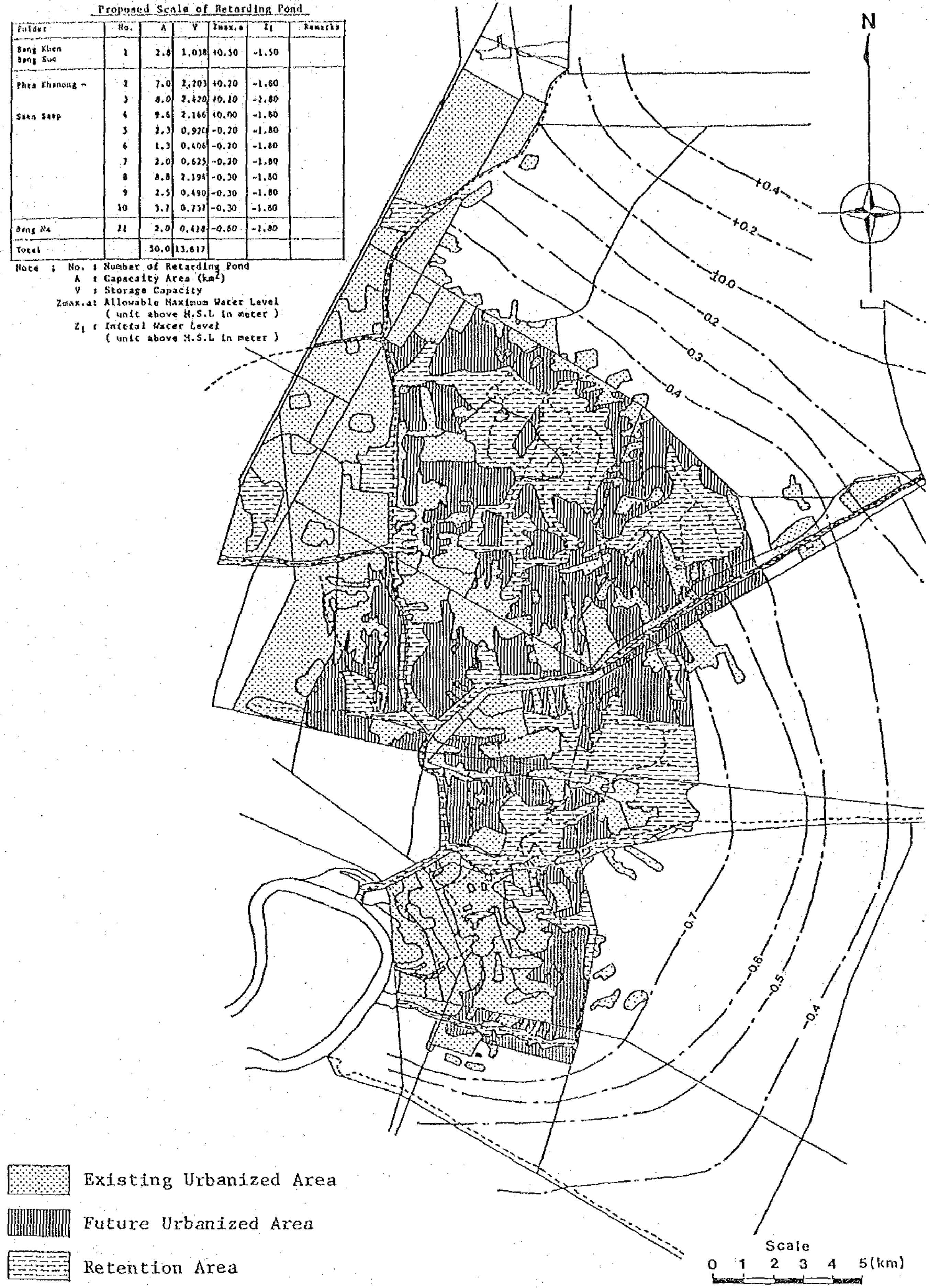


Fig. I.8 LOCATION OF RETENTION AREA

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

JICA 2528B.E 1985A.D

TYPICAL TYPE OF NOTICE BOARD

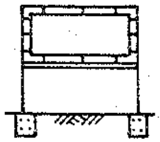
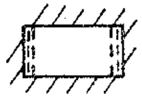
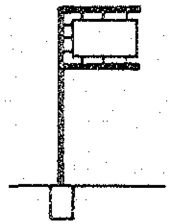
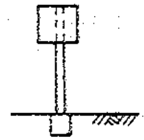
Type	Large (1)	Large (2)	Large (3)	Small (1)	Small (2)
Kind					
Installed Place	Any sites	On wall of the public facilities	Above road	On electric pole	Any sites
Advantage	. Can install any site . Big information	. Cheap . Big information		. Cheap . Easy to install . Can install many sites	. Can install any site
Disadvantage			. Difficult to see	. Little information	. Little information

Fig. I.9 TYPICAL TYPE OF BULLETIN BOARD

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

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TYPICAL TYPES OF FLOOD-PROOFING HOUSE

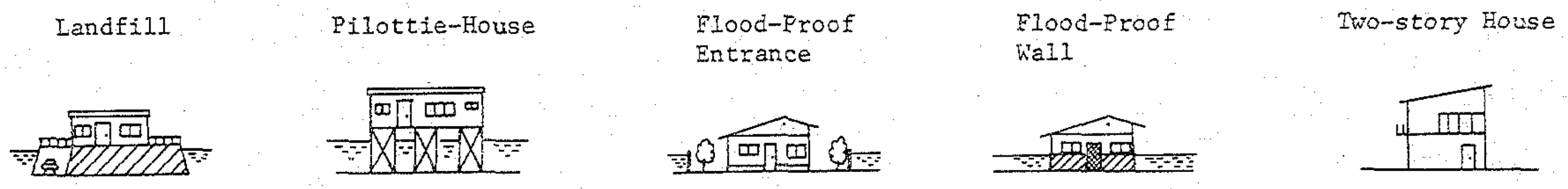

Fig. I.10 TYPICAL TYPES OF FLOOD-PROOFING HOUSE

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

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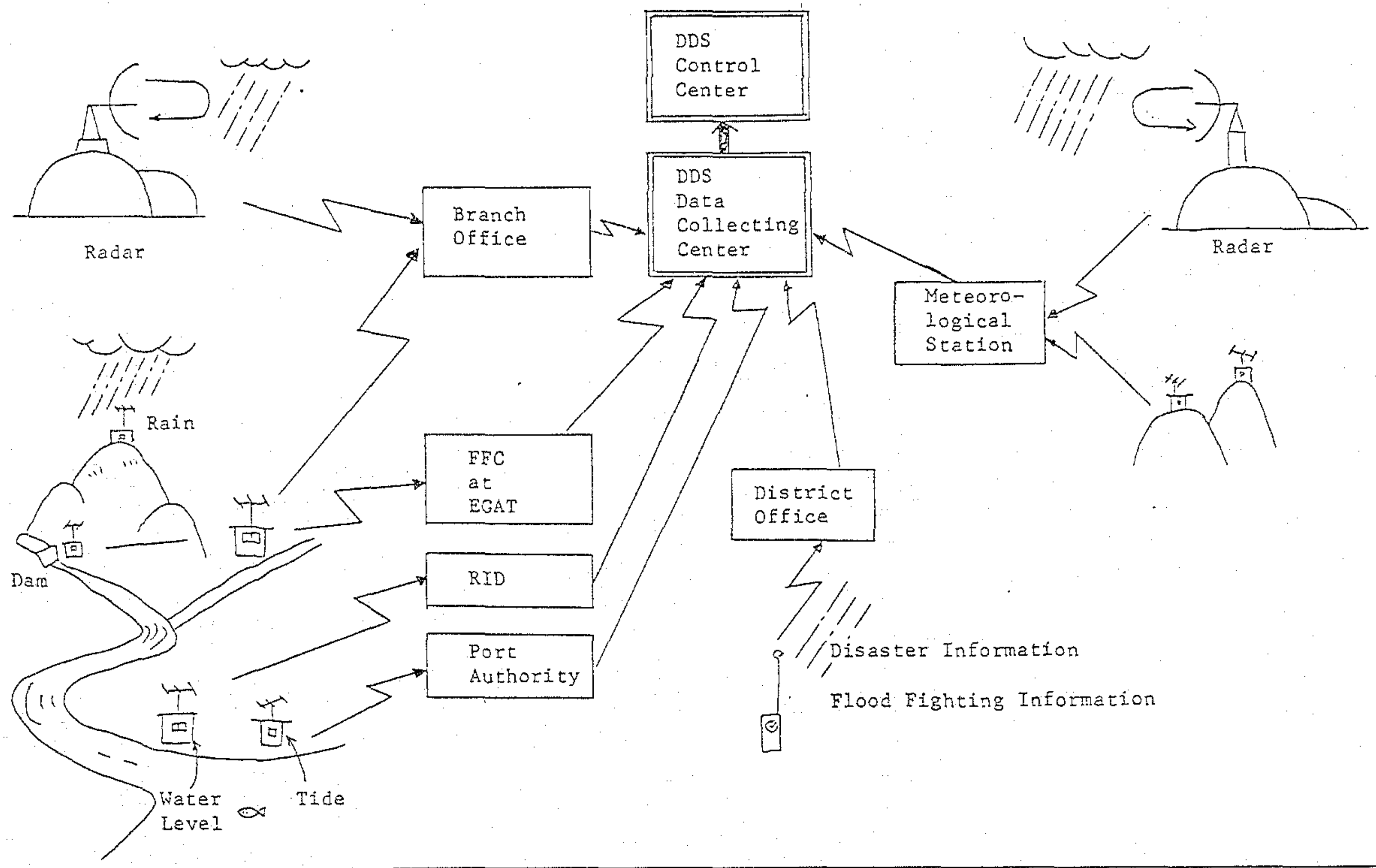

Fig. I.11 DATA COLLECTION SYSTEM

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

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APPENDIX J

CONSTRUCTION MATERIALS AND METHODS

APPENDIX J CONSTRUCTION MATERIALS AND METHODS

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Appendix J CONSTRUCTION MATERIALS AND METHODS

This Appendix describes the existing conditions affecting the construction of the facilities and proposes construction procedures and types of materials which can be used to carry out the Project.

1. General

The existing conditions affecting construction of the flood protection and drainage facilities are:

1.1 Soils

The boring logs indicate a very weak subsoil formation in the Master Plan Area. The zone of excavation for the proposed new facilities extends from the existing ground surface to a depth of approximately 8 metres and tip of a foundation pile will reach approximate 20 metres below ground level. Within this depth, subsoil can be classified into three layers, with the following characteristics:

1) Top layer of 1 to 2 metres depth:
Top layer consists of earth fill or natural topsoil of 1 to 2 metres depth of relatively stiff brown clay. This clay becomes soft after inundation.

2) Second layer of about 12 metres depth:
A soft to very soft, compressible grey clay, normally consolidated.

3) Below second layer:
A medium to stiff, compressible grey clay, normally consolidated.

1.2 Ground-Water Levels

A groundwater level in Bangkok varies from about 1.0 metre above MSL during the wet season to about MSL during the dry season. The mean water level in the Chao Phraya River at Bangkok is about 0.3 metre. From this it is obvious that groundwater will be encountered even in a shallow excavations. The quantity of water in an excavation is normally not large, because of the low permeability of the clay.

1.3 Climate

The climate of the area is described in detail in Appendix A. Average wind velocity is low, and strong winds are rare. Temperatures remain fairly high and relatively constant throughout the year with average monthly temperatures varying less than 5°C from December to April. The extreme temperatures recorded are 18.9°C as lowest and 36.1°C as the highest.

Of all the climatic conditions, rainfall most directly affects construction. Usually during dry season there are one or more days of rain each month, but during the wet season there may be rain on as many as 21 days of the month. From May through October it normally rains an average of 18.5 days per month. This rainfall is usually intense and of relatively short duration. Except for heavy rainfall periods construction can usually continue on a year-around basis, provided that effective de-watering procedures are utilized.

1.4 Work Methods

Mechanical construction equipment of almost any type is available in Bangkok. In addition, a large work force of skills and trades is available. The availability of mechanical equipment, skilled trades and almost unlimited common labour permits a broad scope in the methods of construction.

2. Construction Materials

Most of the materials of construction required for the Project are produced/manufactured in Thailand, and are available in adequate quantities.

2.1 Concrete Products

Reinforced concrete pipes and other concrete products such as prestressed piles, poles, slabs and beams are manufactured in quantity in Bangkok in a large modern plant efficiently operated with reasonably good quality control. These concrete products are manufactured equivalent to the specifications of Japanese Industrial Standard (JIS) and are available in a wide range of sizes and classes.

2.2 Cement

Portland cement production in Thailand is increasing year by year. There are now three factories capable of an annual production of over 1.5 million tons of cement. This is substantially more than required to meet the local demand and cement is currently being exported. Cement is made in three types: Standard Portland cement, Rapid Hardening cement (quick setting), and High Silica cement.

2.3 Concrete Aggregates

Concrete aggregates are available in quantity. Coarse aggregate is obtained by rock crushing operations in the mountainous regions to the north, northeast, and south of Bangkok. Sand is customarily obtained from the north where it is dredged from the rivers and floated by barge downstream to meet the demands of the Bangkok area.

2.4 Reinforcing Steel Bars

Reinforcing steel bars are manufactured in a steel mill approximately 105 kilometres north of Bangkok. The bars are manufactured from imported ingots and from scrap iron and steel. Plain bars are manufactured in quantity to meet most of the demands of the country. Deformed bars, however, are manufactured in limited quantity and the output does not meet the demand. As a result, a substantial quantity of deformed reinforcing bars must be imported.

2.5 Structural Steel Shapes

Structural steel shapes are not manufactured in Thailand nor are there any metal fabricators in large scale. At the present time, therefore, structural shapes and most fabricated metals must be imported. The same is true of heavy mechanical equipment and machinery such as pumps, engines, electric motors, electrical switchgear, construction equipment and machinery and steel sheet, all of which must be imported.

2.6 Others

Common building materials such as wood, lumber, bricks, roofing and floor tiles are readily available from the local market.