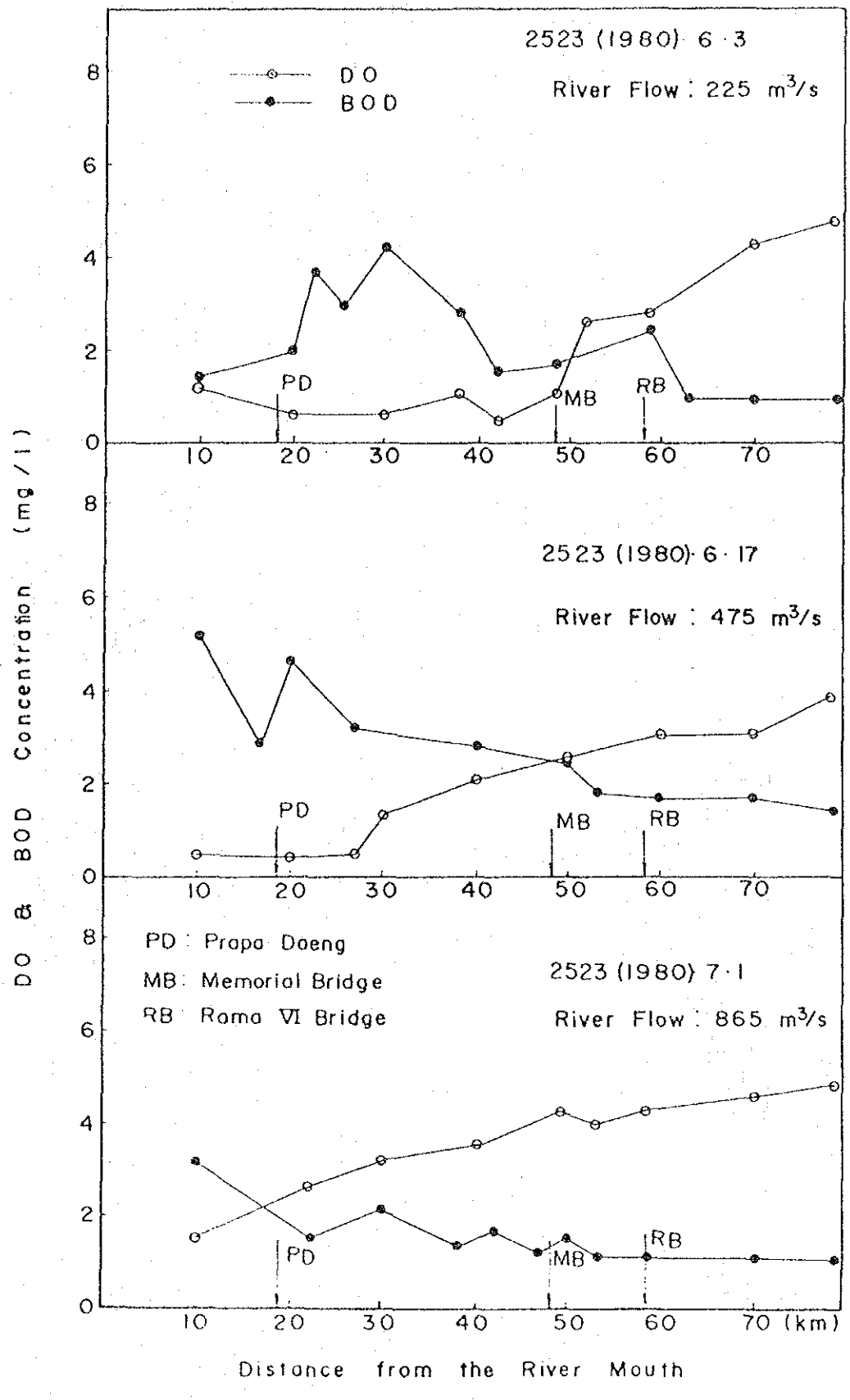
Fig. A.14 MWWA'S WATER SUPPLY SYSTEM AND AREA SERVED

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

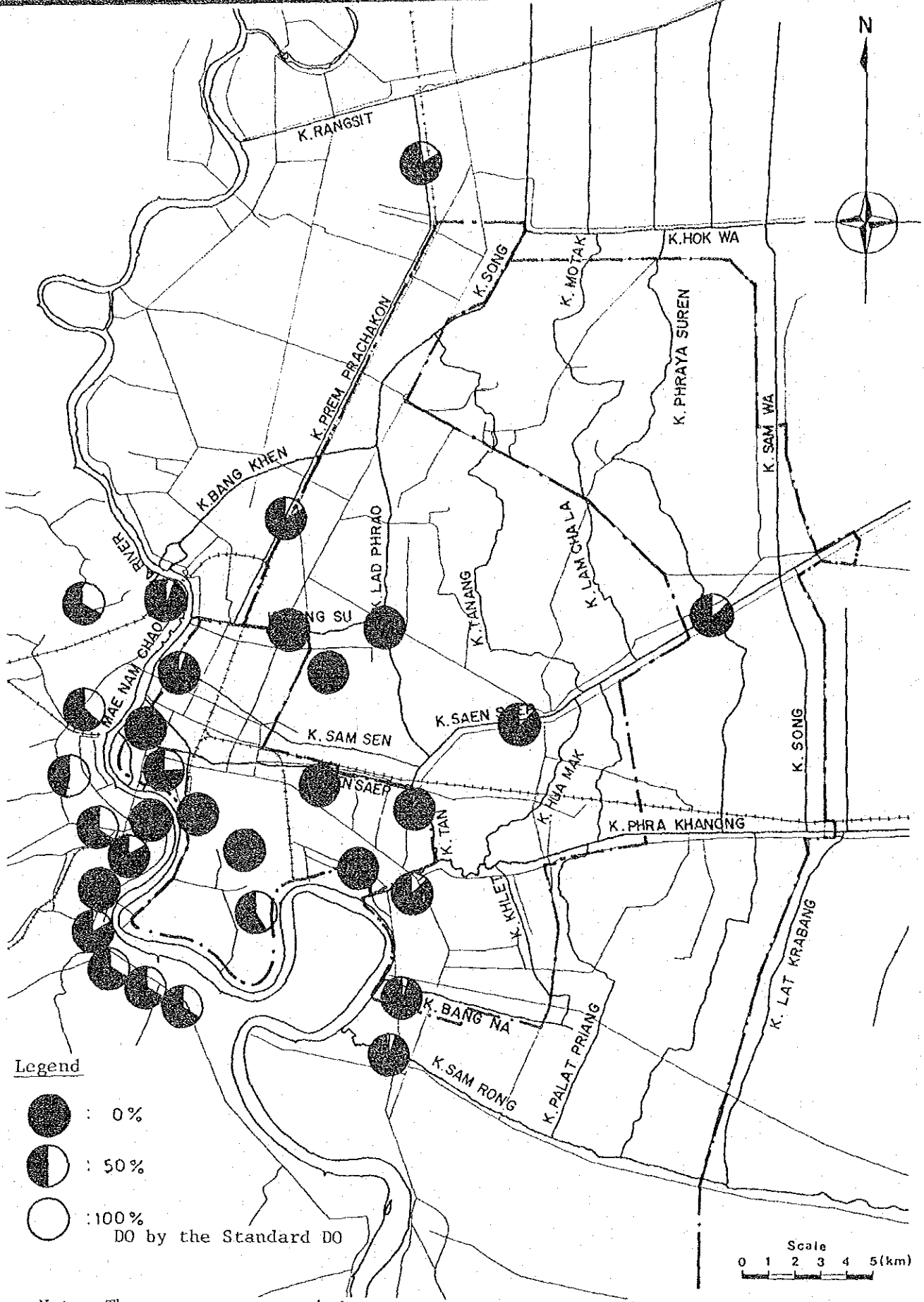
JICA 2528B.E 1985A.D



[Source ; NEB and AIT]

Fig. A.15 DO AND BOD CONTENTS IN THE CHAO PHRAYA RIVER

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

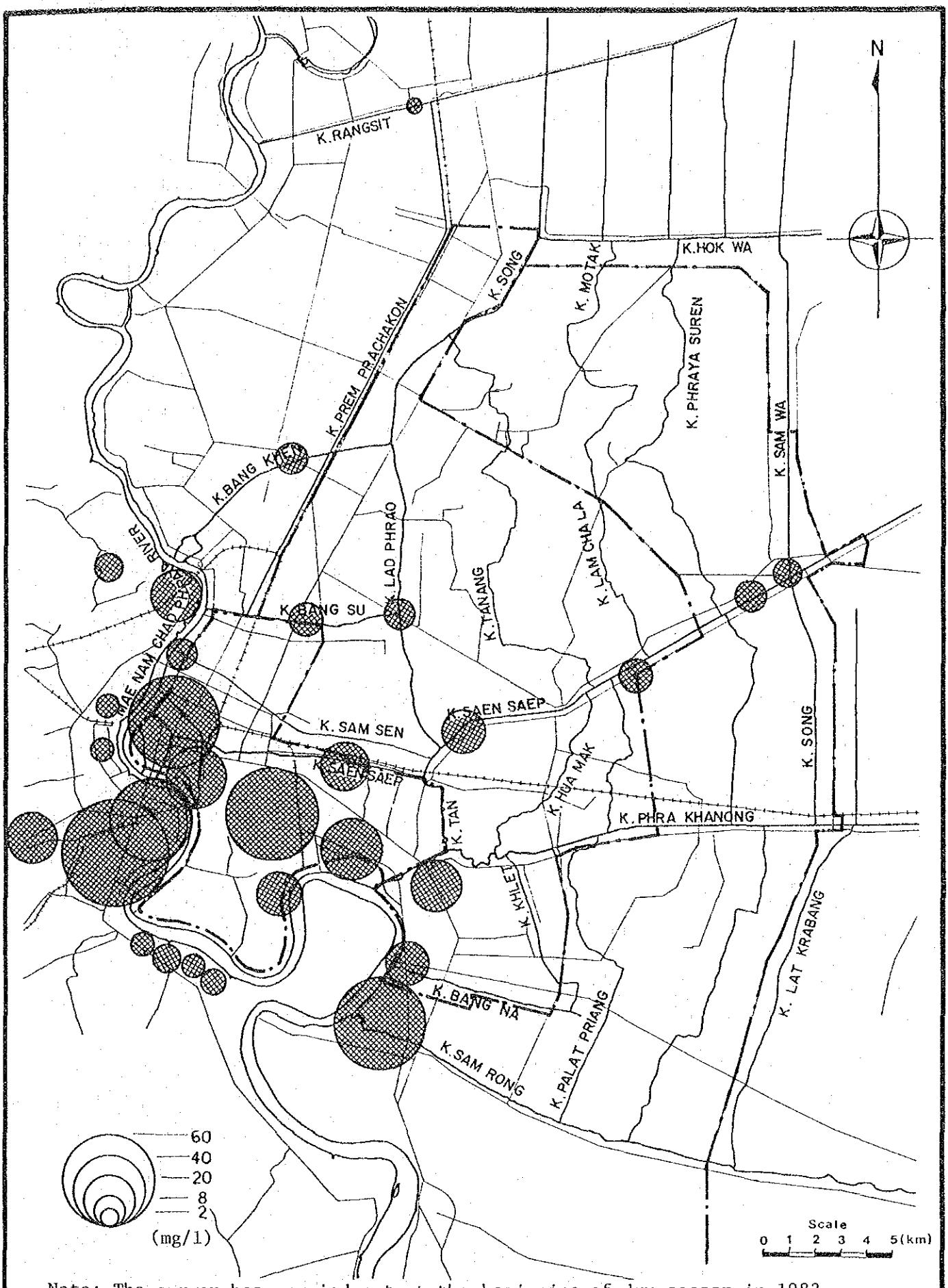


Note: The survey was carried out at the beginning of the dry season in 1983.

Fig. A.16 DISSOLVED OXYGEN (DO) IN BANGKOK

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

JICA 2528B.E 1985A.D

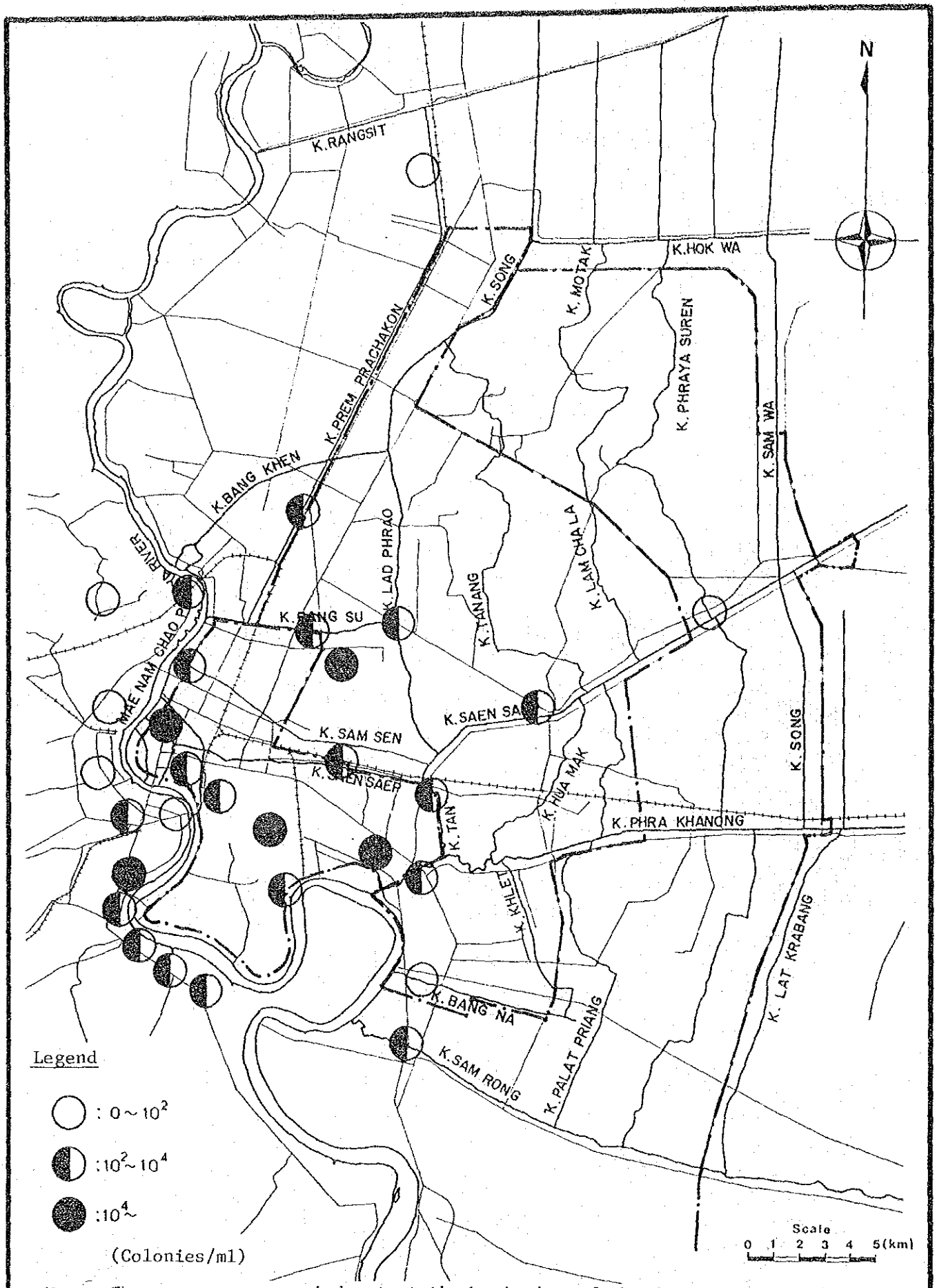


Note: The survey has carried out at the beginning of dry season in 1983.

Fig. A.17 BIOCHEMICAL OXYGEN DEMAND (BOD) IN BANGKOK

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

JICA 2528B.E 1985A.D

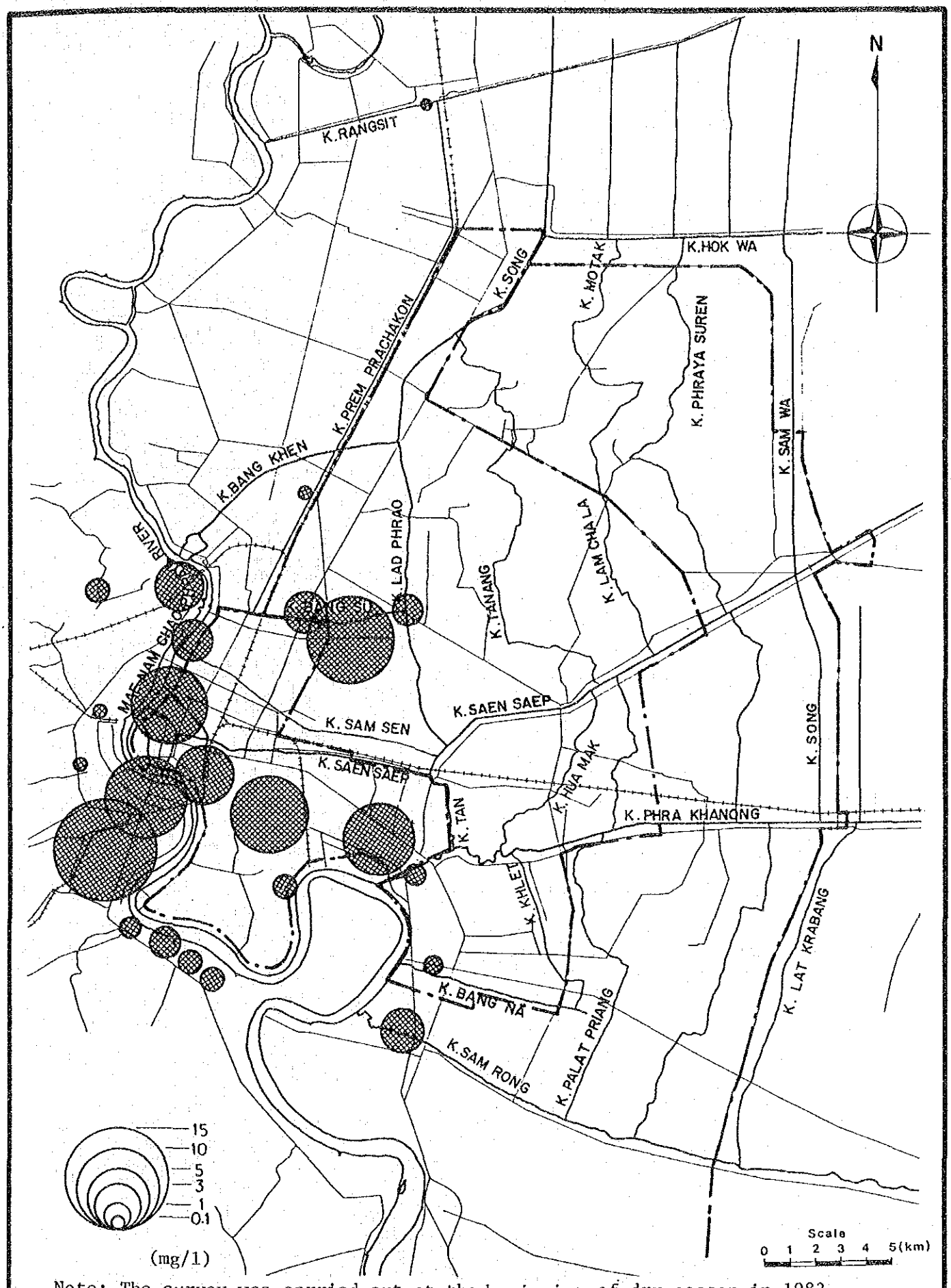


Note: The survey was carried out at the beginning of the dry season in 1983.

Fig. A.18 COLIFORMS IN BANGKOK

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

JICA 2528B.E. 1985A.D



Note: The survey was carried out at the beginning of dry season in 1983.

Fig. A.19	AMMONIUM NITROGEN (NH_4^+ - N) IN BANGKOK

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

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APPENDIX B

PAST FLOODING AND RELEVANT STUDIES

APPENDIX B PAST FLOODING

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Appendix B PAST FLOODING AND RELEVANT STUDIES

From the beginning of the history of Bangkok, the reign of King Rama I, floods have been one of the big problems in the Capital due to its flat low-lying ground area.

On the other hand inundated water has been used for irrigation of paddy fields in the vast Central Plain, including the Eastern Suburban-Bangkok. However, urbanization coupled with land subsidence caused by pumping up of groundwater in the Eastern Suburaban-Bangkok, has induced flood problems almost every year since 1980. In 1983, the lower Central Plain suffered the largest flood damage since 1942, particularly, the flood in the Eastern Suburban-Bangkok was the severest. The maximum flood depth was about 80 cm and the duration was over three months.

1. Flood Damage

1.1 Flood Damage in Bangkok

Several attempts by different organizations were made to estimate the flood damage in the central Bangkok area. These estimates are shown in Table B.1. Flood in Greater Bangkok Area and its satellite provinces (Nonthaburi, Pathum Thani, Samut Prakan, Nakhon Pathom and Samut Sakhon) in 1983 was extensive as shown in Fig. B.1. The flood damage was estimated by the National Statistical Office to be 6,597 million Baht, consisting of 4,868 million Baht to dwelling houses, 1,208 million Baht to industry and commerce, and 521 million in the government sector. 4,397 million Baht damage was cawed in Bangkok Metropolis excluding the government sector.

1.2 Flood Damage in Eastern Suburban-Bangkok

1) Flood Damage in 1982

At the stage of the Preliminary Study, the JICA Study Team conducted a flood damage survey on the 1982 flood. The damage was estimated to be 384 million Baht, consisting of direct damage (260 million Baht), indirect damage (41 million Baht) and uncertain damage (82 million Baht).

Table B.1 FLOOD DAMAGE IN BANGKOK

No.	Year	Area	Estimated Cost of Damage (million Baht)	Investigated Item	Source of Estimate
1	1975 flood	Bangkok	1,100	Direct damage, indirect damage and utility losses	Water Resource Committee, NESDB
2.1	1975 flood	Bangkok	133	Health benefit	World Bank
2.2	1975 flood	Bangkok	1,000	Annual increment of land value	World Bank
3	1980 flood	Central Area in Bangkok	450	Direct damage, indirect damage and flood prevention cost	Burkhard
4.1 4.2	1975 flood Normal flood between 1975 and 1982	Central Area in Bangkok	1,200 800	Damage and losses to households, small establishments, large establishments, institutions, public utilities, road users, tourism sector and environmental conditions	NEDECO
5	1983 flood	Greater Bangkok Area	6,597		National Statistical Office
6	1983 flood	Master Plan Area (Eastern Suburbs of Bangkok)	3,500		JICA

2) Flood Damage in 1983

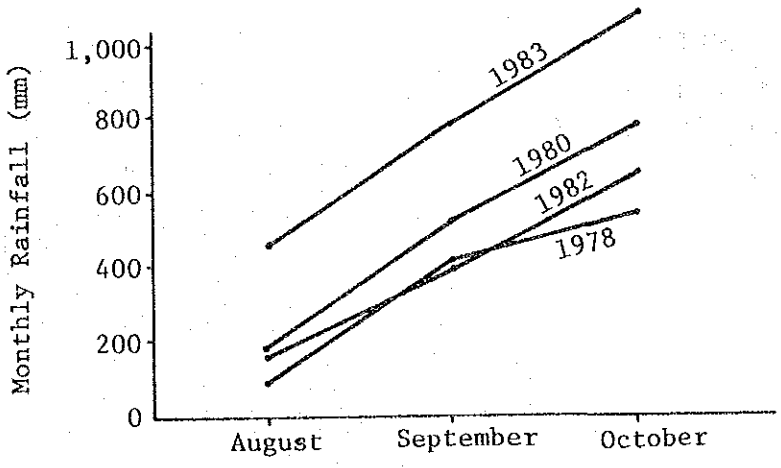
Following the flood damage survey on the 1982 flood, the JICA Study Team surveyed the damage of the 1983 flood in the Master Plan Area. The survey was done in the form of direct interviews from June 16, 1984 to June 24, 1984, with cooperation of Dr. Thavivongse, Institute of Environmental Research, Chulalongkorn University. The number of collected samples was 710, distributing as follows:

444 for households
119 for commerce
105 for industry
21 for schools
21 for government offices

Using the obtained unit damage and number of population, commerce, industry etc., the damage by 1983's flood in the Master Plan Area was estimated as about 3,500 million Baht and the distributing of the damage are indicated in Fig. B.2. The per capita damage of 3,300 Baht in the Master Plan Area was more than twice in the entire Bangkok Metropolis. (See Appendix P).

2. Hydrological Status of the 1983 Flood

Rainfall in the Preliminary Study Area in August 1983 amounted to 461,5 mm, more than twice that of other flood years, e.g., 191,5 mm in 1980.



Comulative Monthly Area Rainfall of Flood Years in the Preliminary Study Area

As the heavy rainfall in August was precipitated in the lower Central Plain as well, much rainfall water flowed into the low-lying Study Area from the outer areas.
Further, as heavy rainfall continued to fall during September and October, the water level of the Chao Phraya River continued to rise (Fig. B.3), discharge amount of water from the Study Area to the River was restricted. As a result, the water level in the Area increased steadily (Fig. B.4). Particularly, the depression storms "Herbert" during 10-11 October, and "Kim" during 18-19 October produced heavy rainfall in the eastern Bangkok plain, when the water levels were reached highest (Fig. B.4). Before the two depressions storms, flooded area was rather limited, covering Bang Na etc. (Fig. B.5).

However, after these two storms, the flood area extended to the entire Master Plan Area. It was at this time that the protected inner polder area in Ramkhamhaeng was entirely submerged by the water overtopping the polder dike from the surrounding area (water levels at station G and H are shown in Fig. B.6).
The surveyed maximum flood depth in the Master Plan Area, varied from about 80 cm along Klongs Saen Saep and Phra Khanong to about 10-20 cm was recorded (Fig. B.7). The flood duration was also long, from about one month in Bang Khen to about three-four months in various areas (Fig. B.8). On the other hand, as flood duration was about 13 days on average in the central Bangkok area, it was found that the Eastern Suburban-Bangkok suffered more heavily from flood than any other area. It is noted that flood status in the Retention Area adjacent to the Green Belt Area was more severe, i.e. flood depth was 80-95 cm. Nevertheless, the flood damage is not so severe due to the smallness of the flood damage potential. However, flood damage potential will increase with future urbanization in this area.

3. Causes of Flooding

3.1 Heavy Rainfall

The rainy season usually extends from mid-May to mid-October as the southwest monsoon brings moist air from Indian Ocean while the heaviest rainfall normally occurs during August to September as a result of heavy monsoon rains and the torrential rainfall caused by tropical storms and depressions. Consequently, flooding usually takes place towards the end of the rainy season when heavy rainfall is more frequent.

The average annual rainfall in Bangkok varies from 900 mm to more than 2,000 mm. In 1983, about 1,800 mm rainfall was recorded in Bangkok during only four months, July to October. Heavy rainfall is the most significant factor causing floods in Bangkok.

3.2 High Water Levels and High Tides of the Chao Phraya River

Almost all storm water in the Eastern Suburban-Bangkok flows out into the Chao Phraya River. Storm water discharged into the river is strongly influenced by the water level of the Chao Phraya River.

Water levels at and near Bangkok fluctuate by tidal effect and are influenced by the runoff of the Chao Phraya River due to rainfall in the North. Hence, the water level of the Chao Phraya River near Bangkok begins to rise gradually at the end of August, reaching a peak in November.

During this period, low water level is above mean sea level (MSL) and high water level exceeds 1.5 m above MSL while ground surface elevations in the Master Plan Area vary from -0.2 m to 1.9 m above MSL.

3.3 Inflow from the North and East

Usually water level in the Central Plain is high enough for the irrigation of paddy fields. The water level in the Plain begins to rise around May and reaches a peak in October. The pattern of fluctuation in Central Plain is the same as in the Chao

Phraya River. In 1980 and 1983, much water in the Central Plain flowed towards Bangkok due to the topographs. About 60 m^3/sec inflow was observed at the end of November, 1983. Based on this observation, the amount of inflow into the Preliminary Study Area of 501 km^2 from August to November in 1983 was estimated to be equivalent of 1,200 mm rainfall while the rainfall there was about 1,000 mm.

3.4 Progression of Land Subsidence

The land subsidence due to excessive withdrawal of groundwater has greatly aggravated the flood problem in Bangkok. In the past, the topography of Bangkok area was very flat with ground elevation varying from 1.9 m to -0.2 m above mean sea level. The study jointly carried out by the Department of Mineral Resources, the Royal Thai Survey Department of the Army and AIT in 1982 shows that there is land subsidence in the Eastern Suburban/Bangkok. The centre of the subsidence is located at around Hua Mark where exsiting ground elevation is about from 0.2 to 0.8 m above MSL. Rainwater has difficulty to drain by gravity, thus causing the flooding.

3.5 Insufficient Drainage Capacity

Besides the major causes of flood described above, the insufficient drainage capacity of klongs, pump, gates and drainage pipes are the other causes.

3.6 Change in Land Use Condition

Urban development brings about a decrease in the surface water retaining capacity of the area.

4. Relevant Studies and Projects

This Project is now under master plan study which aims at alleviating flood damage in the eastern suburban-Bangkok. Besides this project, many plans as shown in Fig. B.9 have been/are being studied to cope with floods in and around Bangkok.

These plans are not independent but are influenced each other. Among many plans, the following studies and projects are investigated to provide the fundamental information for this Project;

- Camp Dresser & McKee (CDM) Plan
- City Core Project (BFCD Project)
- Green Belt Project
- Samut Prakan Seawall Project
- Chao Phraya River Water Level Lowering Plan

The location of these studies and projects are shown in Fig. B.10. In addition, land subsidence which will govern size of the proposed drainage facilities for the eastern suburban-Bangkok, is explained separately in Appendix D.

4.1 Camp Dresser & Mckee (CDM) Plan

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

The proposed Master Plan includes the establishment of 11 polders as shown in Fig. B.11, whose area varies from 1 to 100 square kilometers each. Each polder, surrounded either by a river or a large klong, was planned to be protected from external flood waters by a flood protection barrier, consisting of a combination of embankments, highways and concrete walls. Stormwater runoff in each polder is pumped through the internal drainage klongs into the external klongs such as Klongs Phra Khanon, Saen Saep and Lat Phrao, or directly into the Chao Phraya River. Each polder requires from one to eight pumping stations. Fig. B.11 indicates the principal components of the proposed system consisting of the flood barriers, the internal drainage klongs and the stormwater pumping stations.

According to the CDM plan, the crest elevation of the flood protection barrier is 2.2 meters above MSL at Memorial Bridge (47km upstream from the river mouth) and 1.9 metres at Bangkok Port (28km). These are planned on the 100-year frequency flood

levels and a freeboard of 0.37 metres. Stormwater drainage in the residential area was designed to carry away the run-off expected from a storm occurring only once every two years. In other developed parts of the study area, the drainage was designed for a storm with an expected frequency of once in five years.

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

This difference creates a need for temporary stormwater storage within the polders.

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

The significant portion of the Project including core area was to be completed within 14 years or by the year 1980 which was 1,150 million baht in terms of 1968 costs.

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

4.2 Flood Control and Drainage Project in City Core Area

In order to accelerate the flood control and drainage project of the city core area of 92 km^2 and to review and revise the CDM plan, this project was initiated.

In February 1984, the general study report was presented by the BFCD Joint Venture, and the detail design is scheduled to be completed by February 1985, followed by implementation of the project up to 1989.

According to the general study report, the main physical features proposed are as follows:

1) Flood protection barriers

Some 50km of flood barriers are proposed to withstand external floods in 100-year frequency high water level at the River with a height allowance to compensate for land subsidence during the next 10 years.

2) Improvement of drainage system:

Improvement of some 110 km of klongs and construction of some 12 km of drainage conduits are proposed to cope with rainfall of 2-year frequency.

3) Pumping Stations:

Some 11 new, low-lift pumping stations with a total capacity of 175 cubic meters per second (CMS) are proposed and about 200 CMD including existing pumping capacity will be needed to cope with 10-years land subsidence. Among this 120 CMS pumps will be installed within 5 years.

Two existing pumping stations which were constructed according to the CDM plan will be modified to increase their capacity and efficiency.

4) Control Gates:

Some 15 new drainage and/or flushing sluice gates are proposed.

5) Project Cost:

The total project cost implemented during next five years is estimated at 2,050 million Baht with a foreign exchange component of 610 million Baht. The World Bank loan covering 75% of total project cost is expected, and the remaining 43% of the cost will be financed equally by BMA and the central government.

6) Inflow from the City Core Area to Klongs in Master Plan Area:

To be specially noted, is the planned inflow from the City Core Area to the klongs in the Master plan Area. Klongs Tan, and Bang Sue located in the Master Plan Area, are to receive stormwater of 14 and 12 cubic metres per second (CMS) respectively. Such amount is to be taken in consideration for the planning of the main klongs and primary pumping stations of the flood protection cum drainage project in the Eastern Suburban-Bangkok.

4.3 Green Belt Project

The Master Plan of the Royal Initiated Flood Prevention Scheme, the so-called "Green Belt Project" was worked out in 1981 after the serious flooding which occurred in 1980. The plan covers the area of the eastern cultivated fields as shown in Fig. B.13. The area between Klong Sam Wa and Klong Sib See has been declared a Green Belt Area, which clearly separates the urbanized area and the surrounding agricultural land. The project is aimed at draining the water quickly to the south, directly into the Gulf of Thailand.

Parts of the Green Belt project are expected to be completed by 1985 as the urgent flood control measures established in 1983 (see Appendix C). The project is to be executed jointly by NESDB, RID, BMA, the Highways Department and the State Railway of Thailand (SRT). Besides the constructed dikes and regulators which are incorporated into the urgent flood control measures, improvement of klongs is included in this project. Dredging of 30 canals, 325.2 kilometers in total length, are expected to improve the flow of water in the klongs. The planned discharge capacities southward as shown in Fig. B.14 are about 75 - 100 m^3/sec.

4.4 Samut Prakan Sea Wall Project

Samut Prakan Province, covering an area of 934 kg^2 which had a population of 536,000 in 1980 is adjacent to the south of the Master Plan Area. Some Parts of Samut Prakan have changed substantially from a rural area, consisting of farmers, fruit growers and fishermen, into an industrial area which is located near Bangkok Port along the Chao Phraya River (Fig. B.15).

The problem of drainage and flooding in Samut Prakan has become similar to that of Bangkok since the 1960s. The excessive withdrawl of groundwater due to the increase of factories and population has caused land subsidence. For the prevention of land subsidence, the Metropolitan Water Works Authority (MWWA)

is planning to supply surface water as a substitute for groundwater. A flood protection Master Plan on "Samut Prakan Sea Wall Project" was presented in February 1984 by the Thailand Institute of Scientific and Technological Research. As the project name denotes, the embankments along the Chao Phraya River, the Gulf of Thailand and the Green Belt Area are planned to prevent inflow from outer areas. Pumps and gates will be constructed for drainage.

4.5 Chao Phraya River Water Level Lowering Plan

The water level of Chao Phraya River usually experiences the first rise in May or June over a period of 1-3 weeks. The second rise occurs gradually and reaches its maximum in October in the upper reaches and in November in the lower reaches. When the water level rises, a considerable quantity of water escapes into tributaries and branches. This water overflows the banks of tributaries and spreads out into the low-lying areas on both banks of the Chao Phraya. The lower plain of the Chao Phraya River, between Nakhon Sawan and Bangkok, looks like a large lake during a high flood season. Thus, these areas between Chainit to Ayutthaya play an important role in alleviating the flood damage in the Chao Phraya River basin. About one-third of the discharge of the Chao Phraya River is retained in these areas.

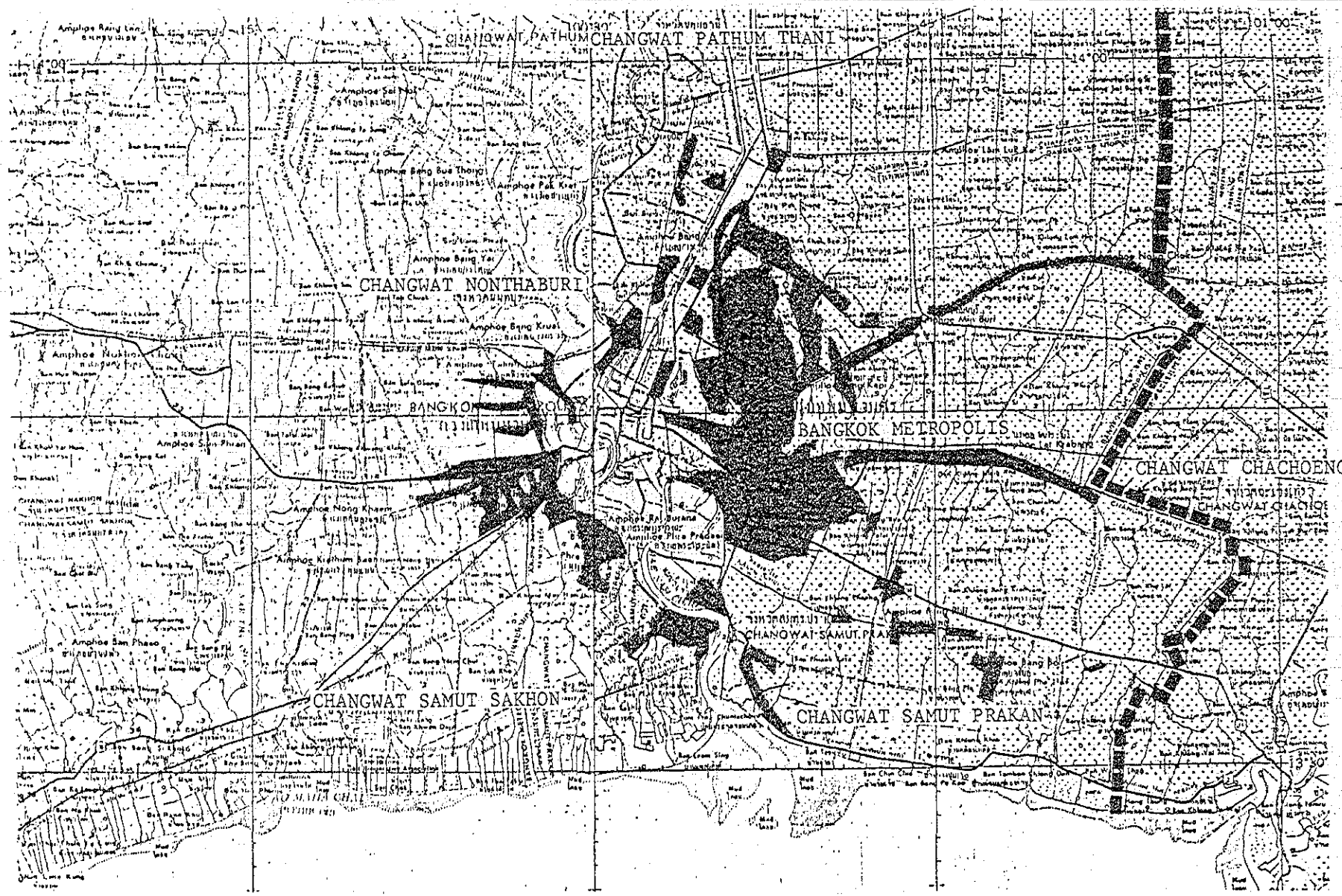
The major existing storage dams in the Chao Phraya River, the Bhumipol dam (effective storage volume, 8,600 million cubic metres) and the Sirikit dam (ditto, 8,800 million cubic metres) have a flood regulation capacity of 500 m^3/sec of the Chao Phraya River. These dams, which have been in operation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

AIT is now undertaking an 18-month study which is called the "Flood Routing and Control Alternatives for the Chao Phraya River for Bangkok" for NESDB. The study began in early 1983. The following flood control schemes are considered according to the interim report (Fig. B.16).

a. Construction of diversion channels through "Green Belt Area".
b. Dredging or widening of the shallow or narrow reaches of the Chao Phraya River to increase flood conveyance capacity.
c. Construction of short-cut channels at meanders between 18km to 34km from the river mouth.
d. Construction of a tidal barrier upstream of Bangkok Port.
e. Construction of embankments along the Chao Phraya River.

These are under study by AIT but it is reported that the flood relief channel is an extremely large one and costly and also the other alternatives are considered to bring only minor relief. It appears that several alternatives would have to be combined to result in the required reduction of flood levels.

Considering the stage of the above studies and the uncertainties with regard to an eventual follow-up, especially considering the large investments required, it is recommended to determine the embankment heights for the Master Plan Area, based on a present conditions with respect to flood water levels in the Chao Phya River.



[Source:Flood Damage Survey by NSO]

Fig. B.1 FLOOD AREA IN GREATER BANGKOK IN 1983

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

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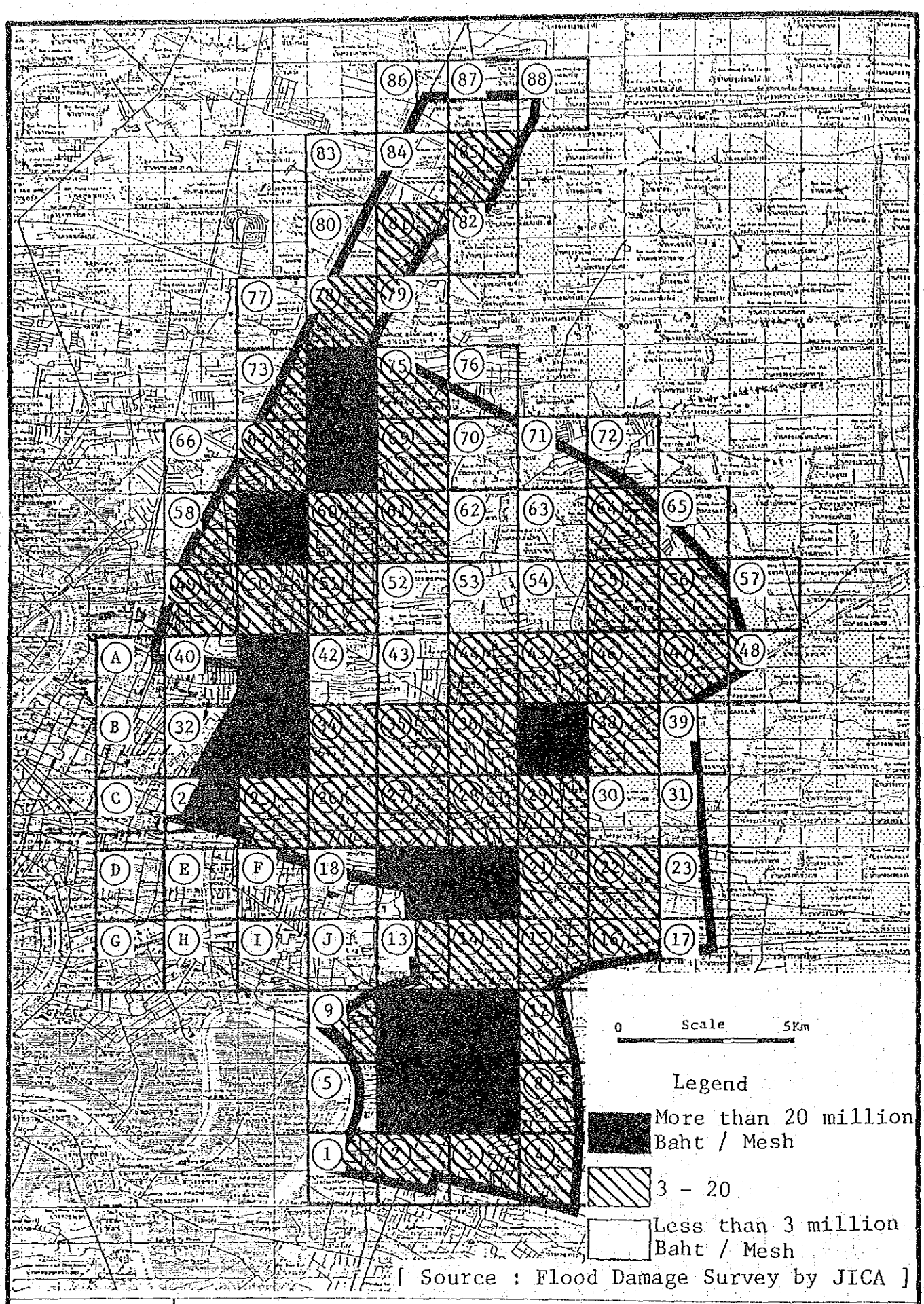
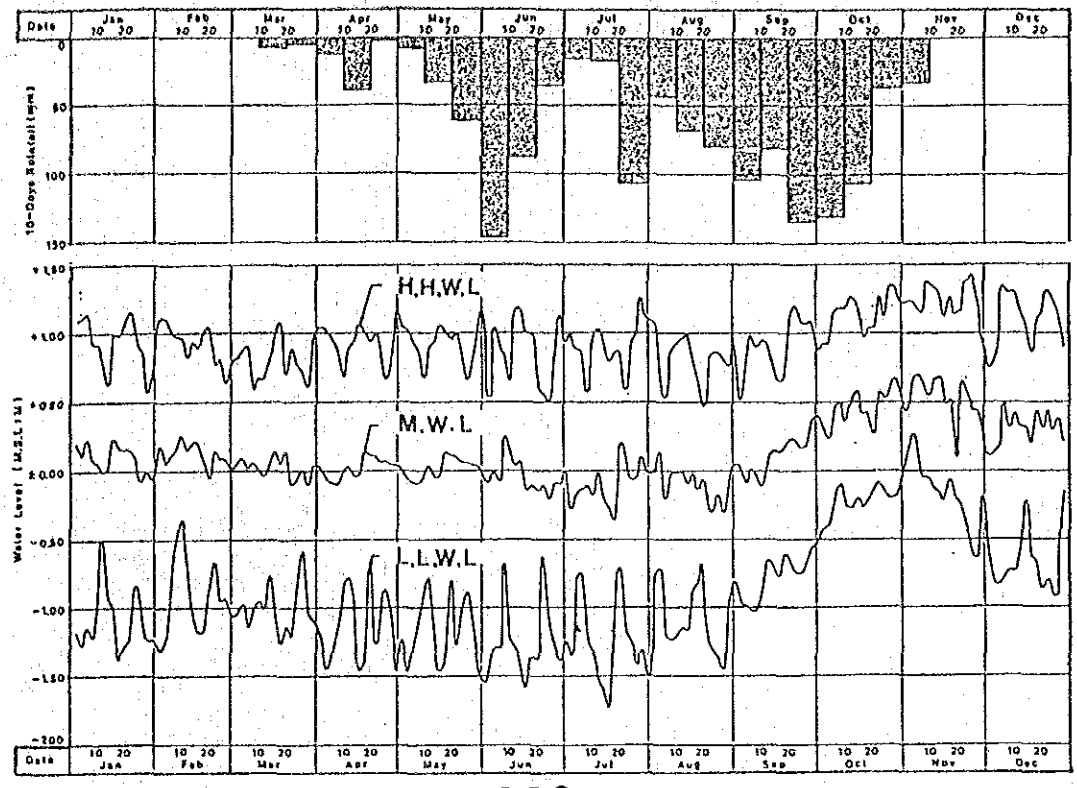
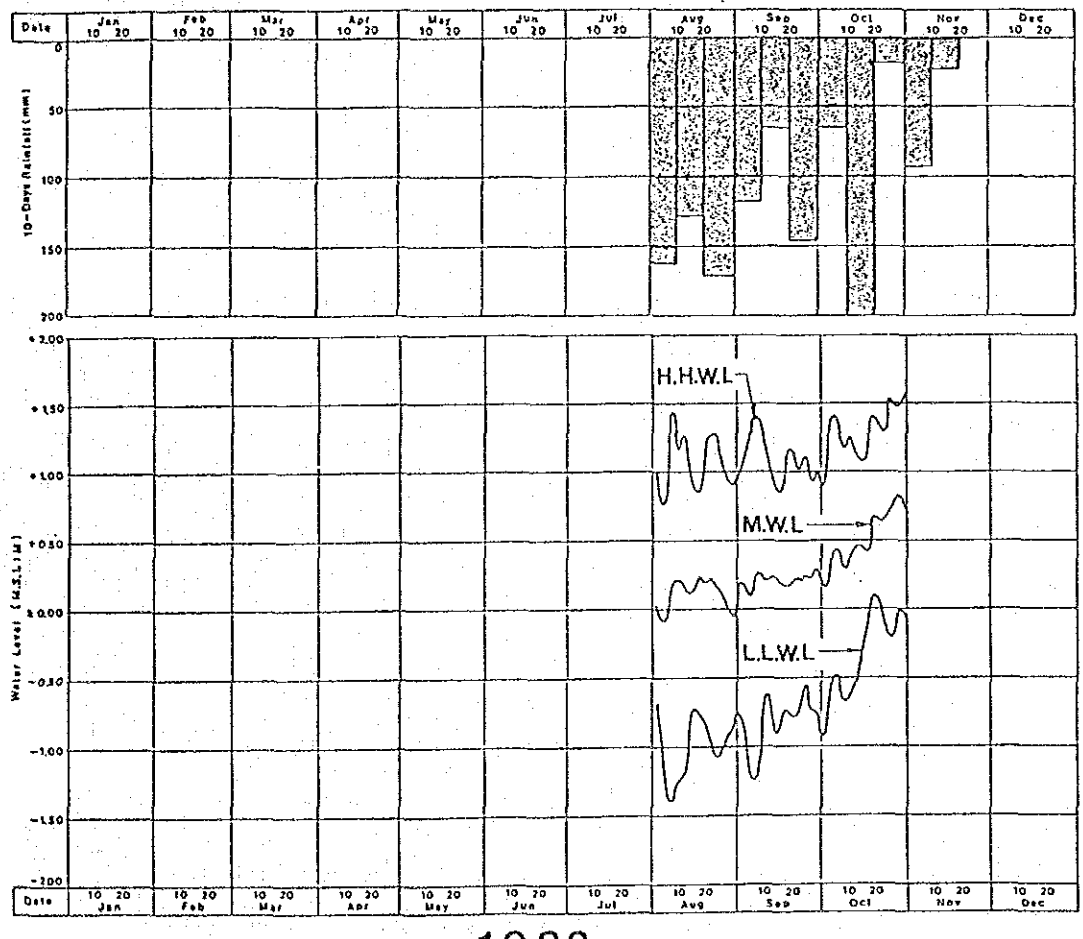


Fig. B.2 FLOOD DAMAGE ON HOUSEHOLD IN MASTER PLAN AREA IN 1983

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



1980



1983

Source : Meteorological Department and P.A.T

Fig. B.3 SEASONAL CHANGES OF RAINFALL IN THE STUDY AREA AND WATER LEVEL AT BANGKOK PORT IN 1980 & 1983

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

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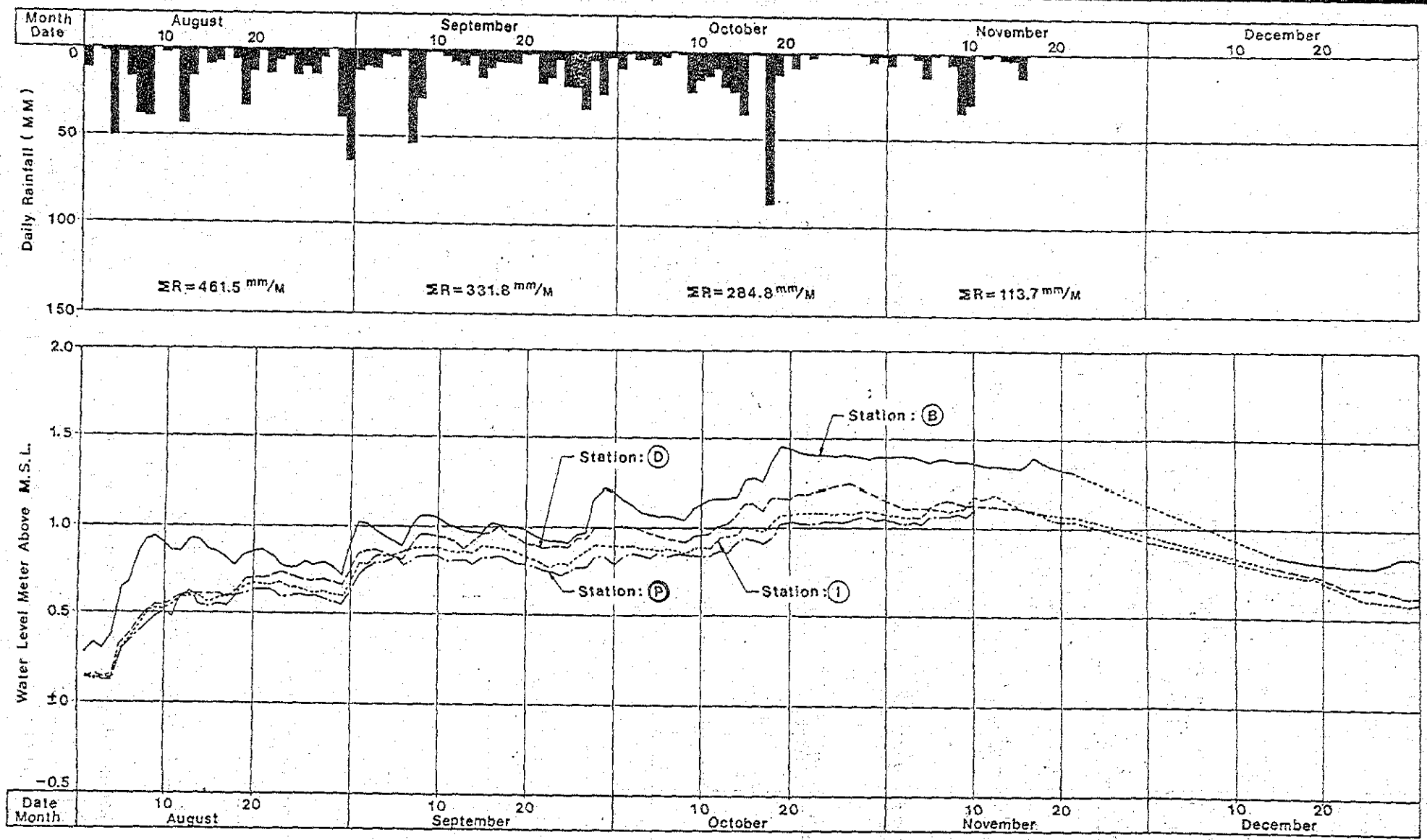

Note: Location of the Station is shown in Fig. F.4.

Fig. B.4 AVERAGE AREAL DAILY RAINFALL IN THE STUDY AREA & WATER LEVEL OF KLONG LAT PHRAO BETWEEN AUG. AND NOV. IN 1983

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

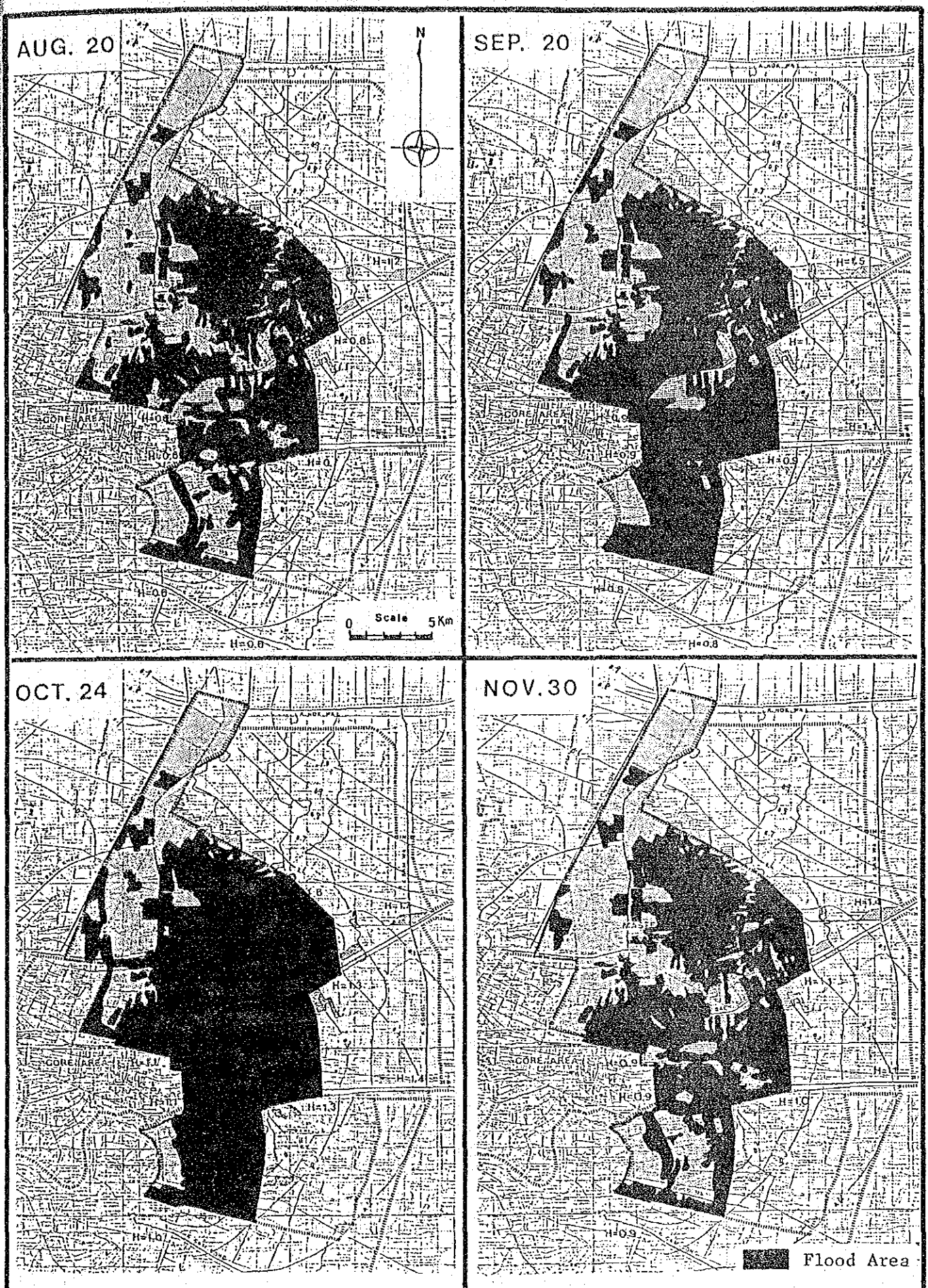

Fig. B.5 FLOOD AREA IN MASTER PLAN AREA IN 1983

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

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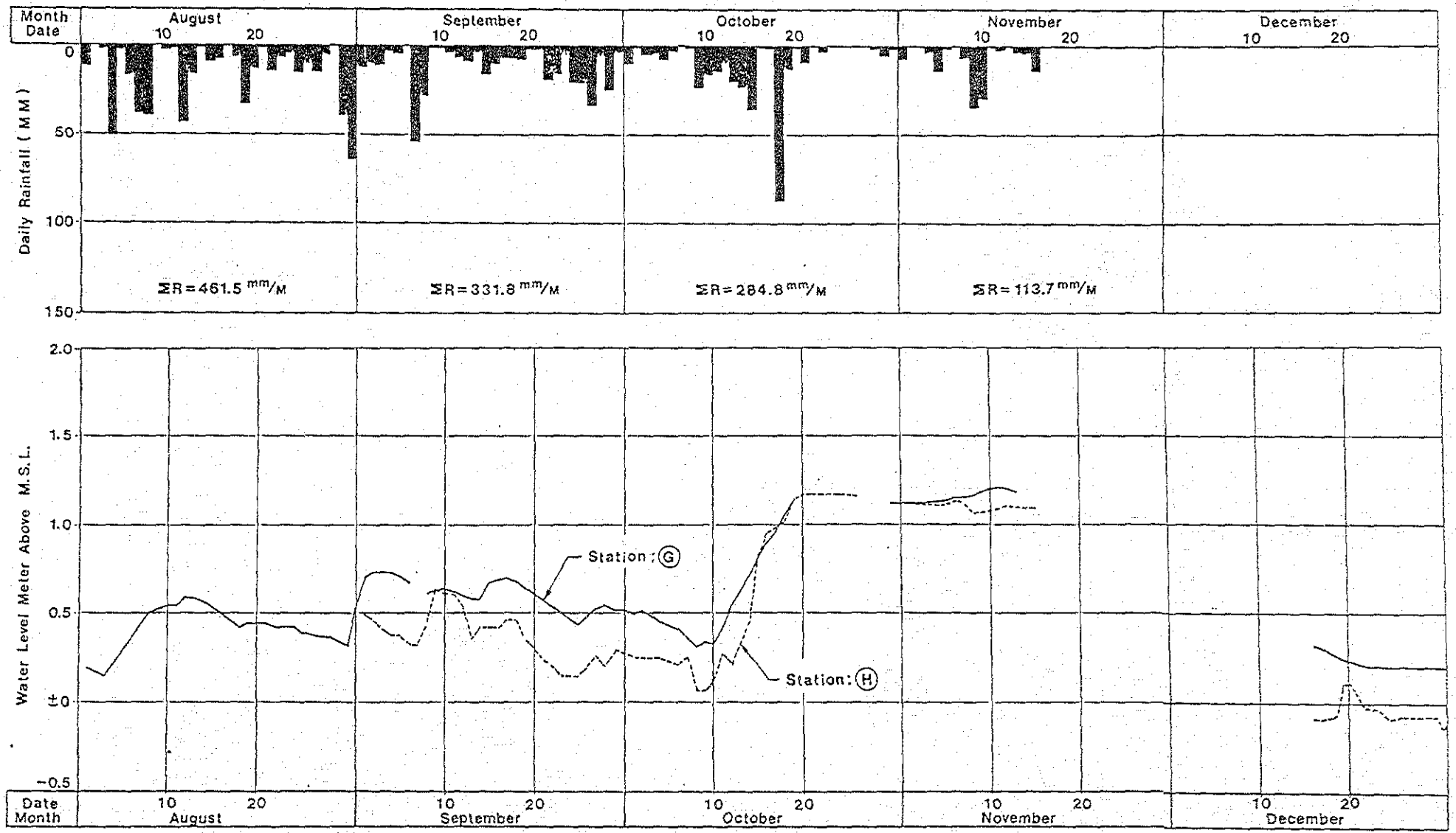

Note : Location of the Station is shown in Fig. F.4.

Fig. B.6 AVERAGE AREAL DAILY RAINFALL IN THE STUDY AREA & WATER LEVEL OF KLONG KACHA BETWEEN AUG. AND NOV. IN 1983

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

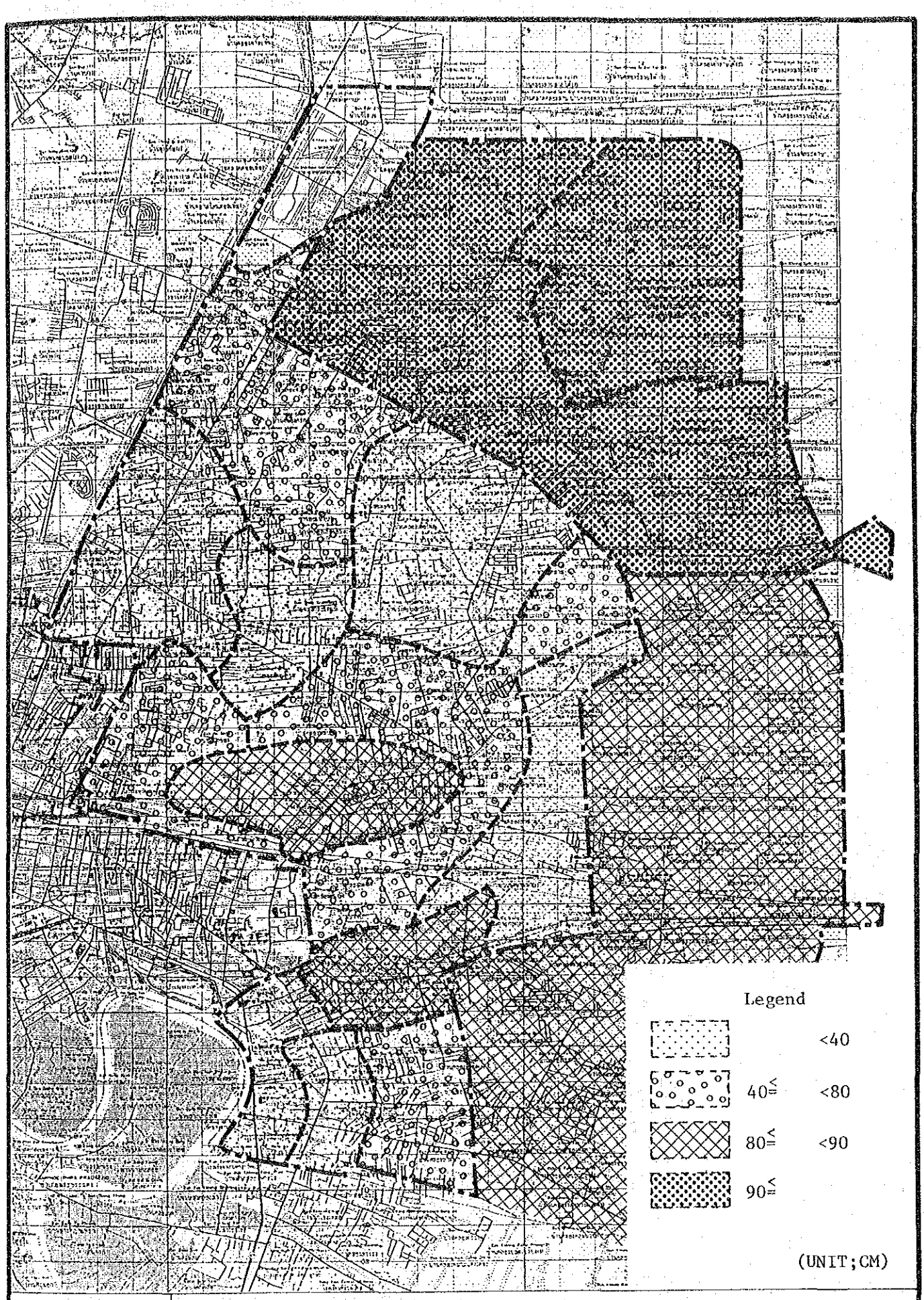

Fig. B.7 MAXIMUM FLOOD DEPTH IN 1983

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

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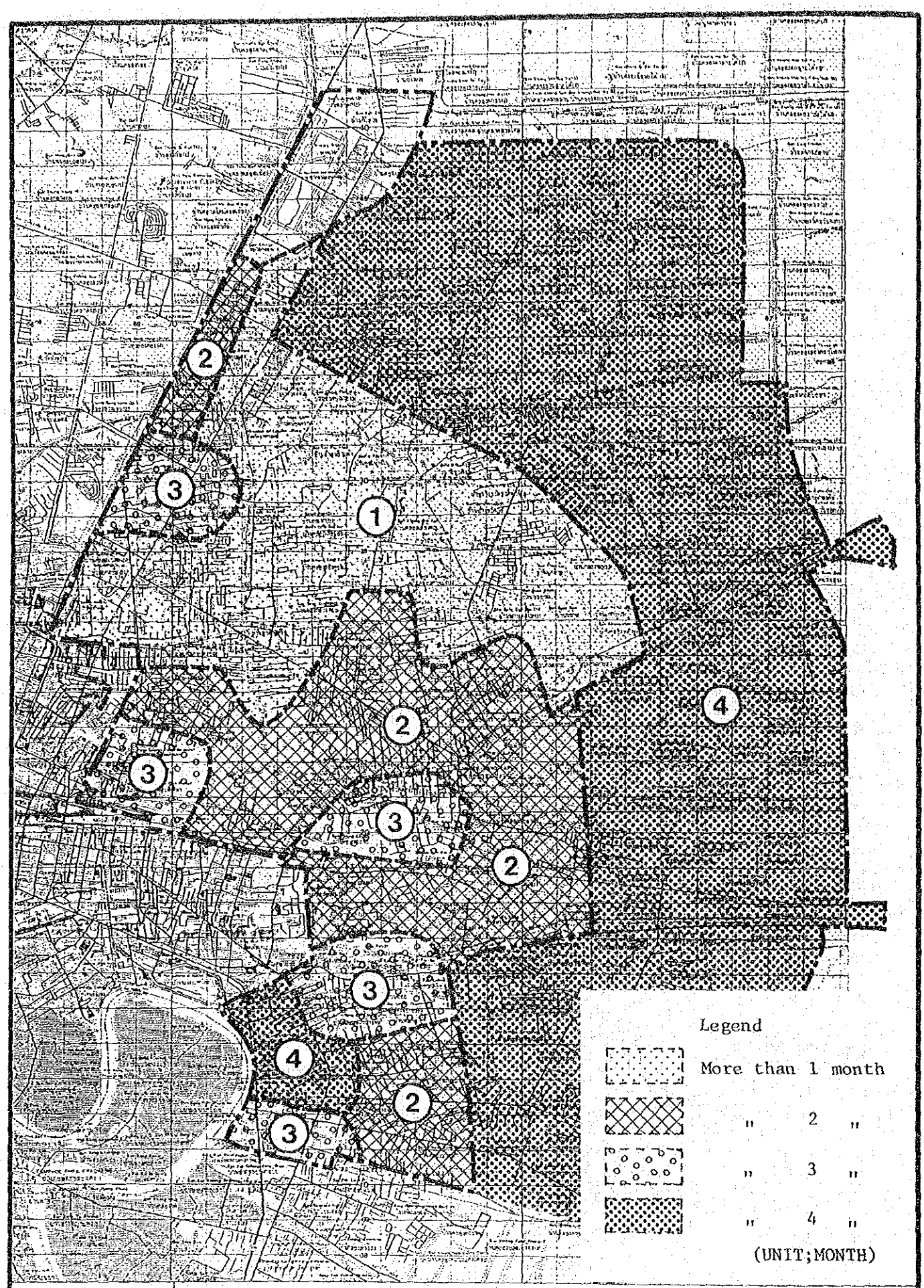
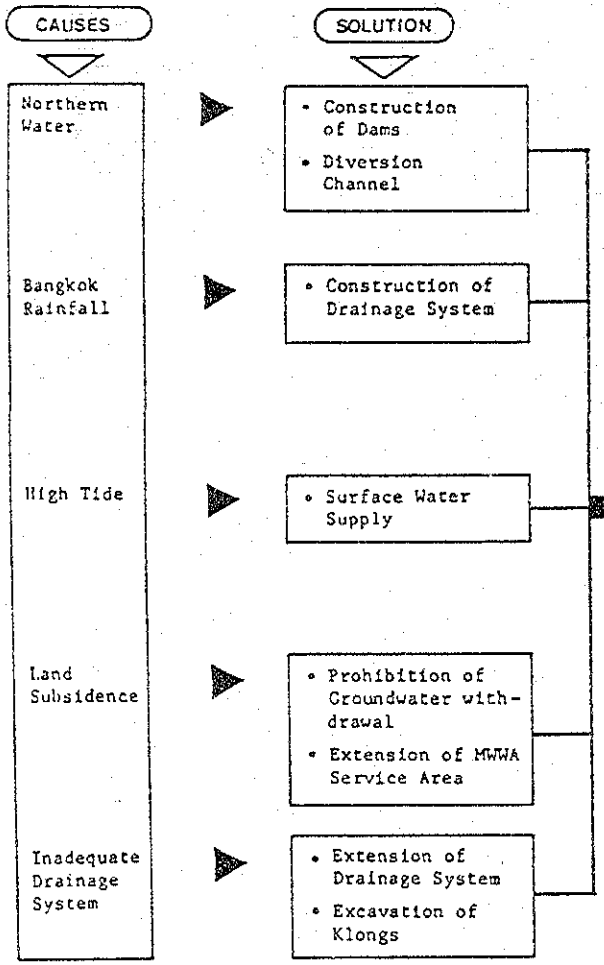


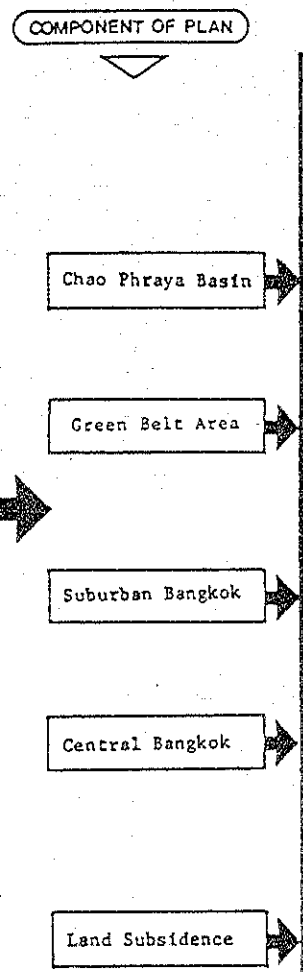
Fig. B.8 FLOOD DURATION IN 1983

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

JICA 2528B.E 1985A.D

Present Status of Flood Protection Plan by National Economic and Social Development Board





GUIDE LINE

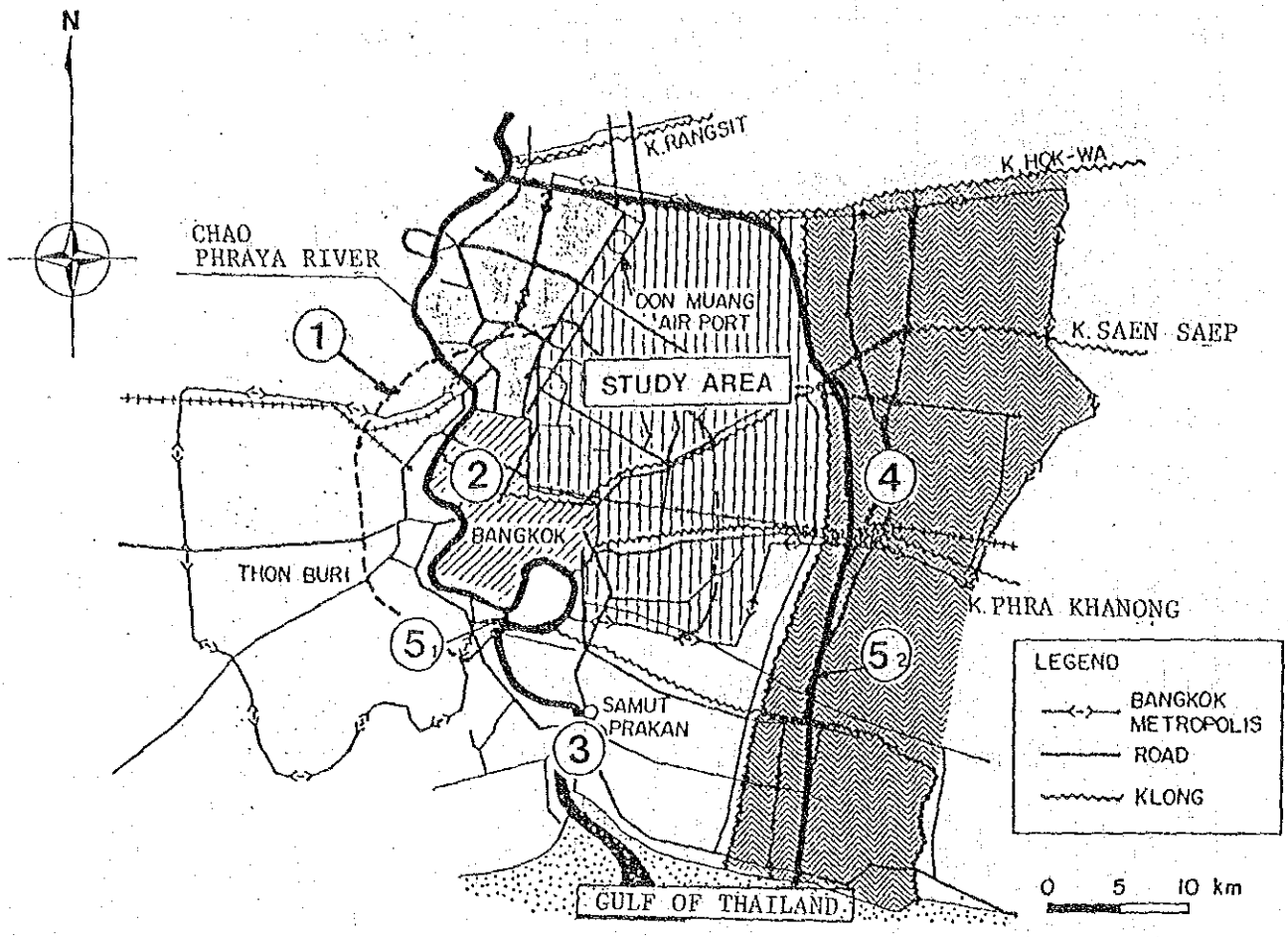
Sub-Project	Present-Status	Continuous Working	Owner of Project
1. Study of division for Chao Phraya Basin Project	Draft of Construction for Green Land	Employment of Consultant	RID
2. Yon River Basin Project	Pre-Feasibility Study	Preparation for Feasibility Study and Detail Design	
3. Pasak River Basin Project	Feasibility Study	Design	RID
4. Sakaerang River Basin Project	Feasibility Study	Design	RID
1. Drainage Project			BMA
2. Green Land Use Study	Preliminary Construction for Green Land	Land Study and City Planning with New Air Port Project	City Planning Division
1. Drainage & Klong Excavation Project in Bangkok	Excavation in Progress	Terms of Reference	BMA
2. Flood Protection & Drainage Project	Master Plan	Terms of Reference of Feasibility Study	BMA
3. Land Use Study & City Planning	Announcement of City Plan	Preparation of City Planning	BMA
1. Flood Protection In Inner City	Consultants are designing	Design	BMA
1. Groundwater Control Project	First step studied	Study the description of Control	Environmental Board
2. Keeping the Ground Water in the Water Works Project	First Step studied	Feasibility Study	RID
3. Supply of Surface Water for Industry in Samut Prakan	MWWA is preparing	Agreement with Industry for Construction	
4. City Planning	Announcement of City Plan	Preparation of City Planning for of Ground Level	BMA

Source: NESDB

Fig. B.9 PRESENT STATUS OF FLOOD PROTECTION PLAN

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

JICA 2528B.E 1985A.D



LEGEND

① CAMP DRESSER & MCKEE (CDM) PLAN

② FLOOD CONTROL AND DRAINAGE PROJECT IN CENTRAL (CITY CORE) AREA

③ SUMUT PRAKAN SEA WALL PROJECT

④ GREEN BELT PROJECT

⑤ CHAO PHRAYA RIVER WATER LEVEL LOWERING PLAN (Short-Cut Channel⑤₁ and Diversion Channel⑤₂)

Fig. B.10 Location of Previous Study and Relevant Plans

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

JICA 2528B.E 1985A.D

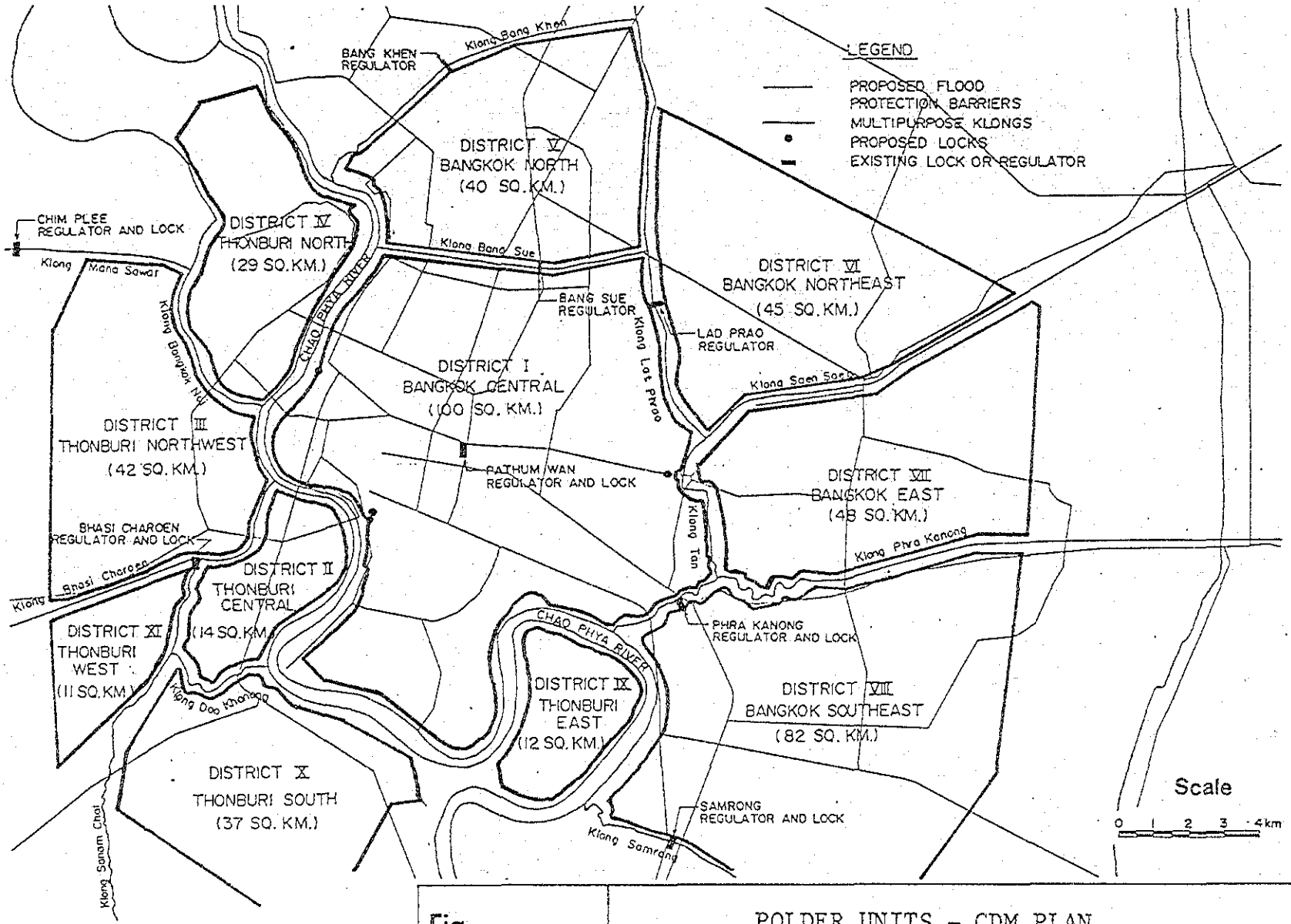


Fig. B.11 POLDER UNITS - CDM PLAN

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