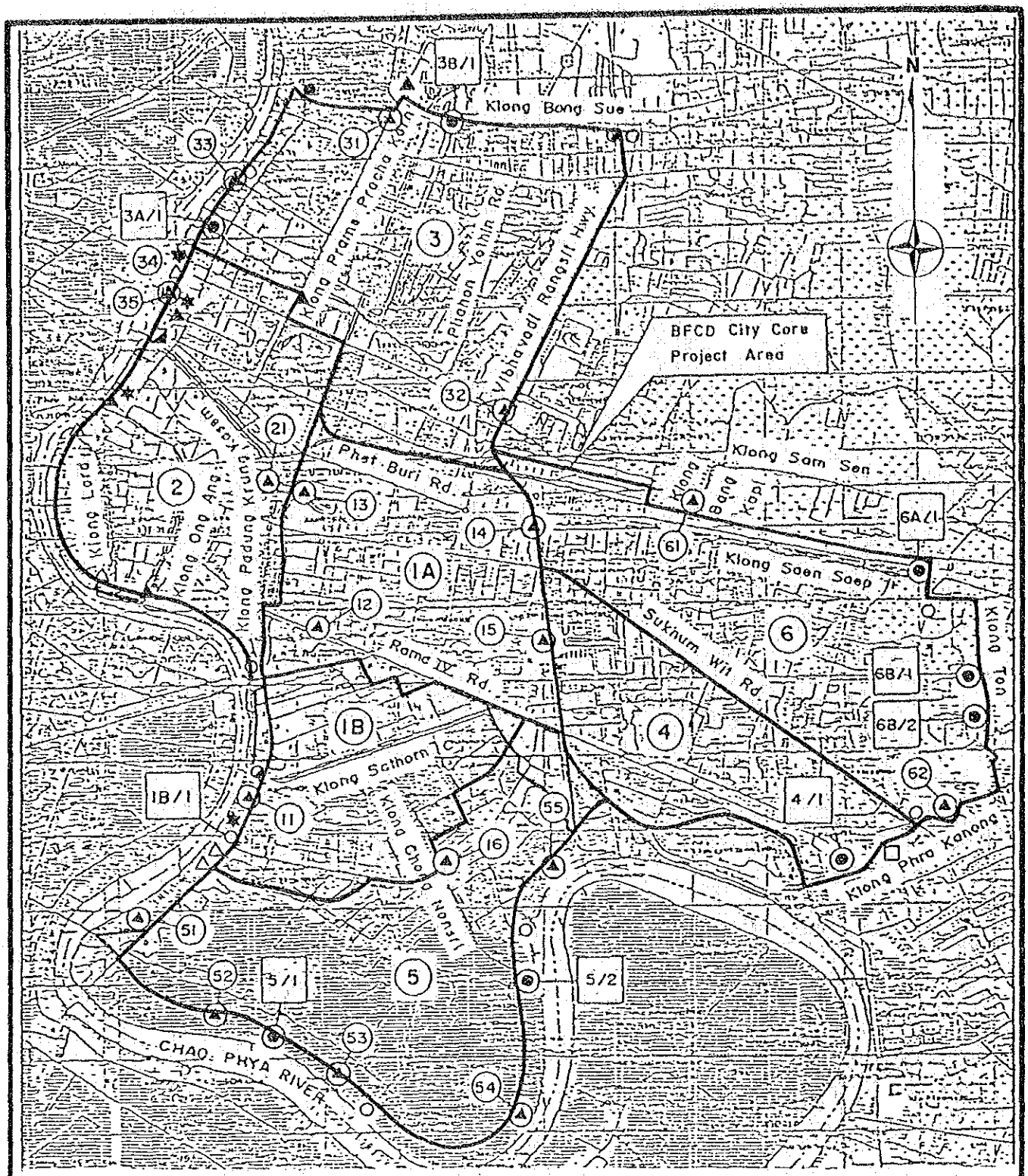


PUMPING STATIONS

- ○ = Existing
- ⊘ = Planned by ODS
- ⊘ = Under Construction
- ⊛ = Proposed by Project
- ○* = Proposed Modification

SHIPPING LOCKS

- □ = Existing
- ◪ = Under Construction

SLUICES

- △ = Existing
- ▲ = Planned by ODS
- △* Proposed Modification
- (▲) = Proposed by Project
- ▲* = Proposed Modification

(2) Polder no. 2

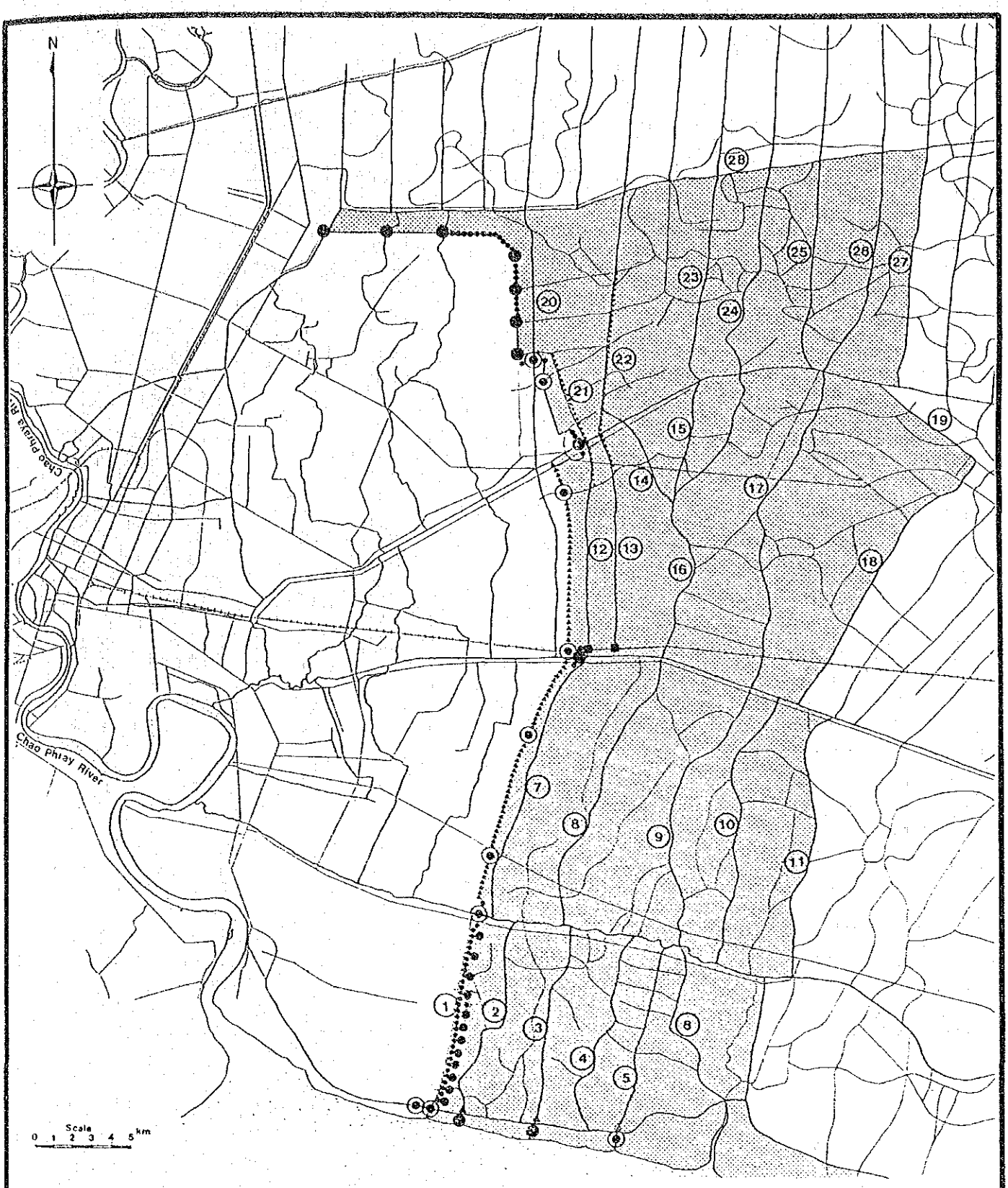
N.B Polder Boundaries, Pumping Stations and Sluices shown for Polders 4,5 and 6 are preliminary.

[Source:BFCD Joint Venture]

Fig. B.12 PROPOSED POLDERS AND RELATED NEW PUMPING STATIONS

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

JICA 2528B.E 1985A.D



[Source : RID]

Fig. B.13 GREEN BELT PROJECT

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

JICA 2528B.E 1985A.D

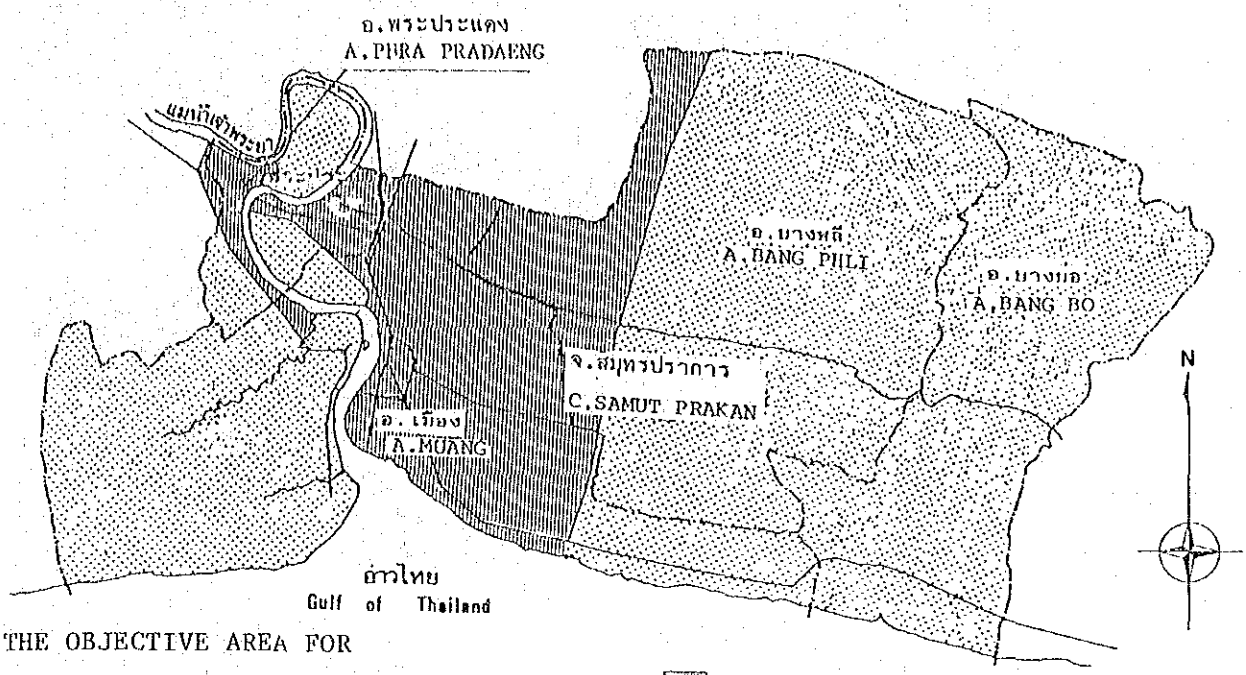
TABLE:1

NO.	NAME	L (Km)	Q (CMS)	S.S	B (m)	D (m)
1	KLONG TRONG	11.000	11.292	1:2.5	3.00	2.50
2	KLONG BANG PLA RA	6.500	5.256	1:2.5	2.00	2.00
3	KLONG BANG PLA	11.400	45.478	1:2.5	15.00	3.00
4	KLONG BANG KRA SUE	14.000	11.292	1:2.5	3.00	2.50
5	KLONG CHAROEN RAJ	9.500	15.543	1:2.5	6.00	2.50
6	KLONG HUA KLUE	7.500	15.543	1:2.5	6.00	2.50
7	KLONG LARD KRA BANG	14.600	11.826	1:2	6.00	2.50
8	KLONG BANG CHARLONG	16.000	20.884	1:2	10.00	2.60
9	KLONG JAWRAKAE YAI	16.000	29.617	1:2	12.00	2.90
10	KLONG PETCH PICHAI	16.000	25.938	1:2	12.00	2.70
11	KLONG BANG BO	13.500	14.215	1:2	7.00	2.60
12	KLONG SARM	11.700	14.215	1:2	7.00	2.60
13	KLONG SEE	11.800	14.215	1:2	7.00	2.60
14	KLONG BUA YAI	5.600	11.826	1:2	6.00	2.50
15	KLONG LUM HIN (No.1)	7.500	11.826	1:2	6.00	2.50
16	KLONG LUM PLA TUE	9.000	20.884	1:2	10.00	2.60
17	KLONG TUB YAO	13.500	25.938	1:2	12.00	2.70
18	KLONG LUANG PANG	16.500	25.938	1:2	12.00	2.70
19	KLONG NAKORN NUENG KHET	6.500	25.938	1:2	12.00	2.70
20	KLONG SARM WA	7.500	21.251	1:2	10.00	2.80
21	NEW KLONG *	5.100	21.251	1:2	10.00	2.80
22	NEW KLONG **	11.900	11.826	1:2	6.00	2.50
23	KLONG LUM HIN (No.2)	4.600	11.826	1:2	6.00	2.50
24	KLONG SIB ET	14.500	11.836	1:2	6.00	2.50
25	KLONG SIB SONG	12.000	14.215	1:2	7.00	2.60
26	KLONG SIB SARM	12.500	14.215	1:2	7.00	2.60
27	KLONG SIB SEE	13.000	21.251	1:2	10.00	2.80
28	KLONG HOK WA	17.000	29.617	1:2	12.00	2.90
29	KLONG SARM SAI TAI	2.500	11.826	1:2	6.00	2.50
30	NEW KLONG ***	6.500	11.826	1:2	6.00	2.50

ABBREVIATION:
L = Length of Canal (meters)
Q = flow Rate (cubic meters per second)
S.S = Side Slope of Channel
B = Channel Bed Width (meters)
D = Expected Water Depth (meters)

[Source : RID]

Fig. B.14 DISCHARGE CAPACITY OF BY-PASS CANALS IN THE GREEN BELT ZONE



THE OBJECTIVE AREA FOR FLOOD CONTROL AREA

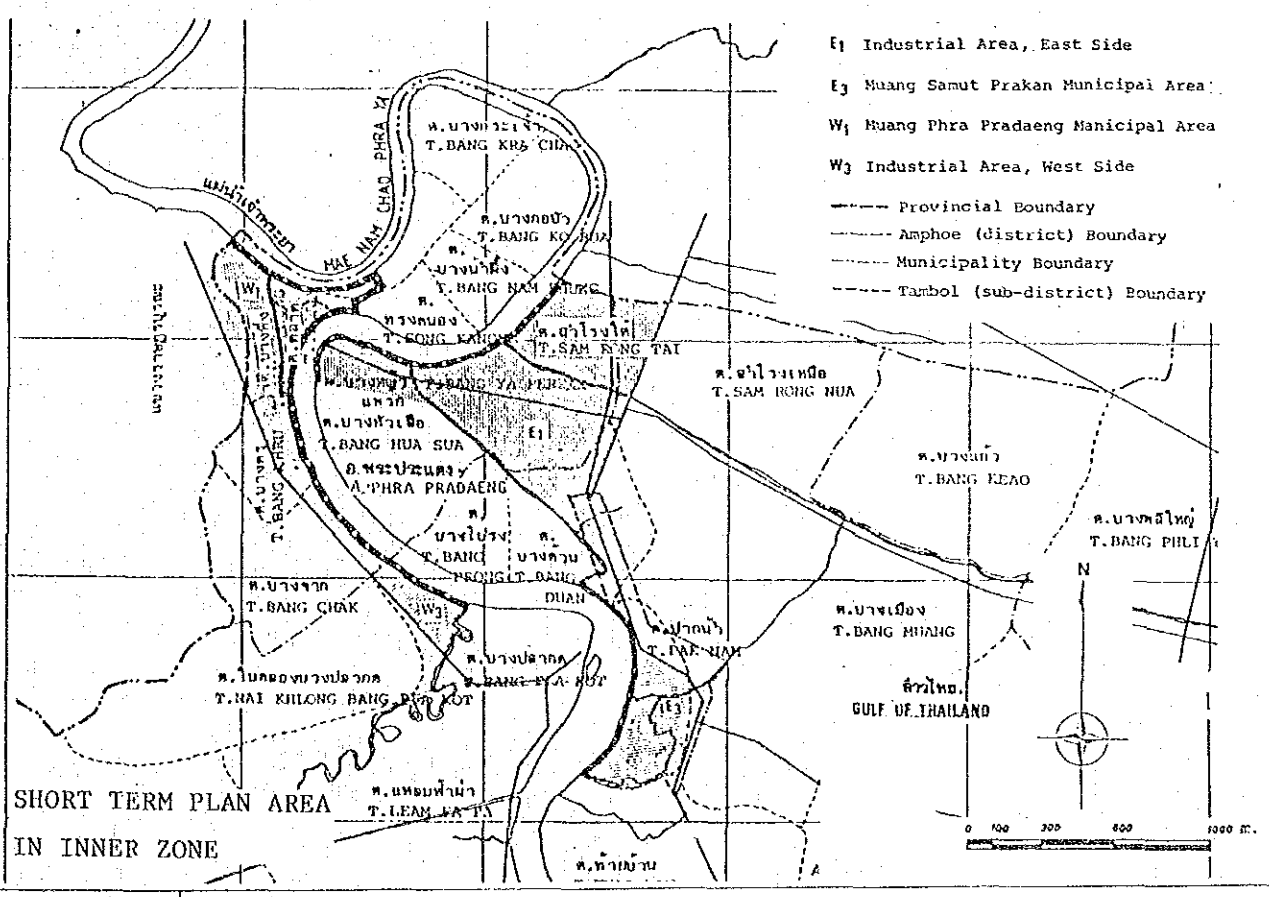
Inner Zone (Urbanized Area)

Short Term Plan Area = 29 km 2
Long Term Plan Area = 167 km 2

Outer Zone (Agriculture Area)

Long Term Plan Area = 694 km 2

Total Objective Area for Flood Control Project
= 890 km 2

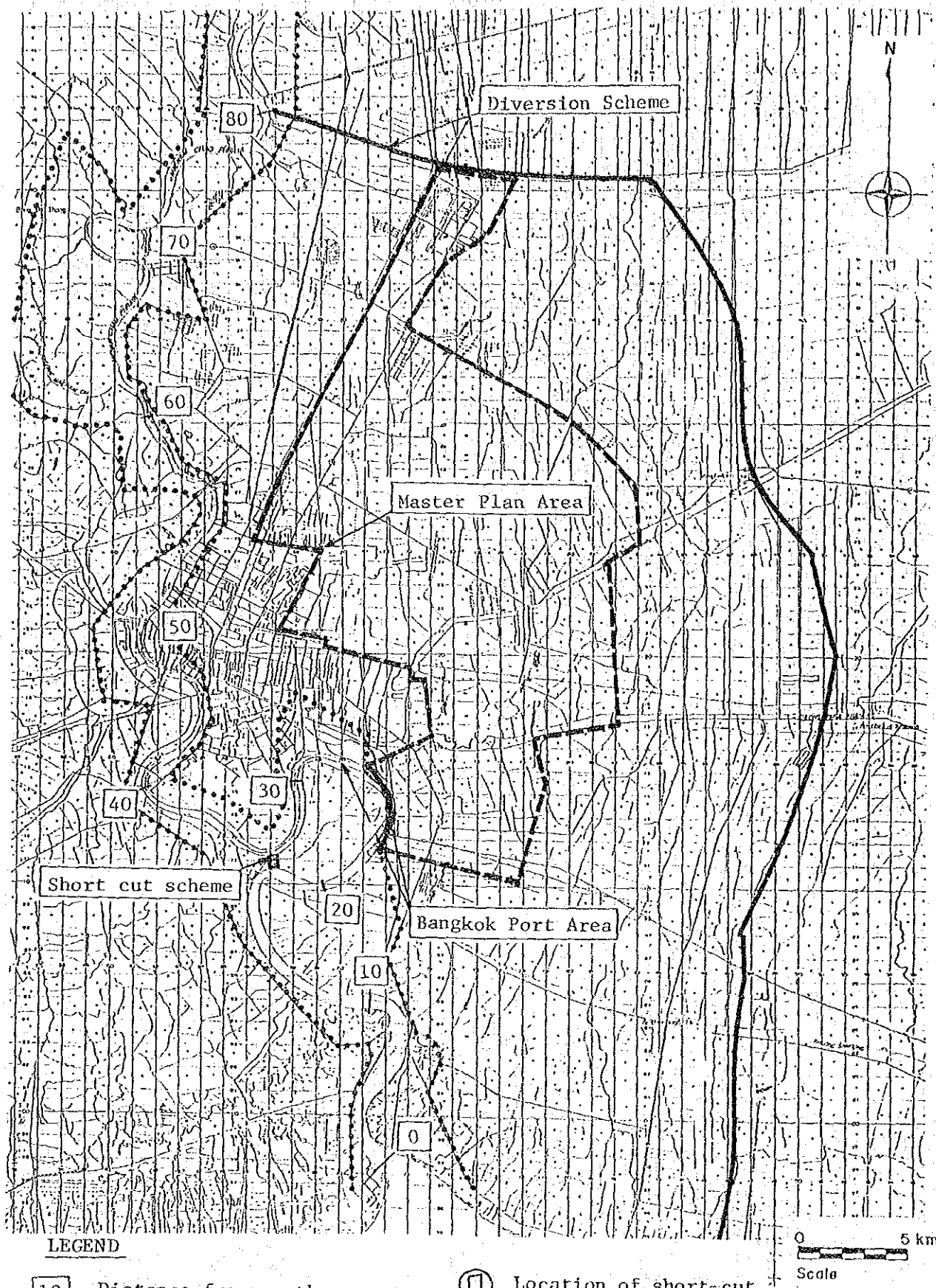


SHORT TERM PLAN AREA IN INNER ZONE

Fig. B.15 SAMUT PRAKAN SEAWALL PROJECT

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

JICA 2528B.E 1985A.D



(Source : AIT)

Fig. B.16 CHAO PHRAYA RIVER WATER LEVEL LOWERING PLAN

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

JICA 2528B.E 1985A.D

APPENDIX C

EXISTING FLOOD PROTECTION AND DRAINAGE FACILITIES

Appendix C EXISTING FLOOD PROTECTION AND DRAINAGE FACILITIES

Table of Contents

List of Tables

List of Figures

Appendix C EXISTING FLOOD PROTECTION/DRAINAGE FACILITIES AND URGENT FLOOD PROTECTION MEASURES

In this Appendix, the existing flood protection and drainage system including executed urgent measures (planned by the Committee in 1983) are presented.

1. General

In order to solve the flood problem in Bangkok Metropolis, the Bureau of Drainage and Sewerage (now called "the Department of Drainage and Sewage") was established in 1977 under the Bangkok Metropolitan Administration and has since undertaken the flood protection and drainage measures with the assistance from RID, DOH and many other organizations.

In 1978, DDS devised emergency flood protection schemes or short-term measures to mitigate the problem aiming at protecting the 100 square kilometres area in the centre of city. Seven polders were planned in which five polders (No. 1 to 5 of Fig. C.1) are in the central area and two polders (No. 6 located in Bang Na and No. 7 in Hua Mark) are located within the Master Plan Area as shown in Fig. C.1. These areas are enclosed by dikes which utilize existing roads and railways, and cofferdams to block outside water from flowing into the areas. Rainfall inside these protected areas is to be pumped out.

Apart from the emergency schemes, a long-term programme for central Bangko, called the "Bangkok Flood Control and Drainage Project (BFCD)" covering an inner core area of 86 km^2 was initiated in June 1983, and the preparation of detailed designs and draft tender documents are expected to be completed by February 1985.

In 1983, severe havoc, which lasted about 4 months, occurred in Eastern Suburban Bangkok and the most seriously affected area was in the Master Plan Area. Coping with this situation, the Government set up the "Committee of Flood Protection and Solution in Bangkok and its Vicinity" in October 1983. The Committee has proposed and been executing urgent programmes, consisting of 27 plans in three stages. The plans related to this Master Plan Study were mostly completed by July 1984. The remaining works, to be executed by the middle of 1985, are the supplemental works for the Green Belt, Samut Prakan, Nontaburi and West Bank. The existing flood protection and drainage facilities related to the Master Plan Area, therefore, have been mainly constructed by the implementation of the urgent measures planned by the Committee in 1983.

2. Existing Flood Protection and Drainage Facilities

The basic concept of the existing flood protection and drainage system is based on the polder system, consisting of the outer polder and inner polders.

(1) The outer polder system is to protect the city area against inflow and overtopping from the north-east area of the city and the Chao Phraya River.

(2) The inner polder system is to protect the high priority area inside the outer polder area.

The facilities in each polder area are principally:

(1) Barrier: In the form of roads, highways, railways, walls, dikes, which have sufficient height to protect against inflow.

(2) Cofferdams and gate(s): To block the canals and sewers along the barrier against inflow from outside, and

(3) Pumping station(s): Comprising main stations, sub-stations, and mobile pumps to discharge the inside water.

2.1 Flood Protection and Drainage System in 1983

The outline of flood protection cum drainage facilities in Bangkok Metropolis before the execution of Urgent Measures in 1983 were as follows (Fig. C.2):

1) About 180 pump units with total capacity of about 180 CMS were installed at 86 locations mostly inside the central areas of Bangkok covering 100 km^2. These pumping facilities were of a temporary nature except of Rama IV and Padung Kurng Kasem pumping stations. In the Master Plan area, about 37 units with nominal total capacity of about 34 CMS were installed at 7 locations along the Chao Phraya River.

2) Most of the cofferdams constructed contained one or more gates and were made of timber of a temporary nature. (Figs. C.3, C.5 and C.6)

3) The flood barriers utilized the existing roads and railways on embankments raised above the natural ground, however, some places were not high enough to protect against inflow from outer areas.

4) Drainage pipes are installed along the main roads, and these with a diameter greater than 1 metre are shown in Fig. C.7.

2.2 Urgent Flood Control Measures

On the occasion of the serious 1983 floods, "Committee of Flood Protection and Solution in Bangkok and its Vicinity" was set up on October 10, 1983 by the order of Prime Minister. The Committee has proposed an urgent programme of 1,021 million Baht, consisting of 22 plans in three stages which is tabulated in Table C.1 and Fig. C.8. Most of the projects related to the Master Plan Area had been completed by August 1984. The remaining works to be executed in 1985 are the supplemental improvement works for the klongs in the Green Belt Project, Samut Prakarn Project and West Bank Project which are adjacent to but outside of the Master Plan Area.

The objectives of the programmes are as follows:

i) To prevent inflow from eastern and northern areas (Parts of Green Belt Project)

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

iii) To increase drainage capacity in the protected area (pumping stations having a total capacity of 354 CMS and dredging of many klongs)

The concept of the urgent measures is consistent with the proposal of JICA Study Team which was presented in the Preliminary Study. The hydrological impact of the urgent measures are presented in section 3. Flood protection and drainage facilities in the urgent measures are classified into three categories: temporary structures (wooden cofferdams), semi-permanent structures (pumping stations) and permanent structures (embankments and control gates) as shown in Fig. C.8.

Table C.1 Urgent Flood Proteciton Program

Stage	Plan	Purpose	Construction Item	Organization	Budget (Million Baht)		
					1984	1985	Total
1.	Green Belt Project	Control the inflow from outer area, Discharge the flood water into the Gulf of Thailand	Embankment, dredging, Control Gate, Expansion of Bridge, Retainig wall and Bridges	RID, BMA SRT, HD	194.5	181.5	376.0
	Samut Prakarn Project	Prevention of overflow from Chao Phraya River	Embankment along the Chao Phraya River	PWD	62.7	59.4	122.1
	Improvement of K.Samrong	Increase the discharge capacity of klongs	Dredging	Samut Prakarn Province	80.0	0	80.0
	Stage 1. Total (3 Plans)				338.0	240.9	578.9
2.	Improvement of Klong Phra Khanong etc. (3 plan)	Increase the puming capacity	K. Bangkhen Pumping Station K. Phra Khanong " K. Sam Ron "	RID	140.0	0	140.0
	Improvement of Klong Bang Sue, etc. (7 plan)	Increase the pumping capacity	K. Bang Sue Pumping Station K. Sam Sen " K. Jek " K. Bang Oa " K. Bang Na " Improvement of K. Phra Khanong K. Sam Sen	BMA	187.0	0	187.0
	Improvement of Klongs (1 plan)	Increase the drainage capacity of klongs	Dredging	Samut Prakarn Province	14.0	0	14.0
	Stage 2. Total (11 Plans)						
3.	Green Belt Project (2 plan)	Reserve budget for BMA and SRT activity	Embankment, Coffer Dam	BMA SRT	48.7	0	48.7
	Samut Prakarn Project (1 plan)	Increase the drainage capacity of klongs	Dredging	Samut Prakarn Province	10.4	0	10.4
	West Bank Project (4 plan)	Alleviation measure of flood in Thonburi Area	Dredging, Water Gare, Pumping Station	BMA HD RID	*28.8	*6.1	34.9
	Nonthaburi Project (1 plan)	Alleviation measure of flood in Nonthaburi Area		RID	7.2	0	7.2
	Stage 3. Total (8 Plans)				95.1	6.1	101.2
	Grand Toatl (22 Plans)				774.1	247.0	1,021.1

Note: 1. Annual budget indicated in * is assumed based on the contruction schedule.

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

The outline of the projects of the urgent measures are described as follows:

I. First Stage

1) To block the inflow from the east and north of Bangkok and drain southwards through the Green Belt Area to the Gulf of Thailand; parts of the Green Belt Project, construction of the 76 km length dike, the gates in the klongs intersected along its dike and the improvement of klong capacity in the Green Belt Area. This plan is being executed under the RID, BMA, SRT and HD. Top elevation of the dike was set as 3.0 metres above MSL which is sufficient to block the inflow from the outer areas, considering the highest water level of 2.5 metres above MSL which occurred in the past.

2) Construction of the dike along the Chao Phraya River in Samut Prakarn Province

3) Dredging work of the Klong Sam Rong

II. Second Stage

The second stage plan has been intended to increase the pumping capacity for the Eastern Suburban area and to improve the prevention of backflow from the Chao Phraya River. Total 59 units of submerged pumps having a capacity of 3 CMS each, were granted by the Japanese Government, and were installed at the mouths of 10 klongs along the east bank of the Chao Phraya River. These klongs except Klong Sam Sen and Klong Sam Rong are the main outlets of the Master Plan Area. As a result, the total pumping capacity in the Master Plan Area increased from 34 CMS (nominal) to 129 CMS while the rest of 48 CMS pumps were installed in the vicinity.

Besides these pumps, the Thai Government has also procured a further 59 units of pumps to the same specification and will install them in the Green Belt, Samut Prakarn, Nontaburi and West Bank areas of the Chao Phraya River. In the second stage, th klong improvement in Samut Prakan Province is also included.

III. Third Stage

As shown in Table C.1, the third stage plan were the construction of the dikes and gates as supplemental works to the Green Belt project, and the improvement of the klongs in Samut Prakarn Province and other works in the West Bank Area in Chao Phraya River and Nontaburi. The third stage plan has only indirect relationship with the flood control measures in the Master Plan Area.

3. Evaluation of the Urgent Flood Protection Measures

3.1 General

Embankments of 76 km length and 18 control gates and cofferdams can block inflow from the vast Central Plain to the north and east of Bangkok. The volume of inflow has been enormous, e.g., equivalent to the rainfall of 1,078 mm (from August to October 1983) precipitated within the protected area (Fig. C.9).

43 sets of Pumps, 129 m^3/sec in the Eastern Suburban Bangkok (out of the total 118 sets, 354 m^3/sec) can discharge rainwater equivalent to rainfall of 20 mm per day without inundation provided that the inland drainage facilities are executed. As there are only about 10 days in total during August to October which have a daily rainfall exceeding 20 mm, the observed flooding can be changed from the long-lasting type to the short duration type. In addition, the 2-year return period rainfall is 60 mm per day and 80 mm in the case of a 5-year return period, flooding will disappear within 3-4 days.

3.2 Hydraulic Evaluation of Urgent Flood Protection Measures

In order to grasp the hydrological effect, hydraulic analysis is made using a 9-basin model. Table C.2 shows the evaluated cases. (See Appendix F for an explanation of the model.) The following five cases are firstly analysed for the three-month rainfall period in 1983.

Case A: Before Urgent Flood Protection Measures
Case B: Effect of Embankment and Gate
Case C: Effect of Pump
Case D: Effect without Inner Barrier
Case E: Effect with Inner Barrier

Table C.2 Cases for Evaluation of Urgent Measures

Name of Case / Item	A Before Urgent Measures (1983)	B Embank-ment and Gate (1983)	C Pump (1983)	D Without Inner Barrier (1983)	E Inner Barrier (1983)	F Pump (1980)	G Inner Barrier (1980)	H Land Subsi-dence (2000)
Rainfall	1,078 mm from August to October, 1983 (Area Average, 25-year frequency)					872 mm from August to October, 1980 (Design Rainfall of 5-year frequency)		
Topography	Existing in 1983							Future in 2000
Green Belt Levee	X	O	O	O	O	O	O	O
Urgent Pump	X	X	O	O	O	O	O	O
Inner Barrier	△	△	△	X	O	△	O	O
Pump Capacity	21 m^3/s	21 m^3/s	159 m^3/s (Including Sam Rong Pump of 30 m^3/s)					

Note: X : Not considered.
O : Considered.
△ : Existing Cofferdams in K. Saen Saep and K. Phra Khanong be considered.

Table C.3 Impact of Urgent Measures

(Unit: million m^3)

Item \ Case			A Before Urgent Measures (1983)	B Embank-ment (1983)	C Pump (1983)	D Without Inner Barrier (1983)	E Urgent Barrier (1983)	F Urgent Pump (1980)	G Inner Barrier (1980)	H Land Subsi-dence (2000)
Conditions of Calculation	Rainfall		1,078 mm from August to October, 1983 (Area Average, 25-year frequency)					872 mm from August to October, 1980 (Design rainfall of 5-year frequency)		
	Topography		Existing in 1983 (Fig. 2.X)							Future in 2000 (Fig. 2.X)
	Green Belt		X	O	O	O	O	O	O	O
	Urgent Pump		X	X	O	O	O	O	O	O
	Inner Barrier		△	△	△	X	O	△	O	O
	Pump Capacity		21 m^3/sec				159 m^3/sec (Including Sam Rong Pump of 30 m^3/sec)			
Water Balance in 605 km^2 Area	Input	Inflow	499	0						
		Rainfall	721					528		
	Output	Evapotranspiration	173							
		Discharged	627	395	341	405	325	263	265	278
	Stored	Protected Area (605 km^2)	352	288	240	105	257	187	193	198
		Master Plan Area (260 km2)	132	91	66	74	61	57	58	70
		Retection Area (345 km^2)	220	197	174	95	196	130	135	128

As an inner barrier is proposed along the eastern periphery of Master Plan Area by the JICA Team, the effect of the inner barrier is also analysed. Secondly, the effect of pump and inner barrier is analysed for the three month rainfall of a 5-year return period. Finally, the effect of land subsidence on the flood protection measures are investigated.

Table C.3 and Fig. C.10 show calculated water balance. In all cases, flooding can be expected. However, flooding above the residential-land level, which produces most of the flood damage will be alleviated.

It can be said that the executed urgent measures will reduce flood depth from 35 cm to 16 cm for 1983 rainfall on average over the whole area. If land subsidence occurs flood depth increase from 8 cm to 18 cm for 1980 rainfall due to decrease of storage capacity.

Fig. C.11 shows the highest water level, maximum flood depth and total duration in 9 basins (5 basins in the Master Plan Area). The following can be concluded by examination of the data presented:

1) By the comparison of case B with case A, it is said that the embankments of the urgent measures can reduce maximum flood depth by about half to 40 cm - 70 cm and that flood duration in total will be shortened by one-third.

2) By the comparison of case C with case B, the pumps installed by the urgent measures can much reduce flooding. The significant effect is on the flood duration which is reduced to about 10 days. In other words, long-lasting inundation is replaced by short-duration flooding. This is clearly seen in Figs. C.12 and C.13 which show daily water level in Bang Na (basin 3) and Lat Phrao (basin 7).

3) By the comparison of case D with cases B and C, the following are found; if there were no existing cofferdams between the Master Plan Area and the Retention Area (Basins 5 and 8 are included), flooding status in the Retention Area, particularly in the north (basin 8) would be improved. However, the flood status in the Master Plan Area would become worse than case C (urgent pump), and be the same as case B (embankment).

4) If inner barrier is completed (case E), flooding status will be improved and be similar to case C (urgent pump).

5) For the rainfall of a 5-year return period (cases F and G), flood duration in total will decrease in comparison with cases C and E (1983 rainfall) respectively.

6) In the year 2000 (case H), maximum flood depth and flood duration will be about 50 cm and 2-3 months which are almost the same as case A, i.e., before implementation of flood protection measures. This is caused by developed urbanization and land subsidence.

7) Flooding status in the Retention Area is improved mainly by embankments and control gates but is not so affected by pumps. This is caused mainly by the existing natural barrier such as east-bound railway, Bang Kapi-Min Buri road and On-Nuch road and lack of capacity of the north-south klongs.

It is concluded that the implemented urgent measures could change long-period, large-area flooding to short duration small-area flooding. However, there still remain flood-prone areas especially in Hua Mark, Huay Kwang, Bang Kapi, etc. Therefore, further improvement measures are necessary to solve short duration but frequent flooding. Besides as land subsidence is expected despite the effort of its prevention, it can be said that the additional measures should be executed to alleviate future flooding, otherwise the flood situation may return to "before urgent measures" status hydrologically.

3.3 Evaluation of Drainage Facilities for Urgent Flood Protection Measures

By virtue of the recent development of compact and large capacity submerged pump motors, submerged pumps with low head and large capacity for temporary flood control facilities have been recently manufactured. The adoption of the submerged pump design will be able to decrease the scale of civil works for the related sub-structures and super=structures, compared with other pump types. The significant advantage of this type of pump is the low construction cost, short construction period and the ease of maintenance.

For a permanent pumping station for flood control purposes, however, this submerged pump type has seldom been adopted in the other countries.

1) Because the pump motor is electrical and is installed under th water, the submerged type pump has a high occurence rate of electrical and mechanical troubles.

2) Since various parts of the submerged pump are designed to be compact and of small size there may be some structural weak points. Therefore, it may require careful maintenance works including the daily inspection, washing, oil supply and repair works or exchanging spare parts. The maintenance works for a large number of installed pumps are rather heavy work.

As for the life of a pump, it is difficult to be predict because of few past experiences with this pump type. However, it may be assumed that 10,000 to 15,000 hours in operation is to be expected provided that maintenance is done normally.

According to the record of the 1984 rainy season for the installed pumps in urgent measures, near the Chao Phraya River, the operated hours of the pump ranged from 300 to 1,500 hous. As the rainfall in 1984 was rather small, the annual average operaton time may be a range of 1,000 to 2,000 hours. If the annual operation hours is assumed 1,500 hours, the operational life of the pump is a range of 7 to 10 years. After this the rate of troubles will increase and it may be necessary to replace main components.

In addition to above mentioned view points, the following comments are envisaged for the structure executed as an urgent measure.

1) The lowest water level of pump operation designated for the urgent flood control facilities is shown in the Table . For example Phra Khanong pumping station, the designated Low Water Level is +0.40 metres MSL. If this value is adjusted by the survey result performed by JICA (it is found that there is some difference between benchmarks of RID or BMA and JICA survey), this LLWL +0.40 becomes plus/minus 0.00 and with land subsidence in the year 2000, this LLWL will become -0.60 metres MSL. Therefore, the Phra Khanong Pumping Station cannot correspond to the planned maintenance water level of -0.80 MSL at present and -1.80 MSL in the year 2000, and there is big difference of 0.80 m at present and 1.20 metres in the year 2000.

2) Considering th future land subsidence, the efficiency of the pump will decrease since the total required head will become greater. Under the condition that the land subsidence is expected in one metre as described in Appendix D, the effective capacity of the pump will decrease from 3.0 to 2.4 CMS approximately since the pump efficiency will decrease. When the age of the pump is considered, the efficiency will decrease more than that mentioned.

The pumping stations constructed as urgent measures have future operational problems, therefore, these should be considered only as semi-permanent. For pumping stations of the flood control facility for Bangkok, therefore, it is recommended to adopt the permanent pump type such as the mixed and/or axial flow type because of high reliability and the many examples in operation.

Table C.4 Designated Lowest Low Water Level of Installed Pumps as Urgent Measures

Item / Pumping Stations	Lowest Low Water Level lowered by Pumps			(4) Planned Maintaining Water level in Master Plan
	(1) Designed	(2) Converted	(3) Considered Settlement	
1) Bang Khen P.S.	*-0.10 m	*-0.45(0.35)m	*-1.05 m	-1.50(-0.500
2) Bang Sue P.S.	-0.98	-1.33(0.35)	-1.93	-1.50(-0.50)
3) Phra Khanong P.S.	*+0.40	* 0.00(0.40)	*-0.60	-1.80(-0.80)
4) Bang Jek P.S.	-0.63	-1.20(0.60)	-1.83	-1.80(-0.80)
5) Bang Chak P.S.	-	-	-	-1.80(-0.80)
6) Bnag Oa P.S.	-0.63	-1.20(0.60)	-1.83	-1.80(-0.80)
7) Bang Na P.S.	-0.63	-1.20(0.60)	-1.83	-1.80(-0.80)

Table Designated Lowest Low Water Level of Installed Pumps as Urgent Measures

where;

Col. (1) Lowest Low Water Level (LLWL) indicated on the design drawings prepared by RID and BMA.

Col. (2) LLWL converted to JICA topographic survey results with difference shown in parenthesis.

Col. (3) LLWL are adjusted by the settlement (0.60 m) of pumping station by land subsidence in the year 2000 (Refer to Appendix D).

Col. (4) LLWL in the Master Plan as the maintenance water level in the year 2000. Figure in parenthesis shows the water level based on present topography.

4. Existing Klong Network

4.1 General

The extensive improvement works of klongs, which were originally excavated for navigation, irrigation and drainage, became a part of "the Greater Chao Phraya Project" in the 1950's. This Project aimed at increasing irrigation area. For that purpose, water was conveyed from the Chainat Dam in the Chao Phraya River and the Rama VI Dam on the Pasak River, and is stored in the low-lying flat area by the regulators.

Distribution klongs with a density of one kilometre per square kilometre serves to supply irrigation water to nearby paddy fields as well as drains. Fig. C.14 shows the klong network in the Master Plan Area along with the width of klongs.

4.2 Width and Gradient of Klong

The width of klong in the Master Plan Area varies from a few to 50 metres. Typical cross sections are shown in Figs. C.15 and C.16. Except main klongs of Phra Khanong, Saen Saep, Tan and Lat Phrao, all other klongs are generally 5 to 15 m wide and 1 to 2 m deep. The cross sectional area of klongs except main klongs are only in the order of 10 m^2 as shown in Table C.4. According to the result of the topographic survey, average longitudinal gradient of the main klongs are about 1:15,000 to 1:20,000. In addition, water surface gradient of the main klongs are also very mild as shown in Fig. C.17.

4.3 Discharge Capacity of Klong

Reflecting the very mild gradient and small size of klongs, their discharge capacity is small. Their actual discharge usually fluctuates, depending on various factors such as the water level of the Chao Phraya River. They have been recorded as 20 m^3/sec in Klong Saen Saep and 33 m^3/sec in Klong Phar Khanong in October and November, 1983 as shown in Fig. C.18. The discharge capacities of existing klongs in the Master Plan Area are calculated by uniform flow method assuming gravitational flow with water surface gradient 1:20,000 and no overflow. The results are shown in Fig. C.19. The discharge capacities of the main klongs range generally as follows:

Klong Phra Khanong	10 - 80 m^3m/sec
Klong Tan	25 - 30 m^3m/sec
Klong Saen Saep	10 - 37 m^3m/sec
Klong Lat Phrao	10 - 20 m^3m/sec

The capacities of other klongs are in order of 2 to 3 m^3/sec.

4.4 Maintenance of Klongs

Klongs are maintained by the Canal Maintenance Division of DDS, BMA. DDS is in charge of garbage collection and dredging works in the klongs. The dredging of the klongs has been carried out recently almost every year. Tables C.5 to C.6 show the amount of dredging and cost of garbage collection respectively. The costs for dredging are 200 - 300 Baht per m^3 in case of labour and 70 - 80 Baht m^3 by machine, while garbage collection costs is 110 Baht per m^3.

4.5 Right-of-Way

As information about the right-of-way of klongs is not available, the right of way is assumed to be about the same width of the existing klongs from th result of field survey.

Table C.5 Outline of Existing Klongs

Klong		Length	Width	Cross Station Area (m^2)	Discharge Capacity (m^3/S)
Main	Small	(km)	(m)		
Bang Ken*		10.4	10-20	5-15	0.5-3.0
Bang Sue*		8.0	15-25	10-35	1.5-16
	Huay Kwang Bon	2.0	10-17	5-12	0.6-1.5
	Nam Kaew	2.2	8-10	6-20	0.7-3.8
Saen Saep		18.5	20-50		10-37
	Ta Nang	6.3	7-11	5-12	0.5-2
	Chan	9.1	6-18	3-12	0.5-1.8
	Lan Cheak	4.0	8-12	6-9	0.7-1.3
	Sua Nai	4.0	8-12	6-17	0.8-3.0
	Song Kla Tiam	3.8	6-11	5-11	0.5-1.7
	Wat Tuk	3.2	6-25	3-13	0.3-1.3
Lat Phrao		22.0	20-40		10-20
	Lum Phai	2.4	5-6	2-4	0.2-0.5
	Lad Plakao	6.2	6-12	3-10	0.4-1.5
	Plab Pla	5.1	8-26	7-20	0.8-26
	Huay Kwang	4.6	6-7	3-6	0.3-0.8
	Sam Saen	4.0	7-16	9-18	1.2-3.2
Tan		3.5	20-30		25-30
	Saen Sab	7.6	8-14	3-15	0.3-2.4
Phra Khanong		21.0	30-45		10-80
	Hua Mark	7.4	9-18	4-18	0.4-3.0
	Klet	5.0	8-15	5-20	0.5-3.2
	Ban Lai	3.2	8-9	6-12	0.7-2.0
	Suan Aoi	1.1	5-15	4-7	0.4-0.7
	Kwang Lang	1.3	5-12	3-10	0.3-1.3
	Kwang Bon	1.3	5-10	5-6	0.7-0.8
	Bang Nang Jen	2.4	3-17	1-12	0.1-1.5
	Bang Jac 1	1.0	10-15	10-16	1.4-2.7
	Bang Jac 2	1.1	9-20	9-11	1.3-1.4
	Bang Jac 3	1.4	7-19	5-42	0.6-1.0
	Bang Oa	2.0	7-19	9-47	1.4-12
Bang Na		6.5	10-24	10-42	1.6-10
Total		181.6			

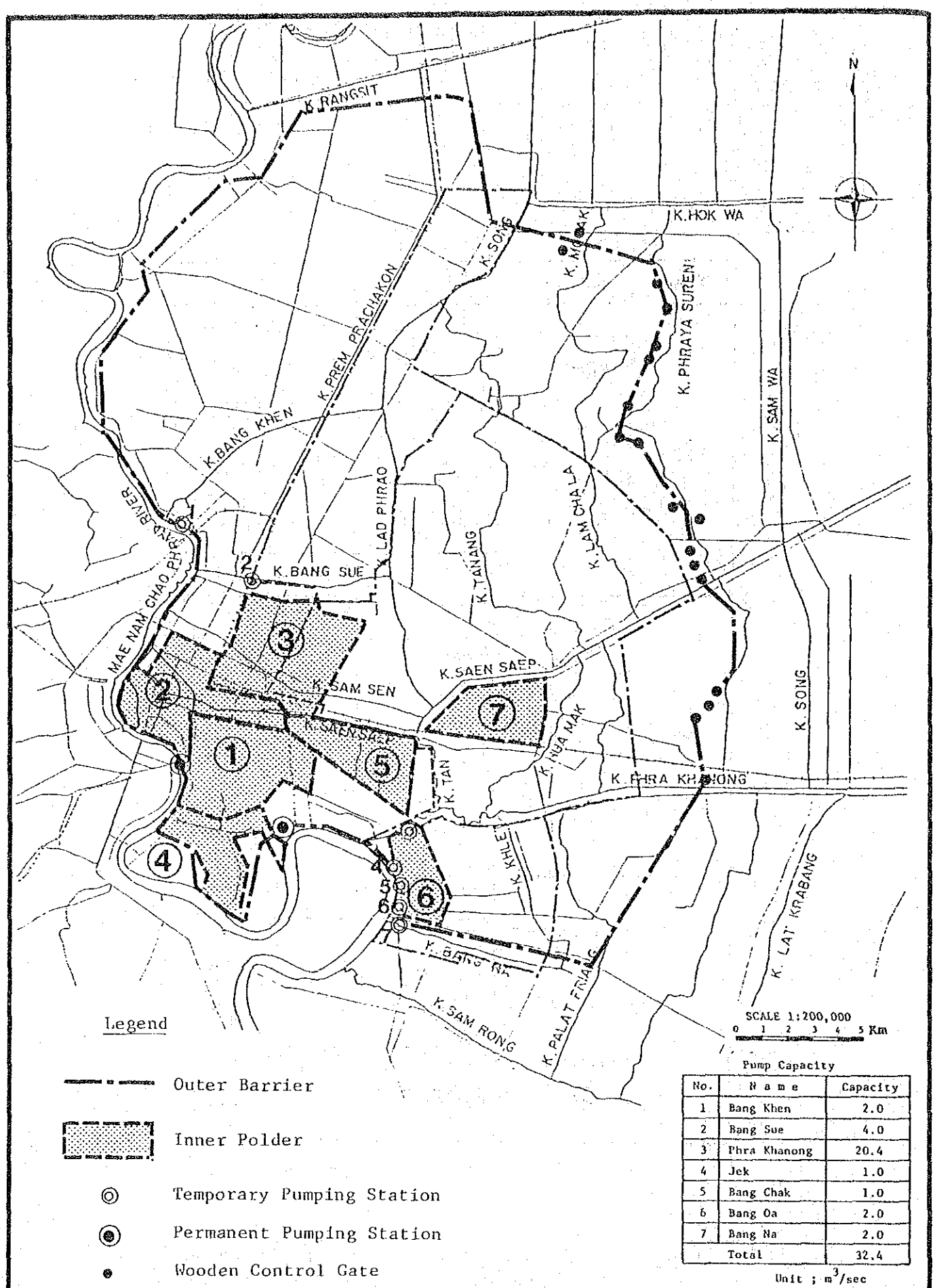
Note: * includes length in the outside of Master Plan Area

Table C.6 Klong garbage collection

Klong	Cost in Monthly basis ฿/month	Average unit cost for removed and deposited garbage ฿/m^3
Lord	45,400	378
Ong Ang and Bang Lum Phu	75,400	300
Padung Krung Kasem	115,100	193
Maha Nak	75,400	214
Saen Saep	71,200	35
Sam Sen	30,600	59
Bang Sue	22,800	95
Total/average	435,900	106

Table C.7 Dredging of Klong

YEAR	METHOD	ITEM	CONTRACTORS
1980	Mechanical	Cost (฿)	3,038,300
		Lengths (m)	11,922
		Volumes (m^3)	58,344
	manual labour	Cost (฿)	2,531,140
		Lengths (m)	14,088
		Volumes (m^3)	(28,908)
1981	Mechanical	Cost (฿)	2,913,750
		Length (m)	1750
		Volumes (m^3)	(-)
	manual labour	Cost (฿)	1,664,560
		Lengths (m)	11,235
		Volumes (m^3)	(22,709)
1982	Mechanical	Cost (฿)	4,607,800
		Lengths (m)	14,586
		Volumes (m^3)	71,199
	manual labour	Cost (฿)	2,842,000
		Lengths (m)	15,482
		Volumes (m^3)	37,222



Pump Capacity

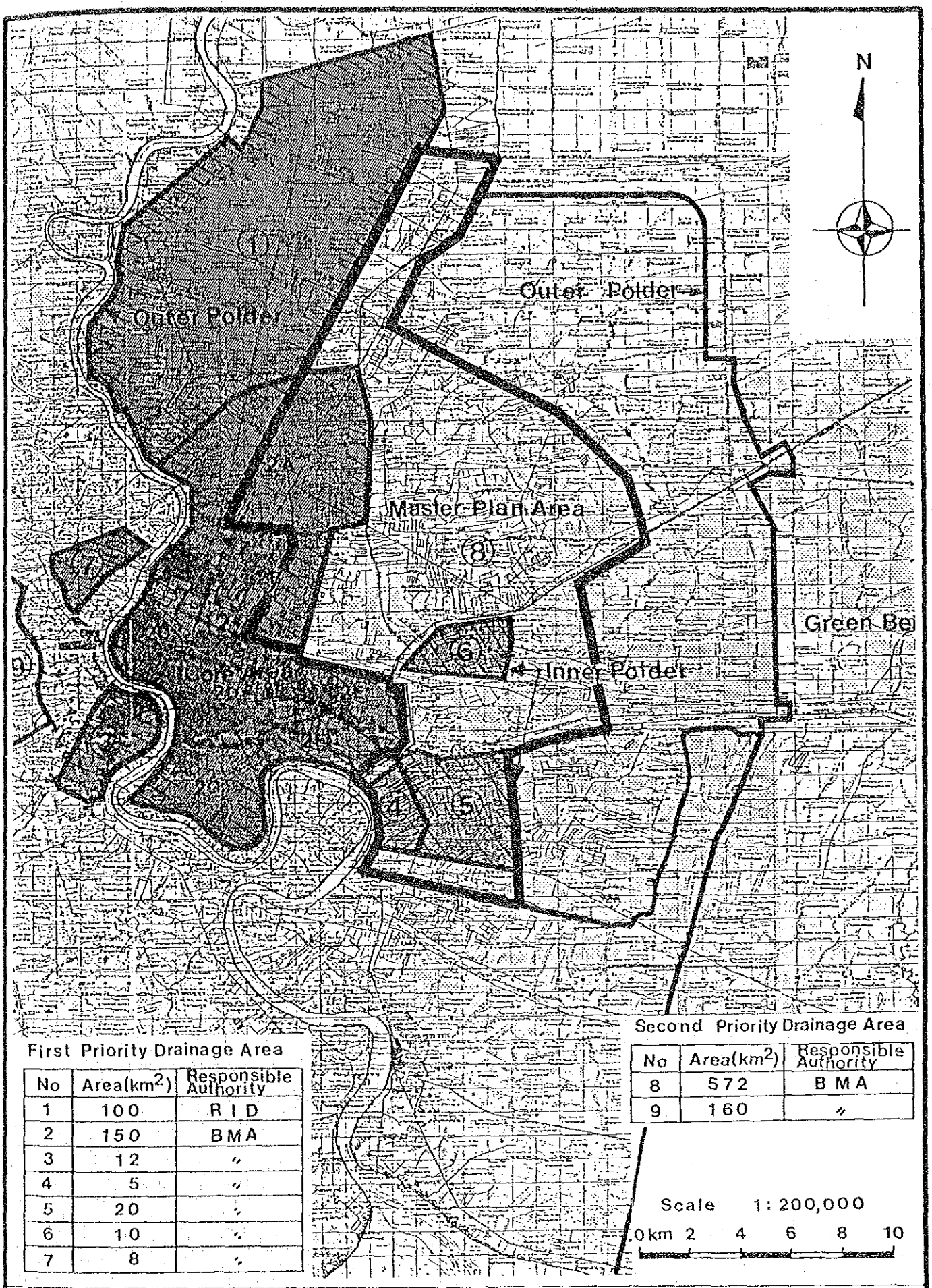
No.	Name	Capacity
1	Bang Khen	2.0
2	Bang Sue	4.0
3	Phra Khanong	20.4
4	Jek	1.0
5	Bang Chak	1.0
6	Bang Oa	2.0
7	Bang Na	2.0
	Total	32.4

Unit ; m^3/sec

Fig. C.1 LOCATION OF FLOOD PROTECTION MEASURES IN 1983

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

JICA 2528B.E 1985A.D



First Priority Drainage Area

No	Area(km^2)	Responsible Authority
1	100	RID
2	150	BMA
3	12	〃
4	5	〃
5	20	〃
6	10	〃
7	8	〃

Second Priority Drainage Area

No	Area(km^2)	Responsible Authority
8	572	BMA
9	160	〃

Scale 1:200,000

0km 2 4 6 8 10

Fig. C.2 AREAS PROTECTED FROM FLOODING IN 1983

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

JICA 2528B.E 1985A.D

Pump Capacity in Master Plan Area

No	Station	Capacity
1	Bang Khen	2
2	Bang Sue	4
3	Phra Khanong	20.4
4	Jek	1
5	Bang Chak	1
6	Bang Oa	2
7	Bang Na	2
Sub-Total		32.4
8 - 33		11.5
Total		43.9

Unit: m^3/s

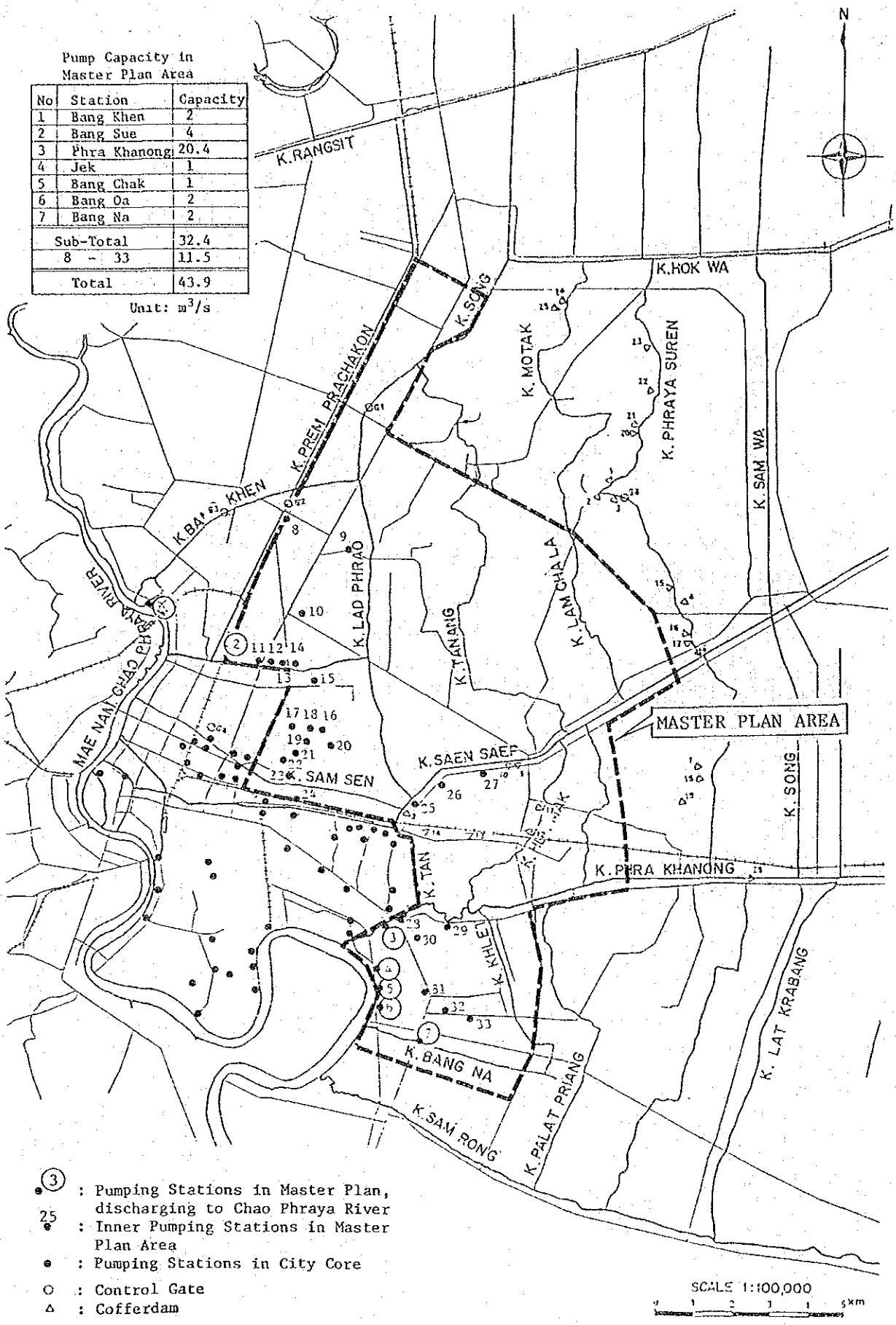


Fig. C.3 LOCATIONS OF PUMPS GATES AND COFFERDAMS IN 1983

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

JICA 2528B.E 1985A.D

	Pumping Station	Number of Pump Unit	Pump Size (inch)	Total Pump Capacity (Nominal m^3/sec)	Remarks
1	New Klong Bang Khen	2	24	2.00	
2	Klong Bang Sue	4	24	4.00	
3	Phra Khanong	14 4	24 36	20.40	
4	Klong Jek	2	20	1.00	
5	Klong Bang Chak	2	20	1.00	
6	Klong Bang Oa	2	24	2.00	
7	Klong Bang Na Sukhumvit Rd.	2	24	2.00	
8	Klong Lad Yao	2	20	1.00	
9	Soi Senanicom 1	2	14	0.50	
10	Lad Prao Road	1	8	0.08	
11	Norther Paholyothin 1	2	12	0.40	
12	Northern Paholyothin 2	2	12	0.40	
13	Vipavadee Rangsit Road 1	2	10	0.25	
14	Vipavadee Rangsit Road 2	2	20	1.00	
15	Soi Intramara 45	2	12	0.20	
16	Klong Huay Kwang	2	24	2.00	
17	Prachasongcraw	1	8	0.08	
18	Prachasongcraw Rd. at Flat 38	1	6	0.06	
19	Promphan	1	12	0.20	
20	Klong Yai Soon Rachadapisake Rd.	1	12	0.20	
21	Soi Suthipon Prachasongcraw	1	8	0.08	
22	Northern Fatima Church 1	1	14	0.25	
23	Northern Fatima Church 2	2	8 8/6	0.08 0.10	

Fig. C.4-(1) LIST OF PUMPING STATION IN 1983(FOR MASTER PLAN AREA)

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

JICA 2528B.E 1985A.D

Pumping Station		Number of Pump Unit	Pump Size (inch)	Total Pump Capacity (Nominal m^3/sec)	Remarks
24	Salaloy	1	12	0.20	
		2	24		
25	Klong Kracha	1	20	3.00	
		2	14		
26	Klong Gig	1	14	0.45	
		1	12		
27	Klong Chit	1	12	0.20	
28	Phra Khanong Bridge	1	8	0.08	
		2	8/6	0.20	
29	Mitraphao Villege Soi on Nush	1	8	0.08	
30	At the end of Soi Sukhumvit 91	1	4	-	
31	Bang Auo, Sukhumvit Rd.	2	10	0.25	
32	At the entrance of Sukhumvit 103	1	8	0.08	
33	Sukhumvit 103, in front of Tanin	1	6	0.06	
	Total Pump Capacity of Master Plan Area	75		43.88	

Fig. C.4-(2) LIST OF PUMPING STATION IN 1983(FOR MASTER PLAN AREA)

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

JICA 2528B.E 1985A.D

No.	Name	Dimension (m)		
		width	Length	Material
	Cofferdams, District Bangkapi			
1.	Klong Lum Phai	2.00	12.00	Wooden
2.	Klong beside Cannayav Police Station	2.00	14.50	"
3.	Klong Lat	2.00	8.00	"
4.	Klong Khet	2.00	8.10	"
5.	Klong Ton	2.00	8.00	"
6.	Klong Bang Chan	2.50	45.00	"
7.	Klong Lat Bua Khao	3.00	26.00	"
8.	Klong Kacha	1-2.50	12.50-25.00	"
9.	Klong Chit (Ramkhamhaeng Road)	1-2.00	10.00-16.00	"
10.	Klong Chik (Ramkhamhaeng Road)	1-2.00	9.00-10.00	"
11.	Klong Chik (Rajagreetra Road)	1-2.00	10.00-12.00	"
12.	Klong Rail-Road	1&2.00	9.70-10.00	"
13.	Klong Lao	1-2.00	7.00-9.00	"
14.	Klong Sakae	1-2.50	7.50-20.00	"
15.	Klong Bang Lumget	2.00	12.00	"
16.	Klong Suraui Bangchan 1	2.50	13.50	"
17.	Klong Suraui Bangchan 2	2.50	25.00	"
18.	Klong Yagraulae	2.50	19.00	"
19.	Klong Tap Chang Bon	2.50	26.00	"
	Cofferdams, District Bangkhen			
20.	Klong Bua Mon	2.00	14.00	Wooden
21.	Klong Bua Mon	2.00	9.00	"
22.	Klong Tarang	2.00	11.50	"
23.	Klong Aripeng	2.00	18.00	"
24.	Klong Motak	2.00	12.00	"
25.	Klong Mon Si Sip	2.00	14.00	"
	Cofferdams, District Phra Khanong			
26.	Klong Phravai	2.50	42.00	Wooden
27.	Klong Lot Km. 2	1-2.00	8.00-12.00	"
28.	Klong Lot Km. 3	1-2.00	10.00-13.00	"

(Refer to Fig.C.3)

Fig. C.5 LIST OF COFFERDAMS IN 1983

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

No.	Name	Width	Remarks
		1.6.00	
1	Song Lek See	2-2.50	
2	Pram Bang Sue	1-6.00	
3	Bang Khen	1-6.00	
4	Sam Sen	2-4.00	
5	Kaseu	1-4.00	
6	Bang Sue	1-6.00	
7	Lad Praou	1-6.00	
8	Phraya Suren	1-6.00	
9	Sam Wa	1-6.00	
10	Bang Na		
11	Sam Rong		
	Phra Khanong	2-6.00	same as No. 12 pump facility

Fig. C.6 LIST OF CONTROL GATE IN 1983

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

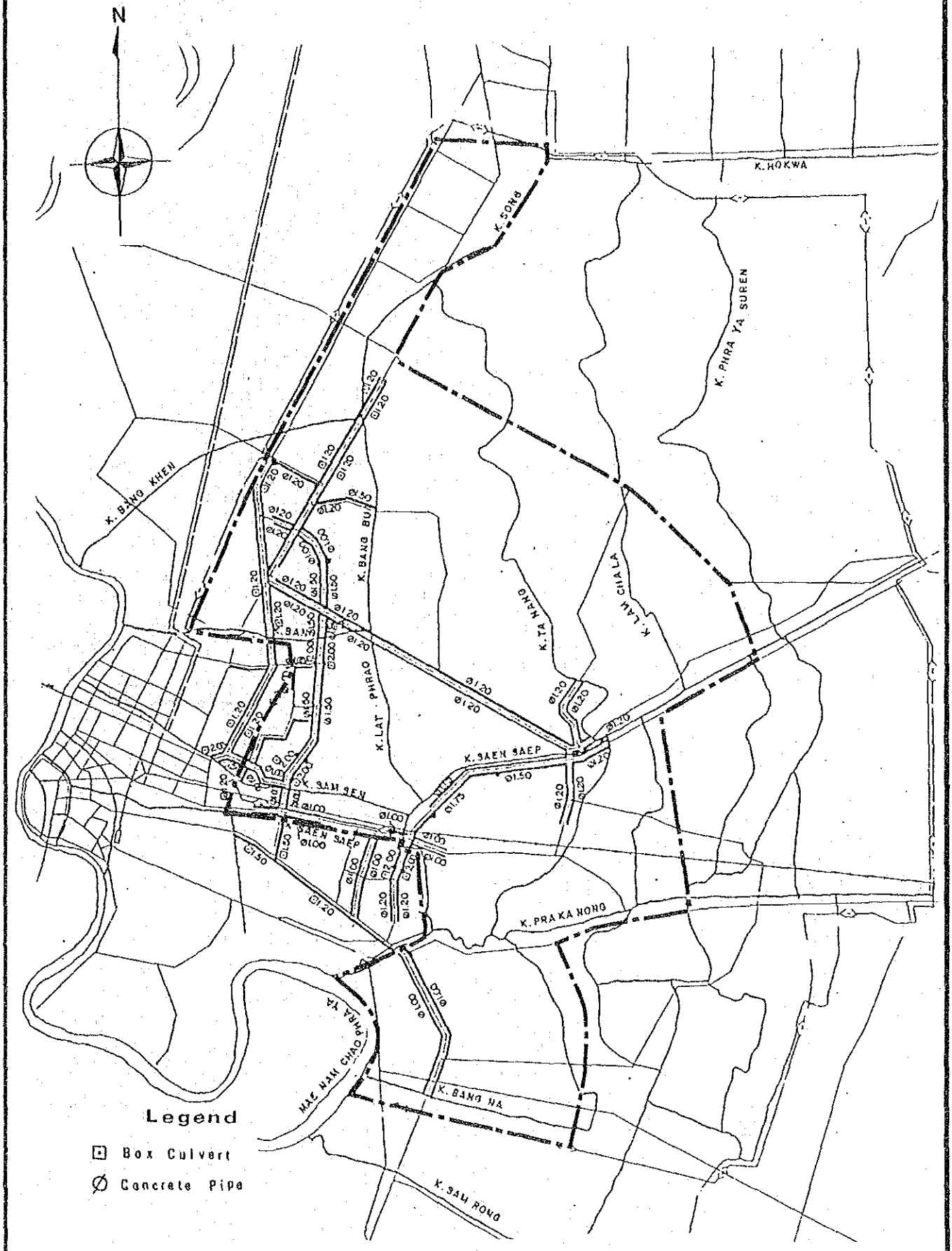
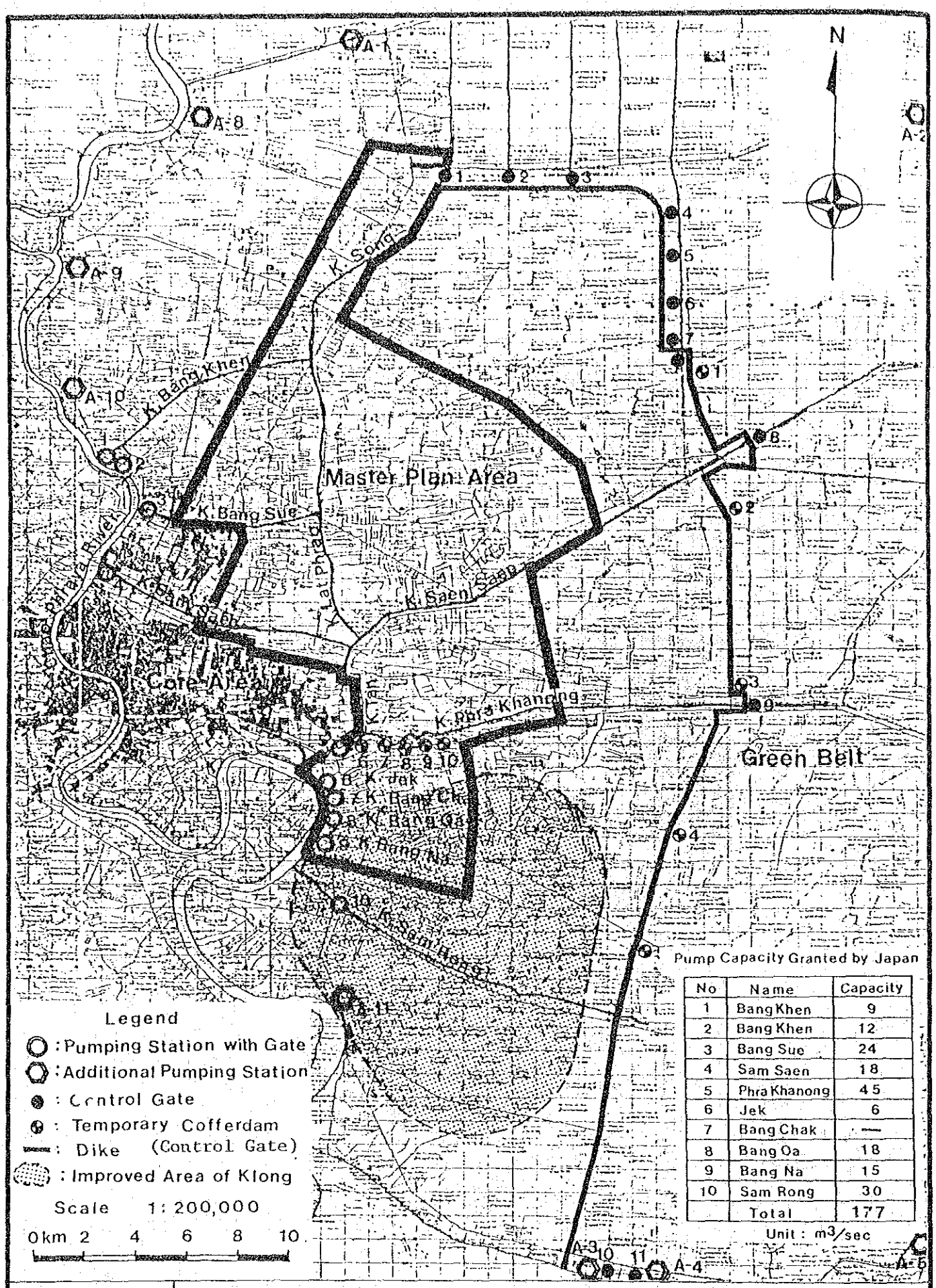


Fig. C.7 MAIN PIPE DRAINS IN 1983

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

JICA 2528B.E 1985A.D



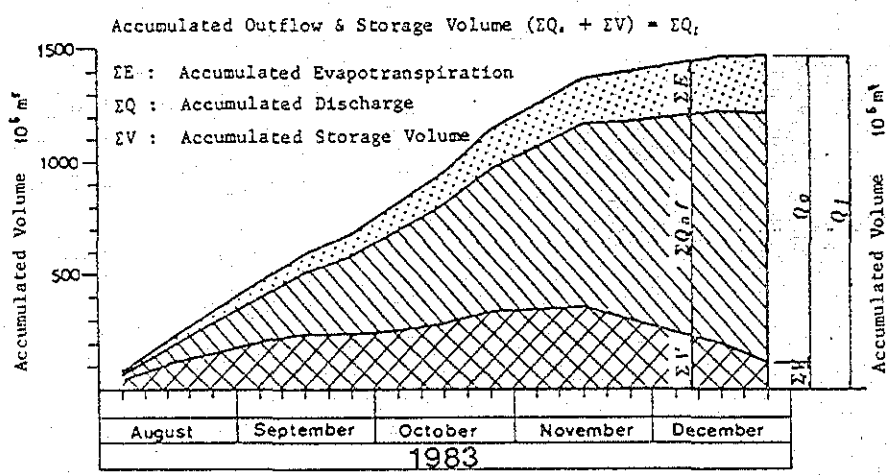
No	Name	Capacity
1	Bang Khen	9
2	Bang Khen	12
3	Bang Sue	24
4	Sam Saen	18
5	Phra Khanong	45
6	Jek	6
7	Bang Chak	—
8	Bang Oa	18
9	Bang Na	15
10	Sam Rong	30
	Total	177

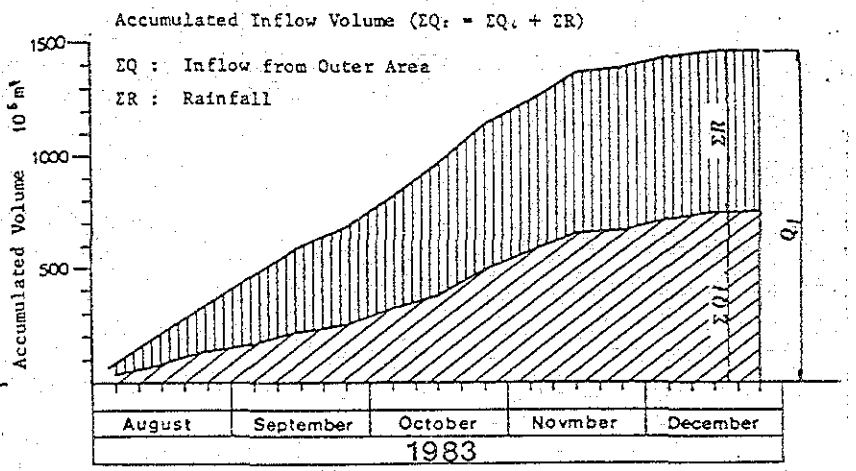
Fig. C.8 URGENT FLOOD PROTECTION MEASURES

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

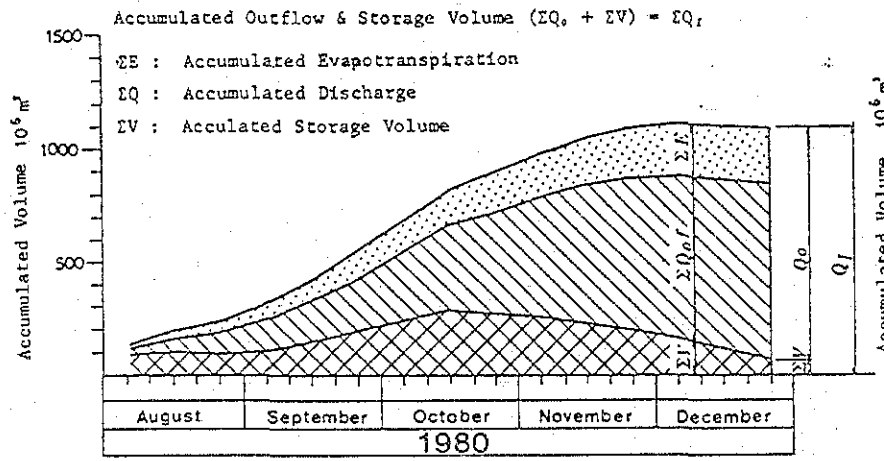
JICA 2528B.E 1985A.D

AD 1983





AD 1980



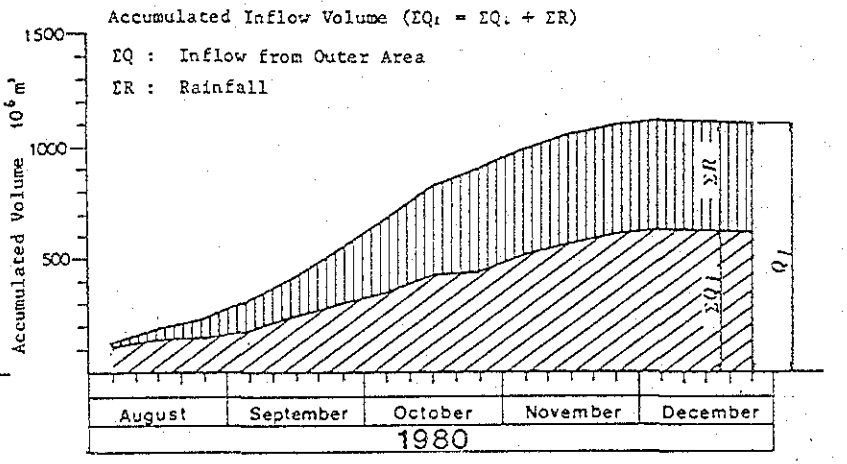
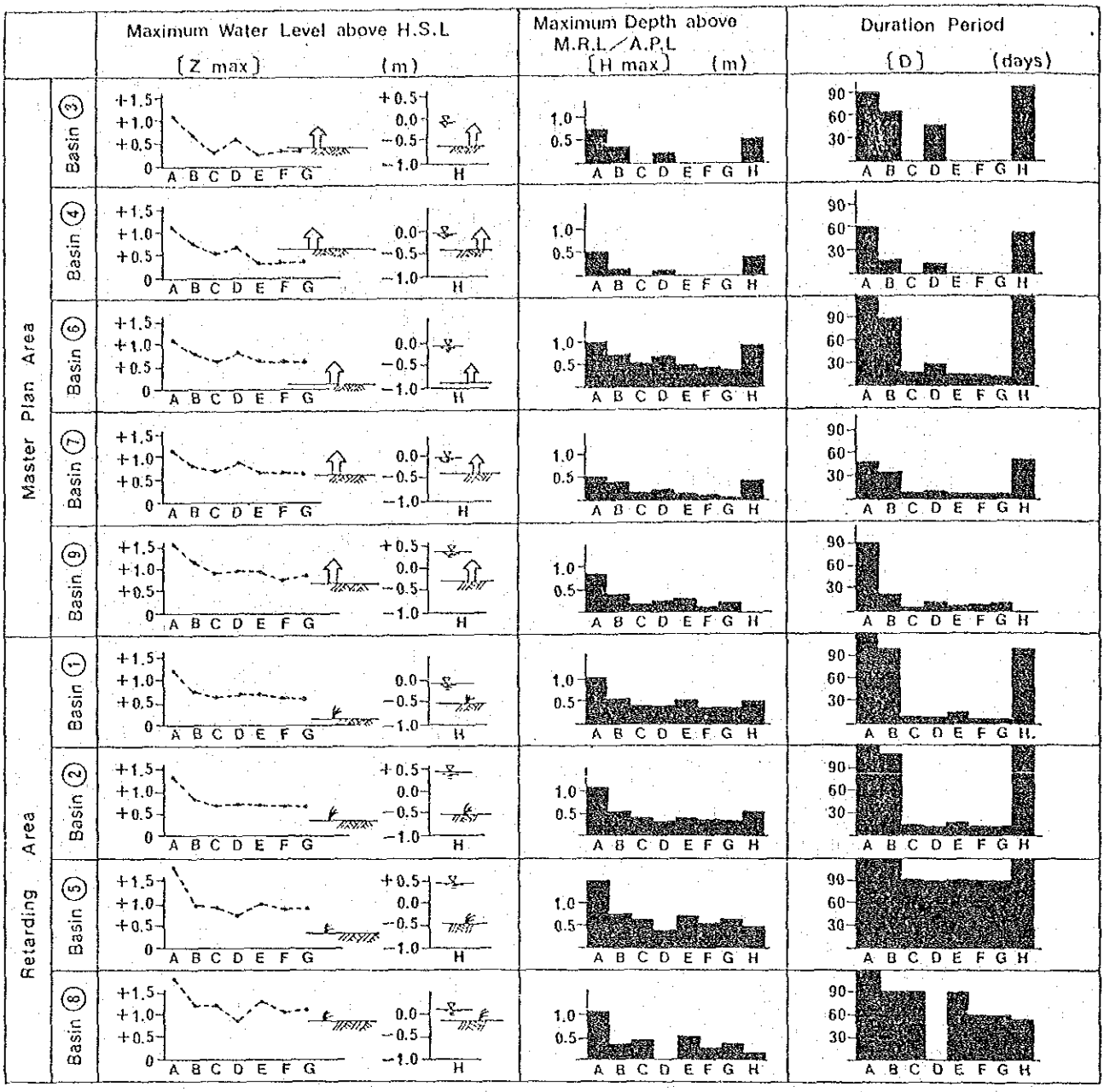


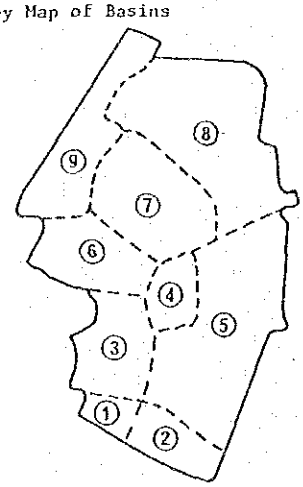
Fig. C.9 INPUT AND OUTPUT OF WATER DURING FLOOD SEASON IN 1980 AND 1983

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

JICA 252BIE 1985A.D



1. Key Map of Basins



③ : Number of Basin

2. Area size of Basin

	No. of Basin	Area (km^2)	MRL/APL in 1983	MRL/APL in 2000
Master Plan Area	③	52	+0.4	-0.6
	④	22	+0.6	-0.4
	⑥	42	+0.1	-0.9
	⑦	80	+0.6	-0.4
	⑨	64	+0.7	+0.3
Retarding Area	①	19	+0.3	-0.6
	②	35	+0.3	-0.5
	⑤	105	+0.4	-0.6
	⑧	160	+0.8	-0.2

3. Condition of Calculation Case

case	A	B	C	D	E	F	G	H
Rain fall	Areal Average Rainfall in 1983 ΣR=1078mm/3M					Design Rainfall 1/N=1/5 ΣR=872mm/3M		
Topo-graphy	Existing (1983)							Future (2000)
Green Belt	×	○	○	○	○	○	○	○
Urgent Pump	×	×	○	○	○	○	○	○
Inner Barrier	△	△	△	×	○	△	○	○
Pump Capacity	CMS 21	CMS 21	CMS 159	CMS 159	CMS 159	CMS 159	CMS 159	CMS 159

×: Not considered

○: Considered

△: Existing Cofferdam in Klong Saen Saep and Klong Phrakhanong cosidered

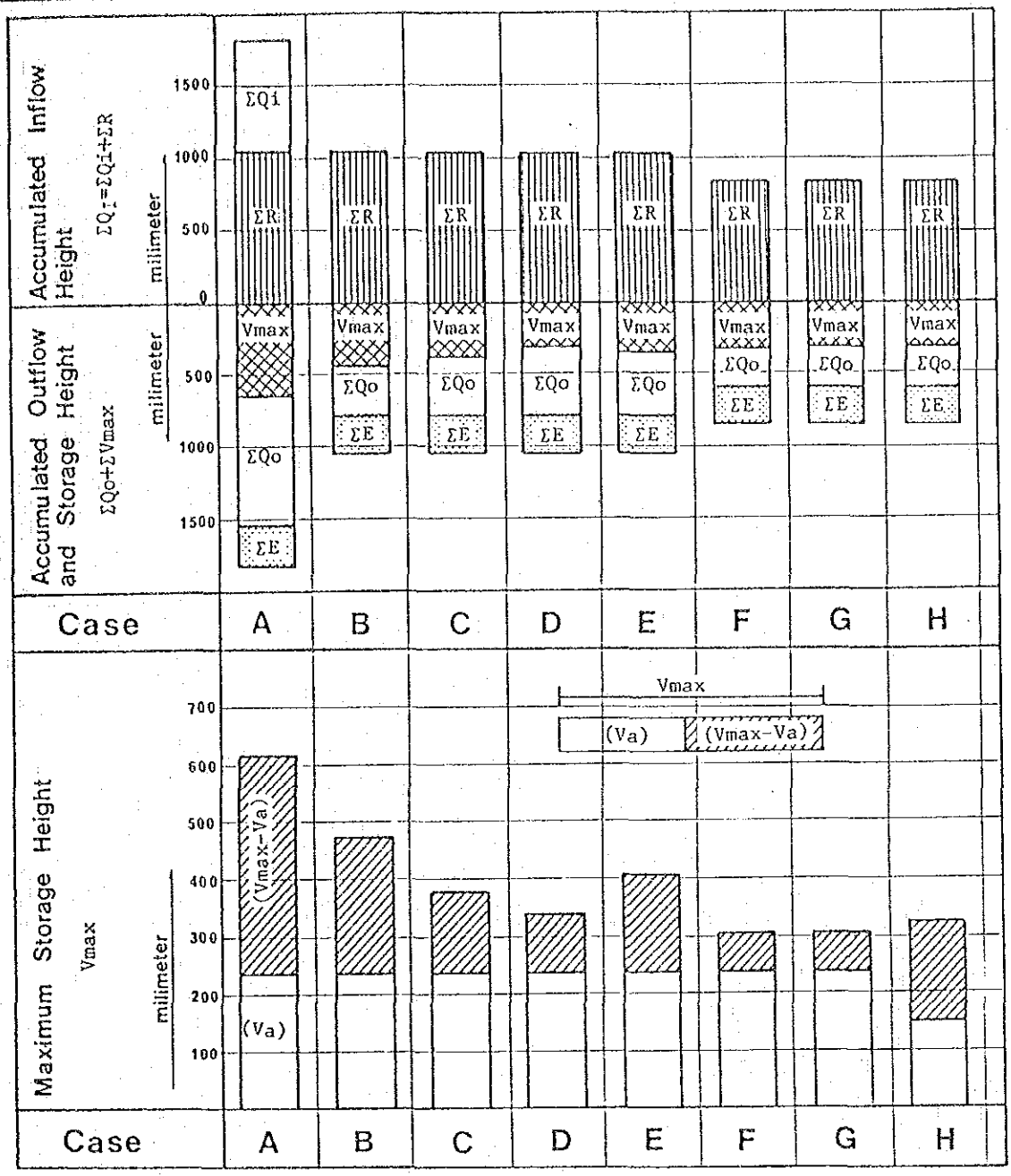
MRL : Minimum Residential-Land Level above MSL(m)

APL : Average Paddy Field Land Level above MSL(m)

Fig. C.10 EFFECT OF URGENT MEASURES--(1)
(MAXIMUM WATER LEVEL DEPTH DURATION PERIOD)

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

JICA 2528B.E 1985A.D



Legend

ΣQi : Inflow from Outer Area
ΣR : Rainfall
Vmax : Maixmum Storage Volume
ΣQ_0 : Discharge Volume
ΣE : Evapotranspiration
Va : Allowable Storage Capacity
(under lowest residential-land level)

AREA : Preliminary Study Area (including Master Plan Area) + Surrounding Area (605 km^2)

Study Case

case	A	B	C	D	E	F	G	H
Rain fall	Areal Average Rainfall in 1983 ΣR=1078mm/3month					Design Rainfall 1/N=1/5 ΣR=872mm/3month		
Topo-ghraphy	Existing (1983)							Future (2000)
Green Belt	×	○	○	○	○	○	○	○
Urgent Pump	×	×	○	○	○	○	○	○
Inner Barrier	△	△	△	×	○	△	○	○
Pump Capacity	CMS 21	CMS 21	CMS 159	CMS 159	CMS 159	CMS 159	CMS 159	CMS 159

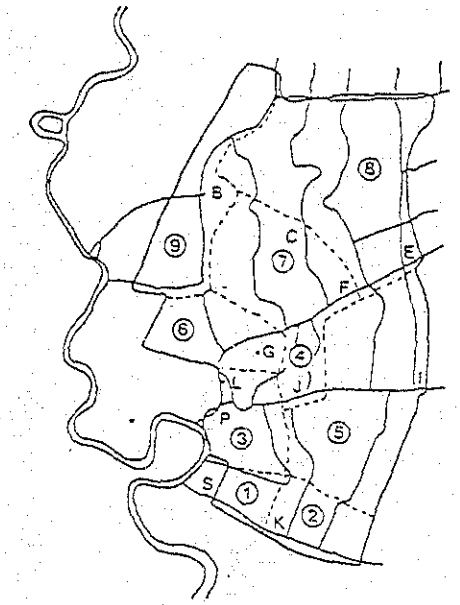
× : Not considered
○ : Considered
△ : Existing Cofferdam in Klong Saen Saep and Klong Phrakhanong cosidered

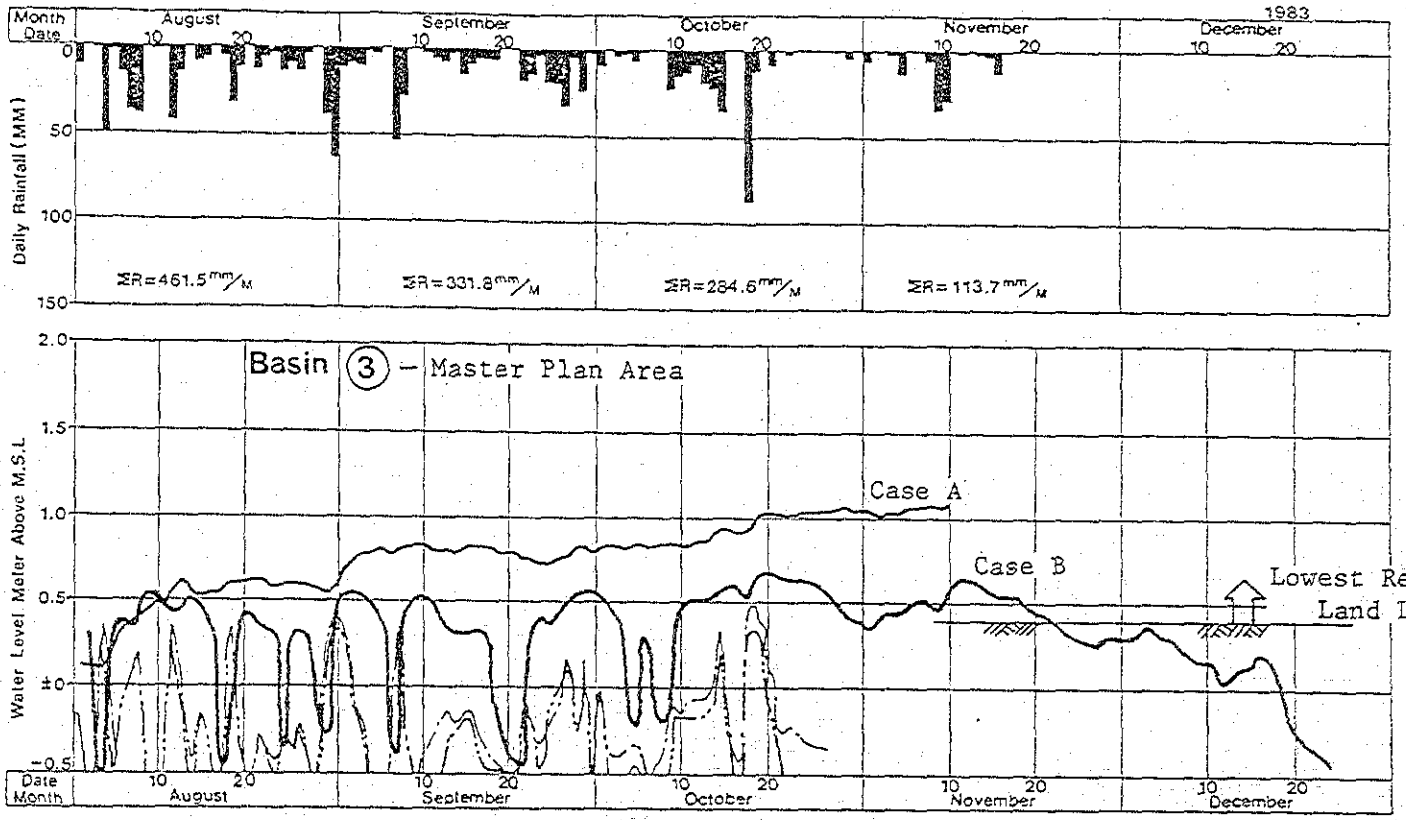
Fig. C.11 EFFECT OF URGENT MEASURES--(2) (STUDY OF WATER BALANCE)

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

JICA 2528B.E 1985A.D

Key Map





Legend

① : Basin Number

· B : Water Level Gage station

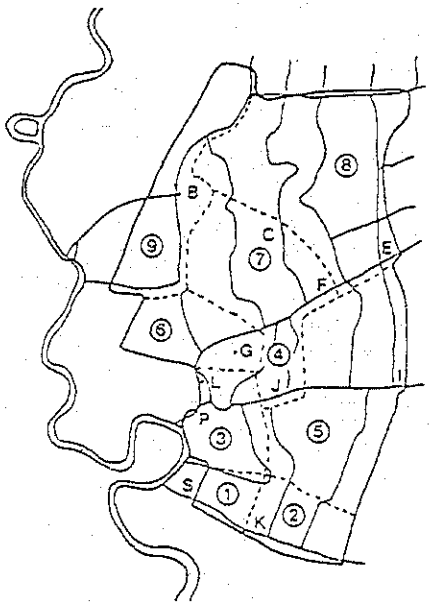
		Rain fall	Topo-graphy	Green Belt	Urgent Pump	Inner Barrier	Pump Capa-city m³/s
CaseA	—— Observed Water Level	1983	Exist-ing	X	X	△	21
CaseB	—— Calculated Water Level	〃	〃	○	X	△	21
CaseC	—·— 〃	〃	〃	○	○	△	159
CaseD	—··— 〃	〃	〃	○	○	○	159

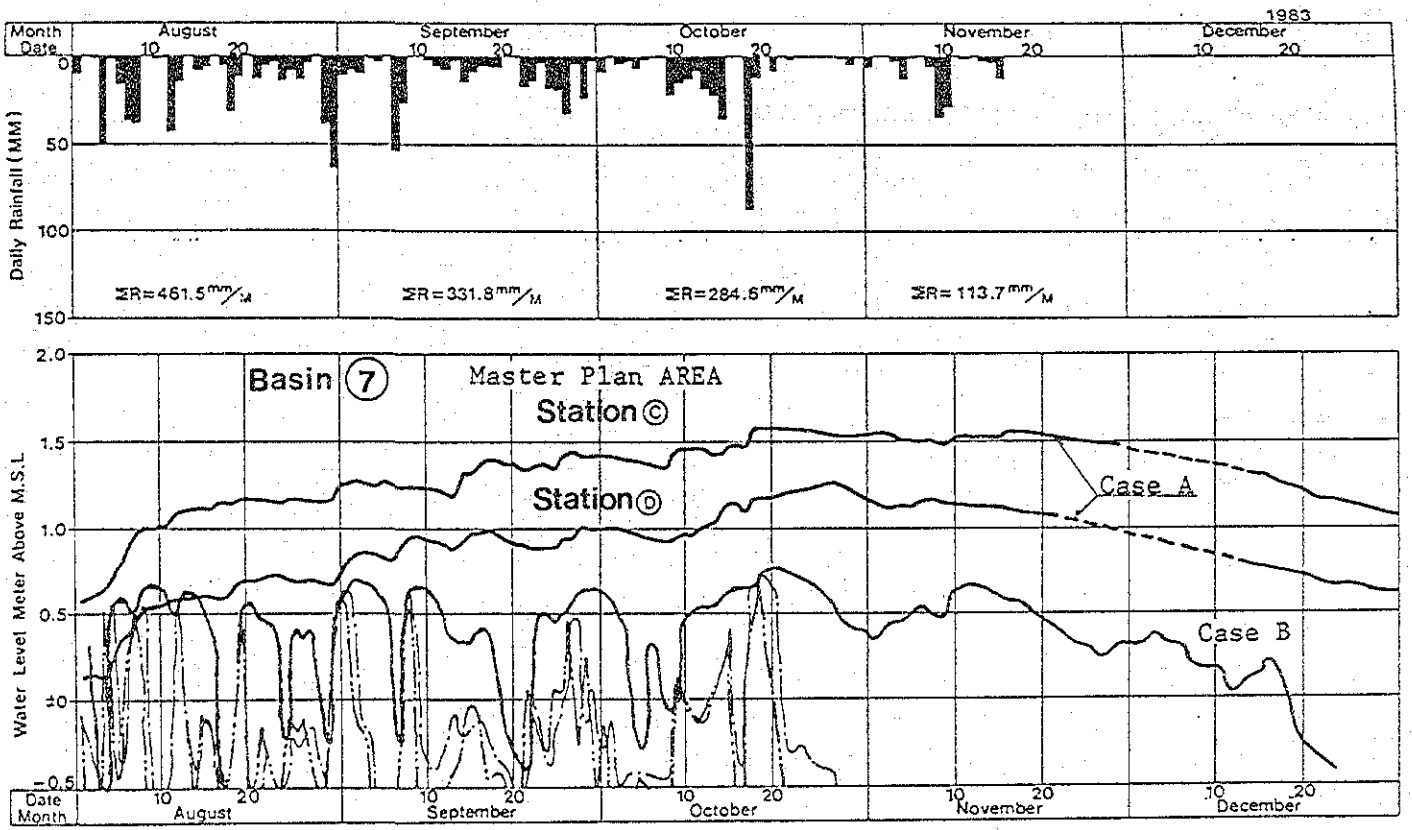
[Estimated by 9-Basin Model]

Fig. C.12 EFFECT OF URGENT MEASURES--(3)
(VARIATION OF WATER LEVEL IN BASIN 3)

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

Key Map





Legend

① : Basin Number

·B : Water Level Gage station

		Rain fall	Topo-graphy	Green Belt	Urgent Pump	Inner Darruer	Pump Capa-city m³/s
CaseA	—— Observed Water Level	1983	Exist-ing	X	X	△	21
CaseB	- - - Calculated Water Level			○	X	△	21
CaseC	—·—			○	○	△	159
CaseD	—··—			○	○	○	159

Fig. C.13 DAILY WATER LEVEL IN LAT PHRAO (BASIN 7) DUE TO URGENT FLOOD PROTECTION MEASURES

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

JICA 2528B.E. 1985A.D

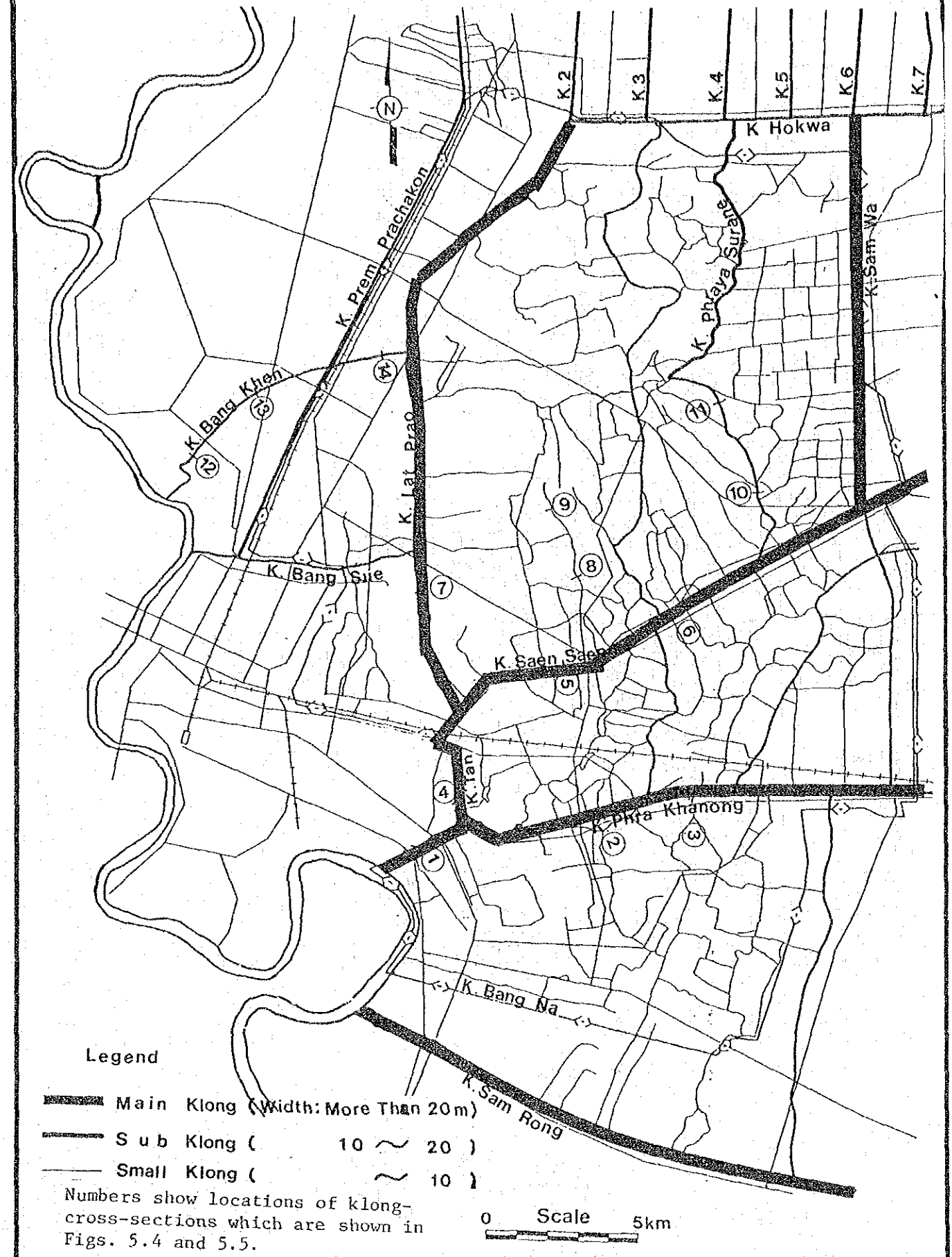
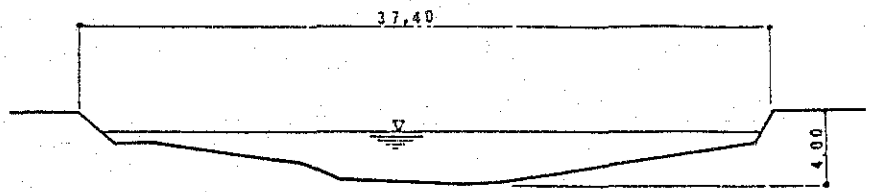


Fig. C.14 KLONG NETWORK IN MASTER PLAN AREA

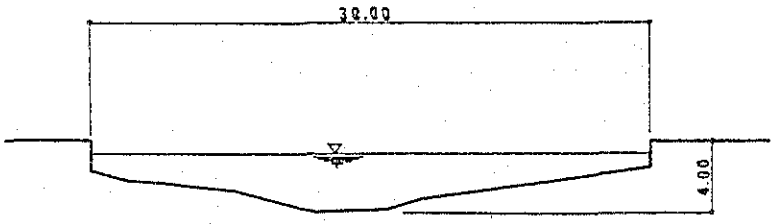
MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK

JICA 2528B.E 1985A.D

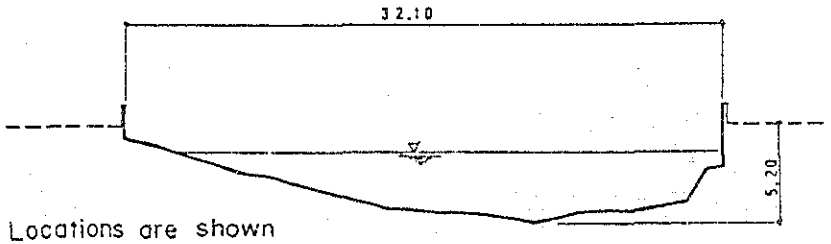
NO 3



NO 2



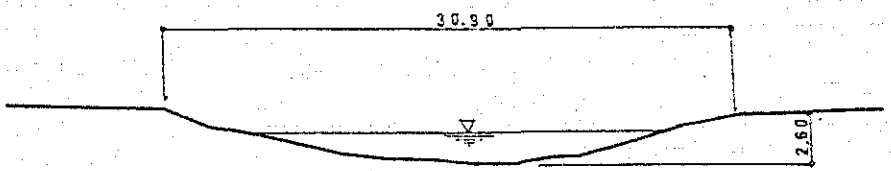
NO 1



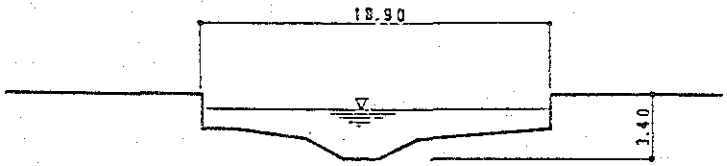
Note : Locations are shown in Fig 5.3

Scale
Not to Scale

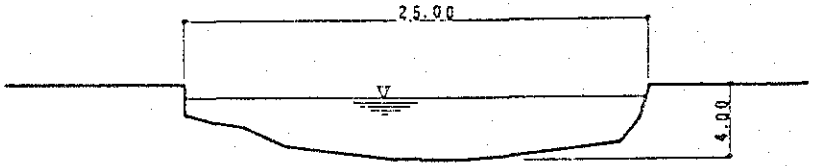
NO 7



NO 6



NO 5



NO 4

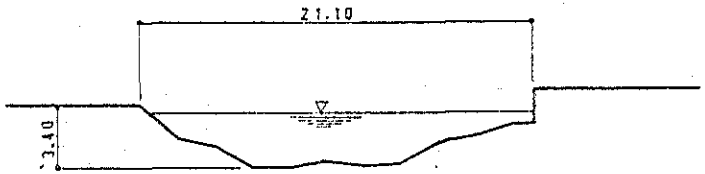


Fig. C.15 CROSS SECTIONS OF MAIN KLONGS (1)

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

JICA 2528 B.E 1985 A.D.