During high water level of the Chao Phraya River, discharge from the Preliminary Study Area to the River is usually carried out by the assistance of the operation of gates and pumps as shown in Fig. F.21 and Fig. F.22.

4.1.4 Estimation of Probable Water Level

Based on the adjusted annual maximum H.H.W.L, M.W.L and L.L.W.L at five stations, the probable water level of the Chao Phraya River was estimated using th Thomas plotting method as shown in Fig. F.23.

According to the calculation, it has been proven that the flood water level between the mouth of the Chao Phraya River and the Rama IV Bridge (mouth of the Klong Bang Khen, 58 km upstream from the river mouth) does not differ much in a less than 10 year return period due to the influence of the tide in the Gulf of Thailand as shown in Fig. F.24.

4.2 Klong Water Level

4.2.1 Investigation on DDS and RID Data

As mentioned in Section 2 (Data collection), water level data in the klongs could only be obtained since 1981 except at the klong Phra Khanong and the Klong Sam Rong Flood Gates (F.G.) of RID. Besides, as every gauging station is influenced by land subsidence, adjustments are necessary to correct the MSL. According to the check survey by the Study Team, water levels at the Klong Phra Khanong F.G, the Klong Sam Rong F.G and the Klong Tan Pumping Station have to be adjusted by -0.930 m, -0.580 m respectively.

4.2.2 Observed Water Level in 1983 and 1984

As described before, twelve new recording water level gauges have been installed at th hydrologically important points in te main klongs and data has been obtained from th beginning of August in 1983. These data were used to verify the hydraulic calculation model in combination with rainfall and to understand the discharge situation of main klongs for this Study.

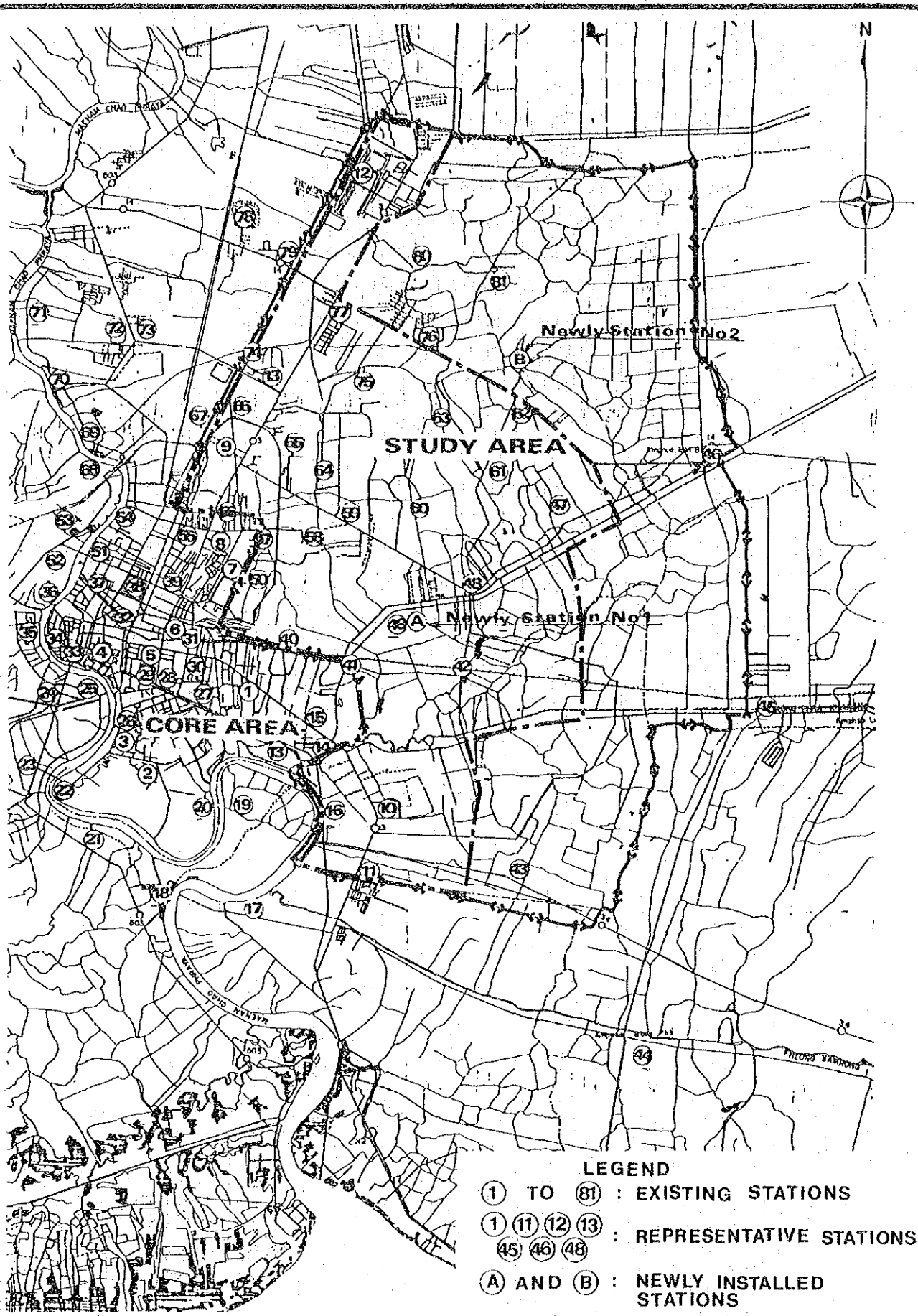
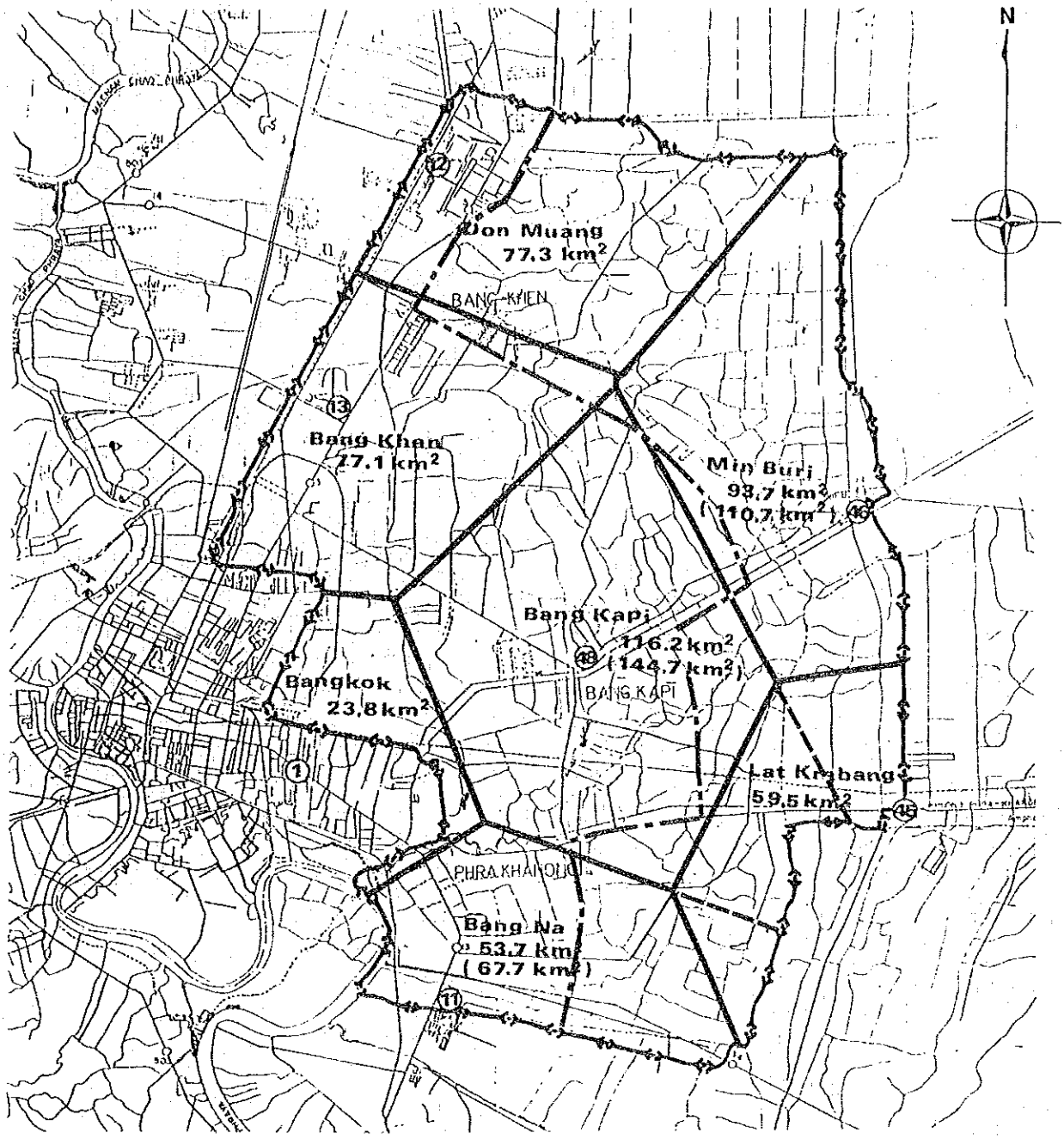


Fig. F.1 LOCATION OF EXISTING AND NEWLY INSTALLED RAIN GAUGE STATIONS IN AND AROUND THE STUDY AREA

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

JICA 2528B.E 1985A.D



Thiessen Polygon

Table of Controlled Area for Each Representative Station

Item \ Station		DonMuang	BangKhen	Bangkok	BangNa	BangKapi	MinBuri	LatKrabang	Total
Case 1	Area (km^2)	77.0	77.1	23.8	53.7	116.2	93.7	59.5	500.1
	Thiessen coefficient	0.1537	0.1539	0.0475	0.1072	0.2319	0.1870	0.1188	1.000
Case 2	Area (km^2)	77.0	77.1	23.8	67.7	144.7	110.7	-	500.1
	Thiessen coefficient	0.1537	0.1539	0.0475	0.1351	0.2888	0.2210	-	1.000

Fig. F.2 REPRESENTATIVE RAIN GAUGE STATIONS AND THIEESEN POLYGON IN THE STUDY AREA

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

JICA 2528B.E 1985A.D

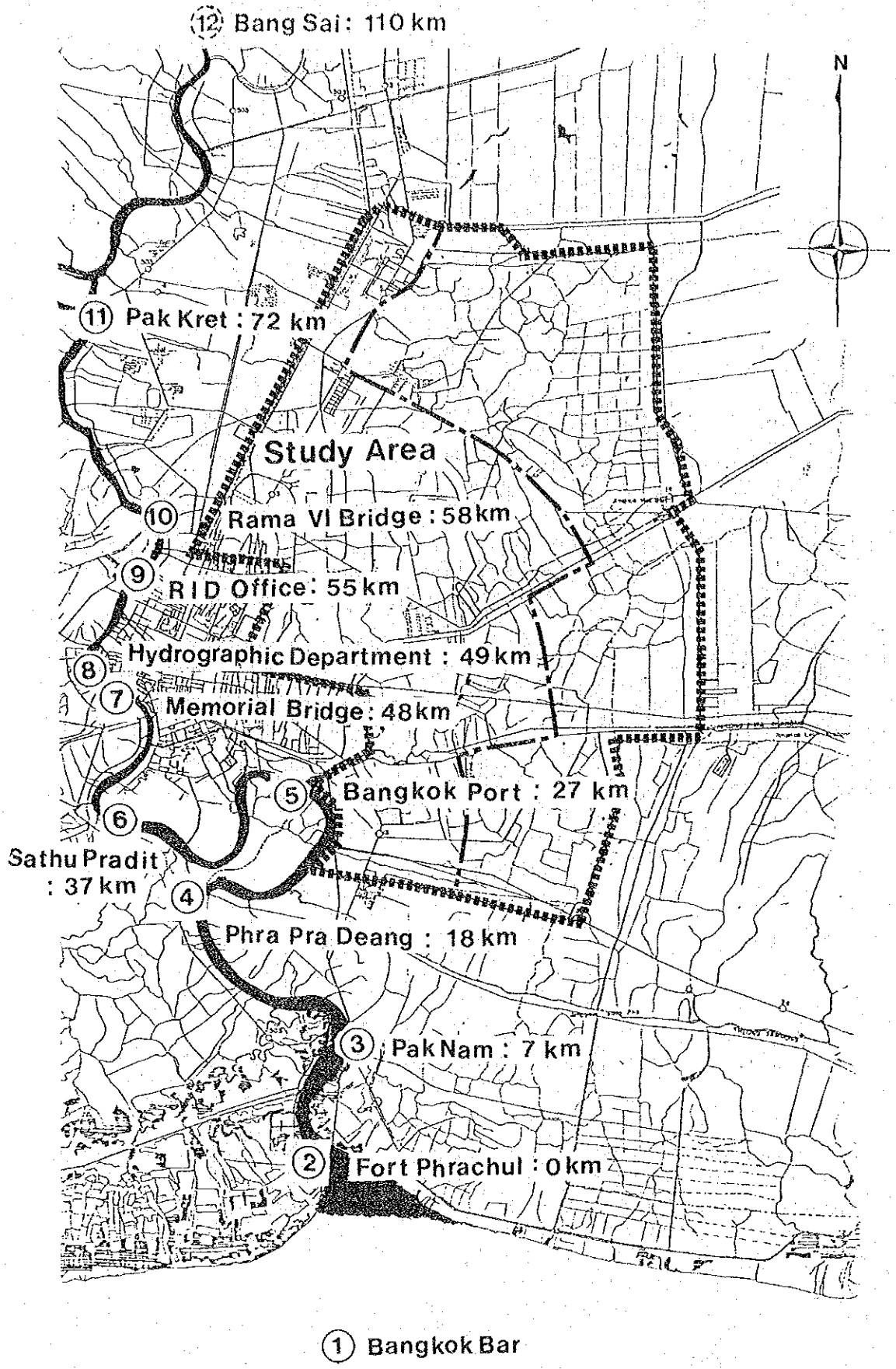


Fig. F.3 LOCATION OF EXISTING WATER LEVEL GAUGE STATIONS IN THE LOWER CHAO PHRAYA RIVER

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

JICA 2528B.E 1985A.D

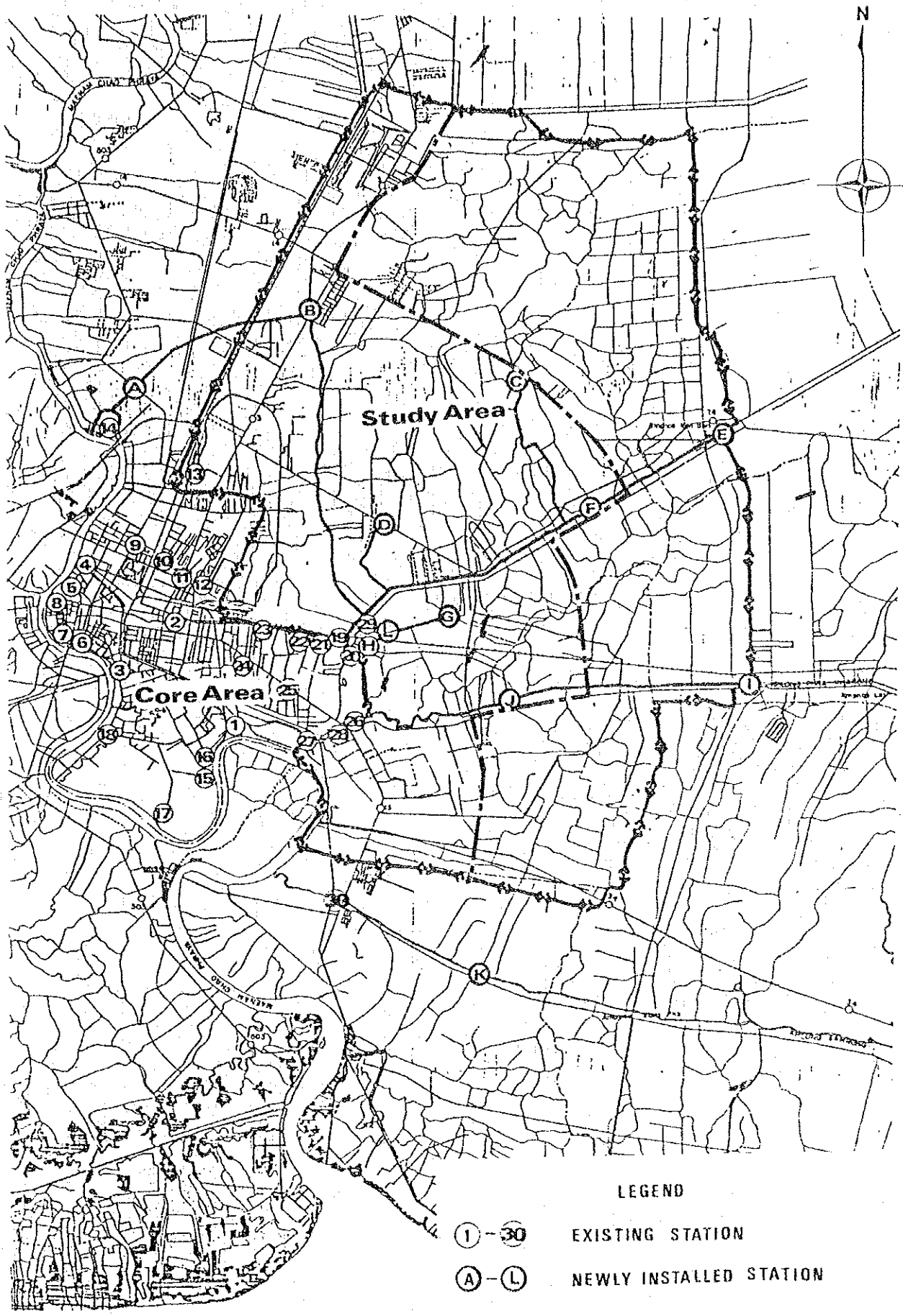
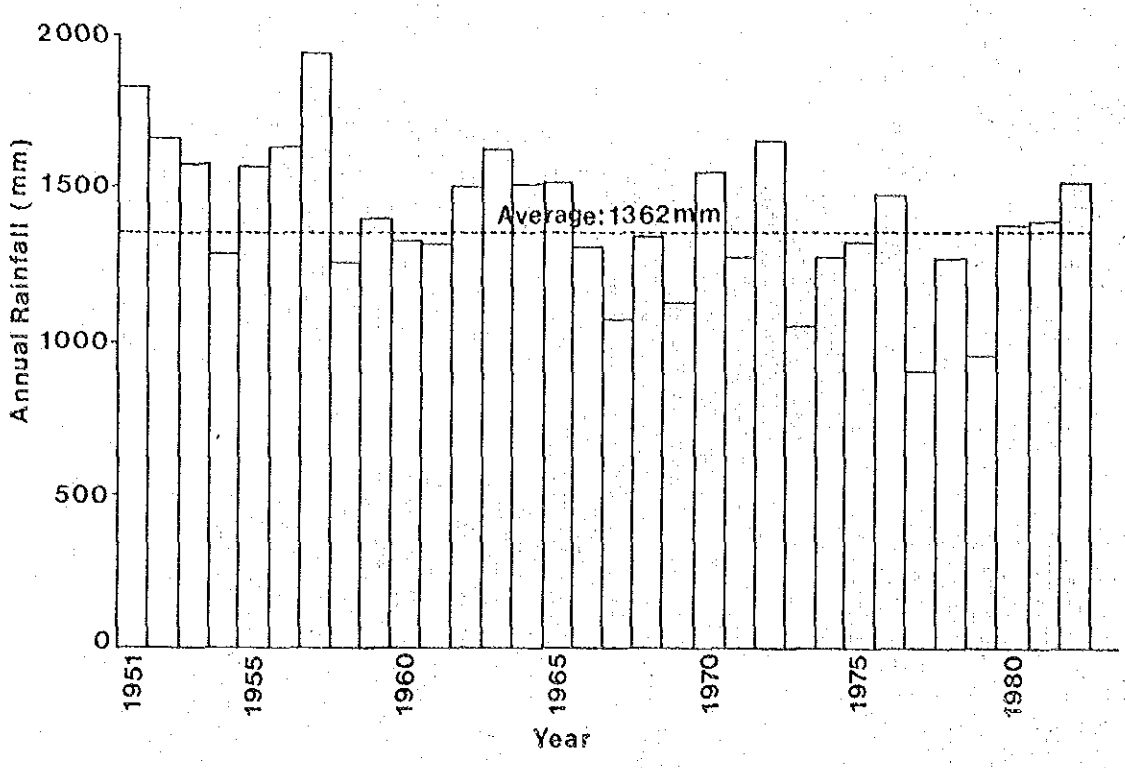


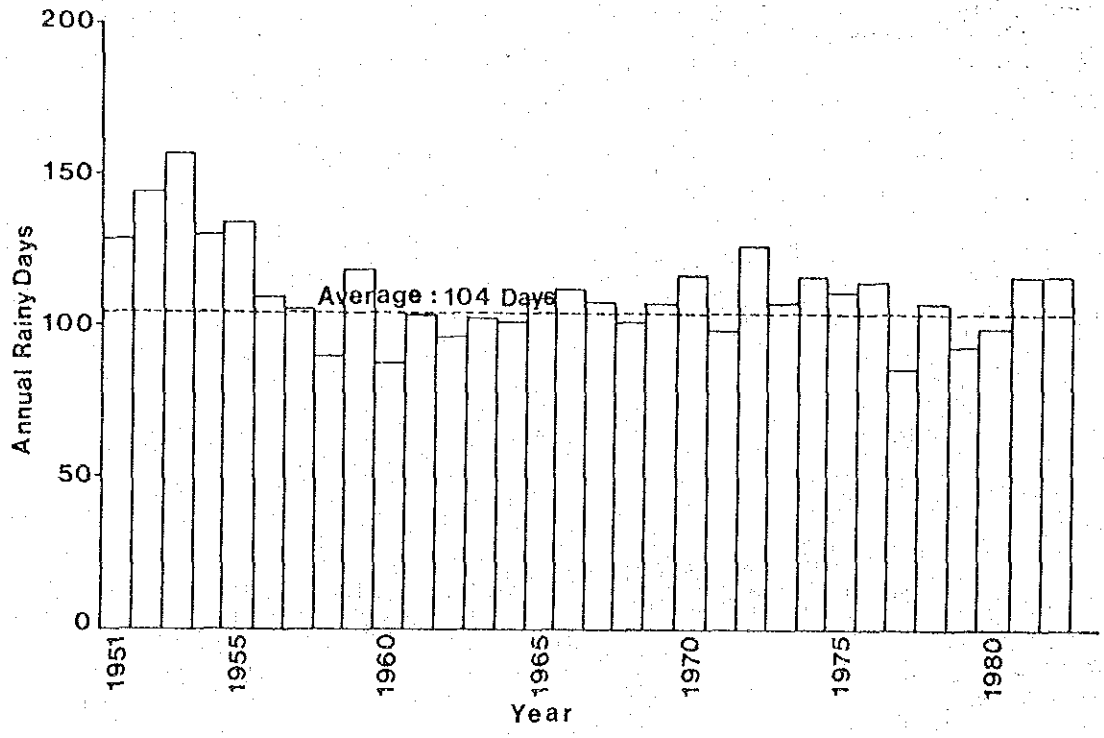
Fig. F.4 LOCATION OF EXISTING AND NEWLY INSTALLED WATER LEVEL GAUGE STATIONS IN THE MAIN KLONG

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

JICA 2528B.E 1985A.D



Annual Rainfall



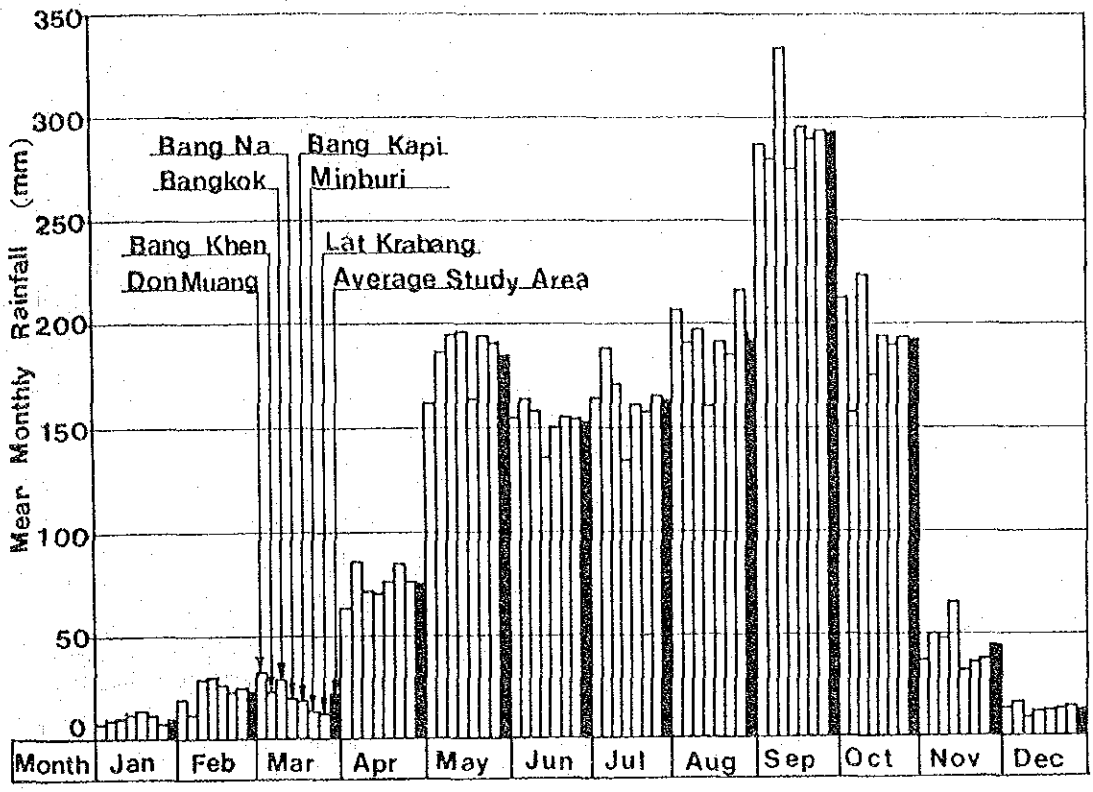
Annual Rainy Days

Source : Meteorological Department

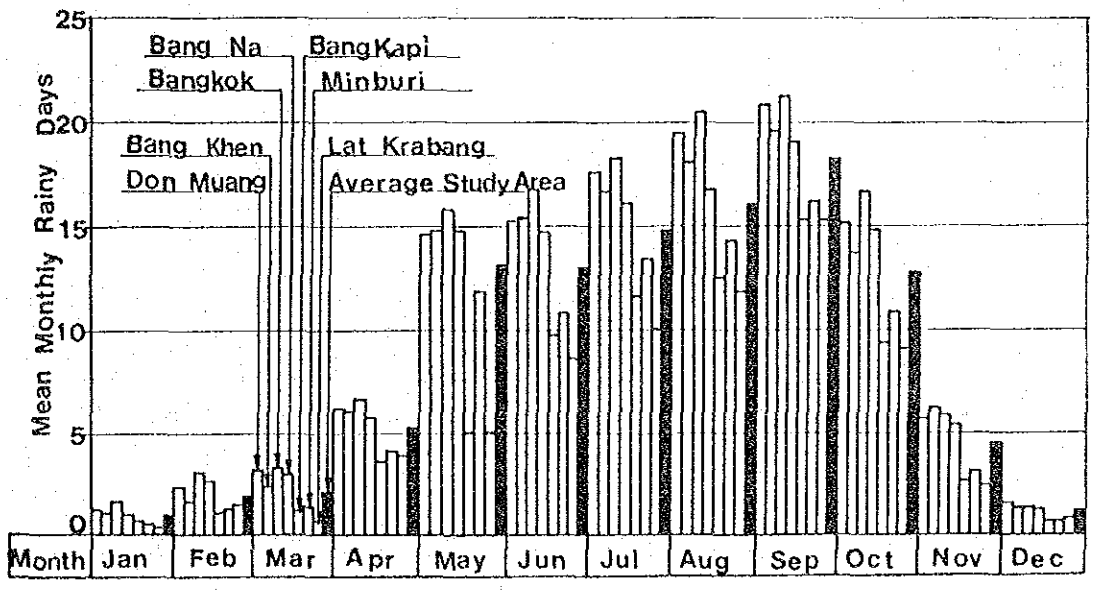
Fig. F.5	ANNUAL RAINFALL AND RAINY DAYS IN THE STUDY AREA BETWEEN 1951 AND 1982

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

JICA 2528B.E. 1985A.D.



Average Monthly Rainfall



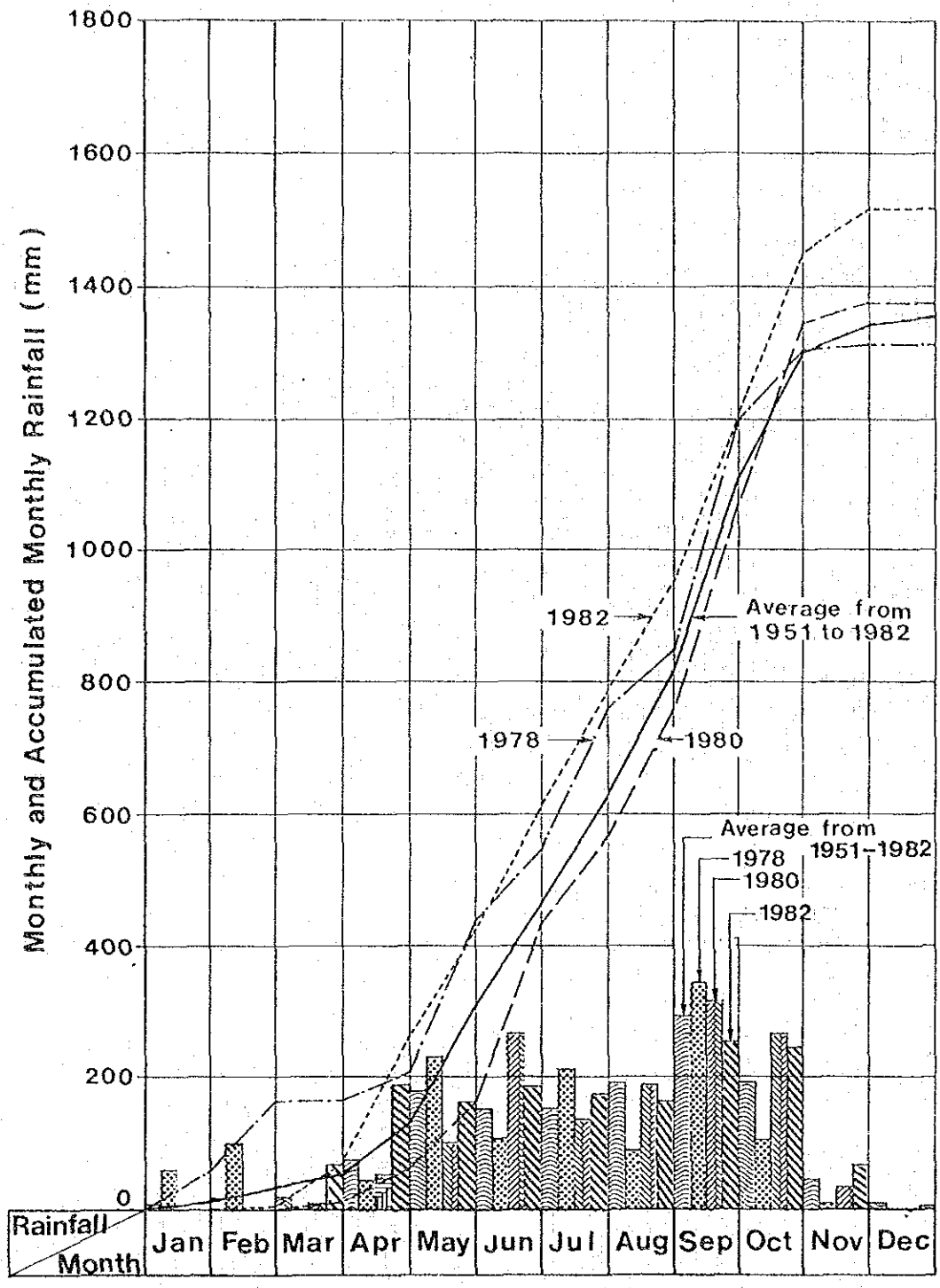
Average Monthly Rainy Days

Source : Meteorological Department

Fig. F.6	AVERAGE MONTHLY RAINFALL AND RAINY DAYS IN THE STUDY AREA BETWEEN 1951 AND 1982

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

JICA 2528B.E 1985A.D



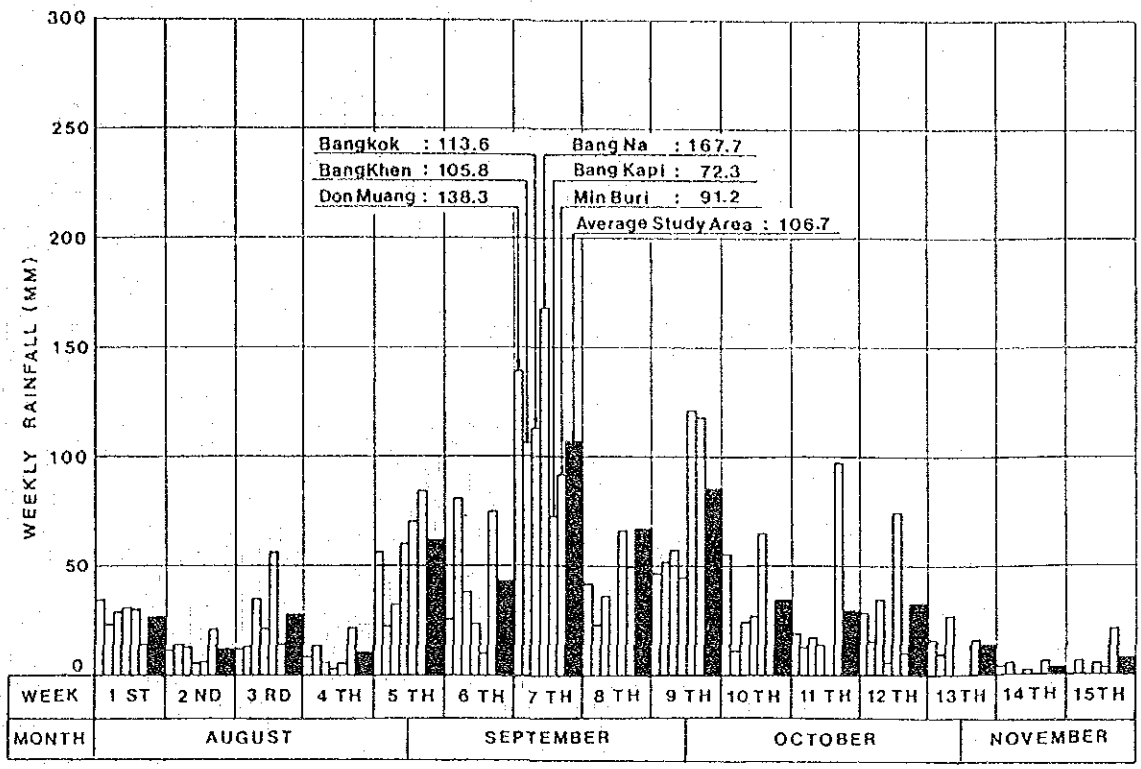
Unit : mm/month

Year	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average from 1951 - 1982	9.7	23.2	20.9	75.0	184.0	153.3	163.4	192.4	293.5	192.2	43.8	13.3	1365
1978	60.0	103.8	0	43.8	229.1	110.1	212.6	90.0	321.4	119.2	9.5	0	1319
1980	0	0	11.2	50.8	100.9	269.5	137.5	191.5	318.9	274.3	32.9	0	1388
1982	0	2.6	70.1	189.0	164.4	184.2	175.0	166.7	252.9	246.6	65.1	1.7	1517

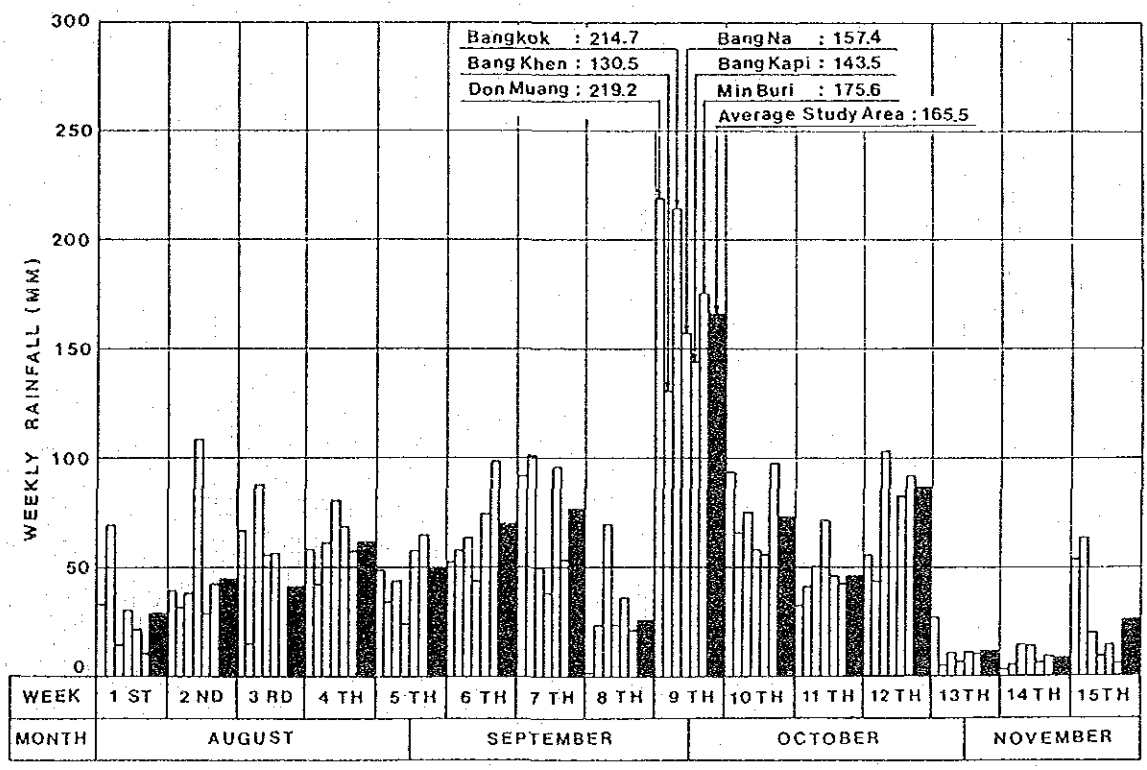
Fig. F.7 MONTHLY & ACCUMULATED MONTHLY RAINFALL IN THE STUDY AREA FOR RECENT FLOOD YEAR, 1978, 1980 AND 1982

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

JICA 2528B.E 1985A.D



1978



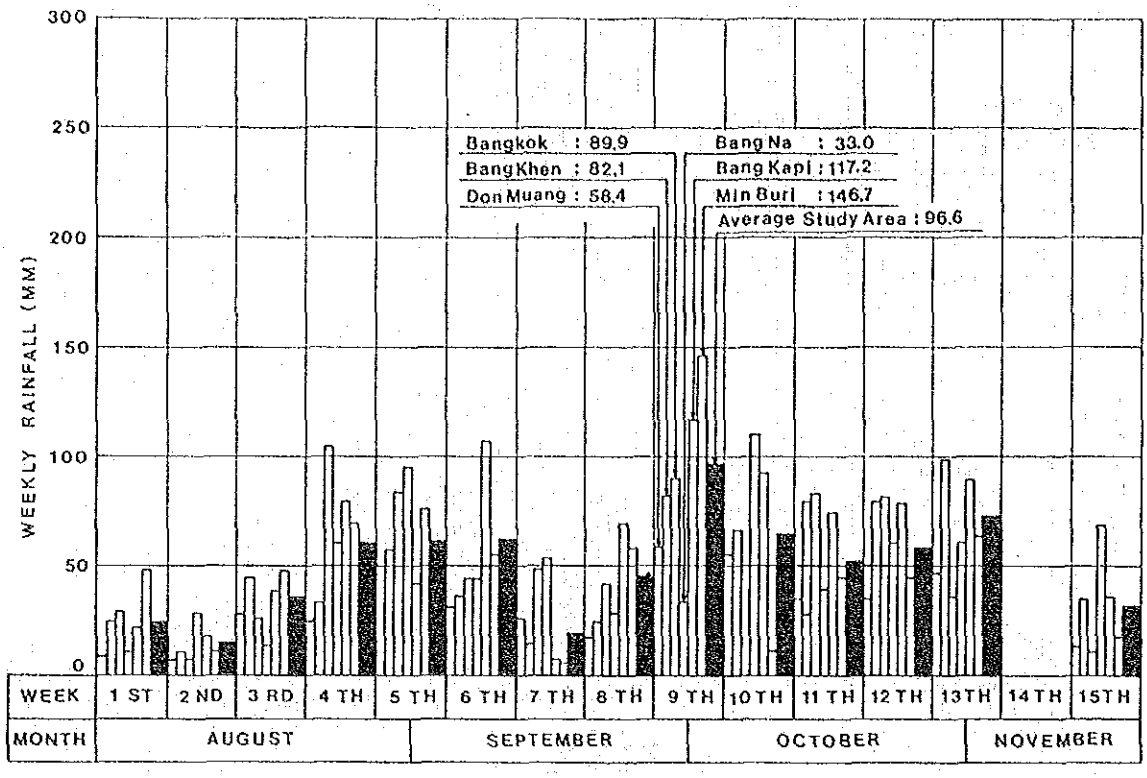
1980

Source : Meteorological Department

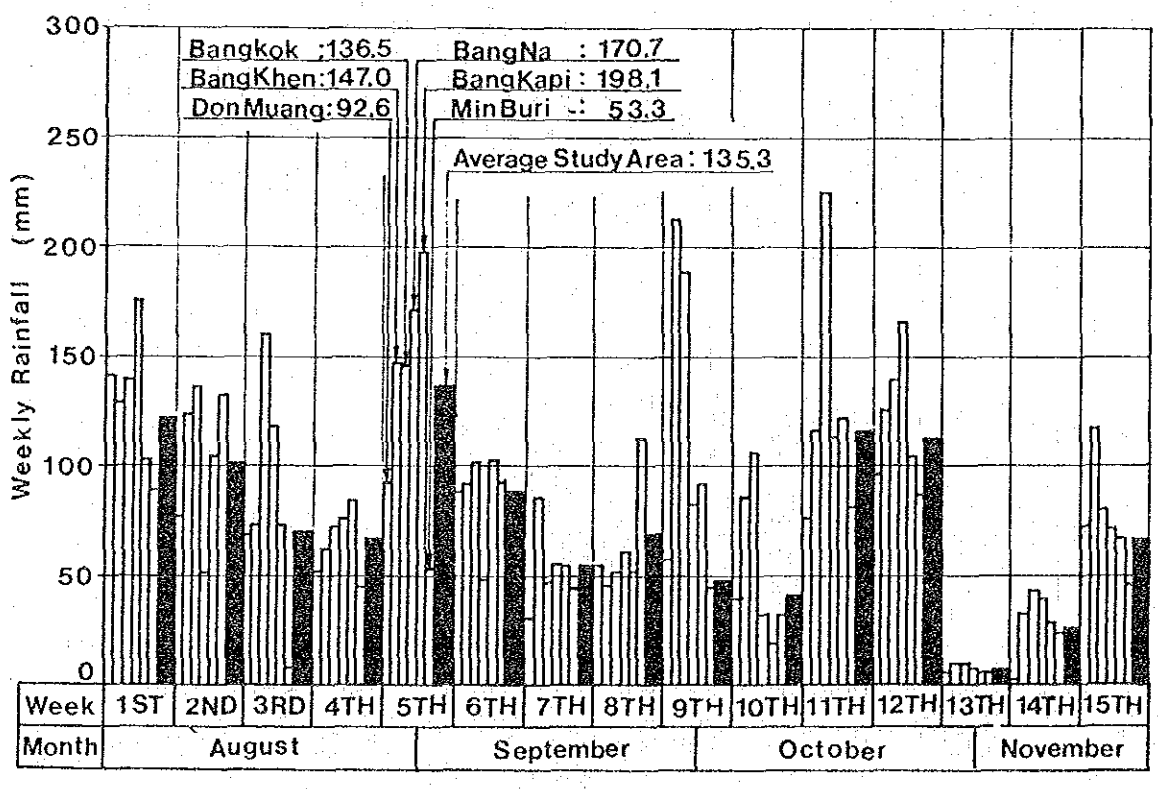
Fig. F.8	WEEKLY RAINFALL IN THE STUDY AREA BETWEEN AUG. AND SEP. IN 1978 & 1980

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

JICA 2528B.E 1985A.D



1982

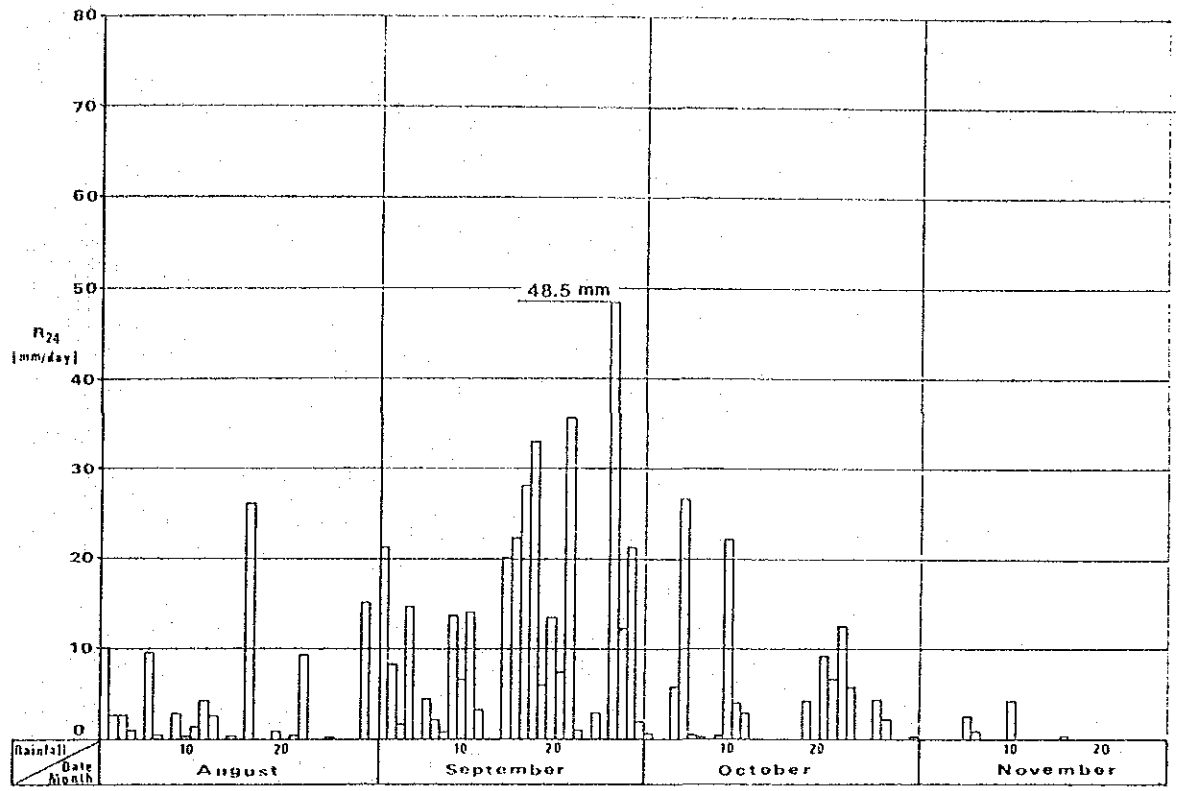


1983

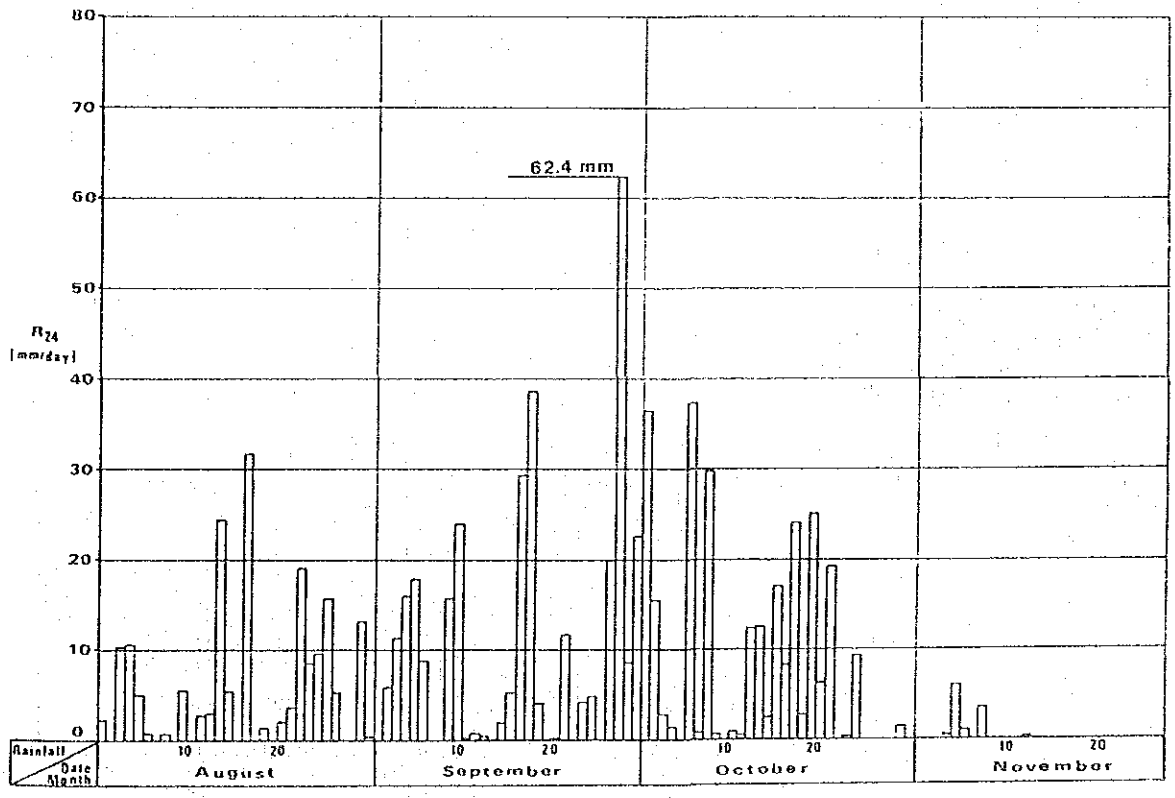
Source : Meteorological Department

Fig. F.9	WEEKLY RAINFALL IN THE STUDY AREA BETWEEN AUG. AND SEP. IN 1982 & 1983

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



1978



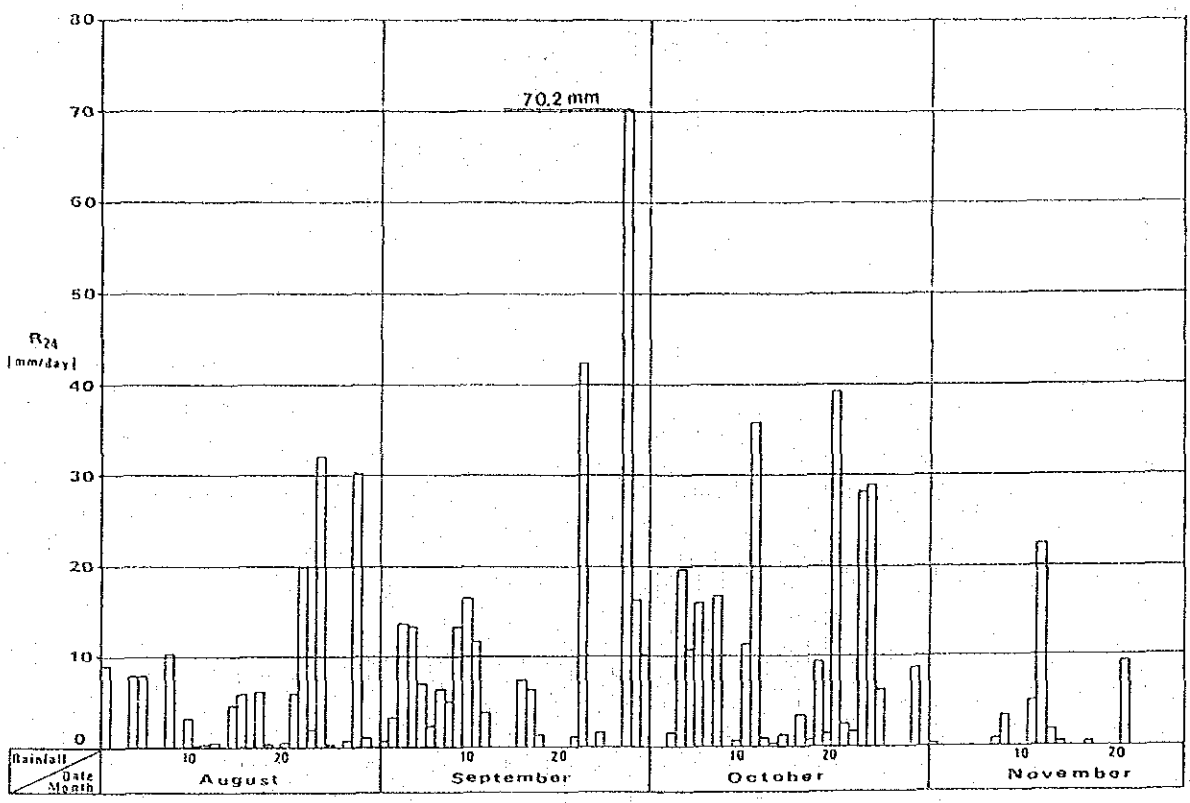
1980

Source : Meteorological Department

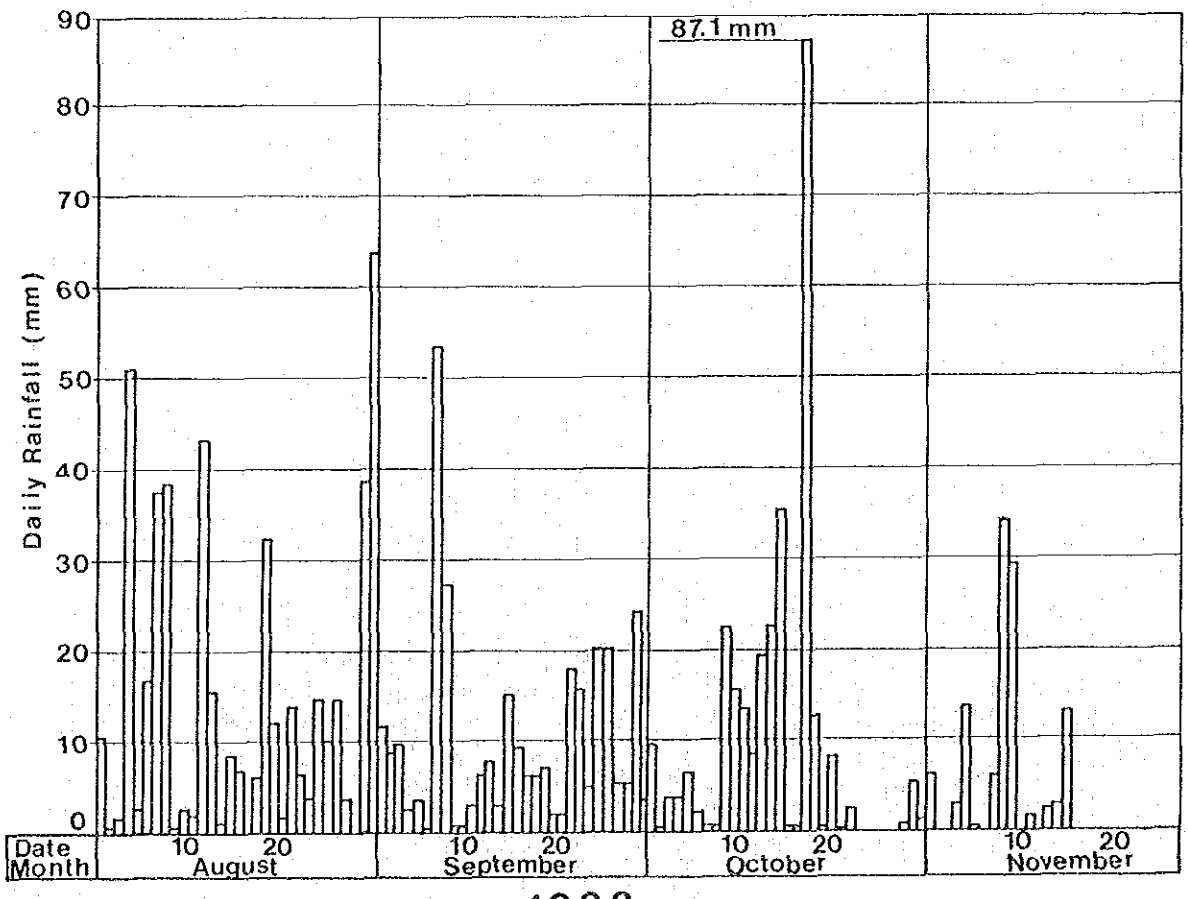
Fig. F.10	AVERAGE AREAL DAILY RAINFALL IN THE STUDY AREA BETWEEN AUG. & NOV. IN 1978 & 1980

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

JICA 2528B.E 1985A.D



1982

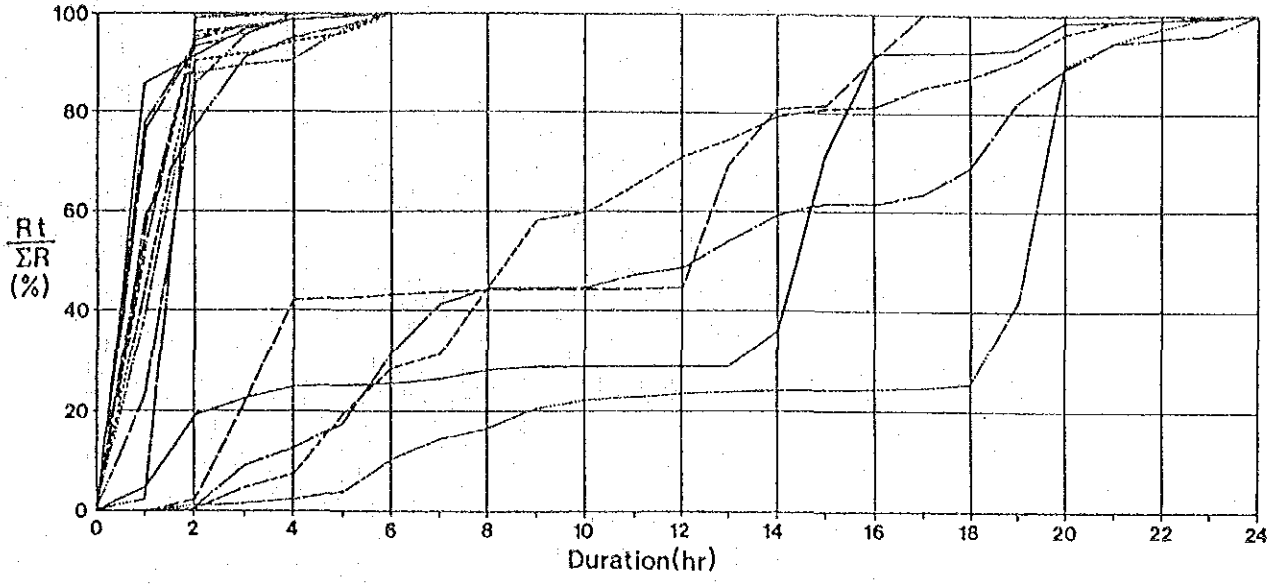


1983

Source : Meteorological Department

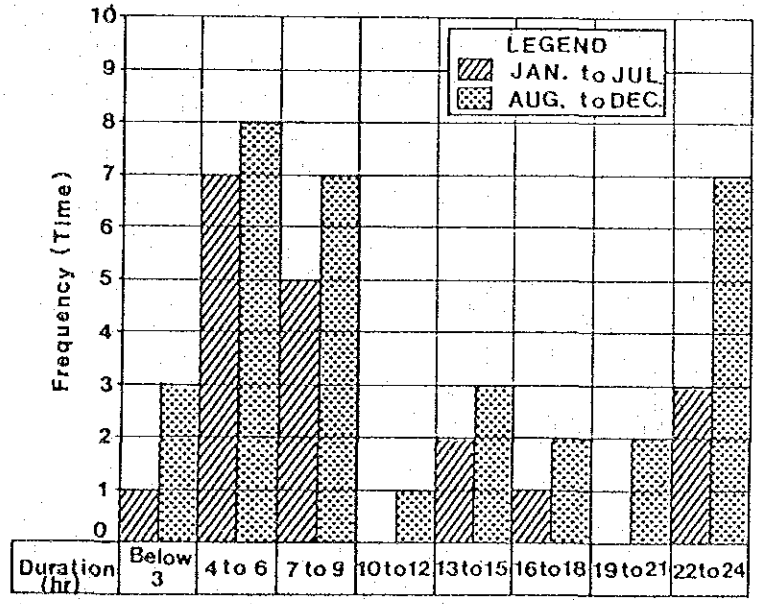
Fig. F.11	AVERAGE AREAL DAILY RAINFALL IN THE STUDY AREA BETWEEN AUG. & NOV. IN 1978 & 1980

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



Time Distribution Diagram for Duration of Daily Rainfall above 90 mm/day

Note; Daily rainfall data(15 samples) above 90 mm/day were recorded at the Bangkok Station between 1951 and 1982.

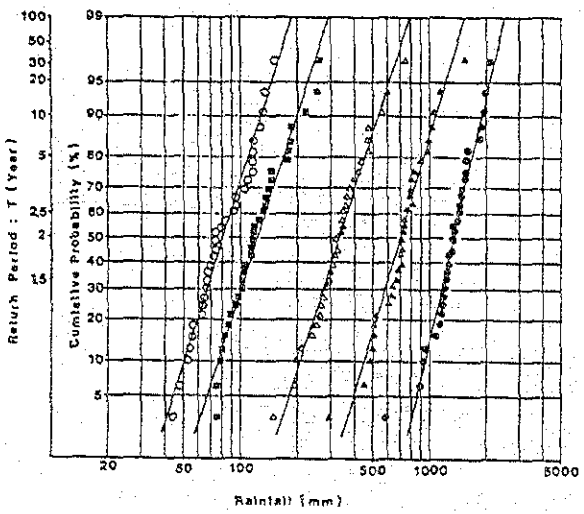


Frequency Diagram for Duration of Daily Rainfall above 60 mm/day

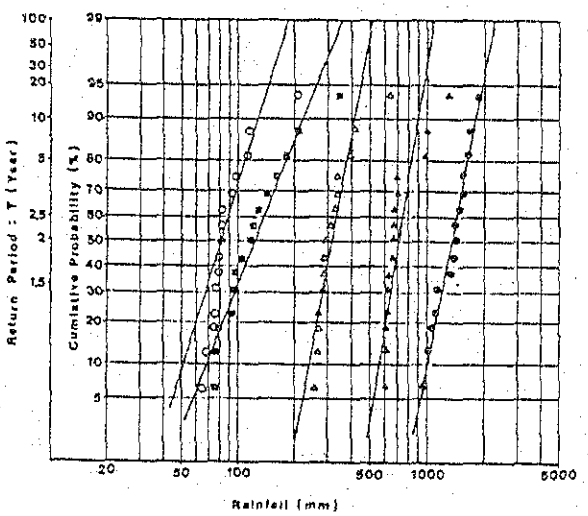
Note ; Daily rainfall data(52 samples) above 60 mm/day recorded at the Bangkok Station between 1951 and 1982 were used.

Fig. F.12	TIME DISTRIBUTION AND FREQUENCY OF DAILY RAINFALL

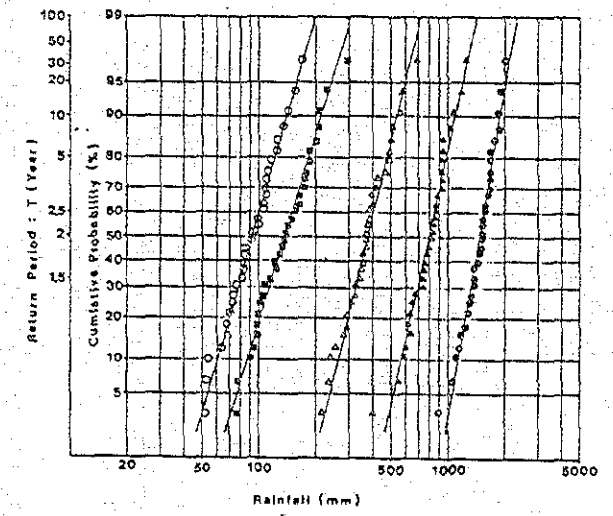
MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



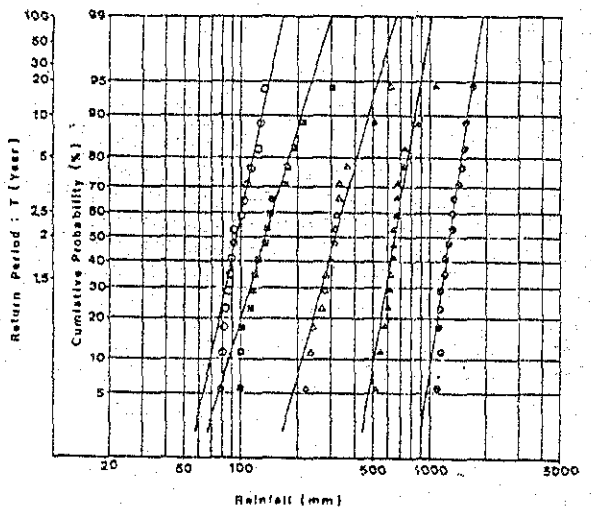
Don Muang



BangKhen



Bangkok



BangNa

Legend

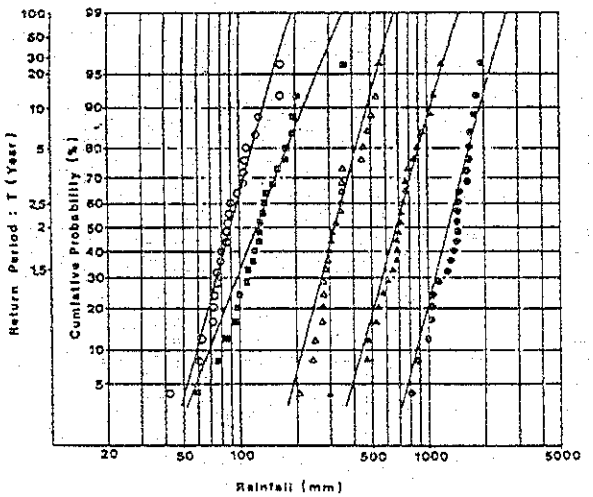
- ○ : Probable Daily Rainfall
- ■ : Probable 3-Days Rainfall
- △ : Probable Monthly Rainfall
- ▲ : Probable 3-Months Rainfall
- ● : Probable Yealy Rainfall

Unit : mm

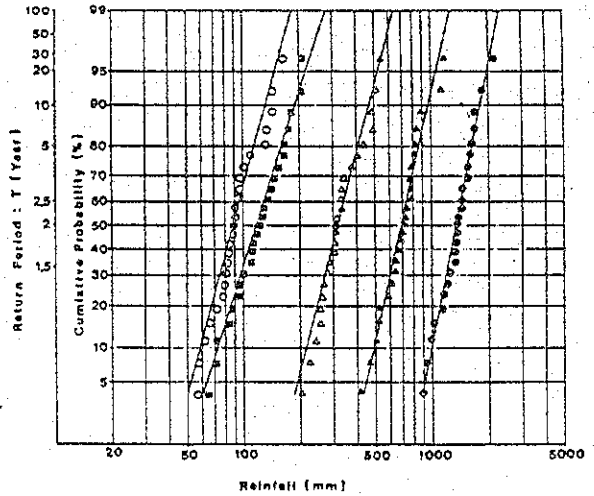
Item \ Station \ Return Period		Don Muang	Bang Khen	Bangkok	Bang Na
Daily Rainfall Probability	2 Year	80.5	80.3	91.0	94.0
	5	108.5	108.2	120.2	114.9
	7	117.6	117.5	129.4	121.3
	10	126.9	126.5	138.7	127.7
	20	144.3	143.9	156.0	139.3
	30	154.3	153.9	165.9	145.7
	50	166.9	166.3	178.2	153.6
	100	183.9	183.3	194.7	163.9
3-Days Rainfall Probability	2	121.8	122.2	137.4	133.8
	5	165.3	179.3	184.2	178.6
	7	179.5	198.7	199.3	193.0
	10	194.0	219.0	214.7	207.7
	20	221.4	258.4	243.7	235.3
	30	237.1	281.6	260.3	251.1
	50	256.8	311.2	281.0	270.7
	100	283.5	352.3	309.0	297.3
Monthly Rainfall Probability	2	329.8	314.9	368.5	315.7
	5	446.8	376.0	468.9	409.6
	7	484.7	394.3	500.2	439.2
	10	523.6	412.5	531.9	469.4
	20	596.9	445.3	590.2	525.2
	30	639.0	463.4	623.0	556.9
	50	671.7	485.3	663.4	596.1
	100	763.2	514.0	717.3	648.6
3-Months Rainfall Probability	2	714.7	706.6	786.4	657.0
	5	943.1	826.2	976.8	767.4
	7	1016.0	861.5	1035.3	800.0
	10	1090.3	896.5	1094.1	832.2
	20	1229.0	959.1	1201.4	889.9
	30	1308.0	993.4	1261.4	921.5
	50	1406.2	1034.7	1334.9	959.6
	70	1538.5	1088.5	1432.1	1009.1
Yearly Rainfall Probability	2	1319.0	1337.9	1451.0	1271.1
	5	1653.9	1614.2	1711.2	1453.5
	7	1757.3	1697.6	1788.6	1506.8
	10	1861.5	1780.7	1865.3	1559.1
	20	2052.4	1930.9	2002.8	1652.1
	30	2159.5	2014.1	2078.4	1702.6
	50	2290.8	2115.3	2169.8	1763.3
	70	2456.2	2248.1	2289.1	1841.7

Fig. F.13 PROBABILITY OF DAILY, 3-DAY, MONTHLY, 3-MONTH AND YEARLY RAINFALL IN THE STUDY AREA

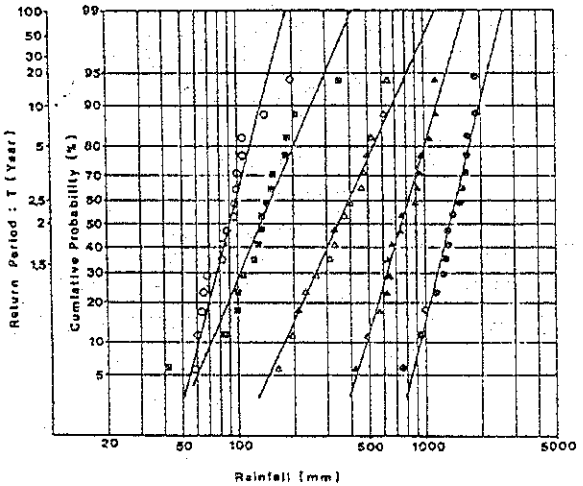
MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



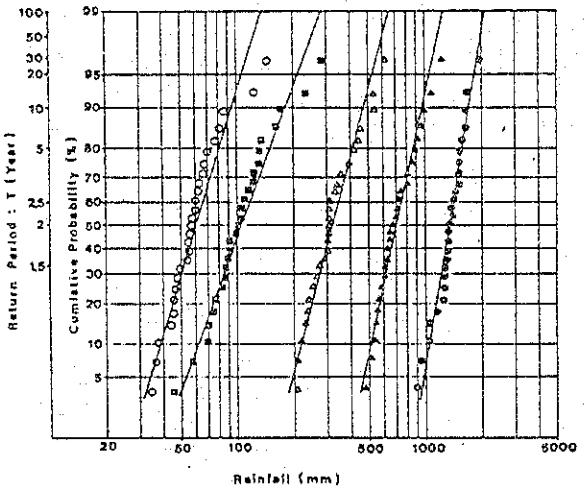
BangKapi



MinBuri



LatKrabang



Average Study Area

Legend

- ○ : Probable Daily Rainfall
- ■ : Probable 3-Days Rainfall
- △ : Probable Monthly Rainfall
- ▲ : Probable 3-Months Rainfall
- ● : Probable Yealy Rainfall

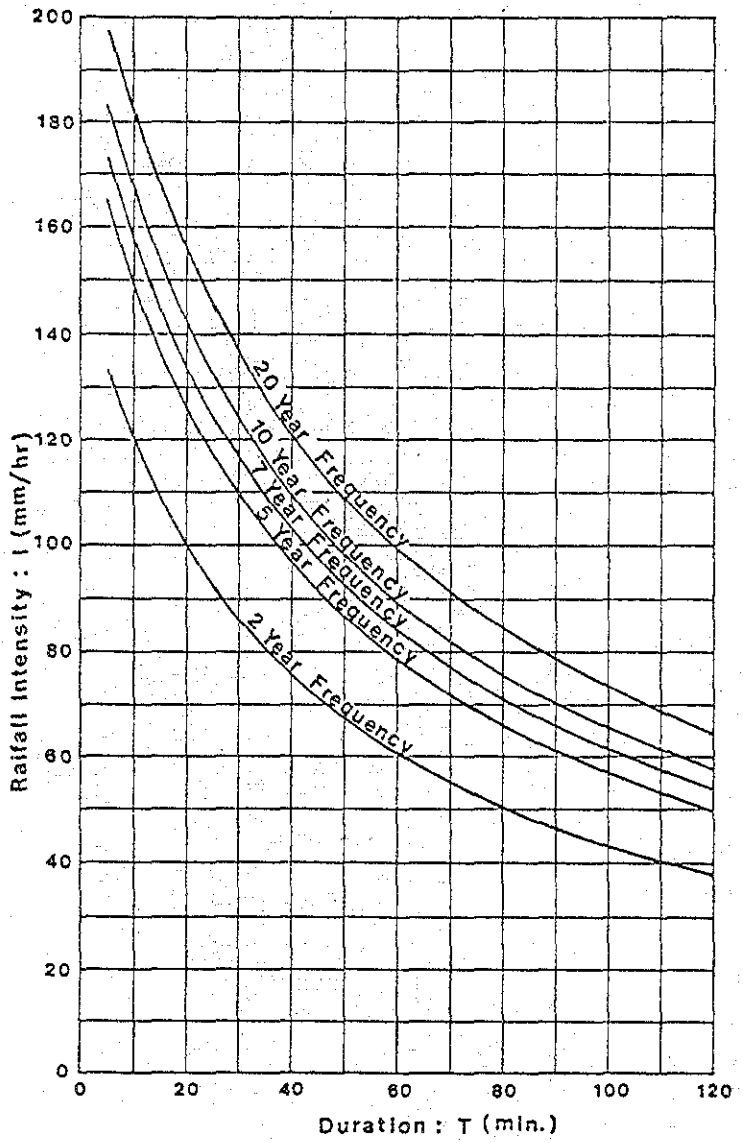
Unit : mm

Item	Return Period \ Station	Bangkapi	Min Buri	Lat Krabang	Average Study Area
Daily Rainfall Probability	2 Year	88.2	91.3	89.6	60.1
	5	115.4	117.5	116.3	80.8
	7	124.0	125.8	124.7	87.4
	10	132.8	134.1	133.3	94.2
	20	149.1	149.5	149.1	107.0
	30	158.3	158.3	158.1	114.3
	50	169.8	169.1	169.3	123.5
	100	185.2	183.5	184.2	135.9
3-Days Rainfall Probability	2	122.2	118.8	132.8	105.9
	5	178.4	161.6	201.0	150.4
	7	197.5	175.5	224.7	165.2
	10	217.5	189.8	249.7	180.6
	20	256.0	216.7	298.6	210.1
	30	278.7	232.2	327.8	227.3
	50	307.7	251.6	365.3	249.0
	100	347.8	278.0	417.9	279.0
Monthly Rainfall Probability	2	318.1	319.3	344.2	324.0
	5	411.4	408.1	509.1	417.3
	7	440.7	435.9	565.5	446.6
	10	470.5	464.0	624.8	476.3
	20	525.7	515.8	739.8	531.3
	30	557.0	545.0	807.8	562.4
	50	595.6	581.1	894.7	600.8
	100	647.4	629.2	1015.8	652.2
3-Monthe Rainfall Probability	2	680.8	683.5	753.7	707.3
	5	901.1	852.8	999.0	872.4
	7	971.4	905.0	1077.4	922.8
	10	1043.2	957.4	1157.5	973.4
	20	1177.3	1053.4	1307.2	1065.7
	30	1253.8	1107.1	1392.6	1117.1
	50	1348.9	1172.9	1498.8	1179.9
	70	1477.3	1260.2	1642.2	1263.0
Yearly Rainfall Probability	2	1286.9	1324.3	1347.3	1355.2
	5	1652.3	1612.9	1709.3	1583.8
	7	1766.8	1700.5	1821.9	1651.4
	10	1882.8	1788.0	1935.7	1718.2
	20	2097.2	1946.7	2145.0	1837.7
	30	2218.4	2035.0	2262.8	1903.2
	50	2367.9	2142.3	2407.8	1982.3
	70	2567.8	2283.8	2601.0	2085.0

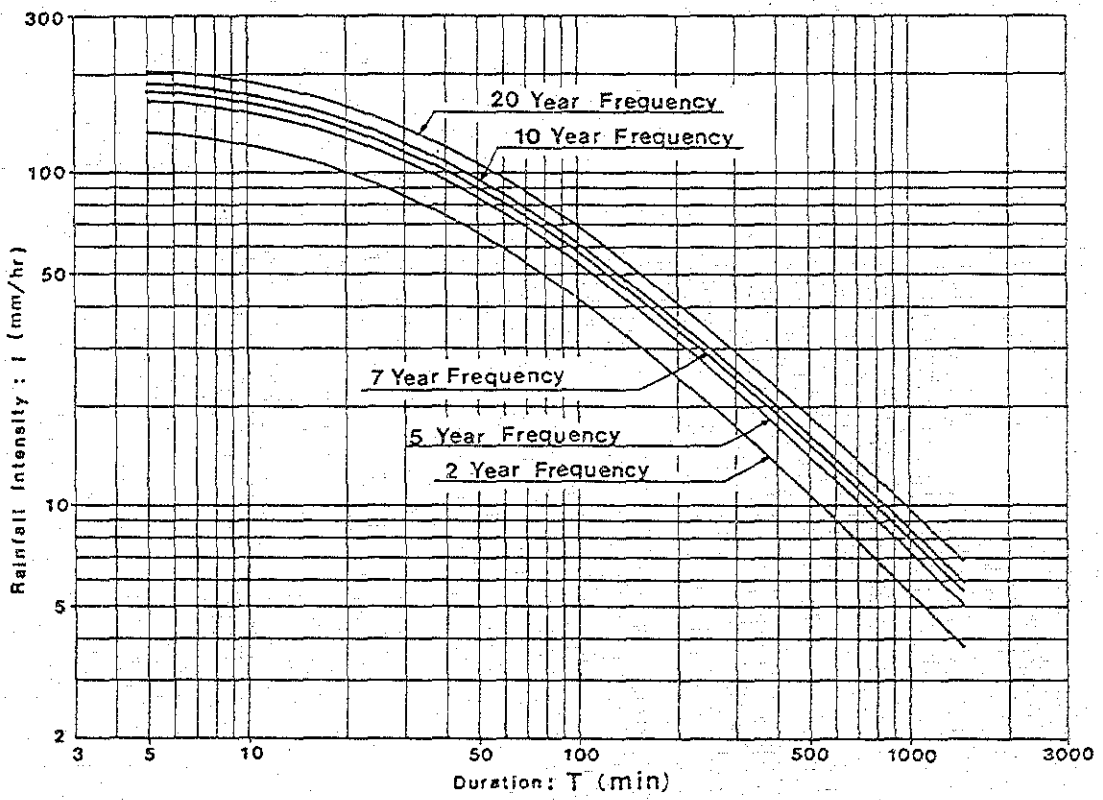
Fig. F.14 PROBABILITY OF DAILY, 3-DAY, MONTHLY, 3-MONTH AND YEARLY RAINFALL IN THE STUDY AREA

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

JICA 2528B.E 1985A.D



Case A'



Case B'

Rainfall Intensity-Duration Formula

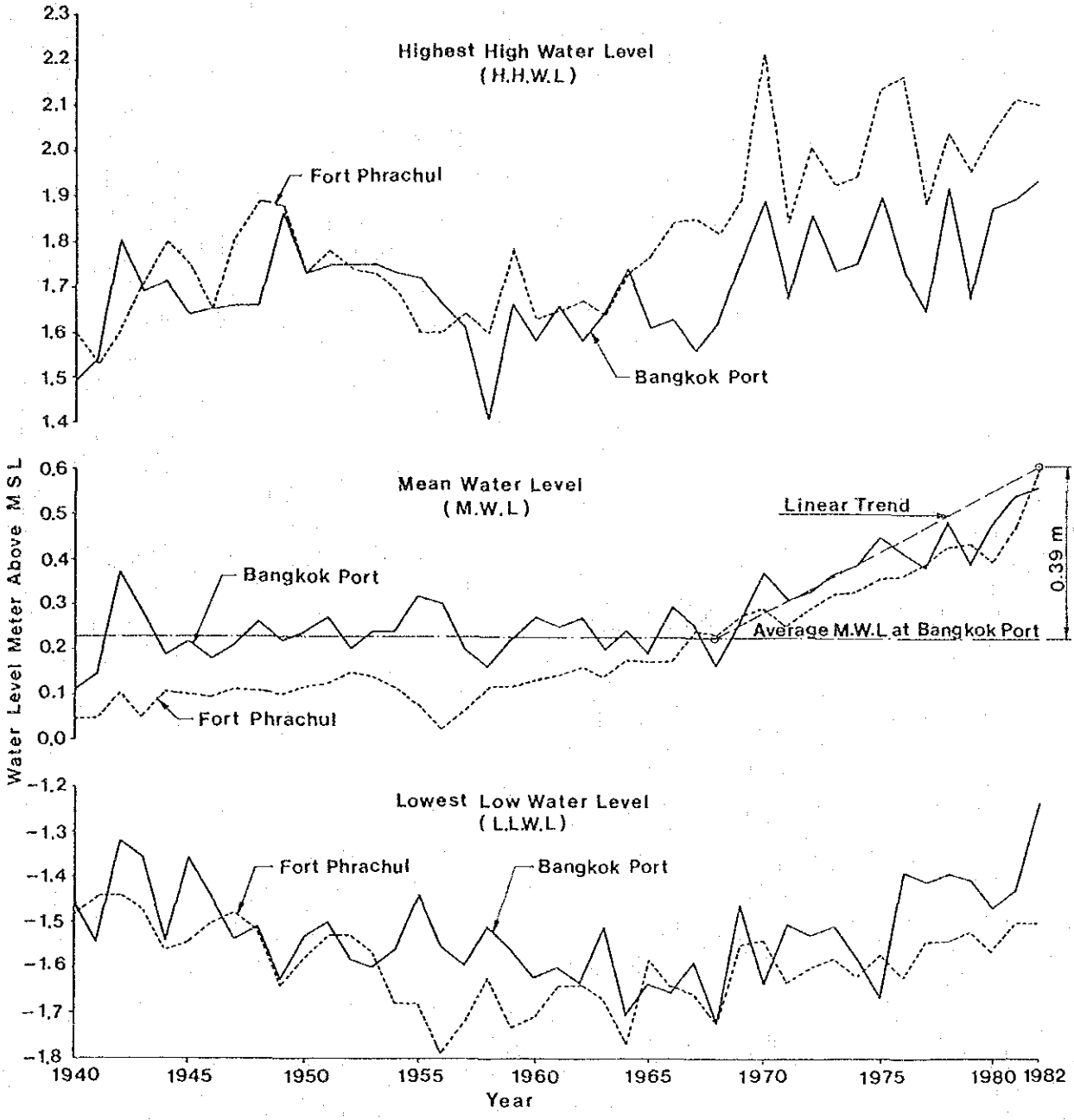
2 Year Probability	: $i = \frac{5,690}{t + 37}$	
5 " "	: $i = \frac{7,600}{t + 40}$	
7 " "	: $i = \frac{8,230}{t + 41}$	
10 " "	: $i = \frac{8,850}{t + 42}$	
20 " "	: $i = \frac{10,040}{t + 44}$	

Note : 1. Case A' is used for the case when the time of concentration is within 2 hours.

2. For case B', the time of concentration is between 2 hours and 24 hours

Fig. F.15 RAINFALL INTENSITY-DURATION CURVES

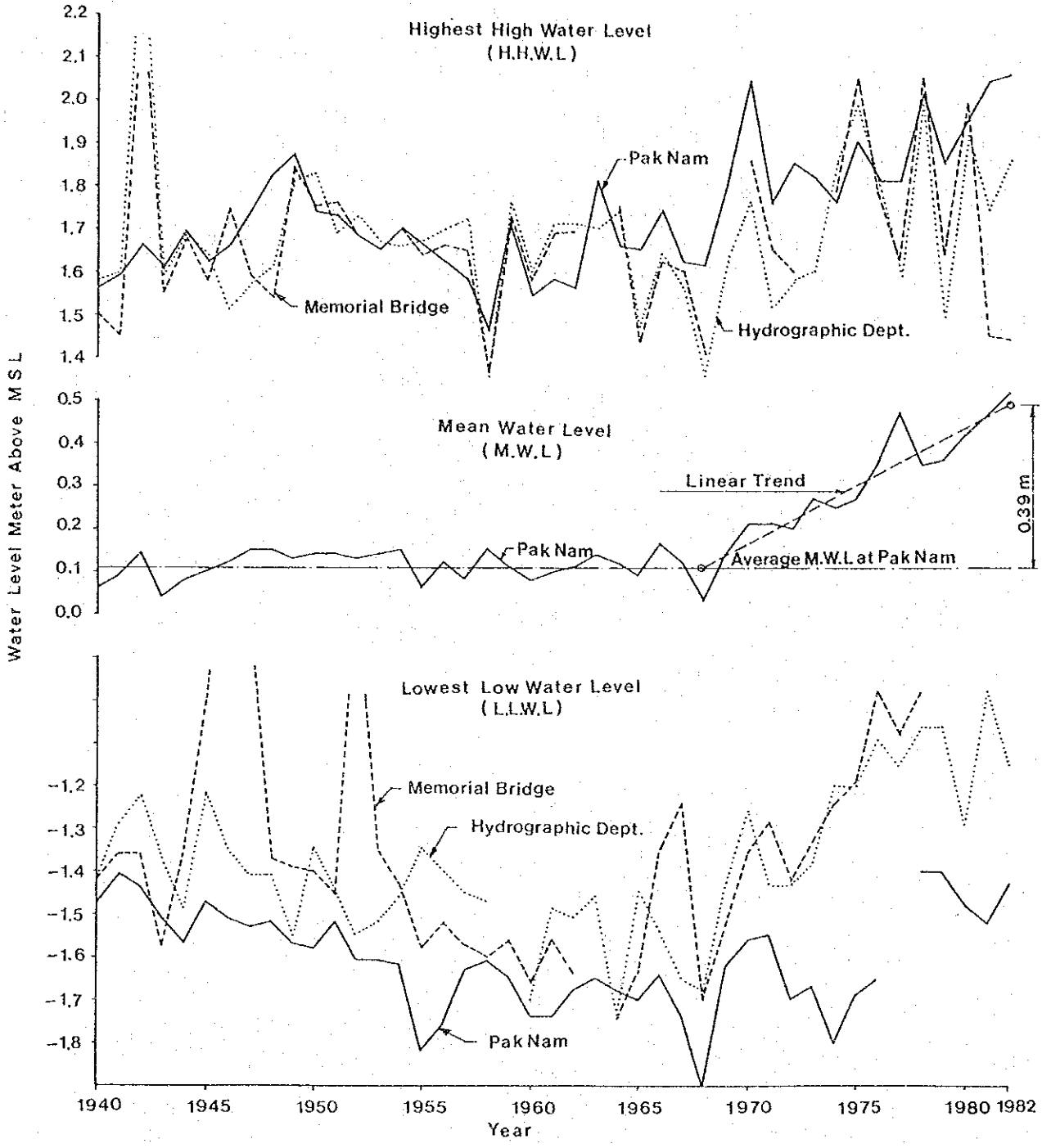
MASTER PLAN ON FLOOD PROTECTION/DRAINAGE PROJECT IN EASTERN SUBURBAN-BANGKOK



Source: Port Authority of Thailand

Fig. F.16 ANNUAL H.H.W.L, M.W.L, L.L.W.L AND EFFECT OF LAND SUBSIDENCE ON WATER LEVEL OF CHAO PHRAYA RIVER

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



Source: Port Authority of Thailand, **Hydrographic Dept. and RID**

Fig. F.17	ANNUAL H.H.W.L, M.W.L, L.L.W.L AND EFFECT OF LAND SUBSIDENCE ON WATER LEVEL OF CHAO PHRAYA RIVER

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

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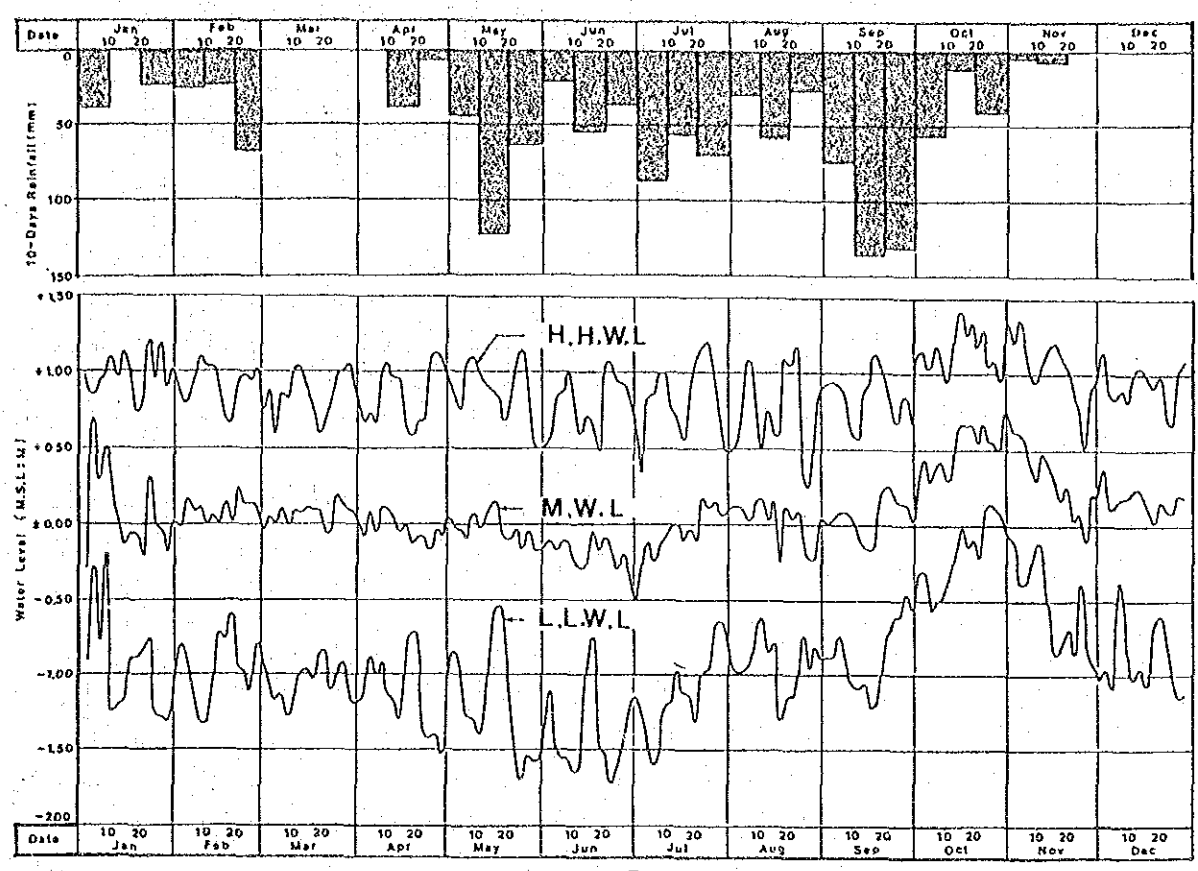
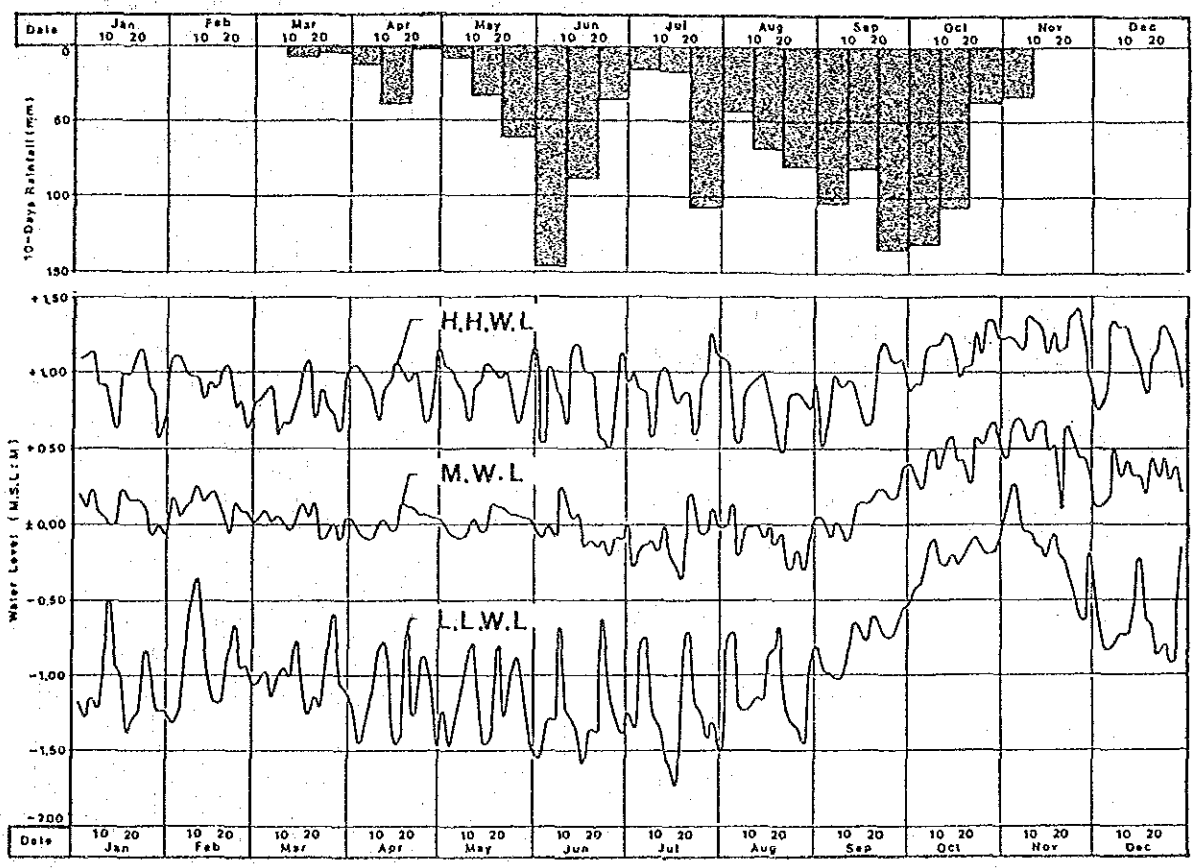


1978



1980

Source : Meteorological Department and P.A.T

Fig. F.18 SEASONAL CHANGES OF RAINFALL IN THE STUDY AREA AND WATER LEVEL AT BANGKOK PORT IN 1978 & 1980

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

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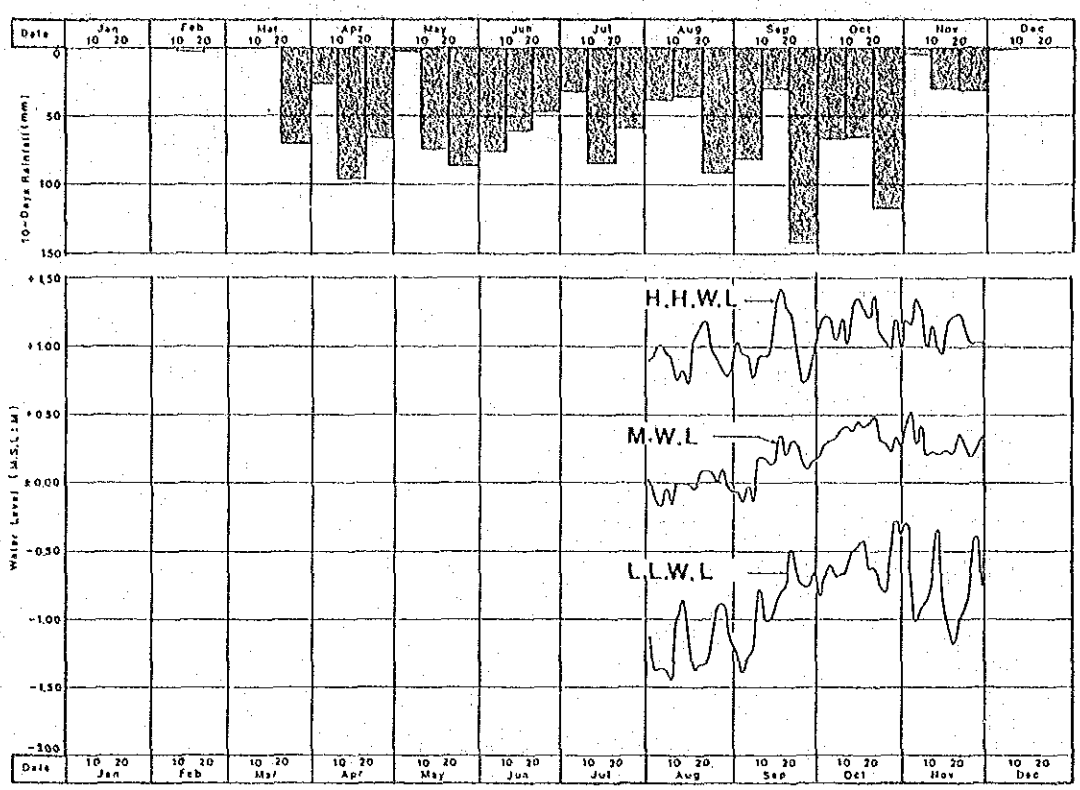
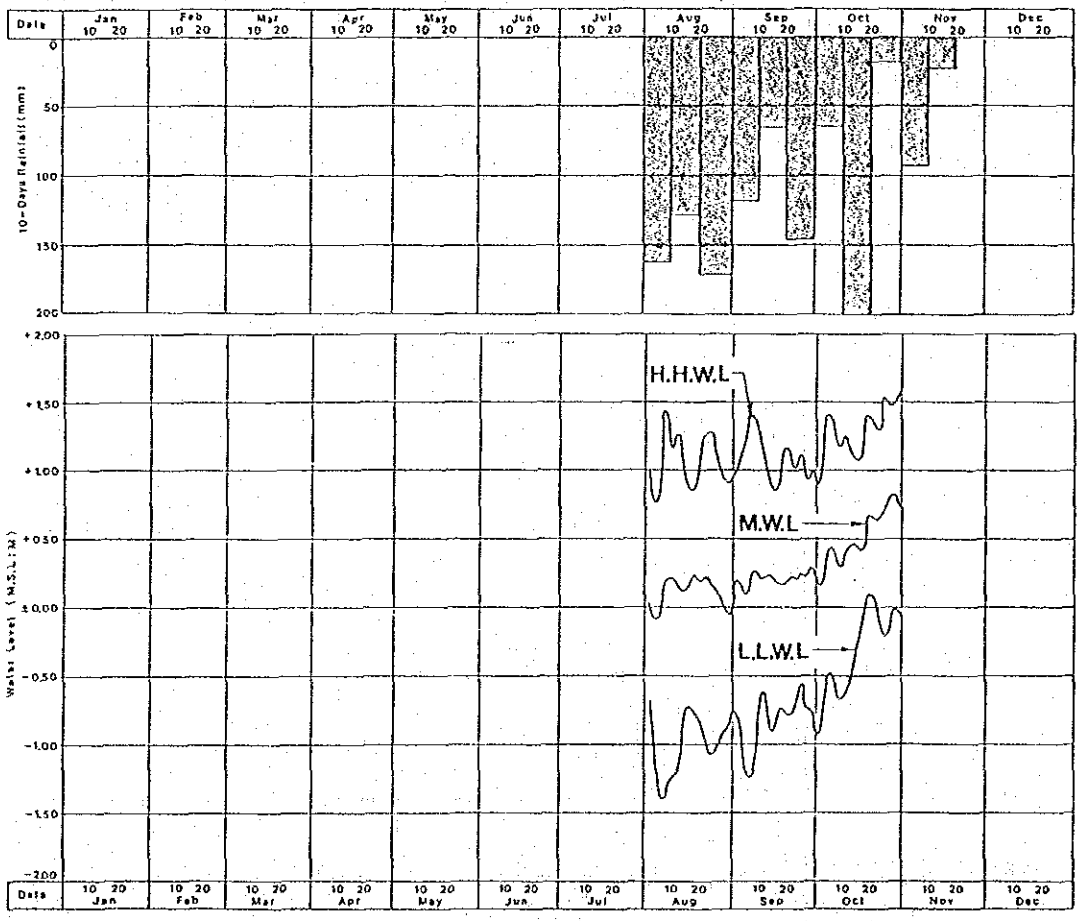


1982



1983

Source : Meteorological Department and P.A.T

Fig. F.19	SEASONAL CHANGES OF RAINFALL IN THE STUDY AREA AND WATER LEVEL AT BANGKOK PORT IN 1982 & 1983

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

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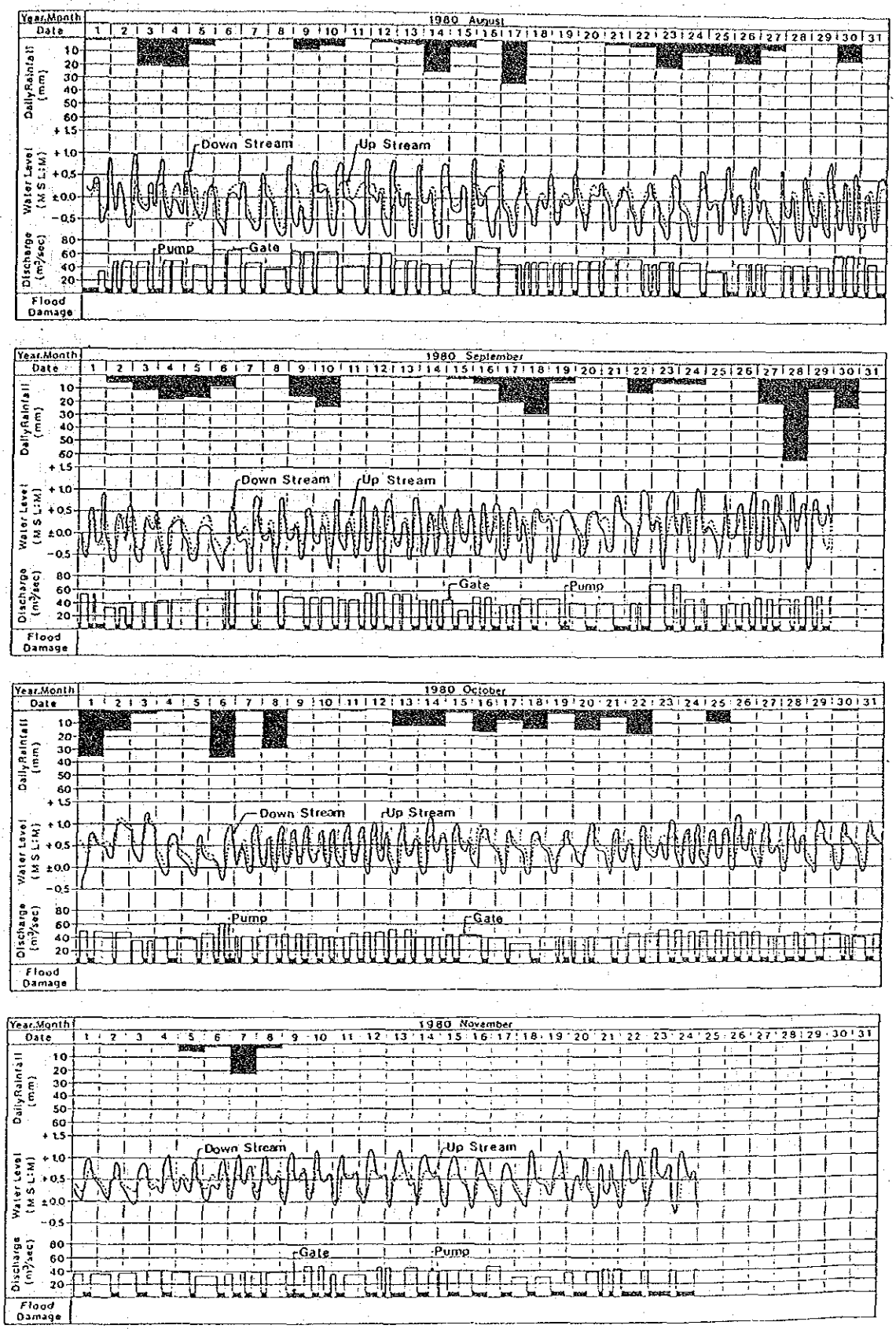

Source : RID

Fig. F.20 OPERATION RECORD AT PHRA KHANONG FLOOD GATE AND PUMP BETWEEN AUGUST AND NOVEMBER IN 1980

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

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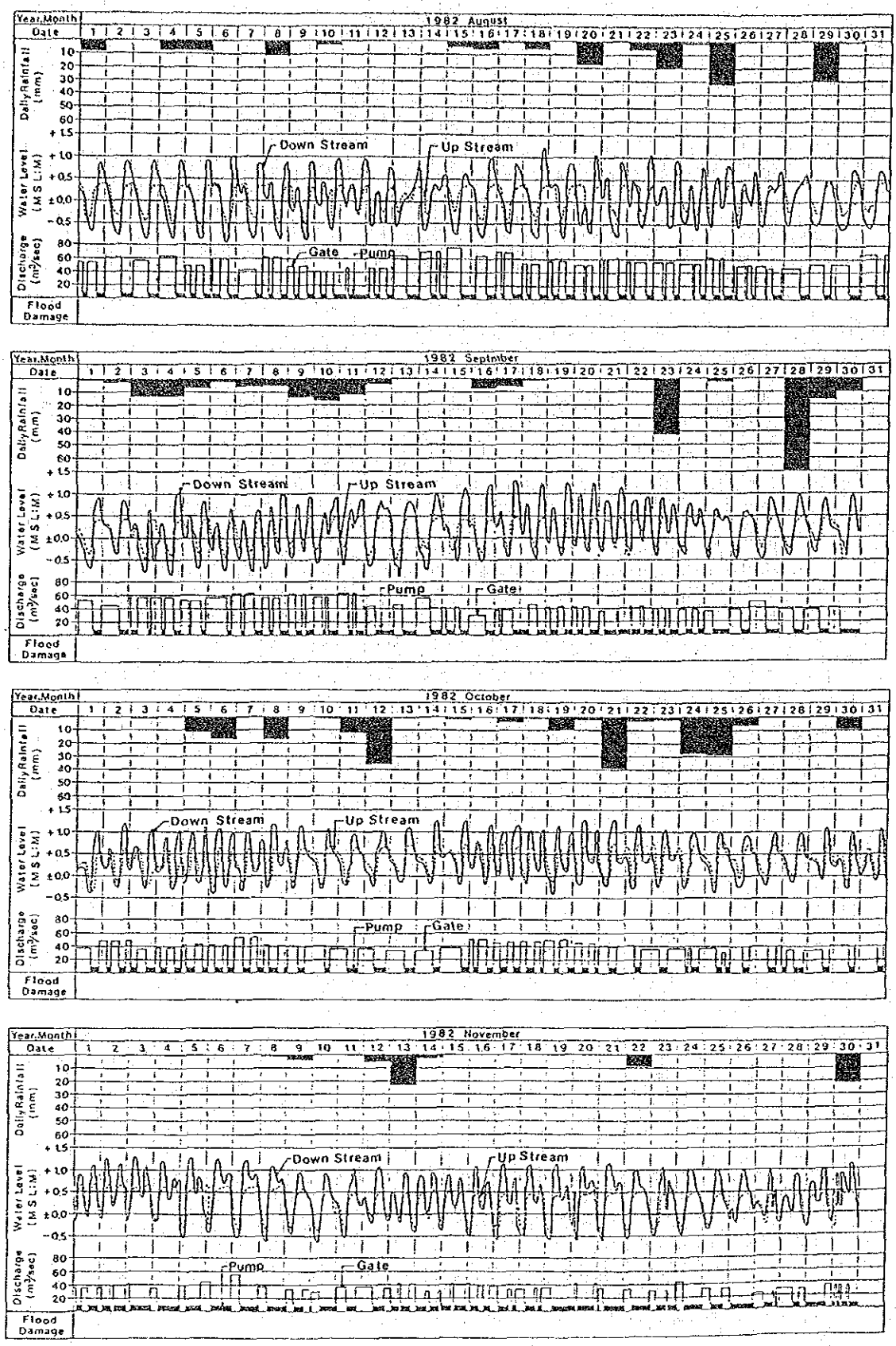

Source : RID

Fig. F.21 OPERATION RECORD AT PHRA KHANONG FLOOD GATE AND PUMP BETWEEN AUGUST AND NOVEMBER IN 1982

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

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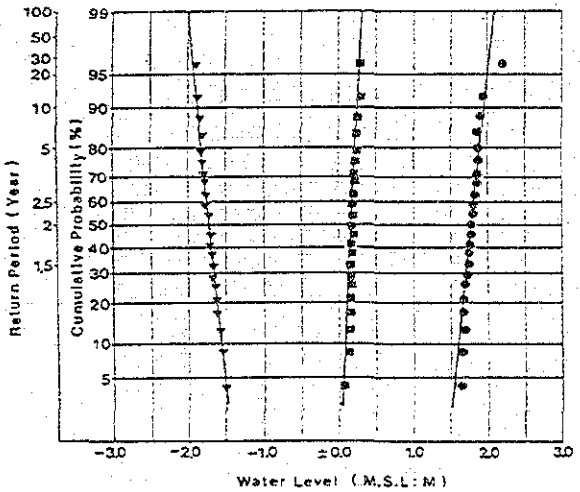
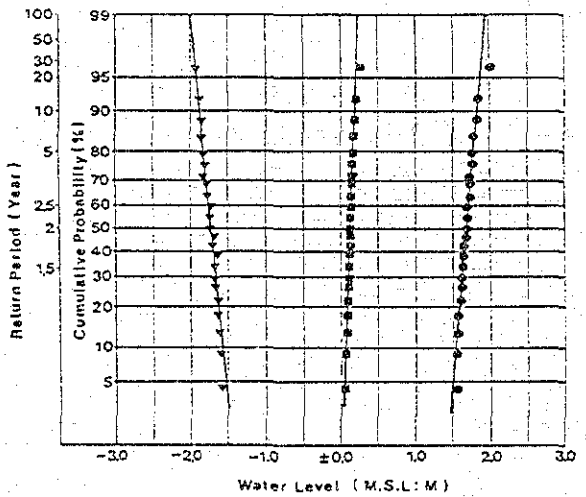
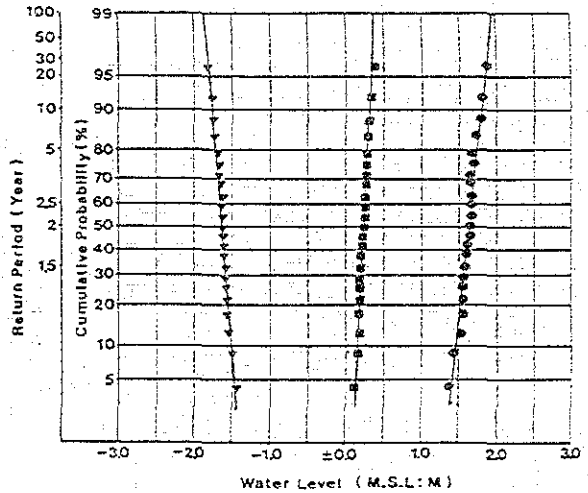


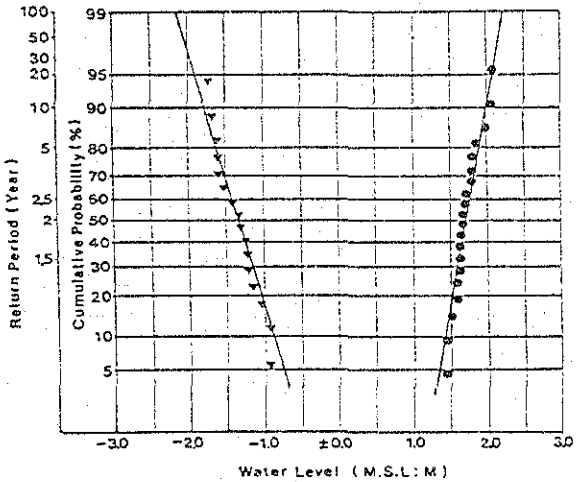
Fort Phrachul



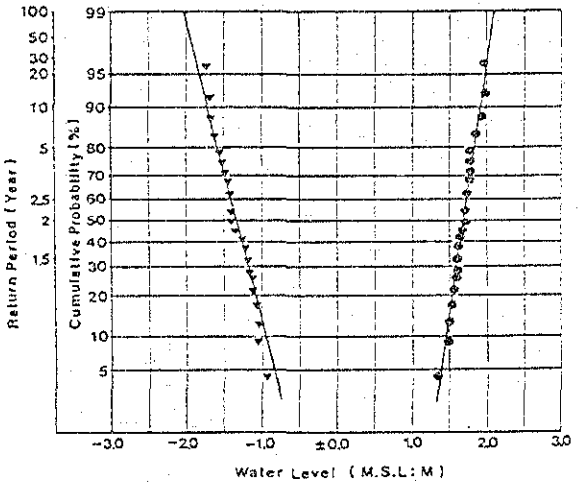
Pak Num



Bangkok Port



Memorial Bridge



Hydrographic Dep

Legend

- ● : Highest High Water Level
- ✱ : Mean Water Level
- ▽ : Lowest Low Water Level

Item	Year \ Station	Fort Phrachul	Pak Num	Bangkok Port	Memorial Bridge	Hydrographic Dep.
Highest High Water Level (H.H.W.L.)	2	1.78	1.67	1.61	1.68	1.67
	5	1.89	1.77	1.72	1.86	1.83
	10	1.95	1.82	1.77	1.96	1.91
	20	2.00	1.86	1.82	2.04	1.99
	30	2.02	1.88	1.85	2.09	2.03
	50	2.06	1.91	1.88	2.14	2.08
	100	2.10	1.95	1.92	2.21	2.14
Mean Water Level (M.W.L.)	2	0.18	0.12	0.22		
	5	0.22	0.16	0.27		
	10	0.25	0.18	0.30		
	20	0.27	0.19	0.32		
	30	0.28	0.20	0.34		
	50	0.29	0.21	0.35		
	100	0.30	0.23	0.37		
Lowest Low Water Level (L.L.W.L.)	2	-1.72	-1.74	-1.64	-1.36	-1.34
	5	-1.81	-1.84	-1.73	-1.63	-1.57
	10	-1.87	-1.89	-1.77	-1.79	-1.70
	20	-1.91	-1.93	-1.81	-1.93	-1.82
	30	-1.93	-1.96	-1.83	-2.01	-1.88
	50	-1.96	-1.98	-1.85	-2.11	-1.96
	100	-1.99	-2.02	-1.88	-2.24	-2.06

Unit : Meter above MSL

Fig. F.22 PROBABLE YEARLY WATER LEVEL OF CHAO PHRAYA RIVER

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

JICA 2528B.E. 1985A.D

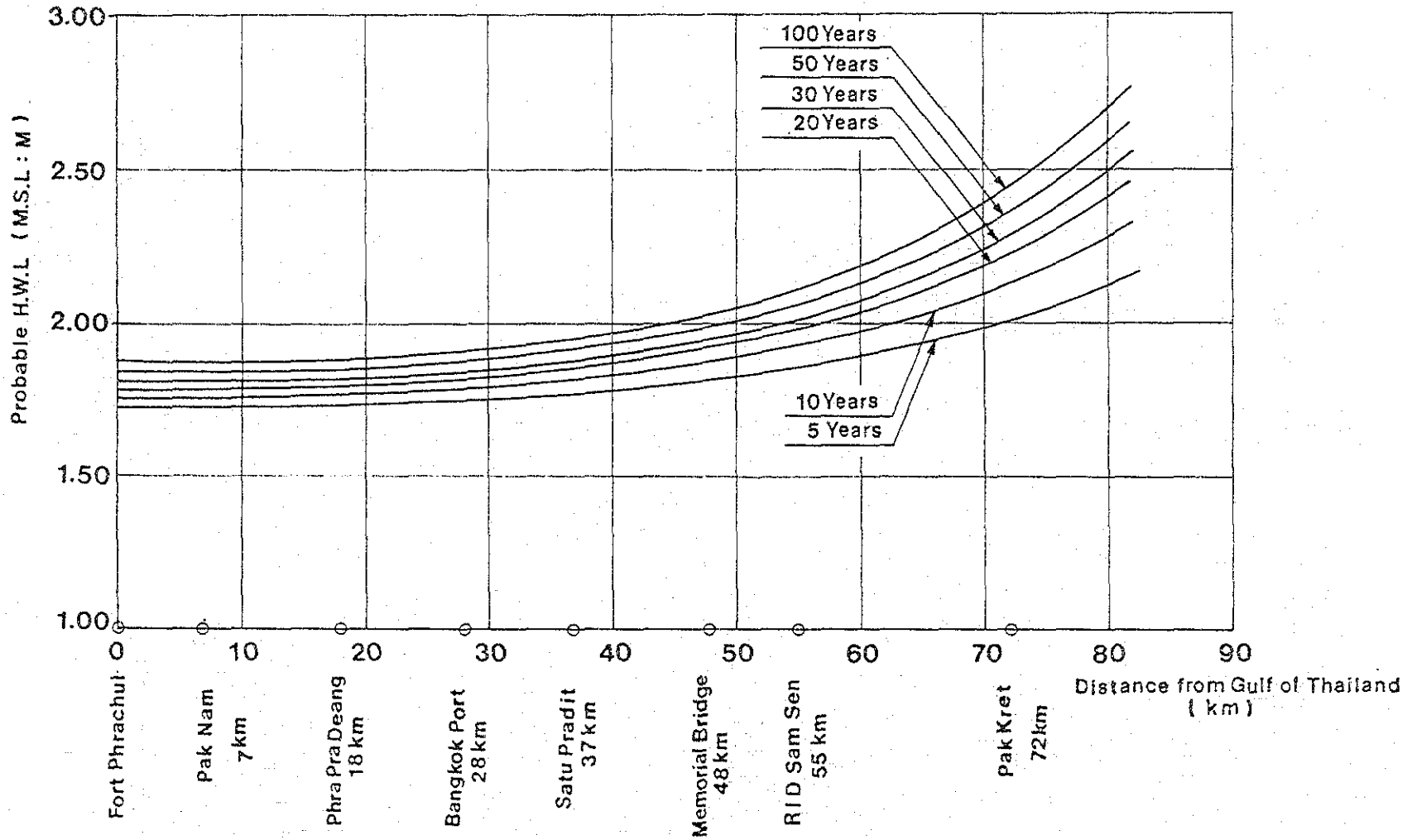


Fig. F.23	PROBABLE FLOOD WATER LEVEL OF CHAO PHRAYA RIVER

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

JICA 2528(B.E.) 1985(A.D.)

APPENDIX G

FLOOD PROTECTION BARRIER

APPENDIX G FLOOD PROTECTION BARRIER

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Appendix G FLOOD PROTECTION BARRIER

This Appendix describes the required flood protection barrier for the external flood water flowing from outer areas or the Chao Phraya River. The facilities described in this chapter include the flood protection barriers, control gates and cofferdams.

1. General

The proposed flood protection barrier is to be constructed at the border of the established polders in the Master Plan Area which are Polder Bang Khen-Bang Sue, Phra Khanong and Bang Na. Each polder will be protected from external flood waters by a flood protection barrier consisting of embankments, roadways, railways and cofferdam gates. The rain-water in the polder will be discharged into the Chao Phraya River by gravity or by pumping when the outside water levels are high.

The floods in Bangkok seldom exceed 2.0 meters above mean sea level since the large flat areas of the river delta are able to retain a huge amount of water. As shown in Fig. G.1, derived from the hydraulic study, the flood levels for the design rainfall surrounding the Master plan Area are low and do not exceed more than 40 cm over ground levels when based on the condition that the City Core, Green Belt and Sumut Prakan flood control projects prevent inflow from outer areas. Thus, a relatively low flood barrier will provide efficient protection for the Master Plan Area against the high water in the river.

2. Basic conditions for flood barrier planning

For the planning of the flood protection barrier, the design criteria is established as shown in Table G.1, taking into account the following:

2.1 Barrier utilizing the existing embankments

Utilizing the existing embanked roads and railways in the Master Plan Areas as much as possible the proposed individual drainage areas will be protected from external flooding. However, there

are some existing embankments of lower elevation and at some locations these are no embankments, which permit flood waters to enter into the Master Plan Area. Such low spots along the proposed barrier alignments, as well as other drainage openings which cross the periphial roads, must be eliminated or controled in order to ensure adequate flood protection. To provide such protection, new embankments are required or existing ones raised, and gates and cofferdams are required.

2.2 Barrier height

For the planning of the barriers having a sufficient height to prevent over topping by outside water, the following high water levels are considered.

(1) Flood level along Chao Phraya River

The 100 year frequency flood level of 1.90 metre above MSL is considered for the crest elevation of the barrier in Bang Na. In the City Core Project and Samut Prakan Project, the same 100 year frequency water levels have been adopted.

(2) Flood level along the Eastern Border of Master Plan

The 5 year frequency flood levels are considered for the barrier along the eastern border of the Master Plan Area, being compatible with the design magnitude of the trunk facilities.

(3) Flood level inside the Master Plan Area

The 2 year frequency flood levels are considered for the barrier at border of each drainage area which is compatible with the design magnitude of the inner polder facilities.

The flood barrier should be planned to have a freeboard taking into account the effects of waves and a safety allowance. Considering the importance of the proposed barriers, a freeboard of 30 cm has been adopted along the Chao Phraya River and the eastern border of Master Plan Area. For the inner barrier, a freeboard has been considered unnecessary.

2.3 Land subsidence and settlement

The crest level of the barrier should be considered in relation to the land subsidence estimated as 0.7 to 1.0 metres in the target year 2000 as described in Appendix. The ground elevations described in this section, therefore, are those of year 2000. The high water levels have been also been calculated by considering this land subsidence.

In addition, settlement of embankment fill normally occurs immediately after placing and continues for a long time, caused by consolidation of the lower soft ground layers.

3. Alignment of Flood Protection Barrier

The flood protection barrier is divided into 8 sections as shown in Fig. G.1. The section 1 is the stretch along the Chao Phraya River, section 2 along the City Core project, section 3 along the Northern Bangkok, section 4 and 5 along the eastern border of Master Plan Area and Samut Prakan Province, section 6 for the border between Polder Bang Sue and Phra Khanong, section 7 for the border between Polder Phra Khonong and Bang Na, and section 8 for the inner polder at the Ramkhamhaeng University area.

Section 1: As shown in Fig. G.3, the barrier length of the section 1 is about 6.2 km along the left bank of Chao Phraya River from the boundary between Bangkok city and Samut Prakan Province, to the Phrakanong pumping station via the mouth of Klong Phrakanong. Due to land subsidence, the future ground elevation will be about 2 m lower than design water level of Chao Phraya River, therefore, the river banks with a crest level of 2.2 meter above MSL is required to be constructed for the flood protection barrier. The flood protection barriers along the Chao Phraya River in the City Core Project and Samut Prakan Project connected with this project have been planned with a crest elevation of 2.25 and 2.10 meters respectively.

Section 2: As shown in Fig. G.4, section 2 is about 19.4 km length from the Phrakanong pumping station to Klong Bang Sue along the

periphery of the City Core Project. The future crest elevation of the barriers consisting of the existing roads and railways in this section will be at MSL more or less. Considering land subsidence of 1.0 meter this will be higher than expected inner high water level of about -0.20 metres.
Therefore, the new barrier in section 2 is not necessary for the master plan.
In the study for City Core Project, the barrier with crest elevation of 1.6 - 2.2 meters above MSL in present topography has been proposed to protect the external floods and this is basically consistent with this Master Plan.

Section 3: The existing embankment of railways and roadways will be utilized for the barrier of 20.9 km length in the section 3 as shown in Fig. G.5. The crests of the embankments at 1.5 metres above MSL will be adequate comparing with the expected inner water level of -0.4 below MSL.
Therefore, the construction of new barriers is not necessary in section 3.

Sections 4 and 5: The barrier with a total length of 50 km in sections 4 and 5 is the barrier between the Master Plan Area and the retention area (Figs. G.6 to G.7). The barrier utilizes the existing roads such as the Klong Song, Phahol Yothin road, Rum Intru road, Bang Khen to Bang Kapi road, Hua Muk to Sum Rom road and the soi located the boundary of Bangkok city and Samut Prakan Province. The maximum flood depth in the eastern outer area is expected to be only 20 to 30 cm over the ground elevation. The height of embankment of the existing roads of 70 to 100 cm is enough to protect from the inflow of the storm water from the outer area.

Sections 6 and 7: The barriers of sections 6 and 7 are at the border between Polder Phra Khanong and Polder Bang Sue, Polder Bang Na in order to independently control the stormwater of the three drainage areas (Figs. G.8 to G.9). The crest of barrier utilizing the existing roads and railways is higher than the expected inner water level, therefore, new embankment construction is not necessary.

4. Control gates, cofferdams and lock

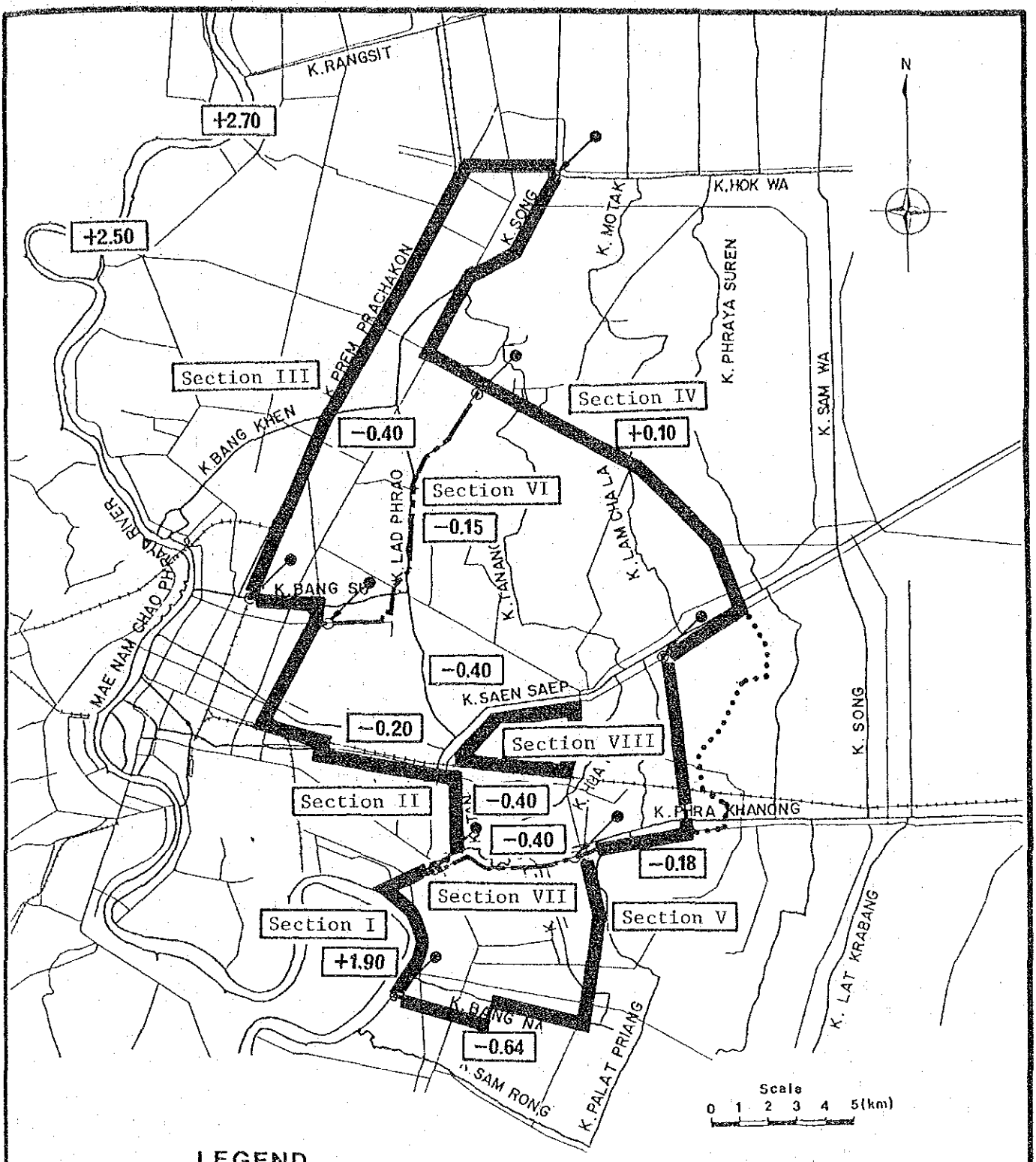
Where the proposed barriers intersect the klongs as shown in Fig. H.10, control gates or cofferdams are required in order to control the stream flow. The 7 planned control gates facing to the Chao Phraya River will be operated corresponding to the water level of the river, opening in case of low water level and closing in case of high water level. The 48 planned cofferdams having one or two gates in the land side barrier will be mostly closed in the rainy season and opened in the dry season for flushing, cleaning klongs and irrigation.

In the urgent 1984 programme, the gates along Chao Phraya River which are in the same klongs required in the Master Plan have been newly constructed. In the near future, however, these gates will require improving as the beds of the Klong will have settled due to land subsidence. In the Master Plan, therefore, they will be considered for reconstruction as a long range development although it will not be necessary in the first stage of the Master Plan construction. Furthermore, at some of the planned locations, especially Bang Na area, there are existing cofferdams but are of a temporary nature, therefore, these cofferdams are proposed for new construction.

In addition to the control gates and cofferdams, the navigation lock in klong Phrakanong, which is one of large navigable klongs, will be necessary with the capability to handle river barges and boats under any hydraulic conditions. In the urgent programme, the existing navigation lock has been improved, however, this lock will have to be further improved as a long range development in the Master Plan in order to provide sufficient height against settlement following land subsidence.

Table G-1 Design Criteria of Barrier for Year 2000

Section	Length	Required Crest Elev.	Ave.G.L.	Design Water Level	Free Board	Land Subsidence
I	6.2 Km	+2.20 m	+0.20 m	+1.90 m	0.30 m	1.00 m
II	19.4 Km	+0.10 m	±0.00 m	-0.20 m		
III	20.9 Km	-0.10 m	+1.40 m	-0.40 m		0.70 m
IV	26.4 Km	+0.40 m	+0.80 m	+0.10 m		
V	23.6 Km	+0.12 m (L=6.5 Km)	-0.60 m	-0.18 m		1.00 m
		-0.34 m (L=17.1 Km)	+0.20 m	-0.64 m		
VI	12.1 Km	-0.05 m	+0.10 m	-0.15 m	-	
VII	5.6 Km	-0.30 m	-0.20 m	-0.40 m		
VIII	13.0 Km	-0.30 m	±0.00 m	-0.40 m		



LEGEND

Section I — Flood Protection Alignment

+1.90 — Design Water level (m.MSL)

Note: The barrier alignment (••••),utilizing the existing road is adopted for part of section V,instead of the originallystudied alignment (▬) running on the future extension of the Outer Ring Road.

Section	Length
I	6.2 km
II	19.4 km
III	20.9 km
IV	26.4 km
V	23.6 km
VI	12.1 km
VII	5.6 km
VIII	13.0 km
Total	127.2 km

Fig. G.1 PROPOSED FLOOD PROTECTION BARRIER

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

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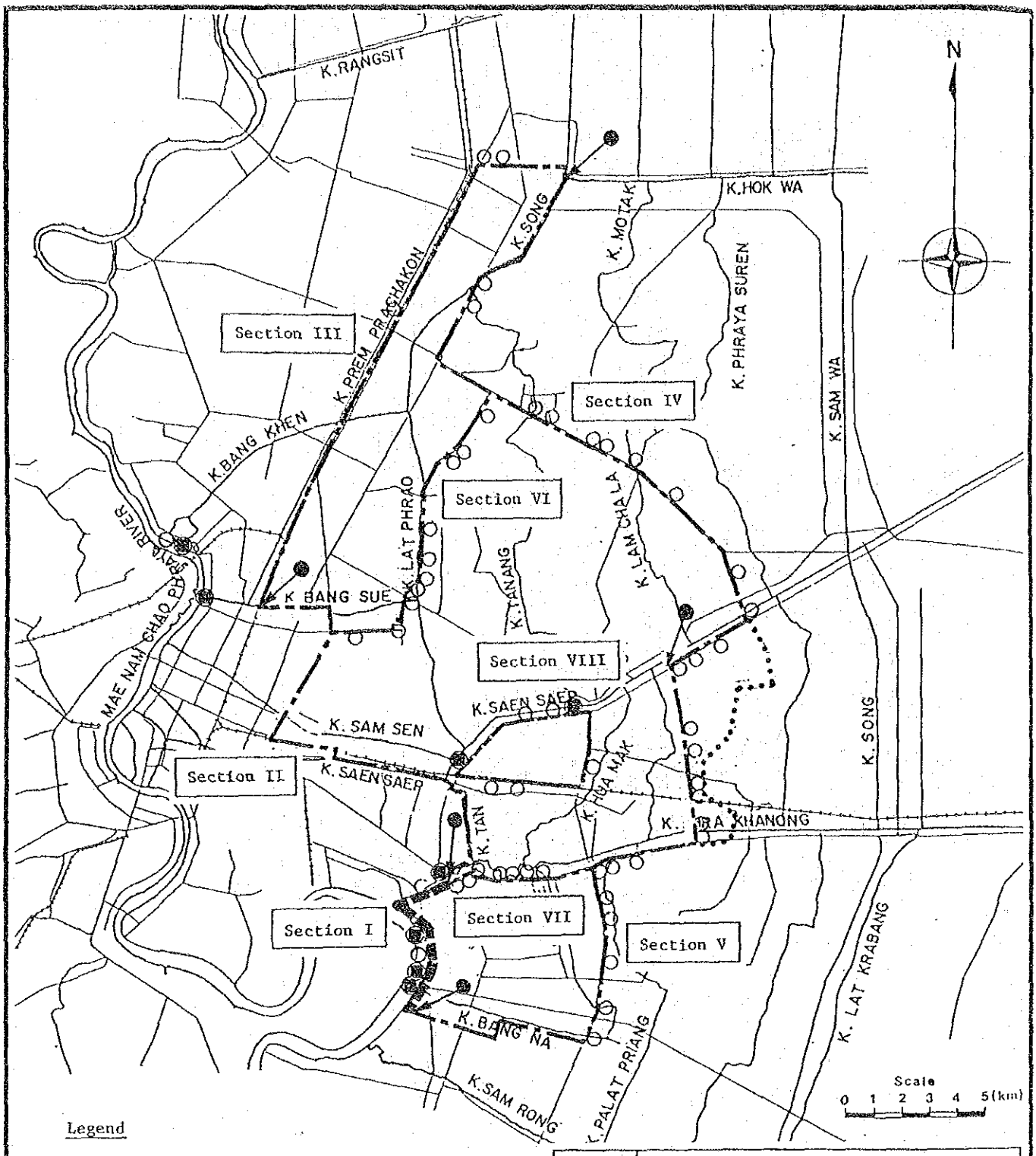

Legend

Barrier to be newly constructed

Section III — Barrier utilizing existing road & railway

Gate

Pumping Station with Gate

Note: The barrier alignment (•••),utilizing the existing road is adopted for part of section V,instead of the originallystudied alignment (— —) running on the future extension of the Outer Ring Road.

Section	Barrier		
	Exist. Road/ Railway	To be Constructed	Total Length
I	- km	6.2 km	6.2 km
II	19.4	-	19.4
III	20.9	-	20.9
IV	26.4	-	26.4
V	23.6	-	23.6
VI	12.1	-	12.1
VII	5.6	-	5.6
VIII	13.0	-	13.0
Total	114.5 km	6.2 km	121.0 km

Fig. G.2 PROPOSED BARRIER AND GATE

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

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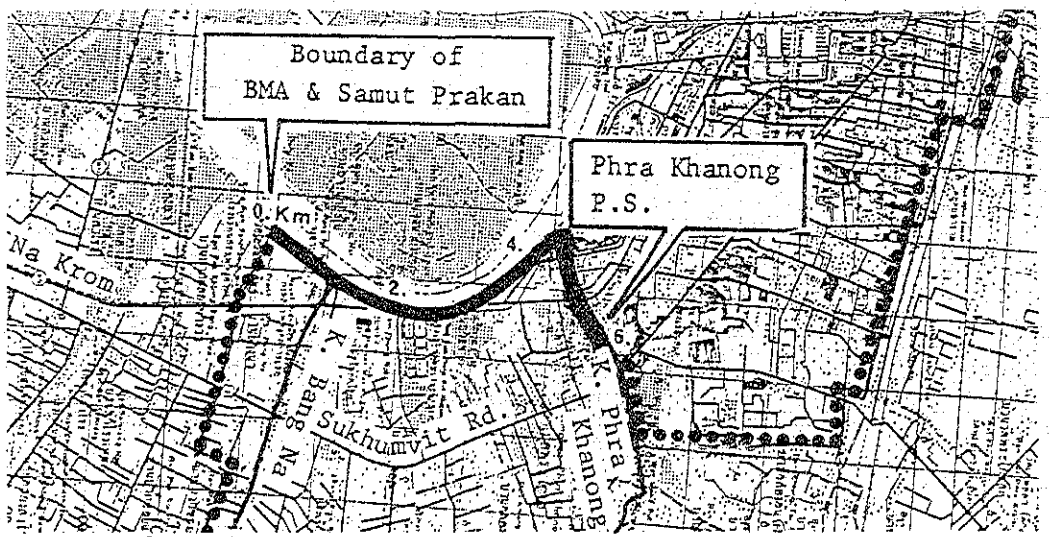

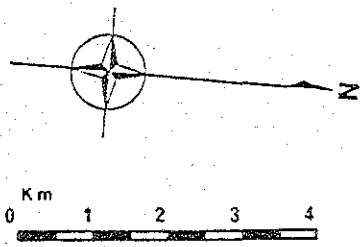

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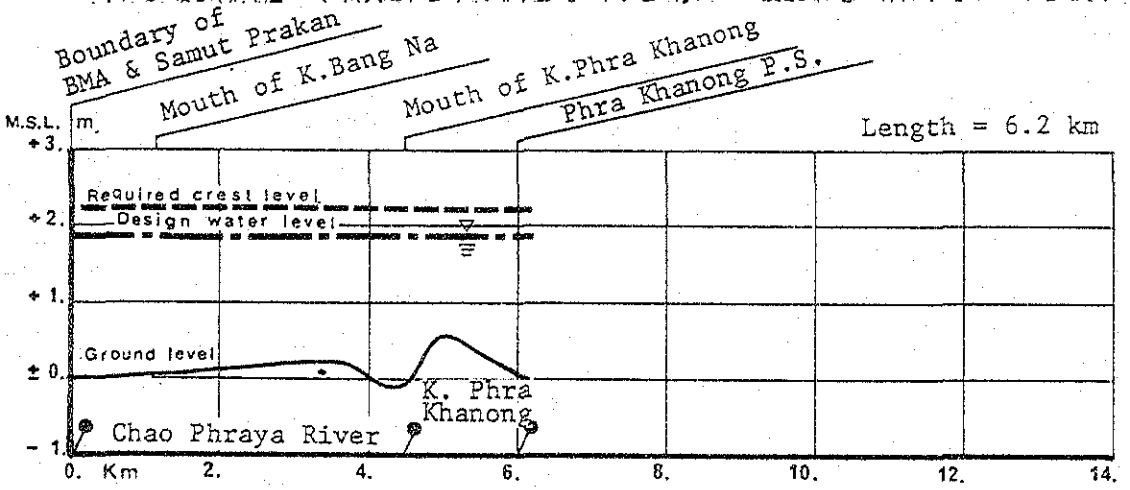

Ground level (Road)	0.15 −0.22 0.47 0.17
Required crest level	2.20
Design water level	1.90
Land subsidence	1.00

Section I

Fig. G.3 ALIGNMENT AND PROFILE OF FLOOD PROTECTION BARRIER-1 (BANG NA DRAINAGE AREA)

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

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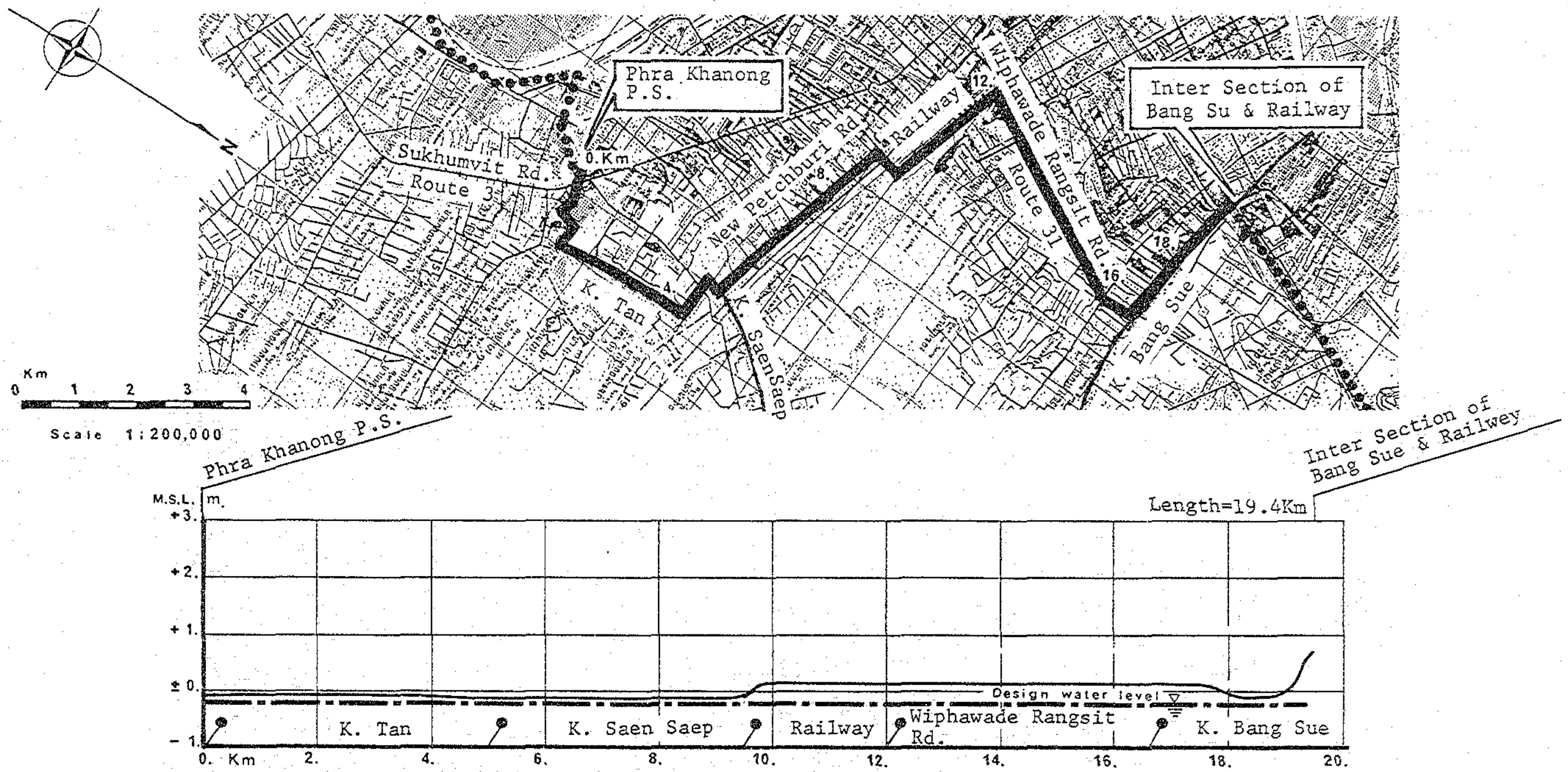
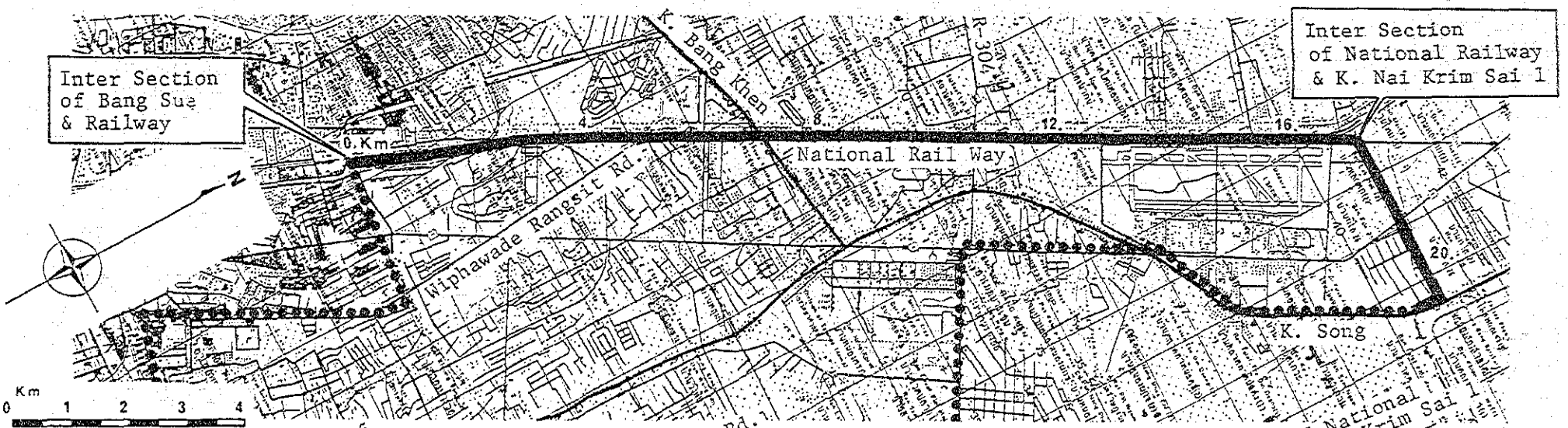


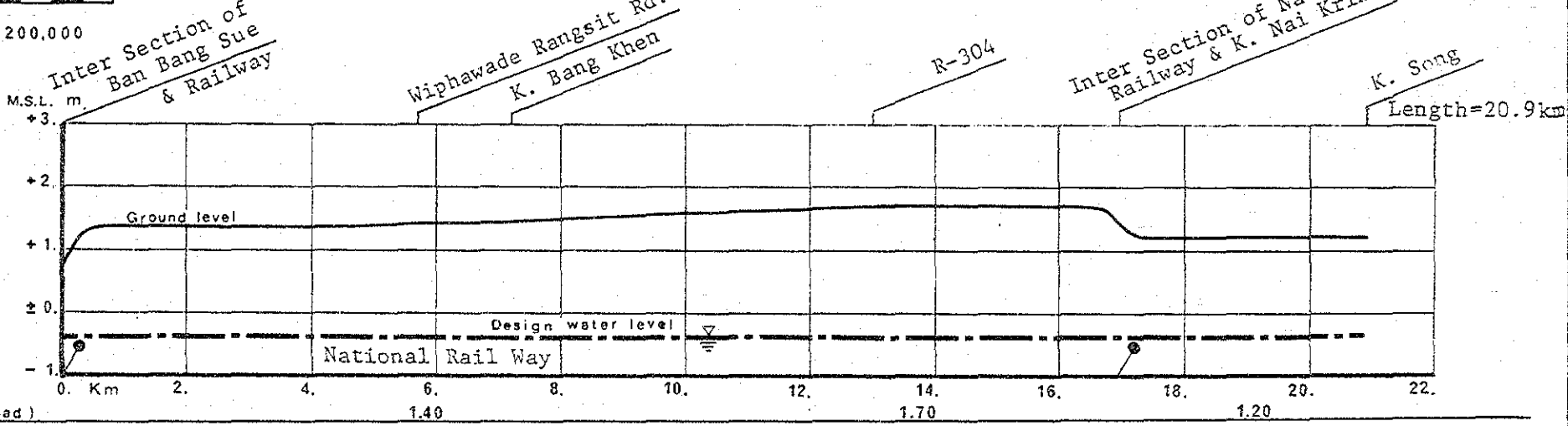
Ground level (Road)	-0.1	-0.1	-0.1	0.3	0.15	0.16	-0.11	0.74
Required crest level	-0.1							
Design water level	-0.2 (Inner)							
Land subsidence	1.0							

Section II

Fig. G.4 ALIGNMENT AND PROFILE OF FLOOD PROTECTION BARRIER-2 (HUAY KWANG AND HUA MARK DRAINAGE AREA)

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



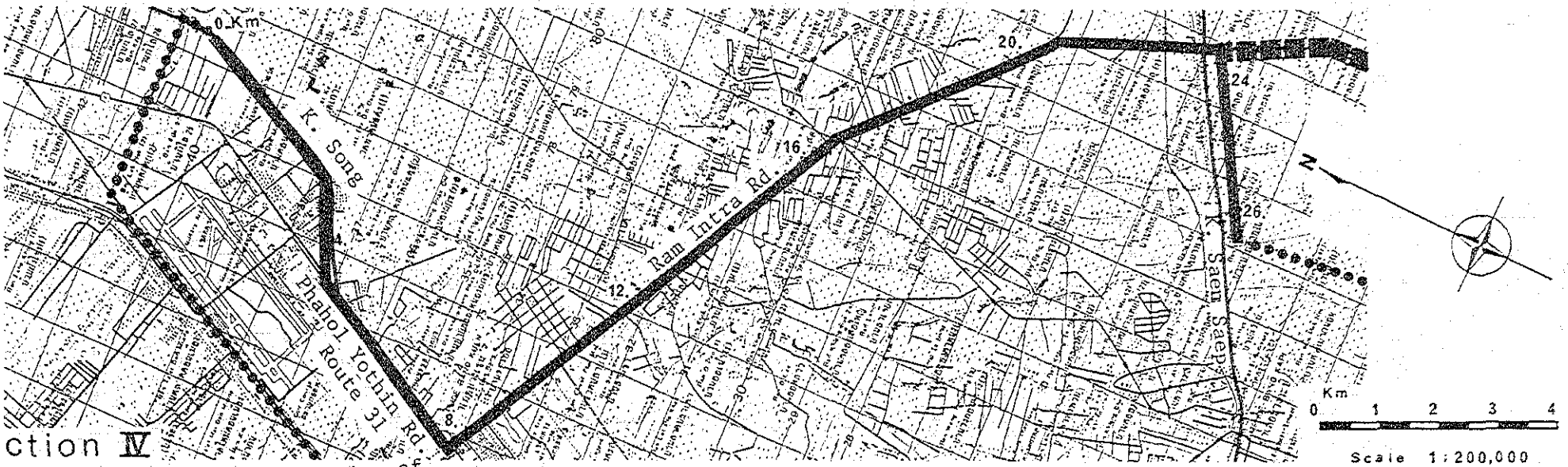


Ground level (Road)		1.40	1.70	1.20
Required crest level	-0.1		
Design water level	-0.4		
Land subsidence	1.0		0.7	

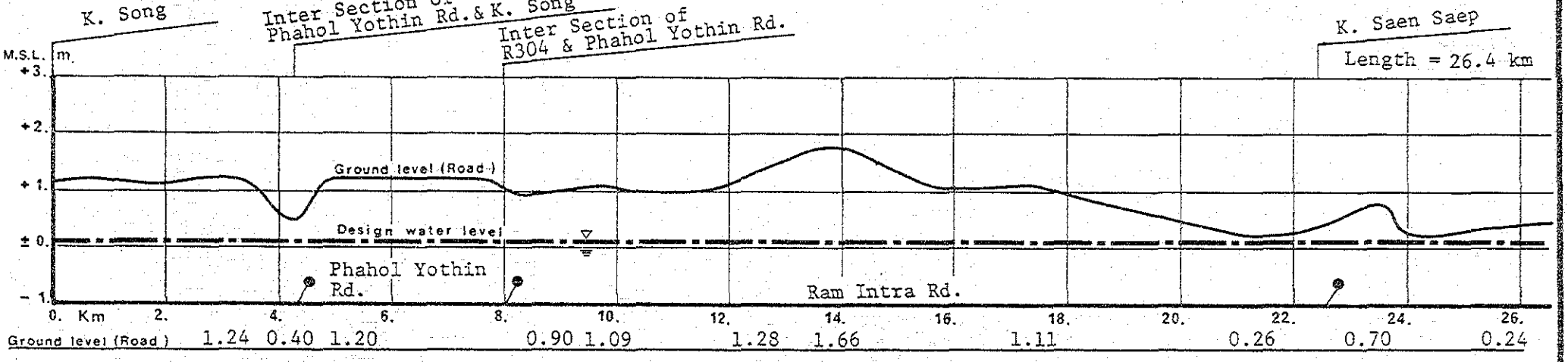
Section III

Fig. G.5 ALIGNMENT AND PROFILE OF FLOOD PROTECTION BARRIER-3 (BANG KHEN AND BANG SUE DRAINAGE AREA)

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



Section Ⅳ



Ground level (Road)	1.24	0.40	1.20		0.90	1.09	1.28	1.66		1.11		0.26	0.70	0.24
Required crest level						0.40								
Design water level						0.10								
Land subsidence		0.70								1.00				

Note: The barrier alignment (■■), utilizing the existing road is adopted for part of section V, instead of the originallystudied alignment (▬) running on the future extension of the Outer Ring Road.

Fig. G.6 ALIGNMENT AND PROFILE OF FLOOD PROTECTION BARRIER-4 (LAT PLRAO AND KLONG CHANG DRAINAGE AREA)

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