THE GOVERNMENT OF THE KINGDOM OF THAILAND

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

SUPPORTING REPORT

FEBRUARY 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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APPENDIX A.

CHAO PHRAYA RIVER CONDITION

APPENDIX A. CHAO PHRAYA RIVER CONDITION

1. General

The Chao Phraya River, flowing southerly through the central part of Thailand into the Gulf of Thai, is the most important river in the country. The River has a total trunk length of 980 km and drains an area of 162,600 km^2, about one-third of the whole country. The River consists of the four (4) major tributaries, the Ping, Wan, Yom and Nan Rivers which join at Nakhon Sawan.

The River irrigates a vast agricultural land extending over the downstream of Nakhon Sawan. In addition to the agricultural use, it is highly used for hydropower generation, navigation and domestic and industrial water supply. While, in the rainy season, it floods a wide area of the downstream delta, including Bangkok city.

2. River Flow and Water Use

2.1 River Flow

River flow data in the downstream of the Chao Phraya River is available at Bang Sai for the period from 1963 to 1976. Bang Sai is located approximately 50 km upstream of the Study Area.

Monthly average discharge at Bang Sai during the 14 years (1963 - 1976) is shown in Table A.1. Average seasonal discharge in the typical dry season (Jan. - April) and typical rainy season (Aug. - Nov.) during this 14 year period is calculated in Table A.2. The maximum, minimum and average seasonal discharges during the 14 years are as follow.

	Dry Season (Jan. - April)	Rainy Season (Aug. - Oct.)
Maximum	233 m^3/s	2,172 m^3/s
Minimum	120	264
Average	174	1,095

2.2 Water Use

(1) Domestic and Industrial Use

Water of 2.65 million m^3/day is consumed currently for domestic and industrial purposes in Bangkok and its vicinity. The Metropolitan Water Works Authority (MWA) supplies 1.75 million m^3/day of water to approximately 3 million people. Out of this MWA supply, 0.5 million m^3 is obtained from groundwater and 1.25 million m^3 is drawn from the Chao Phraya River. An additional groundwater of 0.9 million m^3/day is used by the private sector. The water intake of the Chao Phraya River is located in between the Study Area and Bang Sai.

According to the MWA plan, the existing groundwater source is to be replaced by surface water by the year 2000. The water demand of 3.75 million m^3/day in the year 2000 is to be supplied entirely by surface water from the Chao Phraya River.

(2) Irrigation Use

Most part of the Lower Central Plain of the Chao Phraya River has already been developed for paddy cultivation with the aid of extensive canal networks of the Greater Chao Phraya Project. The present irrigation water withdrawals in the Delta during the dry and rainy seasons are estimated to be about 700 million m^3/month and 1,100 million m^3/month respectively.

However, there exists no irrigation water withdrawal from the Chao Phraya River in between the Study Area and Bang Sai.

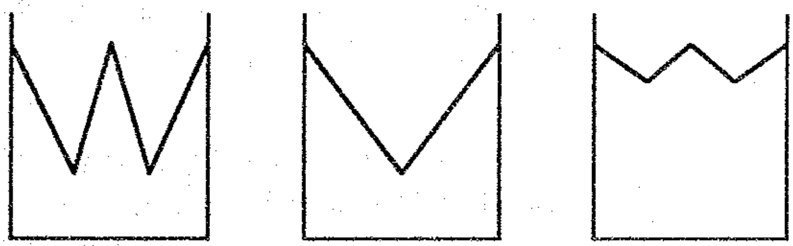
3. River Water Stage

The stages of the Chao Phraya River have been observed at twelve (12) stations in a 110 km section from the river mouth at Bangkok Bar to Bang Sai at upstream. The location of the stations are shown in Fig. A.1.

The river stage data obtained during the 5 year period from 1983 to 1987 at the Memorial Bridge (one of the twelve stations located in the mid of the Study Area) were adopted to analyze the river stage characteristics in the Study.

Since the Memorial Bridge is located within the tidal compartment of the Chao Phraya River, the river stage at the station varies hourly and is strongly influenced by tidal action. Thus, the hourly river stage profile were classified into three (3) patterns and the period and the amplitude of each pattern for dry and rainy seasons were tabulated in order to understand the characteristics of the river stage.

The classified three river stage patterns are as shown below:



I II III

Pattern I is a semidiurnal tide. Pattern II is one tide in one day. Pattern III shows the condition that does not have a significant tidal effect. The pattern III appears during the high discharge period in the rainy season.

The analyzed frequencies of each pattern during the 5 year period from 1983 to 1987 are as follows (Refer to Table A.3).

	I	II	III
Dry Season	107 days (19.5%)	441 days (80.5%)	0 days (0%)
Rainy Season	91 days (21.0%)	328 days (75.5%)	15 days (3.5%)

The frequency of occurrence of pattern II is the highest, nearly 80% for both during the dry and rainy seasons, followed by that of pattern I. The frequency of occurrence of pattern III is negligible.

The average values of the daily highest and lowest stages of patterns I, II, and III are as given below (for details refer Table A.4).

		Pattern I	Pattern II	Pattern III
Dry Season:	Highest Stage (m)	0.91	1.01	-
	Lowest Stage (m)	-0.14	-0.47	-
Rainy Season:	Highest Stage(m)	1.01	1.06	1.51
	Lowest Stage (m)	-0.04	-0.41	-0.99

The amplitude of pattern I was low which was approximately 1 m during both the dry and rainy seasons. The amplitude of pattern II was high which was approximately 1.4 m.

Hence, it was decided upon to adopt the river stage profile of pattern II for the Study. The adopted design tidal levels are:

During dry season:

High tide level	:	1.00 m
Low tide level	:	-0.45 m

During rainy season:

High tide level	:	1.10 m
Low tide level	:	-0.40 m

4. Water Quality of Chao Phraya River

4.1 Water Quality

The water quality of the Chao Phraya River has been observed by NEB. The available parameters are as follows.

Water Quality Parameter	Period
PH, DO, BOD, COD, SS, Cl^-, NH_4-N NO_3-N, T-P, H_2S, Coliform Count	1983 - 1984
DO,BOD	1978 - 1982

In 1983 and 1984, the water quality was observed at 18 locations distributed over the whole downstream reaches of the Chao Phraya River (Samut Prakan - Bang Pain). The sampling locations are shown in Fig. A.2.

The water stage of the Chao Phraya River usually reaches the highest level in October and recedes to the lowest in April. The distancial distributions of the water quality observed in October 1983 and April 1984 are shown in Fig. A.3.

Monthly variation of the water quality observed in 1983 and 1984 at the Bangkok area (Mouth of Klong Phra Khanong and Wat Chalermprakeit) are shown in Fig. A.4.

Yearly variation of BOD and DO during the period from 1978 to 1982 in the lower reaches of the Chao Phraya River are shown in Fig. A.5.

The characteristics of the water quality of the Chao Phraya River are summarized as follows.

(1) The water quality of the Chao Phraya River is affected by tide, river discharge and wastewater form Bangkok city. DO, BOD and COD concentrations vary in the rang of:

DO	:	1 - 5 mg/l
BOD	:	1 - 3 mg/l
COD	:	5 - 30 mg/l

(2) The water quality in rainy season varies very little along the whole river distance. While in dry season, there is a marked difference in the water quality between the downstream and upstream stretches of the 60 km river distance. In the downstream stretches, the water quality become worse in dry season than in rainy season. On the other hand, the water quality in the upstream stretches remains nearly constant throughout the year. Seasonal and regional variation of DO and BOD are summarized below (See Fig. A.3).

		River Distance	
		0 - 60 km	60 - 130 km
DO	Rainy Season	3 - 4 mg/l	3 - 4 mg/l
	Dry Season	1 - 2 mg/l	3 - 5 mg/l
BOD	Rainy Season	1 mg/l	1 mg/l
	Dry Season	2 - 3 mg/l	1 mg/l

(3) The river water is polluted by the discharge of wastewater from the Bangkok city. The water quality at the mouth of Klong Phra Khanong (28 km distance) and Wat Chalermprakeit (62 km distance) are compared as follows (See Fig. A.4).

	Yearly Average Water Quality (mg/l)				
	DO	BOD	COD	NH4-N	T-P
Mouth of Klong Phra Khanong	1.0	2.5	20	2.5	0.8
Wat Chalermprakeit	3.0	1.5	18	0.5	0.5

(4) No significant yearly change has been recognized in the water quality of the Chao Phraya River (See Fig. A.5).

4.2 Salinity Intrusion

Data on the salinity intrusion of the Chao Phraya River are available at the Port Authority of Thailand. The data of 1976 are the latest available ones.

Monthly variation of the salinity intrusion distance in 1976 is shown in Fig. A.6. This figure shows the distance of salinity intrusion for the river sections with a measured Cl^- content of 0 ppm and 1,000 ppm respectively. The furthest distance of salinity intrusion was registered in April when the river flow was the minimum (180 m^3/s). The saline water sections with Cl^- contents of 0 ppm and 1,000 ppm reached 40 km and 35 km respectively at high tide.

The distribution of saline water content during the typical dry season (April) and rainy season (October) of 1976 is shown in Fig. A.7. The saline water content decreases gradually towards upstream. The reduction of salinity is also shown in Fig. A.7.

The JICA Study Team observed the salinity intrusion of the Chao Phraya River on August 8 and November 1, 1988. The distribution of observed saline water content is shown in Fig. A.8.

Judging from the above studies, salinity intrusion of the Chao Phraya River is limited to about 40 km of river distance upstream from the River Mouth.

Table A.1 Monthly Average Discharge of the Chao Phraya River at Bang Sai

(m^3/sec)

Year	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1963	286	137	87	135	78	50	121	742	1,316	2,050	1,839	1,269
1964	372	208	113	71	53	86	251	310	837	864	1,726	801
1965	196	139	70	142	177	230	231	274	1,052	1,298	708	882
1966	410	164	237	224	206	641	350	752	1,529	1,758	922	663
1967	268	126	131	142	168	169	150	153	487	1,377	553	483
1968	223	104	109	77	292	278	153	237	303	320	197	483
1969	193	79	114	94	97	183	394	329	1,075	1,946	748	598
1970	212	150	124	110	275	792	1,261	1,472	2,096	2,973	2,148	1,160
1971	407	160	129	127	138	180	173	599	1,395	1,563	770	777
1972	341	232	161	146	113	199	112	184	932	1,158	578	1,072
1973	280	149	137	121	156	232	151	243	734	1,879	624	675
1974	212	129	142	152	260	242	184	310	604	1,613	1,726	855
1975	385	184	154	171	197	383	333	340	1,819	2,670	2,032	1,140
1976	302	250	201	179	557	432	360	500	1,463	1,822	1,395	1,000
Average	292	158	136	135	198	293	302	460	1,117	1,664	1,140	847

Table A.2 Average Seasonal Discharge at Bang Sai

(Unit: m^3/s)

Year	Dry Season	Rainy Season
1963	161	1,487
1964	191	934
1965	137	833
1966	167	1,240
1967	167	643
1968	128	264
1969	120	1,025
1970	149	2,172
1971	206	1,082
1972	220	713
1973	172	870
1974	159	1,063
1975	224	1,715
1976	233	1,295
Average	174	1,095

Table A.3 (1) Frequency of the River Stage Pattern at Memorial Bridge (Dry Season)

Type / Year	I (day)	II (day)	III (day)	Total (day)
1983 / Jan.	2	29	-	31
Feb.	5	23	-	28
Mar.	12	19	-	31
Apr.	6	21	-	27
Sub Total	25	92	-	117
1984 / Jan.	1	21	-	22
Feb.	7	21	-	28
Mar.	9	21	-	30
Apr.	9	13	-	22
Sub Total	26	76	-	102
1985 / Jan.	3	27	-	30
Feb.	5	23	-	28
Mar.	7	24	-	31
Apr.	6	21	-	27
Sub Total	21	95	-	116
1986 / Jan.		26	-	26
Feb.	4	10	-	14
Mar.	6	25	-	31
Apr.	6	21	-	27
Sub Total	16	82	-	98
1987 / Jan.	3	28	-	31
Feb.	6	22	-	28
Mar.	6	23	-	29
Apr.	4	23	-	27
Sub Total	19	96	-	115
Total	107	441	-	548

Table A.3 (2) Frequency of the River Stage Pattern at Memorial Bridge (Rainy Season)

Type / Year	I (day)	II (day)	III (day)	Total (day)
1983 / Aug.	5	21	-	26
Sep.	6	23	-	29
Oct.	3	13	13	29
Sub Total	14	57	13	84
1984 / Aug.	5	25	-	30
Sep.	8	22	-	30
Oct.	6	23	-	29
Sub Total	19	70	-	89
1985 / Aug.	3	28	-	31
Sep.	8	21	-	29
Oct.	10	17	2	29
Sub Total	21	66	2	89
1986 / Aug.	4	26	-	30
Sep.	5	25	-	30
Oct.	9	19	-	28
Sub Total	18	70	-	88
1987 / Aug.	7	23	-	30
Sep.	5	23	-	28
Oct.	7	19	-	26
Sub Total	19	65	-	84
Total	91	328	15	434

Table A.4 Average Values of the Daily Highest and Lowest River Stages at Memorial Bridge

Pattern (I)

Year	Dry Season (Jan.-Apr.)			Rainy Season (Aug.-Oct.)		
	Cycle (hour)	Highest (m)	Lowest (m)	Cycle (hour)	Highest (m)	Lowest (m)
1983	24:08	0.87	-0.19	24:17	1.03	0.06
1984	23:55	0.88	-0.10	23:50	0.99	-0.11
1985	24:00	1.01	-0.03	23:14	1.14	0.15
1986	24:04	0.95	-0.14	24:10	0.89	-0.15
1987	24:13	0.86	-0.23	24:07	1.02	-0.13
Average	24:04	0.91	-0.14	23:53	1.01	-0.04

Pattern (II)

Year	Dry Season (Jan.-Apr.)			Rainy Season (Aug.-Oct.)		
	Cycle (hour)	Highest (m)	Lowest (m)	Cycle (hour)	Highest (m)	Lowest (m)
1983	24:11	0.95	-0.51	24:08	1.12	-0.23
1984	24:04	1.04	-0.40	24:07	1.05	-0.48
1985	24:08	1.08	-0.45	24:08	1.09	-0.40
1986	24:04	1.04	-0.45	24:27	1.00	-0.48
1987	24:16	0.96	-0.53	24:04	1.05	-0.45
Average	24:09	1.01	-0.47	24:11	1.06	-0.41

Pattern (III)

Year	Dry Season (Jan.-Apr.)			Rainy Season (Aug.-Oct.)		
	Cycle (hour)	Highest (m)	Lowest (m)	Cycle (hour)	Highest (m)	Lowest (m)
1983	-	-	-	24:37	1.54	1.03
1984	-	-	-	-	-	-
1985	-	-	-	24:15	1.36	0.74
1986	-	-	-	-	-	-
1987	-	-	-	-	-	-
Average	-	-	-	24:34	1.51	0.99

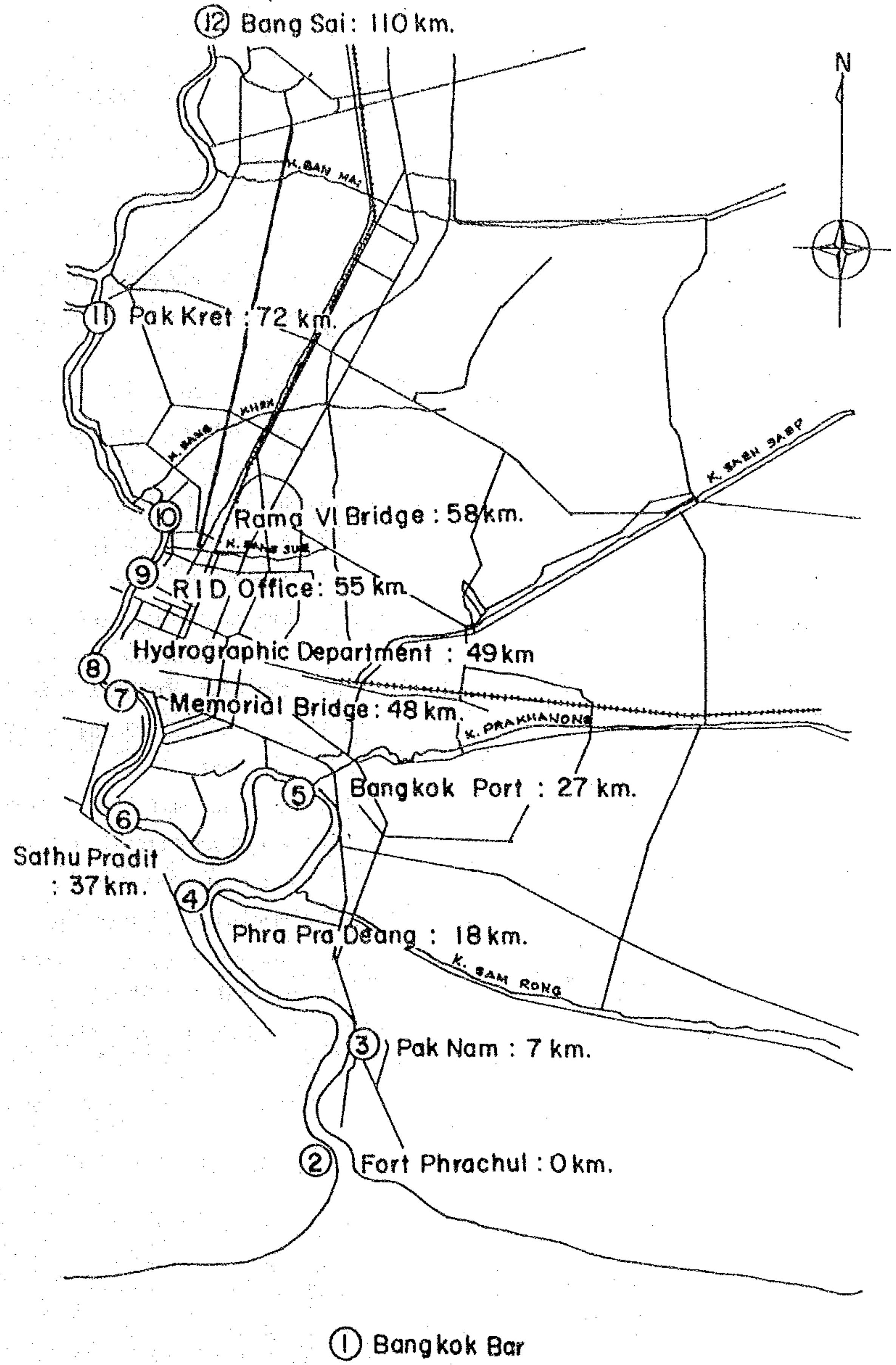


FIG. A.1	LOCATION OF CHAO PHRAYA RIVER WATER STAGE MONITARING STATIONS

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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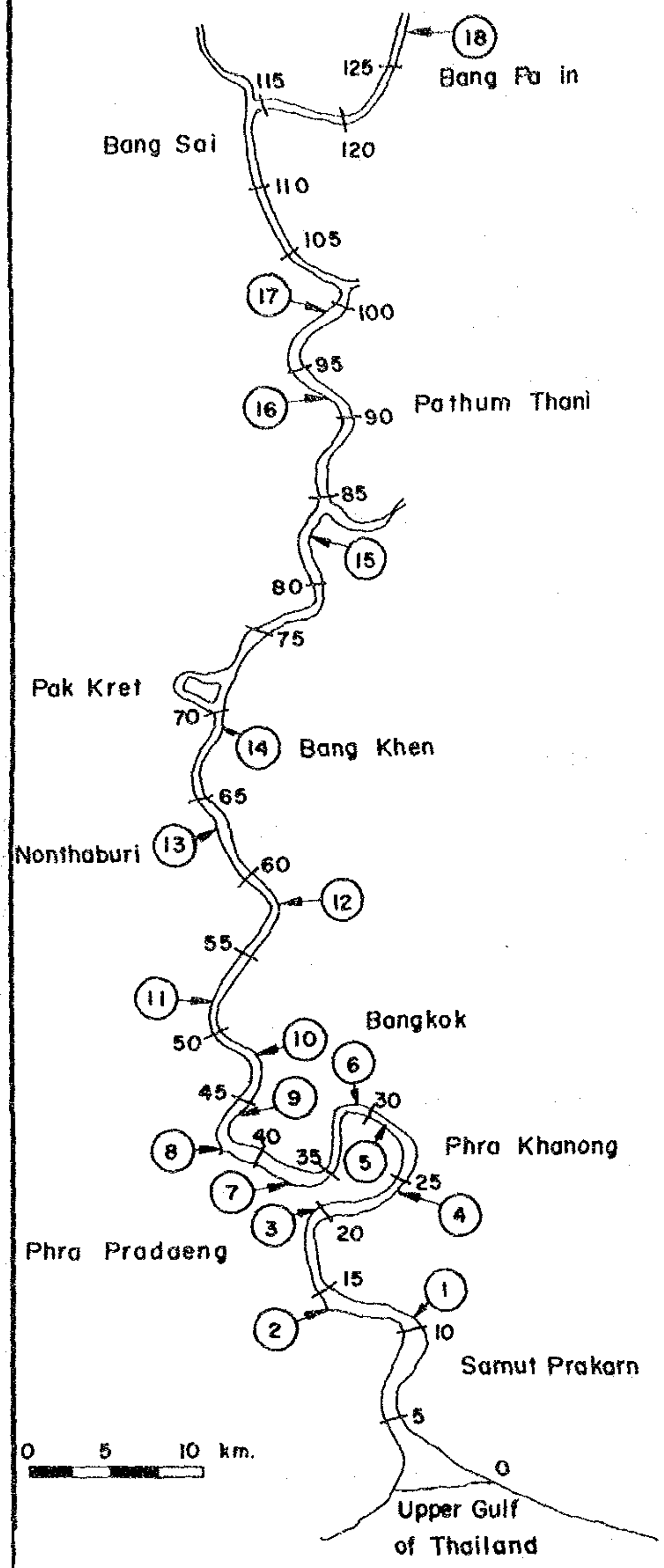


Sampling Station

1. Phra Samut Chedi (10 km)
2. South Electric-Generation Plant (14 km)
3. Phra Pradaeng (20 km)
4. Wat Yothin Pradit (24 km)
5. The Mouth of Khlong Phra-Khanong (28 km)
6. Port Authority of Thailand (30 km)
7. Rice-Bran Oil Factory (36 km)
8. Bangkok Bridge (42 km)
9. Tobacco Factory (44 km)
10. Memorial Bridge (48 km)
11. The Mouth of Khlong Thae Waet (52 km)
12. Phraramhok Bridge (58 km)
13. Wat Chalermprakeit (62 km)
14. Wat Cheunglen (68.8)
15. Nonthaburi Bridge (82.4 km)
16. Phathum Thani (91.6 km)
17. Sam Khok (98.6)
18. Bang Pa In Paper Mill (131.1 km)

FIG. A.2 SAMPLING STATIONS OF WATER QUALITY IN CHAO PHRAYA RIVER

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

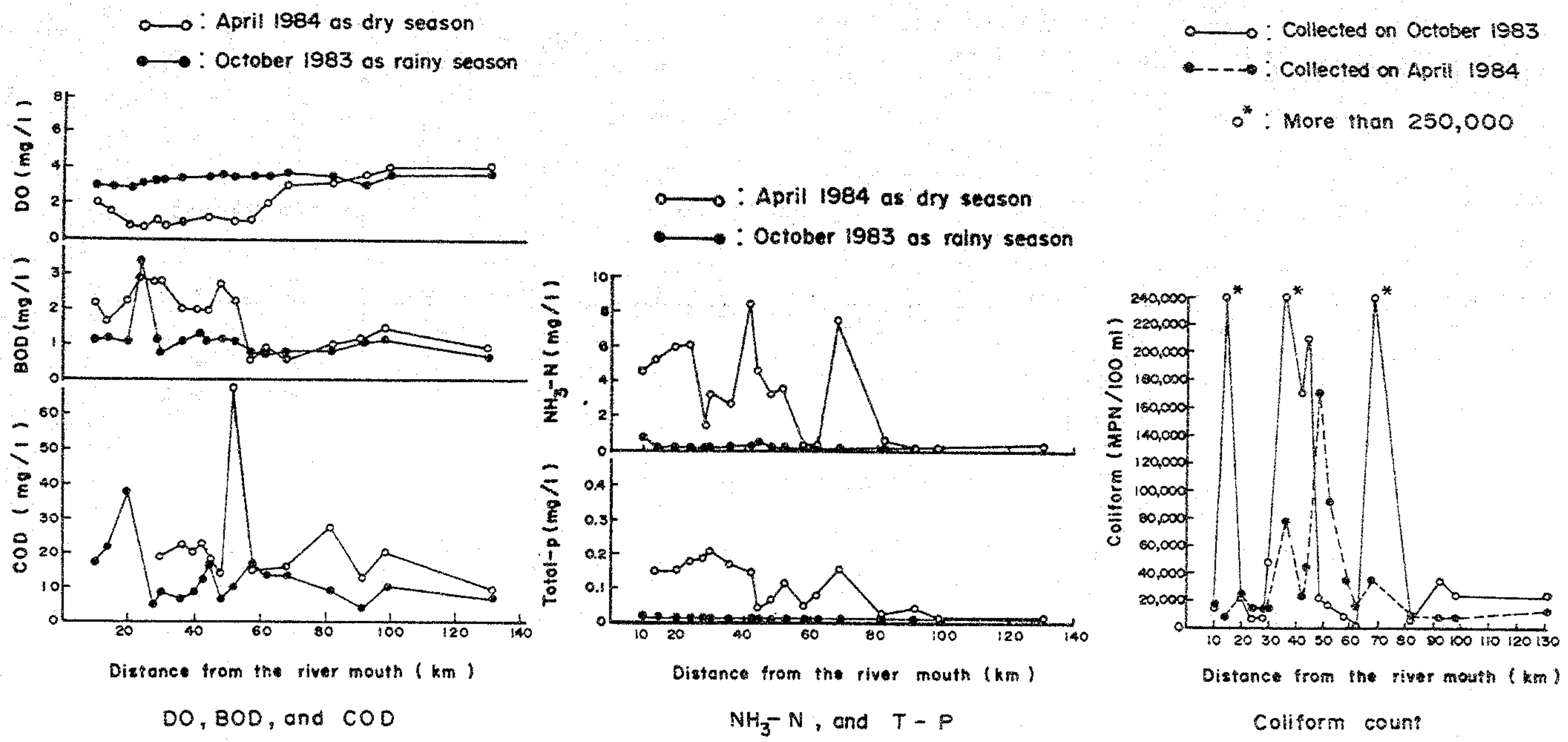


FIG. A.3	DISTANCIAL DISTRIBUTION OF WATER QUALITY IN CHAO PHRAYA RIVER

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

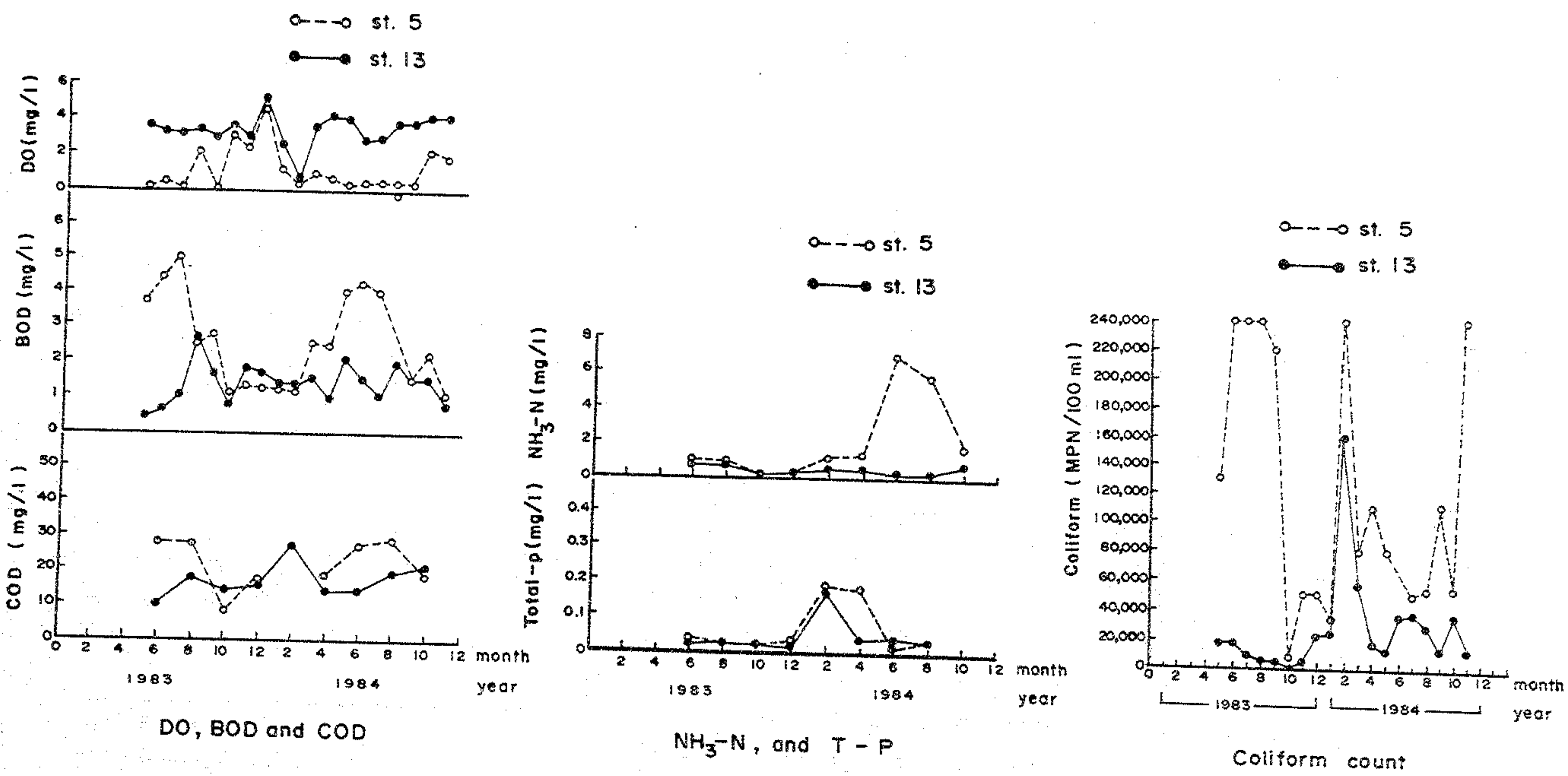
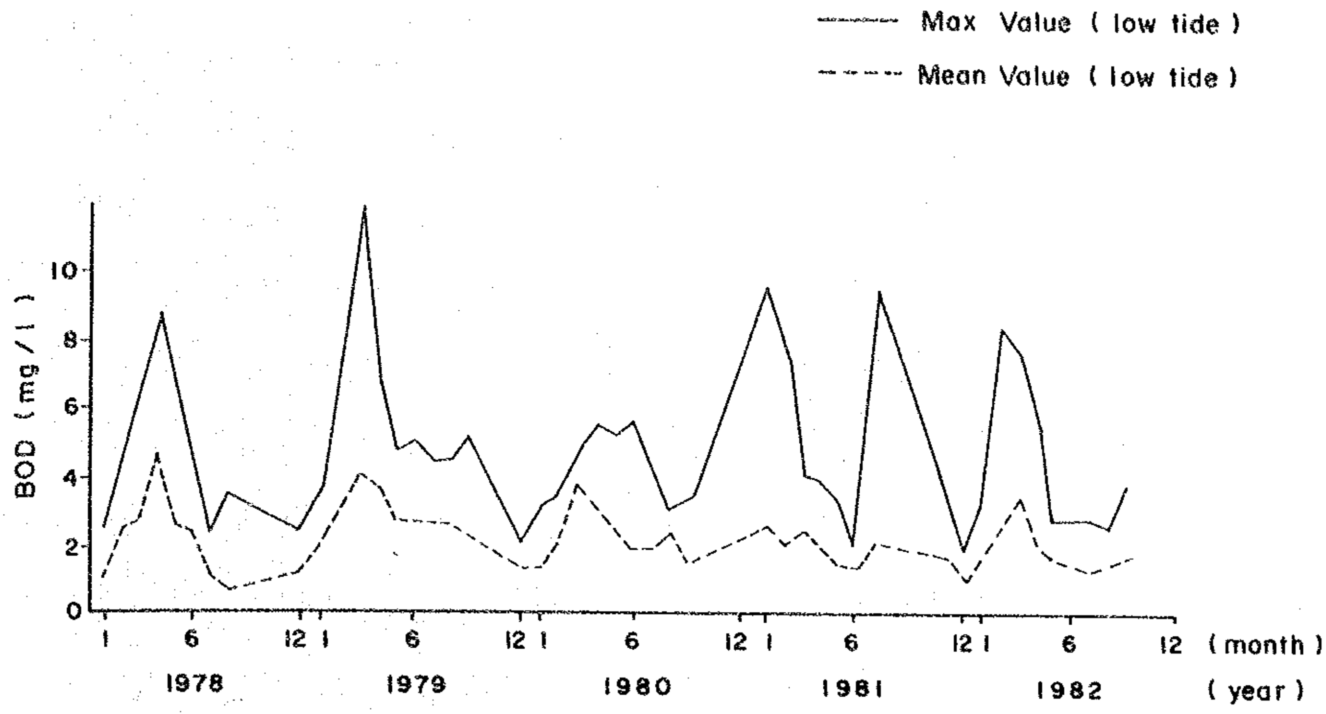


FIG. A . 4 MONTHLY VARIATION OF WATER QUALITY IN CHAO PHRAYA RIVER

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

JICA 2532B.E. 1989A.D.



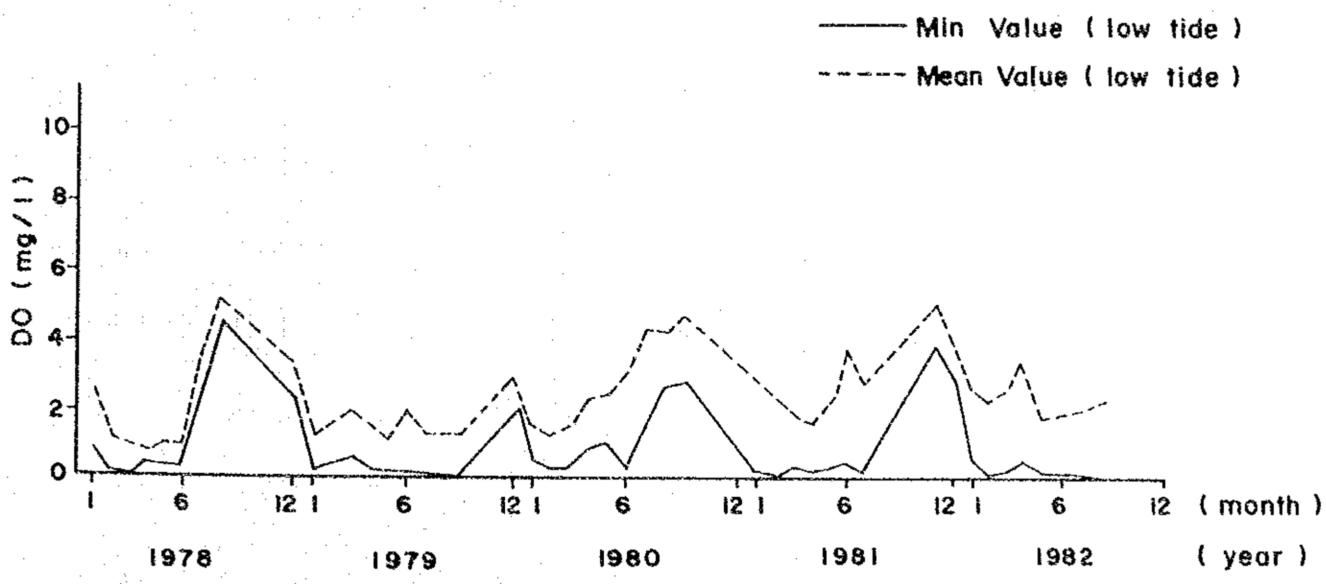
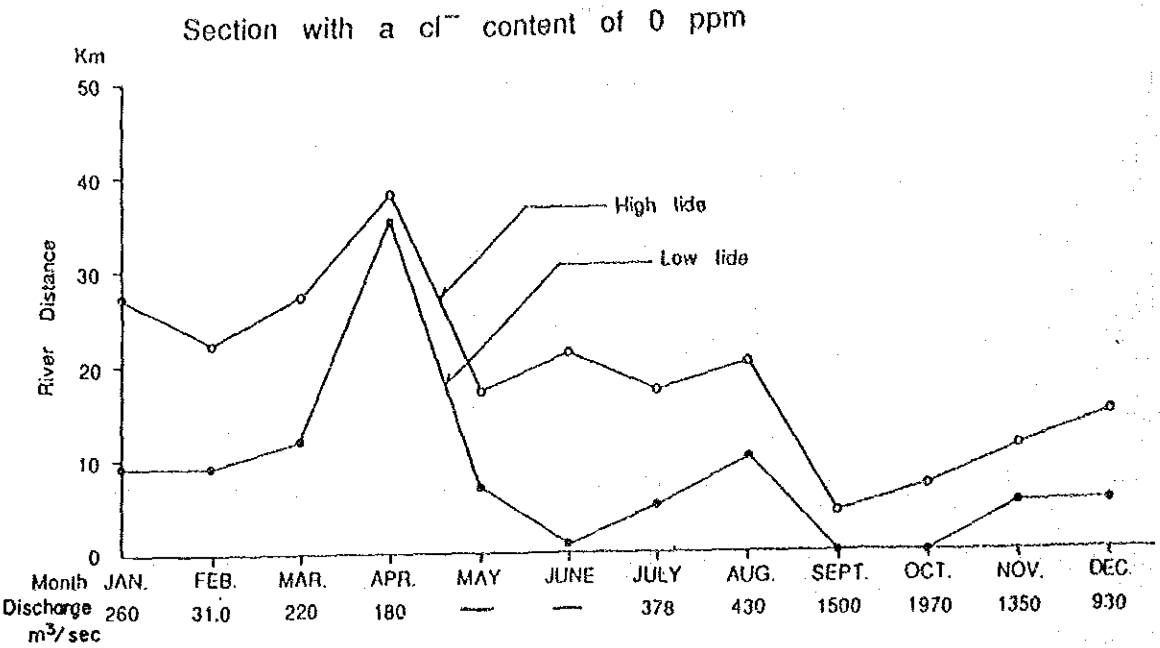


FIG. A.5	YEARLY VARIATION OF WATER QUALITY IN LOWER REACHES OF CHAO PHRAYA RIVER

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK



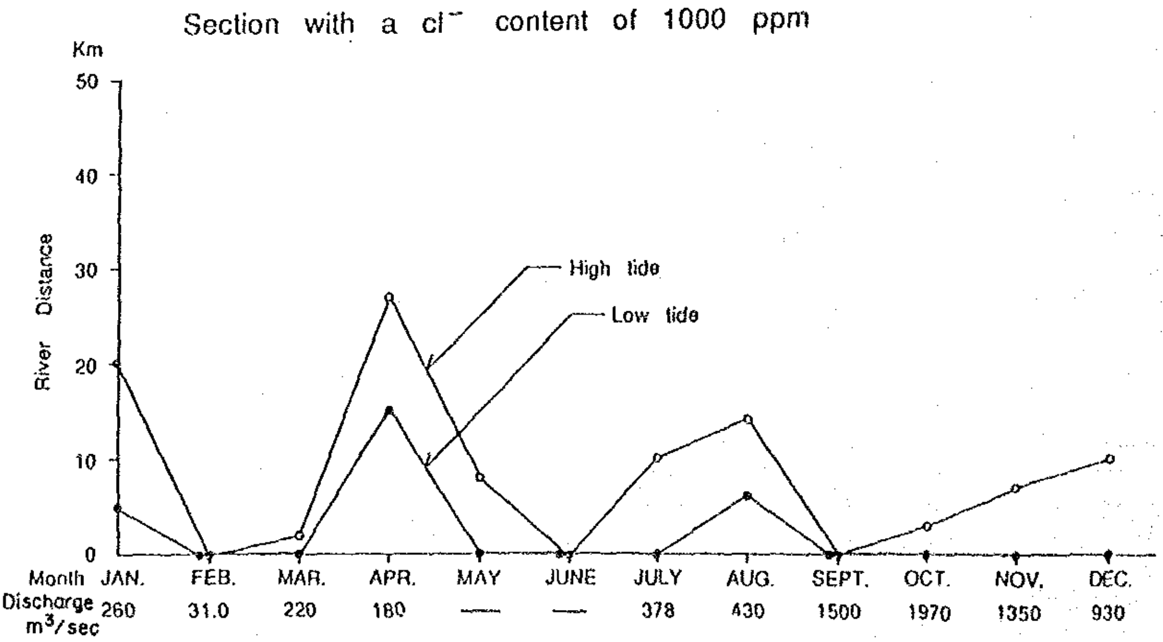


FIG. A . 6 MONTHLY VARIETION OF SALINITY INTRUSION OF CHAO PHRAYA RIVER

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

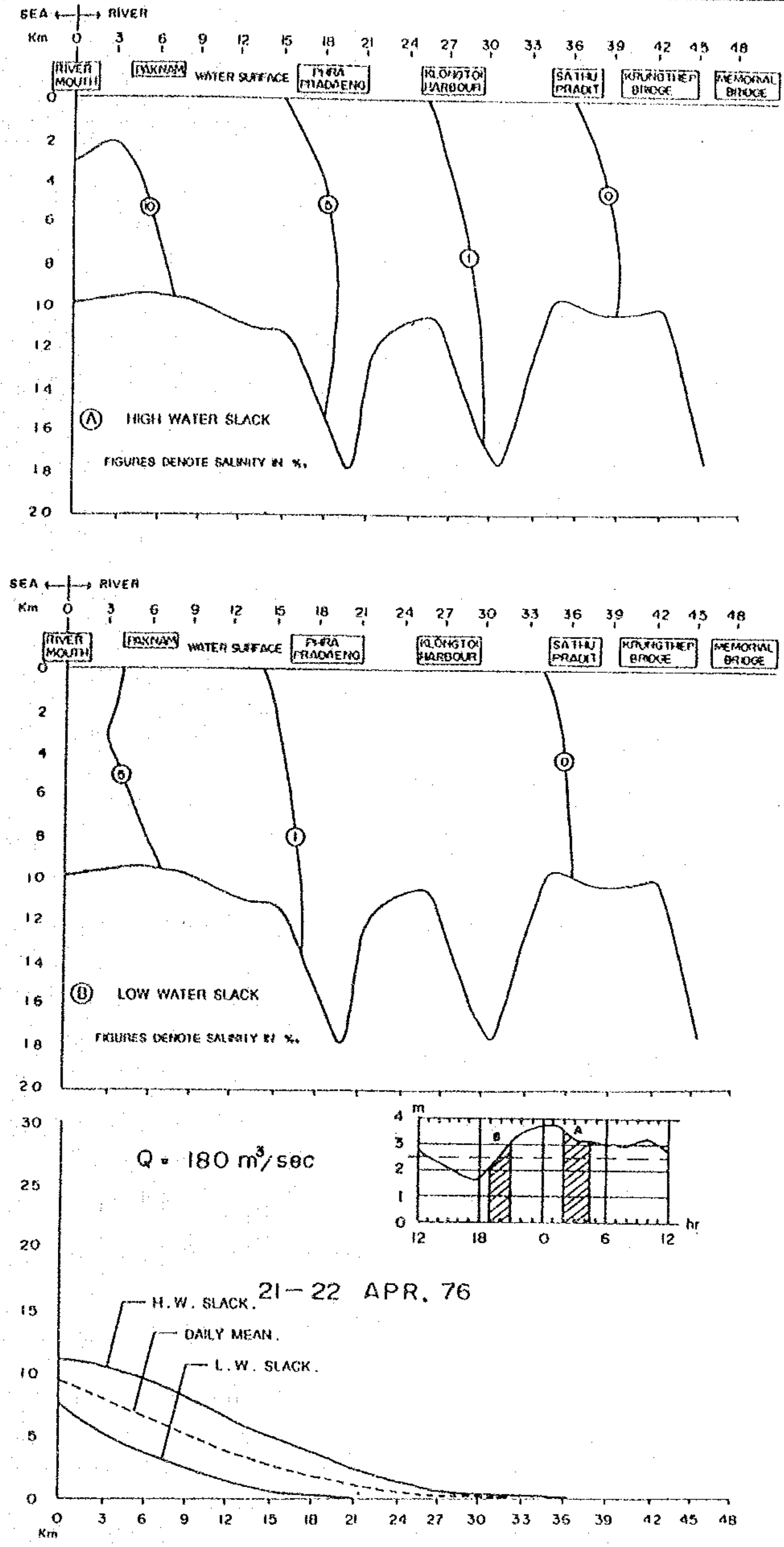


FIG. A . 7 (1) DISTRIBUTION OF SALINE WATER CONTENT IN TYPICAL DRY AND RAINY SEASONS

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

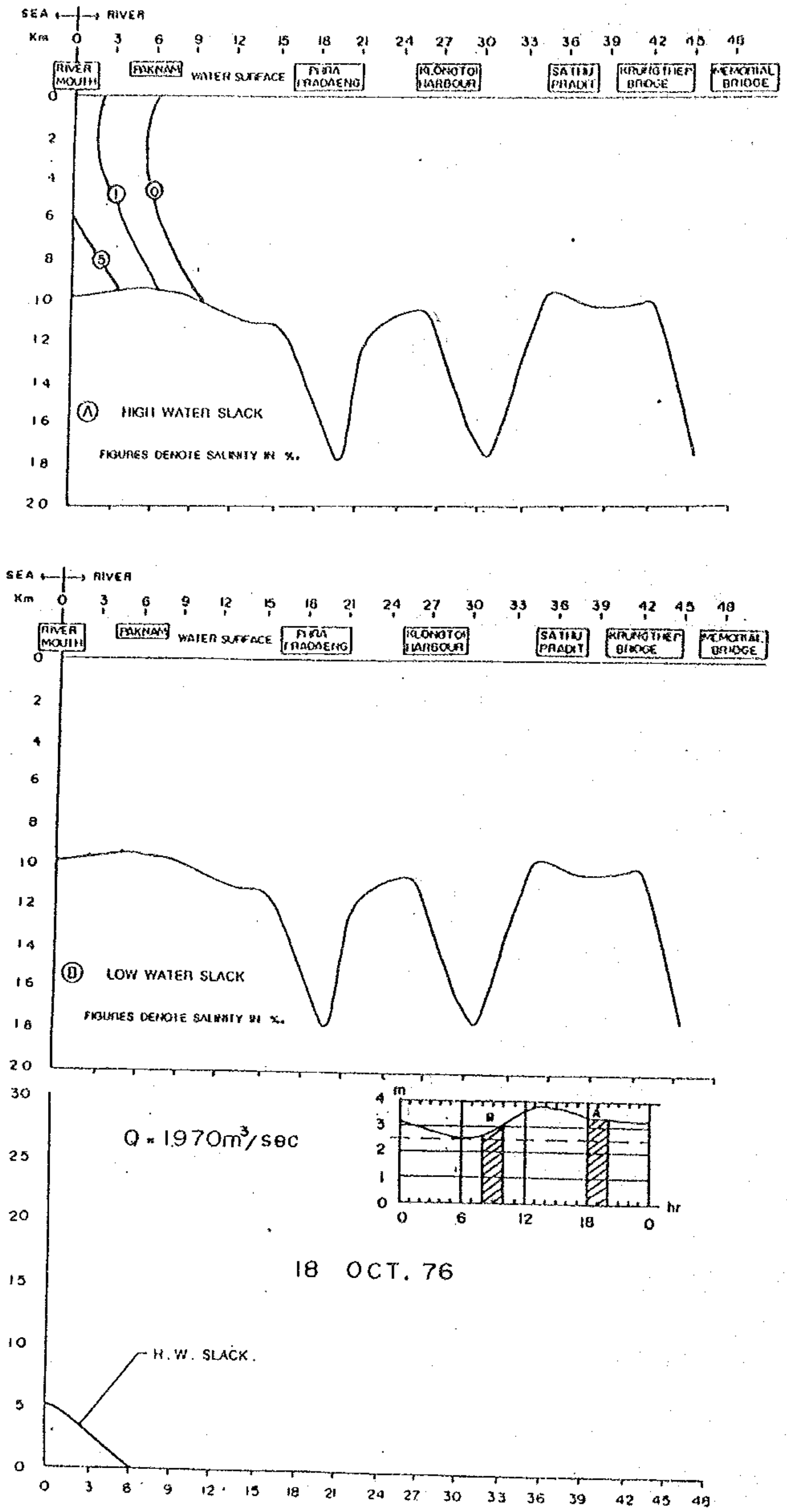
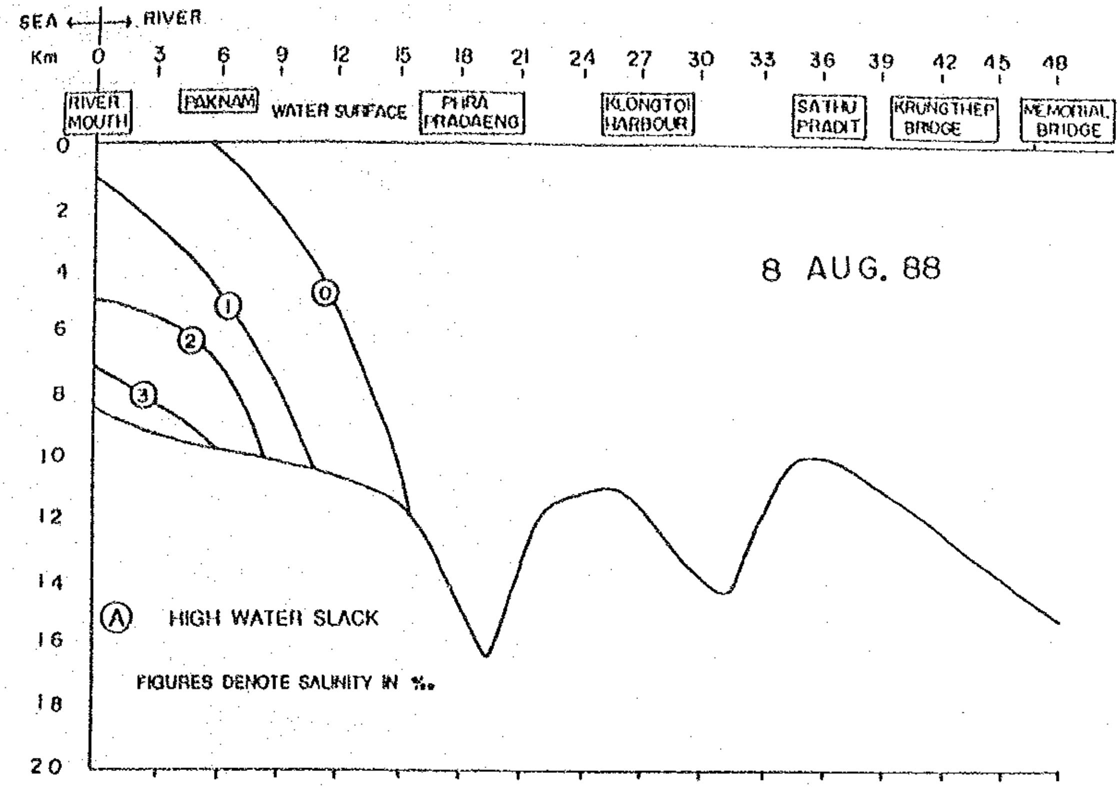


FIG. A.7 (2) DISTRIBUTION OF SALINE WATER CONTENT IN TYPICAL DRY AND RAINY SEASONS

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK



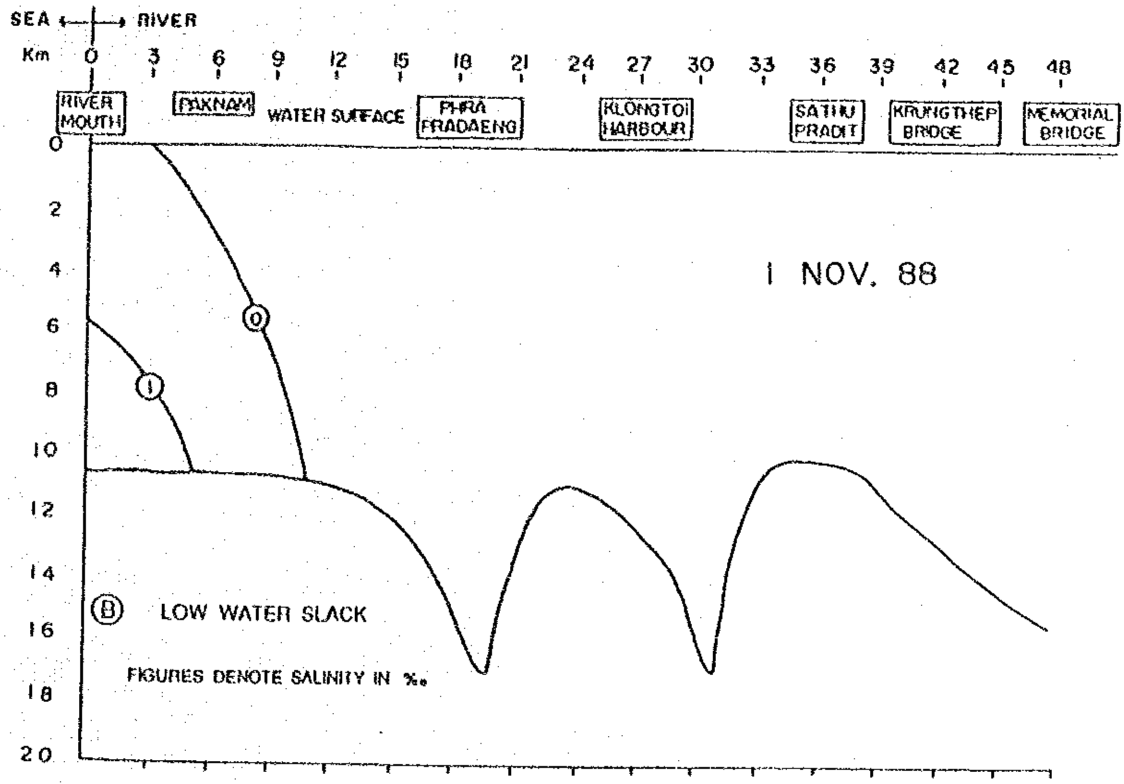


FIG. A.8	SALINITY INTRUSION OF CHAO PHRAYA RIVER AS OBSERVED BY JICA STUDY TEAM

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

APPENDIX B.

KLONG CONDITION

APPENDIX B. KLONG CONDITION

1. Klong Network

The klongs run in all directions through the whole Study Area with a high density of one (1) km/km^2 approximately. Out of all the existing klongs, 37 klongs were selected for the Study. The selected klong networks are shown in Fig. B.1.

The total length of the networks is 219.1 km. The width of the klongs ranges from a few meters to 50 m. Major klongs with a width of more than 20 m are K. Saen Saep, K. Lad Phrao, K. Phadung Krung Kasem and K. Phra Khanong.

The length, width and water surface area of all the selected 37 klongs are shown in Table B.1.

2. Drainage System and Facilities

The Study Area (380 km^2) is surrounded by the Chao Phraya River banks on the west and south sides, and by the polders on the north, east and south sides. The river banks and polders are provided with gates and pumps at the inlets or outlets of the klongs to prevent flood waters coming from outside and to drain inner water. Fourteen (14) pumps with gates and five (5) gates are provided on the Chao Phraya River banks. 16 gates are installed on the polders.

In rainy season, all the above mentioned gates are closed, in principle, and no river water enters into the Study Area. In dry season, the gates are kept open. The Study Area receives surplus irrigation water of the outer areas from the north and east sides, and dilution water of the klongs from the Chao Phraya River.

Inner water of the Study Area generally consists of:

Rainy Season : rainfall and wastewater
Dry Season : rainfall, wastewater, surplus irrigation water and dilution water

The inner water is drained through the klongs into the Chao Phraya River by gate and pump operation.

The Ramkamhaeng area (9 km^2) is surrounded by a secondary polder. Inner water of the area is discharged by gate and pump operation into the K. Saen Saep. Three (3) pumps with gates and three (3) gates are installed for the secondary drainage.

Moreover, the klongs are provided with 24 gates and one (1) pump in the middle of their courses to control water flow of the klong networks.

Locations of the river banks, polders, gates and pumps are shown in Fig. B.2.

The main features of the gates and pumps installed on the Chao Phraya River banks are shown in Table B.2. Their locations are shown in Fig. B.3.

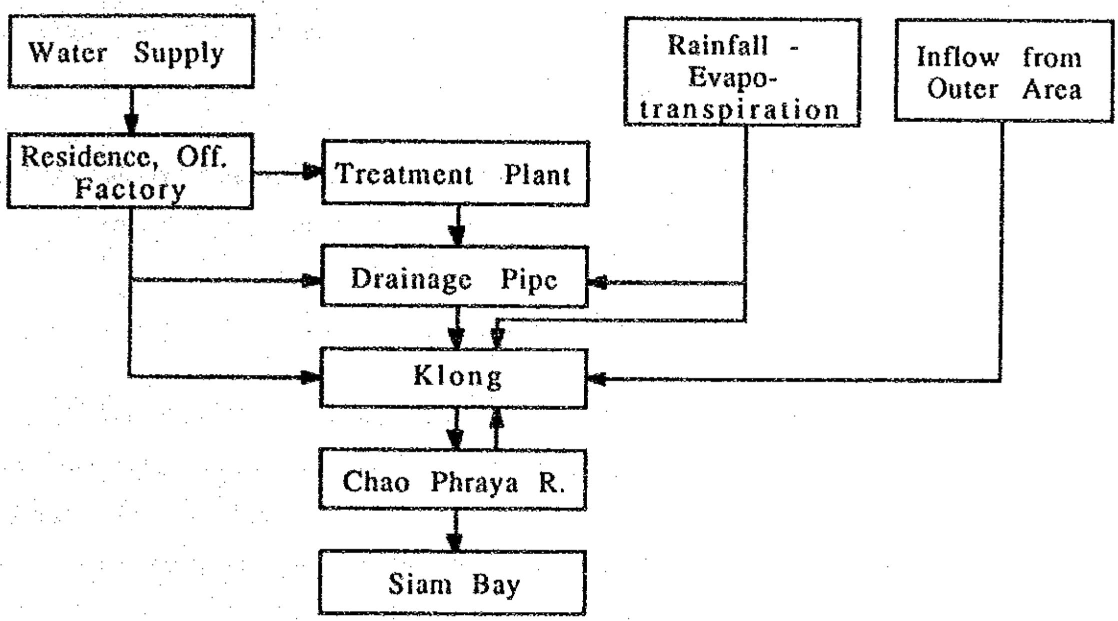
The layouts of the major gates and pump stations in the Study Area are shown in Fig. B.4.

3. Water Balance of the Study Area

The waters governing the water balance of the Study Area are:

- Water supply to the Study Area
- Rainfall in the Study Area
- Evapo-transpiration from the Study Area
- Inflow water from the outer areas of the polders
- Inflow water from the Chao Phraya River
- Outflow water to the Chao Phraya River

The water run-off routes of the Study Area are conceptualized as follows.



Water balance of the Study Area in January 28, February 3-4, February 11, February 18, July 9-10 and July 16-17 of the year 1988 were calculated as follows.

(1) Water supply

Water supply to the Study Area by MWA amounts to 620,000 m^3/d. Private groundwater draw within the Study Area is estimated to be 360,000 m^3/d. The total amount of water supply is 980,000 m^3/d.

(2) Rainfall and Evapo-transpiration

Average monthly rainfall in the dry and rainy seasons is estimated to be 31.5 mm/month and 215 mm/month respectively. However, the actual rainfall recorded during the discharge observation period of the klongs are as follows.

January 28, 1988	:	None
February 3-4, 1988	:	None
February 11, 1988	:	None
February 18, 1988	:	None
July 9-10, 1988	:	None
July 16-17, 1988	:	3.7 mm/day

The location of the rainfall observation station in the Study Area is shown in Table B.3 and Fig. B.5.

Average monthly evapo-transpiration is estimated to be 55 mm/month in dry season and 105 mm/month in rainy season.

(3) Inflow Water from Outer Area

In dry season, surplus irrigation water is introduced into the Study Area from the outer areas of the polders. The amount of water introduced during the periods from January to March in 1985 and 1986 are estimated based on the records of the gate operation. Those are, on an average, 15 m^3/s and 25 m^3/s, respectively.

The average inflow of water during the period from January to March 1988 is estimated to be 10 m^3/s considering that the gates were more closed in 1988 than in 1985 and 1986 to maintain the required irrigation water for the outer areas.

In rainy season, introduction of the water from the outer areas of the polders is prohibited, in principle, to protect the inner area from flooding. However, some water is admitted from the outer areas, when the water level of the outer areas is too high for irrigation and the inner area is not faced with an imminent threat of flooding by severe rainfall.

The water introduced in this manner on July 9-10 and July 16-17, 1988 is estimated to be 35 m^3/s on an average.

(4) Inflow and Outflow from and to the Chao Phraya River

Water is introduced into and as well as discharged from the Chao Phraya River to the klongs, through 18 gates and pumps on the Chao Phraya River banks.

Actual inflow and outflow from and to the Chao Phraya River were observed during the following periods:

- Jan. 28, 1988, 8:00 - 20:00 (12 hours)
- Feb. 3-4, 1988, 9:00 - 9:00 (24 hours)
- Feb 11, 1988, 7:00 - 19:00 (12 hours)
- Feb. 18, 1988, 7:00 - 19:00 (12 hours)
- July 9-10, 1988, 9:00 - 9:00 (24 hours)
- July 16-17, 1988, 9:00 - 9:00 (24 hours)

The results are shown in Table B.4.

(5) Water Balance of the Study Area

The water balance of the Study Area for a 24 hour period on Jan. 28, Feb. 3-4, Feb. 11, Feb. 18, July 9-10, July 16-17 in 1988 is estimated as shown in Table B.5.

On January 28 and February 3-4, normal gate and pump operations of dry season were conducted. In this case, the incoming and outgoing water to the klongs were well balanced. While, on February 11 and February 18, inflow from the Chao Phraya River was curbed and instead, outflow to the Chao Phraya River was increased because of the occurrence of rainfalls of 5 mm and 50 mm respectively, in the Study Area during the preceding days (Feb. 10 and Feb. 17). This has resulted in the imbalance between the incoming and outgoing waters.

On July 16-17, a typical gate and pump operation of rainy season was conducted. Introduction of dilution water from the Chao Phraya River was rather low. While, on July 9-10, a gate and pump operation similar to that in dry season was performed because of no rainfall. A considerable quantity of water was introduced from the Chao Phraya River for flushing the klongs. Incoming and outgoing water to the klongs was imbalanced in both the cases of July 9-10 and July 16-17. This is due to the considerable amount of rainfall that occurred in the Study Area during the preceding days (24.2 mm for July 4-8 and 25.4 mm for July 12-15), thereby increasing the outflow to the Chao Phraya River in order to lower the water level of klong.

In consideration of the above facts, a normal inflow from the Chao Phraya River in dry season is assumed to be the average of the records on January 28 and February 3-4, and in rainy season the discharge recorded on July 16-17 is assumed.

Normal inflows from the outer areas during dry and rainy seasons are assumed to be 10 m^3/s and 35 m^3/s respectively.

Typical monthly water balances both in dry and rainy seasons are estimated as shown in Table B.6 and Fig. B.6.

4. Bank Condition

In the city core area, the banks of the klongs are all protected by concrete retaining wall, except some parts of K. Mahanak, Chong Non Sri and Toey. While, in the eastern suburban areas, the concrete retaining wall is limited to some areas and most of the klongs are still under natural condition.

Length of the existing concrete retaining wall totals 112.5 km, covering 26% of the total klong stretches of 219.1 km (total bank length: 438.2 km). The existing condition of the klong embankments are shown in Table B.7.

Location of the existing concrete retaining walls of the klongs is shown in Fig. B.7.

5. Discharge Capacity

The water level and gradient of the klongs are largely affected by the water stage of the Chao Phraya River. The actual discharge capacity of the klong sections varies depending on their downstream water level. The expected maximum discharge capacity is calculated by the following uniform flow formula on the assumption that the hydraulic gradient is equal to the existing bed slope.

$$Q = 1/n \cdot R^{2/3} \cdot I^{1/2} \cdot A$$

where,
- Q : Discharge (m^3/s)
- n : Manning's roughness coefficient, assuming n=0.03
- R : Hydraulic depth (m)
- I : Hydraulic gradient (bed slope)
- A : Flow section area (m^2)

The existing average bed slopes of the major klongs are shown in Fig. B.8.

The calculated maximum discharge capacities of the major klongs are roughly summarized as follows.

(1)	K. Bang Khen	: mostly 10 - 30 m^3/s
(2)	K. Bang Sue	: mostly 10 - 30 m^3/s
(3)	K. Sam Sen	: 10 - 30 m^3/s for 50% of the course and less than 10 m^3/s for the remaining 50%
(4)	K. Mahanak	: mostly 10 - 30 m^3/s
(5)	K. Phadung Kurung Kasem	: more than 50 m^3/s
(6)	K. Bang Lum Phu	: more than 50 m^3/s for 50% of the course and 30 - 50 m^3/s for the remaining 50%
(7)	K. Ong Ang	: 30 - 50 m^3/s
(8)	K. Lod	: more than 50 m^3/s
(9)	K. Prem Prachakorn	: mostly 10 - 30 m^3/s
(10)	K. Lad Phrao	: 10 - 30 m^3/s
(11)	K. Saen Saep	: 30 - 50 m^3/s for 50% of the course and 10 - 30 m^3/s for the remaining 50%
(12)	K. Tan	: 30 - 50 m^3/s for 50% of the course and 10 - 30 m^3/s for the remaining 50%
(13)	K. Phra Khanong	: more than 30 m^3/s at downstream and mostly 10 - 30 m^3/s at upstream

The calculated maximum discharge capacities of all the klongs are shown in Fig. B.9.

6. Water Flow

6.1 Consecutive Observation of Water Flow

The water flow of the klongs vary widely in a complicated manner both with respect to quantity and flow direction. In dry season, during the high tide of the Chao Phraya River, dilution water is introduced to the klongs from the Chao Phraya River. In this case, flow to the east-ward is dominant. Thereafter, when the tide recedes, the klong water is drained into the Chao Phraya River. At this time, flow to the west-ward is dominant.

While in rainy season, during the high tide of the Chao Phraya River, gates on the Chao Phraya River bank are normally closed and the inner water of klongs is pumped into the Chao Phraya River, and the flow is predominantly west-wards. Besides, when the tide recedes, gates are opened to discharge the water to the Chao Phraya River, and again the flow is predominantly west-wards.

The JICA Study Team made a consecutive 24 hour observation of the klong water flow to establish the existing conditions of the klong water flow variation, both during dry season and rainy season.

In dry season, the consecutive observation was made at 31 selected locations of main klongs, along with water quality observation. The selected locations are shown in Fig. B.10.

In rainy season, the JICA Study Team added five (5) more locations of consecutive observation to supplement the survey in dry season. There were two (2) new locations on K. Lad Phrao and one (1) each on K. Bang Sue, K. Prem Prachakorn and K. Saen Saep. While, four (4) original ones (No. 1, No. 9, No. 19, No. 20) were eliminated because of their limited water flow. These revised locations are shown in Fig. B.11.

The observation was made at every one hour interval during the following periods:

Dry season (1988)
(1) January 28, 8:00 - 20:00
(2) February 3-4, 9:00 - 9:00
(3) February 11, 7:00 - 19:00
(4) February 18, 7:00 - 19:00

Rainy season (1988)
(5) July 9-10, 9:00 - 9:00
(6) July 16-17, 9:00 - 9:00

6.2 Observed Water Flow

The observed discharge variation at each station during the period of 24 hours on February 3-4, July 9-10 and 16-17, 1988 are shown in Fig. B.12. In these figures, the positive flow directions are defined as shown in Fig. B.14. The operational records of the gates and pumps on the Chao Phraya River banks on February 3-4, July 9-10 and July 16-17, 1988 are shown in Table B.8.

Flow quantities of the 24 hours at the respective klong sections are calculated and shown in the same figures of Fig. B.12.

6.2.1 Flow Route of Dilution Water

Among the six (6) time observations of klong water flow, the observed flow patterns of Jan. 28 and Feb. 3-4 are considered to be typical of dry season. On and around Jan. 28 and Feb. 3-4, the Study Area experienced no rainfall. The gates and pumps on the Chao Phraya River bank were operated by the operation mode typical for dry season. While, the observed flow pattern of July 16-17 is considered as typical of rainy season. Introduction of water from the Chao Phraya River was negligibly small. Storm water in the Study Area and surplus irrigation water from the outer areas were discharged by the gates and pumps to the Chao Phraya River (Refer to Tables B.4 and B.8).

The observed maximum discharges of the major klongs along with their flow directions on Jan. 28, Feb. 3-4 and July 16-17 are shown in Fig. B.13 and Fig. B.15 respectively. Those flow directions are considered to be the typical ones of dry and rainy seasons, respectively. The JICA Study Team defined the typical flow direction of dry season (Jan. 28 and Feb. 3-4) as the normal flow direction (positive direction) for this project study. The normal flow direction of the major klongs are shown in Fig. B.14.

However, the flow patterns of Feb. 11, Feb. 18 and July 9-10 are different from the typical ones of dry and rainy seasons to some extent. Because, on the preceding days of Feb. 11 and Feb. 18 (Feb. 10 and Feb. 17), the Study Area experienced some rainfall. The gates on the Chao Phraya River were closed and klong water was discharged by the pumps. While, on July 9-10, some dilution water was introduced from the Chao Phraya River although it was rainy season (Refer to Tables B.4 and B.8). In both these cases the practices were nonconventional.

(1) The major routes of dilution water in dry season under the existing conditions are:

1) Bang Khen → Lad Phrao → Tan → Phra Khanong
2) Phadung Krung Kasem
3) Bang Lum Phu, On Ang, Phadung Krung Kasem → Mahanak → Saen Saep → Tan → Phra Khanong

However, the route (3) did not display a complete function during the consecutive observation period because part of K. Saen Saep was under construction.

Introduction of dilution water into the inner parts of K. Bang Sue and K. Sam Sen is limited due to the bottlenecks existing along their courses (See Fig. B.13).

Dilution water to K. Prem Prachakorn is introduced mainly through K. Bang Sue.

(2) The major routes of dilution water in rainy season under the existing conditions are as follows:

1) Eastern Outer Areas → Lad Phrao → Tan → Phra Khanong
2) Eastern Outer Areas → Saen Saep → Tan → Phra Khanong
3) Eastern Outer Areas → Phra Khanong

During rainy season no dilution water is supposed to be introduced from the Chao Phraya River, in principle. However, some dilution water was introduced into K. Bang Khen during the observation period. This is because the gate of the Old Bang Khen pump station was kept open.

Surplus water in the eastern outer areas is introduced to some extent into the inner areas under normal conditions of rainy season to prevent flooding in the outer areas. (See Fig. B.15)

6.2.2 Characteristics of Water Flow

Characteristics of the klong water flow in typical dry and rainy seasons are summarized as follows.

(1) The klongs in the Chao Phraya River side areas are affected by the tide of the Chao Phraya River in dry season. However, they are not affected in rainy season because the gates along the Chao Phraya River bank are usually closed. The largely affected klongs are K. Bang Sue (St. 7), K. Prem Prachakorn (St. 5) and K. Sam Sen (St. 11).

Reduction of the tidal effects in the inner areas is large as shown below.

Klong	Station	Discharge Variation Range (m^3/s)
Bang Sue	St. 7 (River Side)	40 (+22 ~ -18)
	St. 8 (Inner)	14 (+10 ~ -4)
Prem Prachakorn	St. 5 (River Side)	21 (+11 ~ -10)
	St. 4 (Inner)	12 (+9 ~ -3)
Sam Sen	St. 11 (River Side)	17 (+6 ~ -11)
	St. 12 (Inner)	3 (+2 ~ -1)

Note: positive: normal direction defined in Fig. B.14
negative: opposite to normal direction

(2) The Chao Phraya River side klongs in the Ratanakosin area

In dry season, Upper Phadung Krung Kasem (St. 14), Bang Lum Phu (St. 17), Lod (St. 22), Ong Ang (St. 18) are maintained only to introduce the dilution water from the Chao Phraya River by a proper gate operation. On the other hand, the lower Phadung Krung Kasem is kept only to drain the introduced dilution water and wastewater by gate and pump operation. The rate of introduction of dilution water varies hourly, while the pump discharge remains constant and limited in capacity. As a result:

- When the introduced water is large, it is drained by the Krung Kasem P.S., K. Mahanak and K. Saen Saep.
- When the water introduction is small, the Krung Kasem P.S. drains not only the introduced water but also the water of K. Mahanak and K. Saen Saep.
- The water of K. Mahanak flows both in the normal and opposite directions.

During rainy season, the gates along the Chao Phraya River bank are closed and inner water is drained by pumping from the Krung Kasem P.S. Hence the water of the klongs flows towards the Krung Kasem P.S.

(3) Flow of K. Lad Phrao is nearly constant at 6 m^3/s, both in dry and rainy seasons. Its flow direction is always from north to south, the normal one throughout the year.

(4) Drainage discharge of the Phra Khanong P.S. varies to a great extent. The maximum discharge in dry season is estimated to be approximately 30 m^3/s. It is drained by opening the gates at the time of low tide. At the time of high tide, the pumps are operated to discharge the water at 9 m^3/s to 24 m^3/s. While in the rainy season, a large number of pumps are operated to discharge the water at 60 to 80 m^3/s.

(5) Dilution water from the Chao Phraya River is introduced during high tide. However, part of the introduced water is discharged again into the Chao Phraya River during low tide.

The actual amount of dilution water introduced from the Chao Phraya River into the inner parts of the Study Area during the 24 hour period on February 3-4 and July 16-17, 1988 are estimated to be as follows.

Klong	Station	Introduced Volume (10^3 m^3)/1 Dry Season (Feb. 3-4)	Rainy Season (July 16-17)
Bang Khen	(St. 3)	126	207
Bang Sue	(St. 7)	263	0
Sam Sen	(St. 11)	0	0
Phadung Krung Kasem	(St. 14)	80	0
Bang Lum Phu	(St. 17)	154	0
Ong Ang	(St. 18)	200	0
Lod	(St. 22)	97	23
Total		920	230

/1: Difference between the inflow and outflow volumes.

Based on the above survey results, it is concluded that

- Introduction of dilution water from the Chao Phraya River during typical dry season is approximately one (1) million m^3 per day. (about 12 m^3/s)
- Introduction of dilution water from the Chao Phraya River during typical rainy season is negligible, considering that the gates of K. Bang Khen was kept open only exceptionally on July 16-17, 1988.

7. Water Quality

7.1 Water Quality under Steady State

7.1.1 Water Quality Monitoring

Water Quality of the klongs in the Study Area has been monitored by DDS since 1981 at 37 locations. Location of the monitoring stations are shown in Fig. B.16. The observed water quality parameters are as follows.

PH, DO, BOD, COD, SS, Cl^-, NH_4-N,
NO_3N, T-P, H_2S, Coliform Count

7.1.2 Yearly and Seasonal Change

Yearly changes of the water quality (BOD and SS) during the period from 1981 to 1986 are shown for the 10 stations where sufficient data are available (See Fig. B.17(1) - Fig. B.17(3)). No significant yearly change is recognized during the period.

Clear seasonal changes of the water quality have been observed in some part of the Study Area in recent years. Average water quality (BOD) in dry (Nov.-Apr.) and rainy (May-Oct.) seasons during the period between 1984 and 1986 is shown in Fig. B.18.

(1) In the Chao Phraya River side and the Ratanakosin areas, the klong water shows a lower BOD concentration in dry season than in rainy season. This may be due to the effects of the gate and pump operation that was improved after the 1983 floods. Flushing / dilution water is introduced into the klongs from the Chao Phraya River in dry season. While in rainy season, the gates are closed, receiving no flushing water and the klong water level is drawn down to meet coming storms.

(2) The water in K. Tan and the lower reaches of K. Phra Khanong is less contaminated in rainy season than in dry season. This may be due to the fact that the klongs collect the rainfall water of a wide area in rainy season thereby diluting the pollution loads.

(3) However, the klongs in the other inner parts of the Study Area show no clear difference between dry and rainy seasons. It seems that the inner areas are little benefited either by the dilution water from the Chao Phraya River or by the dilution effects of rainfall.

7.1.3 Regional Distribution

Average water quality during the period from 1981 to 1986 at each sampling station is shown in Fig. B.19(1) - Fig. B.19(5).

(a) DO

A comparatively high DO value (1-2 mg/l) is observed in the Chao Phraya River side and Eastern Suburban areas. While in the inner part areas, DO is nearly zero.

(b) BOD

Moderate BOD contents less than 20 mg/l is observed in the Chao Phraya River side and Eastern Suburban areas. High BOD values with 20 - 50 mg/l are observed in the inner areas. The reasons are:

- The klong water in the Chao Phraya River side areas is improved by dilution / flushing water from the Chao Phraya River in dry season.
- The Eastern Suburban area is sparsely populated.
- The klongs in the core and inner areas receive a high pollution load from the drainage areas.

(c) COD

The regional distribution pattern of COD is the same as BOD.

(d) SS

The SS value, which is highest in the Chao Phraya River side areas, decreases toward the inner areas. This is because the Chao Phraya River water contains a high SS. SS value in rainy season is higher than that of dry season.

(e) NH_4-N

It shows the same regional distribution pattern as BOD.

7.1.4 Color and Odor of Klong Water

The effects of dilution / flushing water from the Chao Phraya River and the eastern suburban areas can be easily judged from the color and odor of the klong water.

Color and odor tests were conducted during the middle of March and the beginning of August, 1988 for the whole Study Area. The tests were additionally performed during the early period of July, 1988 for the City Core Area. The test results are shown in Fig. B.20, Fig. B.21 and Fig. B.22.

(1) Dry Season

The water in the klongs along the Chao Phraya River such as K. Bang Khen, K. Bang Sue, K. Sam Sen, K. Prem Prachakorn, K. Phadung Krung Kasem, K. Bang Lum Phu and K. Maharak had a greenish appearance but no odor. This good condition is attributable to the flushing effects of dilution water from the Chao Phraya River. However, the water in some klongs of the Ratanakosin area such as K. Lod and K. Ong Ang showed a darkish gray color and emitted foul odor of H_2S. This is due to the fact that the gates of the klongs are kept open only for a short time.

In the inner areas where dilution water of the Chao Phraya River does not reach, the klong water exhibited a blackish hue and emitted foul odor of H_2S.

The klongs of the eastern suburban areas which receive no heavy pollution loads are greenish in color with no odor.

(For the above discussions, refer to Fig. B.20.)

(2) Rainy Season

Most klongs along the Chao Phraya River appeared dark gray color and emitted a strong odor of H_2S. This is because the gates of such klongs were closed to keep the inner water level low for flood control purpose. However, the water in the K. Bang Khen and part of K. Prem Prachakorn were light yellow in color with almost no smell. This is due to the fact that the gate of K. Bang Khen was kept open though it was rainy season. The water of K. Phra Khanong was also light yellow, with almost no smell. This is because of the dilution effects of the water from the eastern outer areas.

In the inner areas where no flushing / dilution effects were received, the klong water was in bad conditions.

In the eastern suburban areas, the klong water was yellow in color with almost no smell. This is because of the dilution effects of water from the eastern outer areas.

(For the above discussions, refer to Fig. B.21.)

The color and odor of the water in the klongs in the City Core during the early period of July 1988 were as shown in Fig. B.22. The water levels in the klongs during that period were kept high and the Chao Phraya River water flowed into the klongs through the opened gates. Accordingly, the water in most of the klongs appeared light yellow or yellowish gray in color and, compared to the water during the period when the gates are closed, the H_2S odor was weaker.

7.1.5 Mud

Investigation of mud is an important factor in evaluating the environment of a water basin. In general, the existence of little or no organic soft soil indicates that the water quality in the basin is high. If an area has a thick layer of organic soil which tends to accumulate pollutants, there is a high possibility that the water is of low quality.

(1) Mud Layer

Mud layer investigations were conducted in the main klongs in the Study Area during mid-March and mid-August, 1988. The investigation results are shown in Fig. B.23. Mud layers thicker than 1.0 m were found in the K. Bang Khen, K. Bang Sue, K. Sam Sen, K. Mahanak, K. Saen Saep, and K. Huai Khway. Other klongs had mud layers varying from 0.5 to 1.0 m thick. As shown in the aforementioned Fig. B.19, the water in these klongs have high BOD values.

(2) Bed Material

Bed material investigations along with water quality tests were conducted on March 3 and July 28, 1988. The nine locations shown in Fig. B.24 were investigated. At Station 7 it was impossible to obtain a sample of the bed material because of the extremely thin mud layer and the existence of gravel. Bed material samples were taken at eight locations. The I-L, COD, BOD and T-P values of the samples were analyzed and the results are shown in Fig. B.25 and Fig. B.26.

Except for the samples taken at Station 11 during the rainy season, the I-L values of all the other samples were less than 5%.

The COD values were high and in the range of from 73 to 451 mg/g during the dry season and from 120 to 731 mg/g during the rainy season. The T-P values were also high and were in the range of from 0.6 to 4.3 mg/g (average 1.3 mg/g) during the dry season and from 0.1 to 1.8 mg/g (average 0.5 mg/g) during the rainy season.

Bed material samples obtained during the dry season were black organic soil having a soft texture and emitted a foul odor. During the rainy season at Station 11 a gray clay layer was observed on the bed surface. At Station 6, the klong was dredged and the bed material consisted mainly of clay having a low pollution level in comparison with the samples taken during the dry season.

7.2 Water Quality under Unsteady State

7.2.1 Consecutive Water Quality Observation

Klong water quality in the Study Area varies hourly corresponding to the fluctuation of its water flow.

The JICA Study Team made consecutive water quality observations to examine the state of water quality variations of the klongs.

The water quality observations, together with the discharge and flow direction, were made at thirty-two (32) locations during the dry season and at thirty-five (35) locations during the rainy season at selected main klongs. These locations are shown in Figs. B.10 and B.11. The observations were made every four (4) hours during the following periods:

Dry season	:	1. Jan. 28, 1988:	8:00 - 20:00
		2. Feb. 3 - 4, 1988:	9:00 - 9:00
		3. Feb. 11, 1988:	7:00 - 19:00
		4. Feb. 18, 1988:	7:00 - 19:00
Rainy season	:	5. Jul. 9 - 10, 1988:	10:00 - 6:00
		6. Jul. 16 - 17, 1988:	10:00 - 6:00

7.2.2 Observed Water Quality

The observed water qualities (BOD, SS, and Cl^-) are shown together with the observed discharges and flow directions in Fig. B.27.

(1) Average Water Quality

The averages of the observed water qualities (BOD, SS, and Cl^-) are shown in Figs. B.28 (dry season) and B.29 (rainy season).

The average values of BOD were in the range of 10 to 35 mg/l during the dry season and 6 to 32 mg/l during the rainy season. These figures closely correspond to the aforementioned BOD distribution of the 1984 thru 1986 dry and rainy seasons (See Fig. B.18).

The average values of SS at all stations, but the station 11, during the rainy season were less than 50 mg/l. The station 11 was affected by the sludge from the Sam Sen Water Treatment Plant. These values were almost the same or slightly less than those of the Chao Phraya River.

The average values of Cl^- were in the range of 30 to 100 mg/l throughout the Study Area except for the eastern and southern fringe areas. Klong water is not affected by saline water.

(2) Hourly Water Quality Variations

The hourly water quality variations observed during the periods of February 3 - 4, and July 16 - 17, 1988 are shown respectively in Figs. B.30 and B.31. The figures also show the hourly variations of the discharge and flow directions.

From the figures, the following general tendency (except for a few points) can be noted:

1) During dry seasons, the gates of the K. Bang Sue and the K. Sam Sen to the Chao Phraya River (at Stations 7 and 11) are opened and the water of the K. Bang Sue and the K. Sam Sen alternate with the Chao Phraya River water. Therefore, the BOD values at the two stations decrease. On the other hand, during rainy seasons, the gates are closed and the inner water is pumped out to the Chao Phraya River and the BOD values increase but deviate widely.

2) At the City Core locations, where klong discharges are small but carry heavy pollution loads, the BOD values during the dry and rainy seasons vary widely.

3) During rainy seasons the discharges of the K. Saen Saep, K. Tan, and K. Phra Khanong increase due to rain water and the inflow from the eastern suburb. Thus, the BOD values are low and uniform.

4) At the inland locations, such as Stations 10, 13, 26, and 28, the relationship between water qualities and discharges are weak.

5) At intermediate points, such as Stations 8, 12, 24, and 25, there are time lags between the flow changes and the water quality changes. When the flows are in the normal (positive) directions, the BOD values decrease. When the flows are in the negative directions, the BOD values increase.

7.2.3 Characteristics of Klong Water Quality

From the above-mentioned consecutive observation results, the characteristics of the klong water in the Study Area are summarized as follows:

(1) Fig. B.32 (A):

Fig. B.32 (A) shows the daily average BOD values and the daily flow volume (the total of the discharges from both directions) at the respective stations.

- Lower BOD values were observed in the klongs that had large discharges. The klongs having this tendency were the Bang Sue (at Station 7), Sam Sen (at Station 11), Phadung Krung Kasem (at Station 15), Tan (at Station 28), and Phra Khanong (at Station 30) during the dry season, and the Tan (at Station 28), Phra Khanong (at Station 29 and 30), Lad Phrao (at Station 103), and Saen Saep (at Station 104) during the rainy season.

- High BOD values were observed in the klongs having small discharges. The klongs having this tendency were the Huai Khwand (at Station 9), Wat Teptida (at Station 19), Sam Sen (at Station 12), Wat Rachabopith (at Station 20), and Lod (at Stations 21 and 22) during the dry season, and the Lod (at Stations 21 and 22), Mahanok (at Stations 23 and 24), Saen Saep (at Station 25), Bang Kapsi (at Station 26), and Sam Sen (at Station 12) during the rainy season.

(2) Fig. B.32 (B):

Klong water quality fluctuates to a large extent during a 24 hour period. Fig. B.32 (B) shows the daily total discharges and the BOD fluctuation ranges during a 24 hour period at the respective stations. The ranges of maximum and minimum variations are 50 mg/l and 10 mg/l respectively.

- Large BOD fluctuations take place in klongs having small discharges. The klongs having this tendency are the Huai Khwang (at Station 9), Wat Teptida (at Station 19), Bang Lum Phu (at Station 17), Wat Rachabopith (at Station 20), and Lod (at Stations 21 and 22) during the dry seasons, and the Sam Sen (at Station 11), Kasem (at Station 14), Bang Lum Phu (at Station 17), Ong Ang (at Station 18), Lod (at Station 21), and Bang Kapi (at Station 26) during the rainy season.

- Stable water qualities were observed in klongs having large discharges. The klongs having this tendency are the Bang Sue (at Station 7), Sam Sen (at Station 11), Phadung Krung Kasem (at Station 15), Tan (at Station 28), and Phra Khanong (at Station 30) during the dry season, and the Bang Sue (at Station 7), Phadung Krung Kasem (at Station 15), Tan (at Station 28), Phra Khanong (at Stations 29 and 30), and Saen Saep (at Station 104) during the rainy season.

(3) Fig. B.32 (C):

Fig. B.32 (C) shows the BOD fluctuation ranges during a 24 hour period and the daily average BOD values at the respective stations.

- Large fluctuations were observed in the highly polluted klongs.

- Water quality in the less contaminated klongs is stable.

(4) Distancial Variation

Klong water quality deteriorates in proportion to the distance away from the Chao Phraya River. After reaching the Lad Phrao, Tan, and Phra Khanong, the water quality recovers to some extent due to the dilution effects of the water coming from the eastern suburban areas.

1) Dry Season:

The water quality variation along the existing routes of the klong flow observed during the period of February 3 - 4 is shown below and in Fig. B.33.

① Bang Khen → Lad Phrao → Tan → Phra Khanong Route:

	St. 3 →	St. 2 →	St. 10 →	St. 28 →	St. 30
Ave. BOD:	11	12	14	15	16
Max. BOD:	21	30	31	26	21

② Bang Sue → Prem Prachakorn Route:

	St. 7 →	St. 5 →	St. 4
Ave. BOD:	9	7	14
Max. BOD:	17	17	33

③ Bang Sue → Lad Phrao → Tan → Phra Khanong Route:

	St. 7 →	St. 8 →	St. 10 →	St. 28 →	St. 30
Ave. BOD:	9	17	14	15	16
Max. BOD:	17	48	31	26	21

④ Sam Sen → Tan → Phra Khanong Route:

	St. 11 →	St. 12 →	St. 13 →	St. 28 →	St. 30
Ave. BOD:	12	24	27	15	16
Max. BOD:	15	34	48	26	21

⑤ Phadung Krung Kasem → Mahanak → Saen Saep → Tan → Phra Khanong Route:

	St. 14 →	St. 24 →	St. 25 →	St. 28 →	St. 30
Ave. BOD:	12	15	26	15	16
Max. BOD:	28	24	50	26	21

2) Rainy Season:

The observed BOD values along each route during the periods of July 16 - 17, 1988 are shown in Fig. B.34.

During the period of July 16 - 17, the rainfall was heavy and the gates along the Chao Phraya River were closed for the purpose of pumping the inner water. Therefore, the BOD values were generally low. The BOD values increased from the inland areas towards the Chao Phraya River.

The BOD values in the K. Saen Saep and K. Phra Khanong were low (about 10 mg/l) because of the water inflow from the eastern suburban areas.

The water quality changes during the July 16 - 17, 1988 period were as follows:

① K. Bang Khan → Prem → Bang Sue:

	St. 2 →	St. 4 →	St. 5 →	St. 7
Ave. BOD:	6	7	17	15
Max. BOD:	12	13	30	19

② K. Lad Phrao → Bang Sue:

	St. 102 →	St. 101 →	St. 8 →	St. 7
Ave. BOD:	16	8	17	15
Max. BOD:	28	12	23	19

③ K. Lad Phrao → Saen Saep → Tan → Phra Khanong:

	St. 102 →	St. 10 →	St. 103 →	St. 28 →	St. 30
Ave. BOD:	16	8	7	7	8
Max. BOD:	28	11	11	14	20

④ K. Sam Sen → K. Tan → K. Phra Khanong:

	St. 13 →	St. 28 →	St. 30
Ave. BOD:	9	7	8
Max. BOD:	17	14	29

8. Public Opinion Survey on Purification of Klong Water

The JICA Study Team conducted a sampling house visit investigation to identify the existing status of klongs as assessed by the citizens of Bangkok and positive impacts of the purification of klong water on their every day lives as estimated by them. Also, the team conducted a sampling interview investigation to know positive impacts of klong water purification on tourism as estimated by foreign visitors.

In the first investigation, investigators visited households and asked questions in accordance with a fixed format of questionnaire. The number of households visited in a district was proportionate to the size of its population and investigators' main target was households living near klongs. The total number of samples was 463.

In the second investigation, investigators approached foreign visitors at various places and asked questions in accordance with a fixed format of questionnaire. The total number of samples was 276.

Questionnaire forms used for the two investigations are attached in Table B.9 and the results are summarized in Tables B.10 and B.11.

The questions on positive impacts accruing from the klong water purification project were made based on the assumption that the project will improve the level of klong water quality to that of the Chao Phraya River.

8.1 Results of Household Investigations

8.1.1 Profile of Sampled Households

The sampled households in the district of Phra Khanong are 75, sharing 16.2%. The number of samples for the districts of Dusit, Phya Thai and Bang Khen was 67, 52 and 47, sharing 14.5%, 11.2% and 10.2%, respectively. The number of samples for these four (4) districts sums up to 241 or 52.1%.

The average age of interviewees was 38. Occupation wise, private owners such as owners of retail shops, hotels, transport companies and factories had the major share of 52.7%, followed by private employees with 36.3%.

The households whose monthly income falls under the Baht 2,001-3,000 group shared 21.2%. Those whose monthly income is of Baht 5,001-6,000 occupied 15.8%. Those under the Baht 3,001-4,000 group and Baht 7,001-10,000 group accounted for 11.9% and 10.6%, respectively. The average monthly income for the whole households visited is Baht 5,574.

8.1.2 Importance of Klong Water Purification

90.3% of interviewees answered affirmative to the question asking whether klong water purification is important or not. 7.8% answered negative and 1.9% did not answer.

Concerning the comparative importance of five major projects, each of which has a great bearing upon the lives of Bangkok citizens, namely mitigation of floods, new construction / expansion of water supply system, new construction / expansion of sewerage system and new construction / improvement of roads as well as purification of klong water, 25.0% of interviewees are convinced that purification of klong water is the most important. 20.7% selected new construction / expansion of sewerage system as the most important project and 20.2% favoured mitigation of floods.

Though purification of klong water is recommended by the largest proportion of interviewees , each of other four projects also has a solid backing from them.

One interesting finding is that the comparative importance of the five projects changes by district and by klong. People living in the districts of Phra Nakhon, Dusit, Pathumwan and Yan Nawa consider klong water purification is the most important. But, for those living in the districts of Pom Prab Sattru Pai and Huai Khwang construction of sewerage is the highest priority, and for the people of the districts of Phra Khanong and Bang Kapi the highest priority is flood mitigation. (Refer to Fig. B.35.)

Klong wise, people living near Klong Bang Lum Phu, Bang Khen, Lad Phrao, Lod, Saen Saep, Mahanak, Phadung Krung Kasem, Chong Non Sri and Phra Khanong opt for purification of klong water. However, those near Klong Ong Ang and Toey opt for construction of sewerage, those near Klong Tan and Prem Prachakorn for construction of roads, those near Klong Huai Kwang for flood mitigation and those near Klong Bang Sue for construction of water supply system. (Refer to Fig. B.36)

Another important finding is that there is a close correlation between the combined percentage of those who use a particular klong for sewerage and of those who use it for a dumping ground and the combined percentage of those who place the top priority on purification of klong water and of those who place the top priority on new construction / expansion of sewerage system: the correlation coefficient between them is 0.7742, and T-value is as much as 5.0435. (Refer to Table B.12)

Figs. B.37 and B.38 are based on Table B.9, Fig. B.39 and Data Book. As Fig. B.38 shows, people living along Klong Lad Phrao, Ong Ang, Bang Lum Phu, Saen Saep (Bang Kapi district) and Bang Khen have utmost desire for both purification of klong water and construction of sewerage. Behind it lies the existing uses of these klongs: they are intensively used as sewerages and dumping grounds as shown in Fig. B.37.

8.1.3 Uses and Conditions of Klongs

Today the most important use of klongs is sewerage: 52.9% of households visited replied that they use klongs for sewerage. The second most important use is living: 26.8% use klong water for washing and bathing. The third and fourth places are occupied by inland water navigation (18.4%) and shopping from floating market (14.5%), respectively. Other uses are garbage dumping (9.9%), recreation (swimming and fishing) (9.9%), and irrigation and agriculture (8.2%). 25.5% replied they do not use klongs for any purpose.

Regarding conditions of klongs, as much as 83.4% of interviewees replied klongs have obnoxious odour and filthy & dark-coloured water. Also, 52,3% replied that klongs are breeding ground of mosquitoes and germs. Only 6.5% replied that klongs are natural.

Note: The above results are based on the assessments of a particular klong by those living near that particular klong. Also, multiple answer system was adopted.

Detailed assessments on uses and conditions for each of major klongs are shown in Fig. B.38 and Data Book. (For obtaining aggregate points a certain percentage for a negative use or condition is considered negative points, while a percentage for a positive use or condition is treated as positive points.) In terms of aggregate points of uses, Klong Saen Saep (in the district of Bang Kapi), Bang Khen, Phra Khanong, Tha Non, Lad Phrao and Ong Ang are actively used for positive purposes, while Klong Saen Saep (in the district of Phra Khanong), Huai Khwang, Toey, Mahanak and Lod are either abandoned or negatively used. (Refer to Figs. B.40 and B.41).

In terms of aggregate points of conditions, Klong Ong Ang, Mahanak, Phadung Krung Kasem and Phra Khanong are regarded as less intensive with respect to negativeness compared with other klongs, while Klong Saen Saep (in the district of Phra Khanong), Prem Prachakorn, Bang Sue and Bang Lum Phu are assessed as having worser conditions than other klongs. (Refer to Fig. B.42).

In terms of aggregate points of both uses and conditions, Klong Saen Saep (in the district of Bang Kapi), Phra Khanong, Bang Khen, Ong Ang and Lad Phrao have less negative aspects than other klongs, while Klong Saen Saep (in the districts of Phra Khanong), Toey, Tan and Huai Khwang have more negative aspects than other klongs. (Refer to Fig. B.43)

8.1.4 Impacts of Klong Water Purification

(1) Overall Impacts

The citizens of Bangkok are daily annoyed by the stinks of klong water, because it has been revealed that the highest proportion, 87.7% of those interviewed replied that removal of obnoxious odour is the most important effect required by klong water purification. Also, citizens are highly conscious of the ill effects of the existing klong conditions, as 70.8% of interviewees chose contribution to the improvement of hygiene / health and to the reduction in diseases as important effects of klong water purification.

The third most important effect is an increased use of klong water for living (washing, bathing, etc.), which was supported by 61.1% of interviewees. Disappearance of repulsive dark water and regaining natural scenic beauty is placed fourth (55.5%).

Then follow recovery of ecology (fish & plants) in klong water (44.9%), regaining the status and functions of klongs as a place for recreational activities (swimming, fishing, playing, etc.) (39.3%), revival of inland water navigation service in klongs (24.4%) and using klong water for irrigation (16.2%). The effects getting little attention are revival of floating market on klong network (9.5%), regaining the value and position of klongs as tourism resources (8.9%) and revival of inland water fishery (3.0%).

It is clear from the above that what lies foremost in the heart and mind of the citizens of Bangkok regarding klongs is just to bring them back to the naturalness and cleanliness prevalent in the good, old days. Revival / recovery of various derivative uses and functions of klongs is considered rather to be of a secondary importance.

Note: The above results are derived from a question asking multiple answers from an interviewee.

(2) Impacts on Transport

35.2% of interviewees answered that they had used transport by klongs at one time or another. However, 62.6% answered that they have never used it. 2.2% provided no answer. 71.5% of users of klong transport used it for commuting, 20.2% for sight-seeing and 8.3% for shopping.

6.9% of households interviewed regularly use klong transport for commuting and 5.4% of them regularly use it for shopping and other purposes. Average frequency of use of klong transport by regular users is 4.00 times per week for commuting and 4.80 times per week for shopping and others. In case klong water is purified average frequency will rise to 4.32 times per week for commuting and to 5.56 times per week for shopping / others.

Negative effects of klong water purification on other transports arising out of increased competition with klong transport are estimated to be not that severe. 16.0% of the interviewees answered that bus transportation would be affected and for others such as the samlor, taxi and car they expected little or no adverse effects.

40.2% of users chose comfort as the most important reason for using klong transport. Next comes rapidity, which 34.3% of them picked up as the foremost reason. Low charge was selected by 19.7% and accessibility by 5.8%.

(3) Impacts on Market

97.2% of interviewees answered that they had used floating market at one time or another. The remaining percentage of them did not answer.

29.8% of households interviewed regularly visit floating market. Their average frequency of visits is 2.86 times per week. In case klong water is purified this will rise to 3.88 times per week.

83.5% of interviewees replied that open-air fruit market would be affected by purification of klong water through greater competition with floating market. 11.1% of them consider that fruit shops will be affected.

As the most important reason for visiting floating market 59.2% of visitors chose accessibility. Fresh products was selected by 16.8%, low price by 15.5% and informality by 8.5%.

(4) Impacts on Land Price

Average purchasing price of housing lot per m^2 works out to be Baht 2,104. To the question whether the price of housing lot near interviewee's address would rise as a result of klong water purification, 38.9% of interviewees answered affirmative. However, 38.0% answered negative and 23.1% did not answer. Average rate of rise estimated by those who predict a rise in the price of housing lot when klong water is purified is about 24.0%.

(5) Willingness to Pay

To the question whether the interviewed household was willing to pay tax for the purification of klong water, 72.4% replied affirmative. Those who replied negative accounted for 17.7% and those who did not reply was 9.9%. Average amount of payment per month by those who are willing to pay is Baht 18.

It has been found that there is a close relationship between monthly household income and willingness to pay. (Refer to Fig. B.44) The correlation coefficient between them is 0.9831 and T-value is 16.0739.

8.2 Opinion Survey of Tourists

8.2.1 Profile of Sampled Foreign Tourists

The composition by nationality of the sampled foreign tourists numbering 276 was 18.1% from U.K., 12.7% from U.S.A., 8.3% from France, 8.3% from West Germany, 6.9% from Australia, 6.9% from Netherlands, 5.8% from Japan, 4.3% from Switzerland, 4.0% from Canada, 3.3% from Israel and 21.4% from other nationalities. Total number of nationalities was 28.

Average age of interviewed tourists was 30, of which 58.7% were male and 41.3% were female. 87.3% of interviewees replied that their purpose of visit was on holiday. 6.2% were on business and 2.9% were on official mission. 70.6% replied that they were single, while 27.2% replied that they were married.

8.2.2 Impacts on Klong Water Purification on Foreign Tourists

Average frequency of visits by the interviewees to Bangkok in the past 5 years is 1.67 times. On the other hand their estimated average frequency of visits to Bangkok in the next 5 years is 2.04 times.

To the question whether the interviewee noticed the filthy, dark-colored, stinking water of klongs, 86.6% answered affirmative and 13.4% negative. To the question for those who answered affirmative to the above question, whether they thought that the existing state of klongs is a setback in attracting foreign visitors, 44.6% answered affirmative and 55.4% negative. To the question for those who answered affirmative to the above question, whether they wanted to visit Bangkok oftener if klong water is clean, 75.3% answered affirmative and 24.7% negative.

That is to say, 29.1% of interviewed foreign tourists want to visit the Venice of the Orient oftener if klong water is clean than as it is.

Revised estimated average frequency of visits to Bangkok in the next 5 years by those who want to visit oftener if klong water is clean is 3.42 times.

Analysis based on the above data reveals that annual incremental rate of the foreign tourist visits in case klong water is clean is 3.7%.

An interesting finding is that the rate varies according to nationality and also according to sex (Refer to Table B.13) : Israeli, Dutch and American tourists are very sensitive to the purification of klong water, and in addition women are more sensitive than men.