6.7 Proposed Treatment Process for Klong Water Purification

(1) Proposed Treatment Process

The study was done using a treatment configuration consisting of the Aerated Lagoon, the Facultative Pond and the Maturation Pond.

Careful analysis of the results of these experiments and study of other related technical references were also made.

In conclusion, a treatment configuration consisting of Aerated Lagoon only is proposed as the treatment process for klong water quality improvement. The reasons for this are as follows:

- This study, "Purification of Klong Water in Bangkok" is essentially an urgent measure and treatment of klong water by aerated lagoon is to prevent the water quality deterioration of the Chao Phraya River caused by the anticipated increase in pollution load discharged to the Chao Phraya River by dilution water introduction.

- Therefore, the target of the klong water purification is firstly to improve the color and odor in the water, and secondly to reduce the BOD and COD concentration to abate the increase in pollution load discharge to the Chao Phraya River.

- Rapid removal of the organic matter is expected in the Aerated Lagoon. This process is advantageous in view of the reduction of the required pond volume/the detention time, which will, in turn, minimize the requirement of land area.

(2) Ponds as Aerated Lagoons

Judging from the condition, location and shape of the ponds and the present state of pollution in the target klongs, out of the eight (8) potential ponds, the Makkasan Pond and the Rama IX Pond

could be used as Aerated Lagoons for the klong water quality improvement.

Assuming a removal efficiency of 50%, a BOD reduction of 4470 kg/d could be achieved in these two (2) Aerated Lagoons. This reduction is equivalent to 7% of the total existing pollution load run-off in the Study Area.

Table 6.1 Experimental Conditions

Item		Case-1 (Case-1-1 ~ Case-1-3)	Case-2	Case-3 (Case-3-1 ~ Case-3-2)	Case-4
Influent Flow Rate (m^3/day)		28,800	9,600	28,800	57,600
Pump Operation (Units x Hrs.)		1 x 24	1 x 8	1 x 24	2 x 24
Aerator (Units x Hrs.)		3 x 24	3 x 24	2 x 24	2 x 24
Detention Time	A.L (Hrs.)	16	48	16	8
	F.P (Days)	1.7	5.1	1.7	0.9
	M.P (")	1.6	4.8	1.6	0.8
	Total (")	4	12	4	2

Note: A.L : Aerated Lagoon
F.P : Facultative/Maturation Pond
M.P : Maturation Pond

Note: In case-2 pump operation was only for 8 hours per day, from 8:00 am ~ 4:00 pm.

Table 6.2 Water Quality Parameter

Parameter	Point ①	Point ②	Point ③	Point ④	Point ⑤	Remark
Color/Odor	*	*	*	*	*	On-Site
Water Temp.	*	*	*	*	*	"
PH	*	*	*	*	*	"
DO	*	*	*	*	*	"
BOD Total	*	*	*	*	*	Lab.
Soluble	*	*	*	*	*	"
COD Total	*	*	*	*	*	"
Soluble	*	*	*	*	*	"
SS	*	*	*	*	*	"
VS/VSS	*	*				"
NH_4-N	*	*	*	*	*	"
NO_2-N	*	*	*	*	*	"
NO_3-N	*	*	*	*	*	"
T-P	*	*	*	*	*	"
Coliform Count	*	*		*	*	"
Chlorophyll-a				*	*	"

* indicates analysis of the respective parameter at the point concerned.

Table 6.3 Removal Efficiencies (%) in Each Ponds in Case-1-1 to Case-1-3 (Phase 1 - Phase 3)

(1) Case-1-1 (13, Feb. - 17, Feb.) - Phase 1

Parameter		Aerated Lagoon	Open Channel	Facultative Pond	Maturation Pond
BOD	Total	55	6	-	-
	Soluble	47	60	37	54
COD	Total	23	19	0	-
	Soluble	-	3	10	17
Coliform		87.6	-	98.9	99.2

(2) Case-1-2 (13, Mar. - 17, Mar.) - Phase 2

Parameter		Aerated Lagoon	Open Channel	Facultative Pond	Maturation Pond
BOD	Total	60	68	35	10
	Soluble	13	50	47	18
COD	Total	42	50	30	32
	Soluble	32	32	13	42
Coliform		95.6	-	99.1	99.9

(3) Case-1-3 (29, Mar. - 1, Jun.) - Phase 3

Parameter		Aerated Lagoon	Open Channel	Facultative Pond	Maturation Pond
BOD	Total	46	48	35	29
	Soluble	46	68	59	52
COD	Total	35	33	17	15
	Soluble	28	31	21	31
Coliform		97.3	-	91.8	95.6

Note: All efficiencies are determined with respect to the water quality of influent to Aerated Lagoon only.

Table 6.4 Removal Efficiencies (%) in Each Pond in Case-2
(27, Feb. - 10, Mar.)

Parameter		Aerated Lagoon	Open Channel	Facultative Pond	Maturation Pond
BOD	Total	41	32	23	55
	Soluble	56	66	62	66
COD	Total	48	32	25	16
	Soluble	52	55	73	69
Coliform		98.5	-	99.5	99.9

Table 6.5 Removal Efficiencies (%) in Each Pond in Case-3-1 and Case-3-2

(1) Case-3-1 (7, June. - 29, Jun.) - Dry Season

Parameter		Aerated Lagoon	Open Channel	Facultative Pond	Maturation Pond
BOD	Total	63	65	33	22
	Soluble	47	68	65	49
COD	Total	19	14	10	14
	Soluble	17	20	23	30
Coliform		99.2	-	99.8	99.7

(2) Case-3-2 (5, Jul. - 31, Jul.) - Rainy Season

Parameter		Aerated Lagoon	Open Channel	Facultative Pond	Maturation Pond
BOD	Total	39	52	42	-
	Soluble	46	52	46	32
COD	Total	3	11	16	16
	Soluble	4	19	33	19
Coliform		13.0	-	94.8	99.9

Table 6.6 Removal Efficiencies (%) in Each Pond in Case-4
(3, Aug. - 17, Aug.)

Parameter		Aerated Lagoon	Open Channel	Facultative Pond	Maturation Pond
BOD	Total	39	46	44	36
	Soluble	53	46	63	68
COD	Total	18	30	28	38
	Soluble	22	30	30	22
Coliform		97.5	-	99.2	99.7

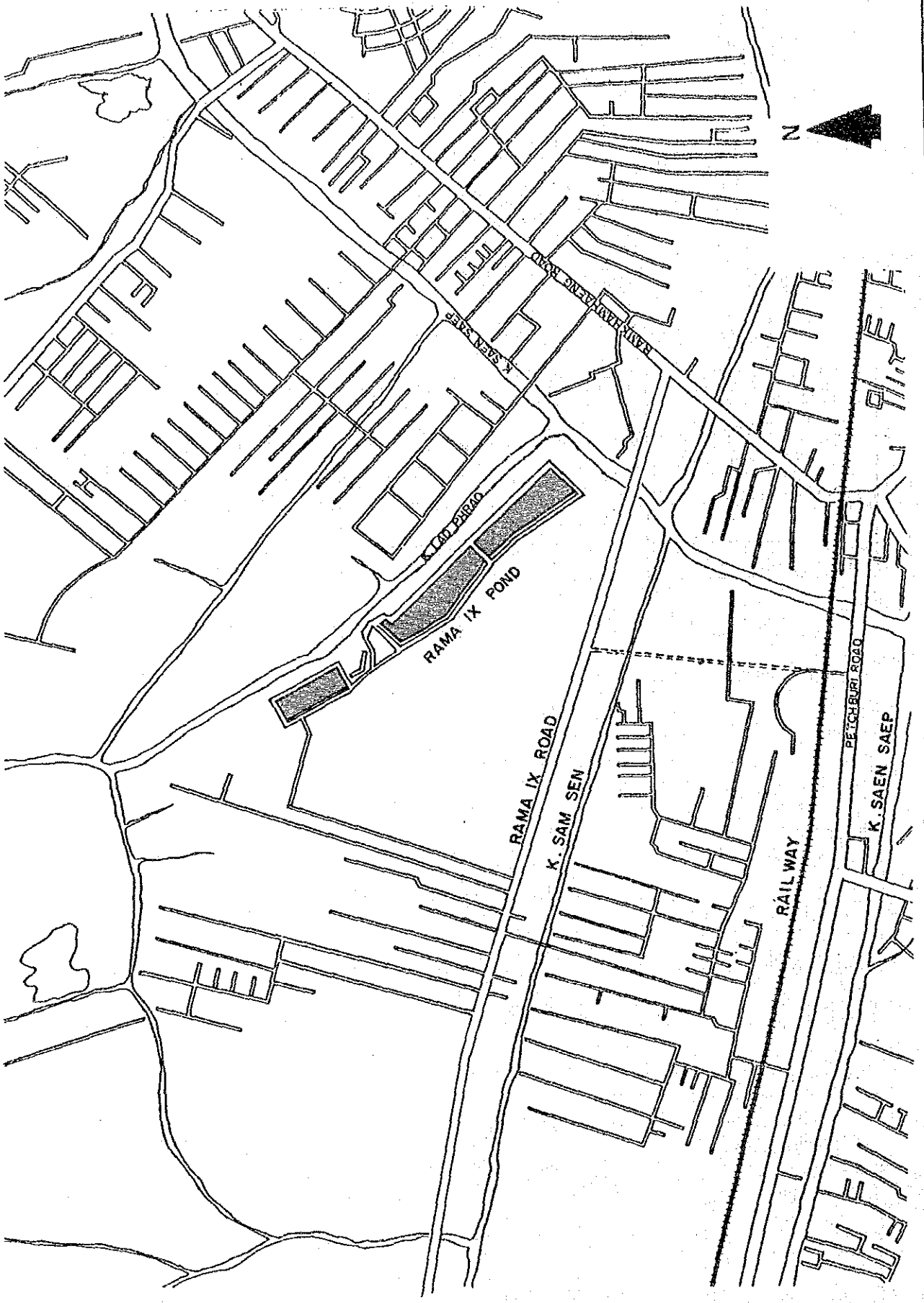

FIG. 6.1 LOCATION OF THE RAMA IX POND

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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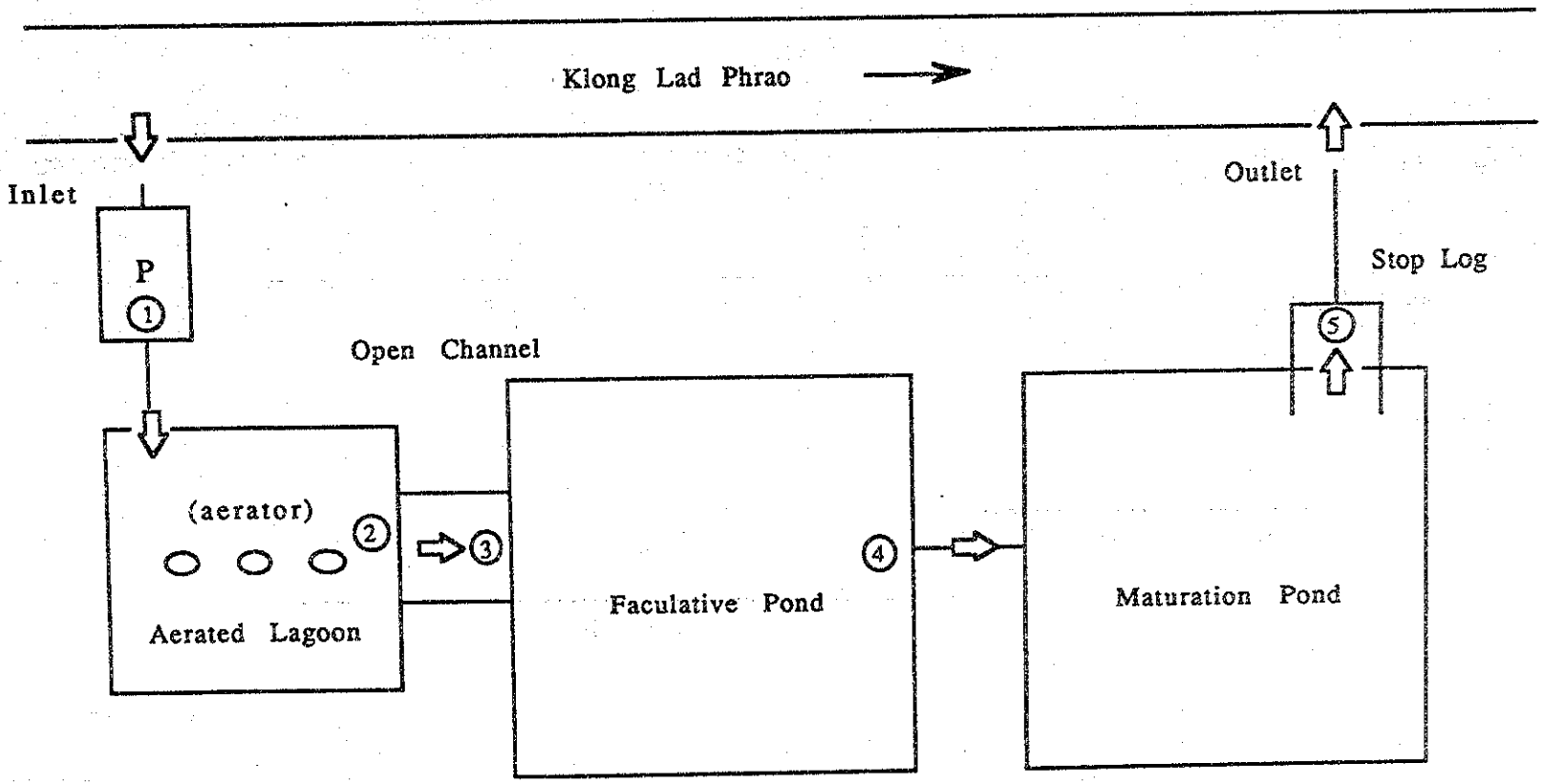

FIG. 6.2 LAYOUT OF THE RAMA IX POND AND LOCATION OF SAMPLING POINTS

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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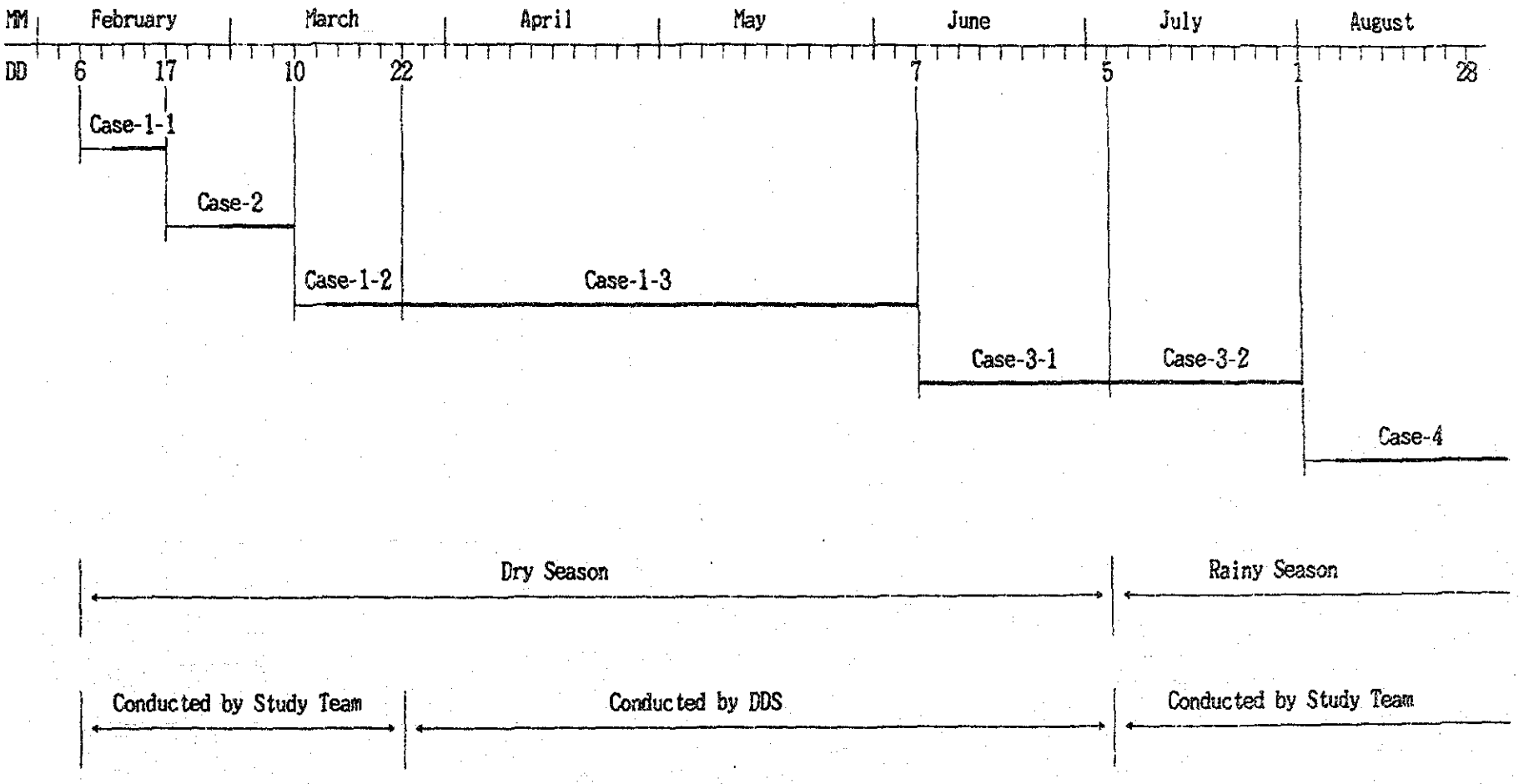
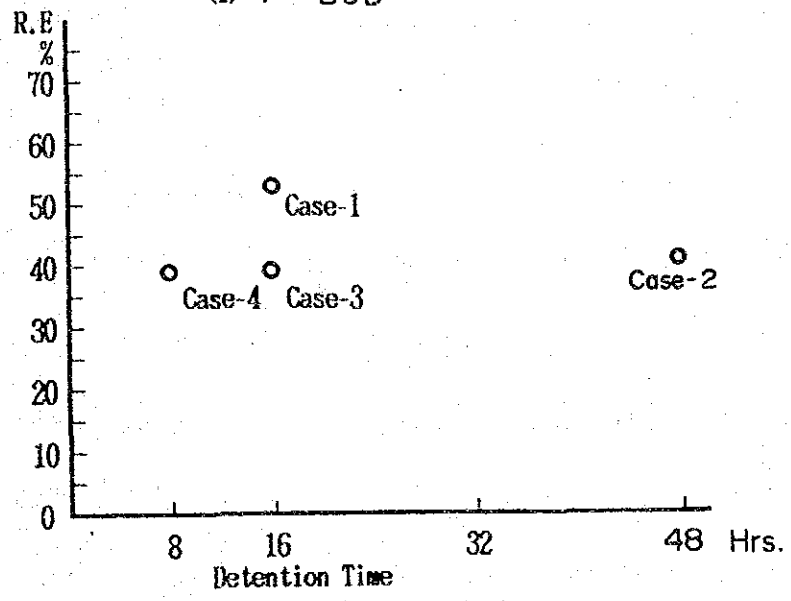


FIG. 6.3 SCHEDULE OF EXPERIMENTAL WORK AT RAMA IX POND

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

(1) T - BOD



(2) T - COD

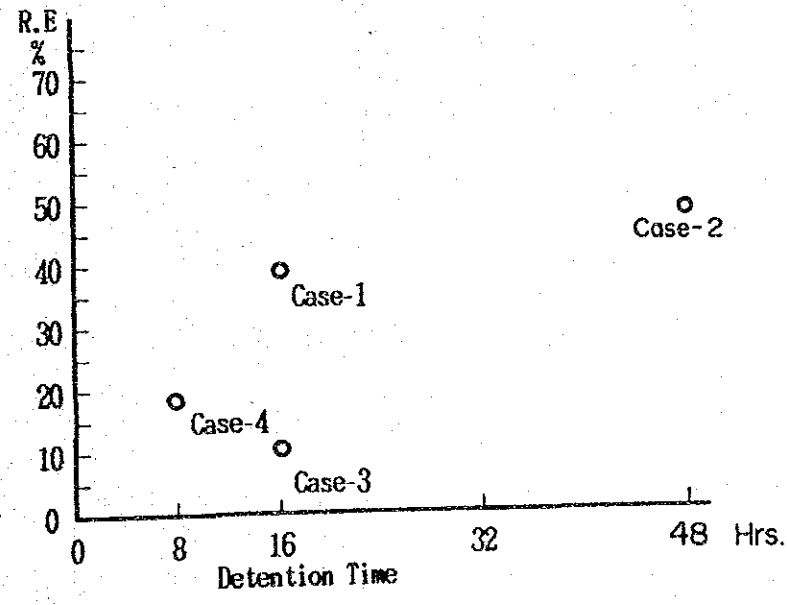


FIG. 6.4	CORRELATION BETWEEN REMOVAL EFFICIENCY AND DETENTION TIME

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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Potential Pond

	Name of Pond	Area (ha)	Stor. Cap. (m3)	Diversion from	Ownership	Remarks
1.	Paholyothin Cargo Station	10	220,000	K. Premprachakorn K. Bang Sue	Government	Dredging, low loading
2.	Makkasan	16	310,000	K. Sam Sen	Government	Squatters
3.	Tobacco Factory	20	680,000	Sewage Line	Government	Low loading, recreation site
4.	Huai Khwang	6	570,000	K. Lad Phrao	Private	Fishery
5.	Rama IX Pond	20	300,000	K. Lad Phrao	Government	Excavation, flood regulation
6.	K. Chan	6	250,000	K. Tanang	Government	Low loading
7.	K. Kum	2.5	30,000	K. Bang Toei	Government	Low loading, Park flood regulation
8.	Rama IX Park	10	90,000	K. Nong Bon	Government	Low loading, Park flood regulation
	Total	90.5	2,450,000			

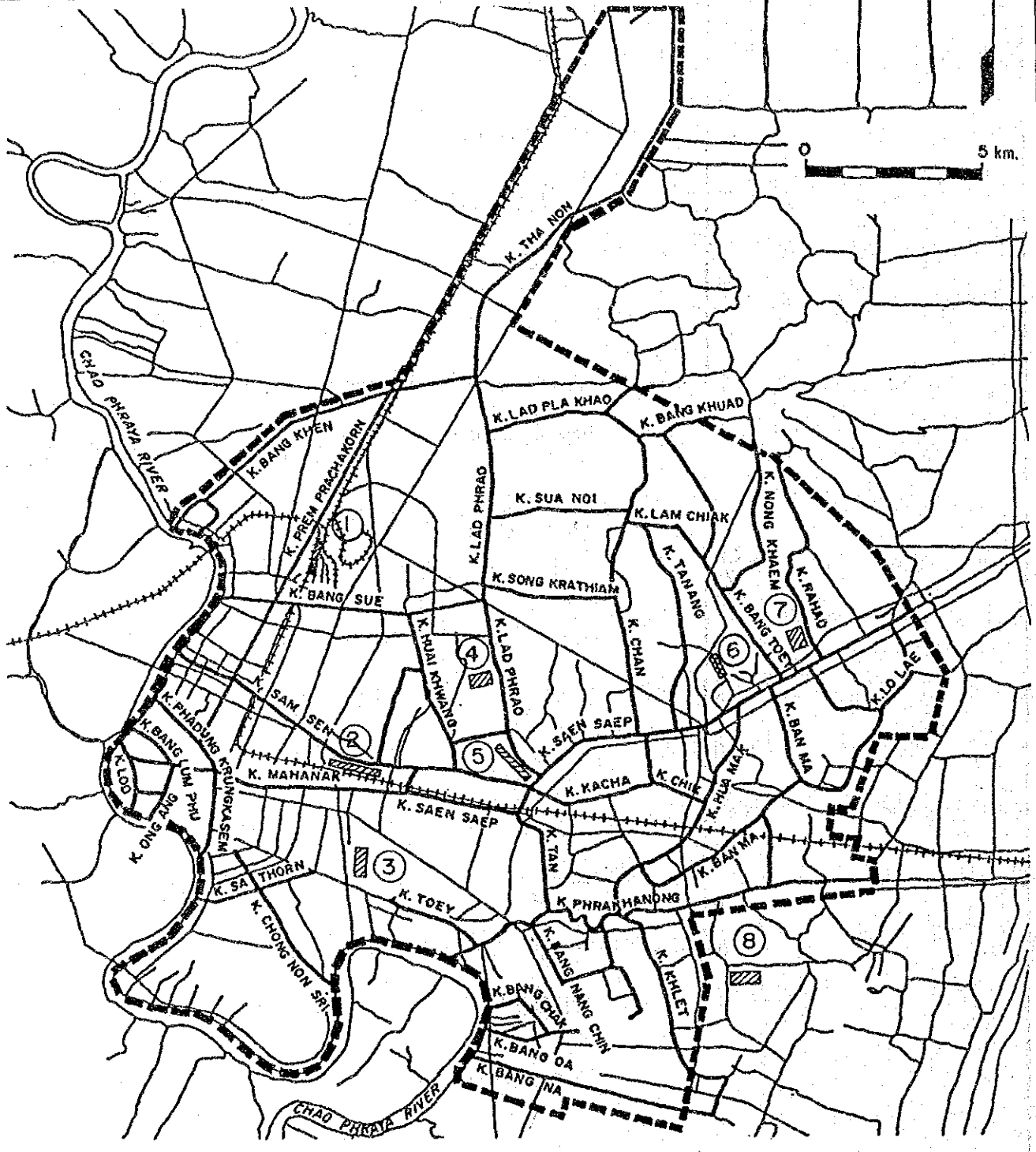

FIG. 6.5 LOCATION OF POTENTIAL PONDS

THE STUDY ON URBAN DRAINAGE AND WASTE WATER DISPOSAL PROJECT IN THE CITY OF JAKARTA

JICA A.D 1991

Chapter 7.

DILUTION WATER INTRODUCTION

CHAPTER 7. DILUTION WATER INTRODUCTION

7.1 Planning Policy and Criteria

Objective of the Study is to propose an urgent water quality improvement plan for the klongs with the introduction of dilution water. The urgent plan is prepared in accordance with the following policy and criteria.

7.1.1 Planning Policy

(1) Plans are to be prepared to abate the existing water pollution of the klongs.

(2) In this Study, the target water quality is set up with respect to klong stream BOD. The relationship between klong appearance and klong water quality expressed as BOD are as follows.

In Chapter 3, existing klong appearance is classified into four (4) Ranks. Rank A is green or light brown color and no odor, Rank B is dark green or dark brown color and faint odor, Rank C is gray color and strong odor and Rank D is blackish color and offensive odor.

The average BOD in the klongs for each classified rank of appearance are about 13 for Rank A, 15 for Rank B, 21 for Rank C and 28 for Rank D.

Accordingly, the klong water quality of the Study Area is characterized as follows:

1) Color

Green or brown	:	BOD < 15 mg/l
Black or black-gray	:	BOD > 20 mg/l

2) Odor

No odor or faint odor	:	BOD < 15 mg/l
Strong odor or offensive odor	:	BOD > 20 mg/l

(3) The klong water quality shall be improved at least to that of Rank B. Average BOD of Rank B is about 15 mg/l, and hence a klong stream BOD of 15 mg/l was selected as the minimum target for simulation analyses of this Study.

(4) Target klongs are the highly polluted klongs (BOD more than 15 mg/l) which are located in the present highly urbanized areas.

The targeted major klongs for water quality improvement are:

- Klongs in Ratanakosin Area:
  K. Lod, K. Ong Ang, K. Wat Tep Tida
  K. Wat Rajabopit, K. Bang Lum Phu
  K. Mahanak, K. Phadung Krung Kasem
- K. Saen Saep
- K. Bang Sue
- K. Sam Sen
- K. Prem Prachakorn
- K. Huai Khwang
- K. Tan
- K. Phra Khanong
- K. Sathorn
- K. Chong Non Sri
- K. Toey

These targeted major klongs are shown in Fig. 7.1.

(5) The project component of dilution water introduction is only an urgent water pollution control measure. As such, large-scale structural measures will not be proposed. The proposed simple structural measures are:

- Introduce dilution water from the Chao Phraya River and the outer areas of the polder by using the existing and planned flood control and drainage facilities (pumps and gates).
- Increase the discharge capacity of the klongs by dredging to facilitate the dilution water introduction.

7.1.2 Planning Criteria for Introduction of Dilution Water

(1) Period of the Dilution Water Introduction

Period of the dilution water introduction from the Chao Phraya River is limited only for dry season (November - June). While in rainy season, the gates on the Chao Phraya River banks shall be closed and the klong water level is kept low to meet the incoming flood discharge. No dilution water introduction from the Chao Phraya River is expected.

(2) Available Water of the Chao Phraya River

The minimum seasonal discharge of the Chao Phraya River in the typical dry season (Jan. - April) at Bang Sai is 120 m^3/s. The existing water withdrawal in the reaches between Bang Sai and Study Area is 14.5 m^3/s.

The available discharge of the Chao Phraya River for the dilution of the klong water is estimated to be 70 ~ 80 m^3/s, taking into consideration the increasing water withdrawal from the Chao Phraya River in future.

(3) Available Water of the Eastern Outer Areas

In dry season, 10 m^3/s of surplus irrigation water is expected from the outer areas of the polder. While in rainy season, 35 m^3/s could be introduced.

(4) Water Level of Klong

Water level of the klongs shall be maintained below +0.77 m M.S.L. in dry season. While in rainy season, the maintenance water level shall be drawn down below -0.23 m M.S.L., in principle, as the flood mitigation measure.

(5) Water Stage of the Chao Phraya River

Water stage hydrograph of the Chao Phraya River in the Study Area varies with the river distance. Therefore, the design water stage hydrographs of the Chao Phraya River for the klong water purification plan are determined at the 13 existing gates and pump stations.

The updated water stage hydrograph records of February 3-4 and July 16-17, 1988 are adopted as the design water stage hydrographs for the dry season and rainy season respectively. This is because, their tidal ranges and patterns are similar to the design ones determined in Chapter 2. These proposed water stage hydrographs are shown in Fig. E.6 and Fig. E.7 of Appendix E.

7.2 Simulation of Klong Water Quality

7.2.1 Simulation Model

The proposed klong network model is shown in Fig. 7.2. The Study Area was divided into 128 subdivided drainage areas. The existing klong networks were divided into 128 stretches.

The water quality parameter of BOD was adopted for the simulation in view of the following fact.

- The water pollution of the klongs is mainly caused by organic pollution loads discharged from Bangkok city. BOD is the most typical parameter of organic pollution load.

The water flow and quality of the klongs vary every moment due to the tidal effects of the Chao Phraya River. The flow velocity and water quality of the klongs does not vary so much both vertically and laterally. In consideration of the above mentioned facts, a mathematical model consisting of one (1) dimensional unsteady flow equation and one (1) dimensional unsteady diffusion equation were applied.

7.2.2 Calibration of Simulation Model

The proposed simulation model was calibrated by using the flow and water quality data observed during the period of February 3-4 (Dry Season), and July 16-17 (Rainy Season) 1988.

Comparison of observed and calculated water quality as BOD in representative stations both during dry season and rainy season are shown respectively in Fig. 7.3 and Fig. 7.4, which are in good agreement.

7.3 Alternative Plans of Klong Water Purification

Under the present condition, dilution water from the Chao Phraya River is introduced through the gates only at the high tide of the Chao Phraya River. The existing pumps on the Chao Phraya River banks function only for drainage of the inner water.

7.3.1 Proposed Alternative Plans

The following three (3) alternative plans are proposed.

(1) Plan A

The existing pump stations are remodelled into reversible type so that the dilution water can be introduced even during low tide of the Chao Phraya River. The proposed pump stations for reconstruction are Bang Sue, Sam Sen, Tavate and Sathorn. The remodelling into reversible type is performed by reconstruction

of the existing gate structures for Bang Sue and Sam Sen. While, for Tavate and Sathorn, additional pumps for the withdrawal of dilution water are proposed. The proposed pump capacity for the introduction of dilution water is shown below.

Name of P.S.	Pump Capacity		
	Existing (Set) x (m^3/s)	Reversible (Set) x (m^3/s)	Additional (Set) x (m^3/s)
Bang Sue	17 x 3 = 51	4 x 3 = 12	-
Sam Sen	15 x 3 = 45	4 x 3 = 12	-
Tavate	5 x 1 = 5	-	2 x 3 = 6
Sathorn	2 x 3 = 6	-	2 x 3 = 6
Total	107	24	12

Location of the proposed pump station is shown in Fig. 7.5.

(2) Plan B

A small-scale dredging of the klongs is considered along with Plan A to increase the capacity of dilution water introduction. The dredging is proposed for the klongs in Ratanakosin Area. The proposed klong dredging is shown below.

Name of Klong	Dredging Plan			
	Length (m)	Width (m)	Volume (m^3)	Bed EL. (MSL, m)
Wat Tep Tida	745	7.0	4,000	-1.5
Wat Rajabopit	1,122	6.8	8,000	-1.5
Chong Non Sri	3,600	6.0 ~ 10.0	77,000	-1.5 ~ -2.0
Total	5,467		89,000	

Location of the proposed klong dredging is shown in Fig. 7.5.

(3) Plan C

In order to increase the capacity of dilution water introduction more than Plan B, a large-scale reconstruction of pump stations and a large-scale dredging of the Klongs are proposed.
The proposed pump capacity for the introduction of dilution water and the proposed dredging are shown below.

Name of P.S	Pump Capacity		
	Existing (Set) x (m^3/sec)	Reversible (Set) x (m^3/sec)	Additional (Set) x (m^3/sec)
Bang Sue	17 x 3 = 51	7 x 3 = 21	-
Sam Sen	15 x 3 = 45	6 x 3 = 18	-
Tavate	5 x 1 = 5	-	3 x 3 = 9
Sathorn	2 x 3 = 6	-	2 x 3 = 6
	107	39	15

Name of Klong	Dredging Plan			
	Length (m)	Width (m)	Volume (m^3)	Bed EL. (MSL, m)
Wat Tep Tida	745	7.0	4,000	-1.5
Wat Rajabopit	1,122	6.8	8,000	-1.5
Chon Non Sri	3,600	6.0 ~ 10.0	77,000	-1.5 ~ -2.0
Bang Sue	8,011	20.0	194,000	-2.5
Sam Sen	6,834	10.0 ~ 15.0	100,000	-2.0
Huai Khwang	3,465	6.0	20,000	-1.4
Lad Phrao	7,100	35.0	271,000	-2.3
Tan	1,922	26.0	14,000	-2.8
Total	32,799		688,000	

Location of the proposed pump station and the proposed klong dredging are shown in Fig. 7.5.

7.3.2 Optimum Suction Water Level of Drainage Pump

(1) Dry Season

The introduced dilution water form the Chao Phraya River is drained again into the Chao Phraya River through Phra Khanong and Krung Kasem pump stations.

The maintenance water level of the klongs is restricted below +0.77 m M.S.L. If the klong water level at the introduction site of dilution water is assumed to be +0.77 m M.S.L., introducible dilution water quantity, the consequent water quality improvement and the required pump up water for dilution water introduction and the subsequent discharge vary corresponding to the suction water level of Phra Khanong and Krung Kasem pump stations.

The optimum suction water level of Phra Khanong and Krung Kasem pump stations, for the three alternative plans, were obtained through comparative studies of the klong water quality improvement and required pump up water volume for introduction and discharge of dilution water.

Suction Water Level (m : MSL)

	Phra Khanong P.S.	Krung Kasem P.S.
Plan A	0	+0.30
Plan B	0	+0.30
Plan C	-0.50	0

(2) Rainy Season

The water level of the klongs shall be maintained below -0.23 m M.S.L. to carry incoming flood discharge. The suction water level of Phra Khanong and Krung Kasem pump stations shall be kept further lower than the above maintenance water level to obtain a sufficient hydraulic gradient in the klongs. In this Study, the

suction water level of the two (2) pump stations is proposed to be -0.35 m M.S.L. in accordance with the existing pump operation mode.

7.3.3 Comparison of Alternative Plans

Project efficiency of the three (3) alternative plans of dilution water introduction are compared in terms of water quality improvement in dry season, construction cost and pump operation cost. The improved water quality of the target klongs is shown in terms of average and maximum BOD for the divided klong groups. The comparison is shown in Table 7.1.

As evident from Table 7.1, Plan B is obviously the most economically efficient. Hence Plan B is recommended.

7.4 Proposed Plan of Klong Water Purification

The Plan B improves the existing water quality of the target klongs to a considerable extent in dry season. The estimated daily average water quality in terms of BOD is not more than 15 mg/l in all the target klongs except for K. Toey. In rainy season, however, no beneficial effects of klong water quality improvement is attained.

The final proposal of klong water purification is summarized below.

7.4.1 Planning Conditions for Dilution Water Introduction in Dry Season

Introduction of the dilution water from the Chao Phraya River in dry season is planned with the following conditions.

(1) Pollution load run-offs into the klongs: Existing ones

(2) Rainfall : 1.1 mm/day

(3) Evapo-transpiration : 1.8 mm/day

(4) Expected dilution water from the eastern outer areas : 10 m^3/s

(5) Maintenance klong water level : +0.77 m M.S.L.

(6) Suction water level of Drainage P.S. : 0 m M.S.L. for Phra Khanong
+0.3m M.S.L. for Krung Kasem

(7) Water stage of the Chao Phraya River: See Fig. E.6 of Appendix E.

7.4.2 Proposed Structural Measures

Four (4) pump stations will be reconstructed for the introduction of dilution water from the Chao Phraya River in dry season. Three (3) shallow klongs will be dredged to increase their discharge capacities.

(1) Pump Station

Bang Sue P.S. : Four (4) pumps among the existing 17 pumps will be remodelled into reversible type by the reconstruction of the existing gate structures. The reversible pumps have a discharge capacity of 3 m^3/s each.

Sam Sen P.S. : Four (4) pumps among the existing 15 pumps will be modified into reversible type by the reconstruction of the existing gate structures. The reversible pumps have a discharge capacity of 3 m^3/s each.

Tavate P.S. : Two (2) additional pumps with a capacity of 3 m^3/s each will be installed.

Sathorn P.S. : Two (2) additional pumps with a capacity of 3 m^3/s each will be constructed.

(2) Dredging

The klongs of Wat Tep Tida, Wat Rajabopit and Chong Non Sri will be dredged according to the following plan.

	Length (m)	Width (m)	Volume (m^3)	Bed EL. (MSL, m)
K. Wat Tep Tida	745	7.0	4,000	-1.5
K. Wat Rajabopit	1,122	6.8	8,000	-1.5
K. Chong Non Sri	3,600	6.0 ~ 10.0	77,000	-1.5 ~ -2.0
Total	5,467		89,000	

7.4.3 Effects of Proposed Plan in Dry Season

The improved klong water quality in dry season by the proposed plan of dilution water introduction is shown below, in comparison to the water quality under the existing conditions. The break down of the calculated water quality by klong stretches is shown in Table 7.2 and Fig. 7.6.

Improved Water Quality (BOD: mg/l)

	Existing	Proposed plan
Ratanakosin Area		
K. Wat Tep Tida & K. Wat Rajabopit	17 (56)	12 (24)
Other klongs/1	12 (22)	10 (18)
Klongs in Surrounding Area/2	20 (33)	12 (16)
K. Toey	23 (30)	25 (31)
K. Satorn & K. Chong Non Sri	47 (52)	12 (15)

Note: 1) /1; Lod, Bang Lum Phu, Ong Ang, Phadung Krung Kasem, Mahanak
2) /2; Bang Sue, Sam Sen, Prem Prachakorn, Saen Saep, Bang Kapi, Huai Khwang, Tan, Phra Khanong
3) Figure in parenthesis is maximum value
4) Figure with no parenthesis is average value

7.4.4 Effects of Proposed Plan in Rainy Season

(1) Simulation Condition of Klong Water Quality

The klong water quality in rainy season was estimated under the proposed plan with the following conditions.

(a)	Expected dilution water from the Chao Phraya River	:	Zero (0)
(b)	Pollution load run-off into the klongs	:	Existing ones
(c)	Rainfall	:	7 mm/day
(d)	Evapo-transpiration	:	3 mm/day
(e)	Expected dilution water from the eastern outer areas	:	35 m^3/s
(f)	Maintenance level of klong water	:	-0.23 m M.S.L.
(g)	Suction water level of Drainage P.S.	:	-0.35 m M.S.L. for Phra Khanong and Krung Kasem
(h)	Water stage of the Chao Phraya River	:	See Fig. E.7 of Appendix E.

(2) Results of Simulation

The simulated klong water quality in rainy season by klong stretches along with the recorded ones, as BOD, is shown in Table 7.3 and Fig.7.7. No beneficial effects of water quality improvement in any klongs is attained.

In addition the simulated water quality of the klongs in Ratanakosin area, K. Bang Lum Phu, K. Ong Ang, K. Lod and

K. Wat Rachabopit, is worser than the existing observed water quality. This is because, no introduction of dilution water is assumed for simulation analysis where as some dilution water was infact introduced from the Chao Phraya River through slightly opened gates of Phra Pinklao and Ong Ang.

Table 7.1 Comparison of Alternative Plans

			Existing	Plan A	Plan B	Plan C
Improved Water Quality in Dry Season (BOD: mg/l)	Ratanakosin Area	K. Wat Tep Tida & K. Wat Rajabopit	17 (56)	16 (27)	12 (24)	11 (24)
		Other Klongs /1	12 (22)	11 (18)	10 (18)	9 (16)
	Klongs in Surrounding Area /2		20 (33)	12 (16)	12 (16)	9 (13)
	K. Toey		23 (30)	25 (31)	25 (31)	24 (30)
	K. Sathorn & K. Chong Non Sri		47 (52)	43 (52)	12 (15)	12 (15)
Construction Cost (million Baht)			0	38.0	46.4	1,080.3
Pump Operation Cost (million Baht/year)			12.8	31.7	34.8	58.2

Note: 1) /1 ; Lod, Bang Lum Phu, Ong Ang, Phadung Krung Kasem, Mahanak

2) /2 ; Bang Sue, Sam Sen, Prem Prachakorn, Saen Saep, Bang Kapi, Huai Khwang, Tan, Phra Khanong

3) Figure in parenthesis is maximum value.

4) Figure outside parenthesis is average value.

Table 7.2 Comparison of Calculated Average and Maximu by Alternative Plans in Rainy Season

Unit : mg/l

	Recorded	A	B	C
K. Bang Sue	11 - 13 (16 - 18)	8 - 10 (9 - 10)	8 - 10 (9 - 11)	7 (8 - 9)
K. Sam sen	16 - 25 (26 - 28)	6 - 16 (7 - 16)	6 - 15 (7 - 16)	5 - 10 (5 - 10)
K. Prem Prachakorn	24 - 25 (29 - 32)	9 - 13 (10 - 15)	9 - 13 (11 - 15)	10 (12)
K. Huai Khwang	31 (33)	15 (15)	15 (15)	10 (10)
K. Mahanak - K. Saen Saep	14 - 25 (21 - 28)	12 - 15 (13 - 16)	11 - 14 (13 - 15)	10 - 12 (12 - 13)
K. Bang Kapi	24 (26)	14 (15)	14 (15)	9 (9)
K. Phadung Krungkasem	14 - 16 (20 - 22)	9 - 13 (10 - 14)	9 - 13 (10 - 13)	8 - 11 (10 - 12)
K. Bang Lamphu	8 (18)	11 (18)	11 (18)	10 (16)
K. Ong Ang	9 (15)	9 (15)	9 (13)	8 (11)
K. Lod	8 - 10 (17 - 19)	8 - 9 (13 - 14)	8 (12 - 13)	6 - 7 (11 - 12)
K. Wat Teptida	18 (56)	15 (26)	10 (16)	9 (14)
K. Wat Ratchabopit	15 (30)	16 (27)	14 (24)	12 (24)
K. Tan	16 (17)	14 (14)	14 (14)	10 (10)
K. Phra Khanong	12 (13)	12 (13)	12 (13)	10 (10)
K. Toey	23 (30)	25 (31)	25 (31)	24 (30)
K. Sathorn	44 (45)	35 (36)	9 (13)	9 (13)
K. Chong Non Sri	50 (52)	50 (52)	14 (15)	14 (15)

cf.) Figure in parenthesis indicates maximum BOD.

Table 7.3 Comparison of Recorded Average and Maximum BOD with Simulated Ones of Proposed Plan in Rainy Season

Unit : mg/l

Name of Klong	Water Quality as BOD		Name of Klong	Water Quality as BOD	
	Recorded	Rroposed Plan B		Recorded	Proposed Plan B
K. Bang Sue	8 - 14 (9 - 15)	8 - 17 (8 - 17)	K. Lod	14 - 22 (18 - 24)	44 - 45 (45 - 46)
K. Sam Sen	11 - 29 (15 - 30)	8 - 22 (8 - 23)	K. Wat Teptida	44 (55)	47 (47)
K. Prem Prachakorn	26 - 35 (27 - 39)	28 - 39 (28 - 41)	K. Wat Ratchabopit	28 (33)	50 (50)
K. Huai Khwang	11 (11)	9 (9)	K. Tan	5 (5)	5 (5)
K. Mahanak K. Saen Saep	20 - 22 (22 - 24)	15 - 45 (15 - 47)	K. Phra Khanong	5 (6)	5 (5)
K. Bang Kapi	16 (20)	8 (9)	K. Toey	19 (26)	18 (23)
K. Phadung Krungkasem	30 - 37 (30 - 38)	30 - 33 (31 - 34)	K. Sathorn	37 (37)	35 (35)
K. Bang Lamphu	18 (23)	48 (49)	K. Chong Non Sri	32 (33)	30 (30)
K. Ong Ang	16 (20)	45 (46)			

Note : Figure in parenthesis is maximum value.
Figure with no parenthesis is average value.

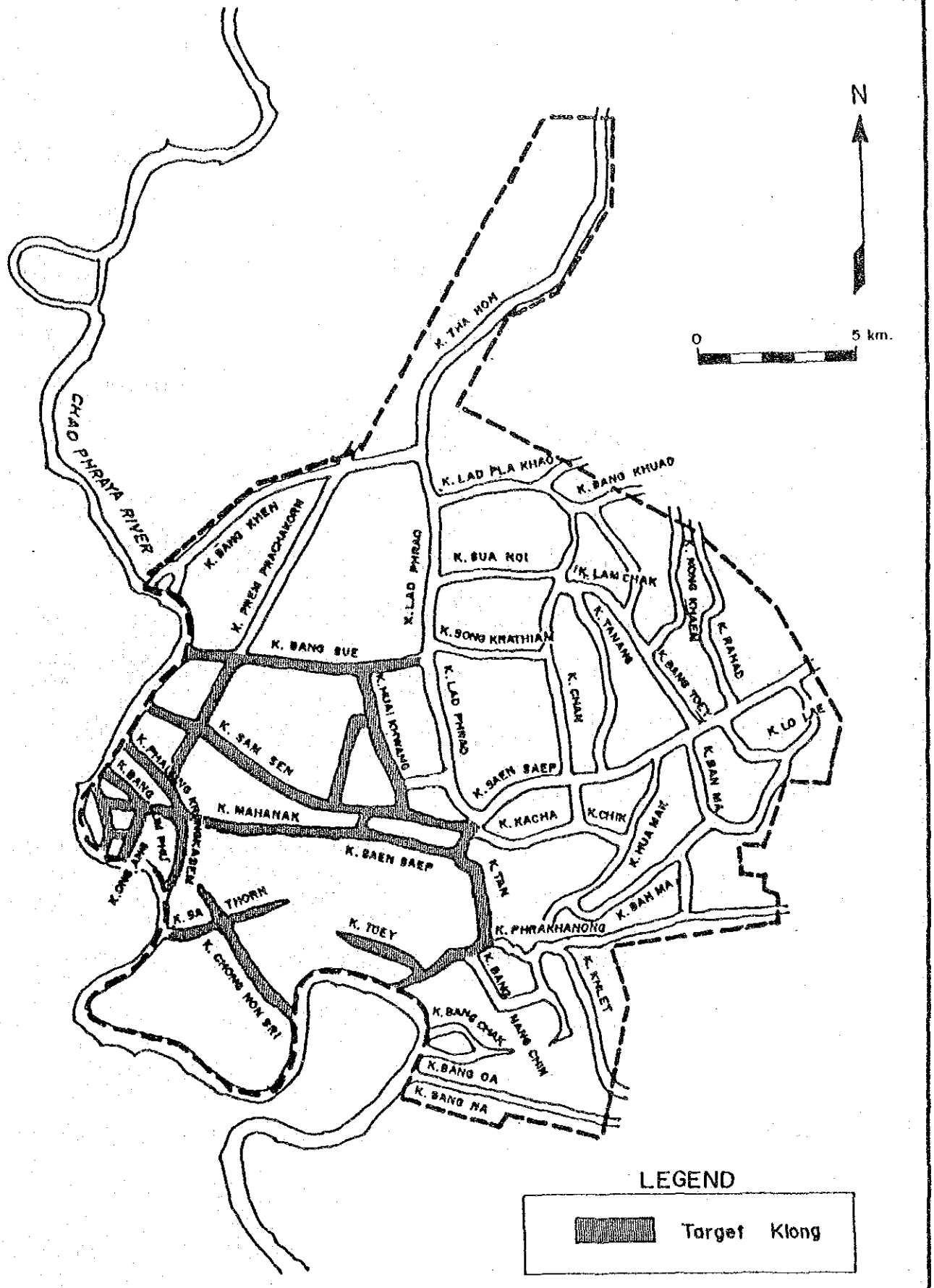

FIG. 7.1 LOCATION OF TARGET KLONG

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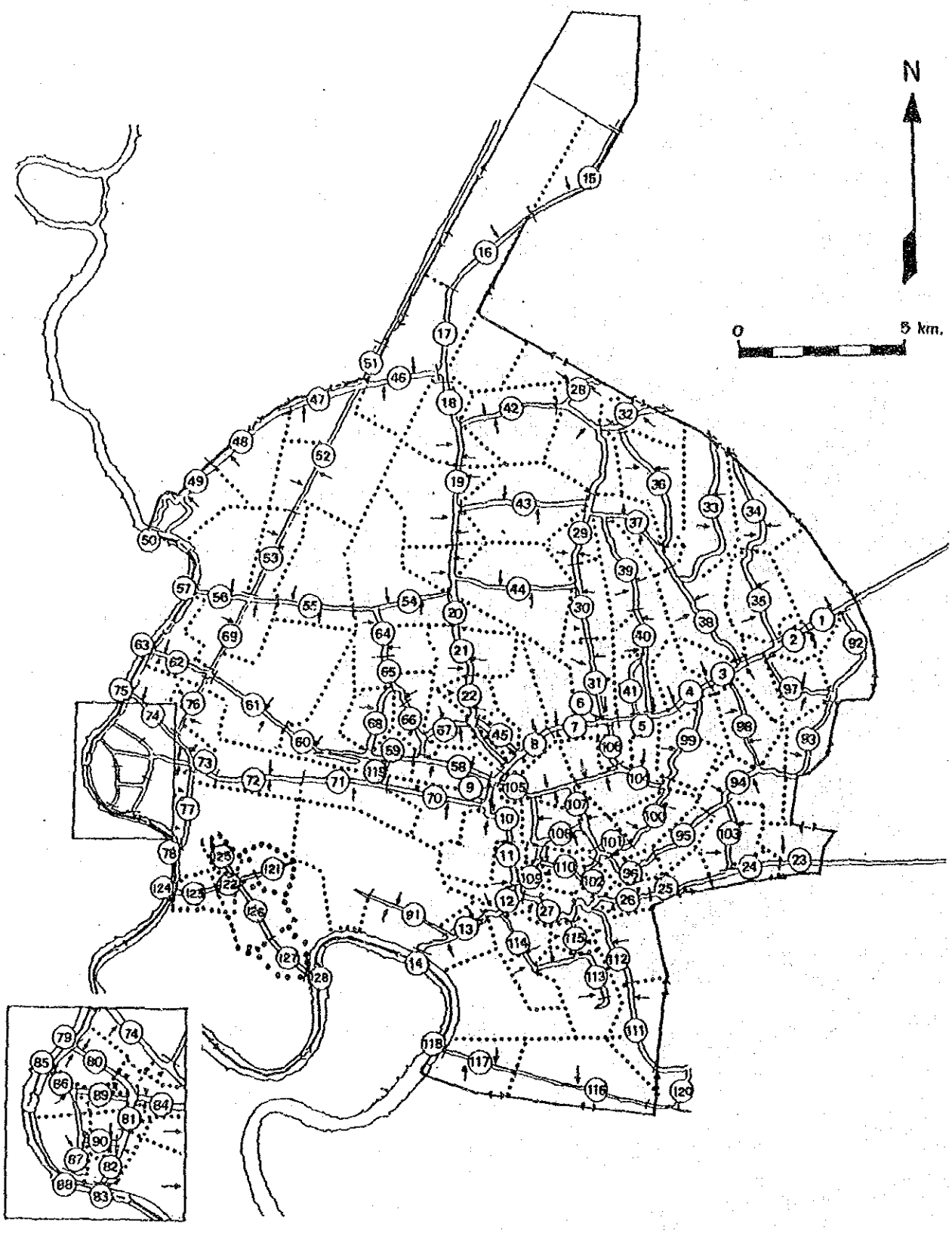

FIG. 7.2 PROPOSED KLONG NETWORK MODEL

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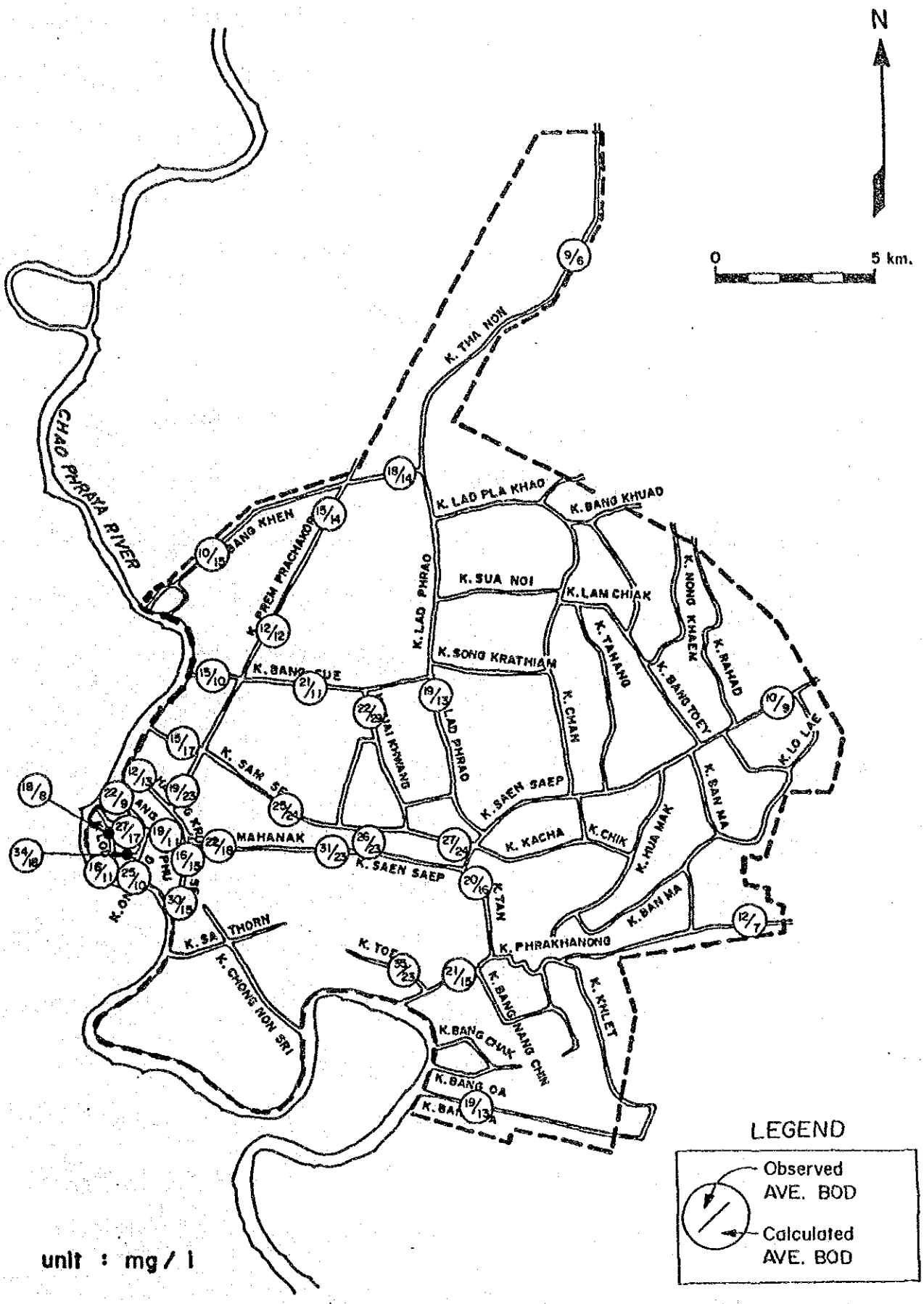

FIG. 7. 3 OBSERVED AVERAGE BOD AND CALCULATED AVERAGE BOD IN DRY SEASON FOR CALIBRATION

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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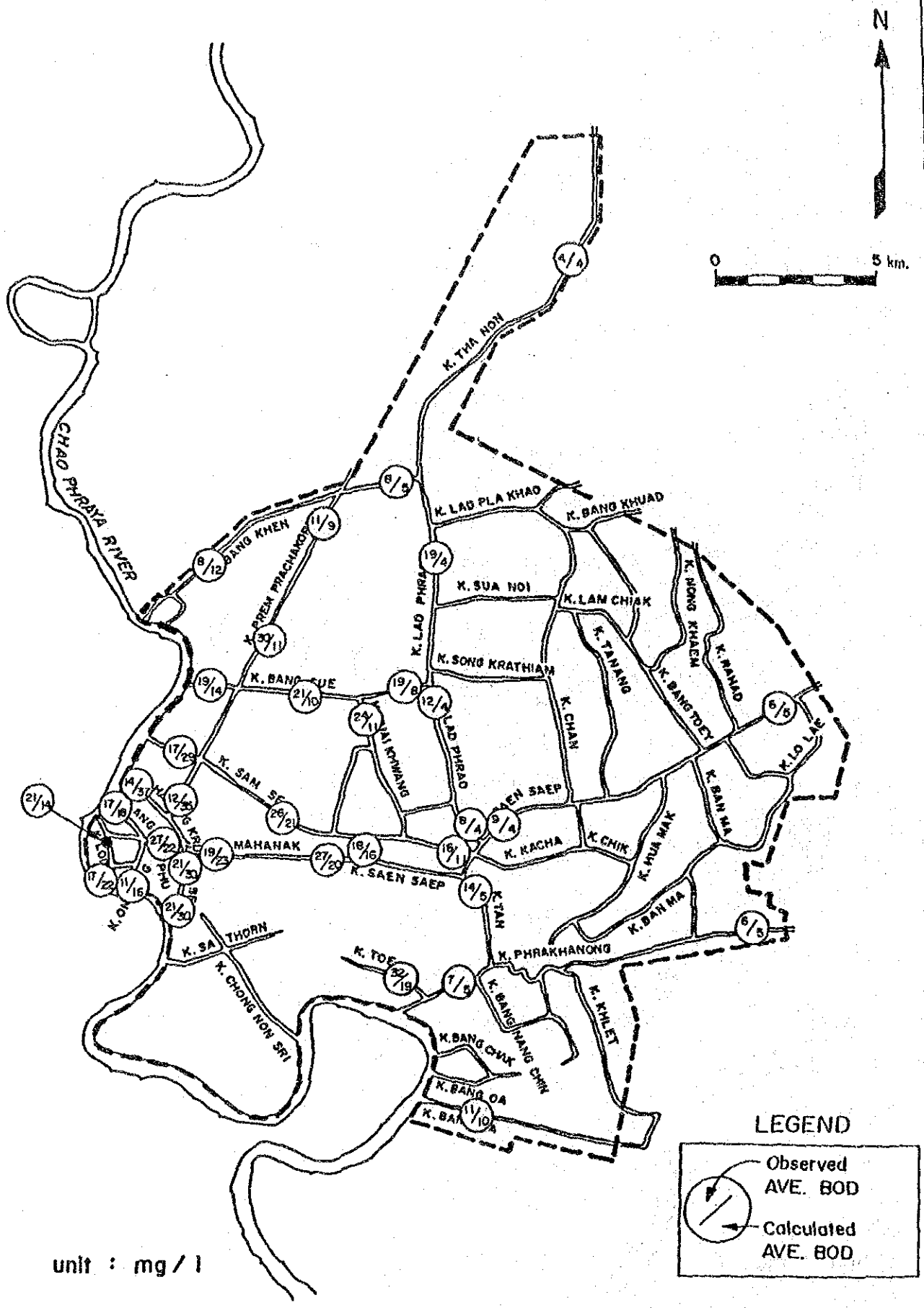

FIG. 7 . 4 OBSERVED AVERAGE BOD AND CALCULATED AVERAGE BOD IN RAINY SEASON FOR CALIBRATION

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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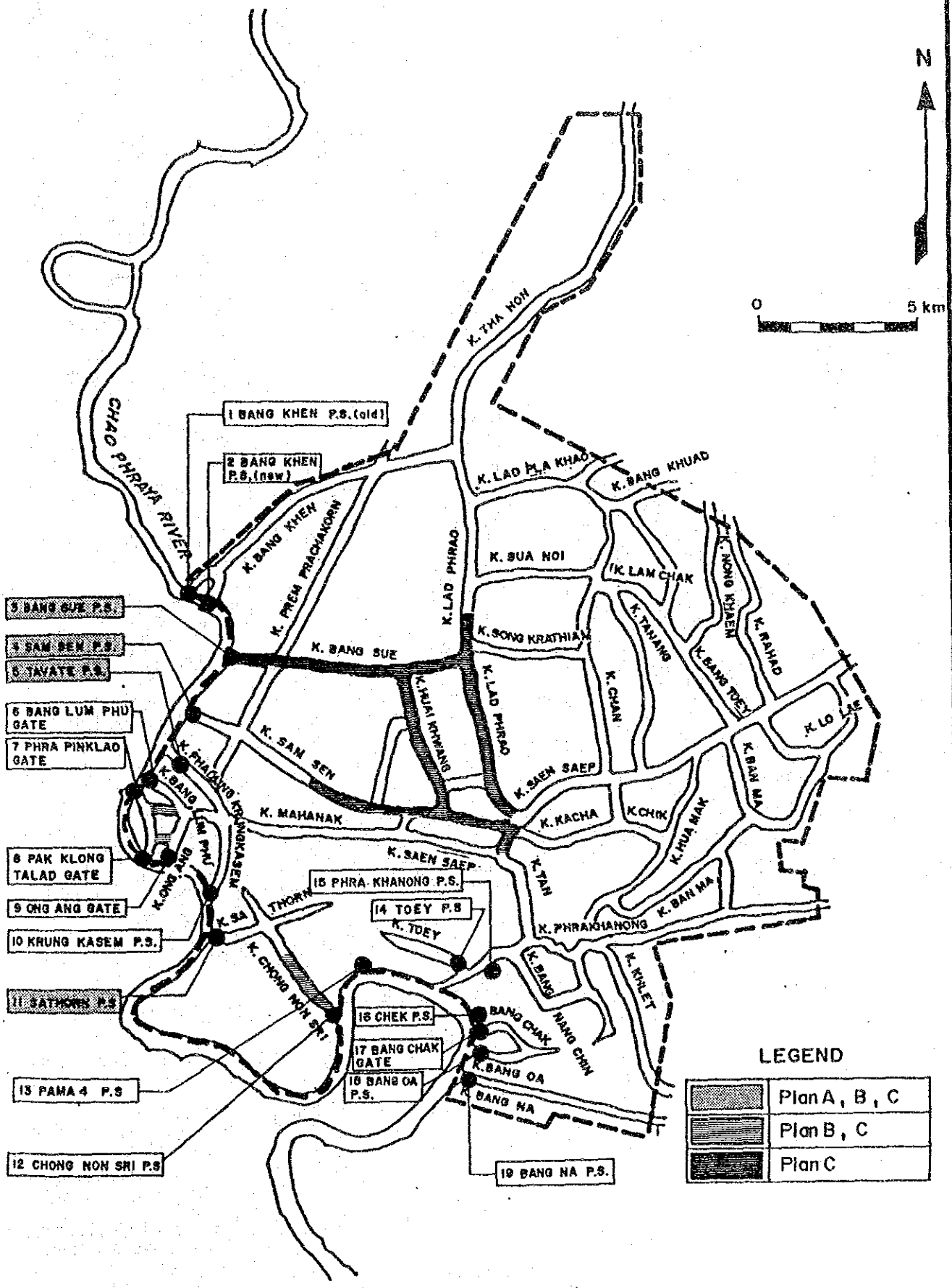

FIG. 7.5 LOCATION OF THE PROPOSED FACILITIES

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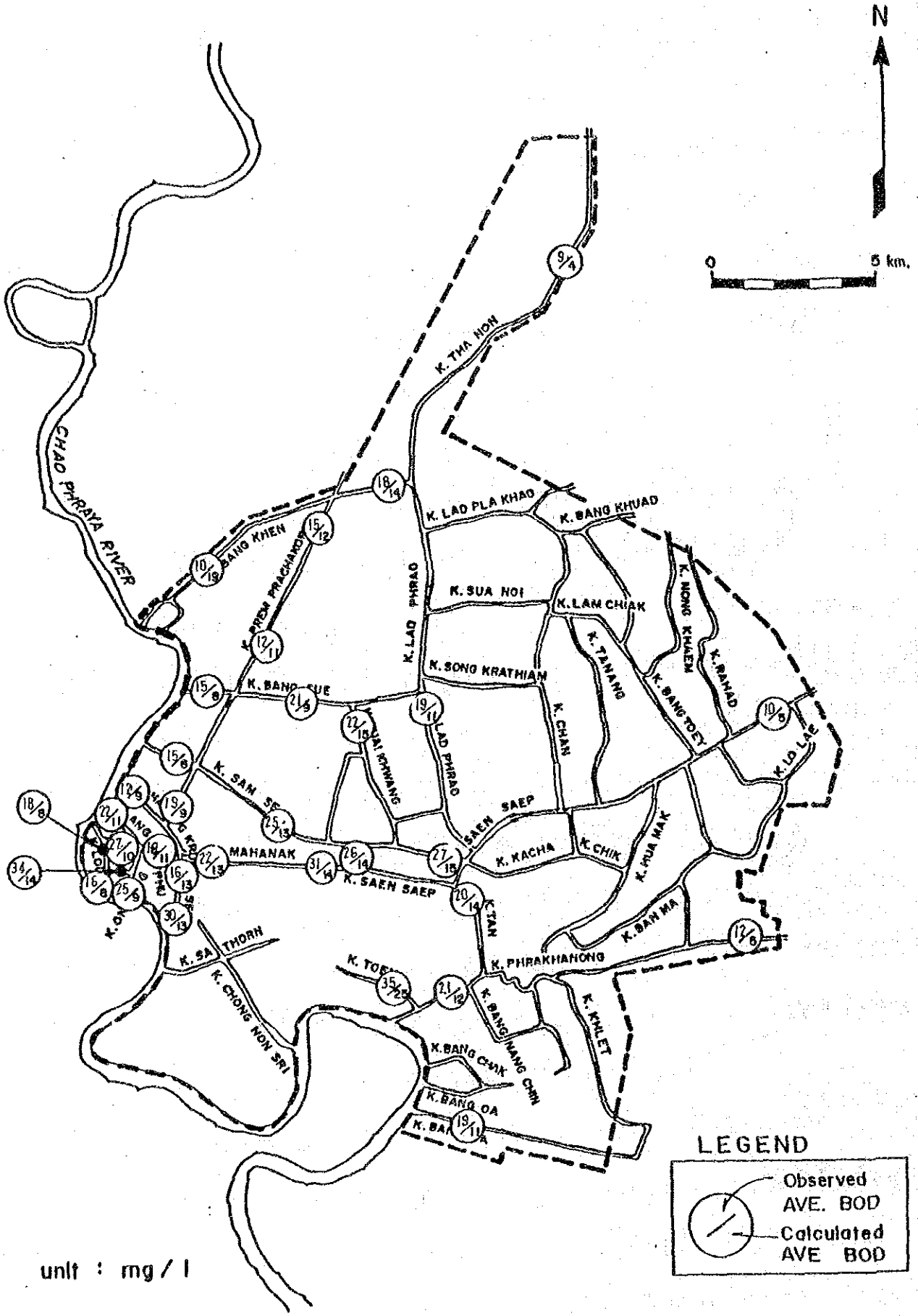

FIG. 7.6 OBSERVED AND ESTIMATED AVERAGE BOD UNDER PROPOSED DILUTION WATER INTRODUCTION IN DRY SEASON

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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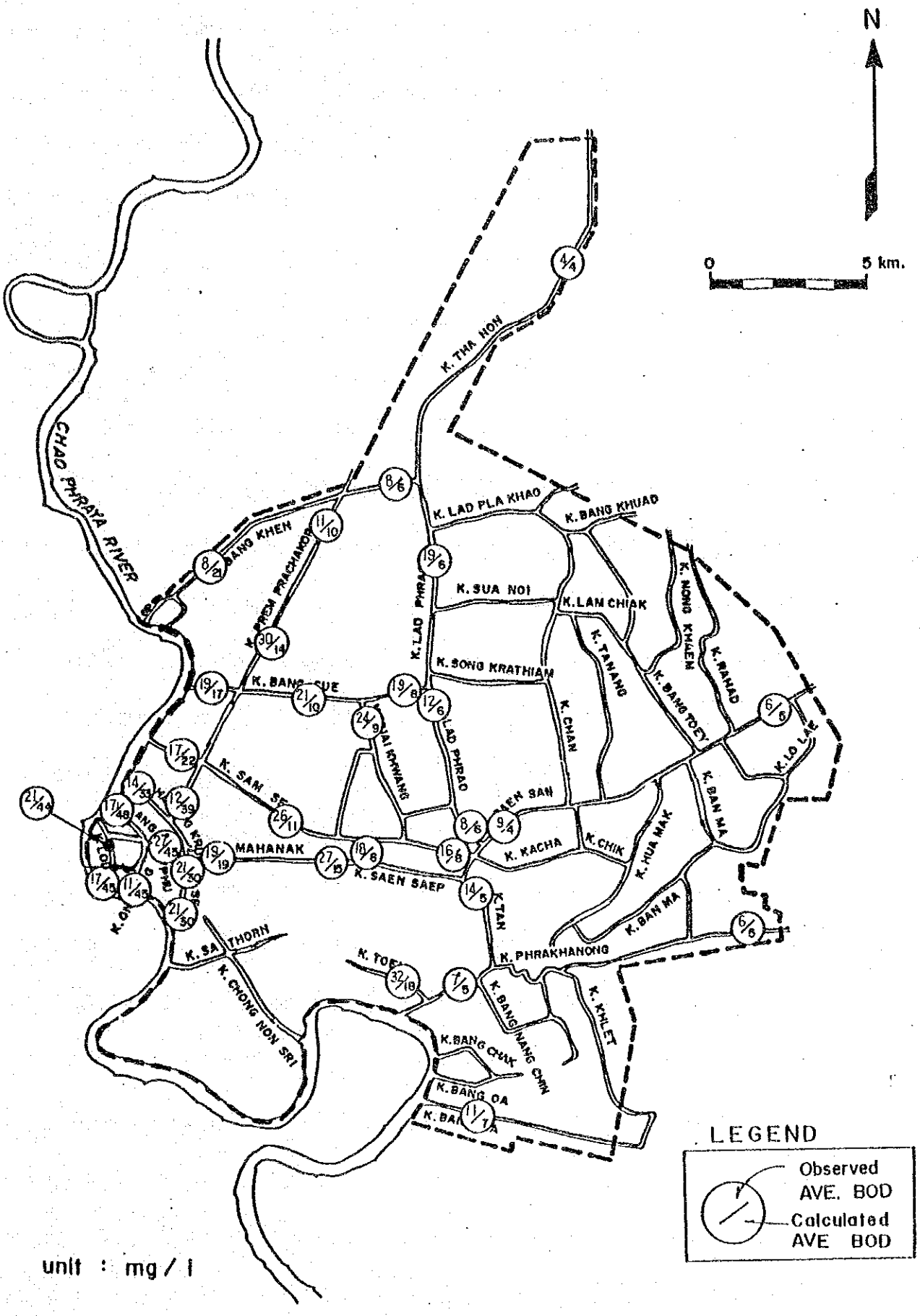

FIG. 7.7 OBSERVED AND ESTIMATED AVERAGE BOD UNDER PROPOSED DILUTION WATER INTRODUCTION IN RAINY SEASON

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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Chapter 8.

CONSTRUCTION PLAN AND COST ESTIMATE

CHAPTER 8. CONSTRUCTION PLAN AND COST ESTIMATE

8.1 Proposed Construction Plan

Proposed klong water purification plan consists of reconstruction of existing pump station, dredging of klong and construction of aerated lagoon.

8.1.1 Reconstruction of Existing Pump Station

Four (4) existing pump stations are to be reconstructed into reversible type to introduce the dilution water from the Chao Phraya River at the low tide. The proposed pump stations for reconstruction are Bang Sue, Sam Sen, Tavate and Sathorn.

(1) Bang Sue Pump Station

The proposed plan employs four (4) sets of pump among the existing 17 pumps for introduction of the dilution water. To introduce the dilution water from the Chao Phraya River, three (3) additional gates shall be constructed. No pump device is incorporated. The main features of the proposed gates are as follows.

		(H) x (W)	
- Gate I :	roller gate,	6.5 m x 6.0 m	(Type A)
- Gate II :	roller gate,	6.5 m x 3.0 m	(Type B)
- Gate III :	roller gate,	6.5 m x 6.0 m x 2 span	(Type C)

The proposed reconstruction plan is shown in Fig. 8.1.

(2) Sam Sen Pump Station

The proposed plan uses four (4) sets of pump for the introduction of dilution water among the existing 15 pumps. To introduce the dilution water from the Chao Phraya River, three (3) additional

gates are installed. No pump device is incorporated. The main features of the proposed gates are as follows.

		(H) x (W)	
- Gate I	: roller gate,	6.0 m x 6.0 m	(Type A)
- Gate II	: roller gate,	6.0 m x 3.0 m	(Type B)
- Gate III	: roller gate,	6.0 m x 6.0 m	(Type A)

The proposed reconstruction plan is shown in Fig. 8.2.

(3) Tavate Pump Station

Installation of additional two (2) sets of pump is proposed for the introduction of dilution water from the Chao Phraya River. The *main features of the proposed pump facilities are as follows.*

- Discharge capacity : 6 m^3/s (2 set x 3 m^3/s)
- Type : submersible motor pump
- Related facilities : discharge pipe, retaining wall

The proposed pump facilities are shown in Fig. 8.3.

(4) Sathorn Pump Station

Construction of additional two (2) sets of pump is proposed for the introduction of dilution water from the Chao Phraya River. The main features of the proposed pump facilities are as follows.

- Discharge capacity : 6 m^3/s (2 set x 3 m^3/s)
- Type : submersible motor pump
- Related facilities : discharge pipe, retaining wall

The proposed pump facilities are shown in Fig. 8.4.

8.1.2 Dredging of Klong

Three (3) shallow klongs: Wat Tep Tida, Wat Rajabopit and Chong Non Sri are to be dredged to carry the required dilution water. The proposed dredging works are as follows.

	Length (m)	Width (m)	Volume (m^3)	Bed EL. (M.S.L., m)
K. Wat Tep Tida	745	7.0	4,000	-1.5
K. Wat Rajabopit	1,122	6.8	8,000	-1.5
K. Chong Non Sri	3,600	6.0 ~ 10.0	77,000	-1.5 ~ -2.0
Total	5,467		89,000	

However, of these three (3) klongs, the dredging works of K. Wat Tep Tida and K. Wat Rajabopit is already under implementation by DDS. Hence, the dredging cost of these klongs are eliminated from the project cost estimation.

8.1.3. Construction of Aerated Lagoon.

Among the eight (8) potential ponds for the aerated lagoon in the Study Area, the Makkasan Pond and the Rama IX Pond are proposed to be used as Aerated Lagoon for klong water quality improvement.

(1) Makkasan Pond

The area of the Makkasan Pond is about 16 ha and pond depth is less than four (4) meter.
Total storage capacity is approximately 310,000 m^3.

The raw wastewater (klong water) to the aerated lagoon will be introduced from K. Sam Sen (discharge, 3 m^3/sec) and after being treated will be discharged into the same klong by pumping.

The conversion of Makkasan Pond into aerated lagoon mainly consists of the following works :

(i) Installation of inlet gate, outlet pump and outlet gate

(ii) Construction of central partition wall to separate the pond into two (2) longitudinal portions, consisting of an initial aeration zone followed with a final sedimentation zone, while allowing a series flow from inlet to outlet

(iii) No additional pond excavation works in required

The main features of the aerated lagoon is as follows :

- Inlet facility : stop log 5.0 m(H) x 1.5 m(W) x 2 spans
  : bar screen 5.0 m(H) x 1.5 m(W) x 2 spans
- Acrator : Floating type 11 kw 10 units
- Discharge Pump : submersible motor pump $60m^3/_{min}$ x 3m 3 units
- Control Gate : roller gate 5.0 m (H) x 4.0 m (W) (installed in K. Sam Sen)
- Partition Wall : 1,600 m (L) x 5 m (H)

The propsed construction plan is shown in Fig. 8.5

(2) Rama IX Pond

The potential pond area at Rama IX Pond is about 20 ha with a storage capacity of 300,000 m^3.

The raw wastewater to the aerated lagoon will be introduced from K. Lad Phrao (discharge, 3 m^3/sec) by pumping and after being treated will be discharged into same klong by gravity.

The conversion of Rama IX Pond into aerated lagoon mainly consists of the following works:

(i) Pond excavation works of 150,000 m^3.
(ii) Installation of inlet pump, inlet gate and outlet gate

(iii) Construction of partition walls to divide the pond into six (6) number cells while allowing a series flow from inlet to outlet. The initial five (5) cells will be utilized as aeration zones while the final one as sedimentation zone.

The main features of the aerated lagoon is as follows :

- Inlet Facility : submersible motor pump 60 $m^3/_{min}$ x 3 m 3 units
  : roller gate 6.0 m (H) x 3.0 m (W)
  : bar screen 6.0 m (H) x 3.0 m (W)
- Aerator : Floating type 11 kw 10 units
- Discharge Facility : stop log 6.0 m (H) x 1.5 m (W) x 2 spans.

The proposed construction plan is shown in Fig. 8.6.

8.2 Construction Cost Estimate

8.2.1 Basis of Cost Estimates

(1) The estimates are made on the assumption that all construction works will be contracted to general contractors through local tender.

(2) All base costs are expressed under the economic conditions that prevailed in October, 1988.

(3) Overhead including profit and tax is assumed at 30% of the total cost of equipment and civil works.

(4) Engineering service and administration costs are assumed at 10% of the total direct construction cost.

(5) A physical contingency allowance is established at 10% of the total cost of direct construction cost, engineering service cost and administration cost.

(6) Annual price escalation is considered to be 5%.

8.2.2 Estimated Project Cost

The total project cost, consisting of direct construction cost, engineering and administration costs, and physical contingency, amounts to 203.0 million Baht at October 1988 prices as given below (฿223.0 million including price escalation).

Cost Item		Amount (10^3 ฿)
A.	Direct Const. Cost	167,790
	(1) Reconst. of Ban Sue P.S.	9,280
	(2) Reconst. of Sam Sen P.S.	7,910
	(3) Reconst. of Tavate P.S.	10,370
	(4) Reconst. of Sathorn P.S.	10,420
	(5) Dredging of Klong	11,010
	(6) Const. of Aerated Lagoon at Makkasan Pond	59,500
	(7) Const. of Aerated Lagoon at Rama IX Pond	59,300
B.	Engineering & Administration Costs (10%)	16,779
C	Physical Contingency (10%)	18,456
	Total (1)	203,025
D.	Price Escalation (10%)	19,975
	Total (2)	223,000

Break-down of the direct construction cost is shown in Table 8.1.

Table 8.1 Estimated Direct Construction Cost

Work Item	Quantity	Unit Cost (B)	Amount (B)
Reconstruction of P.S.			
Ban Sue			
Coffering	40 m	11,300	452,000
Gate, Type A	1 unit	1,898,000	1,898,000
Gate, Type B	1 unit	1,374,000	1,374,000
Gate, Type C	1 unit	2,974,000	2,974,000
Floring	1 unit	38,000	38,000
R.C. Retaining Wall	20 m	20,000	400,000
Overhead (30%)			2,144,000
Total			9,280,000
Sam Sen			
Coffering	35 m	11,300	395,500
Gate, Type A	2 units	1,850,000	3,700,000
Gate, Type B	1 unit	1,351,000	1,351,000
Flooring	1 unit	39,000	39,000
R.C. Retaining Wall	30 m	20,000	600,000
Overhead (30%)			1,824,500
Total			7,910,000
Tavate			
Coffering	20 m	11,300	226,000
Pump Pit	1 unit	543,000	543,000
Pump & Electrical Eq.	2 units	3,250,000	6,500,000
Discharge Pipe	36 m	8,500	306,000
R.C. Retaining Wall	20 m	20,000	400,000
Overhead (30%)			2,395,000
Total			10,370,000
Sathorn			
Coffering	10 m	11,300	113,000
Pump Pit	1 unit	802,000	802,000
Pump & Electrical Eq.	2 units	3,250,000	6,500,000
Discharge Pipe	24 m	8,500	204,000
R.C. Retaining Wall	20 m	20,000	400,000
Overhead (30%)			2,401,000
Total			10,420,000
Dredging of Klong			
Chong Non Sri	77,000 m^3	110	8,470,000
Overhead (30%)			2,540,000
Total			11,010,000
Construction of Aerated Lagoon			
Makkasan Pond			
Aerator and Installation	10 units	950,000	9,500,000
Pump Facilities	3 units	5,600,000	16,800,000
Inlet Facilities	1 unit	3,000,000	3,000,000
Partition Wall	1,600 m	6,000	9,600,000
Coffering	10 m	11,300	113,000
Gate, 5 m (H) x 4 m(W)	1 unit	1,410,000	1,410,000
Other Miscellaneous Works			5,400,000
Overhead (30%)			13,677,000
Total			59,500,000
Rama IX Pond			
Excavation	150,000 m^3	100	15,000,000
Aerator and Installation	7 units	950,000	6,650,000
Pump Facility	3 units	5,600,000	16,800,000
Gate 6.0m (H) x 3.0 m (W)	1 unit	1,268,000	1,268,000
Outlet Facility	1 unit	1,400,000	1,400,000
Other Miscellaneous Works			4,500,000
Overhead (30%)			13,682,000
Total			59,300,000
Grand Total			167,790,000

Note: Overhead includes profit and tax.
Three (3) aerators in the existing Rama IX pond will be reused.

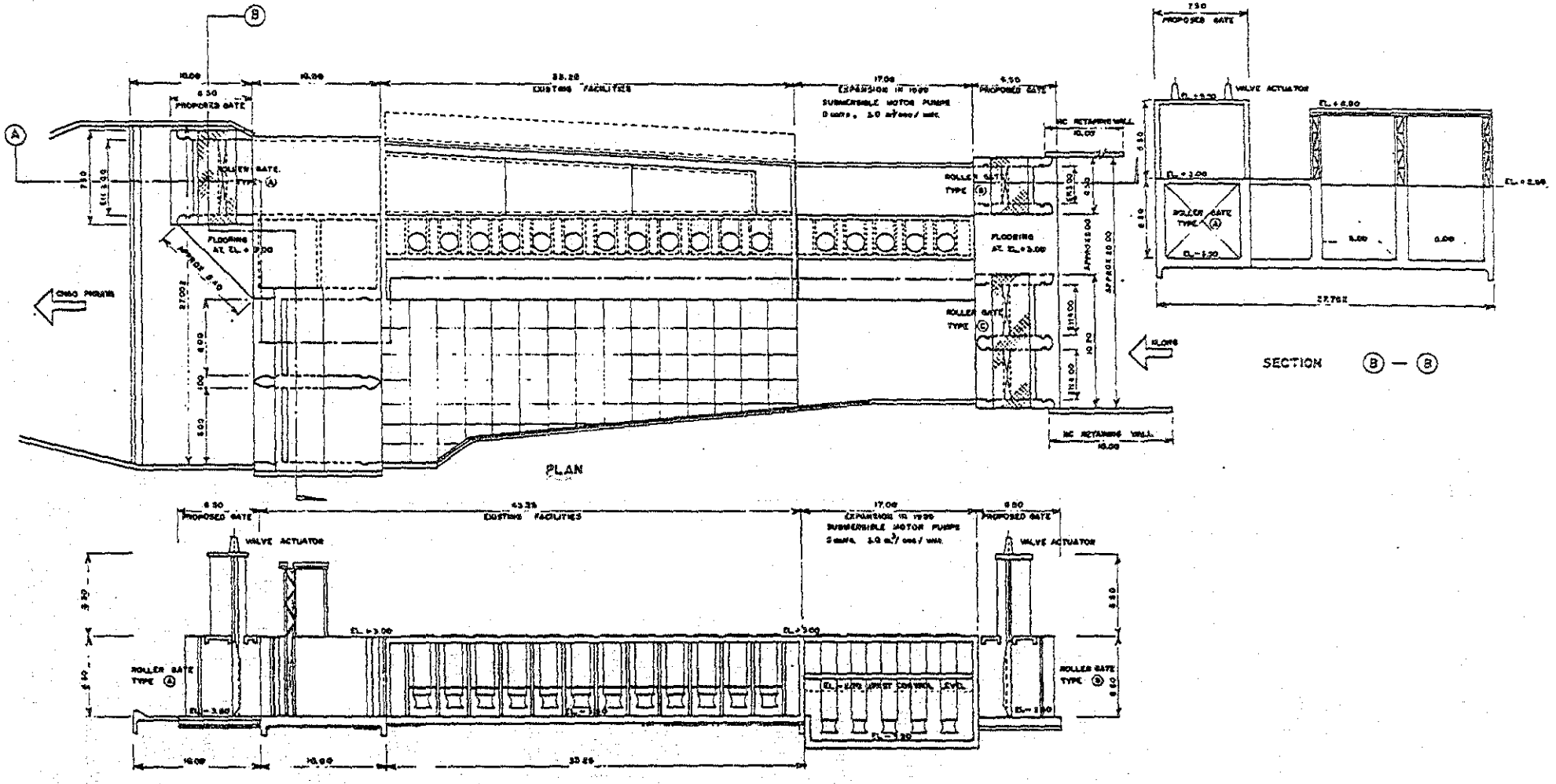

FIG. 8.1 PROPOSED RECONSTRUCTION PLAN OF BANG SUE PUMP STATION

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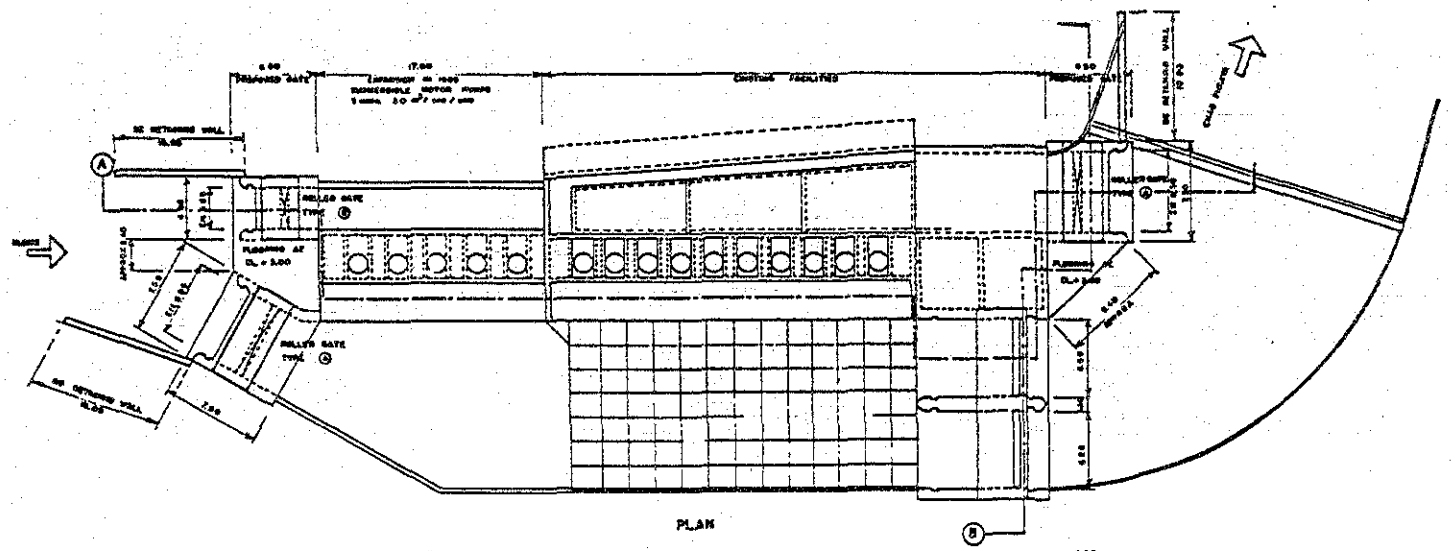
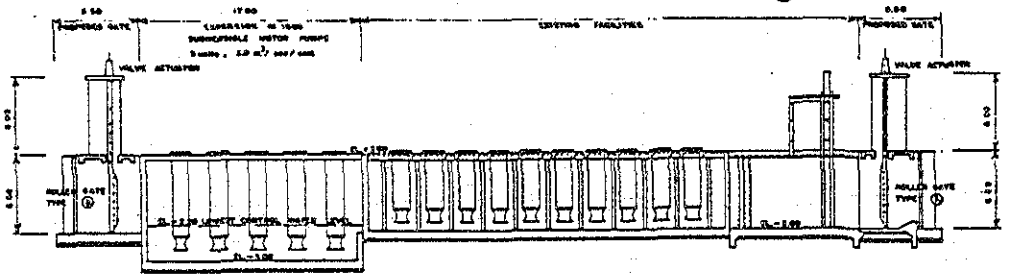
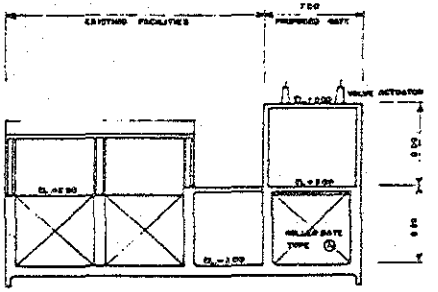




SECTION Ⓐ – Ⓐ



SECTION Ⓑ – Ⓑ

FIG. 8.2 PROPOSED RECONSTRUCTION PLAN OF SAN SEN PUMP STATION

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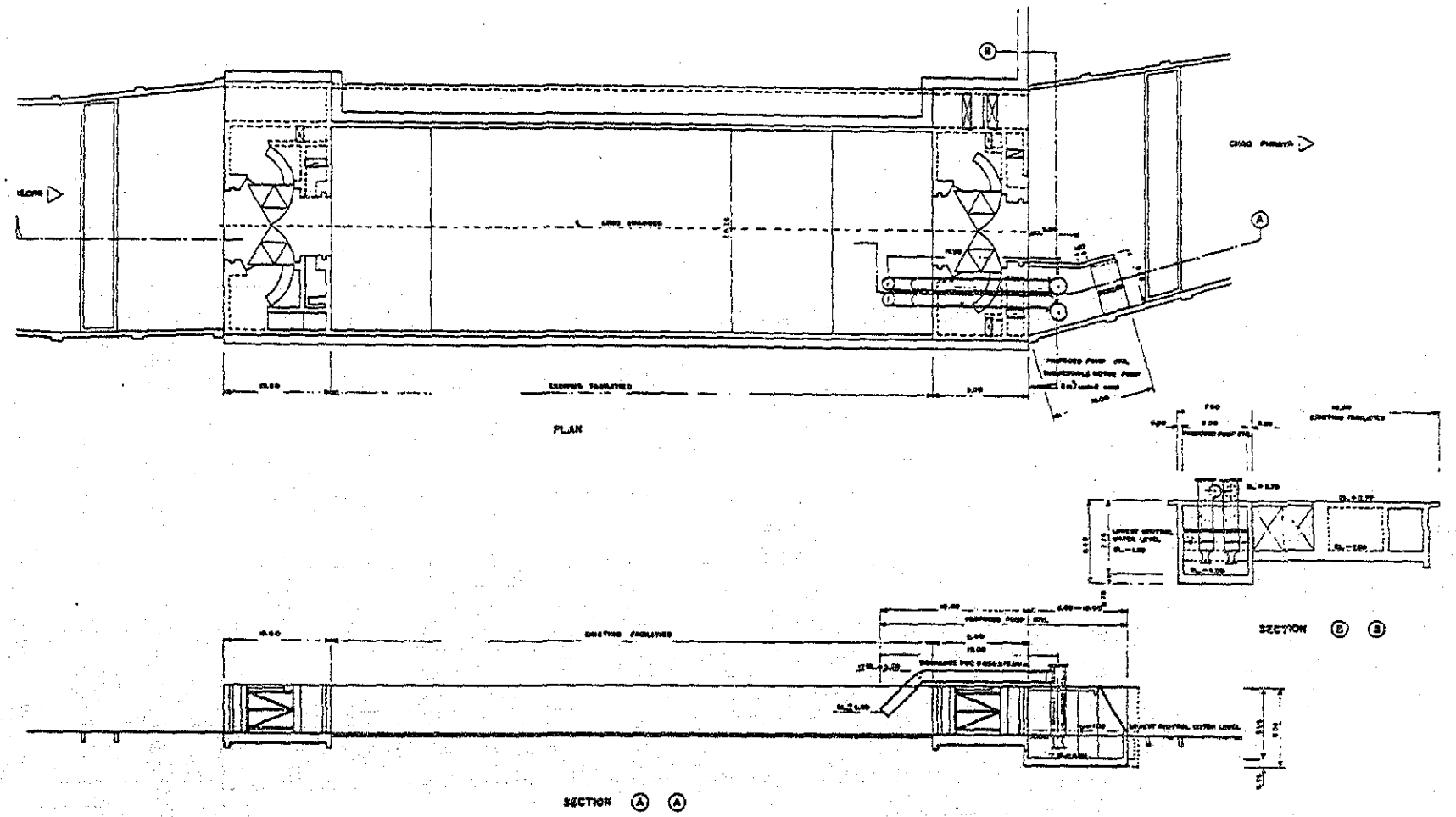

FIG. 8.3 PROPOSED IMPROVEMENT PLAN OF TAVATE PUMP STATION

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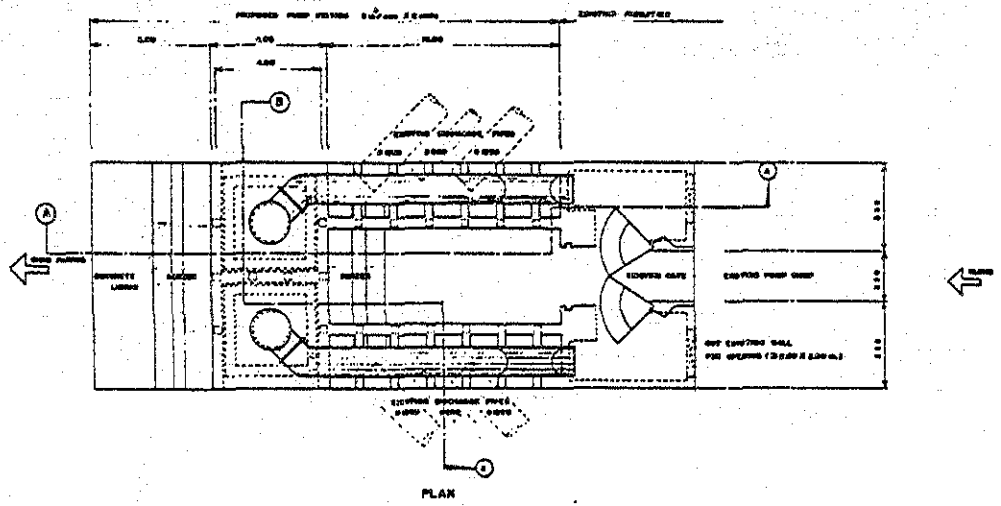

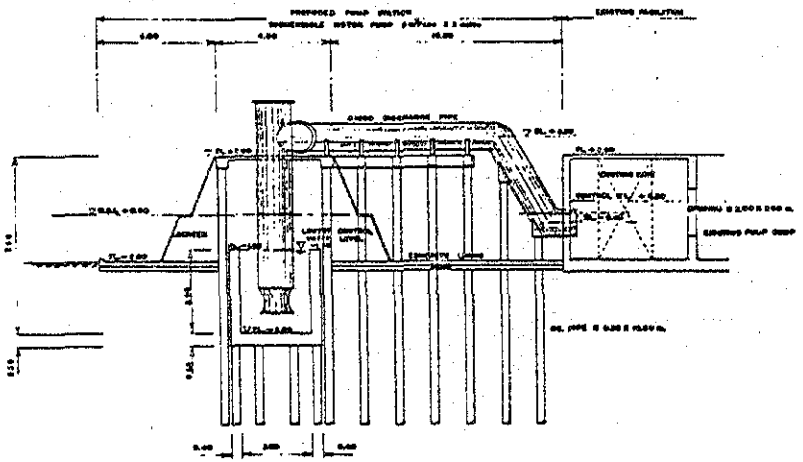

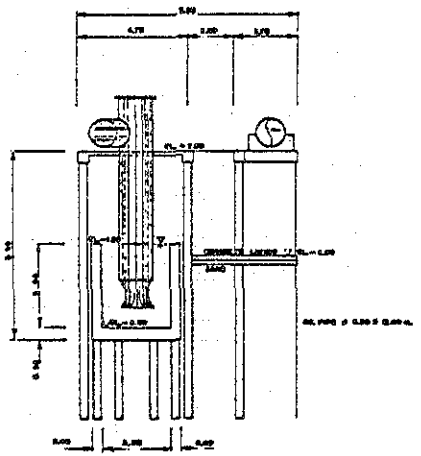

FIG. 8.4 PROPOSED IMPROVEMENT PLAN OF SATHORN PUMP STATION

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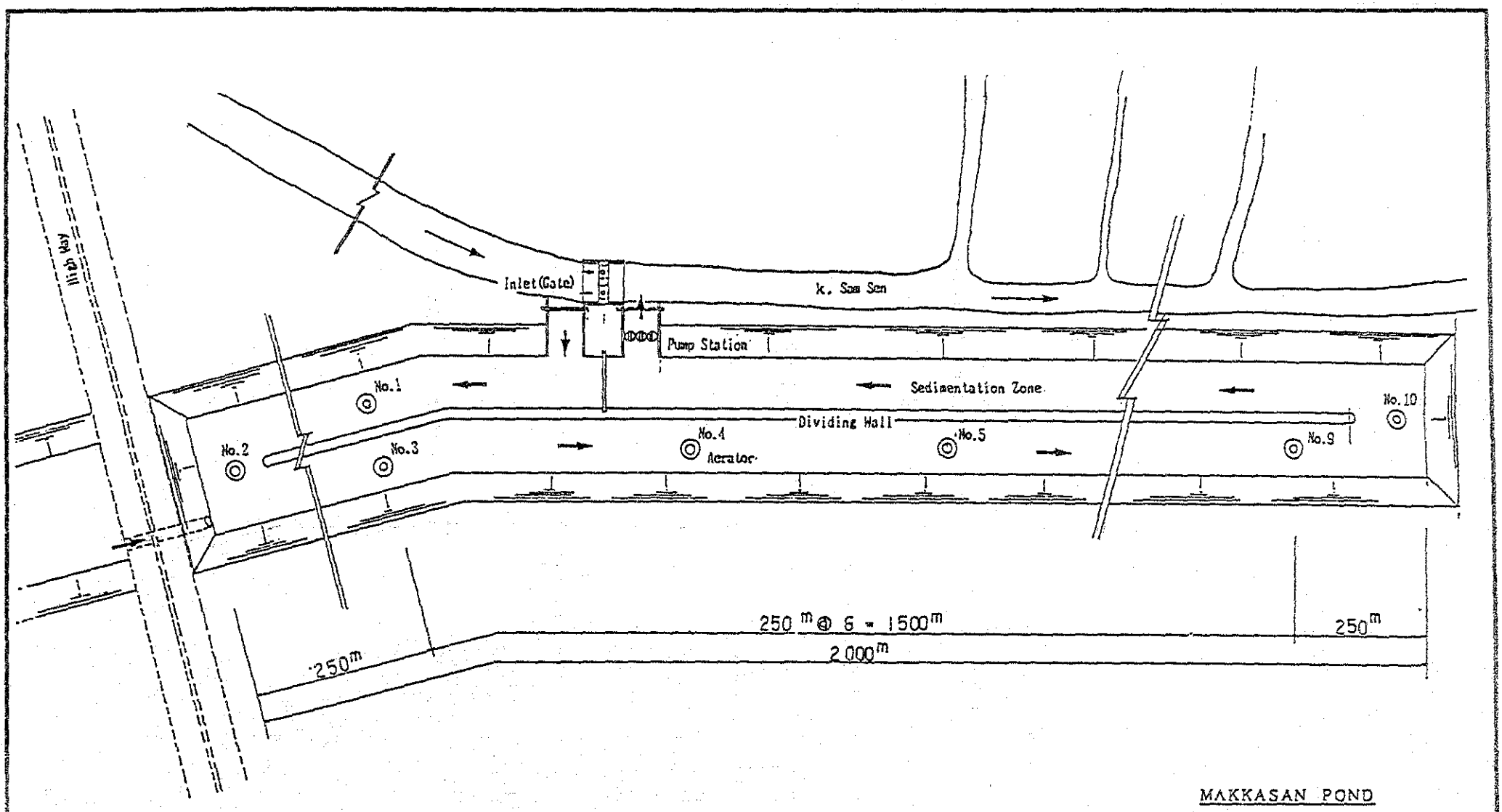

FIG. 8.5 PROPOSED CONSTRUCTION PLAN OF AERATED LAGOON IN MARKASAN POND

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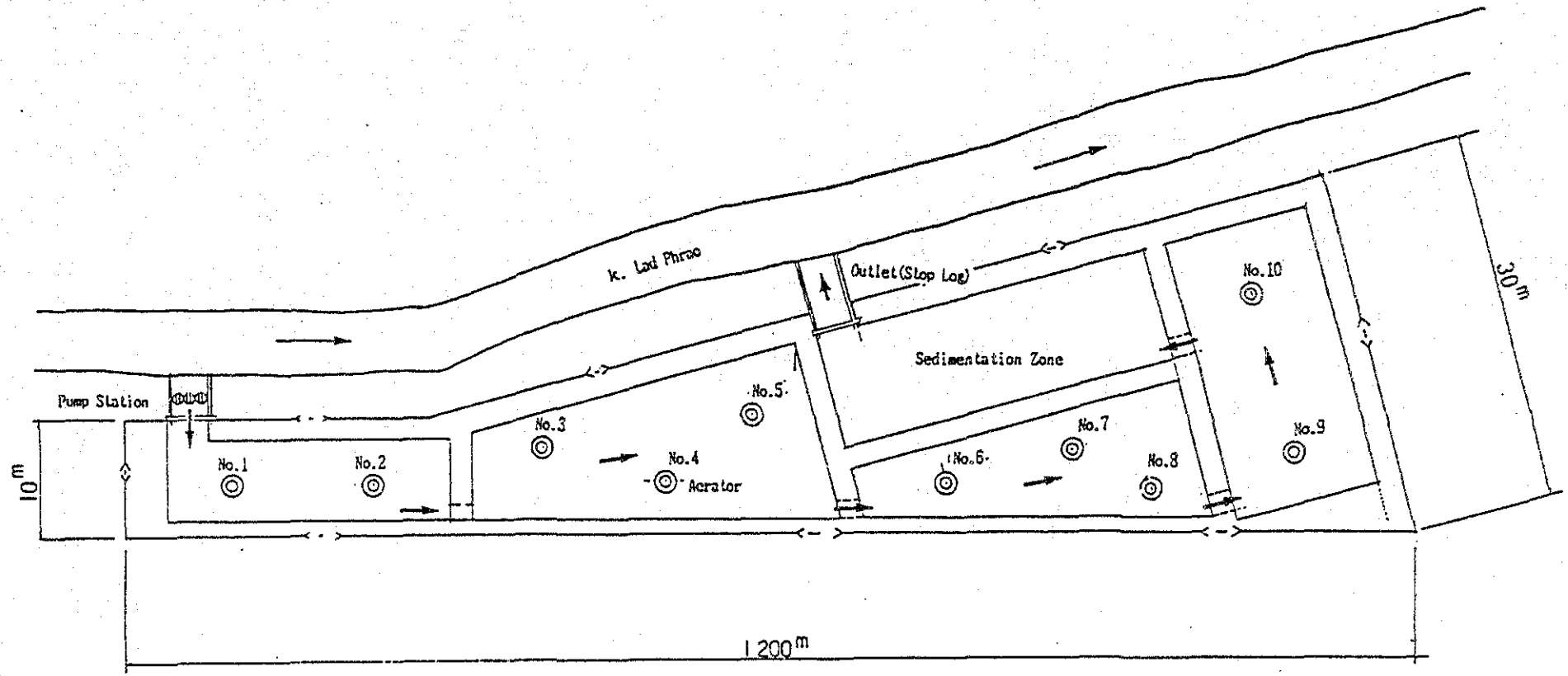

RAMA IX POND

FIG. 8.6 PROPOSED CONSTRUCTION PLAN OF AERATED LAGOON IN RAMA IX POND

THE FEASIBILITY STUDY ON PURIFICATION OF KLONG WATER IN BANGKOK

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Chapter 9.

OPERATION AND MAINTENANCE

CHAPTER 9. OPERATION AND MAINTENANCE

9.1 Operation Mode of Gate and Pump

9.1.1 Existing Operation Mode

At present the introduction of dilution water from the Chao Phraya River to the klongs for the purpose of flushing is being conducted only during dry season on an experimental basis. The dilution water is introduced during high river tide through the opened gates along the Chao Phraya River bank, namely, Bang Khen Old and New P.S., Bang Sue P.S., Sam Sen P.S., Tavate P.S., Bang Lum Phu Gate, Phra Pinklao Gate, Pak Klong Talad Gate and Ong Ang Gate. The water introduced is discharged by Krung Kasem P.S. and Phra Khanong P.S.

The responsibility concerning the operation of the pumps and gates are delegated to the personnel stationed at the respective sites.

By these dilution water introductions, the water quality of the klongs along and near the Chao Phraya River can be improved to a certain degree. However, the klongs in inland areas, such as Bang Sue, Sam Sen and Huai Kuwan, are not benefited to any significant degree.

During rainy season, the water level in the klongs are maintained low to have sufficient flood mitigation storage capacity in the klongs. In principle no dilution water is introduced from the Chao Phraya River.

9.1.2 Proposed Operation Mode

The Study Team proposes the following gate and pump operation mode for the introduction of dilution water into the klongs from the Chao Phraya River in dry season.

The proposed operational functions of the gates and pumps located along the Chao Phraya River banks, during dry season, can be classified into the following four (4) categories:

(1) Introduction of Dilution Water by Combined Gate and Reversible Pump Operations:

These measures are proposed to be conducted at Bang Sue, Sam Sen, Tavate and Sathorn Pumping Stations. While the dilution water is being introduced from the Chao Phraya River, the inner water levels of the pump stations are to be maintained below +0.70m M.S.L. at Bang Sue, Sam Sen and Tavate Pumping Stations, and +0.40m M.S.L. at Sathorn Pumping Station.

- During low tide periods, the dilution water shall be introduced by operating the reversible pump.
- During high tide periods, the dilution water shall be introduced by opening the gate.

(2) *Introduction of Dilution Water by Gate Operation Only*

The introduction of dilution water by gate operation only is proposed at the four (4) gates in Ratanakosin Area, namely, Bang Lum Phu, Phra Pinklao, Pak Klong Talad and Ong Ang.

While the dilution water is being introduced from the Chao Phraya River through the opened gates, the inner water level be maintained below +0.70m M.S.L..

- The dilution water shall be introduced through the opened gate at high tide.
- The gate shall be closed at low tide.

(3) Introduction of Dilution Water by Normal Pump and Gate Operation

Bang Khen Old and New pump stations shall continue to be operated by the same mode as present. At high tide period, the dilution water be introduced through the opened gates, while at low tide, the water in the klongs be discharged to the Chao Phraya River through the same gates.

(4) Discharge by Pump and Gate Operations

These measures are proposed to be conducted at the Krung Kasem, Chong Non Sri, and Phra Khanong pumping stations.

The inner water level shall be maintained below +0.30m M.S.L. at Krung Kasem pump station, ±0.00m M.S.L. at Phra Khanong pump station and +0.30m M.S.L. at Chong Non Sri pump station. When the outer water level is lower than the inner water level, the klong water be discharged through the opened gates. When the outer water level is higher than the inner water level, the klong water be discharged by pump.

9.2 Monitoring System

For satisfactory attainment of the dilution water introduction from the Chao Phraya River, the following improvements to the existing monitoring systems is proposed. The items of monitoring shall be comprised of klong water quality, water stage, rainfall and operating conditions of pumps and gates.

9.2.1 Monitoring of Klong Water Quality

It is not necessary to conduct a real time continuous monitoring of the klong water quality for this project. It is proposed to continue with the existing periodical klong water monitoring programme conducted by DDS, unchanged. Obtained data shall be compiled and utilized for effective pump and gate operations to optimize the dilution water introduction.

For ensuring the effectiveness of monitoring and the preservation of klong water quality, the analysis of toxic compounds and heavy metals shall also be incorporated as the monitoring parameters of klong water quality. The compounds recommended for monitoring are as follows:

CN, Alkyl Hg, Organophosphate, Pb, Cr^{6+}, As, F and Cd.

9.2.2 Monitoring of Water Stage and Pump and Gate Operation Conditions

For estimating the required quantity of dilution water for introduction and discharge from and to the Chao Phraya River, the hourly water stage, and pump and gate operation conditions at the following 13 stations shall be monitored.

- Bang Khen Old P.S., Bang Khen New P.S., Bang Sue P.S., Sam Sen P.S., Tavate P.S., Bang Lum Phu Gate, Phra Pinklao Gate, Pak Klong Talad Gate, Ong Ang Gate, Krung Kasem P.S., Sathorn P.S., Chong Non Sri P.S. and Phra Khanong P.S. (Ref. Fig. 9.1)

For estimating the quantity of the introduced surplus irrigation water from the north and east boundary areas, the hourly water stage and the operating conditions of gates at the following three (3) stations shall be monitored.

- K. Song Gate at Don Muang, K. Saen Saep Gate in Minburi and K. Phra Khanong Gate in Lat Krabang. (Ref. Fig. 9.1)

9.2.3 Monitoring of Rainfall

Three (3) rainfall monitoring stations are proposed for this project. While the pumps and gates are operated under the mode of dilution water introduction to the klongs, an occurrence of sudden heavy rainfall may require immediate change in the operation mode of pumps and gates, to storm water drainage of flood control, based on the monitored rainfall. As the rainfall monitoring stations in the Study

Area, the three monitoring stations that are under implementation as a separate project, "The Procurement of Equipment for Flood Control Center in Bangkok and its Vicinity", are proposed to be used for this project as well. The locations of the proposed monitoring stations, at K. Lad Phrao in Bang Khen, Flood Control Center in Din Deang and K. Saen Saep in Bang Kapi, are shown in Fig. 9.1.

9.3 Operation and Maintenance Cost for Proposed System

The propsed system of klong water quality improvement consists of dilution water introduction from the Chao Phraya River, dredging of klongs to facilitate dilution water infroduction and aerated lagoon treatment of klong water.

(1) Cost of Dilution Water Introduction

The klong water quality improvement plan by the introduction of dilution water will utilize either all or a portion of the existing flood protection facilities.

The facilities to be utilized for the water quality improvement (purification) plan are as follows:

Name of Facility	Present Pump No. and Capacity	Pump Capacity to be Used to Introduce and Discharge Dilution Water
K. Bang Sue P. St.	17 x 3 m^3/sec = 51 m^3/sec	4 x 3 m^3/sec = 12 m^3/sec
K. Sam Sen P. St.	15 x 3 m^3/sec = 45 m^3/sec	4 x 3 m^3/sec = 12 m^3/sec
Tavate P. St.	5 x 1 m^3/sec = 5 m^3/sec	2 x 3 m^3/sec = 6 m^3/sec
Krung Kasem P. St.	5 x 5 m^3/sec = 25 m^3/sec	1 x 5 m^3/sec = 5 m^3/sec
Phra Khanong P. St.	35 x 3 m^3/sec = 105 m^3/sec	5 x 3 m^3/sec = 15 m^3/sec
Chong Non Sri P. St.	2 x 1 m^3/sec	2 x 1 m^3/sec

	+ 1 x 0.5 m^3/sec = 2.5 m^3/sec	+ 1 x 0.5 m^3/sec = 2.5 m^3/sec
Sathorn P. St.	2 x 3 m^3/sec = 6 m^3/sec	2 x 3 m^3/sec = 6 m^3/sec

By assuming the period of dilution water introduction in a year is 8 months, from November to June, the total annual operating hours of pumps for water quality improvement at each pumping station will be as follows:

Bang Sue P. St.	14,048 hour.unit
Sam Sen P. St.	10,072 hour.unit
Tavate P. St.	4,244 hour.unit
Sathorn P. St.	4,416 hour.unit
Phra Khanong P. St.	48,480 hour.unit
Chong Non Sri P. St.	4,066 hour.unit
Krung Kasem P. St.	7,832 hour.unit

Based on the above operating hours, the annual pump operating costs for the water quality improvement plan is estimated as follows:

Pumping Station	Electricity Charges (million Baht)
Bang Sue P. St.	5.3
Sam Sen P. St.	3.8
Tavate P. St.	1.6
Sathorn P. St.	1.7
Phra Khanong P. St.	18.4
Chong Non Sri P. St.	1.5
Krung Kasem P. St.	2.4
Total	34.7

Since the personnel expenditures for the operation and maintenance of pumping stations and the costs of repairs has been appropriated in the flood protection plan, they shall not be included in the water quality improvement plan. However, the

repair costs for the pumps and gates to be installed for the purpose of dilution water introduction only are estimated at 121,000 Baht/year (5% of the total construction cost).

Assuming the average service years of pumps as 7 years, it is decided to appropriate the pump replacement costs of water quality improvement plan by proportioning the operating time for the water quality improvement plan to that of the flood protection plan. The estimated portion of pump replacement costs for the water quality improvement plan are as follows:

Foreign portion : 6.21 million Baht per annum
Local portion : 0.47 million Baht per annum

(2) Cost of Aerated Lagoon Treatment

Aerated lagoon is one of the economical wastewater treatment system in tropical regions if adequate land is available.

By assuming the proposed aerated lagoons at Makkasan Pond and Rama IX Pond operate all the year round, the total annual operation hours of pumps and aerators are estimated at 26,280 hrs and 87,600 hrs, respectively. The total annual electrical charge for operation of the two aerated lagoons is approximately 6.3 million Baht.

The personnel expenditures for the operation and maintenance of these aerated lagoons is about 1.3 million Baht per annum.

The personnel proposed to be assigned for each aerated lagoon treatment plant is given below.

	Makkasan Pond	Rama IX Pond
Chief	1	1
Mechanical Engineer	1	1
Electrical Engineer	1	1
Workers	3	3
Total	6	6

Assuming the average depreciation (service life) of pumps and aerators as seven (7) years, the annual replacement cost of pumps and aerators are estimated as follows :

	Pumps	Aerators
Foreign portion	: 4.18 million Baht per annum	2.4 million Baht per annum
Local portion	: 0.32 million Baht per annum	0.31 million Baht per annum

(3) Other Operation and Maintenance Cost

Other necessary work for the klong water purification project will be:

- Periodical water quality monitoring
- Data collection and processing, preparation of pump and gate operating methods, and transmission of the operating instructions

The above work is assumed to be conducted as a part of the DDS's routine work in the Flood Control Operation Center. Therefore, the operation and maintenance costs related to the above work was not appropriated for the klong water purification project.

(4) Annual Operation and Maintenance Cost

The total annual operation and maintenance cost of the proposed system of klong water purification plan is 56.3 million Baht per annum.

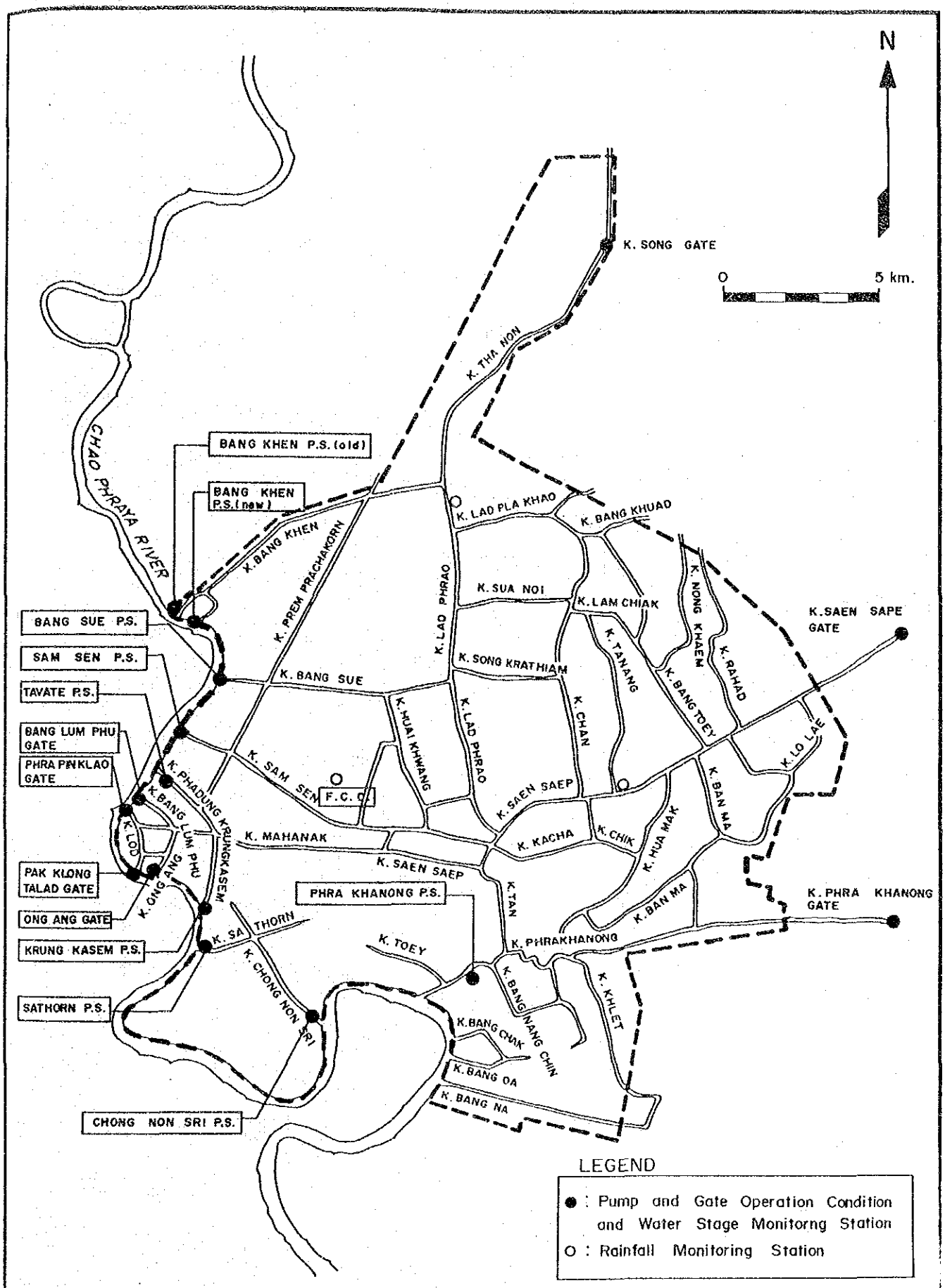

FIG. 9.1 LOCATION OF PROPOSED MONITORING STATIONS

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Chapter 10.

PROJECT EVALUATION

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10.1 Estimation of Benefits

10.1.1 General

The benefits by the proposed klong water purification project is limited to the dry season of eight (8) months (November - June) only. In rainy season (July - October), the gates on the Chao Phraya River are closed and no dilution water is introduced in principle. The klong water quality is left as it is, with no improvement.

Primary benefits are composed of 5 benefits, namely positive impacts on klong transport, klong floating market and public health/hygiene, greater use of klong water for living and greater use of klongs for recreation. Such benefits as removal of obnoxious odour, disappearance of repulsive blackish water, recovery of ecology in klong water and positive impact on tourism were not quantified, and are left as intangible benefits.

10.1.2 Positive Impact on Klong Transport and Floating Market

To estimate benefit in a particular year for klong transport, firstly, the annual incremental frequency (in times) of the use of klong transport per household is estimated. Secondly, profit per time per customer for klong transport operators is estimated. Thirdly, the number of households in the project area in the particular year is estimated. Finally, these three estimates are mutually multiplied. It is expected that full benefits of klong water purification will be realized from 1992 onwards. The benefit for klong transport in 1992 is calculated at Baht 4.3 million.

Similarly the benefit for klong floating market in 1992 is calculated at Baht 17.3 million.

10.1.3 Positive Impact on Health & Hygiene

Contribution to the improvement of hygiene/health and to the reduction in diseases is one of the most important effects of klong water purification according to the results of the sampling investigation. However, qualification of such a benefit is very difficult and no fixed methodology for it has been developed.

It is noticed that the incidence of Japanese encephalitis in Bangkok is disproportionately high, and according to authoritative sources it is directly connected with the existing turbid, stagnant state of klong water. Thus, the reduction of this disease is estimated as representative health benefit, and the resultant benefit in 1992 is calculated at Baht 12.9 million.

10.1.4 Greater Use of Klong Water for Living

The basic philosophy in estimating benefit to be derived from greater use of klong water for living is that it will reduce the requirements for urban water, which in turn will save the cost to construct and operate/maintain water supply system. Accordingly, the corresponding benefit in 1992 is calculated at Baht 27.2 million.

10.1.5 Greater Use of Klongs for Recreation

The basic philosophy in estimating benefit to be derived from greater use of klongs for recreation is that it will reduce the requirements for recreational facilities, thus saving the cost to construct and operate/ maintain such facilities. The corresponding benefit in 1992 is calculated at Baht 0.1 million.

10.1.6 Willingness to Pay

The total amount of tax the households in the project area are willing to pay, is an indication on the extent of the benefits that could be derived from the purification of klong water. It is estimated at Baht 65.5 million in 1992, which is incidentally similar to the summation of

the five quantified primary benefits in the same year (Baht 61.9 million). There are other important primary benefits such as removal of obnoxious odor and disappearance of repulsive blackish water. Hence, the total benefits the households concerned will derive from klong water purification will be much higher than Baht 61.9 million.

10.1.7 Impact on Land Value

Supposing the benefits of klong water purification were fully realized in 1988, the total incremental value of residential space in the project area in the same year is estimated at Baht 6,179.6 million.

Actually the project for the purification of klong water will start in 1990 and the project benefits will be fully realised in 1992, and the present value (PV) of the total incremental value of residential space in the project area works out at Baht 4,398.5 million.

10.2 Economic Evaluation

10.2.1 Benefits and Costs

Five benefits, namely benefit for klong transport, benefit for klong floating market, health benefit, greater use of klong water for living and greater use of klongs for recreation have been incorporated as the project benefits.

The project costs are divided into construction costs and operation/ maintenance costs.

The former are composed of;

- Reconstruction costs of the pump stations for dilution water introduction
- Dredging costs of the klongs
- Construction costs of the aerated lagoon treatment system

The latter are composed of;

- Power costs of the pump stations
- Power costs of the aerated lagoon treatment system
- Other O&M costs of the pump stations and aerated lagoons
- Replacement costs of the pumps and aerators

10.2.2 Economic Analysis

Project life is assumed to be 21 years.
The economic rate of return (EIRR) of the Project is determined to be 5.5%.

10.3 Impact of the Project on Water Quality of Chao Phraya River

Introduction of dilution water from the Chao Phraya River to the klongs may reduce the self purification potential of the klongs, resulting in an increase of pollution load run-off to the Chao Phraya River from the klongs.

Self purification due to settlement and biological dissolution of pollution loads in the klongs would generally decrease with decreasing retardation of the klong water and with decreasing concentration of pollution load in the klong water. Introduction of dilution water and its increase will lead to reduction in self purification capacity of the klongs resulting in increased pollution load to the Chao Phraya River.

BOD load balance of the Study Area in dry season for "Existing Condition" and "With Project" are calculated based on the results of the aerated lagoon treatment of Chapter 6 and of the klong water simulation of Chapter 7 and is illustrated in Fig. 10.1.

The increase in BOD load to the Chao Phraya River by the project component of dilution water introduction is estimated to be 3,800 kg/day. On the other hand, pollution load that would be reduced by the project component of aerated lagoon treatment amounts to 4,470 kg/day as BOD. As a result, the klong water purification project as a