FIGURES

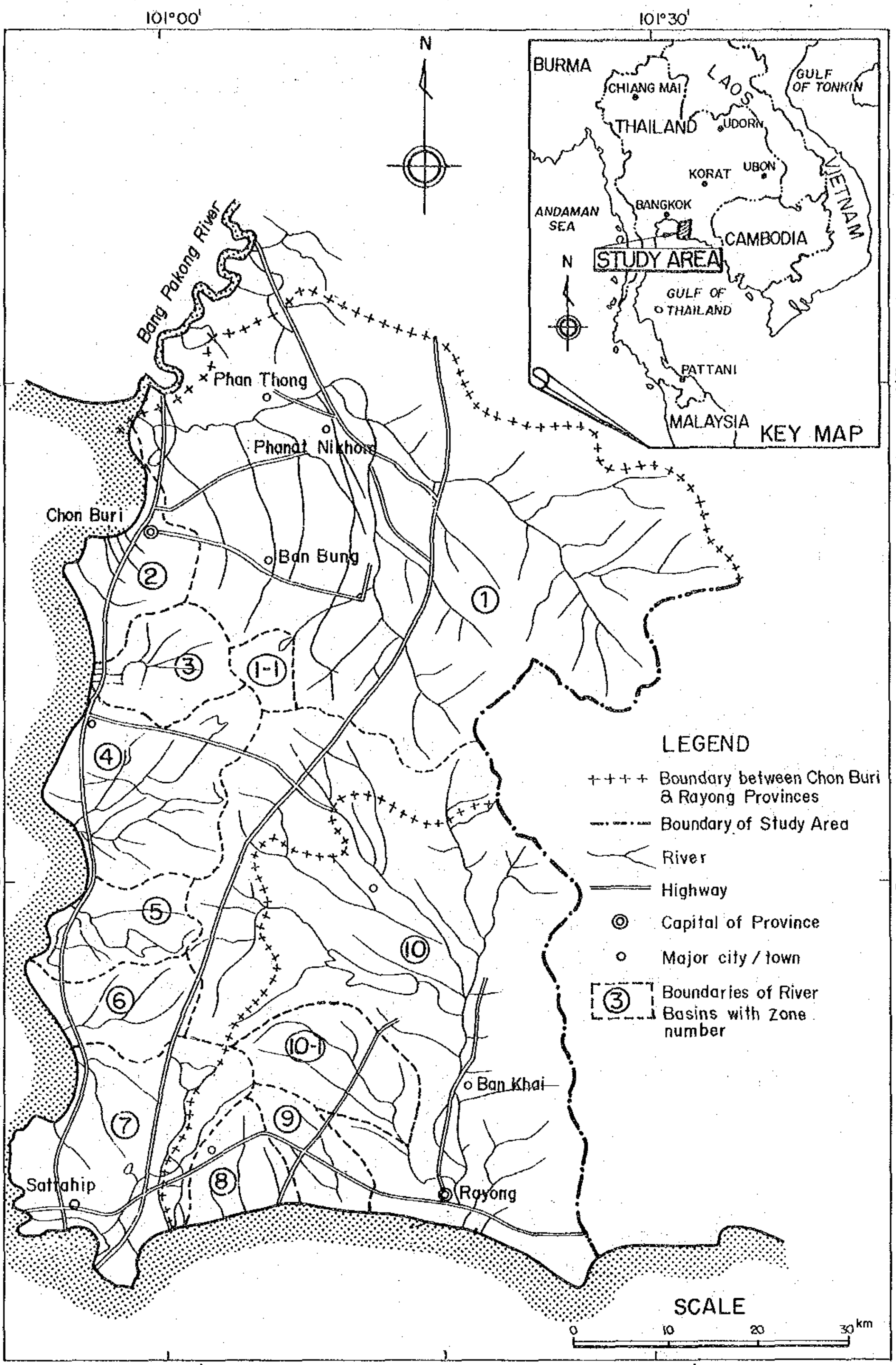

Fig. 1 Division of Study Area

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THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
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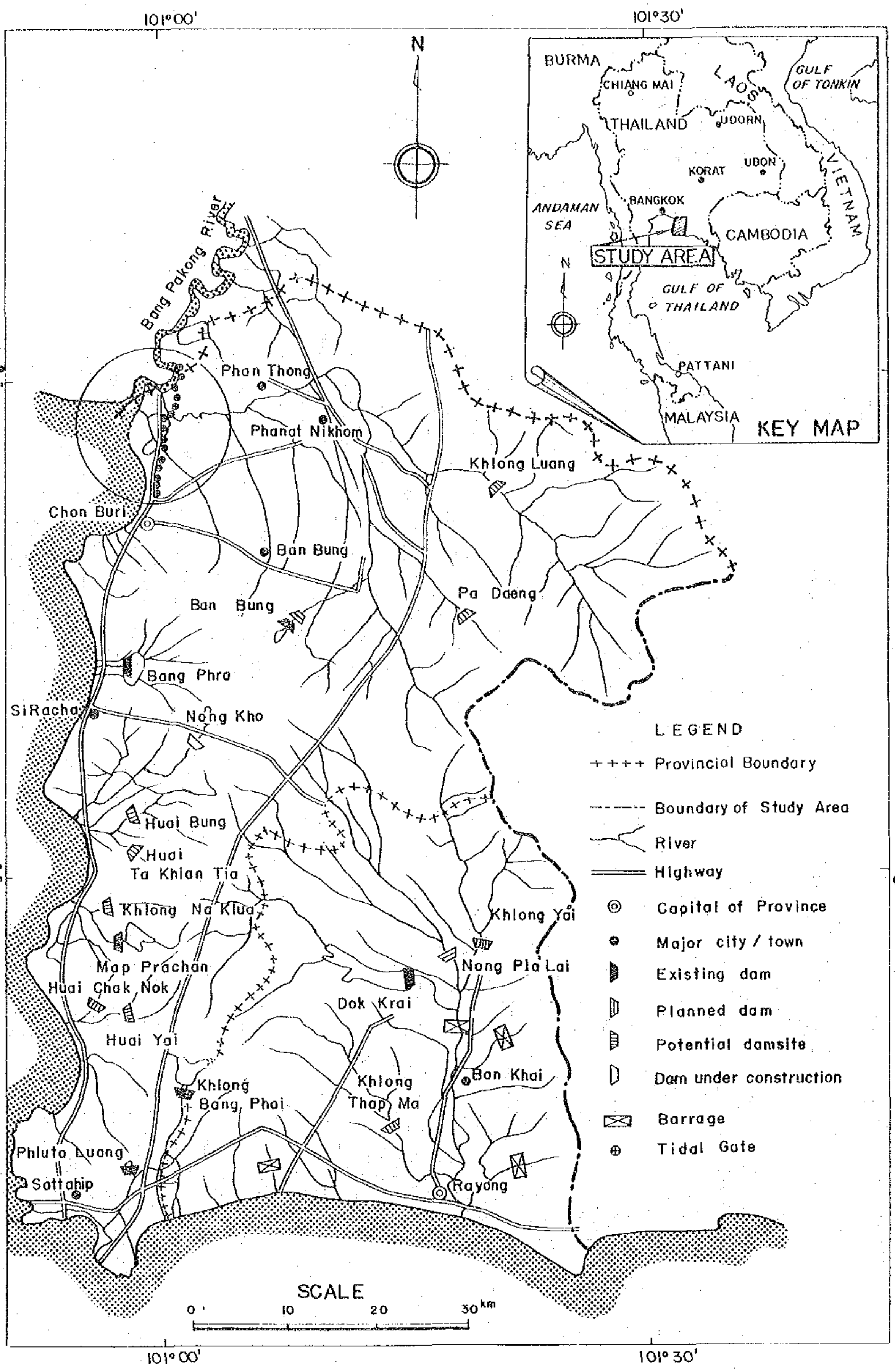

Fig. 2 Location of Dams, Barrages and Tidal Gates

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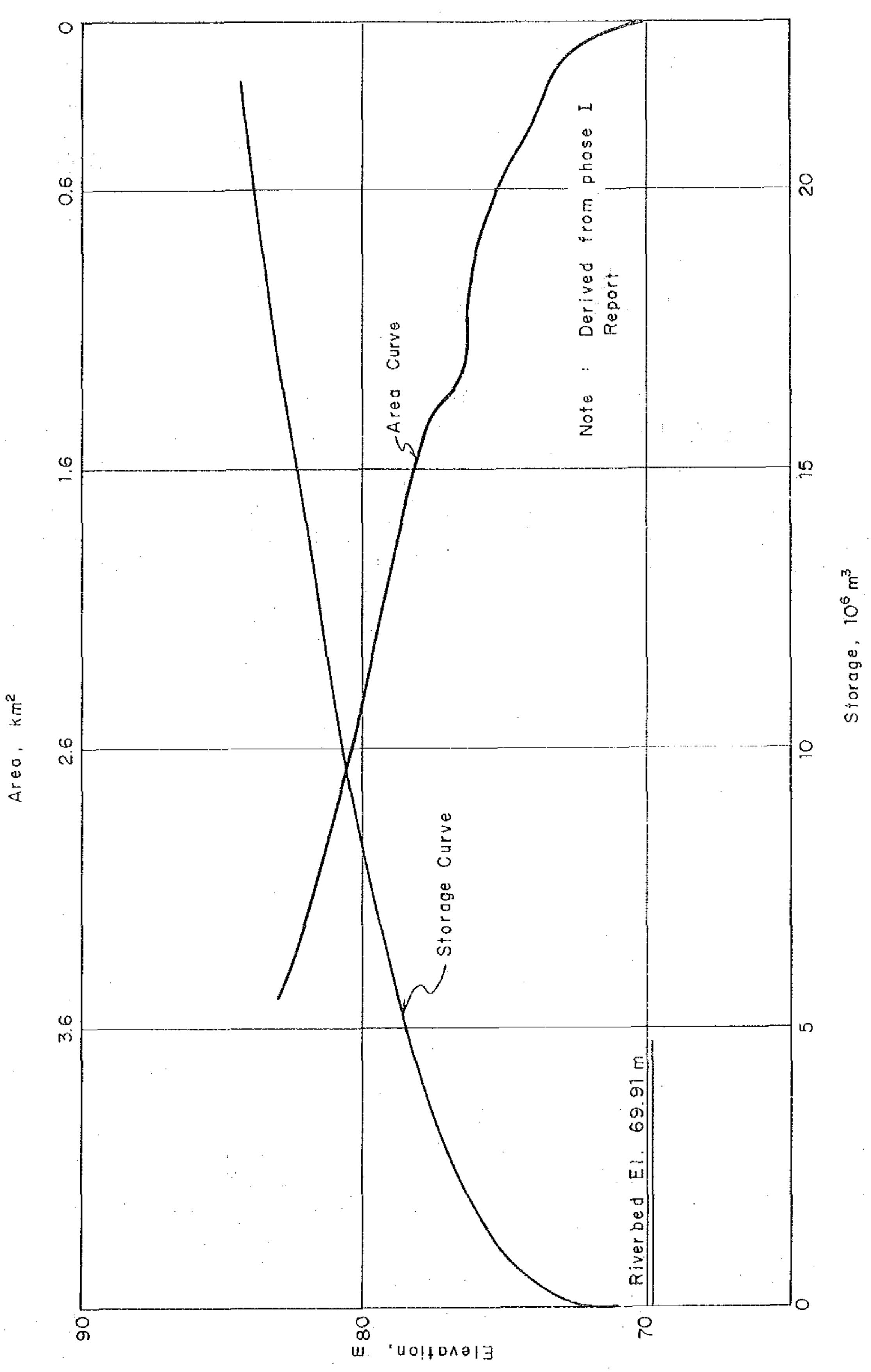

Fig. 3 Ared – Storage Curve, Ban Bung Reservoir

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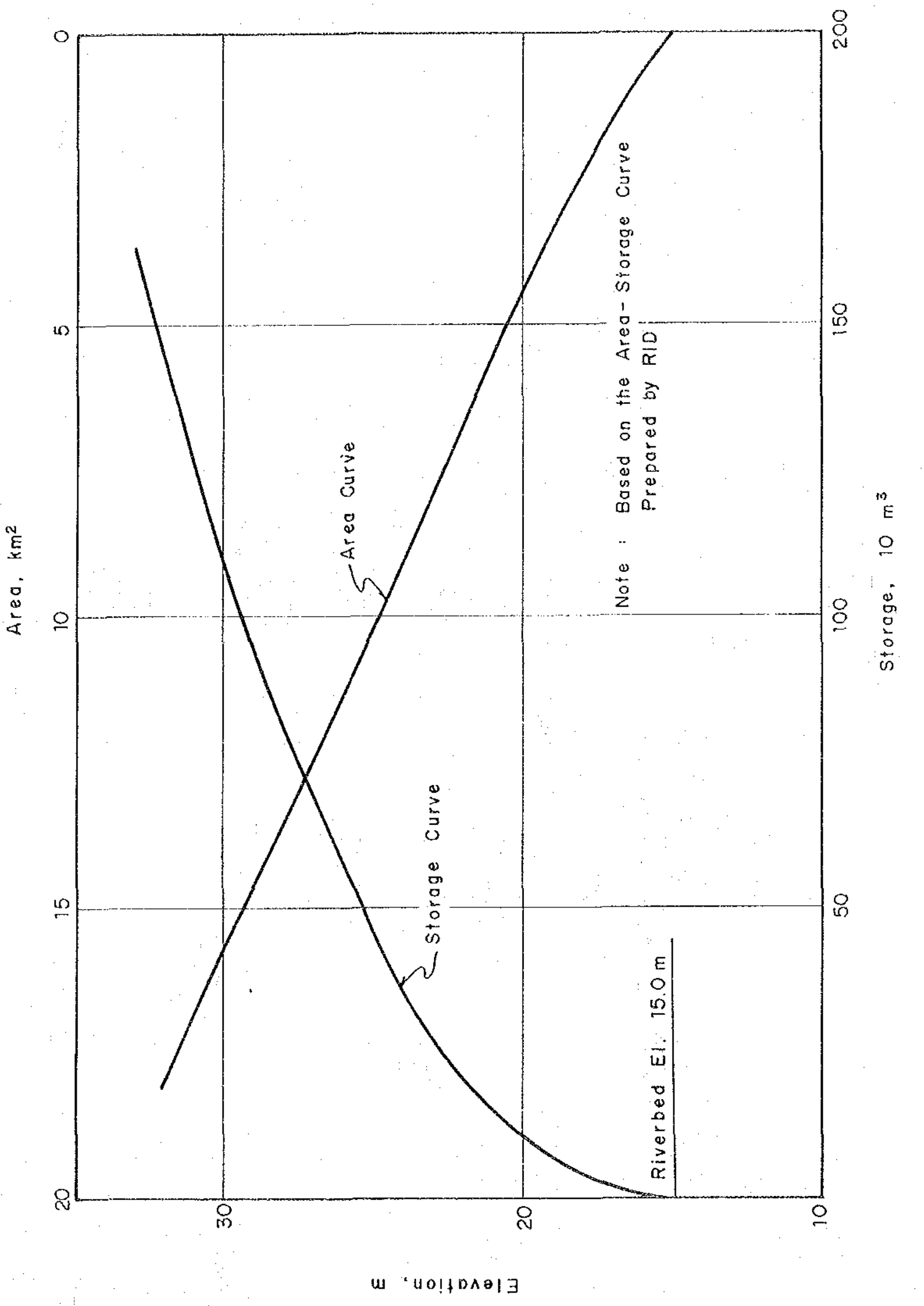

Fig. 4 **Area – Storage Curve, Bang Phra Reservoir**

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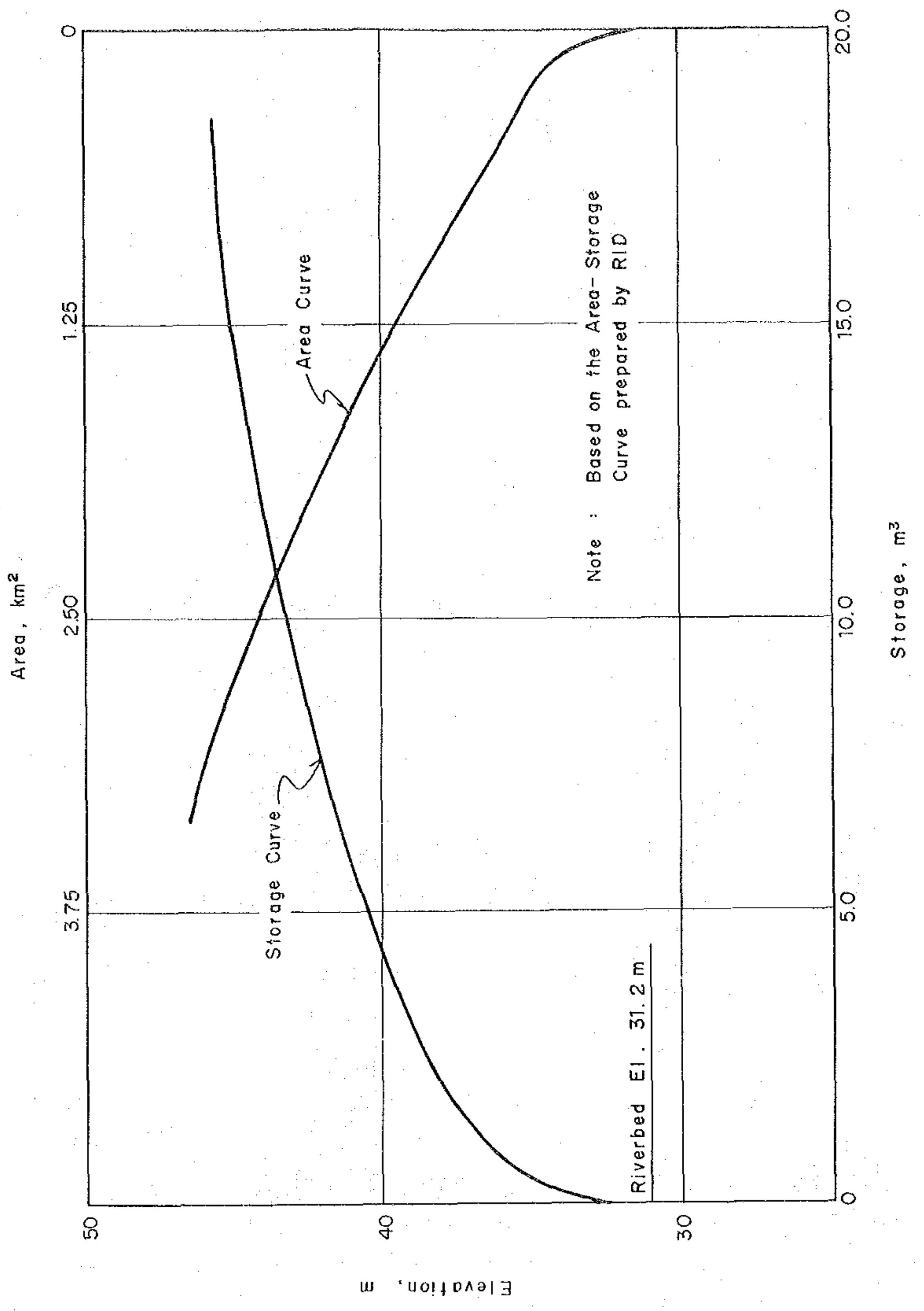

Fig. 5 Area – Storage Curve, Map Prachang Reservoir

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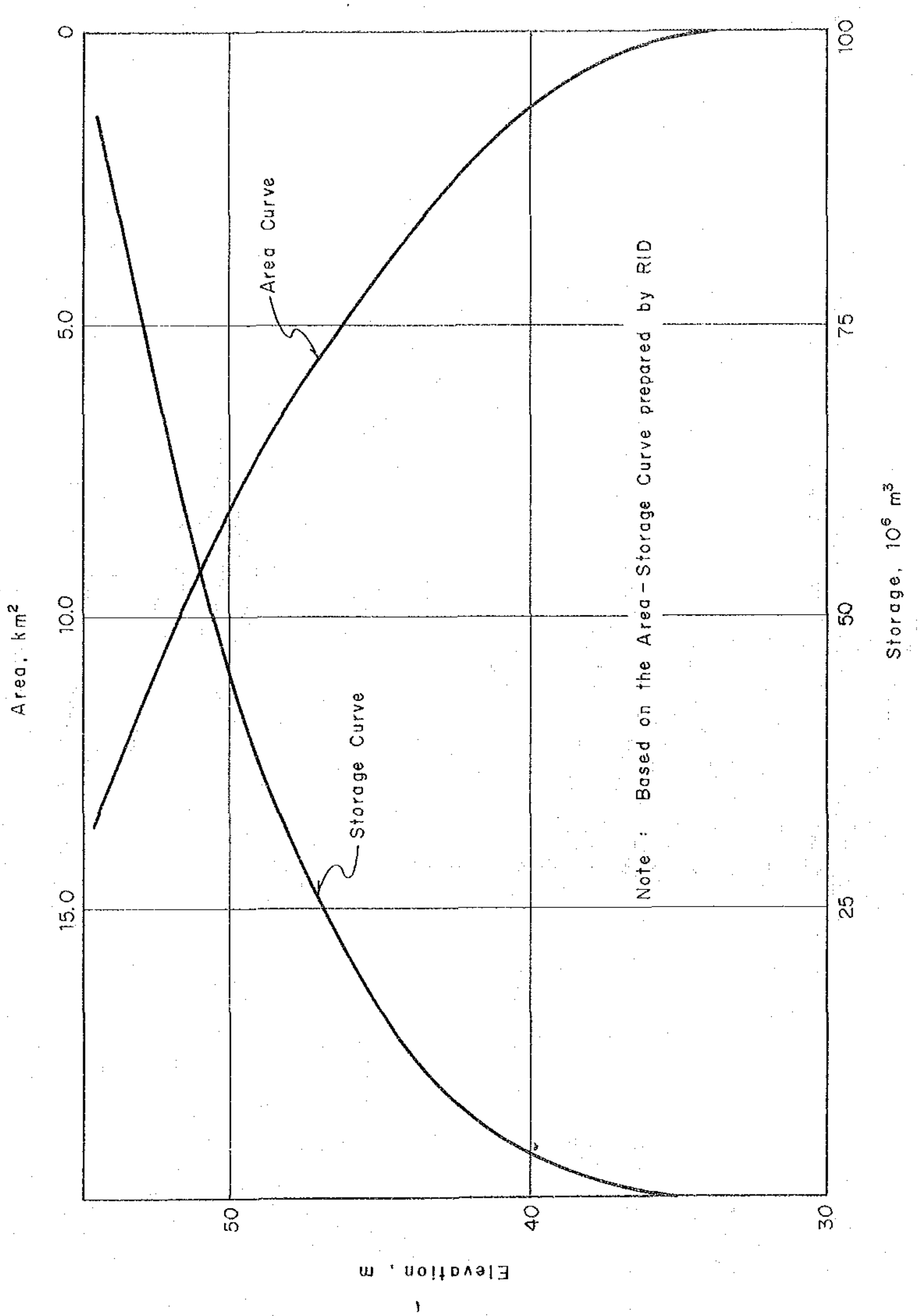

Fig. 6 Area - Storage Curve,
Dok Krai Reservoir

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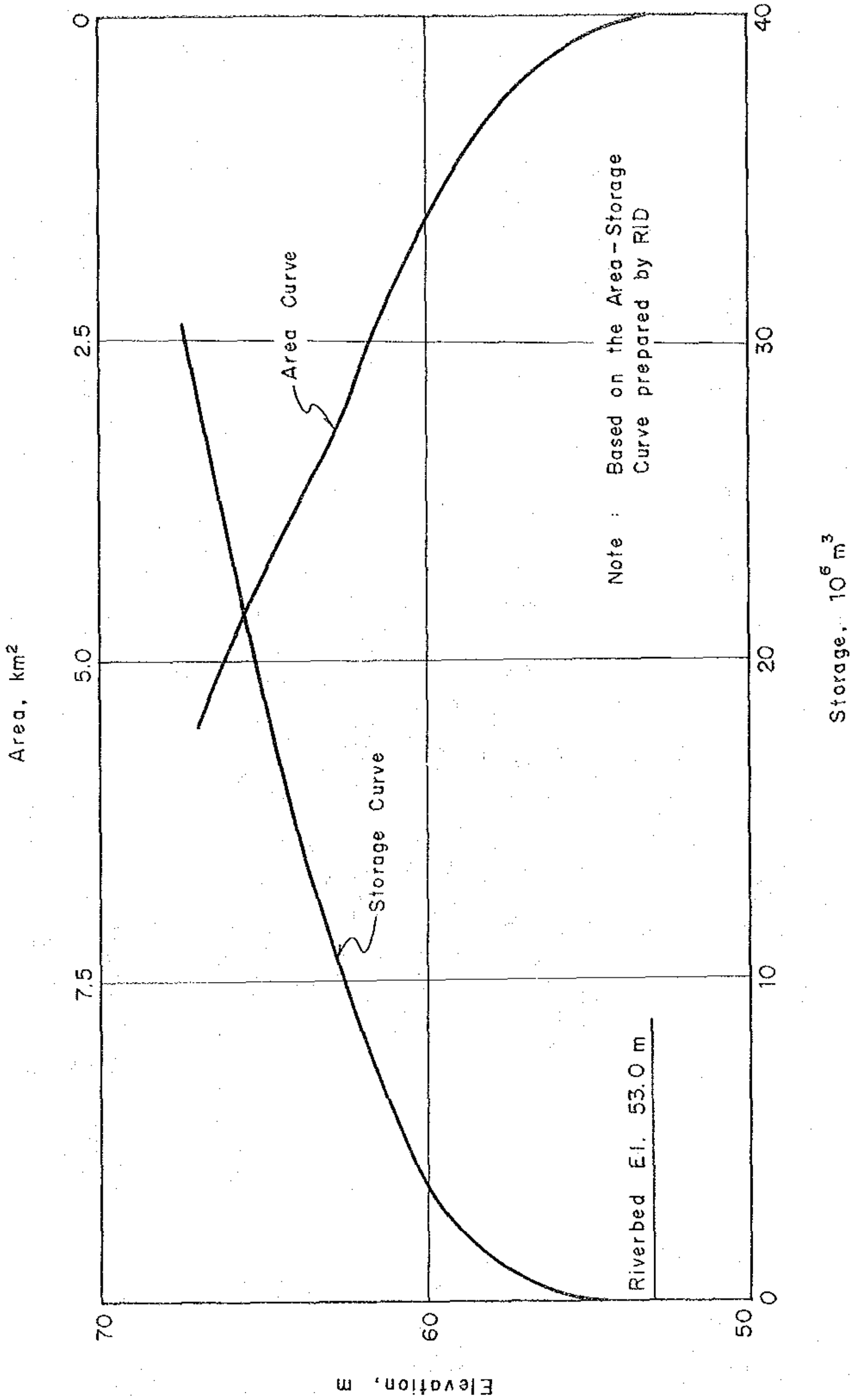

Fig. 7 Area – Storage Curve, Nong Kho Reservoir.

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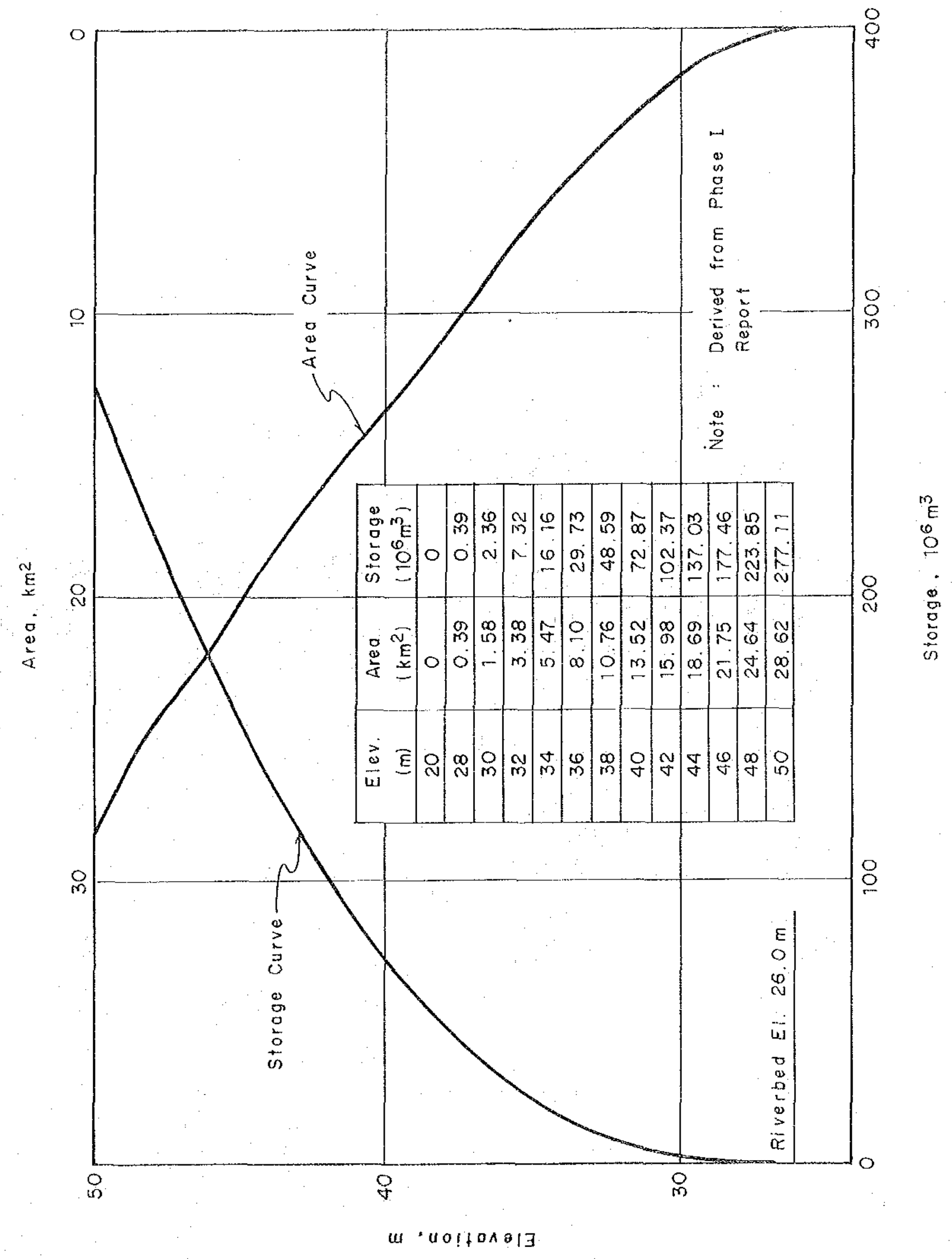

Elev. (m)	Area (km^2)	Storage ($10^6 m^3$)
20	0	0
28	0.39	0.39
30	1.58	2.36
32	3.38	7.32
34	5.47	16.16
36	8.10	29.73
38	10.76	48.59
40	13.52	72.87
42	15.98	102.37
44	18.69	137.03
46	21.75	177.46
48	24.64	223.85
50	28.62	277.11

Fig. 8 Area – Storage Curve
Nong Pla Lai Reservoir

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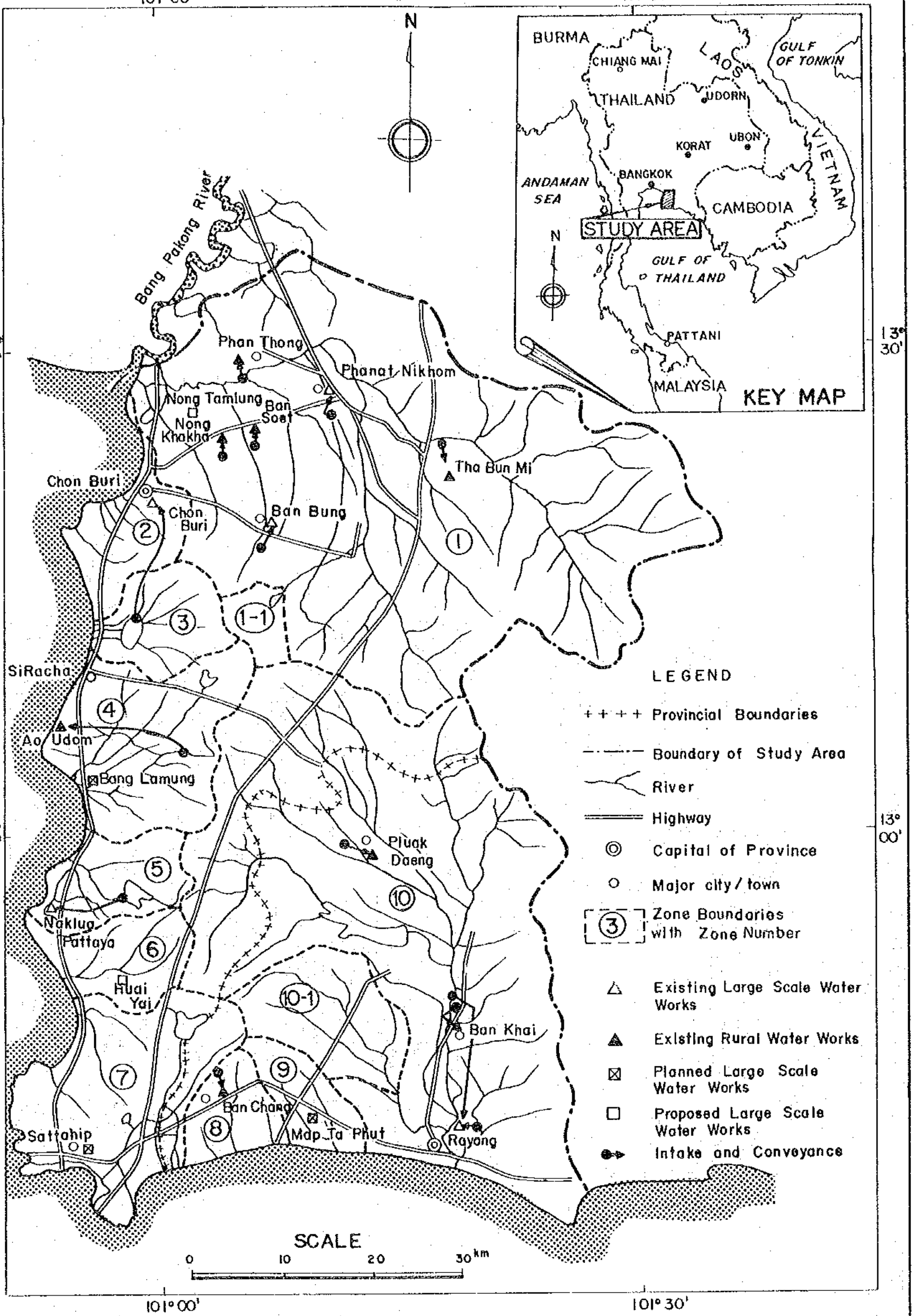

(Expansion to the large scale water works is being planned in the Fifth Five Year Plan of PWWA.)

Fig. 9 Location of Water Works

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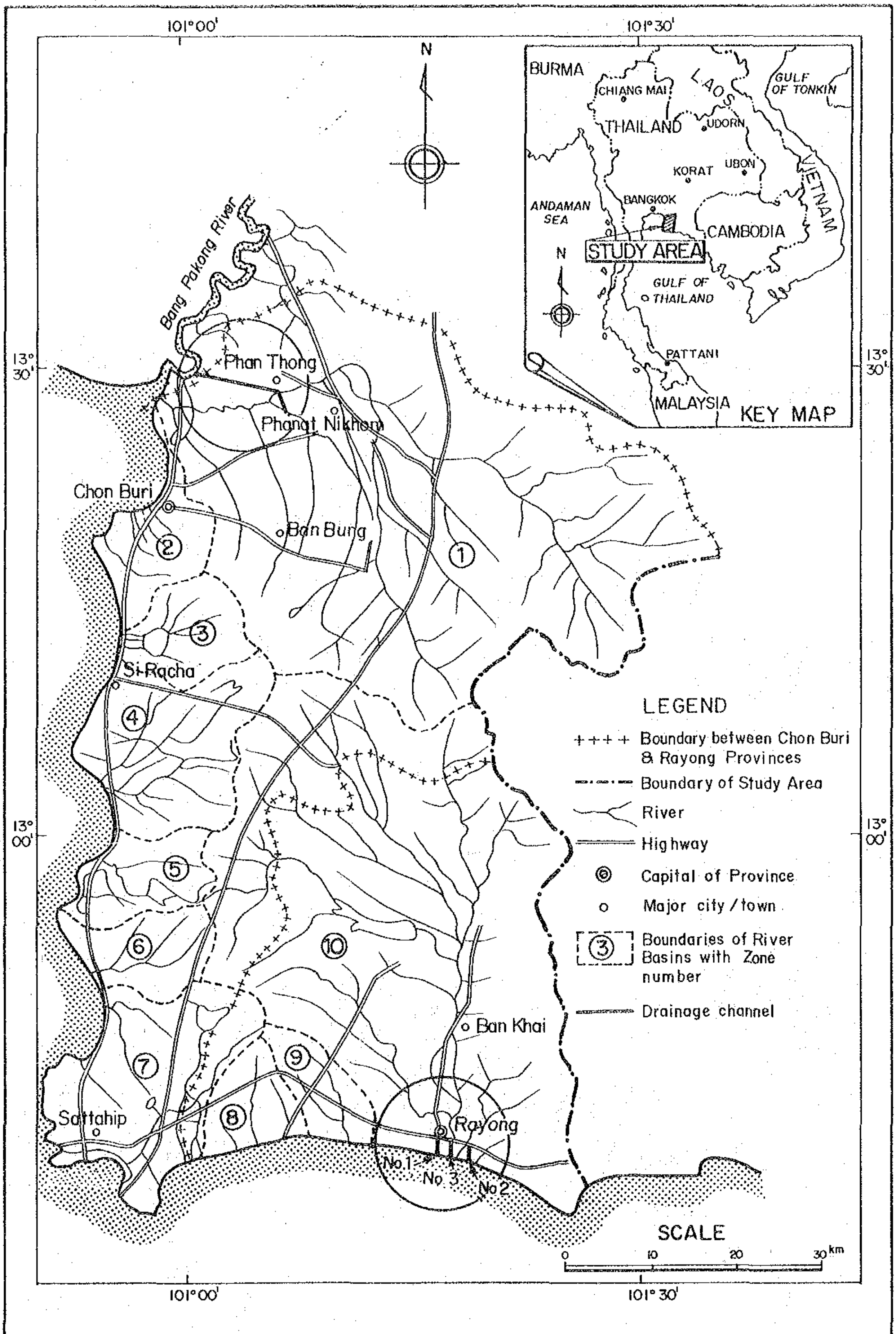

Fig. 10 Location of Drainage Channel

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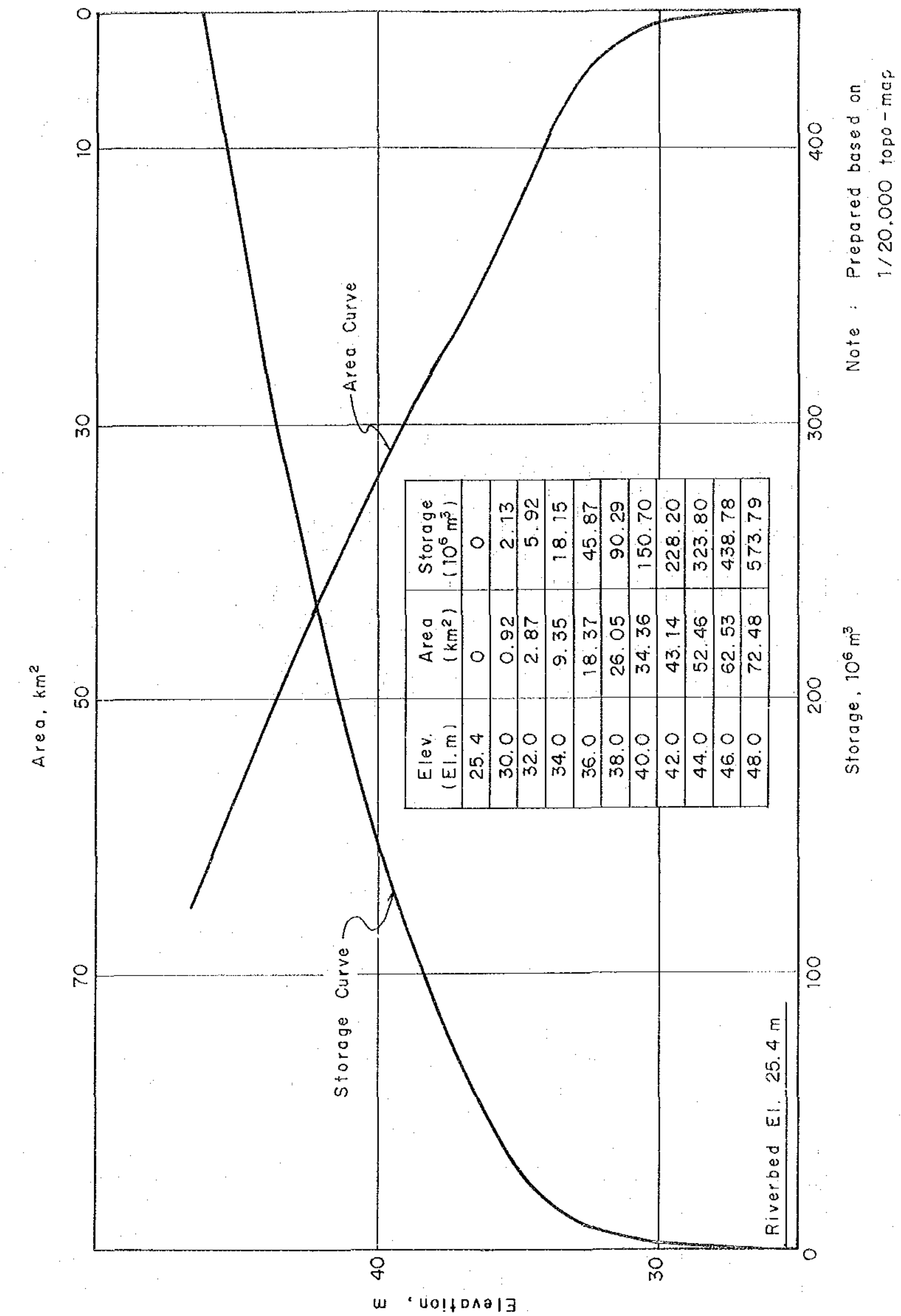

Elev. (El. m)	Area (km²)	Storage (10^6 m³)
25.4	0	0
30.0	0.92	2.13
32.0	2.87	5.92
34.0	9.35	18.15
36.0	18.37	45.87
38.0	26.05	90.29
40.0	34.36	150.70
42.0	43.14	228.20
44.0	52.46	323.80
46.0	62.53	438.78
48.0	72.48	573.79

Fig. 11 Area – Storage Curve, Khlong Luang Reservoir

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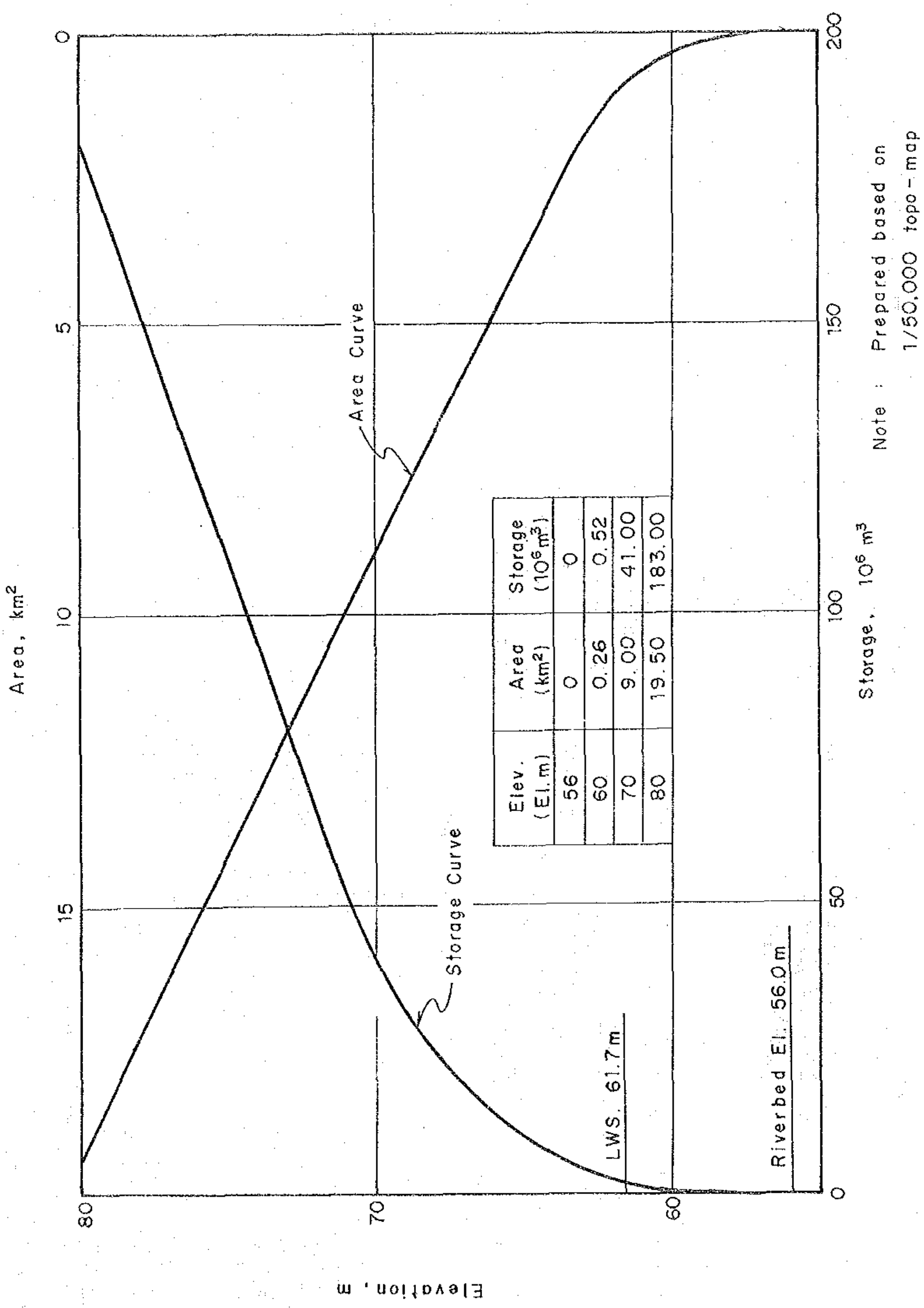

Elev. (El.m)	Area (km²)	Storage (10⁶m³)
56	0	0
60	0.26	0.52
70	9.00	41.00
80	19.50	183.00

Fig. 12 Area – Storage Curve, Pa Daeng Reservoir

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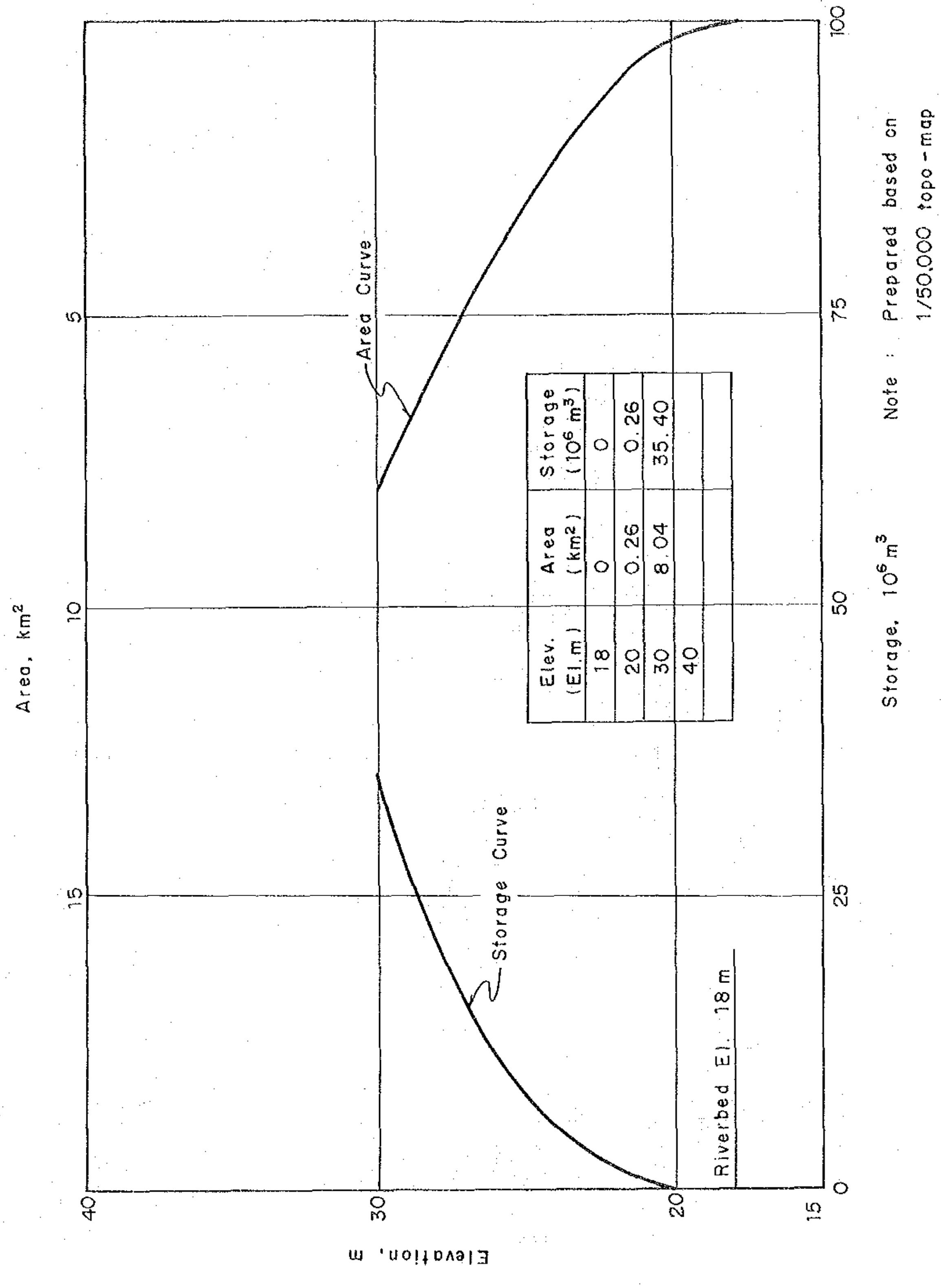

Elev. (El.m)	Area (km^2)	Storage (10^6 m^3)
18	0	0
20	0.26	0.26
30	8.04	35.40
40		

Fig. 13 Area — Storage Curve, Huai Bung Reservoir

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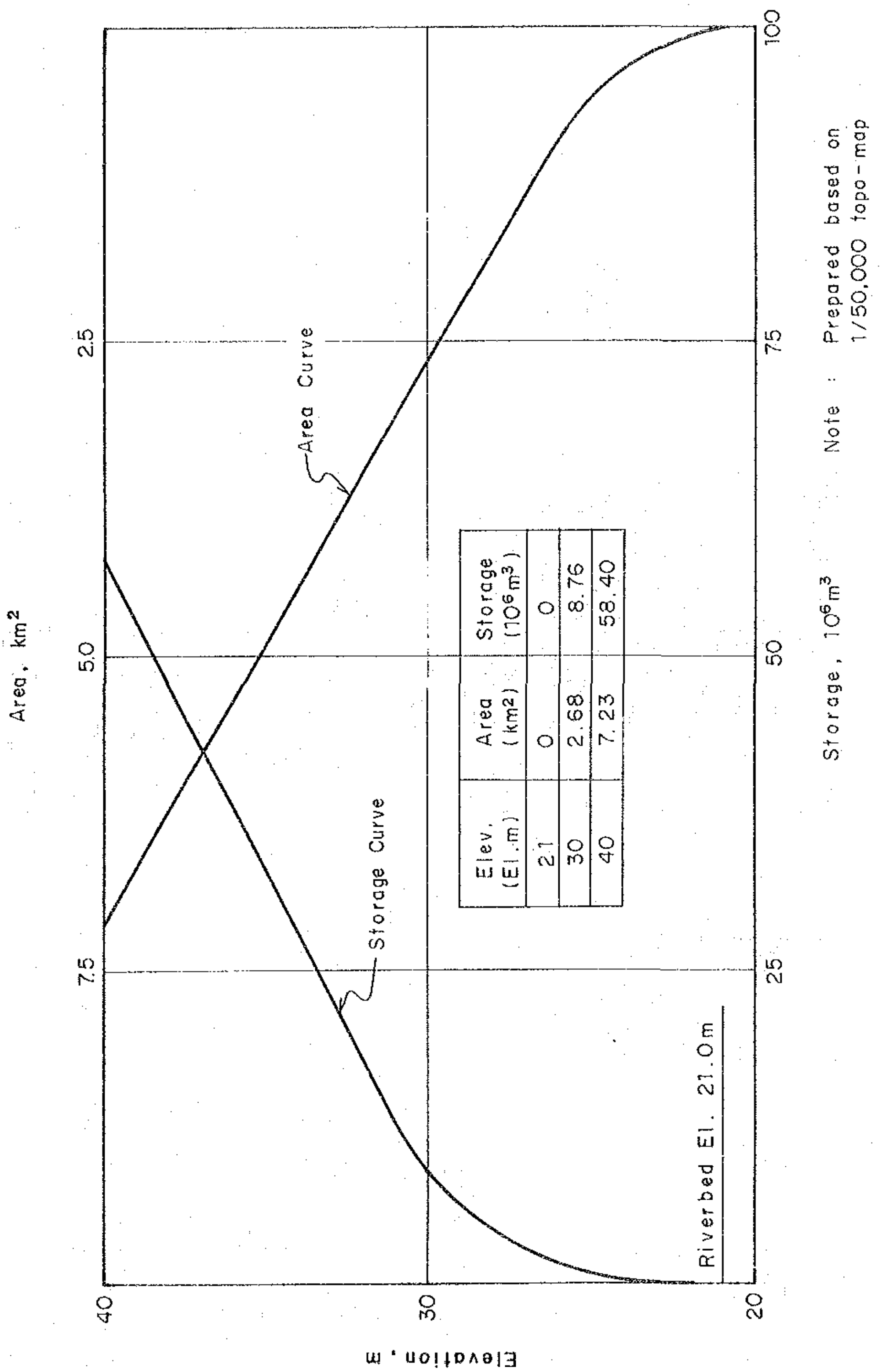

Elev. (El.m)	Area (km2)	Storage ($10^6 m^3$)
21	0	0
30	2.68	8.76
40	7.23	58.40

Fig. 14 Area – Storage Curve, Huai Takhian Tia Reservoir

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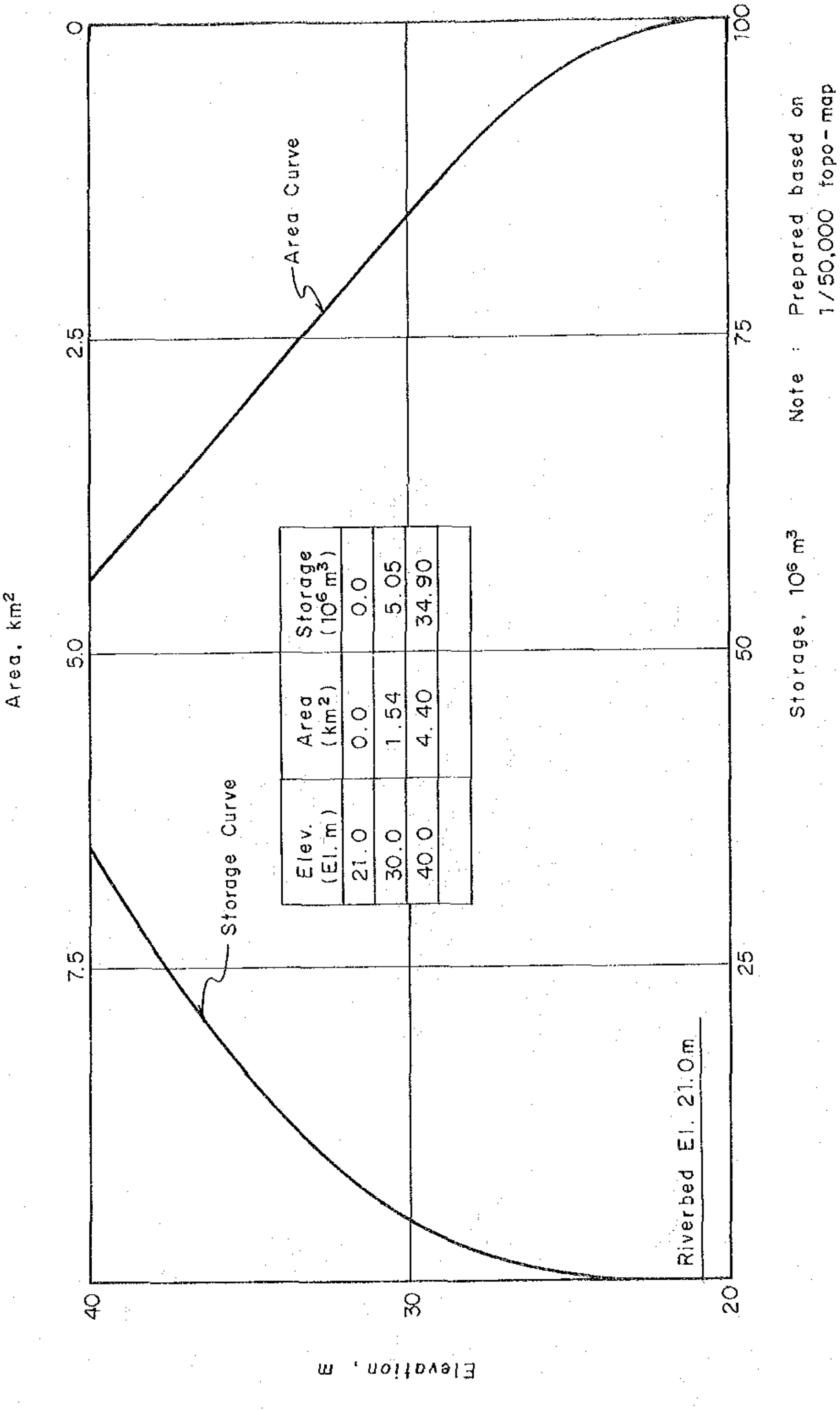

Elev. (El. m)	Area (km²)	Storage ($10^6 m^3$)
21.0	0.0	0.0
30.0	1.54	5.05
40.0	4.40	34.90

Fig. 15 Area – Storage Curve, Khlong Na Klua Reservoir

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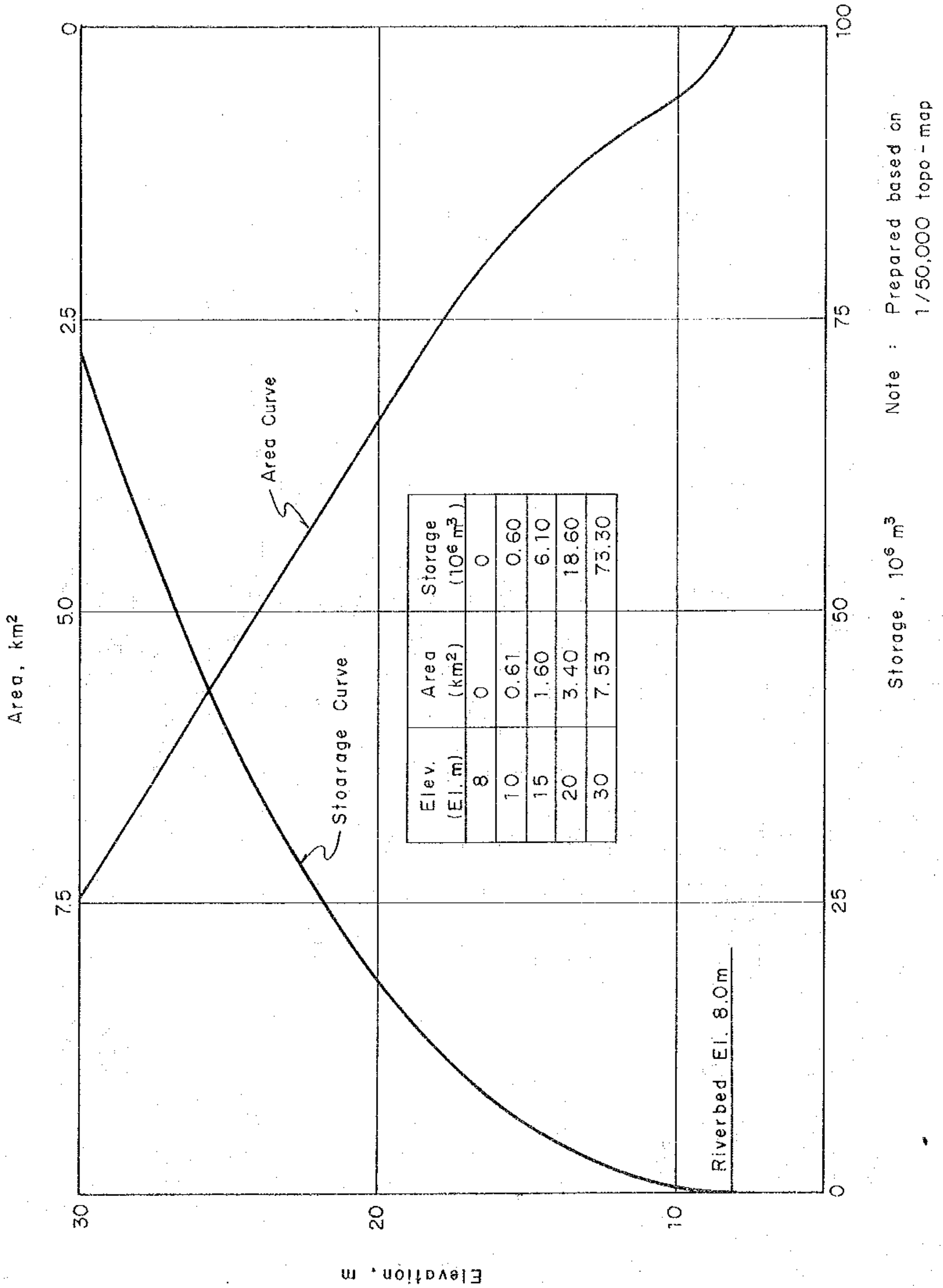

Elev. (El. m)	Area (km²)	Storage (10^6 m³)
8	0	0
10	0.61	0.60
15	1.60	6.10
20	3.40	18.60
30	7.53	73.30

Fig. 16 Area – Storage Curve, Huai Chak Nok Reservoir

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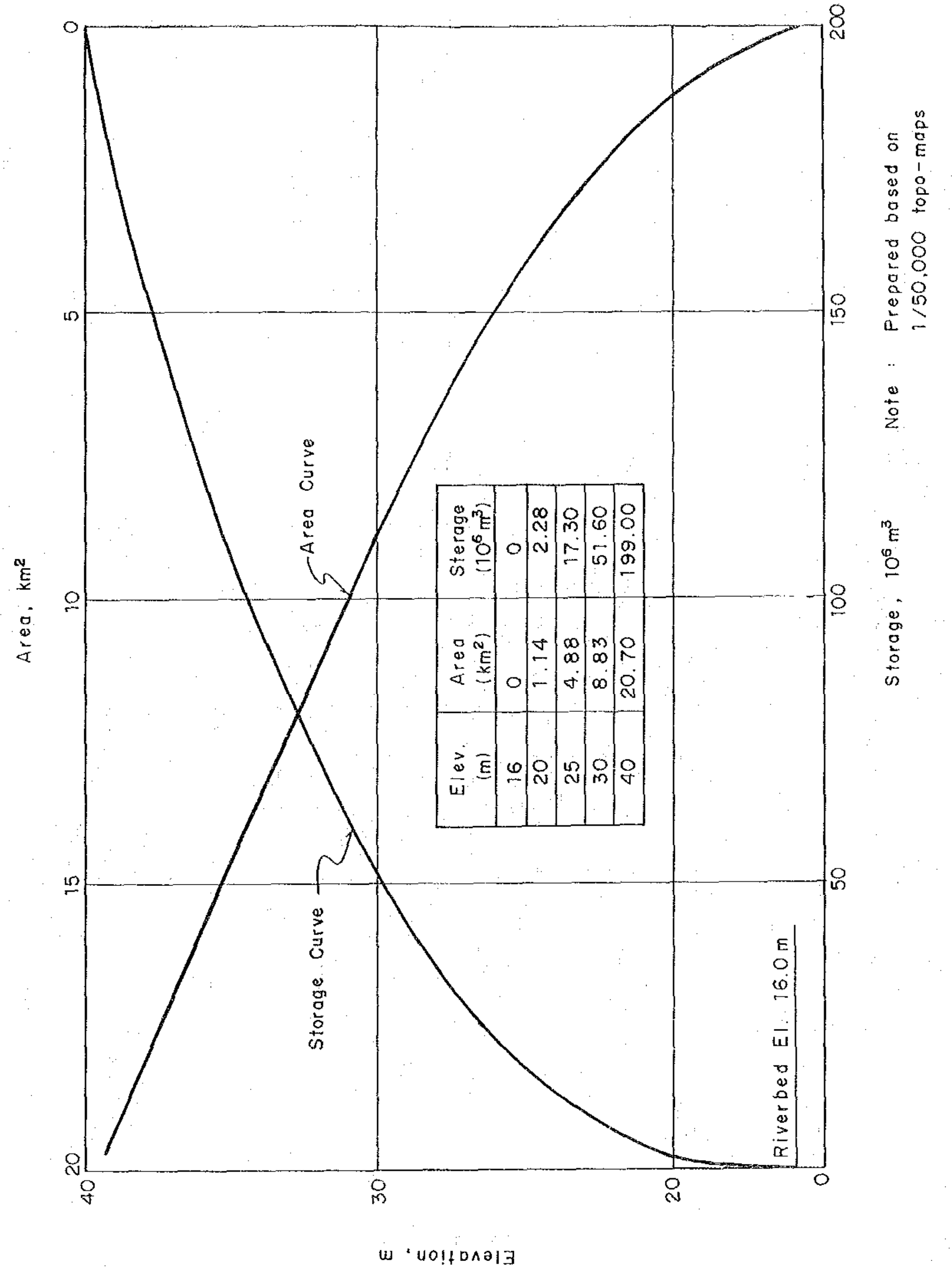

Elev. (m)	Area (km²)	Sterage (10⁶ m³)
16	0	0
20	1.14	2.28
25	4.88	17.30
30	8.83	51.60
40	20.70	199.00

Fig. 17 Area – Storage Curve,
Huai Yai Reservoir

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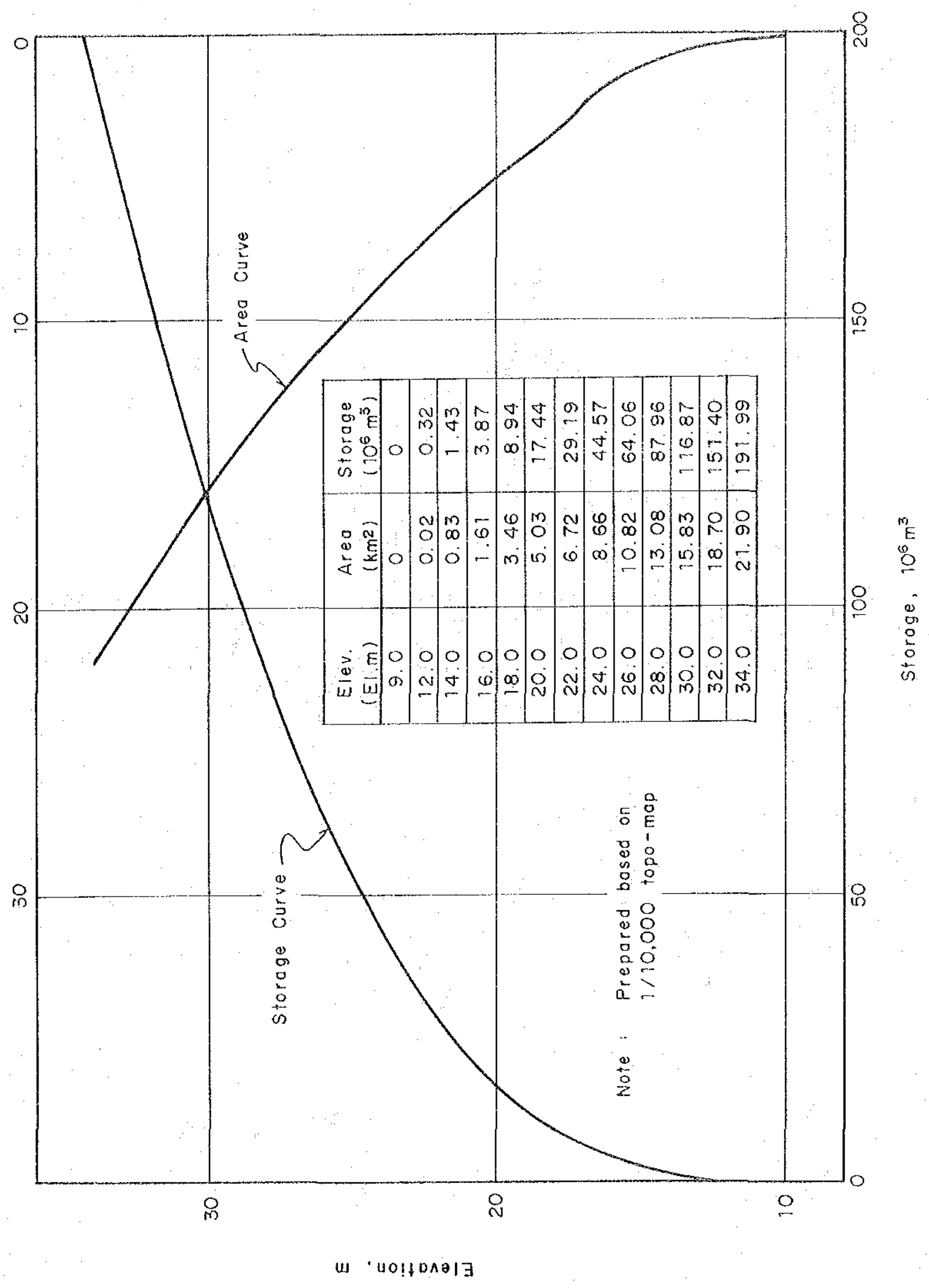

Elev. (El.m)	Area (km^2)	Storage ($10^6 m^3$)
9.0	0	0
12.0	0.02	0.32
14.0	0.83	1.43
16.0	1.61	3.87
18.0	3.46	8.94
20.0	5.03	17.44
22.0	6.72	29.19
24.0	8.66	44.57
26.0	10.82	64.06
28.0	13.08	87.96
30.0	15.83	116.87
32.0	18.70	151.40
34.0	21.90	191.99

Fig. 18 Area-Storage Curve, Khlong Thap Ma Reservoir

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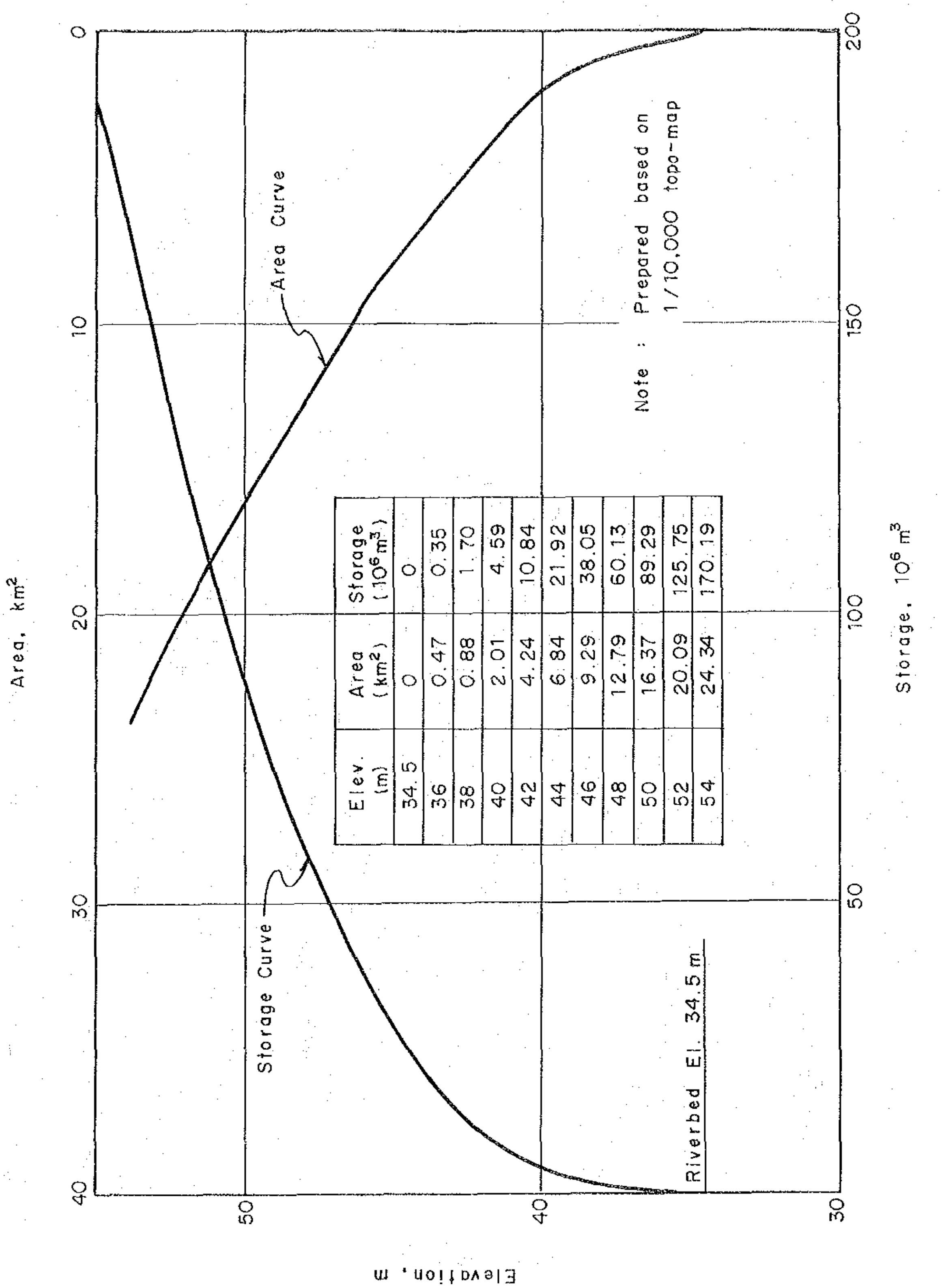

Elev. (m)	Area (km^2)	Storage ($10^6 m^3$)
34.5	0	0
36	0.47	0.35
38	0.88	1.70
40	2.01	4.59
42	4.24	10.84
44	6.84	21.92
46	9.29	38.05
48	12.79	60.13
50	16.37	89.29
52	20.09	125.75
54	24.34	170.19

Fig.19 Area – Storage Curve
Khlong Yai Reservoir

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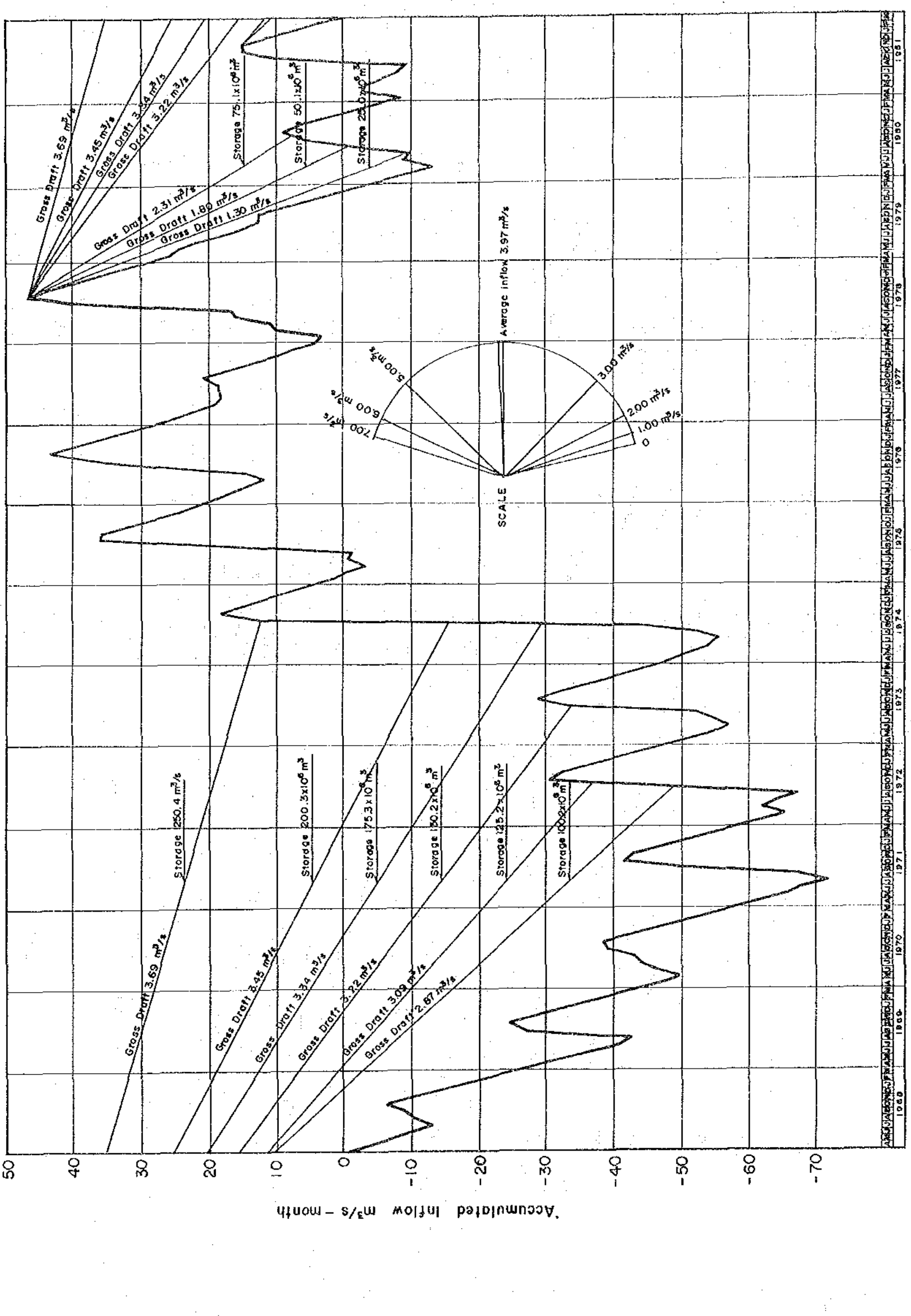

Fig. 20 Mass Curve Khlong Luang

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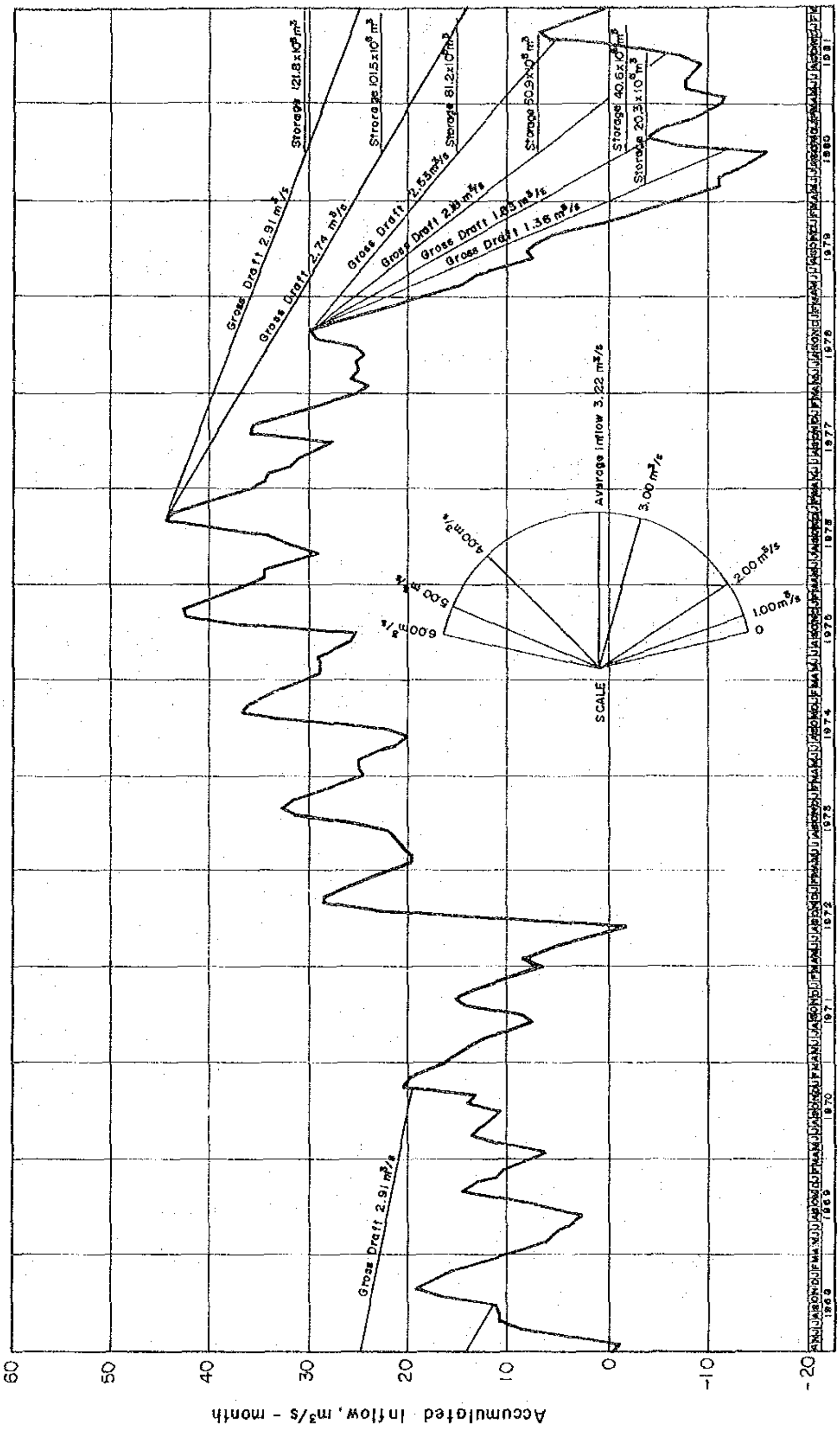

Fig. 21 Mass Curve, Dok Krai

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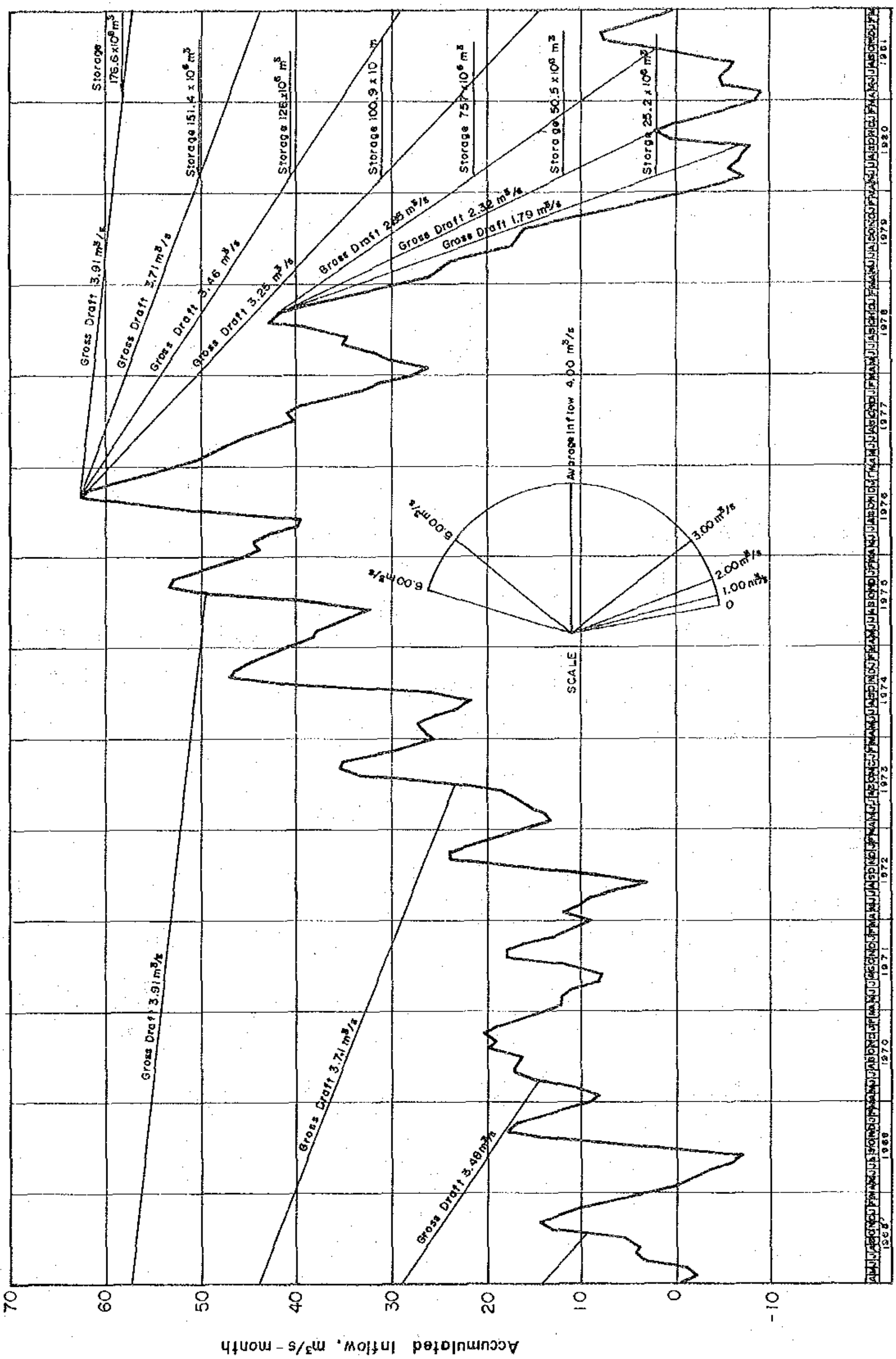

Fig. 22 Mass Curve, Nong Pld Lai

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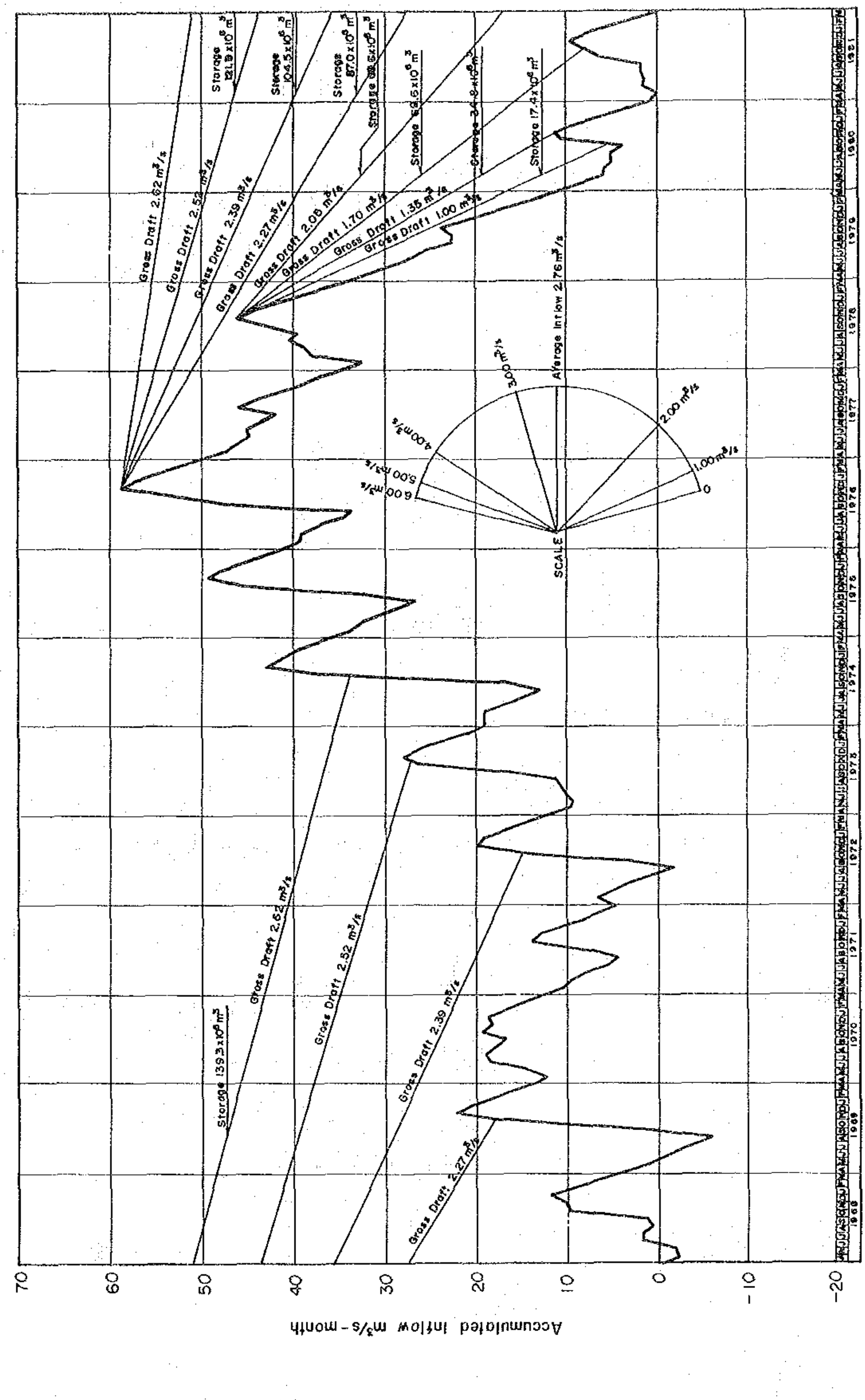

Fig. 23 Mass Curve, Khlong Yai

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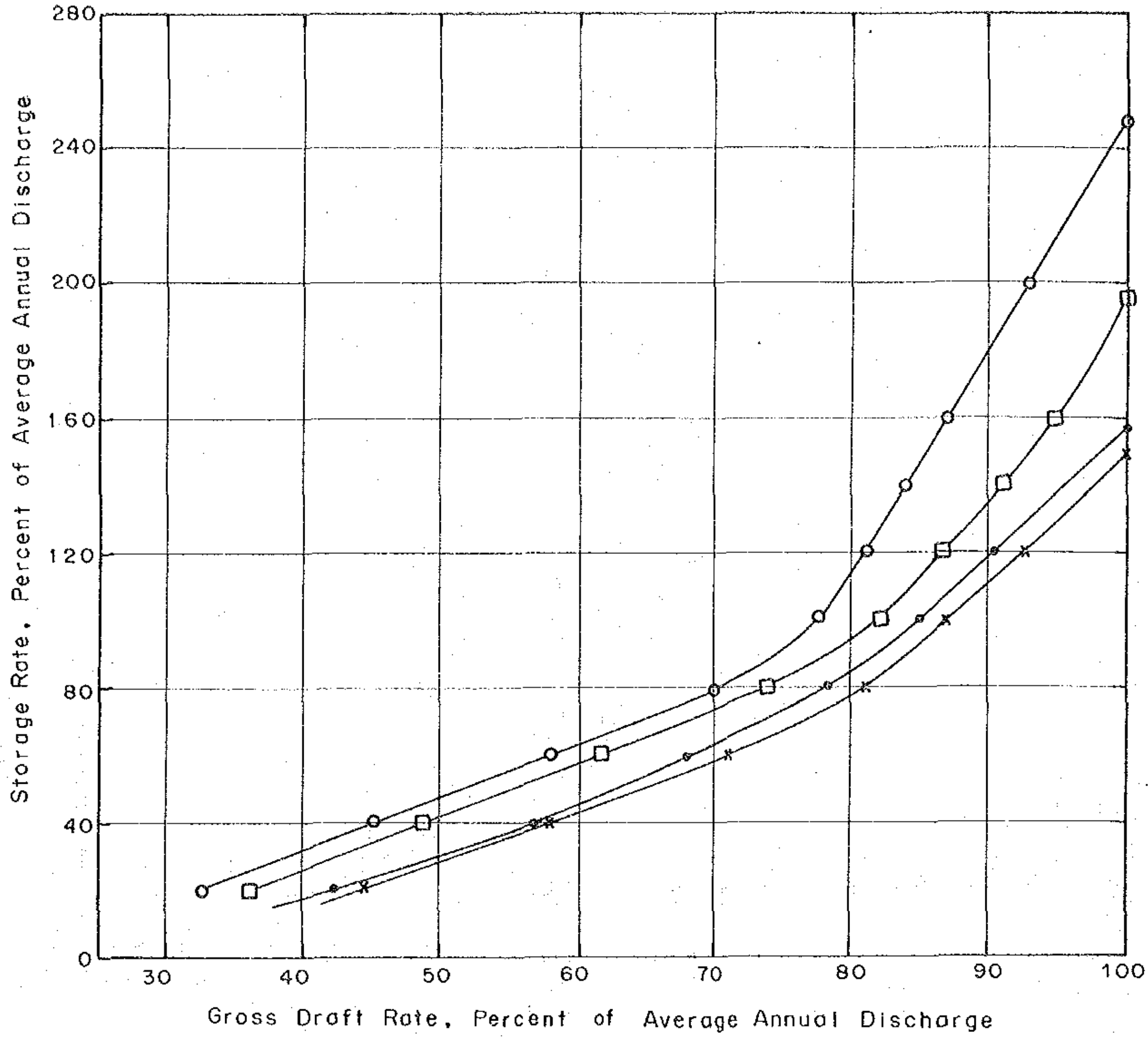

LEGEND

- Dok Krai reservoir, applicable to all existing reservoirs, Khlong Thap Ma and all potential reservoirs, except Pa Daeng
- Nong Pla Lai reservoir
- Khlong Luang reservoir, applicable to Pa Daeng
- Khlong Yai reservoir

Fig. 24 Storage - Draft Curve

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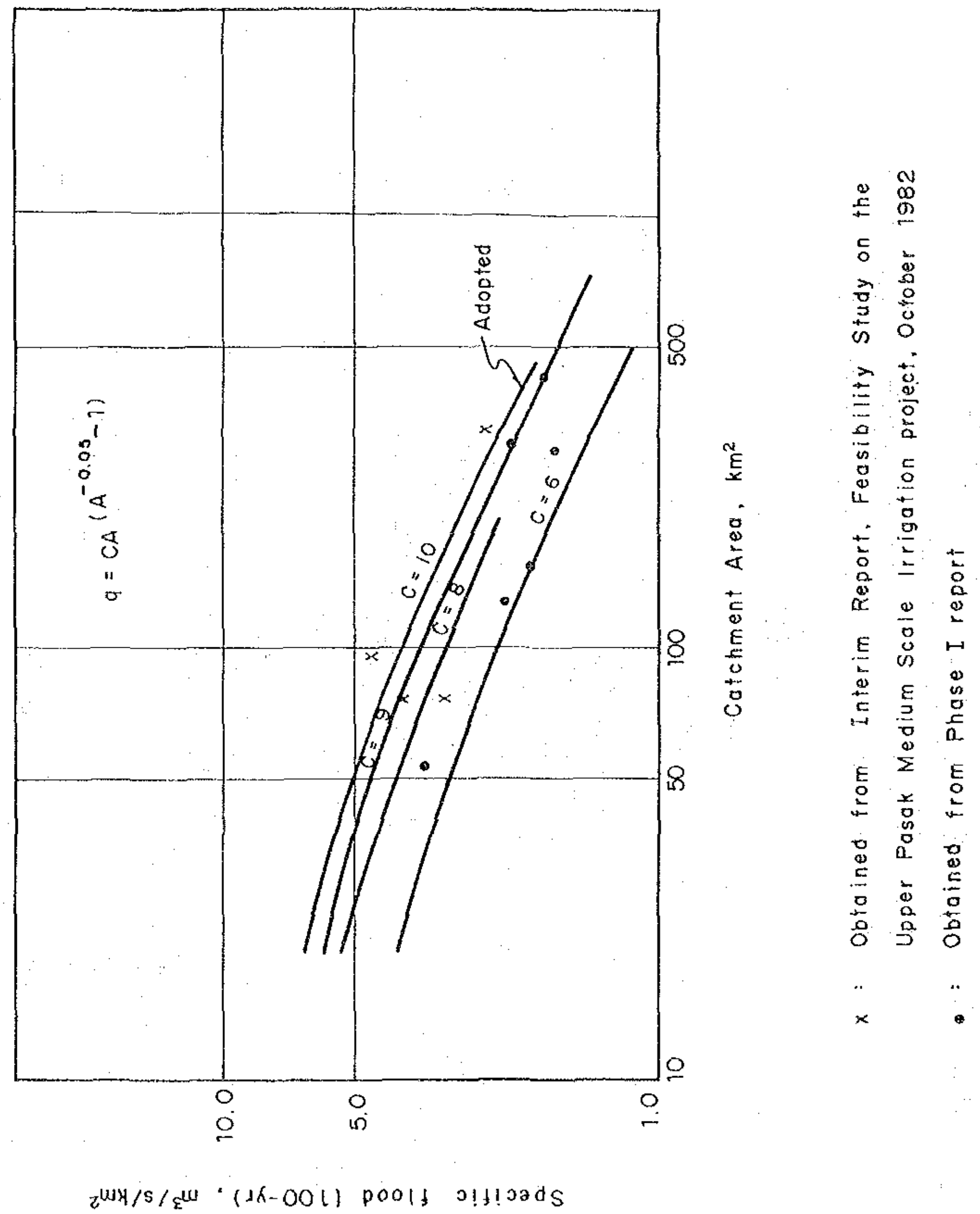

Fig. 25 **Regional Characteristics of 100-year Probable Flood**

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THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
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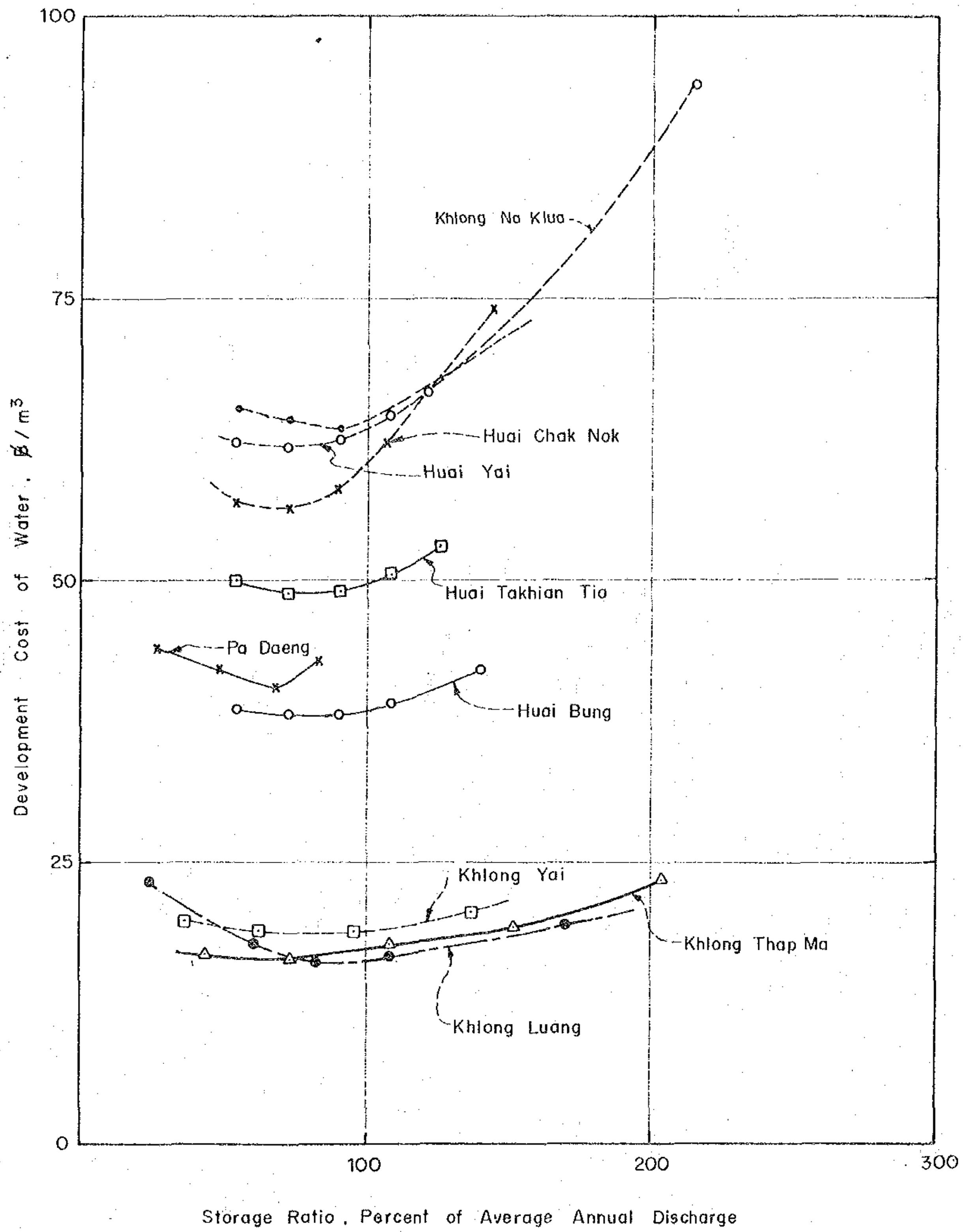

Fig. 26 Relation between Storage Ratio and Developmant Cost of Water

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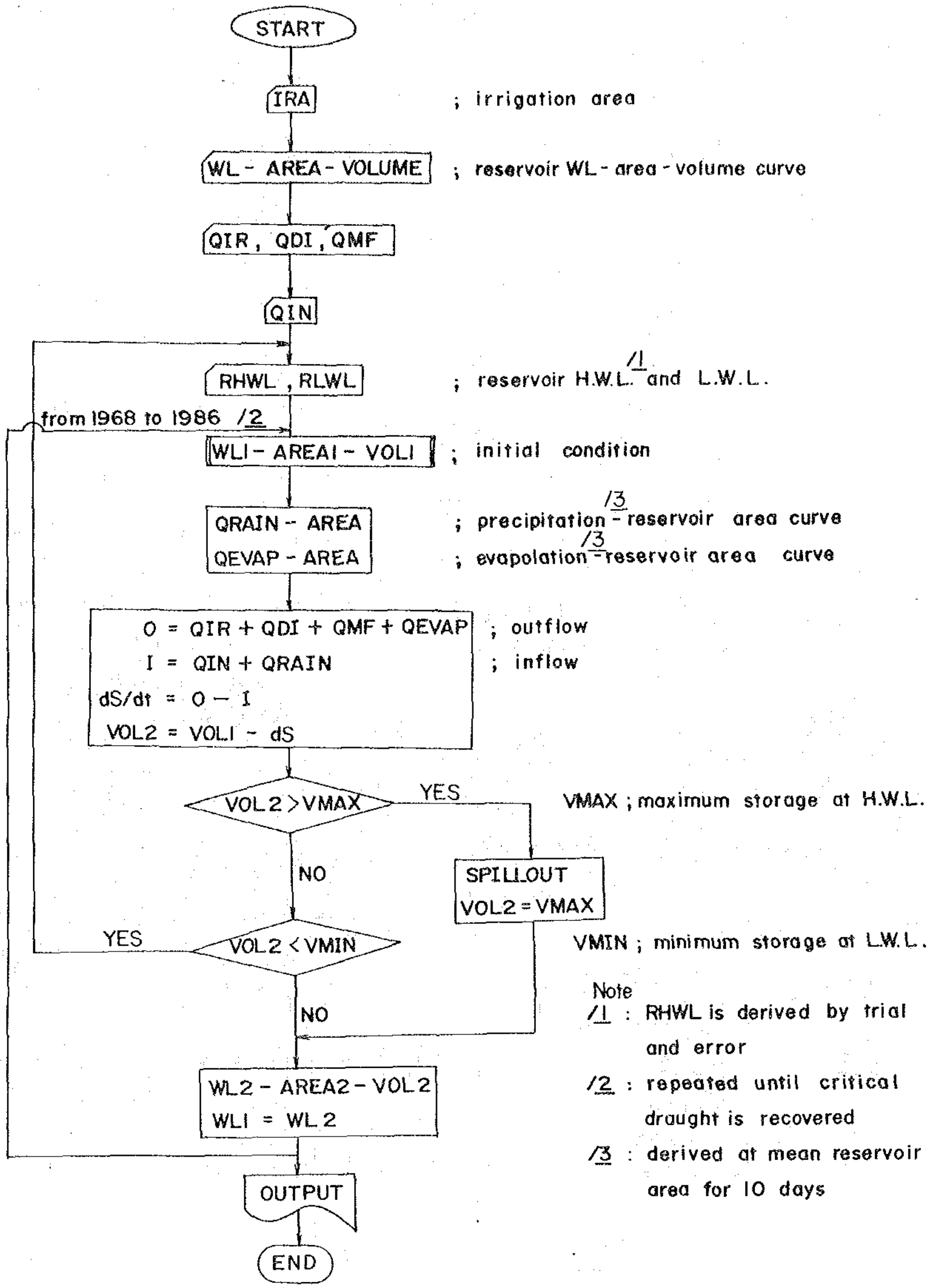

Fig. 27 Flow Chart of Reservoir Operation, Khlong Luang Dam Scheme

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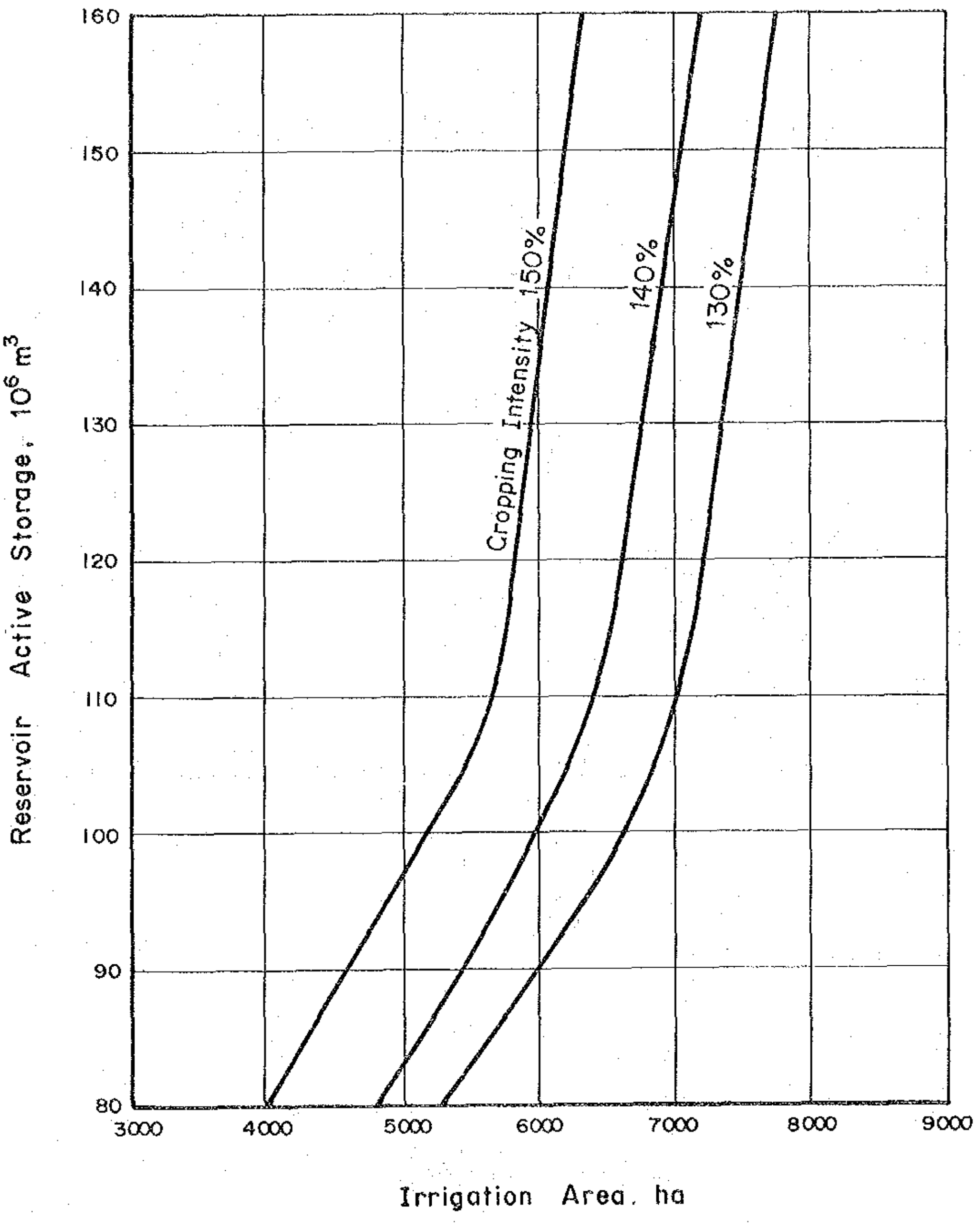

Fig. 28 Relationship between Irrigation Area, Cropping Intensity and Reservoir Active Storage Capacity, Khlong Luang Dam Scheme

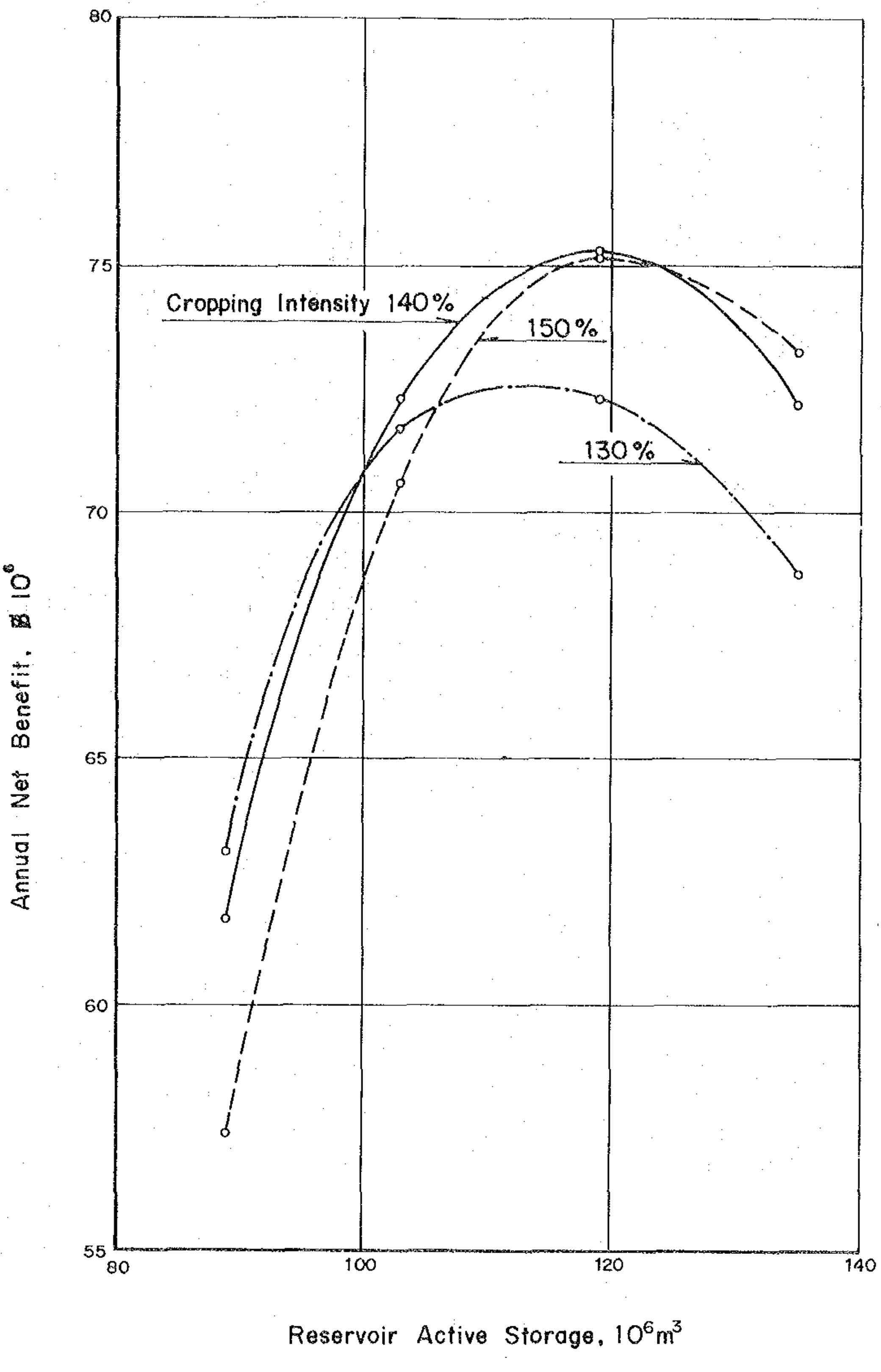

Fig. 29 Economic Comparison of Alternatives, Khlong Luang Dam Scheme

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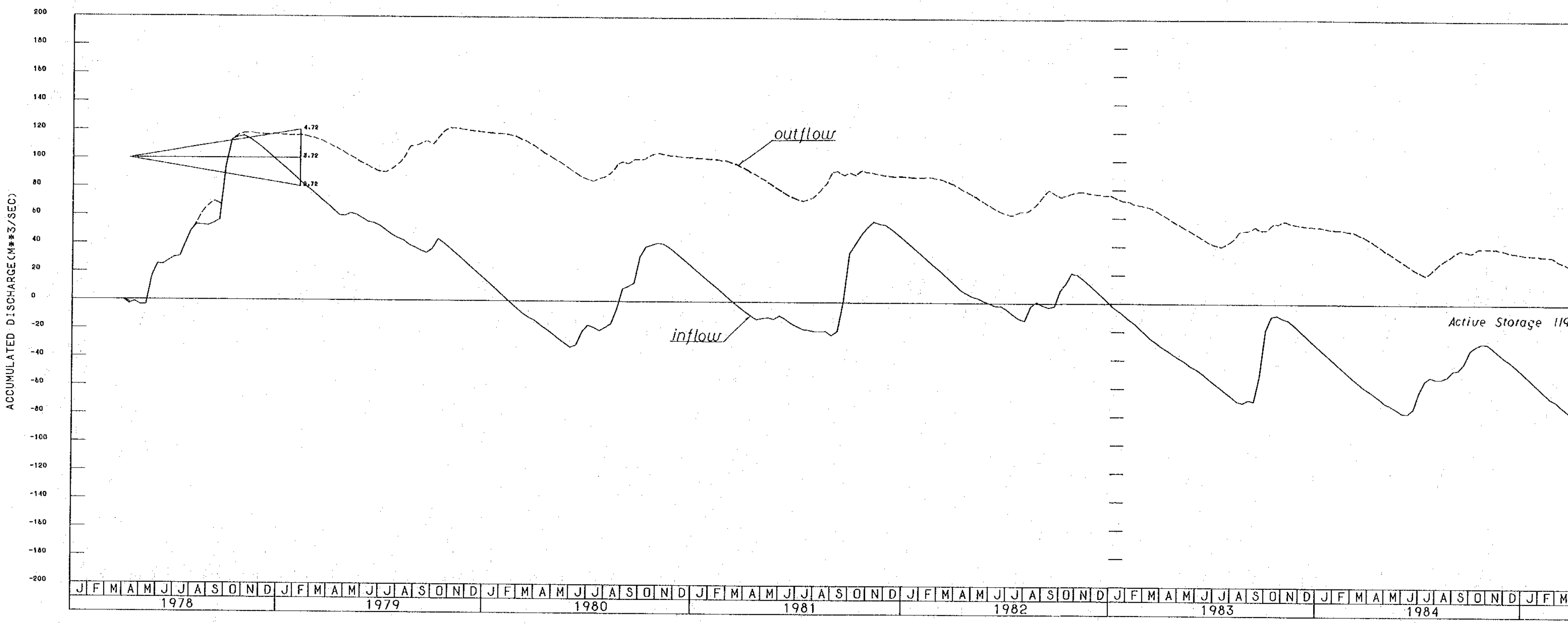

Fig. 30 Mass Curve of Inflow and Outflow at Khlong Luang Dam

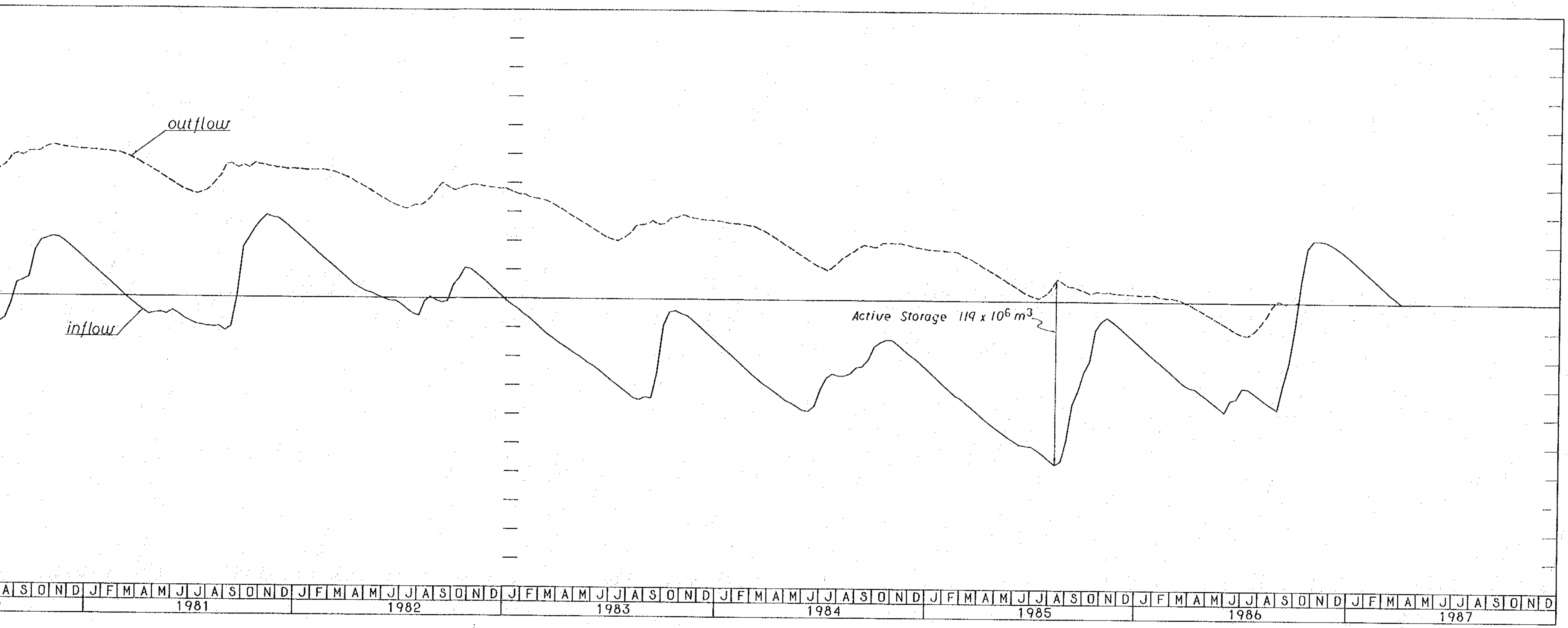

Fig. 30 Mass Curve of Inflow and Outflow at Khlong Luang Dam

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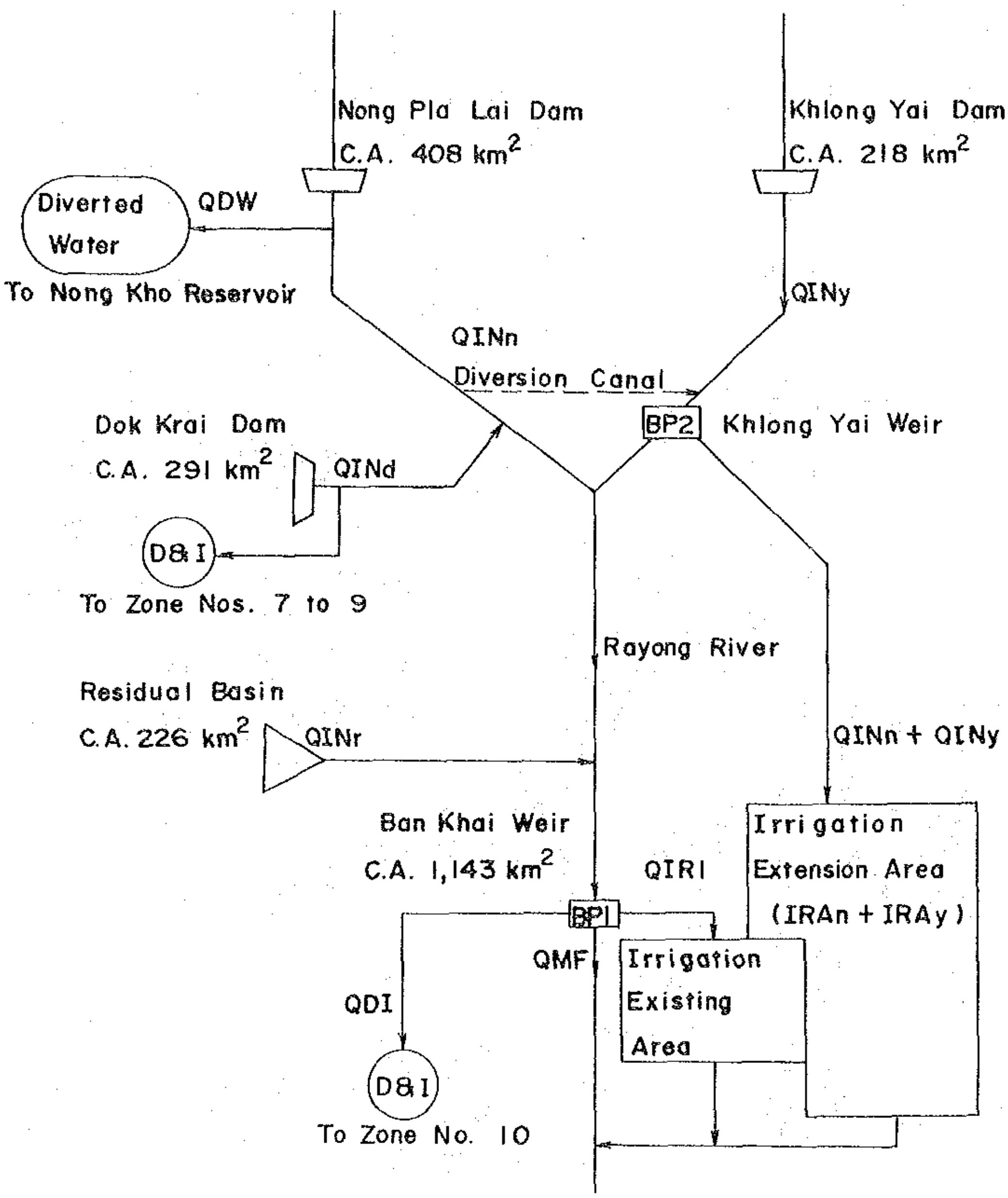

Fig.31 Schematic Outline of Rayong River Basin

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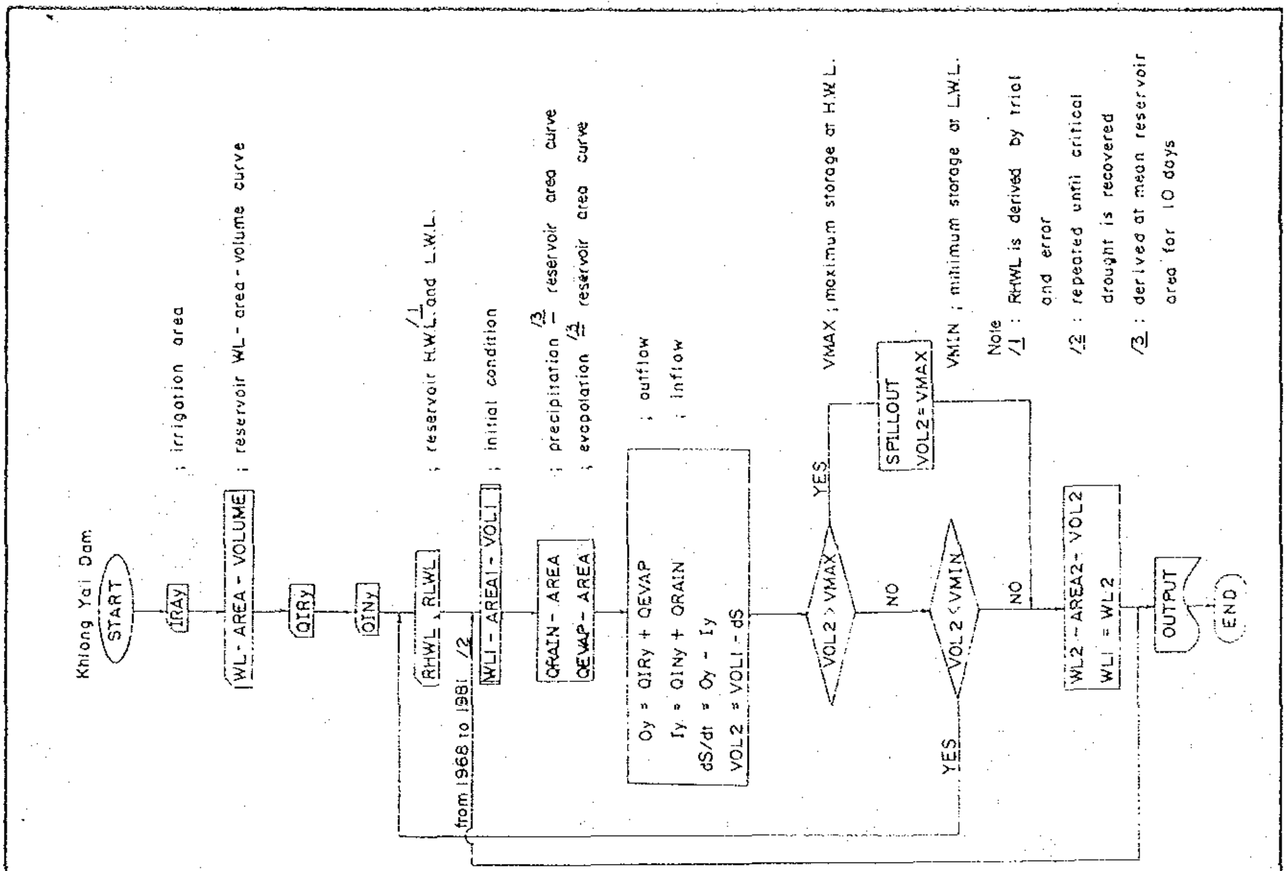

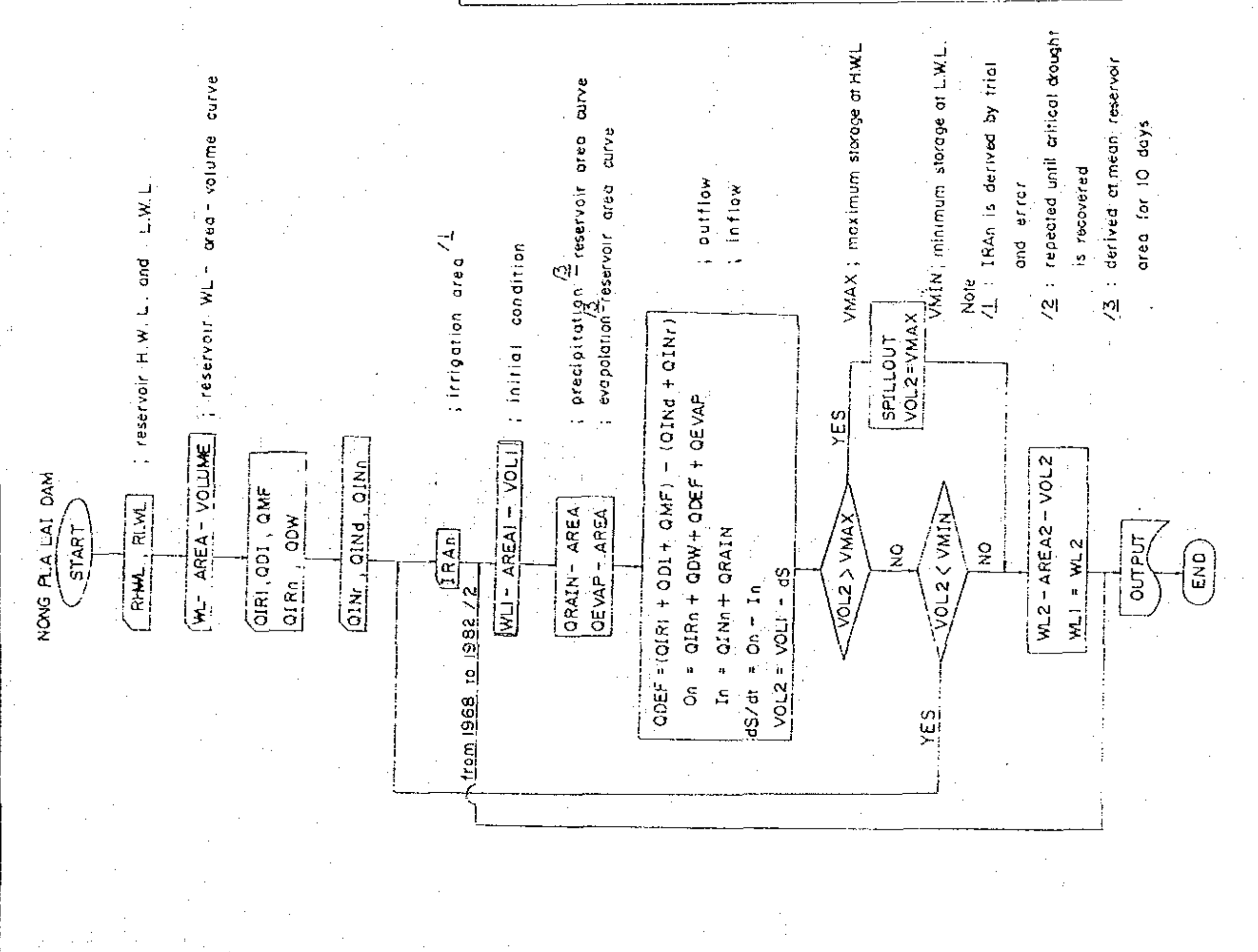

Fig. 32 Flow Chart of Reservoir Operation, Khlong Yai Dam Scheme

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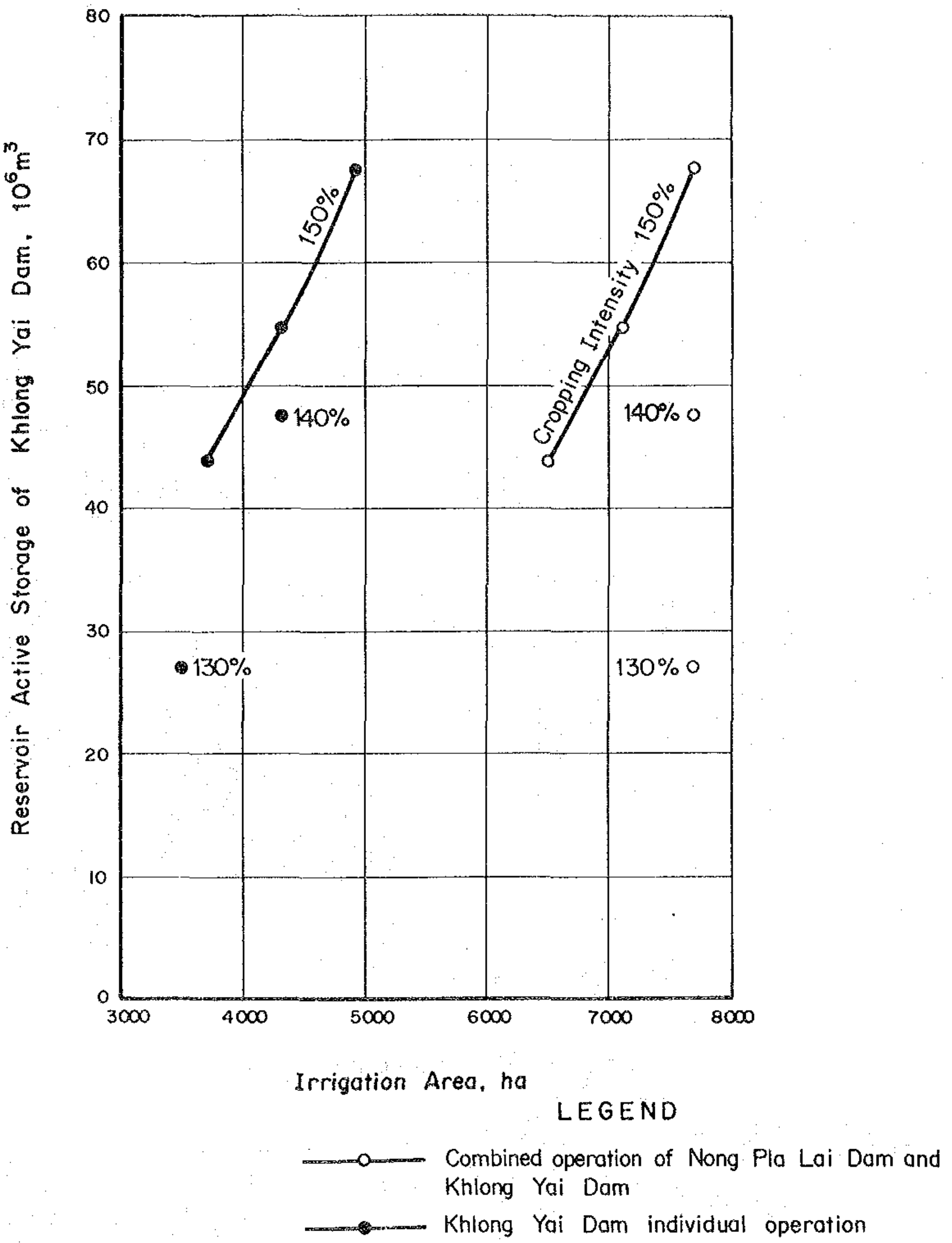

Fig. 33 Relationship between Irrigation Area, Cropping Intensity and Reservoir Active Storage Capacity, Khlong Yai Dam Scheme

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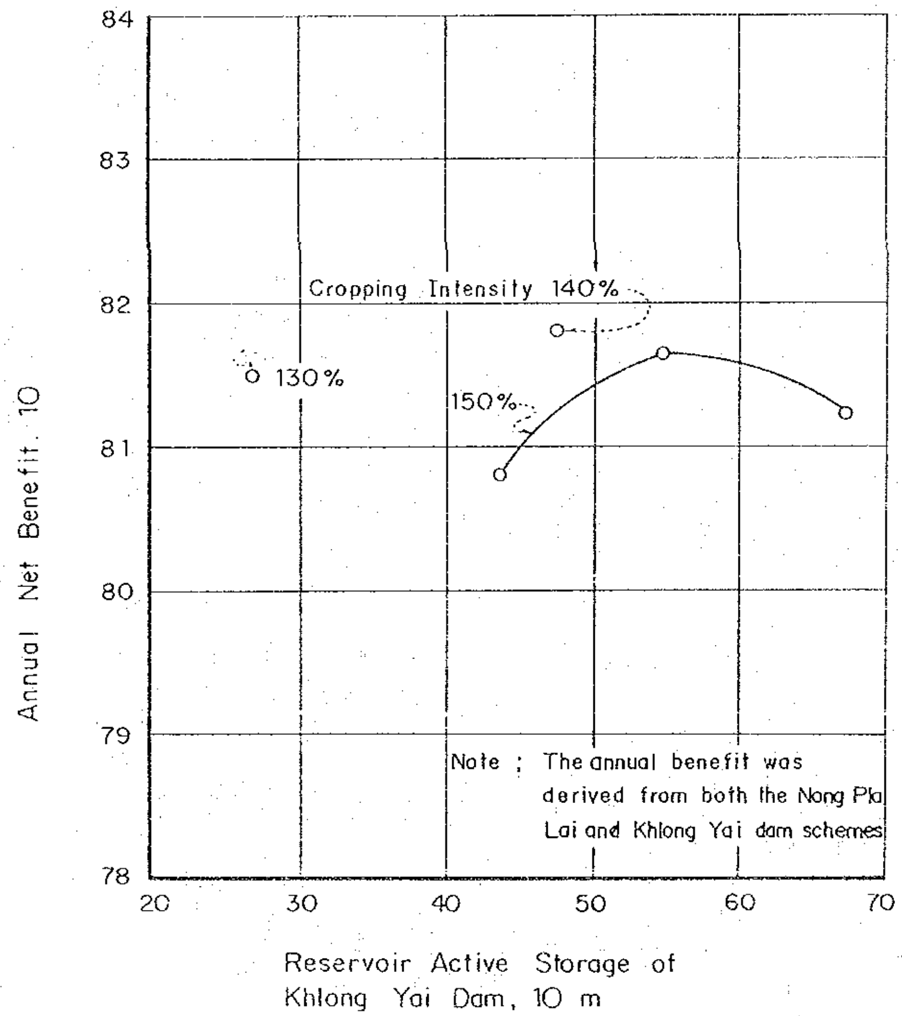

Fig. 34 Economic Comparison of Alternatives Combined Development of Nong Pla Lai and Khlong Yai Dams

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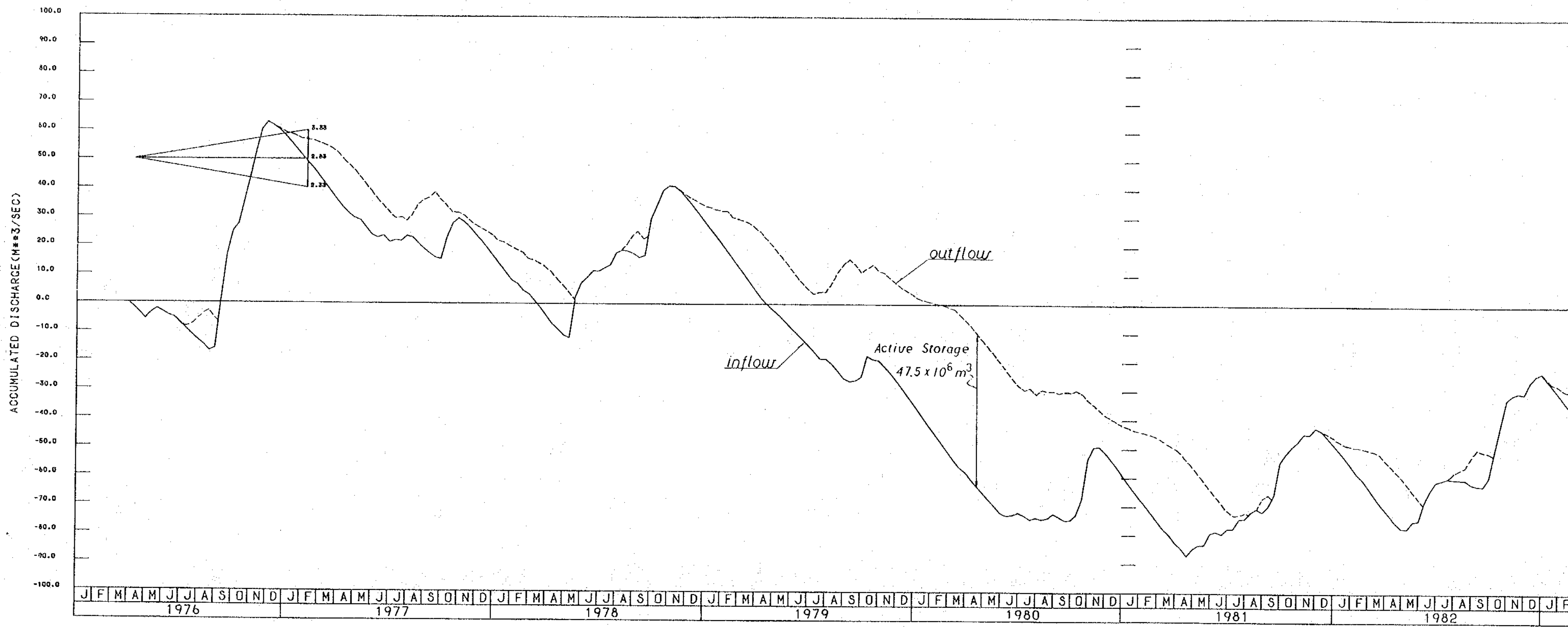

Fig. 35 Mass Curve of Inflow and Outflow at Khlong Yai Dam

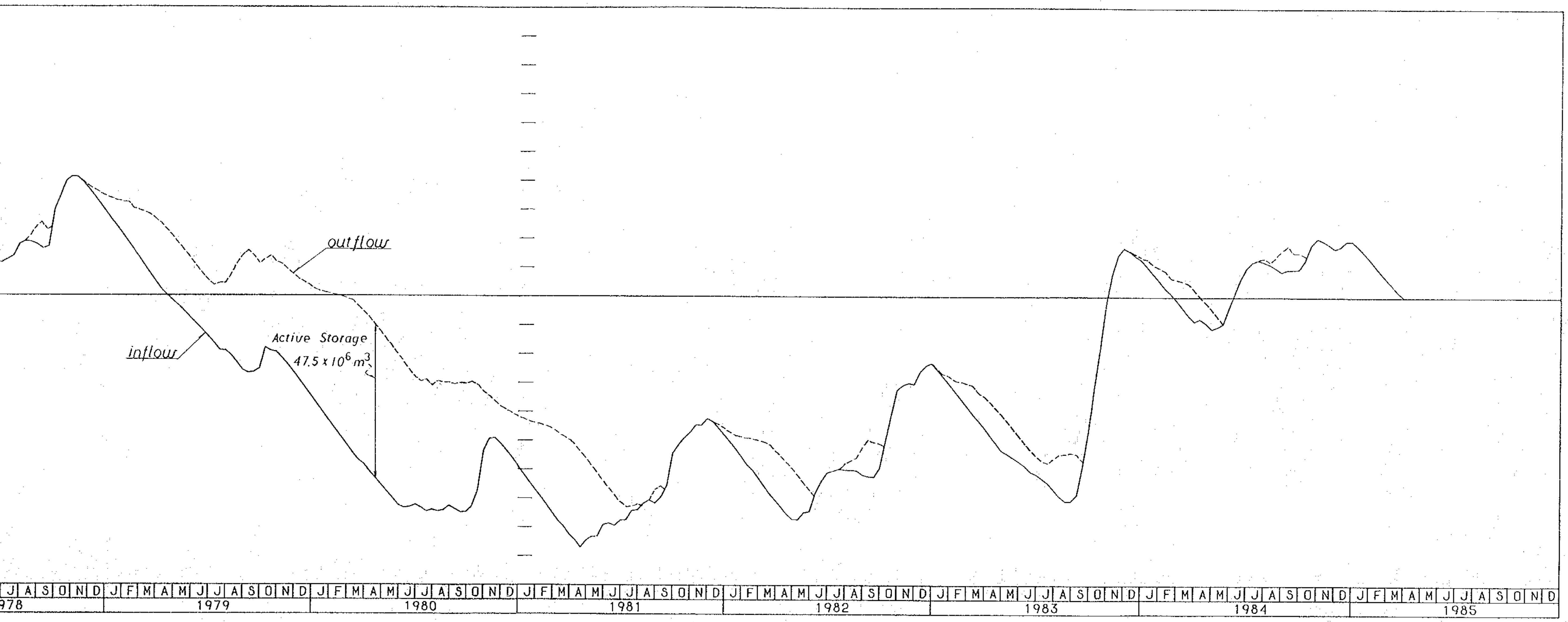

Fig. 35 Mass Curve of Inflow and Outflow at Khlong Yai Dam

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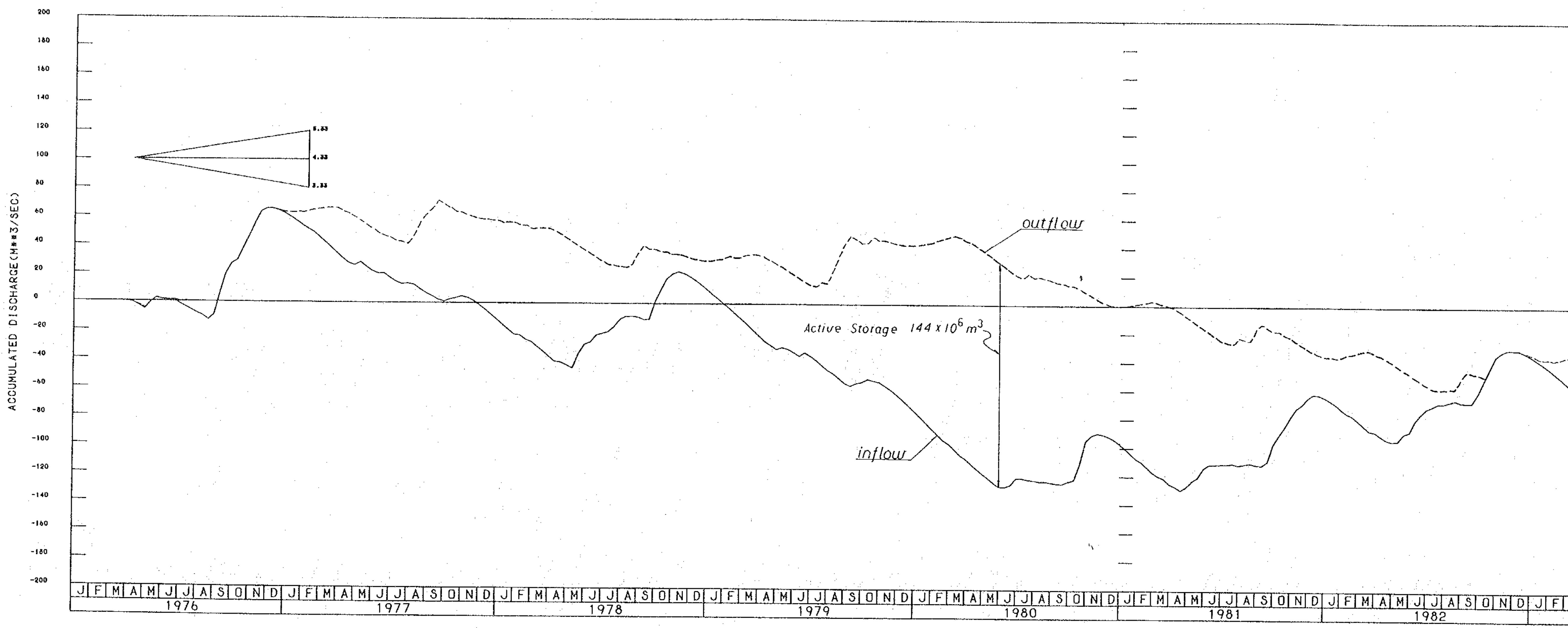

Fig. 36 Mass Curve of Inflow and Outflow at Nong Pla Lai Dam

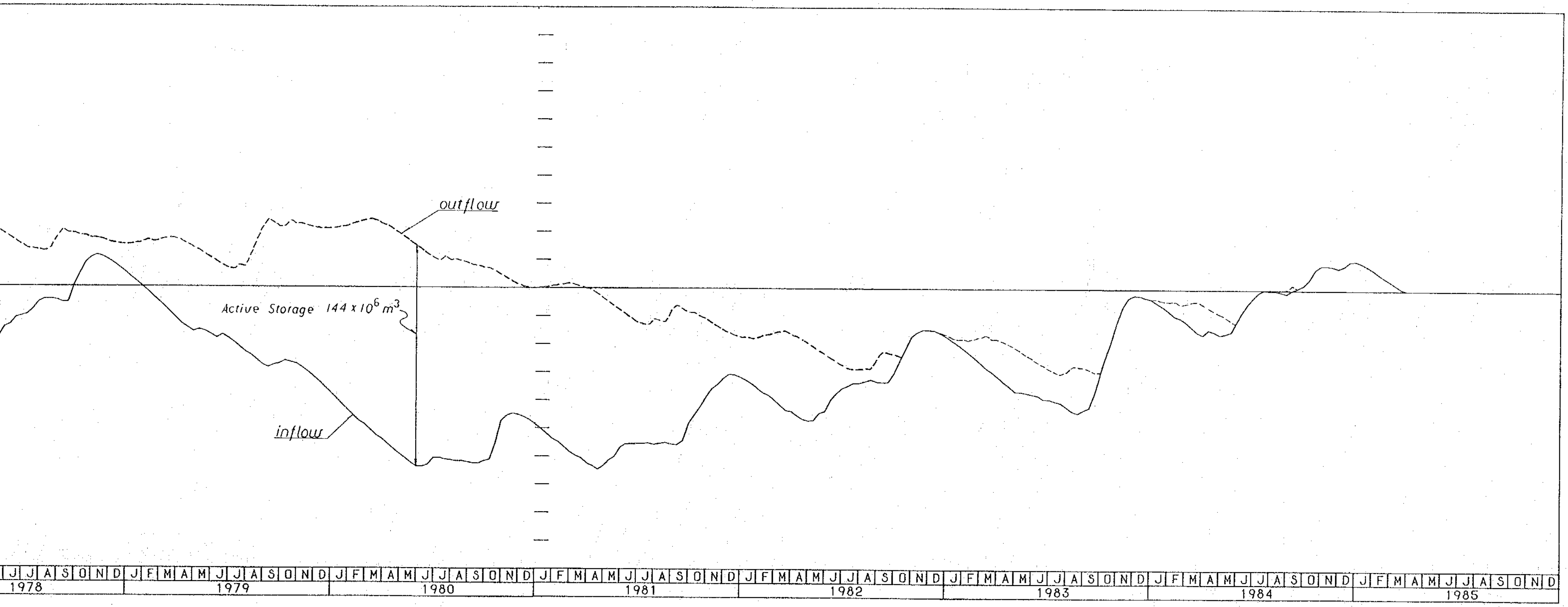

Fig. 36 Mass Curve of Inflow and Outflow at Nong Pla Lai Dam

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THE EAST COAST WATER RESOURCES
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JAPAN INTERNATIONAL COOPERATION AGENCY

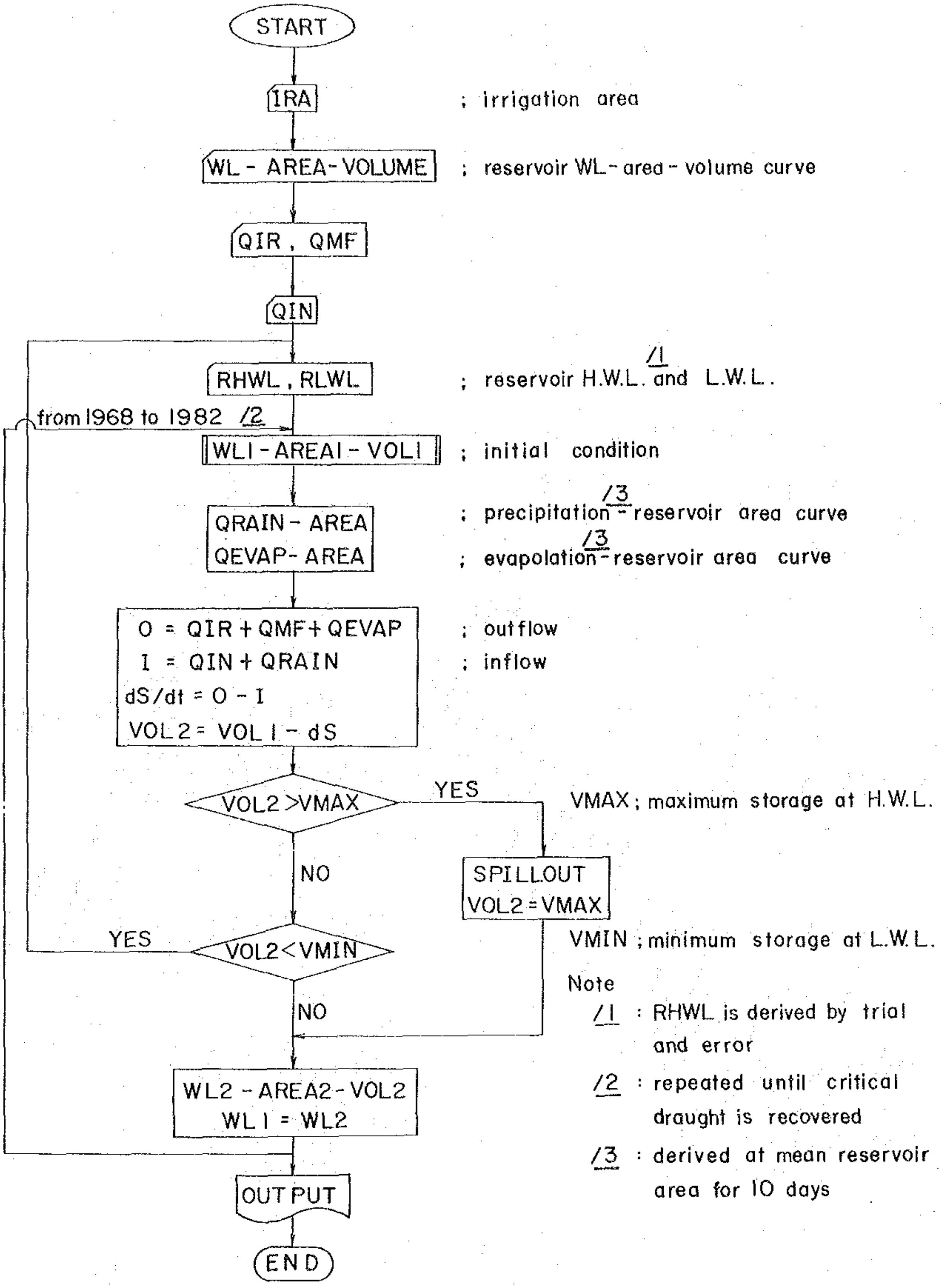

Fig. 37 Flow Chart of Reservoir Operation , Khlong Thap Ma Dam Scheme

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THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
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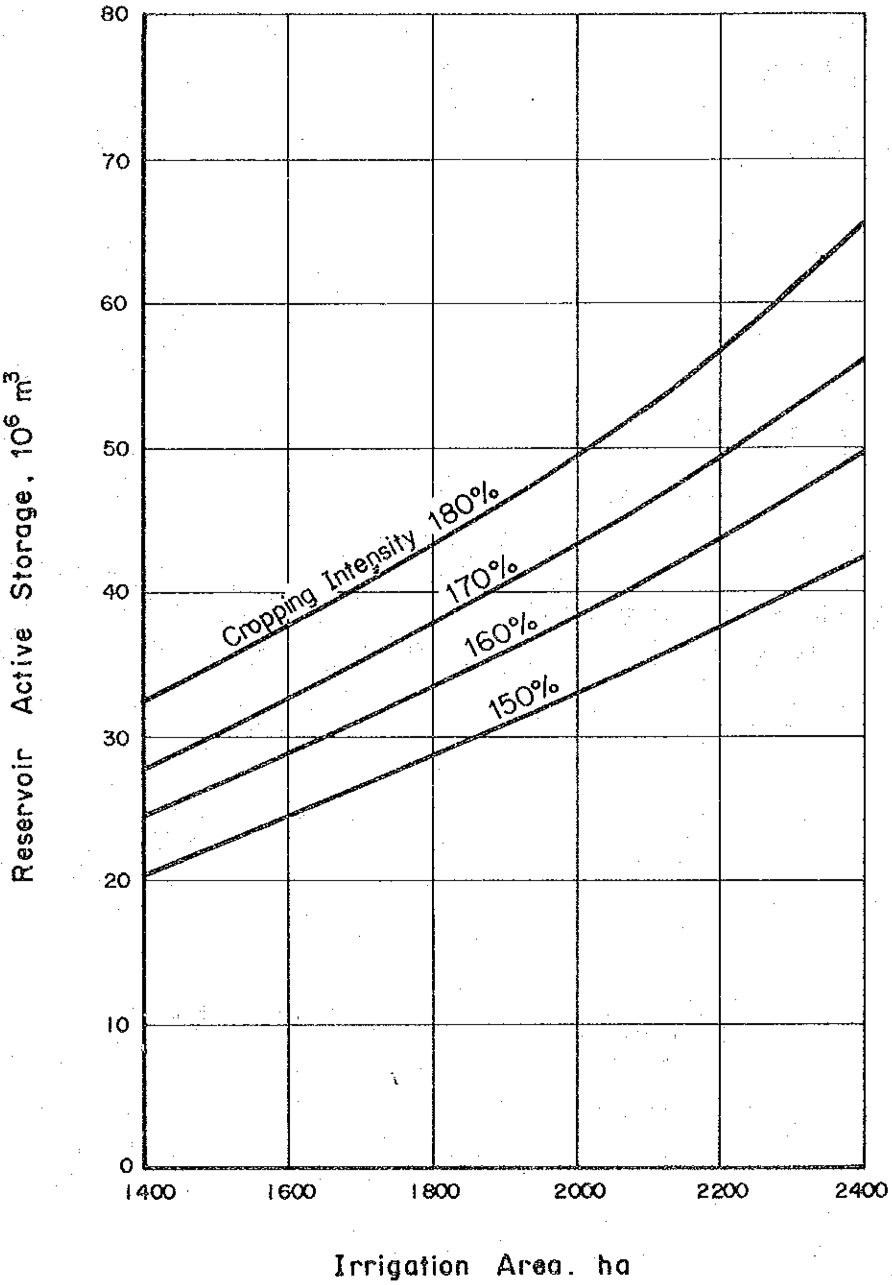

Fig. 38 Relationship between Irrigation Area, Cropping Intensity and Reservoir Active Storage Capacity, Khlong Thap Ma Dam Scheme

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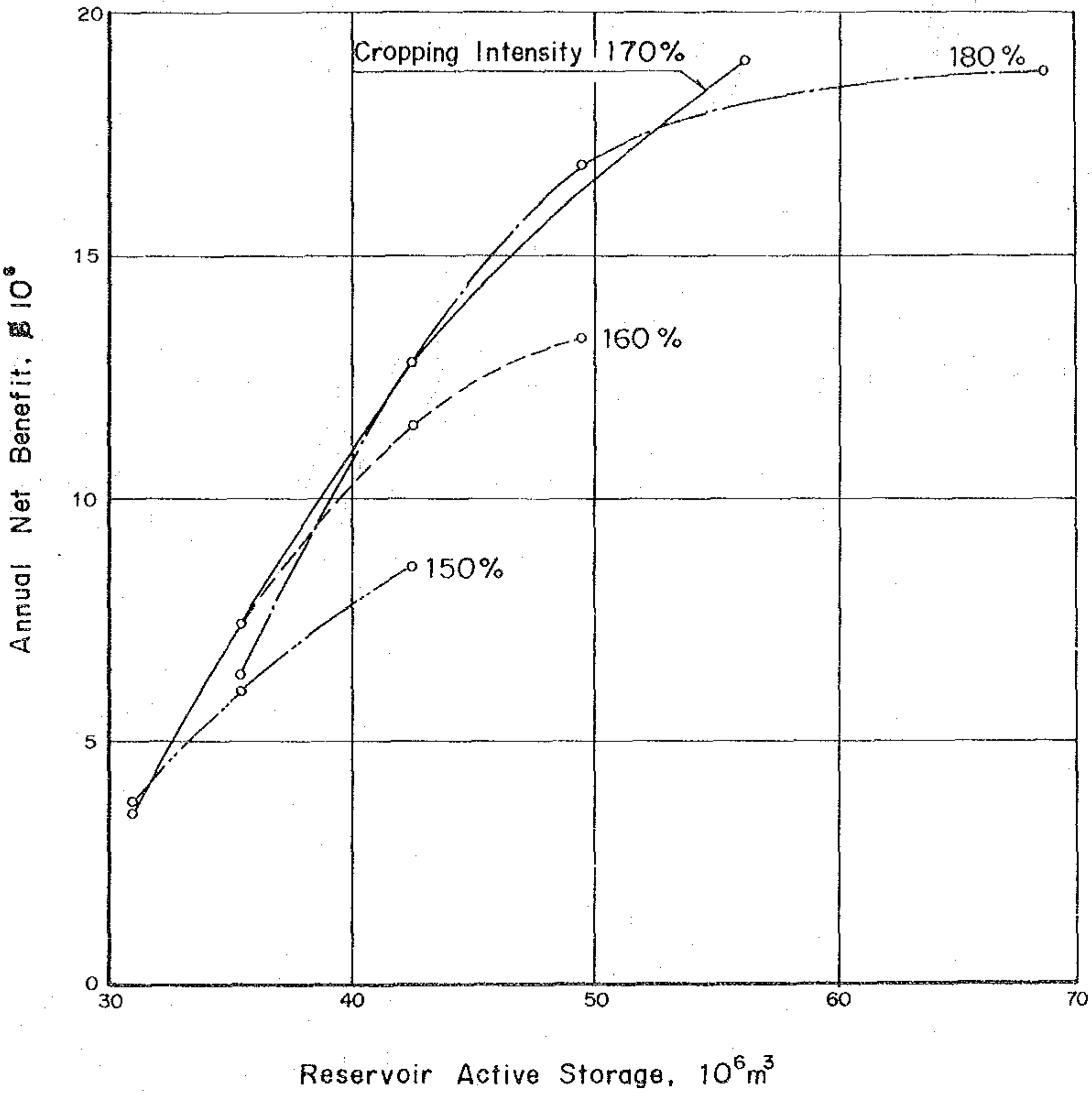

Fig. 39 Economic Comparison of Alternatives, Khlong Thap Ma Dam Scheme

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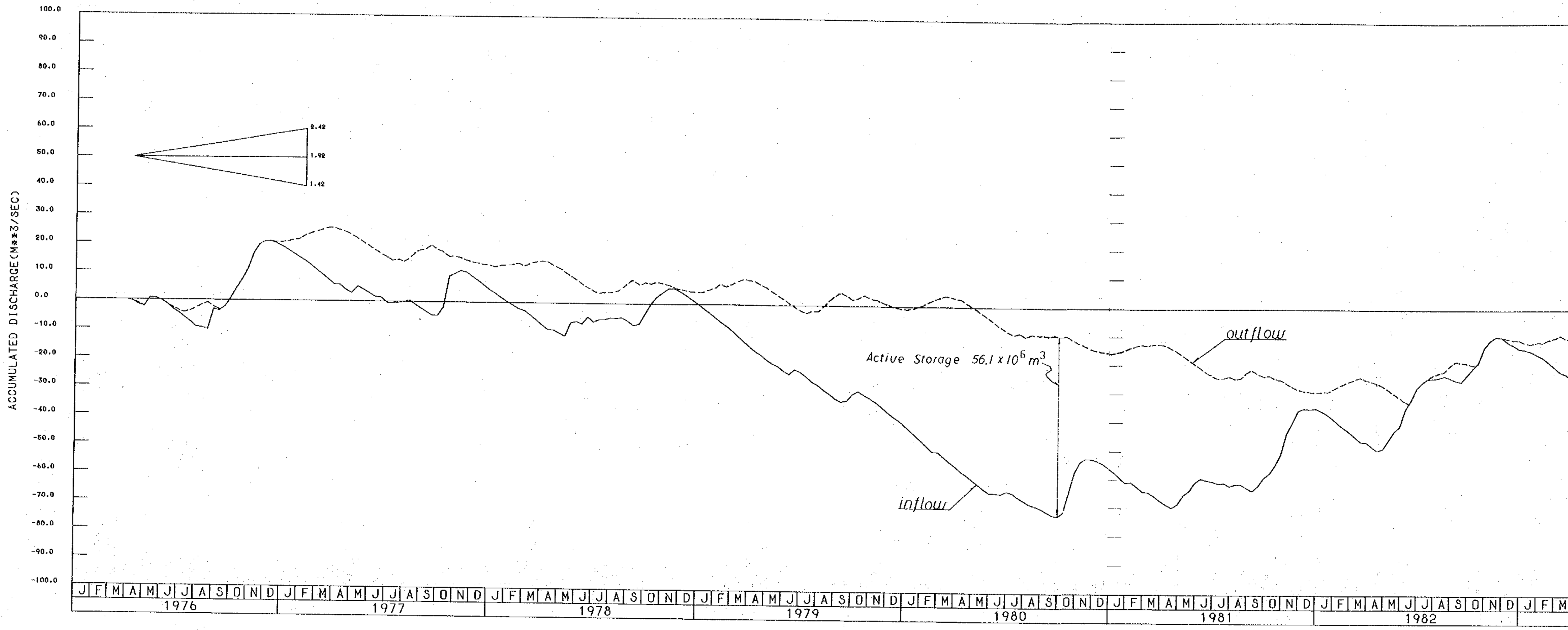


Fig.40 Mass Curve of Inflow and Outflo

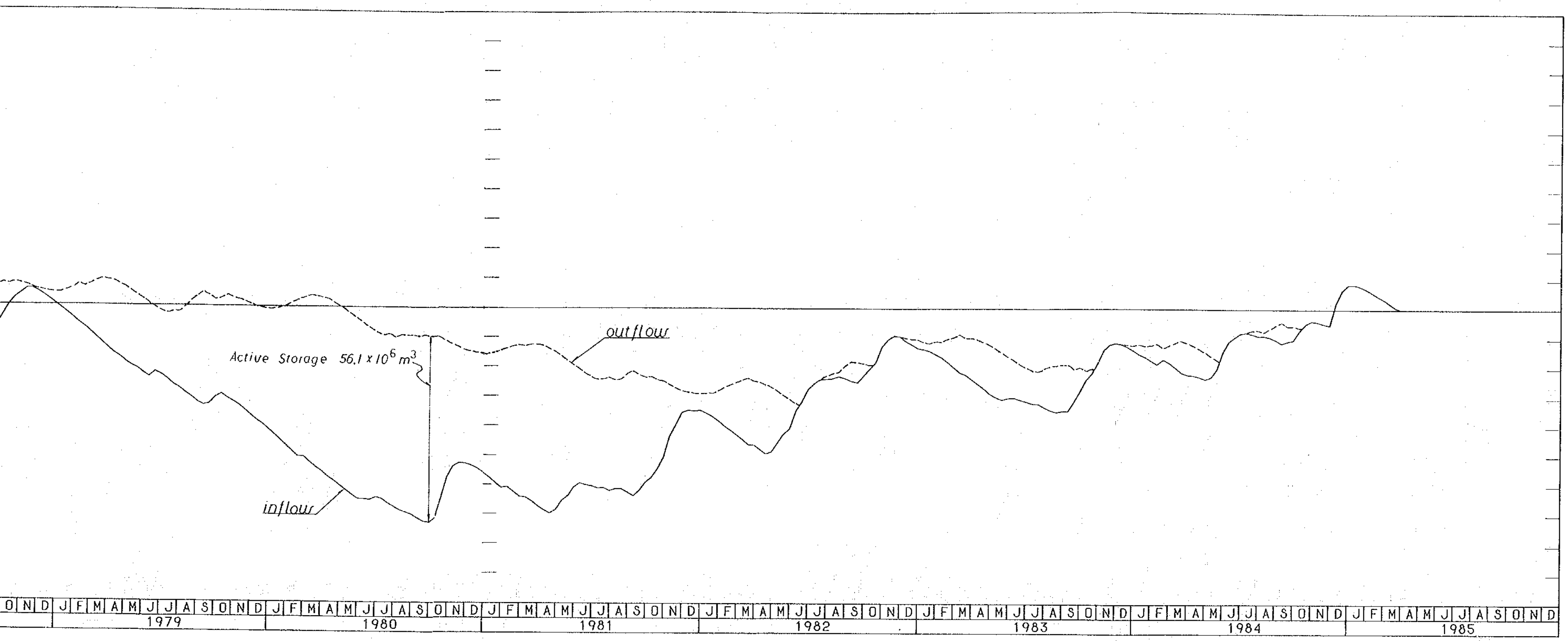


Fig.40 Mass Curve of Inflow and Outflow at Khlong Thap Ma Dam

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

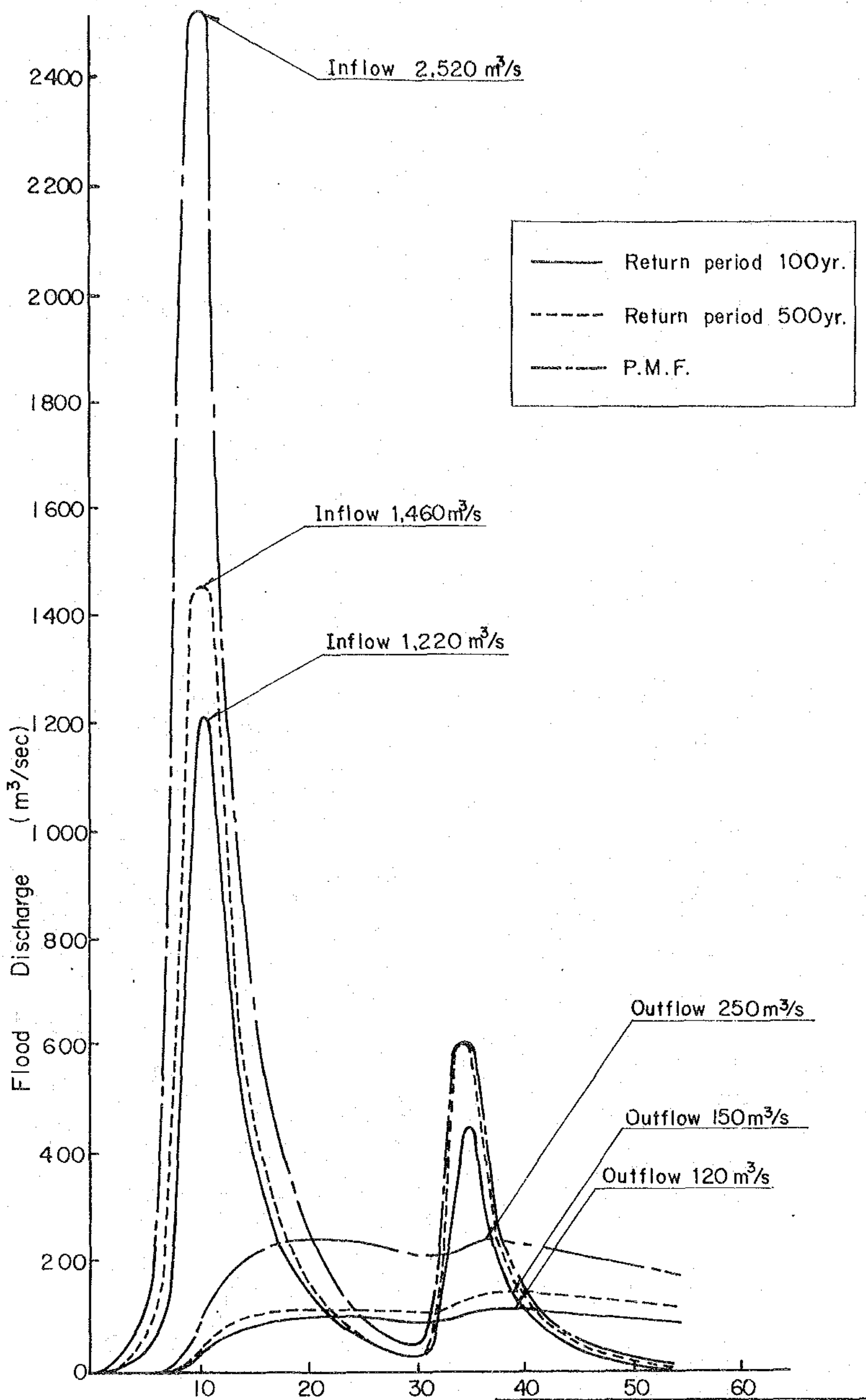


Fig. 41 Flood Routing, Khlong Luang Dam

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II

JAPAN INTERNATIONAL COOPERATION AGENCY

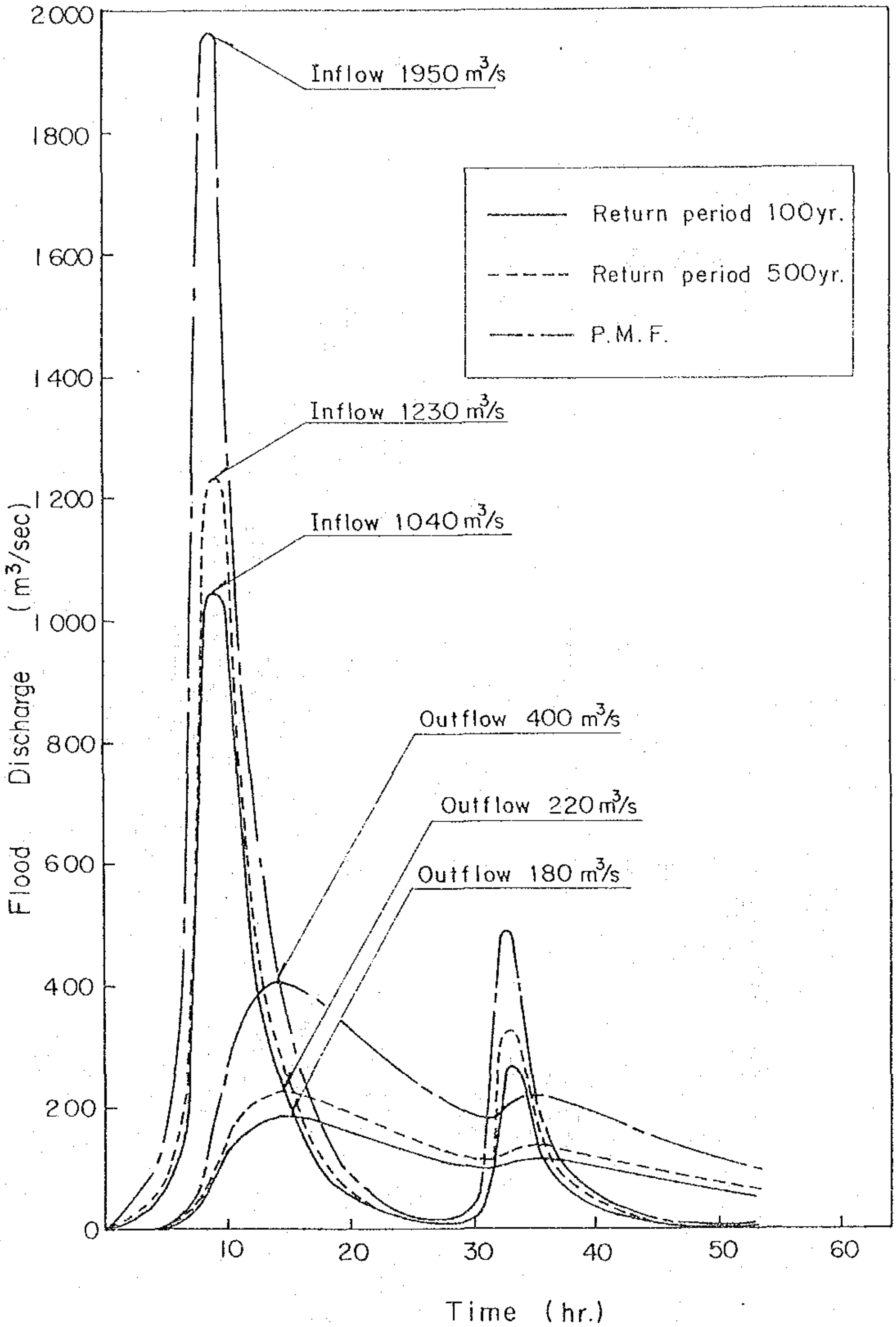


Fig. 42 Flood Routing, Khlong Yai Dam

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

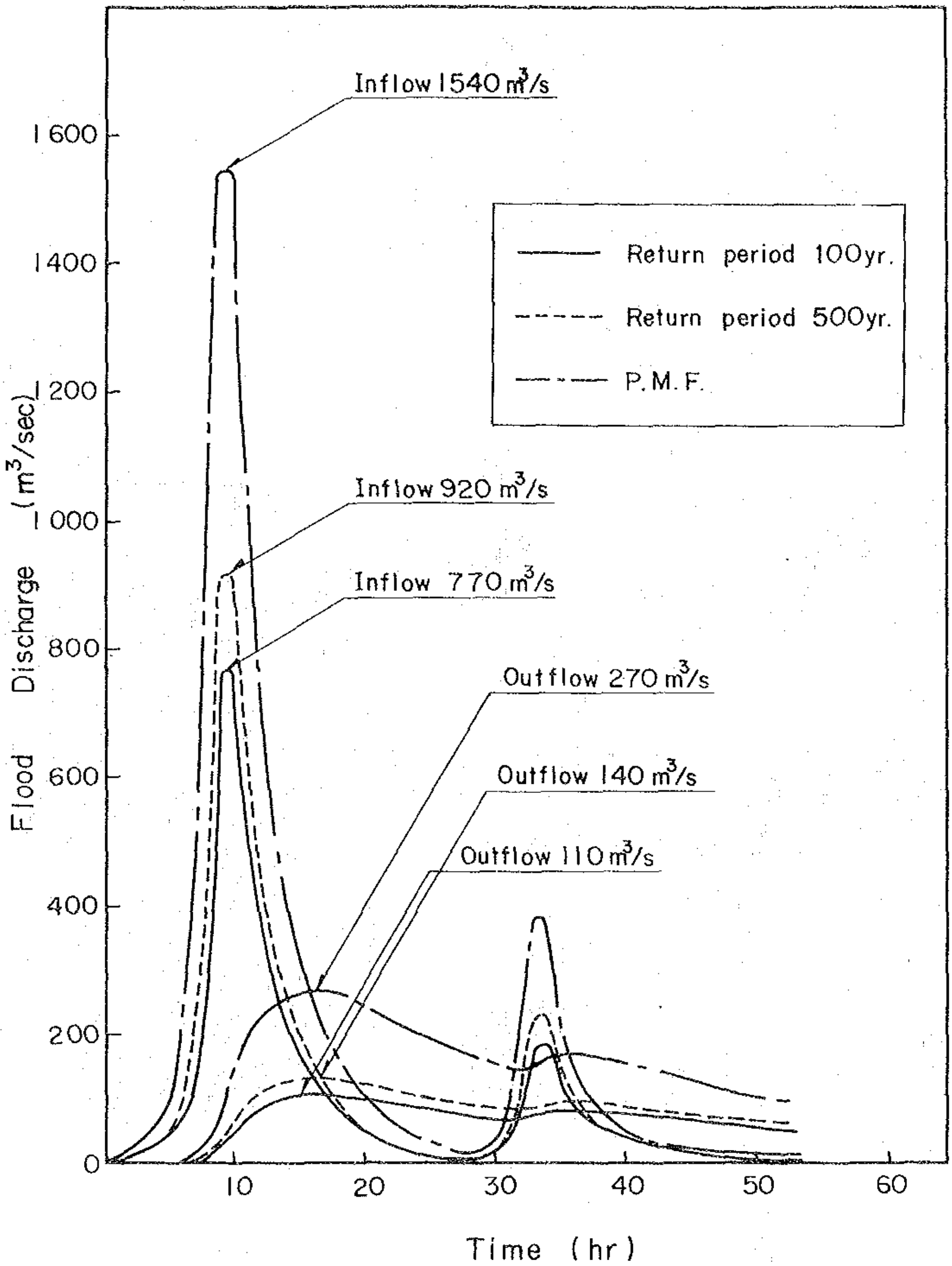


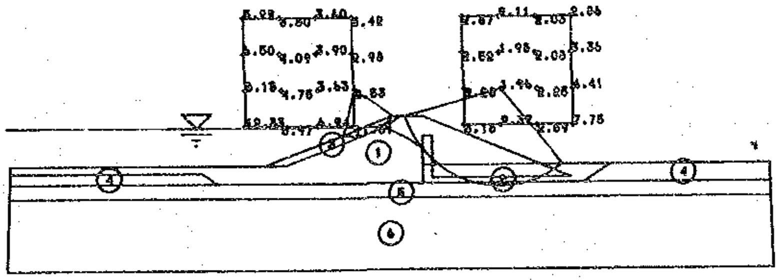
Fig. 43 Flood Routing, Khlong Thap Ma Dam

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M²)	FRICTION (DEG)	W(WET) (T/M³)	W(SAT) (T/M³)	W(SUB) (T/M³)
1	1.00	30.00	1.98	2.14	1.14
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30
ACCELERATION OF EARTHQUAKE				0.050	

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	2.531	1.963
SEISMIC	—	—



MINIMUM SAFETY FACTOR (SEISMIC)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	—	—
SEISMIC	2.106	1.632

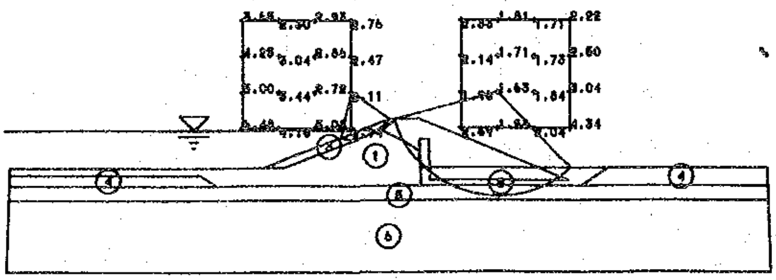


Fig.44 Stability Analysis, Khlong Luang Dam (H.W.L)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M^2)	FRICTION (DEG)	W(WET) (T/M^3)	W(SAT) (T/M^3)	W(SUB) (T/M^3)
1	1.00	30.00	1.98	2.14	1.14
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	1.350	1.258
SEISMIC	—	—

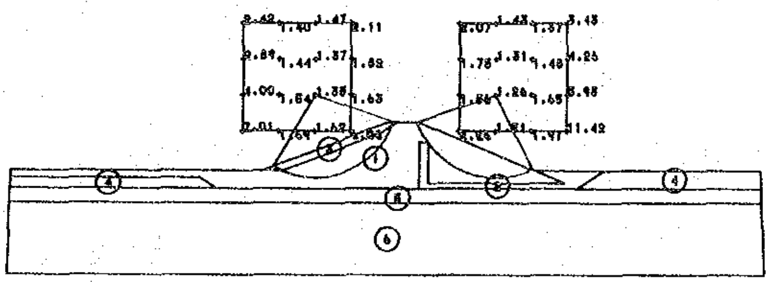


Fig.45 Stability Analysis, Khlong Luang Dam

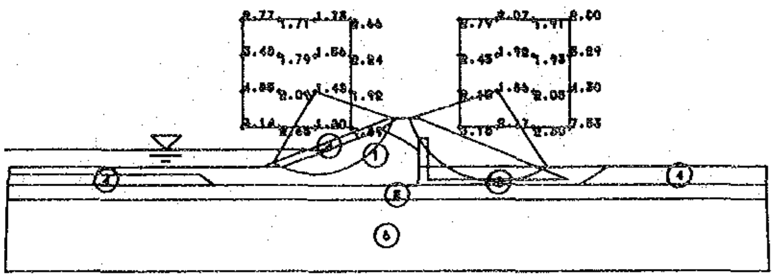
(Reservoir Empty after Completion)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M^2)	FRICTION (DEG)	W(WET) (T/M^3)	W(SAT) (T/M^3)	W(SUB) (T/M^3)
1	1.00	30.00	1.98	2.14	1.14
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30
ACCELERATION OF EARTHQUAKE				0.050	

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	1.483	1.864
SEISMIC	—	—



MINIMUM SAFETY FACTOR (SEISMIC)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	—	—
SEISMIC	1.238	1.572

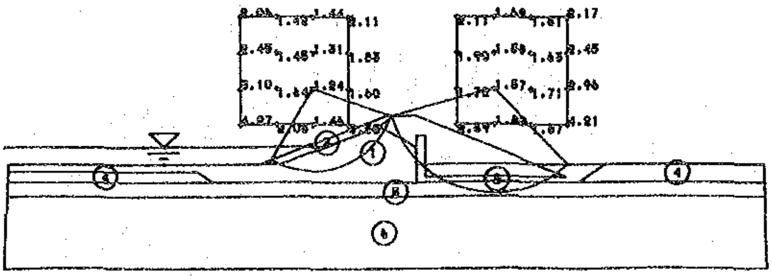


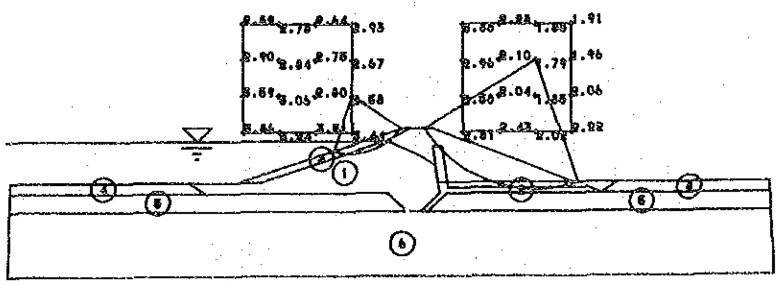
Fig.46 Stability Analysis, Khlong Luang Dam (L.W.L)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M^2)	FRICTION (DEG)	W(WET) (T/M^3)	W(SAT) (T/M^3)	W(SUB) (T/M^3)
1	1.00	28.00	2.00	2.10	1.10
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30
ACCELERATION OF EARTHQUAKE				0.050	

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	2.576	1.792
SEISMIC	—	—



MINIMUM SAFETY FACTOR (SEISMIC)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	—	—
SEISMIC	2.088	1.537

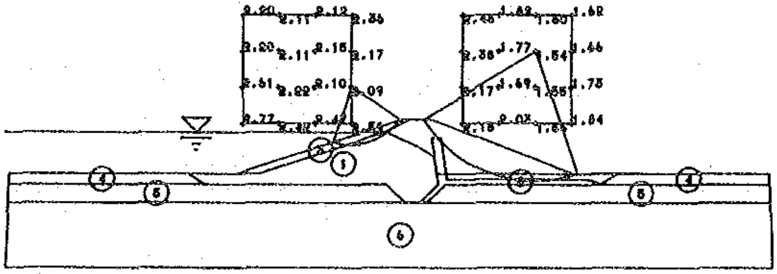


Fig.47 Stability Analysis, Khlong Yai Dam (H.W.L.)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M²)	FRICTION (DEG)	W(WET) (T/M³)	W(SAT) (T/M³)	W(SUB) (T/M³)
1	1.00	28.00	2.00	2.10	1.10
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	1.350	1.251
SEISMIC	—	—

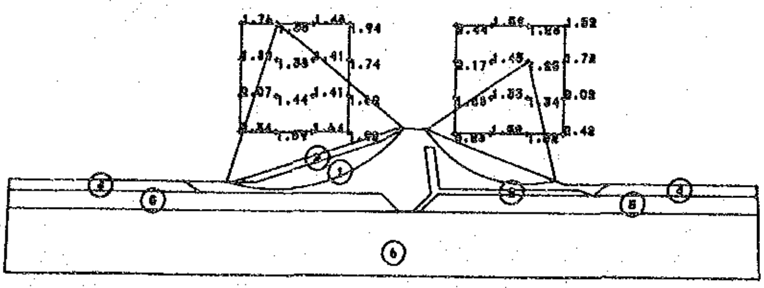


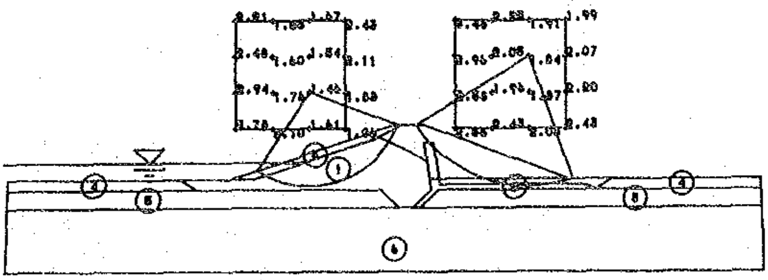
Fig.48 Stability Analysis, Khlong Yai Dam
(Reservoir Empty after Completion)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M²)	FRICTION (DEG)	W(WET) (T/M³)	W(SAT) (T/M³)	W(SUB) (T/M³)
1	1.00	28.00	2.00	2.10	1.10
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30
ACCELERATION OF EARTHQUAKE				0.050	

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	1.464	1.836
SEISMIC	—	—



MINIMUM SAFETY FACTOR (SEISMIC)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	—	—
SEISMIC	1.213	1.567

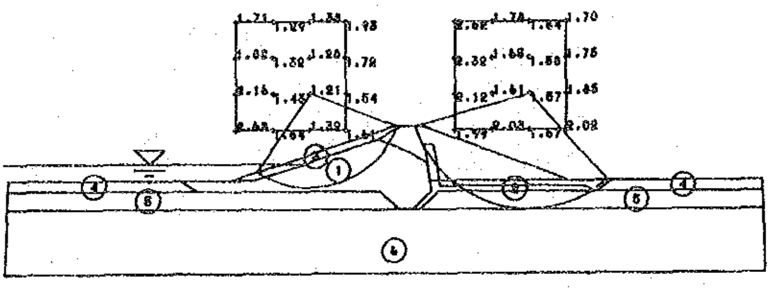


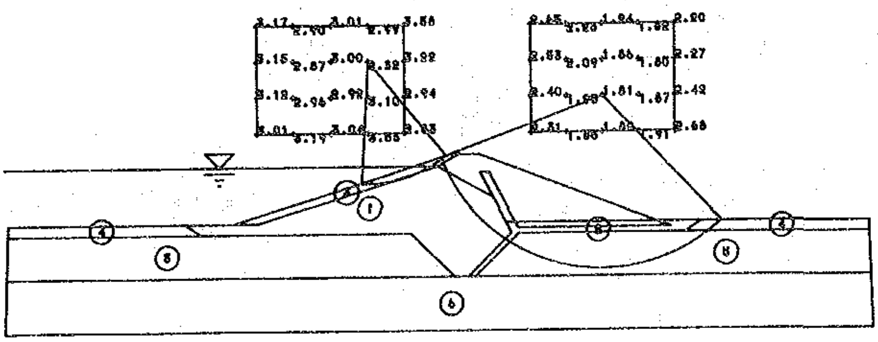
Fig.49 Stability Analysis, Khlong Yai Dam (L.W.L)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M^2)	FRICTION (DEG)	W(WET) (T/M^3)	W(SAT) (T/M^3)	W(SUB) (T/M^3)
1	1.00	30.00	1.97	2.08	1.08
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30
ACCELERATION OF EARTHQUAKE				0.050	

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	2.820	1.806
SEISMIC	-	



MINIMUM SAFETY FACTOR (SEISMIC)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	-	
SEISMIC	2.104	1.480

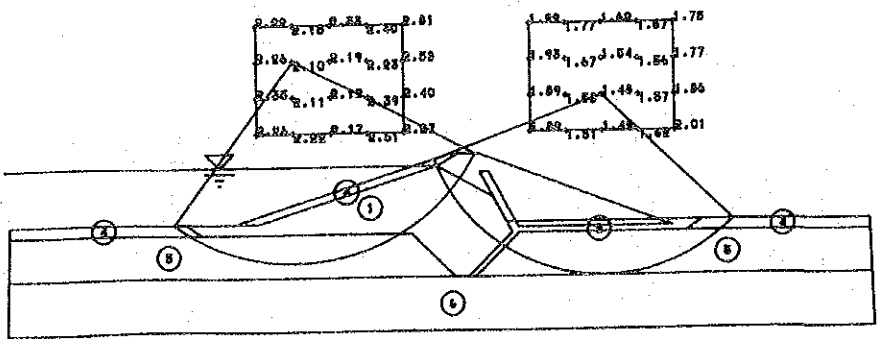


Fig.50 Stability Analysis, Khlong Thap Ma Dam (H.W.L)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M²)	FRICTION (DEG)	W(WET) (T/M³)	W(SAT) (T/M³)	W(SUB) (T/M³)
1	1.00	30.00	1.97	2.08	1.08
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	1.397	1.246
SEISMIC	—	—

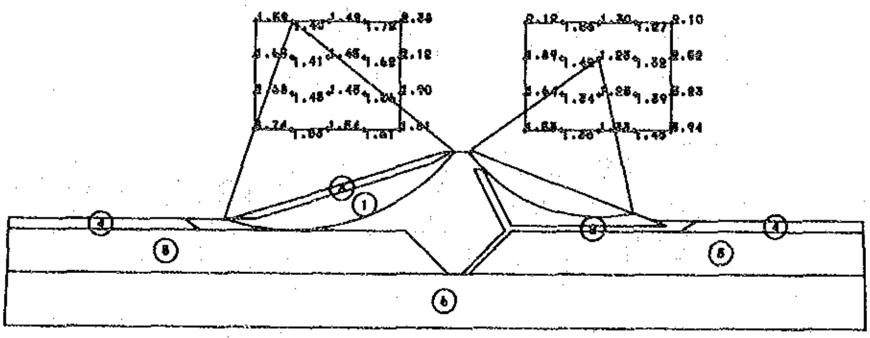


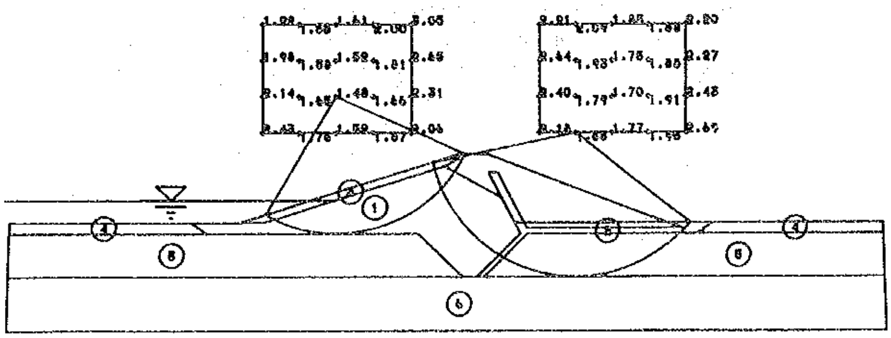
Fig. 51 Stability Analysis, Khlong Thap Ma Dam (Reservoir Empty after Completion)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Design Values of Materials

MATERIAL	COHESION (T/M²)	FRICTION (DEG)	W(WET) (T/M³)	W(SAT) (T/M³)	W(SUB) (T/M³)
1	1.00	30.00	1.97	2.08	1.08
2	0.00	35.00	1.85	2.15	1.15
3	0.00	40.00	1.90	2.15	1.15
4	2.00	25.00	1.80	1.85	0.85
5	2.00	28.00	1.85	1.94	0.94
6	10.00	35.00	2.10	2.30	1.30
ACCELERATION OF EARTHQUAKE				0.050	

MINIMUM SAFETY FACTOR (NORMAL)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	1.477	1.685
SEISMIC	—	—



MINIMUM SAFETY FACTOR (SEISMIC)		
	UP STREAM SIDE	DOWN STREAM SIDE
NORMAL	—	—
SEISMIC	1.216	1.371

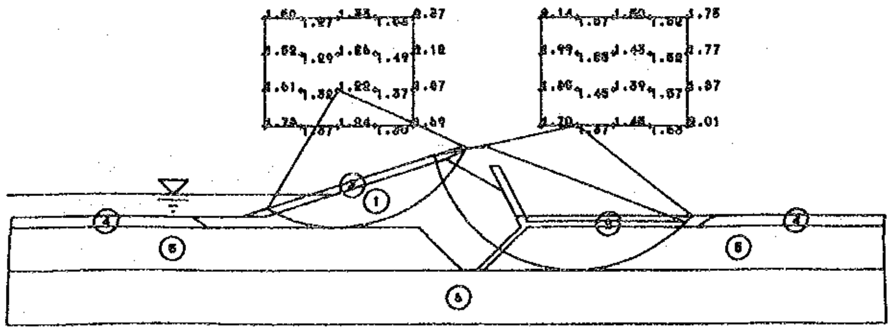
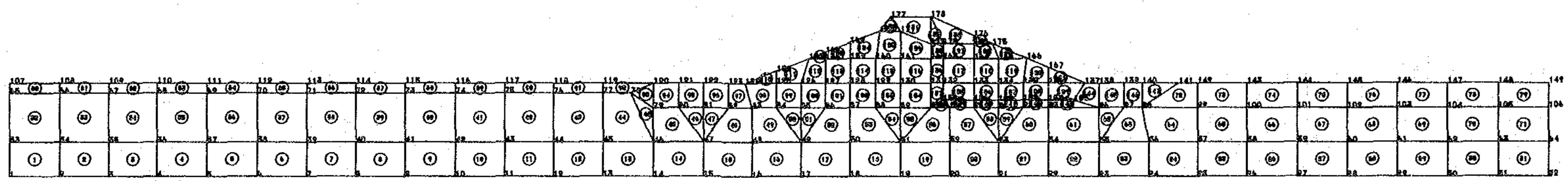


Fig.52 Stability Analysis, Khlong Thap Ma Dam (L.W.L)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

KHLONG LUANG DAM
INPUT DATA MESHES



0 50.0 m
SCALE 1/1000

TOTAL ELEMENTS = 148

TOTAL NODES = 178

Fig.53 Seepage Analysis, Khlong Luang Dam
(Flow Mesh)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

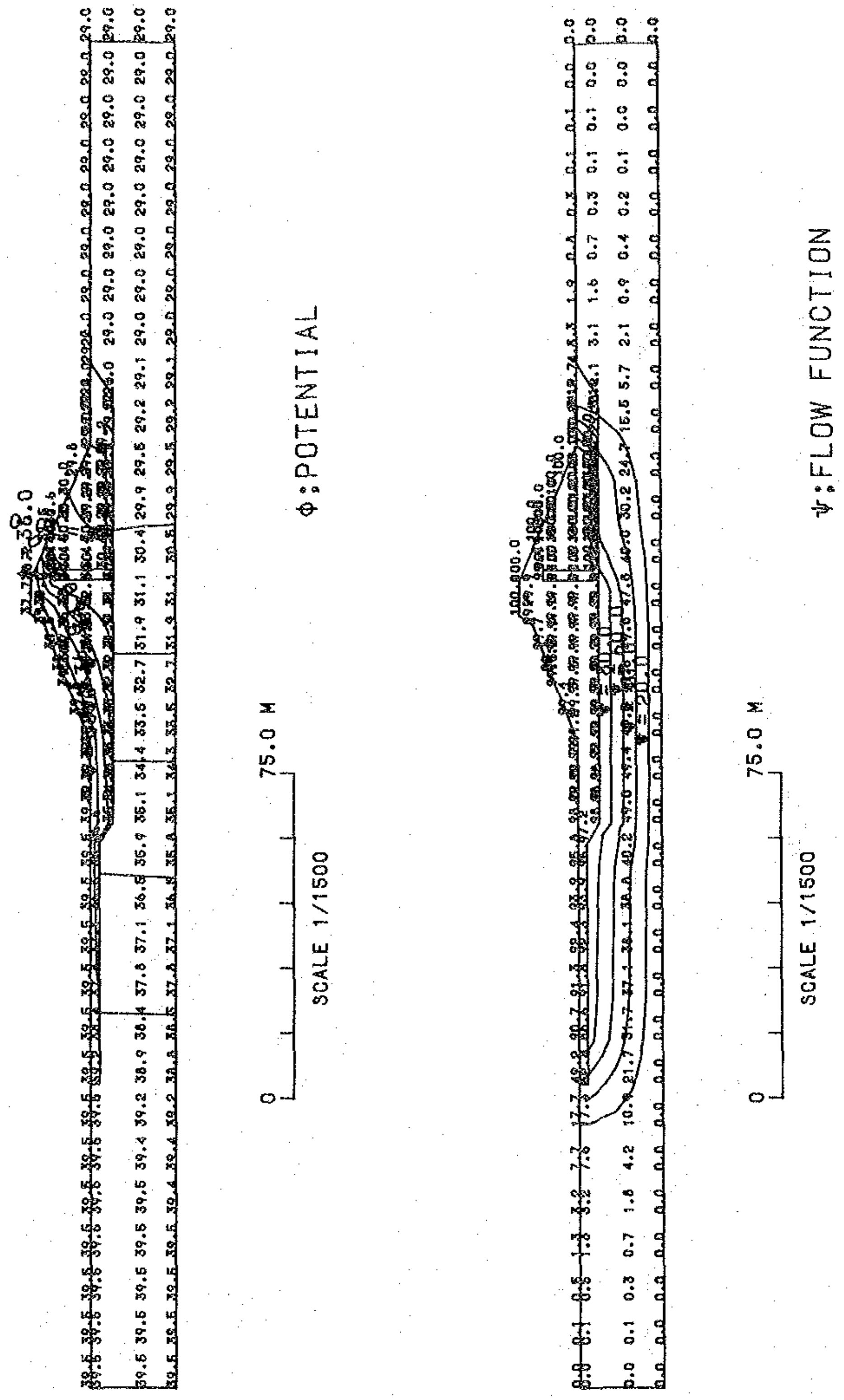


Fig. 54 Seepage Analysis, Khlong Luang Dam

(Potential & Flow Function)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

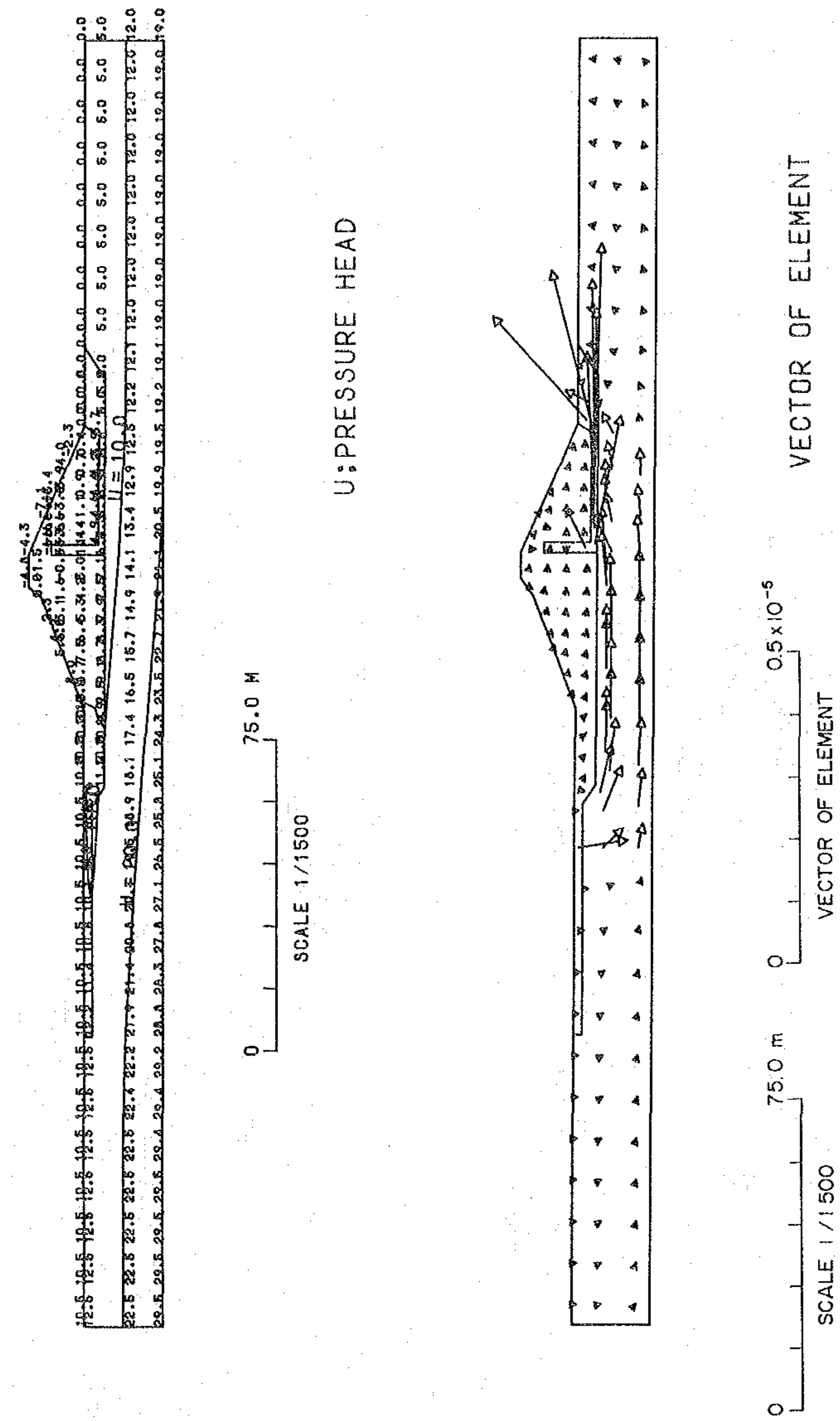


Fig. 55 Seepage Analysis, Khlong Luang Dam
(Pressure Head & Vector of Element)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

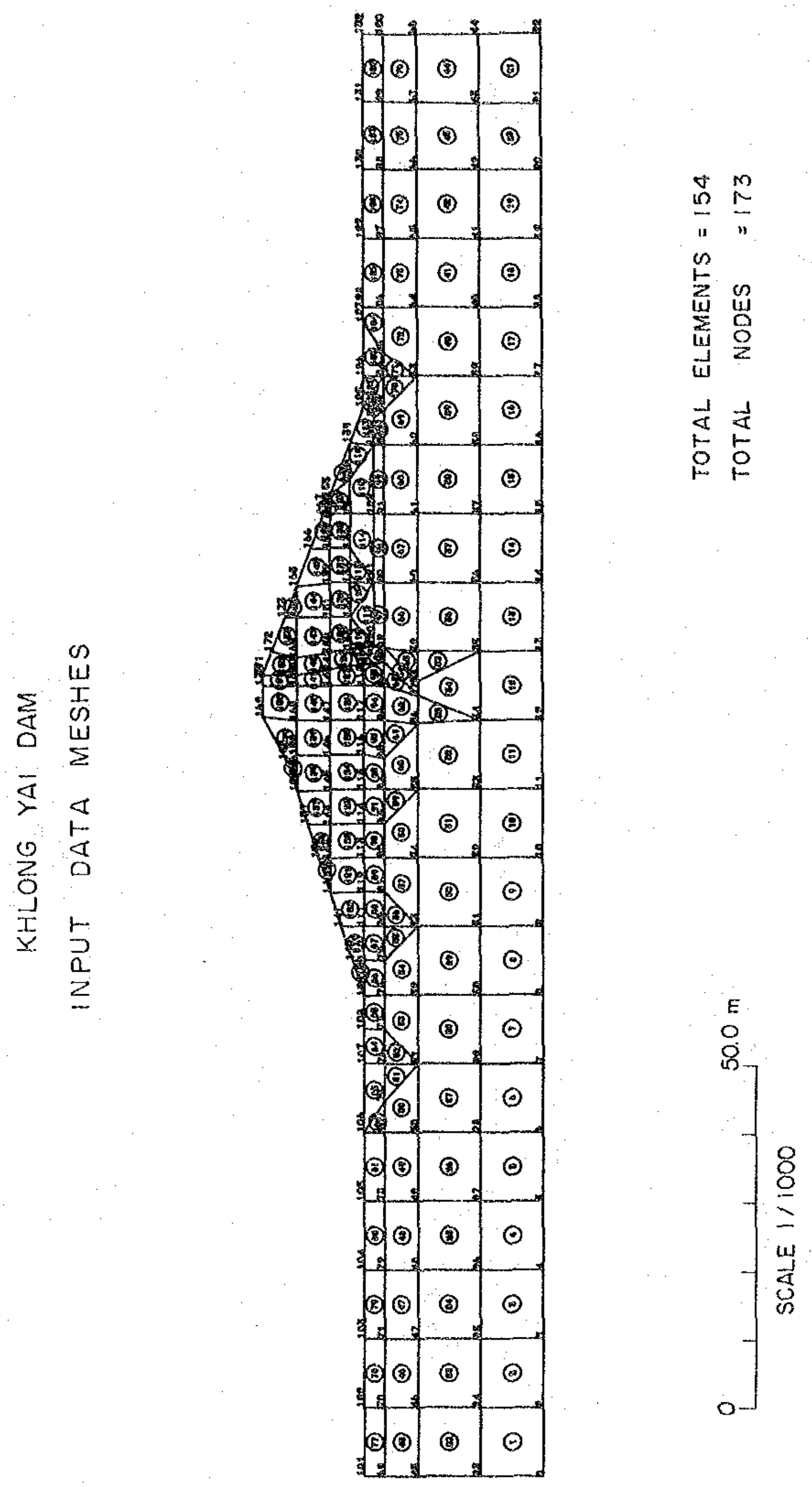


Fig. 56 Seepage Analysis, Khlong Yai Dam (Flow Mesh)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

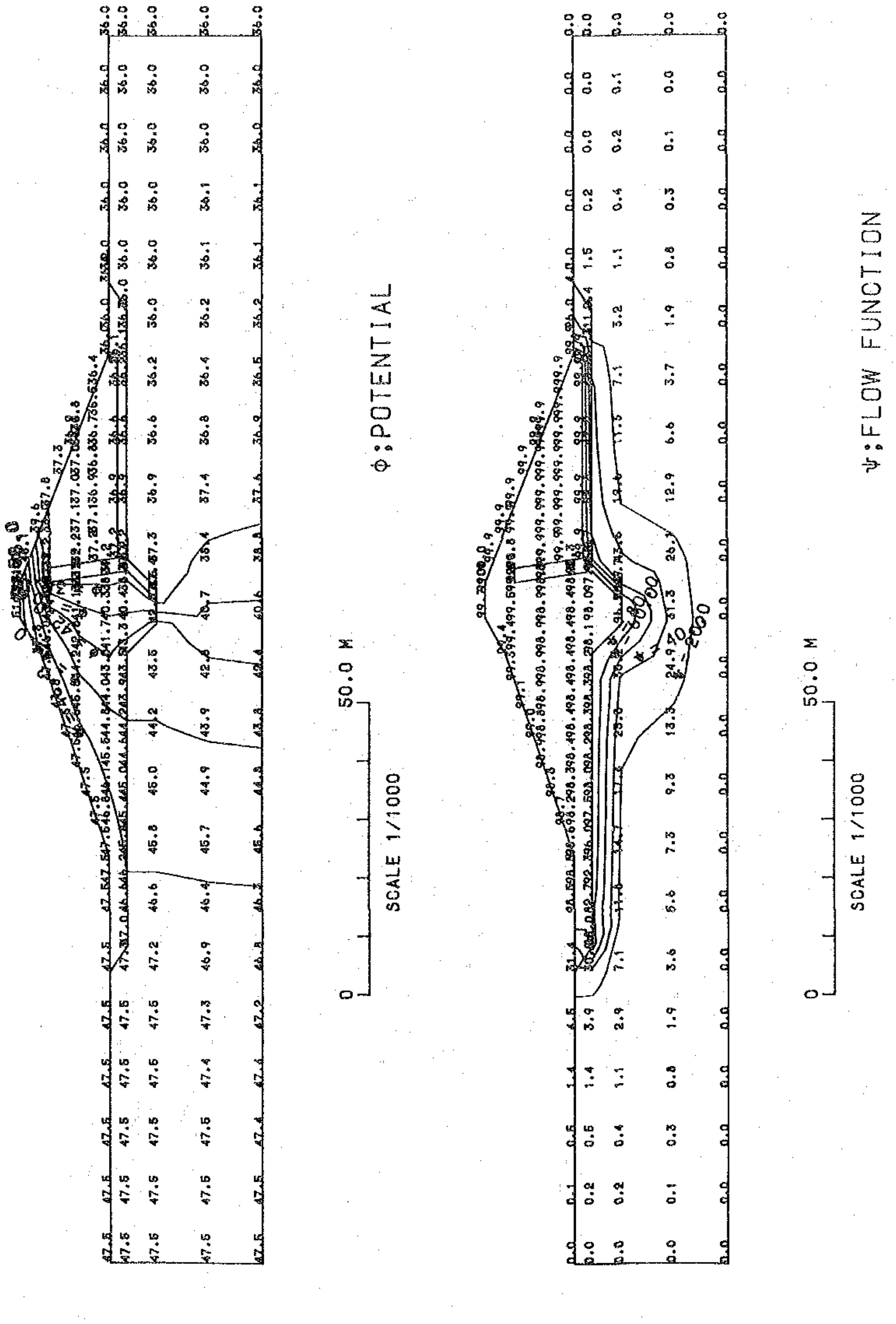


Fig. 57 Seepage Analysis, Khlong Yai Dam
(Potential & Flow Function)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

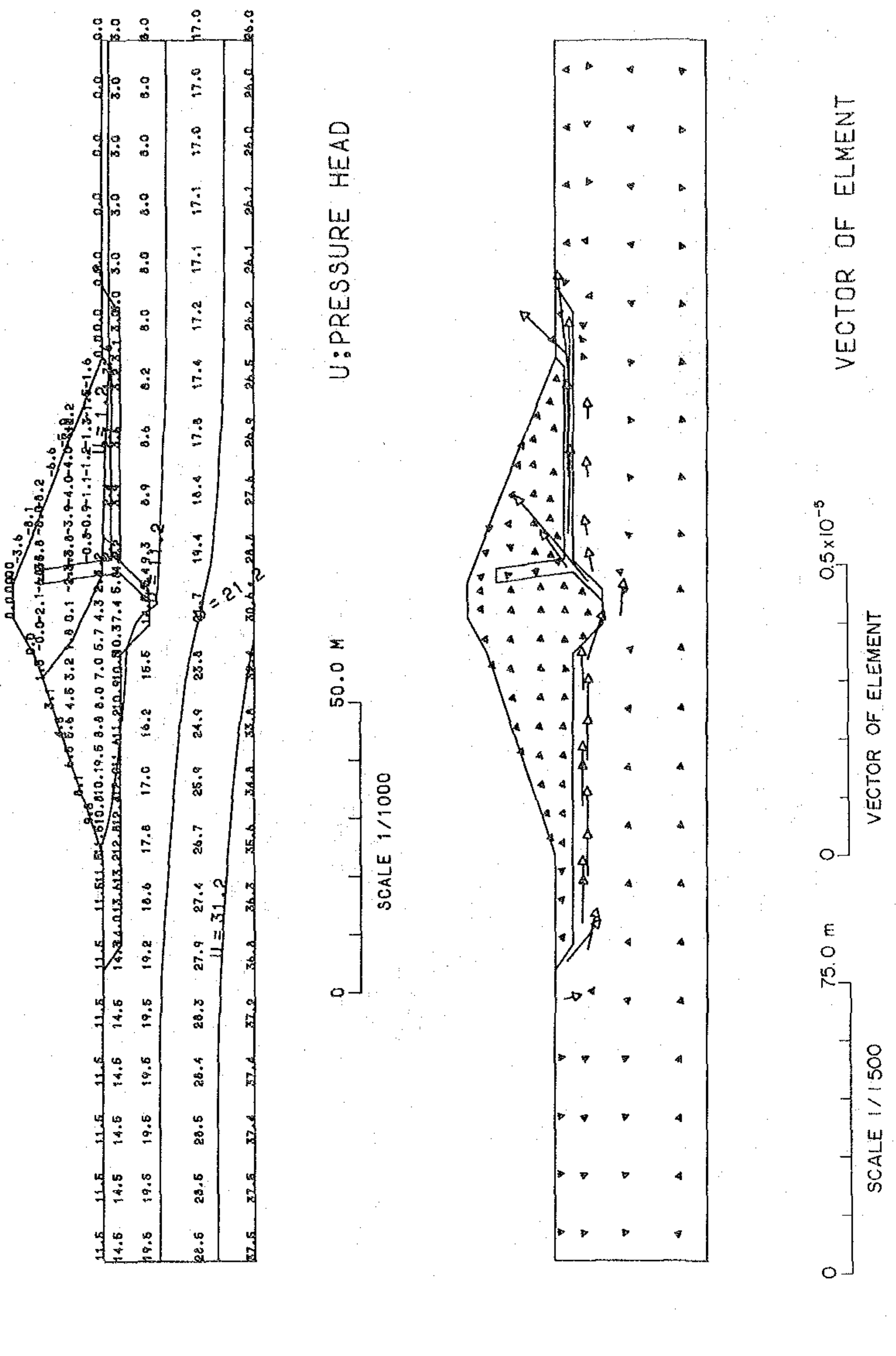


Fig. 58 Seepage Analysis, Khlong Yai Dam
(Pressure Head & Vector of Element)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

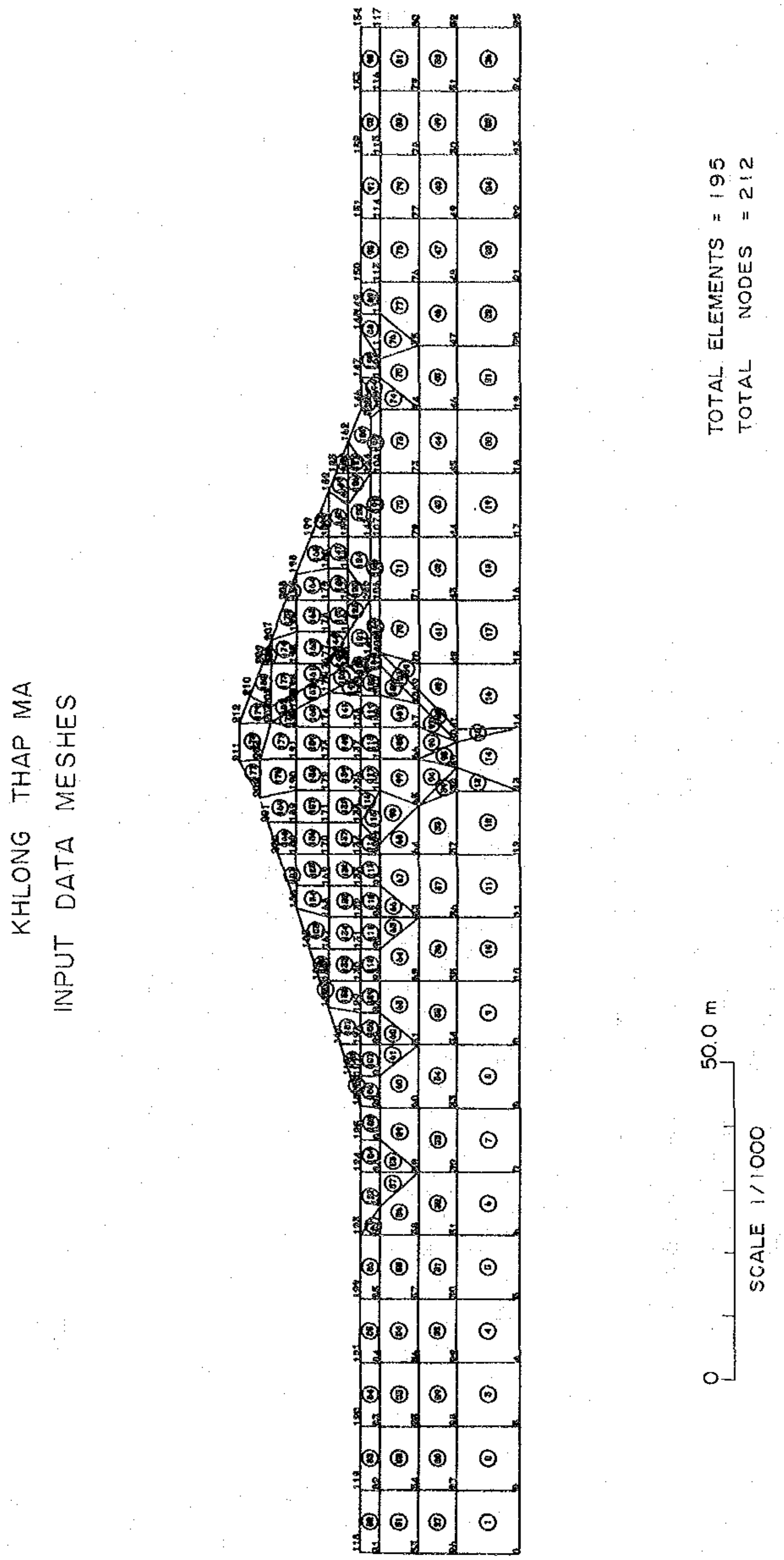


Fig.59 Seepage Analysis, Khlong Thap Ma Dam (Flow Mesh)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

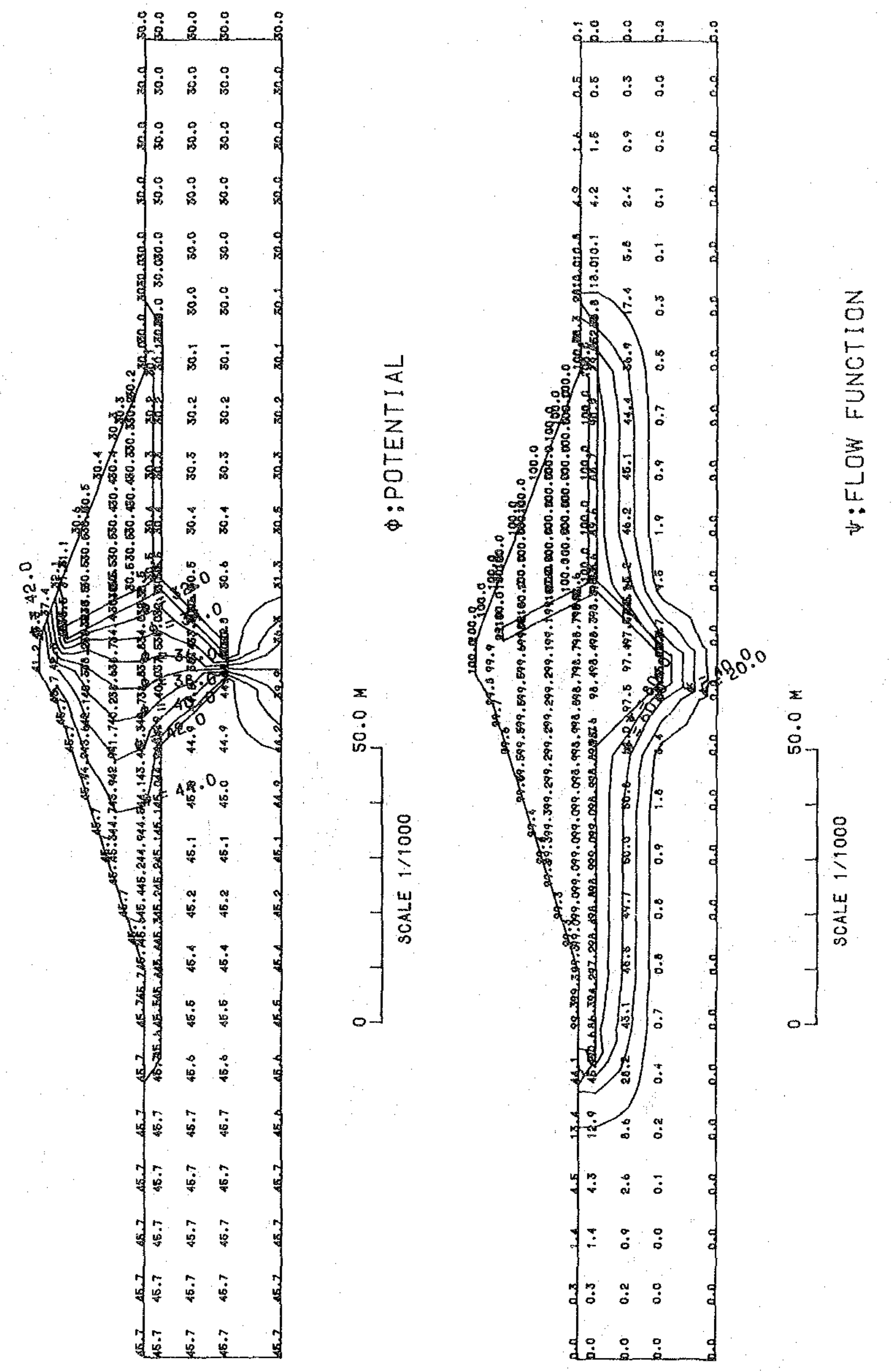


Fig.60 Seepage Analysis, Khlong Thap Ma Dam
(Potential & Flow Function)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

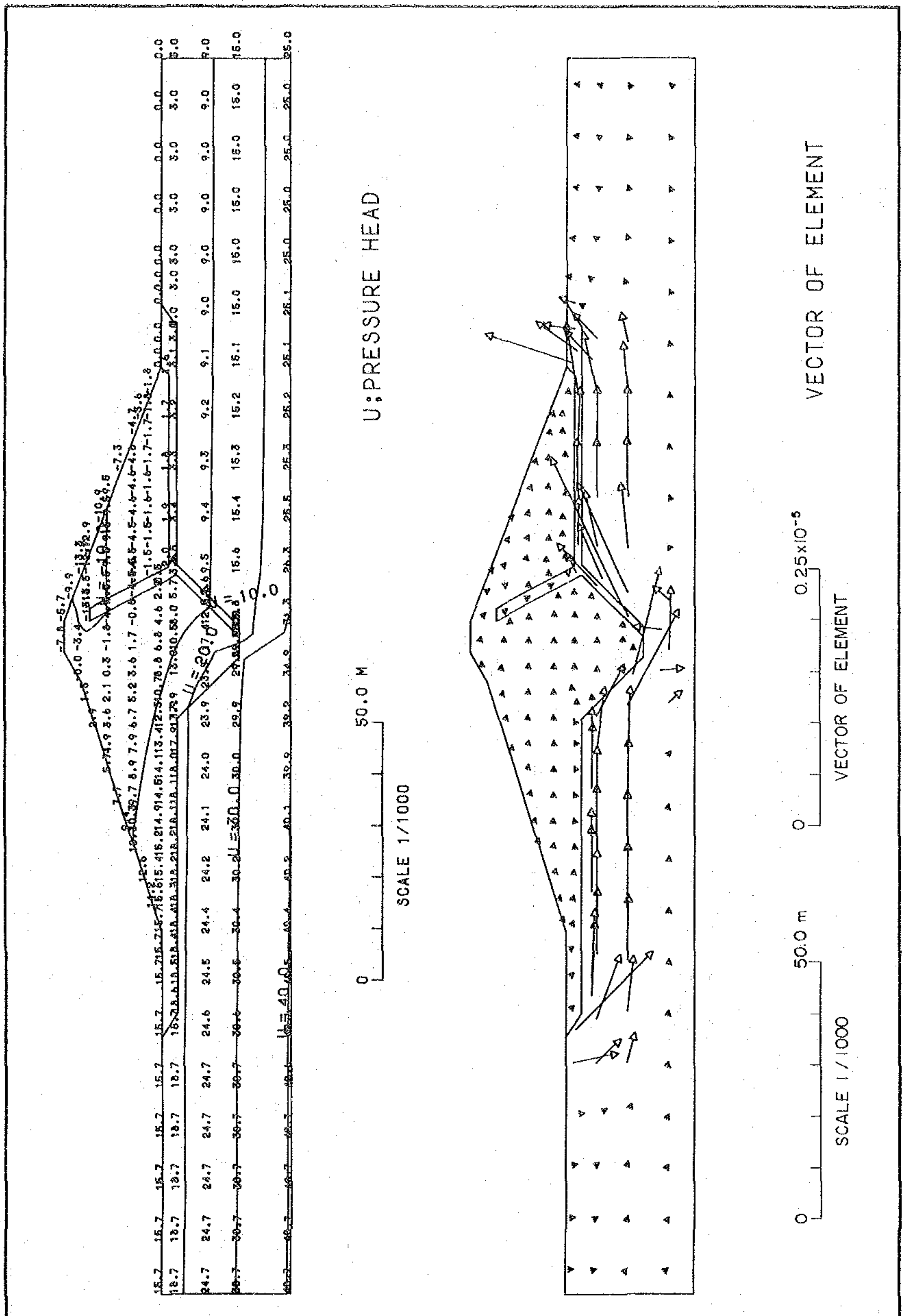


Fig.61 Seepage Analysis, Khlong Thap Ma Dam
(Pressure Head & Vector of Element)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES
DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

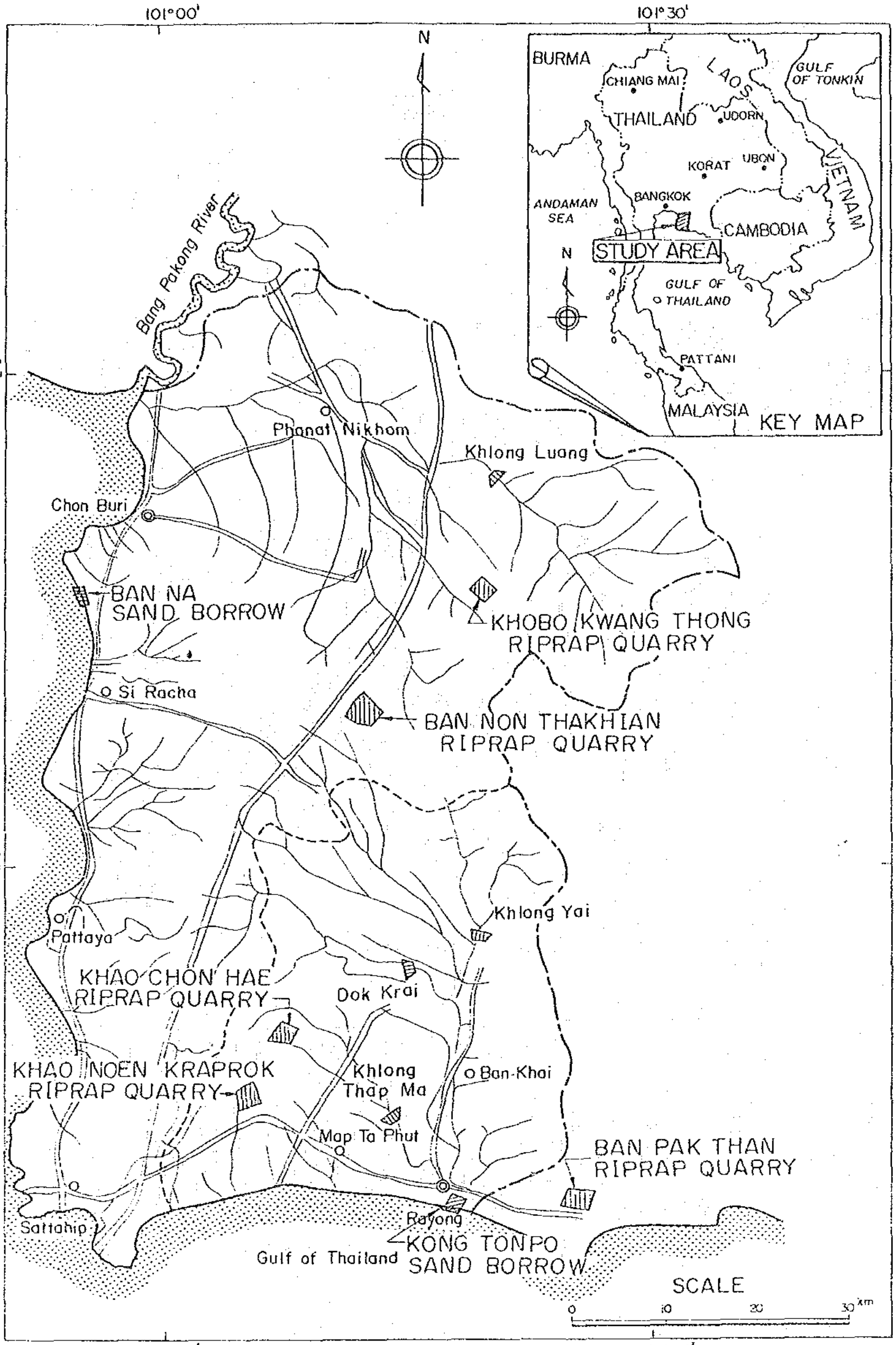
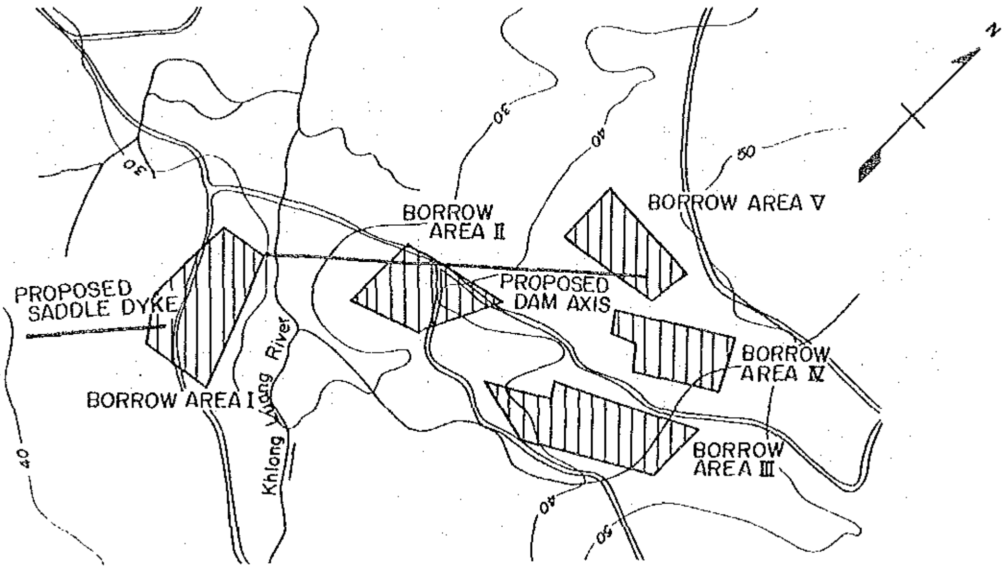
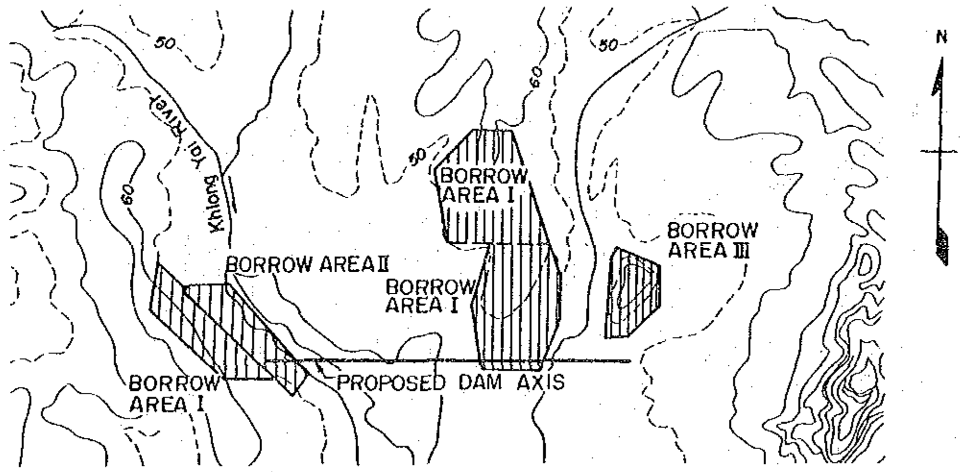


Fig.62 Location Map of Construction Materials (1/2)

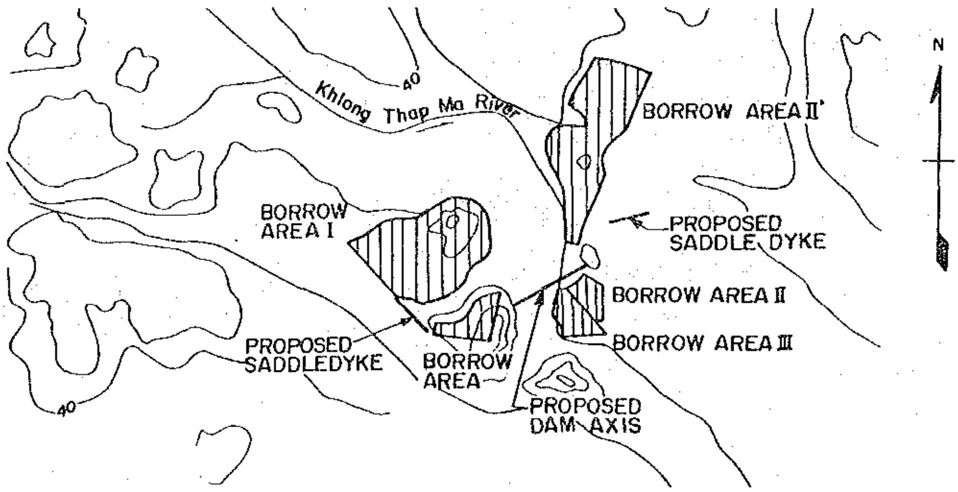
KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY



KHLONG LUANG



KHLONG YAI DAM



KHLONG THAP MA DAM

Fig. 63 Location Map of Construction Materials (2/2)

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

Work Item		Unit	Quantity
Preparatory Works		L.S	
Main Dam			
Excavation	Common	m³	1,971,000
Embankment	Core & Blanket	m³	2,605,000
	Filter	m³	213,000
	Riprap	m³	154,000
Concrete		m³	1,500
Sodding & Asphalt Pavement		m²/m	95,000/3,900
Saddle Dam			
Excavation	Common	m³	148,000
	Trench Cut-off	m³	60,000
Embankment	Core	m³	215,000
	Filter	m³	53,000
	Riprap	m³	31,000
Concrete		m³	1,000
Sodding & Asphalt Pavement		m²/m	16,000/2,300
Spillway			
Excavation	Common	m³	75,000
Backfill		m³	10,000
Concrete		m³	6,800
Relocation Road		km	11
Borrow Pit			
Stripping & Stock Piling		L.S	
Quarry			
Transportation & Stock Piling		L.S	
Spoilbank		L.S	

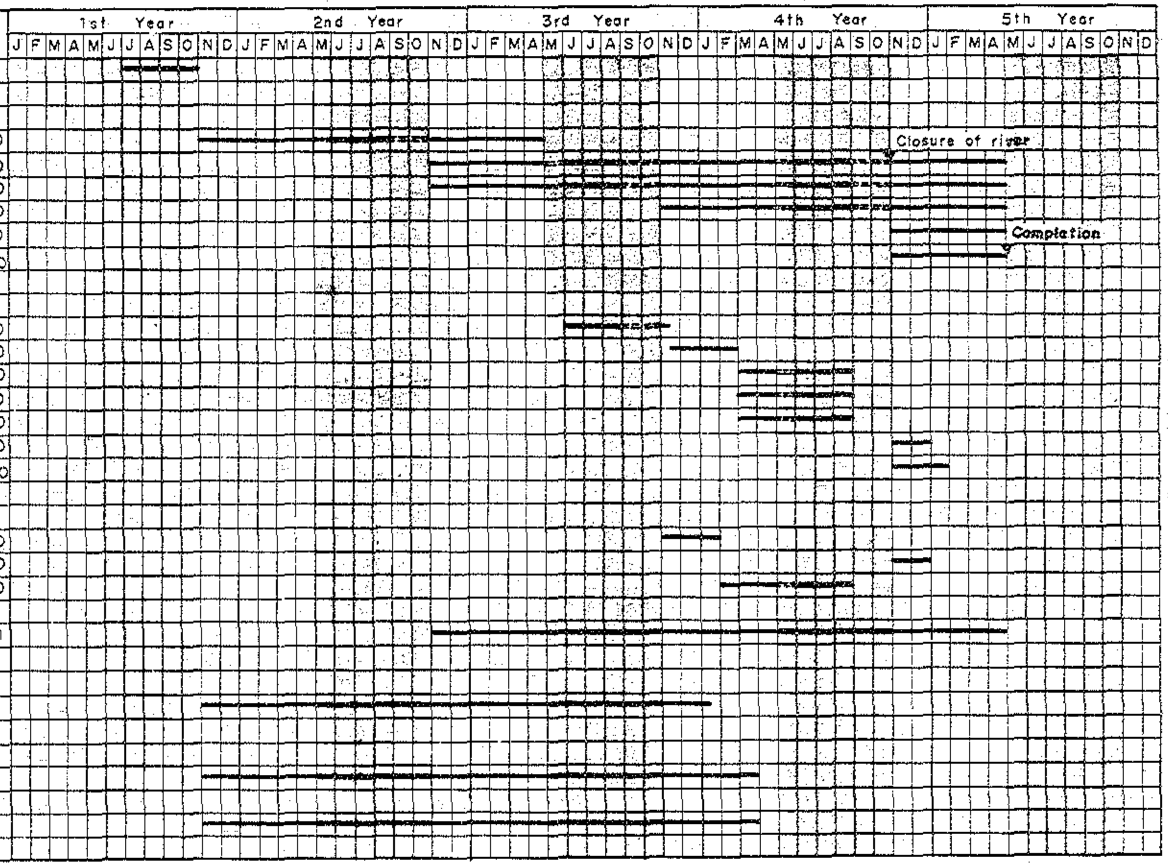


Fig. 64 Construction Time Schedule of Khlong Luang Dam

KINGDOM OF THAILAND
THE EAST COAST WATER RESOURCES DEVELOPMENT PROJECT PHASE II
JAPAN INTERNATIONAL COOPERATION AGENCY

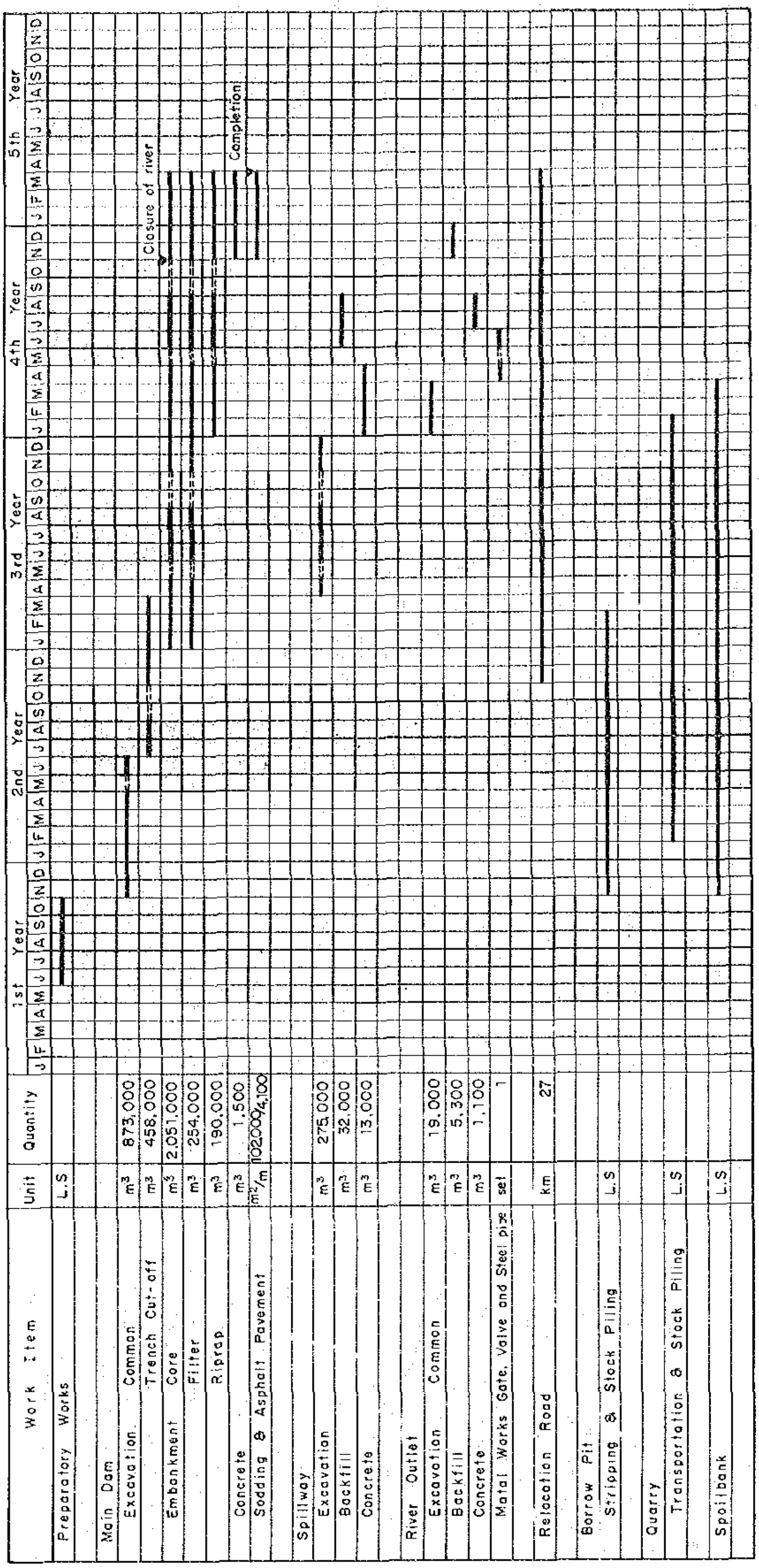


Fig. 65 Construction Time Schedule of Khlong Yai Dam

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Work Item		Unit	Quantity
Preparatory Works		L.S	
Main Dam			
Excavation	Common	m^3	508,000
	Trench Cut-off	m^3	60,000
Embankment	Core	m^3	1,182,000
	Filter	m^3	92,000
	Riprap	m^3	71,000
Concrete		m^3	300
Sodding & Asphalt Pavement		m^2/m	43,000/850
Saddle Dam			
Excavation	Common	m^3	27,000
	Trench Cut-off	m^3	12,000
Embankment	Core	m^3	35,000
	Filter	m^3	9,000
	Riprap	m^3	5,000
Concrete		m^3	200
Sodding & Asphalt Pavement		m^2/m	2,500/420
Spillway			
Excavation	Common	m^3	101,000
Backfill		m^3	28,000
Concrete		m^3	12,000
Relocation Road		km	6
Borrow Pit			
Stripping & Stock Piling		L.S	
Quarry			
Transportation & Stock Piling		L.S	
Spoilbank		L.S	

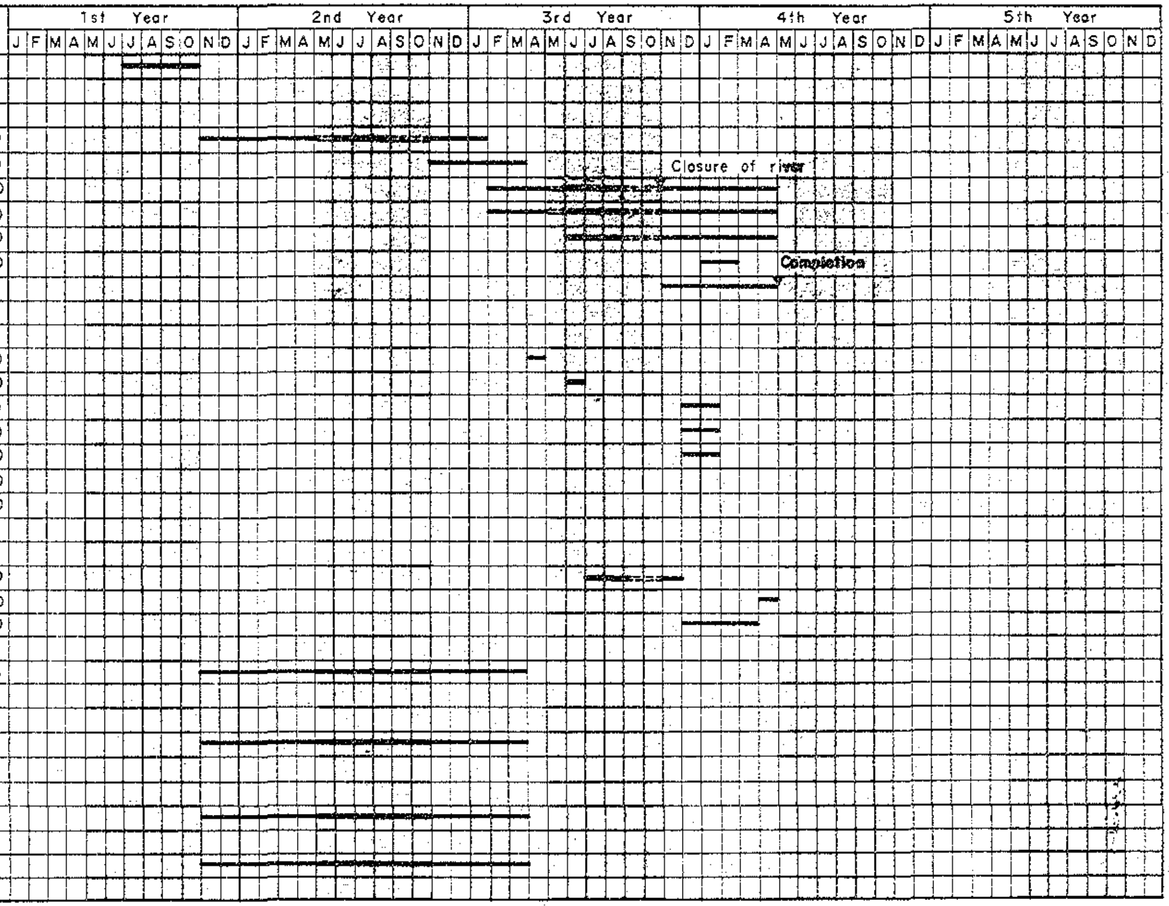

Fig. 66 Construction Time Schedule of Khlong Thap Ma Dam

KINGDOM OF THAILAND
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JAPAN INTERNATIONAL COOPERATION AGENCY

SECTORAL REPORT XII

WATER CONVEYANCE ENGINEERING

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1. INTRODUCTION

The water demand in the Study Area has been foreseen to be rapidly increased due to industrial development attributable to the Eastern Seaboard Development and its associated activities. The East Coast Water Resources Development Project, Phase II was launched aiming at formulating the long-term water supply plan to satisfy the rapidly increased water demand on the one hand and analyzing the economic and financial soundness of the proposed plan on the other hand.

The water transmission engineering takes a part in the Study with the following particulars.

(i) Analysis of the present water supply and use situation to serve the domestic and industrial water demand forecast.

(ii) Analysis of the characteristics of the existing water supply systems to serve the domestic and industrial water demand forecast and to obtain some reference data for preliminary design.

(iii) Description of the government's policy and plan on the water supply which would be incorporated into a study of the long-term water supply plan.

(iv) Formulation of the long-term water supply plan through alternatives study, which would be performed in conjuction with the water resources engineering.

(v) Preliminary design and cost estimate of the proposed water transmission system.

The long-term water supply plan would be formulated for the Target Years 1991 and 2001.

References have been made to the study reports of ESS and the East Coast Water Resources Development Project Phase I, particulary with regard to the water demand centers, proposed water transmission system, etc. The proposed water supply plan covers not only the urban areas but also includes the rural area in accordance with the government's policy on the water supply.

2. PRESENT DOMESTIC AND INDUSTRIAL WATER SUPPLY AND USE

2.1 Organization Related to Water Supply

The water supply in Thailand is administrated by PWWA and MWWA. The PWWA assumes a responsibiliby for the regions other than Bangkok Metropolis. The MWWA is responsible to the water supply solely for Bangkok Metropolis. At present the PWWA operates and maintains 169 large scale water works with 849 x 10^3 cubic meters per day of total supply capacity, which serves approximately 3.7 million people, correspoding to approximately 8.3 % of the total population in Thailand. The large scale water works are principally installed to serve the provincial capitals and sanitary districts having more than 5,000 of population.

Apart from the above authorities, the local administrative organs implement the rural water supply works, for which the PWWA, in general, provides a subsidy, corresponding to two-third of the construction cost and renders various technical assistances such as planning, design, construction supervision and training of operation and mainternance staffs. Such rural water works are generally provided for communities having total population of 1,500 to 5,000. At present in the whole Thailand, there are 663 rural water works with 378 x $10^3 m^3$/day of the total water supply capacity, which secure the water supply for approximately 2.1 million people or approximately 0.5 % of the nation's population.

Although the PWWA constructs its own water source facilities, the source of water supply seldom relies on reservoir which was created by RID. The RID implements the water resources development not only for irrigation but also for multipurposes. In addition, the OARD and DMR take part in rural water supply, practically with exploitation of groundwater resources.

Furthermore, apart from the above-mentioned government administration, there are a number of water supply facilities owned by private enterprises throughout Thailand. This is not uncommon practices. However, such enterprices are generally located in a remote area from the government water supply system.

2.2 Present Water Supply and Use

2.2.1 Domestic Water

The pipe water supply comprises residential, commercial and manufacturing water use. In the Study Area, there are 5 large scale water works and 8 rural water works. The total plant capacity is 89,520 m^3/day, consisting of 84,240 m^3/day of the large scale water works and 5,280 m^3/day of the rural water works. The locations of the water works and their water sources are shown in Fig. 1. The features of the respective water works are presented in Table 1. The location of the water works is indicated by zone number, which was established to carry out the water balance study and is also shown in Fig. 1.

The pipe water supply and use monitored by 5 large water works are shown in detail in Table 2 for the resent 5 years and are summarized hereunder. Such data are not available for the rural water works.

Description	Unit	1977	1981	Annual growth rate
Total quantity of water supplied	(10^3m^3)	7,066	18,103	0.265
Total quantity of water metered	(10^3m^3)	6,644	9,224	0.085
Pipe water served population	(10^3)	97.6	124.0	0.062
Service factor	(%)	49.6	51.7	0.010
Pipe water supply per capita	(l/d/c)	175.8	239.0	0.080
Pipe water use per capita	(l/d/c)	156.6	151.7	-0.007

In the above, pipe water served population, service factor, pipe water supply per capita and pipe water use per capita are calculated based on data of 4 water works; Chon Buri, Ban Bung, Phanat Nikhom and Rayong. Data of Naklua-Pattaya water works are not taken into account, since they are largely subjected by bulk water supply to hotels in Pattaya.

In 1981, approximately 18.1 x 10^6m^3 of water was supplied in terms of treatment plant output by 5 large water works, out of which approximately 17.2 x 10^6m^3 of water is deemed to be properly domestic use. In addition, it is estimated that approximately 1.4 x 10^6m^3 of water is supplied by 8 rural water works, assuming that all the plants are operated under full plant capacity. Therefore, the total domestic water supply is estimated at 18.6 x 10^6m^3.

The population served by pipe supply system is estimated to be 153.3 x 10^3 in 1981, comprizing 130.7 x 10^3 under the large water works and 22.6 x 10^3 under the rural water works. The figure of the rural water works was computed assuming the ratio of water loss at 20% and the water use per capita at 140 l/day. The average service factor over the Study Area remains as low as 16.7%, ranging from 53.6% in the urban area to 3.5% in the rural area. Almost all the population in the rural area depend mainly on rainwater/groundwater for their domestic use. According to the "Sectoral Report IX, Groundwater Resources", approximately 22.5 x 10^6m^3 of groundwater is annually consumed in the Study Area for domestic use. It is broken down into 1.7 x 10^6m^3 in the urban area and 20.8 x 10^6m^3 in the rural area.

Pipe water supply per capita in the urban area has been rapidly increased with the average annual growth rate of 8.0% and is 239.0 l/d in 1981 as shown in the above tabulation. However, pipe water use per capita remains almost unchanged 156.6 in 1977 and 151.7 l/day in 1981. Such large difference between the supply and the use is caused by loss in supply systems.

2.2.2 Manufacturing Water

There is no separate system for manufacturing water supply in public utility in the Study Area. Households, shops and factories share the pipe water supply. It is, however, not uncommon that private enterprises install the water supply system for their own uses. According to the information obtained from RID, there are 6 intake facilities owned by the private enterprises in the Bang Phra, Ban Bung and Map Prachan reservoirs and one private intake facilities in the Rayong river. Their locations and histric water abstraction are shown in Fig. 2 and Table 3, respectively. The total water abstraction from reservoirs for manufacturing amounts to approximately $5.3 \times 10^6 m^3$ in 1981.

Some enterprises sink tube-well to extract the groundwater. As reported in "Sectoral Report IX, Groundwater Resources", approximately $0.5 \times 10^6 m^3$ of groundwater is annually pumped up by the private enterprises for manufacturing.

2.2.3 Thermal-power Generation Water

Near the estuary of the Bang Pa Kong river, oil/gas fired thermal-power station is under construction and is scheduled to be committed in service in 1982. It has been planned that the water necessary for the power station will be led directly from the Bang Phra reservoir. The amount of water is estimated at 3 MCM/yr up to 1986 and it would increase to 6 MCM/yr in 1987 with expansion of the generating capacity, according to the water demand projection made by ESS.

2.3 Characteristics of Existing Water Supply Systems

2.3.1 Plant Operational Conditions

Out of 5 large water works, the Chon Buri, Naklua-Pattaya and Rayong water works are secured of water resources. The former two are dependent on Bang Phra reservoir and Map Prachan reservoir, respectively, and the latter mainly relies on the regulated surface run-off of the Rayong river. The Ban Bung and Phanat Nikhom water works depend on a small stream for their water resources. Therefore their water supply is generally unstable influenced by hydrologic phenomena of the stream.

2.3.2 Water Supply Loss

Water supply loss is defined as the balance between the total quantity of water supplied and the total quantity of water metered, which comprises the followings:

a) Leakage from service reservoirs, mains, service connections;

b) operation of hydrants and blow-offs;

c) losses due to non-sensitiveness of water meter;

d) unauthorized connection.

Ratio of the water supply loss is defined as water supply loss divided by the total quantity of water supplied.

The ratio of water supply loss is shown for 5 large water works in Table 2. It varies from 55.6% in Chon Buri water works to 17.8% in Ban Bung water works. The extremely high ratio of water supply loss in the Chon Buri water works is considered attributable to the timeworn distribution systems in the service area. In order to utilize the limited water resources to the maximum extent, it would be most significant to improve the distribution system.

2.3.3 Seasonal Fluctuation

The seasonal fluctuation of water supply was analyzed in order to obtain reference data for preliminary design of water supply facilities. The seasonal fluctuation is defined as monthly quantity of water supplied divided by average monthly quantity of water supplied. The analysis was made only for the Chon Buri, Rayong and Ban Bung water works for 1981.

Table 4 shows the monthly water supply and fluctuation ratio for the abovementioned 4 water works. Fig. 3 shows a comparison between monthly mean air temperature, monthly rainfall and monthly fluctuation ratio.

As shown in Fig. 3, in general, the fluctuation ratio indicates such tendency as varying with fluctuation of air temperature. Such tendency is clearly observed in the Chon Buri and Rayong water works. On the other hand, fluctuation ratio of the Ban Bung water works is dominated by availability of water at the source rather than air temperature; water supply capacity declines during the dry season and increases with the increase of rainfall.

2.3.4 Water Quality

The DOH has been adopting the WHO's standards for raw water and potable water quality controls, which are attached herewith as Tables 5 and 6.

According to the water quality monitoring records in the Rayong river by DOH, no shortcoming is found out in viewpoint of raw water quality. The quality of pipe water supply is properly preserved by PWWA.

2.4 Water Tariff, Revenues and Expenditures

2.4.1 Water Tariff

The PWWA applies the uniform tariff within its service area. The water tariff was ฿ 2.0 per cubic meters regardless quantity and kinds of water use for the last 20 years from 1960 to April, 1981. The PWWA introduced a new tariff system in May, 1982 as tabulated below.

Quantity of Water Use (m^3)	Tariff (฿/m^3)
- 10	2.00
11 - 20	2.50
21 - 50	3.00
51 - 80	4.00
81 - 100	4.50
101 - 300	5.00
301 -	5.50

2.4.2 Revenues and Expenditures

Revenues and expenditures of PWWA are given in Table 7 for fiscal years 1980 and 1981. The PWWA suffered to the extent of approximately ฿ 130 million in 1980 and 1981.

3. WATER SUPPLY PROJECTS DURING THE FIFTH NATIONAL PLAN

3.1 Basic Policy of PWWA

The PWWA has established a 5-year plan in line with the Fifth National Plan (1982-1986). It stipulates the basic policy of PWWA as follows.

(1) The PWWA continues the development, improvement and expansion of water supply systems in line with the government's urban development plan. The water supply capacity will be increased from 849 x 10^3 m^3/day in 1981 to 1,414 x 10^3 m^3/day in 1986. At the end of the 5-year plan, pipe water served population would be approximately 4.4 million in urban area. The implementation plan consists of ;

a)	Improvement of plant and expansion of distribution area:	125 locations
b)	Construction of new plant:	50 locations
c)	Expansion of plant capacity and distribution area:	75 locations
d)	Expansion of plant capacity and distribution area under foreign assistance:	6 locations
e)	Master planning for water works development:	10 locations

(2) The rural water supply programme will be continued to reduce a gap in standard of living between urban area and rural area. The development of rural water works will be implemented on the basis of 50 water works per year. At the end of the 5-year plan, there will be 900 water works covering over 2,000 communities.

3.2 Large Scale Water Supply Programme

The large scale water supply programme serves municipality and/or sanitary district having more than 5,000 inhabitants. As mentioned in Section 3.1, during the Fifth National Plan, the PWWA will implement the improvement of plant and expansion of distribution area for 125 locations, the construction of new plant for 50 locations and the expansion of plant capacity and distribution for 81 locations, under this programme.

As far as the Study Area is concerned, the under-listed works have been incoporated into the 5-year plan of PWWA.

Work Categories	Water Works
(1) Improvement of plant and expansion of distribution area	Ban Bung Phanat Nikhom Rayong
(2) Construction of new plant	Map Ta Phut Bang Lamung Sattahip Ao Udom
(3) Expansion of plant capacity and distribution area	Chon Buri

As to the Ban Bung, Phanat Nikhom and Chon Buri water works, definite plan has not been established yet by PWWA.

The Rayong water works will be expanded to 16,400 m^3/day in terms of plant capacity, an increase of 10,000 m^3/day. It is capable of delivering the water to the Map Ta Phut water works and is programmed to be completed in 1983.

The development plan of three new water works are as follows:

Water Works	Year of Completion	Plant capacity	Water source	Budget
		(m^3/day)		(฿ 10^6)
Map Ta Phut	1982	2,000	Rayong W.W.	28.2
Bang Lamung	1984	1,000	Naklua-Pattaya W.W.	20.0
Sattahip	1985	2,000	Pondage	35.0
Ao Udom	1983	4,000	Si Racha W.W.	20.0

3.3 Rural Water Supply Programme

The rural water supply programme serves community having 1,500 - 5,000 inhabitants and is mainly implemented by the local administrative authorities under technical and financial assistances from PWWA. The 5-year plan of PWWA sets forth the following targets.

	Location		Annual water supply
	Municipal	Village	
			($10^6 m^3$)
(1) Expansion of water lines and distribution area	100	50	21.9
(2) Construction of new water works	200	50	13.1

The total investment amount is estimated at ฿ 1,596.5 million, of which ฿ 1,406.5 million is borne by PWWA. The local administrative authorities owe the rest of the investment, ฿ 190 million.

The implementation of the rural water supply programme depends on the initiative of the local administrative authority. Therefore, at present, no definite plans are available.

4. LONG-TERM WATER SUPPLY PLAN

4.1 Water Supply Alternatives

The Sectoral Report X, Water Balance Study elaborates the water demand and supply plan in the Study Area until Target Year 2001. It lays out four water supply alternatives for their economic and technical comparative study. The water supply alternatives are shown in Figs. 4 through 7 and are briefly described hereunder.

ALTERNATIVE I:

The plan involves development of four new dams: Khlong Luang dam, New Ban Bung dam, Khlong Yai dam and Khlong Thap Ma dam.

In Zone 4, out of 47.5 MCM/yr of the domestic and industrial water demand, 19.6 MCM/yr of water is made available from the representative river in the zone. The water demand in Zone 6 is wholly met by stream flow of the representative river.

The further water supply shortage in Zones 2 through 5, 49.3 MCM/yr is met by water diversion from both the Khlong Luang and Rayong river basins. The Khlong Luang river basin bears 18.0 MCM/yr, consisting of 7.0 MCM/yr by new Ban Bung dam and 11.0 MCM/yr by Khlong Luang dam. The Rayong river basin supplies the rest of the shortage, 31.3 MCM/yr.

ALTERNATIVE II:

This plan is quite similar to ALTERNATIVE I. The New Ban Bung dam is excluded but the Huai Bung dam is proposed.

In Zone 4, the representative river contributes 16.2 MCM/yr of water to the domestic and industrial water demand. The water supply situation of Zone 6 is the same as the ALTERNATIVE I.

The Khlong Luang and Rayong river basins divert 8.5 MCM/yr and 31.3 MCM/yr respectively, to balance the water demand and supply in Zones 2 through 5.

The Ban Bung Sub-zone encounter the water shortage, 2.5 MTM/yr in the Target Year 2001. The Khlong Luang dam delivers the corresponding water.

ALTERNATIVE III:

The water diversion from the Rayong river basin is eliminated in this alternative. Eight dams are needed in addition to the existing dams. They are the Khlong Luang dam, New Ban Bung dam, Huai Bung dam, Huai Takhian Tia dam, Khlong Na Klua dam, Huai Yai dam, Khlong Yai dam and Khlong Thap Ma dam.

The water demand in Zones 2 to 4, 100.1 MCM/yr will be balanced by 18.0 MCM/yr of water diversion from the Khlong Luang basin, 40.7 MCM/yr of the existing dams, 27.2 MCM/yr of water supply by the Huai Bung, Huai Takhian Tia and Khlong Naklua dams, and 14.2 MCM/yr of the stream flow available from the representative river in Zone 4.

Also the water demand in Zones 5 and 6, 17.3 MCM/yr is satisfied by the existing Map Prachan dam and the Huai Yai dam.

Since there is no water diversion system from the Rayong river basin, development scale of the Khlong Yai dam is reduced to such extent as to meet the water deficit properly in Zone 10.

ALTERNATIVE IV:

This is a case contrary to ALTERNATIVE III. No water diversion is made from the Khlong Luang river basin to the coastal area.

This alternative requires the development of 6 new dams; Khlong Luang dam, New Ban Bung dam, Huai Bung dam, Huai Takhian Tia dam, Khlong Yai dam and Khlong Thap Ma dam.

The Khlong Luang dam is developed specifically for irrigation purpose. The domestic and industrial water demand in Zone 1 is satisfied by the New Ban Bung dam.

The total water demand in Zones 2 through 5 reaches 118.8 MCM/yr, which is met by 31.3 MCM/yr of water diversion from the Rayong river basin, 49.9 MCM/yr of water supply by the existing dams, 21.4 MCM/yr of water supply by the Huai Bung and Huai Takhian Tia dam and 16.2 MCM/yr of the stream flow available from the representative river in Zone 4. The water demand in Zone 6 is wholly met by the stream flow of the representative river.

4.2 Raw Water Conveyance Plans

4.2.1 Raw Water Conveyance Systems

The water supply alternatives involve two structural components; water resources development and raw water conveyance systems. The study on the water resources development is presented in Sectoral Report XI, Water Resources Engineering. This Chapter deals with plan on raw water conveyance systems.

The raw water conveyance systems are planned based on the following basic conditions;

(1) The existing water conveyance systems continue their services even in future.

(2) The water conveyance systems lead all the water deficit in a zone from dam(s) in other zone(s), if water resources in the zone are not able to meet the water demand.

(3) The rural water demand will be directly drawn off from either the dam or the representative river in the zone. Since locations of rural water demand centers are not definitely identified yet, rural water supply systems are exclusive from the present study.

(4) The water conveyance systems carry the raw water to the demand centers from the water resources facilities. Water treatment plant is not included.

In addition to the above, the following concepts are introduced referring to the result of the water balance study and the plan of the on-going projects.

(1) According to the water balance study, the water demand in Zone 6 is wholly satisfied by water resources in the zone. No inter-zone water diversion is therefore needed. In similar way, in Zone 4, a part of the water demand will be supplied by the representative river in the zone.

(2) The water deficit in Zone 2 is wholly dependent on the inter-zone water diversion, since the water resources available in the zone are negligibly small.

(3) According to the plan of the Dok Krai Pipeline Project, the Dok Krai pipeline is presumed to be extended to Zones 7 and 8.

For each water supply alternative, a schematic diagramme is carefully prepared as shown in Figs. 8 to 11, which illustrates the connection of water conveyance systems between the water resources facilities and the water demand centers and the quantity of water to be conveyed annually. Tables 8 through 11 present the calculation of annual water conveyance by the respective conveyance system. Each water supply alternative incorporates several raw water conveyance systems. There are 18 new water conveyance systems in total in four water supply alternatives and they are integrated into 9 systems as follows.

System No.	System Name	Pipeline Connection	Type
1	Khlong Luang	Khlong Luang dam - Chon Buri	Inter-zone
2-1	Ban Bung	Ban Bung dam - Chon Buri	Inter-zone
2-2	Ban Bung	Phanat Nikhom - Ban Bung	Inter-zone
3	Bang Phra	Bang Phra dam - Chon Buri	Inter-zone
4-1	Nong Kho	Nong Kho dam - Bang Phra dam	Inter-zone
4-2	Nong Kho	Nong Kho dam - Laem Chabang	Inner

(to be continued)

System No.	System Name	Pipeline Connection	Type
4-3	Nong Kho	Laem Chabang - Map Prachan dam	Inter-zone
4-4	Nong Kho	Huai Bung dam - Laem Chabang	Inner
4-5	Nong Kho	Huai Bung dam - Map Prachan dam	Inter-zone
4-6	Nong Kho	Huai Takhian Tia dam - Laem Chabang	Inner
4-7	Nong Kho	Khlong Naklua dam - Laem Chabang	Inter-zone
4-8	Nong Kho	Huai Yai dam - Map Prachan dam	Inter-zone
4-9	Nong Kho	Huai Takhian Tia dam - Map Prachan dam	Inter-zone
5	Nong Pla Lai	Nong Pla Lai dam - Nong Kho dam	Inter-zone
6	Bang Lamung	Huai Yai intake - Laem Chabang	Inner
7	Huai Yai	Huai Yai intake - Huai Yai	Inner
8	Dok Krai	Map Ta Phut - Sattahip via Ban Chang	Inter-zone
9	Ban Khai	Ban Khai intake - Rayong via Ban Khai	Inner

The water conveyance systems of the respective water supply alternative are presented in Table 12 in detail and are summarized hereunder.

Water Supply Alternative	Water Conveyance Systems
I	Khlong Luang, Ban Bung (2-1), Nong Kho (4-1, 4-2, 4-3), Bang Lamung, Nong Pla Lai, Huai Yai, Dok Krai Ban Khai
II	Khlong Luang, Ban Bung (2-2), Bang Phra, Nong Kho (4-1, 4-2, 4-4, 4-5), Bang Lamung, Nong Pla Lai, Huai Yai, Kok Krai, Ban Khai

(to be continued)

Water Supply Alternative	Water Conveyance Systems
III	Khlong Luang, Bang Bung (2-1), Nong Kho (4-1, 4-4, 4-6, 4-7, 4-8), Bang Lamung, Dok Krai, Ban Khai
IV	Ban Bung (2-1), Bang Phna, Nong Kho (4-1, 4-2, 4-4, 4-5, 4-9), Bang Lamung, Huai Yai, Dok Krai, Ban Khai, Nong Pla Lai

A preliminary layout of the respective water conveyance system was made based on topographic maps in a scale of 1 to 50,000 and road maps for the purpose of rough cost estimate. Figs. 12 to 15 show the preliminary layout of the water conveyance systems. Main features of the water conveyance systems are given in Table 12.

4.2.2 Rough Cost Estimate

The construction cost was roughly estimated for the respective water conveyance system based on the preliminary layout design and referring to the actual construction prices of similar projects in and outside Thailand. The estimated construction cost reflects a price level in 1982.

The construction cost comprises the cost of preparatory works, direct construction cost, compensation cost, administration and engineering services, contingency and interest during construction.

The cost of preparatory works was assumed to be 10% of the direct cost.

The direct construction cost consists of the costs of intake facilities, booster pumping stations, pipelines and receiving wells. Their cost was estimated based on the contract prices of similar projects.

The compensation cost was referred to the actual compensation cost of Nong Kho dam.

The cost of administration and engineering services were assumed to be 12% of the sum of the cost of preparatory works, direct construction cost and compensation cost.

The contingency was also assumed at 20% of the sum of the cost of the preparatory works, direct construction cost, compensation cost and cost of administration and engineering services.

The interest during construction was estimated assuming the annual interest rate at 8%.

Table 13 shows the estimated construction cost of the raw water conveyance systems of the respective water supply alternatives.

4.2.3 Selected Water Supply Plan

As reported in Sectoral Report X, Water Balance Study, Water Supply Plan Alternative I is selected to be most promissing plan to attain the objective in Target Year 2001. The selected plan can be developed at the minimum of cost among four alternatives and is judged to be technically confident.

4.3 Development Programme

4.3.1 Development Programme for Intermediate Years

The proposed water supply plan would be implemented progressively in a stage-wise way with adjustment to the latest circumstances. The development programme has been studied at 5-year intervals as reported in Sectoral Report X, Water Balance Study.

The raw water conveyance systems can be constructed in relatively short-time and can be expanded their capacity as need arises. However, a careful attention should be paid to the planning of the water conveyance systems so that hydraulic behaviour is the same througout the development programmes. Any hydraulic discrepancy is not permitted between the development programmes.

The annual water demand and supply balance is calculated for the respective zone for three intermediate years, namely, 1986, 1991 and 1996, as presented in Tables 14 to 16. Fig. 16 presents a relationship between the domestic and industrial water demand and the water supply. A space between the D&I water demand line and the upper most line of the supply is met by rural water supply system.

The water conveyance quantity of the respective system is derived from the water demand and supply balance calculation as shown in Tables 14 to 16 and is illustrated in Fig. 17. The followings are the summary.

(Unit: $10^6 m^3/yr$)

Conveyance System	Year			
	1986	1991	1996	2001
Khlong Luang:Khlong Luang dam - B. Not Yoen	0	1.4	6.7	12.4
Khlong Luang:Khlong Luang dam - K. Choeang Thian	0	0.4	5.5	11.0
Ban Bung (2-1):New Ban Bung dam - B. Not Yoen	7.2	7.3	7.3	7.3
Ban Bung (2-1): B. Not Yoen - K. Choeang Thian	7.1	7.0	7.0	7.0
Nong Kho (4-1): Nong Kho dam - Bang Phra dam	5.4	8.8	8.9	8.9
Nong Kho (4-2): Nong Kho dam - Ban Nong Krabok	4.0	5.5	14.7	31.8
Nong Kho (4-3): Ban Nong Krabok - Map Prachan dam	0	2.0	5.2	9.5
Bang Lamung	2.7	13.3	15.8	18.4
Nong Pla Lai:Nong Pla Lai dam - Nong Kho dam	0	4.9	14.2	31.3
Huai Yai	0.4	0.8	0.9	1.0
Dok Krai:Sattahip - Banchang	5.5	6.8	7.8	8.8
Dok Krai:Ban Chang - Map Ta Phut	5.8	7.3	8.4	9.5
Ban Khai:Ban Khai intake - Ban Khai	1.0	2.0	4.5	7.4
Ban Khai:Ban Khai - Rayong	0.8	1.7	4.1	7.0

The development sequence of the respective water conveyance system is studied based on the above data and is shown in Fig. 17. The Khlong Luang, Nong Kho (4-2) and Nong Pla Lai systems are planned to be installed in two stages, since the water conveyance quantity largely varies during the study period. The capacity of the conveyance system includes an allowance of 30% for seasonal fluctuation of water demand.

The development programme by every 5-year periods is briefly described hereunder. Table 17 summarizes the preliminary installation schedule of the respective water conveyance system, and Figs. 18 to 21 show the development sequence of the water conveyance systems.

Development Programme for 1986

The Ban Bung conveyance system will be completed in order to meet the immediate water demand in Zones 1 and 2. It comprises one intake facilities in New Ban Bung dam and 40 km long pipeline in one row with boasting pump station at Ban Not Yoen.

The Nong Kho (4-1) system will commence its service. The system is capable of diverting 11.6 x $10^6 m^3$ of water annually from Nong Kho dam to Bang Phra dam with one intake facilities in Nong Kho dam and 1 km long pipeline in one row.

The first stage of Nong Kho (4-2) system will be realized. The system is equipped with one intake facilities in Nong Kho dam and one row of 21 km long pipeline and has a flow capacity of 20.6 x $10^6 m^3$ per year.

The Ban Lamung system commences its service, and uses the unregulated flow of the Huai Kong Dai river as a part of the domestic and industrial use in Zone 4. The system is composed of one intake facilities in the Huai Kong Dai with intake capacity of 23.9 x $10^6 m^3$ per year and one row of 10 km long pipeline.

The Huai Yai system will be developed to supply the whole domestic and industrial water demand in Zone 6 and also uses the unregulated flow available from the Huai Yai river. The system has a conveyance capacity of 1.3 x $10^6 m^3$ per year and consists of one intake facilities and one row of one km pipeline leading to Ban Huai Yai.

The Dok Krai system between Map Ta Phut and Sattahip, which is practically an extension of Dok Krai Pipeline Project, will be completed in order to secure the domestic and industrial water in Zones 7 through 9. The system will have one intake facilities with intake capacity of 9.5 x $10^6 m^3$ year at Map Ta Phut, one row of 23 km long pipeline and two receiving facilities.

The Ban Khai system will be completed in order to save the water shortage in Rayong area in Zone 10. The existing Ban Khai intake will be expanded with installation of additional intake facilities having an intake capacity of 9.6 x $10^6 m^3$ per year. One row of pipeline will be laid between the intake and the Rayong via Ban Khai. Its total length is approximately 10 km.

Development Programme for 1991

The first stage of Khlong Luang system will be completed with water supply capacity of 8.1 x $10^6 m^3$ per year. It is composed of one intake facilities in Khlong Luang dam, 56 km long pipeline in one row, two boosting pump stations at Ban Not Yoen and Ban Suan Phak and two receiving facilities at Ban Suan Phak and Khao Choeang Thian.

The Nong Kho (4-3) system will be completed to ensure the increased water demand in Zones 4 and 5. It branches off from the Nong Kho (4-2) system at Ban Nong Krabok and has a water conveyance capacity of 12.3 x $10^6 m^3$ per year. The works include one boosting pump station at Ban Nong Krabok, one row of 22 km long pipeline and one receiving well at Map Prachan dam.

The first stage of Nong Pla Lai system will be completed with water conveyance capacity of 20.3 x $10^6 m^3$ per year. Major works are one intake facilities at Nong Pla Lai dam, one row of 56 km long pipeline with a boosting pump station at Ban Thap Thong and a head tank at Ban Khao Khayai and one receiving well at Nong Kho dam.

Development Programme for 1996

The second stage of Khlong Luang system will be completed with a water conveyance capacity of 8.0 x $10^6 m^3$ per year; total system capacity of the system reaches to 16.1 x $10^6 m^3$ per year. The works are expansion of intake facilities at Khlong Luang dam and additional installation of 56 km long pipeline in one row with two boosting pump stations at Ban Suan Phak and Ban Yot Noen.

The second stage of Nong Kho (4-2) system will also be completed. Its water conveyance capacity is 20.6 x $10^6 m^3$ per year; the total conveyance capacity of the system is increased to 41.2 x $10^6 m^3$ per year. The works consist of expansion of intake facilities at Nong Kho dam. The Nong Pla Lai system reaches to its full development scale with completion of its second stage work. The system capacity is 40.6 x $10^6 m^3$ per year at the full development scale. The major works of the second stage are expansion of intake facilities at Nong Pla Lai dam and additional installation of 56 km long pipeline with a boosting pump station at Ban Thap Thong.

4.3.2 Investment Requirement

The investment requirement for the water conveyance systems is estimated for every five-year periods based on the general layouts of proposed development plans as presented in Table 18. The estimated investment requirements are summarized hereunder.

Period	Investment Requirements (฿10^6)	
	By Period	Accumulation
1982 - 1986	1,508.2	1,508.2
1986 - 1991	1,665.8	3,174.0
1991 - 1996	1,399.9	4,573.9
Total	4,573.9	-

5. PRELIMINARY DESIGN

5.1 General Description

The long-term water supply plan over the Study Area evolved a large number of pipeline systems to be newly installed. Out of them, Khlong Luang system is incorporated with Khlong Luang Dam Scheme and Nong Pla Lai system forms one part of components of Khlong Yai Dam Scheme. Their preliminary designs are described herein.

It should be kept in mind that the preliminary designs were conducted mainly based on the topographic map of 1/50,000 scale and road maps so far made available and field reconnaissance survey. The designs must be reviewed during the detailed design based on the detailed topographic and sub-surface geological surveys and in accordance with the latest status of the domestic and industrial water demand and development activities to be undertaken by other agencies.

5.2 Design Criteria

The following design criteria are set forth.

(1) Plant Factor

The plant factor is defined as a ratio between the average delivery and the plant capacity. Taking into account the latest design data of water works in Thailand and actual seasonal and daily fluctuations of water works in the Study Area, it is broadly determined at 1.3.

(2) Hydraulic Calculation

Hazzen-William's equation, which is expressed hereunder, is adopted.

$$V = 0.84935 \times C \times R^{0.63} \times I^{0.54}$$

where,

V : mean velocity, m/s
C : coefficient, assumed to be 110
R : hydraulic radius, m
I : hydraulic gradient,

(3) Retention time

Retention times of storage facilities are determined as follows.

Facilities	Retention Time (min.)
Receiving well, intake	3
Grit chamber	20
Receiving well, boosting P/S	30
Pump well	30
Head tank	30
Raw water basin	240

(4) Capacity of Pump and Motor

The capacity of pump and motor is calculated by the following equations

Pump, $L = 0.163 \times Q \times H \times \gamma / \eta_p$

where,

L : capacity of pump motor, kW
Q : discharge, m^3/min.
H : head, m
η_P : pump efficiency, assumed to be 0.8
γ : specific gravity of water

Motor; $Lm = L (1 + A)/\eta m$

where,

Lm : capacity of motor, kW

A : allowance, assumed at 0.15

η m : transmission efficiency, assumed at 1.0

Water hammer phenomena is not analyzed in detail in this report, since it involves various unknown factor, for instance pump trip. It must be solved at the time of detail design.

5.3 Preliminary Design of Khlong Luang System

5.3.1 Design Discharge

As explained in Chapter 4, the Khlong Luang system functions to convey the raw water necessary for the domestic use in urban areas in the basin and for the domestic and industrial use in Zone 2. Its implementation is programmed in two phases so that the system capacity can be firmly adjusted to possible increase or decrease in water supply requirement. The first phase will be designed to the water supply requirement for 1996 and the second phase for 2001. The system capacity is, therefore, determined based on the annual water supply requirement and the plant factor as shown below.

Description	Year			
	1986	1991	1996	2001
Annual Water Requirement ($10^6 m^3$)				
Basin use	-	1.0	1.2	1.4
Inter-zone diversion	-	0.4	5.5	11.0
System Capacity (m^3/s)				
1st phase, at head	-	0.26	0.26	0.26
at terminal	-	0.23	0.23	0.23
2nd phase, at head	-	-	0.26	0.26
at terminal	-	-	0.23	0.23

A difference in system capacity between head and terminal is attributable to water delivery to Zone 1.

5.3.2 Route Alignment

The intake is selected at the head of the South Main Irrigation Canal so that no specific intake facilities are needed in reservoir. The raw water basin at the end point of the pipeline is proposed to be located in Khao Choeng Thian for the convinience of water delivery. The pipeline between the intake and the raw water basin is aligned along Routes 331,315 and 3 as shown in Fig. 22.

5.3.3 Selection of Optimum System

The raw water basin is situated higher than the intake. Thus the pipeline should be designed in a pressure flow. For the hydraulic design of the pipeline, the following pre-conditions are set forth;

(1) Pipe is of ordinary steel pipe available in market, for instance JIS G 3443 or equivalent.

(2) Static water head should be confined to 80 m (8 kg/cm^2) for the sake of water hammer.

A comparative study is made to choose the most economical combination of pipe size and pump capacity. Four alternatives are considered to be compatible each other. They are illustrated in Fig. 23, together with their hydraulic properties.

(1) Construction Cost

Based on the hydraulic designs shown in Fig. 23, preliminary layout design was made for each alternative as presented in Table 19. The construction cost was estimated for each alternative based on the 1982 price level as shown in Table 20.

(2) Operation and Maintenance Cost

The operation and maintenance cost, excluding electric charge, was assumed to be 0.5% of the construction cost. The electric charge was computed at the rate of ₱1.19/kwh. The estimated O & M cost is as shown in Table 21.

(3) Replacement Cost

The replacement costs of various facilities and equipment were based on the following useful life and shown in with the O & M cost in Table 21.

Equipment/Facilities	Useful Life (year)
Concrete structure	50
Electrical equipment	16
Hydro-mechanical equipment	16
Pipeline	40

(4) Cost Comparison

The economic useful life of the system is taken at 50 years. The construction cost and replacement cost were converted into annual equivalent cost at a discount rate of 8% per annum. The annual cost is shown in Table 21. A relationship between the inside diameter of pipe, the annual equivalent cost and OM & R cost is constructed as shown in Fig. 24.

As shown in Fig. 24, there is little difference in annual cost between the Alternative 2 and the Alternative 3. The Alternative 2 however is selected as the optimum plan, since its initial cost is lesser than that of the Alternative 3. The hydraulic design of the proposed plan is shown in Fig. 25.