Fig. 1-17 Summary of Test Result (Nong Pla Lai)

SUMMARY OF TEST RESULTS PROJECT NONG PLA LAI

Hole No.	Sample No.	Depth m	Description	1½"	1"	¾"	⅜"	No. 4	No. 10	No. 40	No. 200	LL	PL	PI	Soil Class	Nat. Moisture	Pocket Penetrometer TSF	Unit Wt. Dry gr/cc	Uncon. Comp. TSF	Other
				Gradation – Percent Passing								Atterberg Limits								
B-1	US-1	3.60-4.00	Brown & Gray Clayey Sand				100	99	91	66	46	27	14	13	SC	12.3		2.12		K=3.62×10[illegible] cm/sec, φ=21.5°, C=0.8 t/m²
	DS-5	5.00-5.45	Gray Clayey Sand				100	98	75	40	9		–				4.0			
	DS-6	6.00-6.45	Gray Clayey Sand				100	95	70	38	30	38	23	15	SC		>4.5			
	DS-11	11.00-11.45	Gray Silty Clay w/little sand									59	24	35	CH		1.7			
	DS-12	12.00-12.45	Gray Clayey Sand				100	93	94	66	40	58	31	27	SC	23.6	>4.5	1.65	5.05	
	DS-13	14.00-14.45	Gray Clayey Sand				100	99	84	47	21	31	18	13	SC		>4.5			
B-2	DS-2	2.00-2.45	Brown Silty Sand					100	94	54	24		–		SM					
	DS-4	4.00-4.45	Mottled, Clayey Sand				100	80	64	84	18	20	15	5	SM-SC					
	DS-6	6.00-6.45	Gray Sandy Clay					100	96	84	77	76	34	42	CH		4.0			
	DS-7	7.00-7.45	Grey Sandy Clay									51	24	27	CH	21.8	3.5	1.70	2.49	
	DS-9	9.00-9.45	Grey Clayey Sand				100	97	74	46	34	53	24	29	SC		>4.5			
	DS-10	10.00-10.45	Gray Clayey Sand				100	96	81	55	35	56	19	37	SC	16.9	>4.5	1.78	3.96	
	DS-11	11.00-11.45	Grey Sandy Clay					100	96	77	63	48	28	20	CL	13.8	>4.5	1.95	6.22	
	DS-12	13.00-13.10	Gray Clayey Sand				100	92	73	45	28	31	19	12	SC		>4.5			
	DS-13	14.50-14.58	Grey Clayey Sand					100	83	46	22		–		SC					
B-3	DS-3	3.00-3.45	Grey Clayey Sand					100	93	65	29		–				1.7			
	DS-5	5.00-5.45	Grey Clayey Sand					100	96	51	26	24	16	8	SC		3.2			
	US-3	6.60-7.00	Gray Clayey Sand					100	97	57	24	24	13	11	SC	17.4	2.7	1.90		[illegible]
	DS-8	8.00-8.23	Grey Clayey Sand									31	16	15	SC		>4.5			
	DS-9	9.00-9.08	Mottled Clayey Sand				100	95	79	46	20				SC		>4.5			
	DS-12	12.00-12.22	Gray Sandy Silty Clay					100	97	87	65	45	18	27	CL		>4.5			
	DS-15	17.00-17.21	Gray Sandy Silty Clay					100	98	86	68	43	22	21	CL		>4.5			
B-4	DS-3	3.00-3.45	Gray Clayey Sand				100	99	93	70	56	19	16	3	SM		1.5			
	DS-4	4.00-4.45	Gray Clayey Sand					100	95	67	23		–		SC		4.2			
	DS-6	6.00-6.45	Dk Brown Silty Sand					100	99	96	38		NP		SM		0.5			
	US-3	6.60-7.10	Dk Brown Clayey Sand				100	99	80	48	27	19	15	4	SC-SM					φ=12°, C=1.58 t/m²
	DS-7	7.10-7.55	Dk Gray Silty Clay					100	99	98	95	29	16	13	CL	43.7	2.5	1.21	1.01	
	DS-8	8.00-8.45	Dk Gray Sandy Clay					100	99	95	53	25	14	11	CL		3.5			
	DS-10	10.00-10.42	Green Grey Silty Clay					100	98	93	84	49	25	24	CL	19.3	>4.5	1.68	4.77	
	DS-12	12.00-12.25	Green Gray Sandy Silty Clay				100	99	97	78	56	35	23	12	CL		>4.5			
	DS-14	16.00-16.27	Green Gray Sandy Silty Clay				100	99	97	93	76	43	20	23	CL		>4.5			
	DS-15	19.00-18.08	Green Gray Clayey Sand					100	84	46	25		–		SC		>4.5			
B-5A	DS-4	4.00-4.45	Mottled Silty Clay						100	98	67	26	17	9	CL					
	DS-11	11.00-11.45	Gray Silty Clay									50	28	22	CL		>4.5			
	DS-12	12.00-12.44	Gray Clayey Sand					100	92	62	30	52	29	23	SC	18	>4.5	1.83	8.11	
B-5	DS-2	2.00-2.45	Gray Clayey Sand				100	97	78	45	25	26	15	11	SC		2.7			
	DS-4	4.70-5.15	Dk Gray Silty Clay									32	20	12	CL	27	0.2			
	US-1	5.30-5.80	Dk Gray Silty Clay													24	0.5		0.50	
	DS-6	6.75-7.20	Dk Gray Silty Clay									36	25	11	CL					
	DS-7	7.20-7.65	Dk Gray Clayey Sand					100	99	92	49	27	16	11	SC		0.5			
	DS-8	8.00-8.45	Brown Silty Sand						100	92	17	–	–	–	SM					
	DS-11	11.00-11.37	Green Gray Silty Clay					100	99	99	93	49	28	21	CL	16	>4.5	1.69	6.24	Hydrometer
	DS-13	15.00-15.10	Green Gray Clayey Sand				100	95	75	45	28				SC		>4.5			
	DS-14	17.00-17.12	Green Gray Clayey Sand				100	98	88	60	37	30	21	9	SC	11.6	>4.5	2.06	6.60	
	DS-15①	6.20-6.65	Grey Sand						100	42	4				SP					
	DS-15②	6.20-6.65	Dk Gray Silty Clay									33	21	12	CL	24.7	1.0	1.66	2.67	Hydrometer, φ=9.8°, C=2.31 t/m², Compression Index C_c=0.239
	US-6	5.20-5.70	Dk Grey Silty Clay						100	99	83	28	19	9	CL	16.0	0.7	1.55		

Fig. 1-18 Summary of Test Result (Nong Pla Lai)

SUMMARY OF TEST RESULTS PROJECT NONG PLA LAI

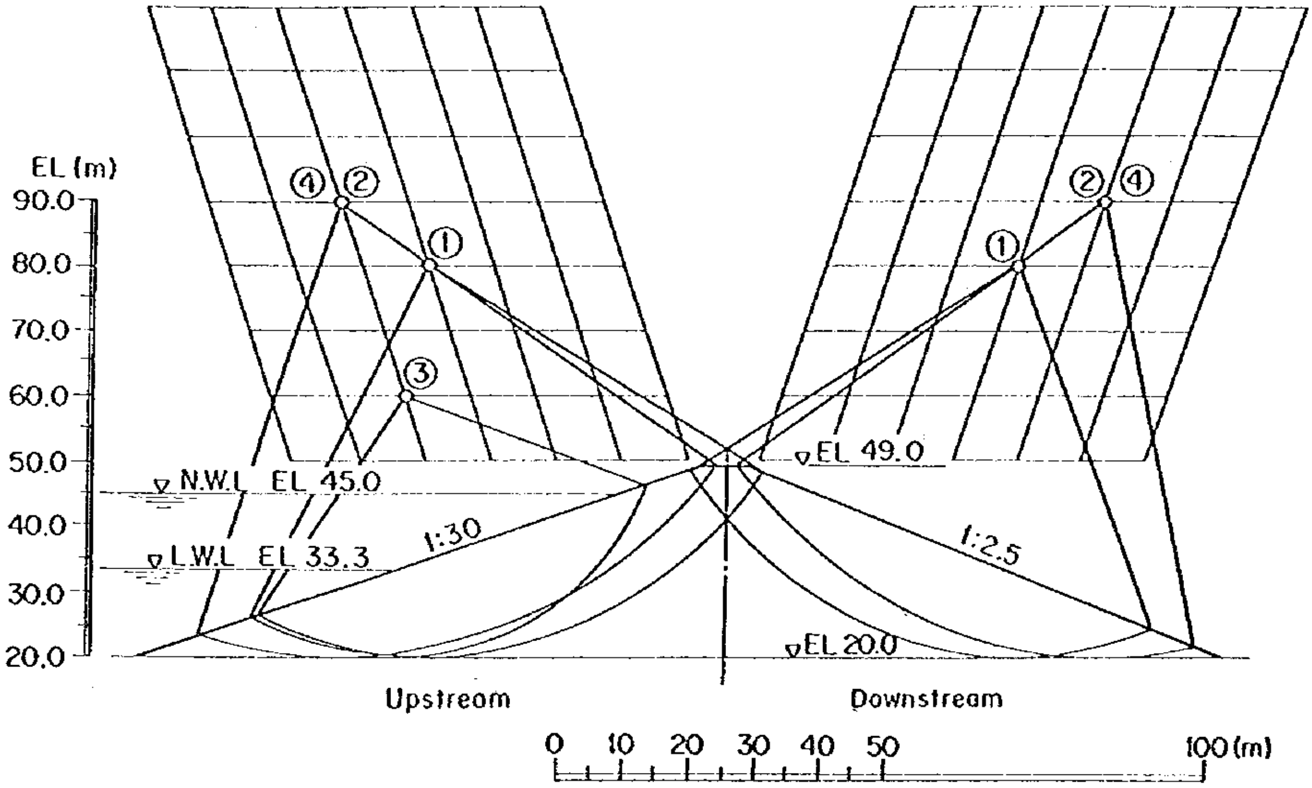
Test No.	Sample No.	Depth m	Description	Gradation – Percent Passing 1½"	1"	¾"	⅜"	No. 4	No. 10	No. 40	No. 200	Atterberg Limits LL	PL	PI	Soil Class	N.M. Moist. %	Pocket Penetrometer	Unit Wt.	Unconf. Comp.	Other
B-5B	DS-2	2.00-2.45	Mottled Sandy Clay					100	98	77	60	20	13	7	ML-CL		3.7			
	US-1	3.60-4.00	Mottled Silty Clay					100	97	94	84	31	18	13	CL	13.6	1.5	1.83		Hydrometer; φ = 3°, C = 2.35 t/m²
	DS-4	4.00-4.45	Mottled Silty Clay					100	99	93	81	23	16	7	ML-CL		0.7			
	US-2	4.60-4.80	Mottled Silty Clay									30	22	8	CL	24.2	1.7	1.60	1.1	
	DS-6	6.00-6.45	Brown Silty Sand					100	97	74	25	NP			SM					
	DS-9	9.00-9.45	Mottled Sandy Clay					100	97	86	70	51	28	23	CH	18.2	> 4.5	1.77	4.78	
	DS-10	11.00-11.25	Green Gray Silty Clay									44	29	15	CL	15.5	> 4.5	1.90	8.30	
B-6	DS-2	2.00-2.45	Gray Clayey Sand					100	99	91	31	20	14	6	SM-SC		0.5			
	DS-3	3.00-3.45	Dk Grey Silty Clay									35	22	13	CL					
	US-2	3.60-4.00	Brown Silty Sand					100	82	27	9				SP-SM					
	DS-6	6.00-6.45	Gray Clayey Sand					100	95	65	38	17	12	5	SM-SC		1.5			
	DS-8	8.00-8.45	Gray Clayey Gravelly Sand		100	94	86	78	57	28	13	-	-	-	SM-SC					
	DS-9	9.00-9.45	Grey Clayey Gravelly Sand									18	13	5	SM-SC					
	DS-11	12.00-12.45	Gray Sandy Clay									40	24	16	CL	23.4	> 4.5	1.68	6.0	
B-7	US-1	2.60-3.00	Brown Silty Sand					100	91	41	27	NP			SM		1.5			K = 2.36×10 [illegible] cm/sec; φ = 18°, C = [illegible] t/m²
	DS-4	4.00-4.45	Gray Clayey Silty Sand									20	16	4	SM-SC					
	DS-5	5.00-5.45	Gray Clayey Silty Sand				100	97	77	40	19									
	DS-7	7.00-7.45	Mottled Clayey Silty Sand					100	98	78	33	NP			SM		4.5			
	DS-9	9.00-9.45	Mottled Clayey Silty Sand				100	96	77	56	31	19	13	6	SM-SC		0.5			
	US-2	8.60-10.00	Mottled Clayey Silty Sand				100	94	71	56	8	20	14	6	SM-SC	13.6		1.99		K = 4.7×10 [illegible] cm/sec; φ = 22.5°, C = [illegible] t/m²
	DS-11	11.00-11.45	Gray, Clayey Sand				100	96	92	76	36	33	17	16	SC		> 4.5			
	DS-13	13.00-13.45	Yell Brown Clayey Sand				100	99	88	64	33	31	20	11	SC		> 4.5			
	DS-14	14.00-14.45	Gray Silty Clay					100	99	91	77	61	27	34	CH	24.1	4.25	1.70	3.34	Hydrometer
	DS-15	15.00-15.24	Grey & Yell Brown Clayey Sand				100	99	85	50	38	-			SC		> 4.5			
	DS-16	16.00-16.14	Gray Clayey Silty Sand									NP			SM		> 4.5			
	DS-17	17.00-17.28	Gray Sandy Clay				100	99	98	87	58	37	21	16	CL		> 4.5			
B-8	DS-2	2.00-2.45	Brown Clayey Sand									24	15	9			0.7			
	US-1	4.60-5.00	Gray Clayey Sand				100	98	65	17	10	30	19	11	SP-SC	13.0		2.08		K = 8.52×10⁻⁵ cm/sec; φ = 35°, C = [illegible] t/m²
	DS-7	7.00-7.45	Mottled Clayey Sand					100	93	68	40	26	17	9	SC		2.0			
	DS-9	9.00-9.45	Gray Clayey Sand	100	97	94	85	73	59	42	33	21	12	9	SC		1.7			
	DS-11	11.00-11.45	Mottled Sandy Clay									36	19	17	CL	19.8	3.0	1.76	2.18	
	DS-13	13.00-13.23	Gray Clayey Sand									27	18	9	SC		> 4.5			
	DS-14	15.00-15.22	Gray Clayey Sand				100	98	96	70	23	-	-	-	SC		> 4.5			
	DS-15	17.00-17.38	Dk Gray Sandy Silt				100	98	91	73	51	36	25	11	ML		> 4.5			Hydrometer
	DS-17	20.00-20.13	Dk Gray Sandy Clay				100	96	89	75	54	34	23	11	CL		> 4.5			
B-9	DS-2	2.00-2.45	Gray Clayey Sand					100	91	63	33	30	23	7	SM		2.5			
	DS-4	4.00-4.45	Gray Clayey Sand					100	65	71	39	46	25	21	SC		3.5			K = 1.7×10⁻⁴ cm/sec
	US-1	4.60-4.79	Gray Clayey Sand				100	94	86	64	29	30	19	11	SC		3.5			
	DS-6	6.00-6.26	Gray Clayey Sand				100	95	60	43	15	37	26	11	SM		> 4.5			
	DS-8	8.00-8.40	Gray Clayey Sand				100	99	91	45	18	37	12	25	SC		> 4.5			
	DS-10	10.00-10.39	Green Gray Silty Clay				100	98	95	90	79	47	27	20	CL-ML	20.2	> 4.5	1.76	2.98	Hydrometer
	DS-12	12.00-12.41	Green Gray Sandy Silt				100	98	93	78	56	39	26	13	ML		> 4.5			
	DS-14	14.00-14.45	Dk Gray Sandy Silty Clay					100	95	86	59	50	28	22	CL-MH	16.6	> 4.5	1.90	6.27	
B-9A	DS-1	1.00-1.43	Gray Brown Sandy Clay				100	98	97	91	56	20	13	7	CL-ML		0.5			
	DS-3	3.00-3.45	Brown Silty Sand					100	98	78	14	-	-	-	SM					
	DS-5	5.00-5.45	Gray Silty Clay									38	23	15	CL					
	DS-6	6.00-6.45	Dk Gray Silty Clay									21	13	8	CL	29.5	0.5	1.59	2.11	
	US-1	6.60-7.00	Gray Clayey Sand				100	99	97	83	35	26	16	10	SC	23.0	3.5	1.70		Hydrometer; φ = 14°, C = [illegible] t/m²
	DS-7	7.00-7.45	Gray Sandy Clay				100	99	98	87	51	29	16	13	CL		3.5			
	DS-9	9.00-9.45	Green Gray Silty Clay									60	32	28	MH	24.2	2.7	1.64	3.07	
	DS-10	10.00-10.15	Gray Clayey Sand				100	96	73	39	16	-	-	-	SC		> 4.5			
	DS-11	12.00-12.40	Mottled Clayey Sand				100	98	92	51	18	32	21	11	SC		> 4.5			

Fig. 1-19 Summary of Test Result (Nong Pla Lai)

SUMMARY OF TEST RESULTS PROJECT NONG PLA LAI

Bor. No.	Sample No.	Depth m	Description	Gradation – Percent Passing 1½"	1"	¾"	⅜"	No. 4	No. 10	No. 40	No. 200	Atterberg Limits LL	PL	PI	Soil Class	Nat. Moist. %	Pocket Penetrometer	Unit Wt. Dry	Unconf. Comp.	Other
B-10	DS-3	3.00- 3.45	Brown Silty Sand				100	93	93	60	22	-	-	-	SM					
	DS-5	5.00- 5.45	Gray Clayey Sand				100	93	87	49	25				SC		3.0			
	DS-6	6.00- 6.45	Gray Clayey Sand									44	20	24	SC		3.0			
	DS-7	7.00- 7.45	Brown & Gray Silty Sand				100	83	69	29	6*				SP-SM		4.5			
	DS-8	8.00- 8.45	Yellow Clayey Sand				100	96	79	47	24	31	21	10	SC		>4.5			
	DS-9	9.00- 9.12	Mottled Clayey Sand				100	95	81	51	26				SC		>4.5			
	DS-10	10.00-10.13	Mottled Clayey Sand									37	22	15	SC		>4.5			
	DS-13	13.00-13.12	Gray Silty Clay				100	94	87	77	69				CL		>4.5			
	DS-14	14.00-14.09	Mottled Clayey Sand									32	19	13	SC		>4.5			
	DS-15	15.00-15.21	Gray Clayey Sand				100	99	90	65	36	42	25	17	SC		>4.5			
	DS-16	17.00-17.25	Gray Sandy Silt					100	98	83	53	35	25	11	ML		>4.5			
	DS-18	21.00-21.14	Gray Clayey Sand						100	87	35	36	21	15	SC		>4.5			
B-11	US-1	2.60- 2.78	Mottled Clayey Sand				100	94	73	53	40	47	24	23	SC	31.5	1.0	1.47		$K = 3.39\times10^{-5}$ cm/sec
	DS-4	4.00- 4.45	Mottled Clayey Sand				100	86	69	50	33	43	26	17	SC-SM		4.0			
	DS-5	5.00- 5.45	Mottled Clayey Sand				100	92	65	45	37						4.5			
	DS-6	6.00- 6.45	Mottled Sandy Clay									64	33	31	MH		2.5			
	DS-7	7.00- 7.45	Mottled Sandy Clay				100	94	85	72	59	65	37	28	MH		2.2			
	US-2	7.60- 8.00	Mottled Sandy Clay				100	99	94	81	67	58	31	27	MH		1.2			$K = 0.88\times10^{-5}$ cm/sec
	DS-9	9.00- 9.45	White Silty Sand					100	92	57	27	43	30	13	SM		>4.5			
	DS-11	11.00- 11.45	White Clayey Sand				100	97	83	43	23				SC		>4.5			
	DS-12	12.00-12.45	Mottled Clayey Sand				100	93	78	48	28	31	23	8	SC-SM		>4.5			
	DS-14	14.00-14.39	Lt. Gray Clayey Sand				100	95	89	47	22	45	22	23	SC		>4.5			
	DS-16	16.00-16.45	Gray Sandy Silty Clay					100	98	95	77	49	27	21	CL		>4.5			Hydrometer
PIT B-12	BAG-2	2.00	Yell. Brown Clayey Sand					100	84	58	33	38	23	15	SC					
	BAG-4	4.00	Mottled Clayey Sand			100	93	73	50	36	21	42	22	20	SC					
PIT B-13	BAG-1	1.00	Brown Clayey Sand					100	86	60	35	37	24	13	SC					
	BAG-3	3.00	Mottled Clayey Sand w/Gravel				100	93	83	52	32	43	25	18	SC					Blend Bag 1 thru 6 [illegible] γ = 112 pcf, Wopt = 15.8 %
	BAG-6	6.00	Mottled Clayey Sand w/Gravel				100	95	81	52	40	51	29	22	SM					
B-14	DS-2	2.00- 2.45	Mottled Clayey Sand					100	83	58	49	64	29	35	SC		4.5			
	US-1	3.60- 3.84	Mottled Sandy Clayey Silt									47	32	15	ML	21.8	2.0	1.57		φ = 20°, c = 10 t/m²
	DS-4	4.00- 4.45	Mottled Sandy Clayey Silt									47	28	19	ML	28.2	2.2	1.50	2.04	
	US-2	4.60- 4.82	Mottled Sandy Clayey Silt					100	97	83	55	44	26	18	CL-ML	19.1	3.0	1.62	-	Hydrometer φ ≈ 15°, C ≈ 12 t/m²
	DS-6	6.00- 6.45	Gray Clayey Sand					100	95	76	47	38	22	16	SC	13.8	4.5	1.94	5.89	
	DS-8	8.00- 8.40	Gray Sandy Clay					100	99	95	65	43	22	21	CL	12.1	>4.5	1.97	5.98	
	DS-10	10.00-10.20	Gray Sandy Clay									38	22	16	CL	8.4	>4.5	2.10	7.64	
	DS-11	11.00- 11.13	Gray Sandy Clay					100	95	82	57				CL		>4.5			
	DS-13	13.00-13.06	Gray Clayey Sand				100	94	75	33	12*						>4.5			
	DS-14	15.00-15.20	Gray Sandy Clay					100	98	92	79	39	23	16	CL		>4.5			
PIT#1	Chunk-1	3.00- 3.20	Yell. Brown Clayey Sand					100	94	66	42	30	22	8	SC	Std. Compaction		Direct Shear		$K = 8.07\times10^{-6}$ cm/sec
PIT#1	BAG-5	5.00	Mottled Clayey Sand			100	94	85	74	53	28	36	23	13	SC	Wopt %	γd max	c t/m²	φ	
PIT#2	BAG-1	0.00- 4.10	Yell. Brown Clayey Sand					100	99	71	42	33	20	13	SC	12.8	1.9			$K = 2.84\times10^{-6}$ cm/sec
PIT#3	BAG-2	2.00- 2.50	Brown & Gray Clayey Sand					100	97	61	16	18	14	4	SC-SM		[illegible]			
PIT#4	BAG-2	2.00	Brown Clayey Sand					100	97	62	41	34	17	17	SC					
PIT#4	BAG-4	4.00	Brown Clayey Sand					100	95	70	43	42	18	24	SC	Note: Samples are compacted to 98 % Std. density for direct shear and permeability test, except PIT#1, CHUNK#1.				
PIT#5	BAG-2	3.00	Brown Clayey Sand					100	98	62	20	28	17	11	SC					
PIT#7	BAG-2	2.00- 2.20	Yell. Brown Clayey Sand					100	96	65	24	38	24	14	SC					
PIT#8	BAG-2	4.00	Brown & Gray Clayey Sand				100	98	91	60	30	38	22	16	SC					
PIT#9	BAG-1	0.00- 3.50	Mottled Clayey Gravelly Sand				100	93	80	61	50	60	27	33	SC	18.3	109	6.7	27.5	$K = 4.23\times10^{-6}$ cm/sec
PIT#10	BAG-1	0.00- 1.50	Lateritic Soil			100	88	65	55	49	44	52	30	22	SM	18.1	112	5.2	28.5	$K = 5.19\times10^{-6}$ cm/sec
PIT#10A	BAG-1	0.00- 1.50	Lateritic Soil		100	94	86	74	59	51	33	44	29	15	SM					
PIT#11	BAG-1	0.00- 4.00	Mottled Clayey Sand			100	96	93	89	70	51	36	20	16	CL	15.6	111	2.7	16.5	$K = 3.35\times10^{-7}$ cm/sec
PIT#12	BAG-1	0.00- 1.50	Lateritic Soil		100	83	71	51	41	38	29	43	29	14	GC					
PIT#13	BAG-1	1.00	Mottled Clayey Sand					100	89	46	22	34	24	10	SC-SM					
	BAG-3	3.00	Mottled Sandy Clay *				100	96	91	83	73	53	31	22	MH					
PIT#14	BAG-2	1.70 - 4.00	Lateritic Soil			100	91	77	62	47	36	48	27	21	SC	16.0	111			
PIT#15	BAG-1	1.30- 4.00	Mottled Clayey Sand w/Gravel			100	95	80	57	45	36	43	31	14	SM	14.6	114.5	0.0	37	$K = 1.22\times10^{-6}$ cm/sec
PIT#16	BAG-2	2.00	Brown Gray Silty Sand					100	95	48	17		NP		SM					Upstream
PIT#17	BAG-1	0.30- 4.00	Mottled Clayey Sand			100	98	84	83	61	48	56	31	25	SM	18.8	106.5	4.4	23	$K = 3.35\times10^{-6}$ cm/sec, Lt. Abut.
WELL-A	BAG-1	1.00	Brown Silty Sand					100	94	58	28	16	12	4	SC-SM					
WELL-B	BAG-2	2.00	Brown Gray Silty Sand					100	97	60	25	19	12	7	SC-SM					Upstream

Fig. 1-20 Results of Stability Analysis of Nong Pla Lai Dam



Design value

Item	Value
γ_t	1.8 t/m³
γ_{sat}	2.0 t/m³
ϕ	25°
C	3.0 t/m²

	Condition	Safety Factor	
		Upstream Slope	Downstream Slope
①	Just after completion of embankment	1.27	1.20
②	N.W.L of Reservoir	2.73	1.92
③	Rapid drawdown of water level of Reservoir (N.W.L EL45.0~L.W.L EL33.3)	1.52	———
④	N.W.L of Reservoir Horizontal seismic coefficient Ek=0.05	2.05	1.66

Fig. 1-21 Inflow and Outflow Hydrograph for Extraordinary Flood

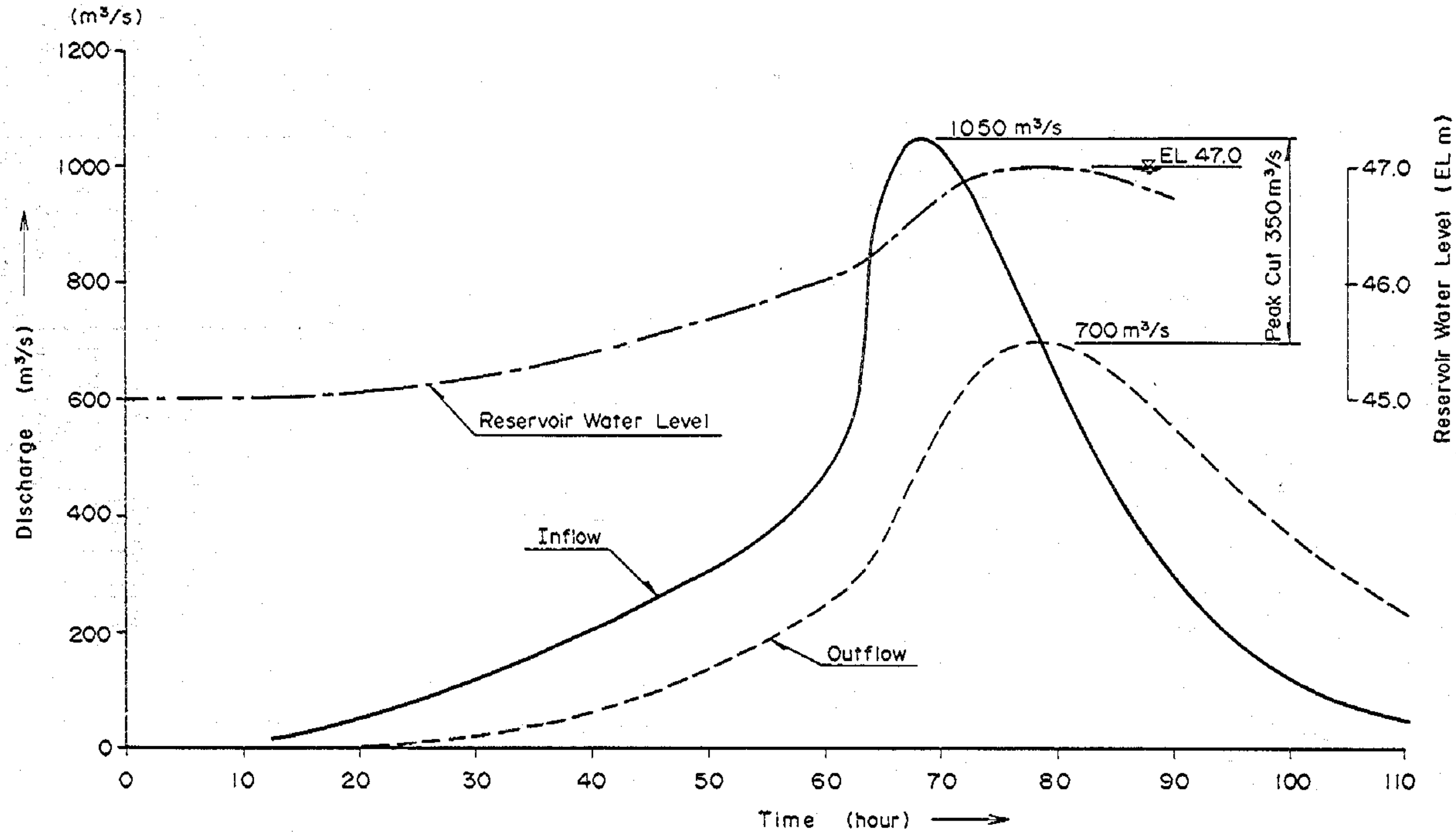


Fig. 1-22 Inflow and Outflow Hydrograph for 30 Year Flood (Nong Pla Lai Dam)

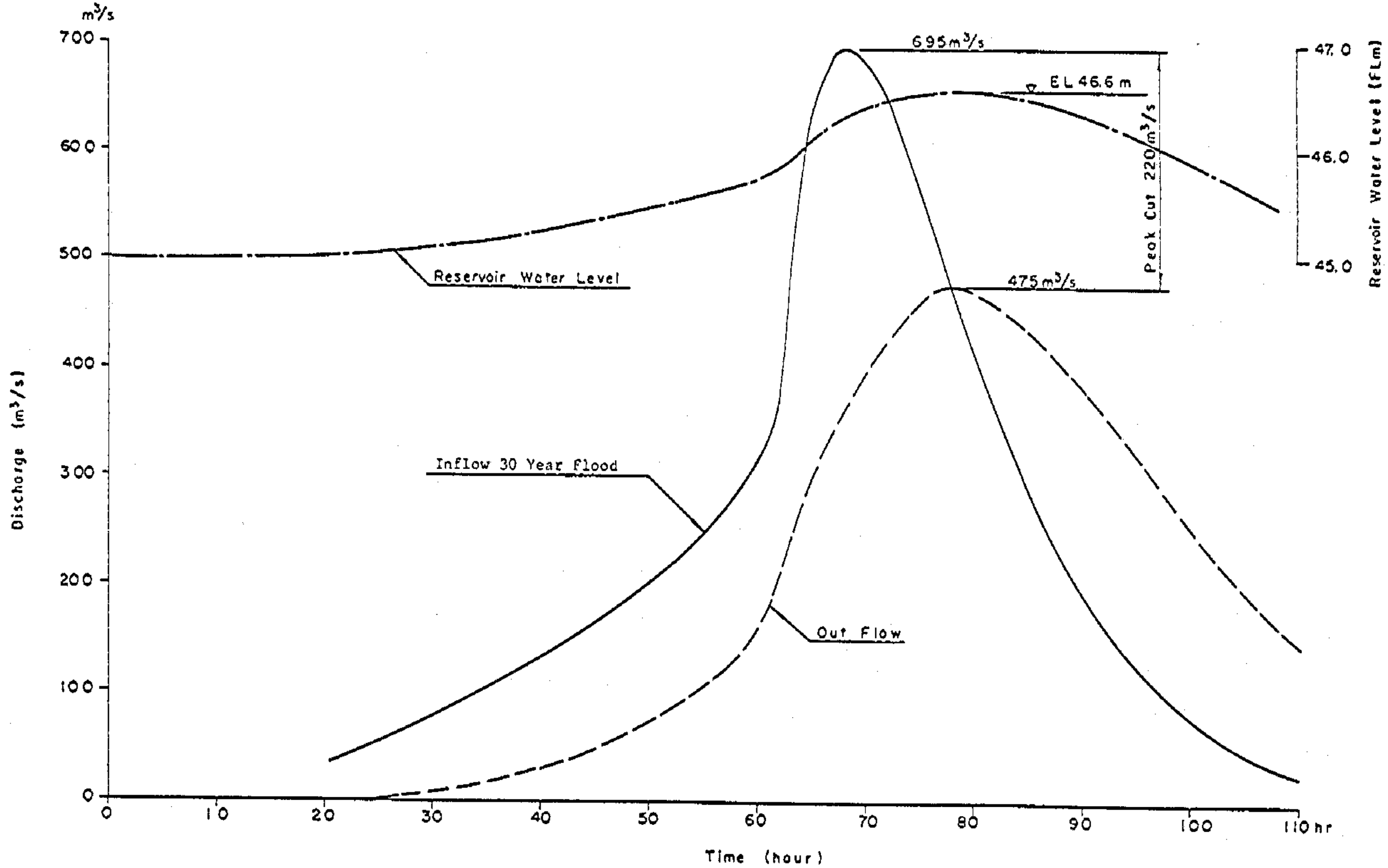


Fig. 1-23 Conduit Diameter vs. Maximum Reservoir Stage

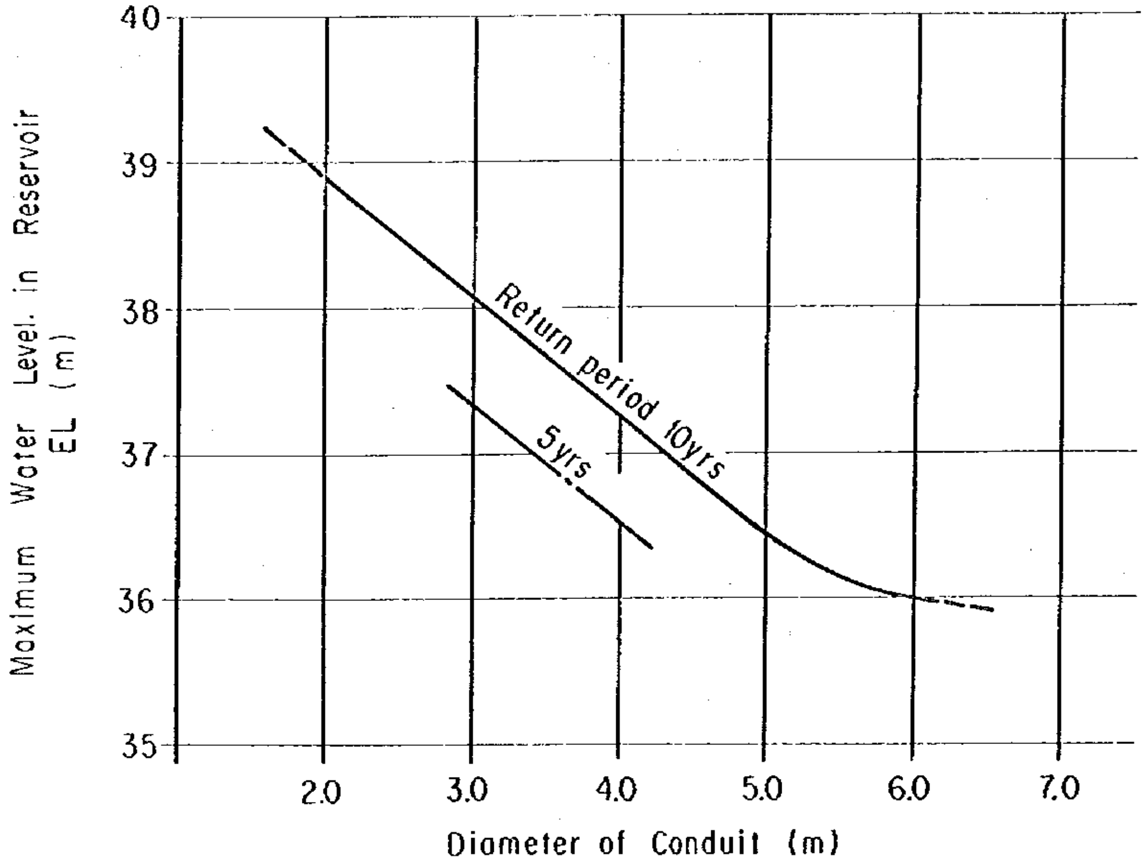


Fig. 1-24 Road Relocation

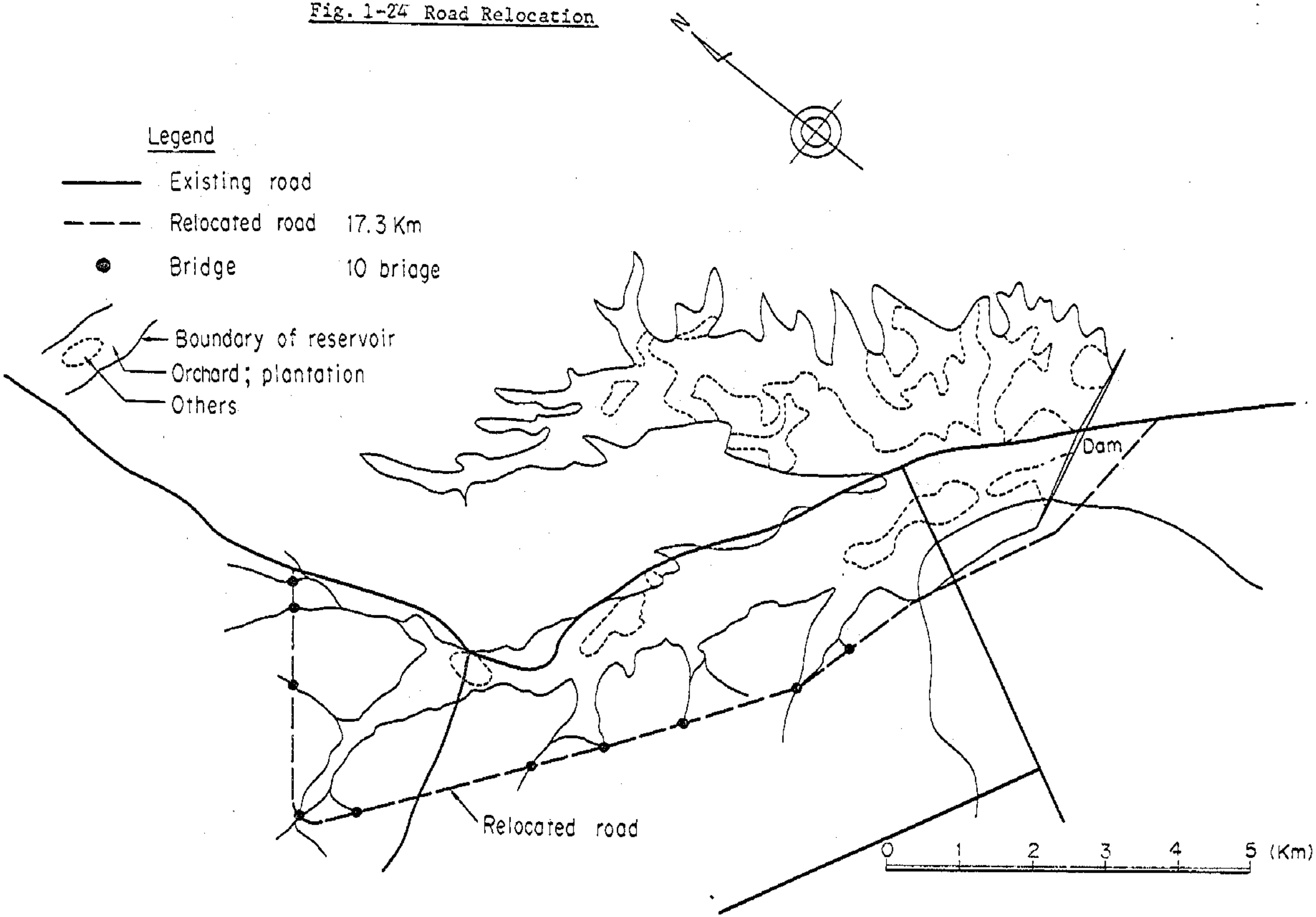


Fig. 1-25 Alternative I of Resettlement Plan

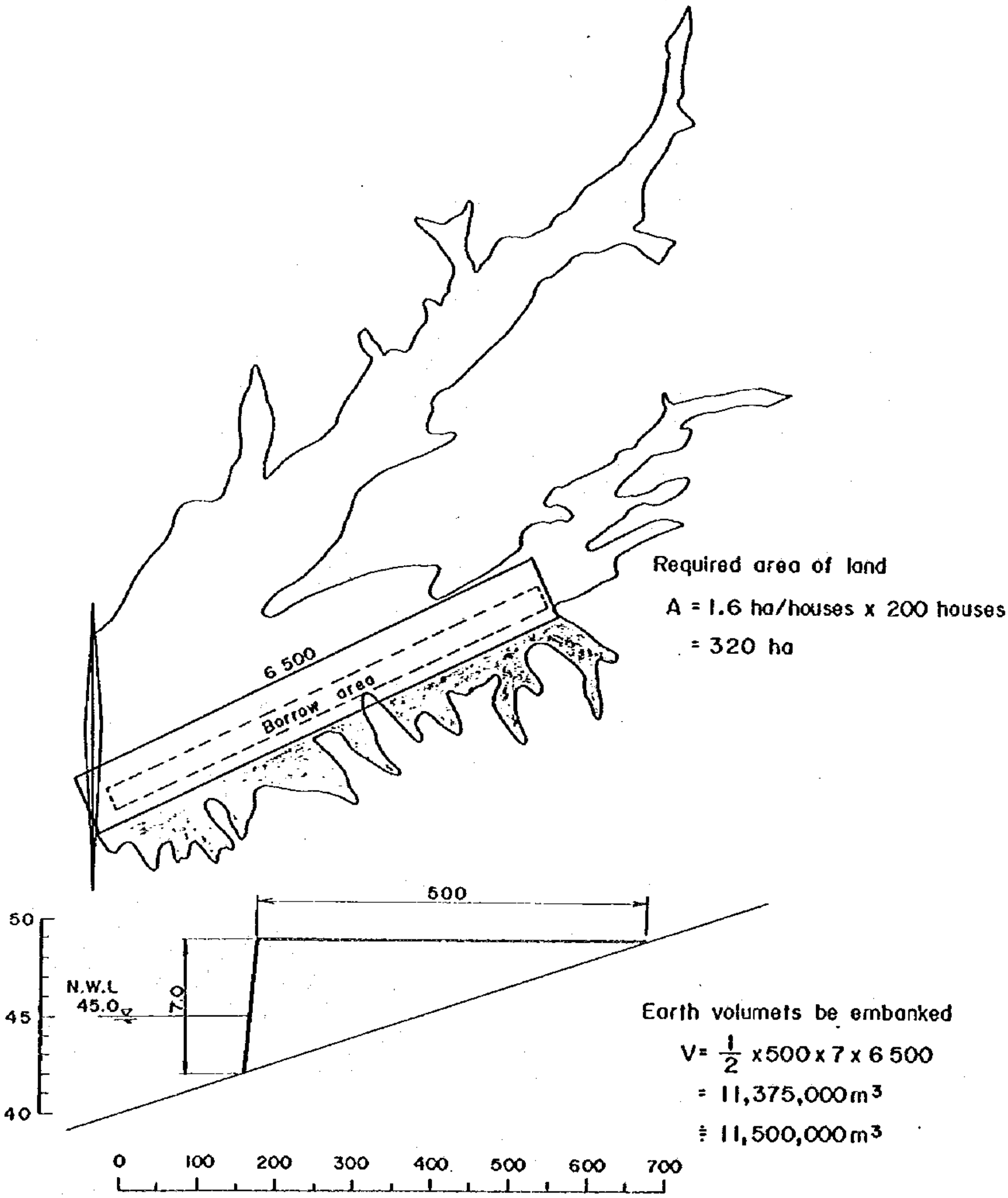
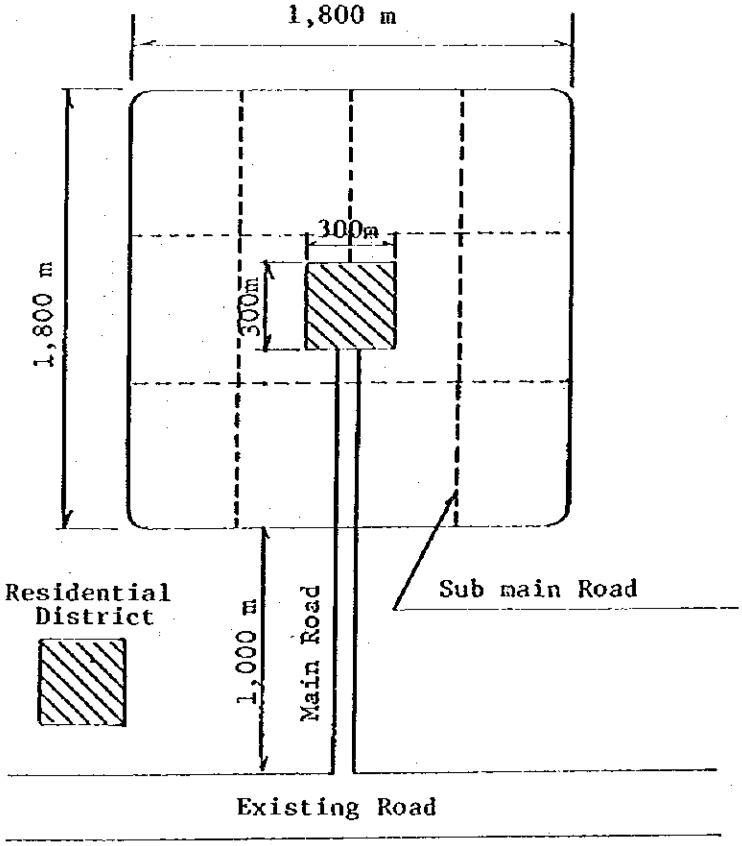


Fig.1-26 Alternative II of Resettlement Plan



Required area of land acquisition: 320 ha

Earth moving work Excavation: 1,000,000 m^3

Embankment: 1,000,000 m^3

Fig. 1-27 General Plan of Nong Pla Lai Dam

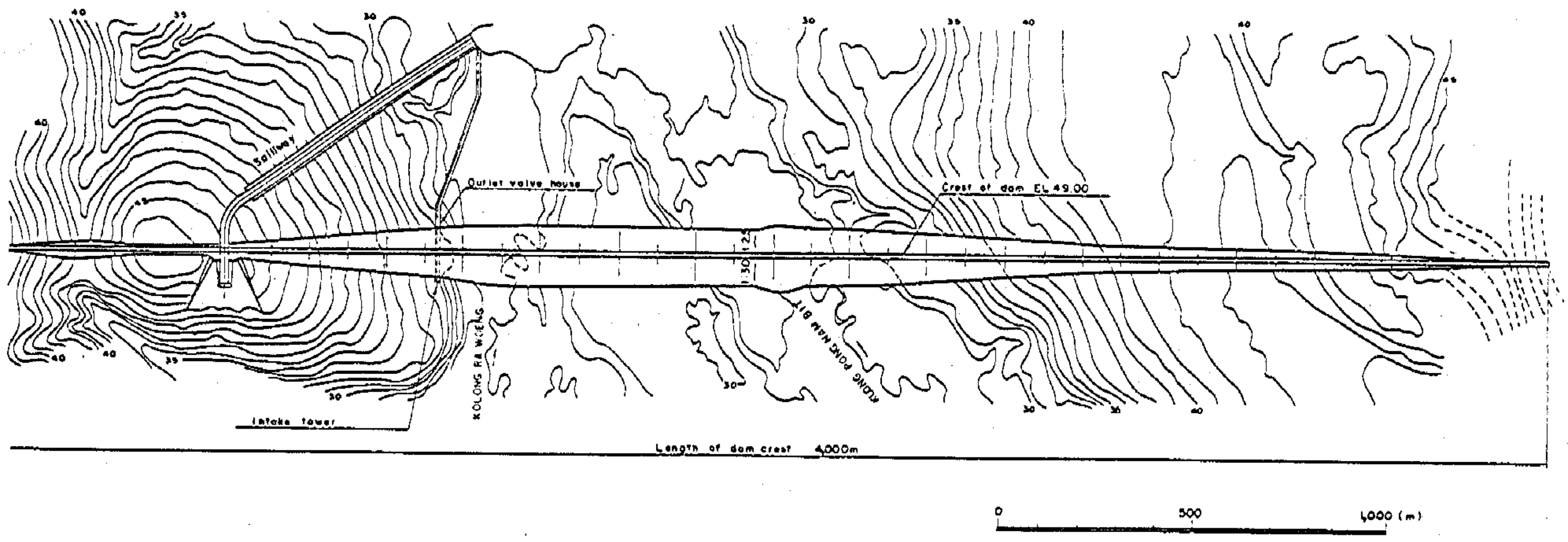


Fig. 1-28 Longitudinal Profile of Nong Pla Lai Dam

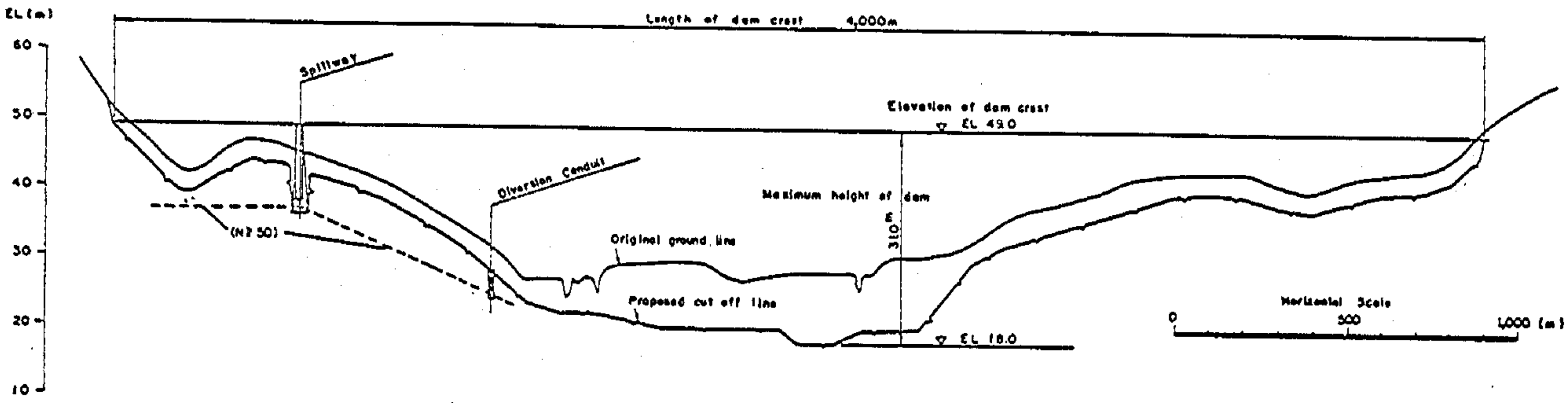
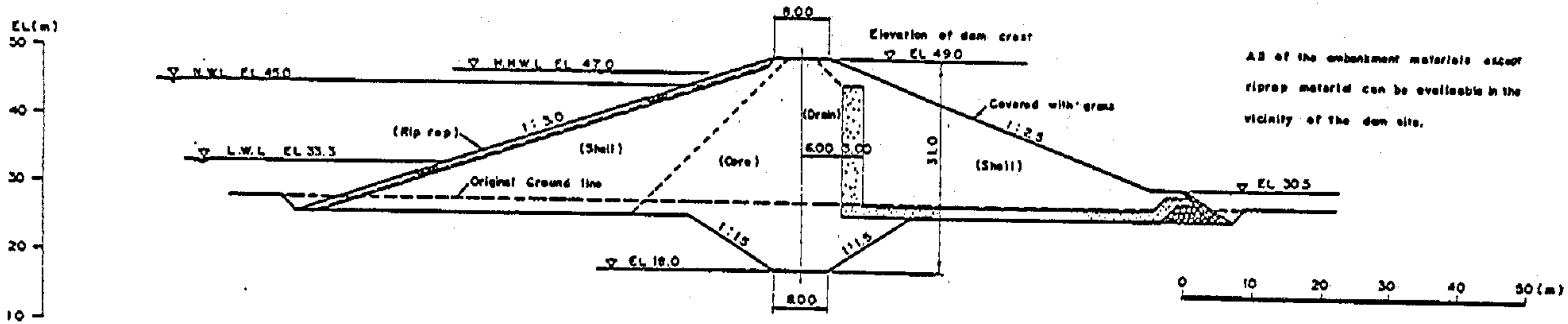


Fig. 1-29 Standard Cross Section of Nong Pla Lai Dam



All of the embankment materials except riprap material can be available in the vicinity of the dam site.

Fig.1-30 Plan of Spillway of Nong Pla Lai Dam

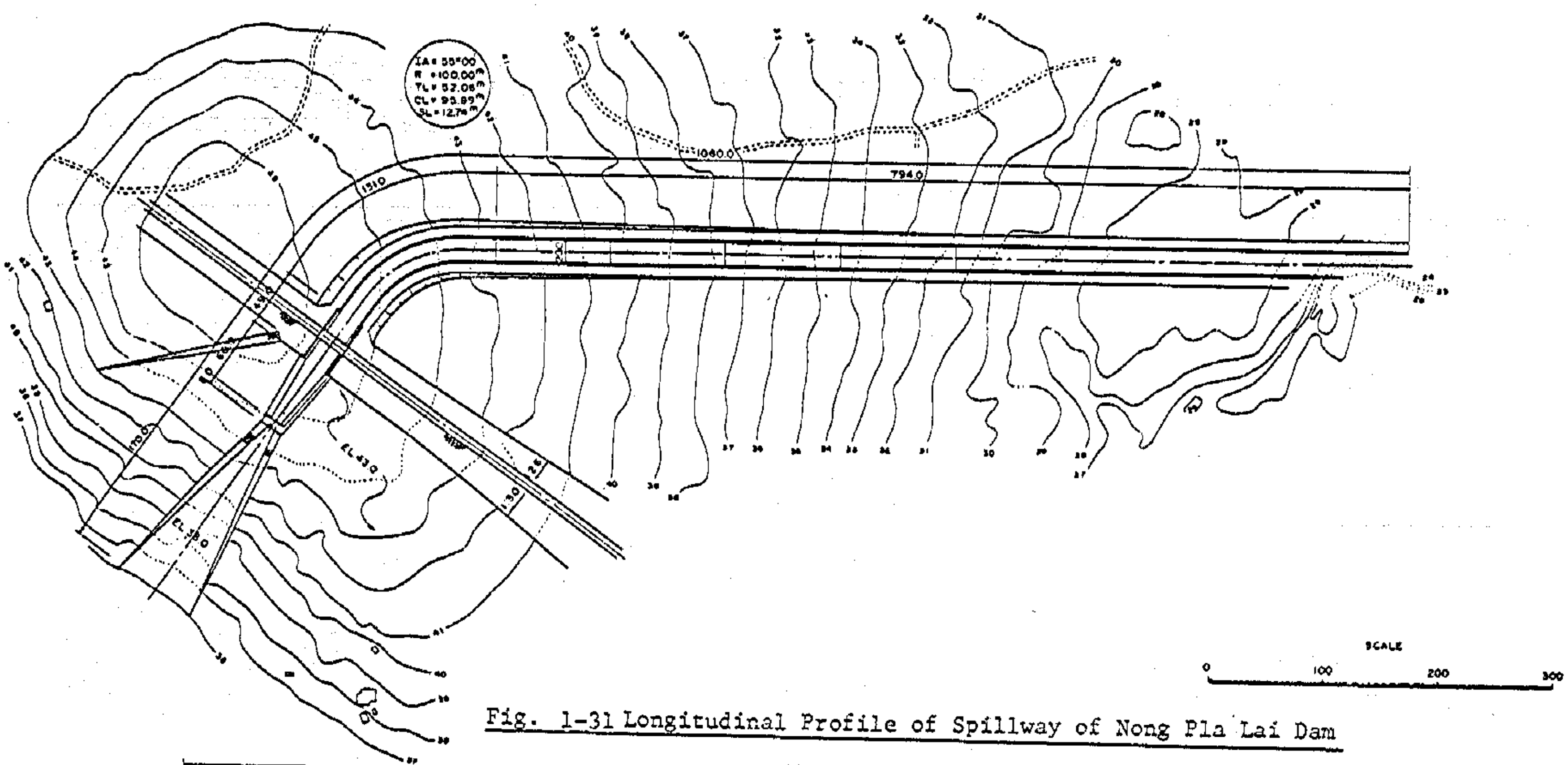


Fig. 1-31 Longitudinal Profile of Spillway of Nong Pla Lai Dam

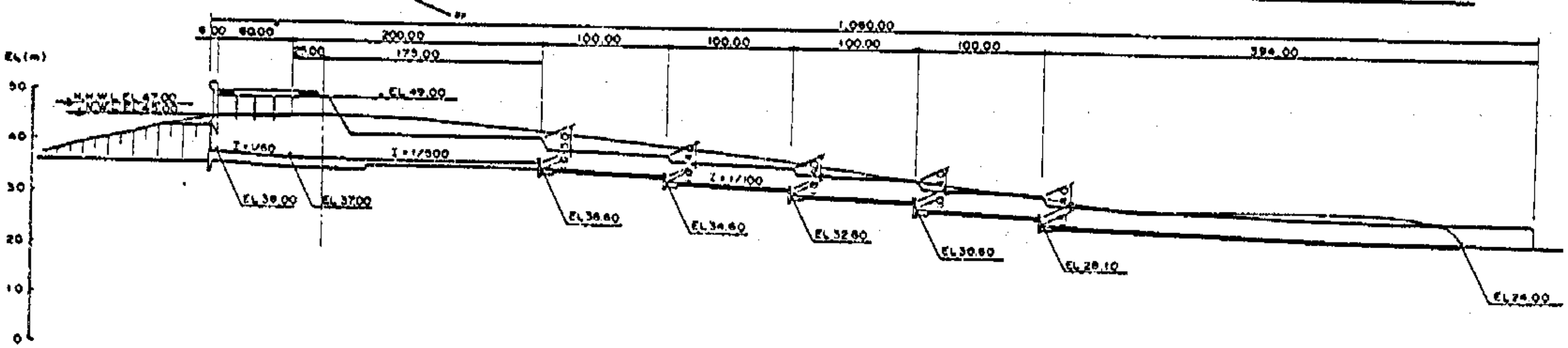


Fig. 1-32 Waterway of Nong Pla Lai Dam

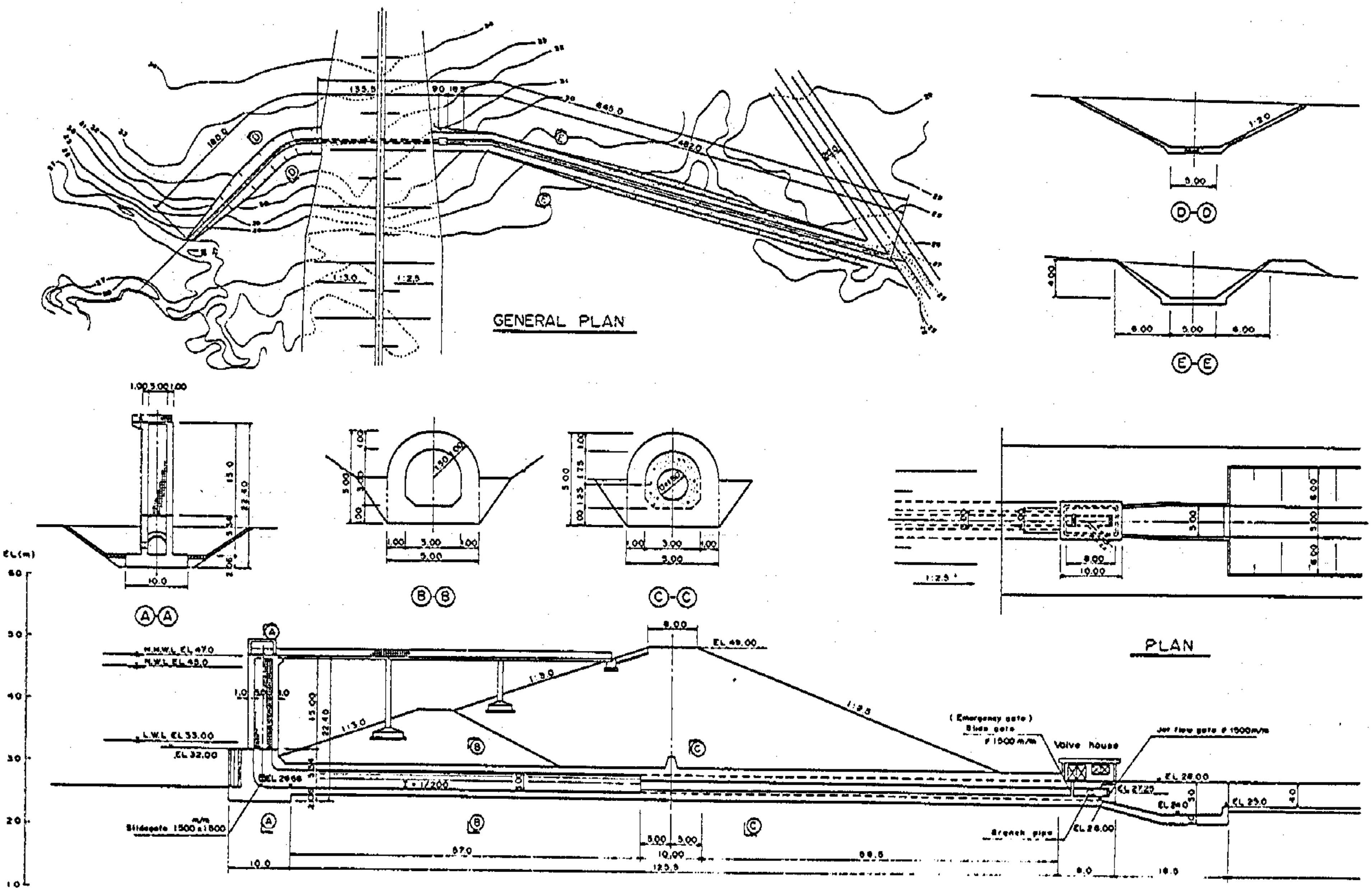


Fig.1-33 Details of Spillway of Nong Pla Lai Dam

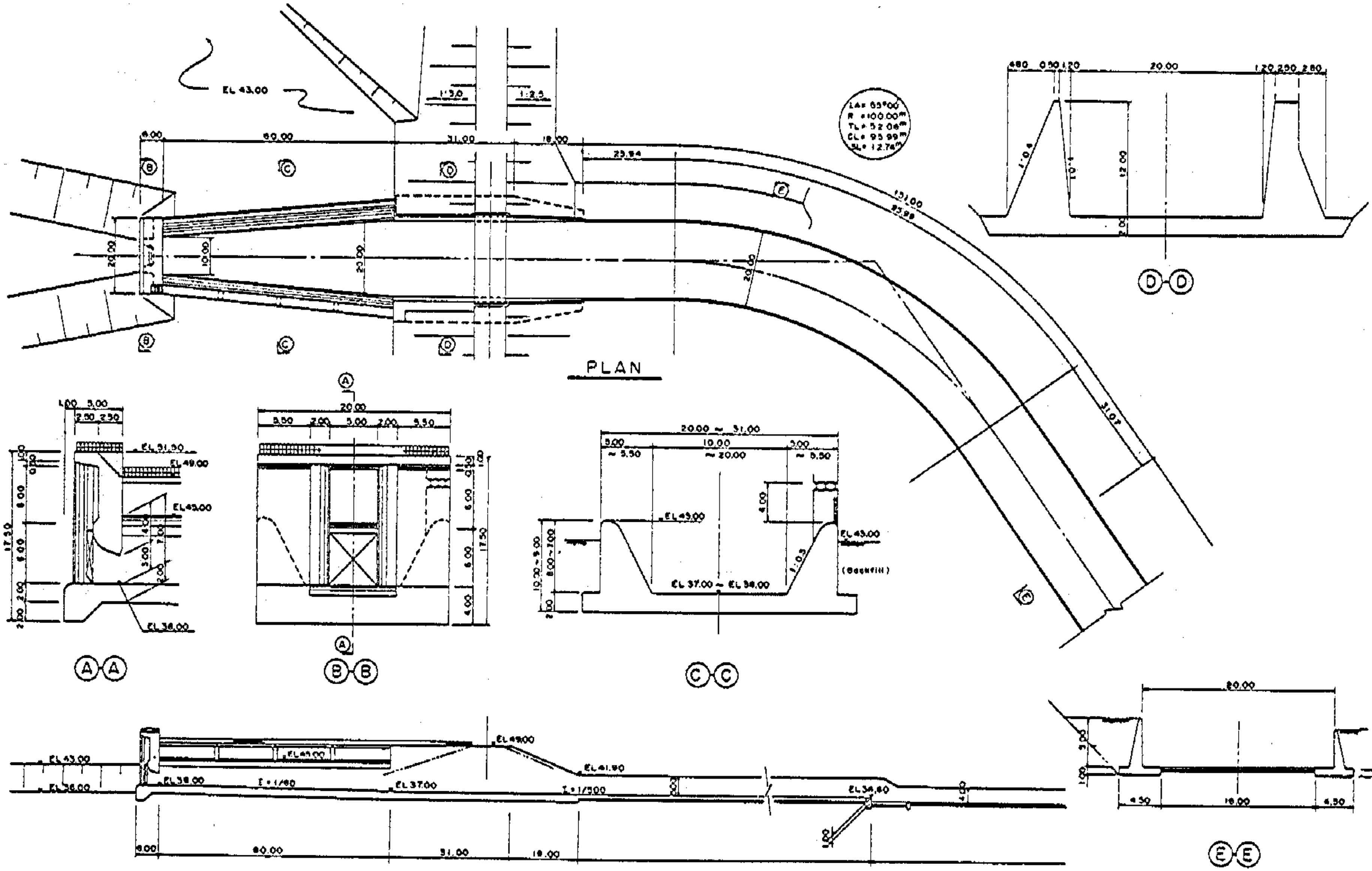
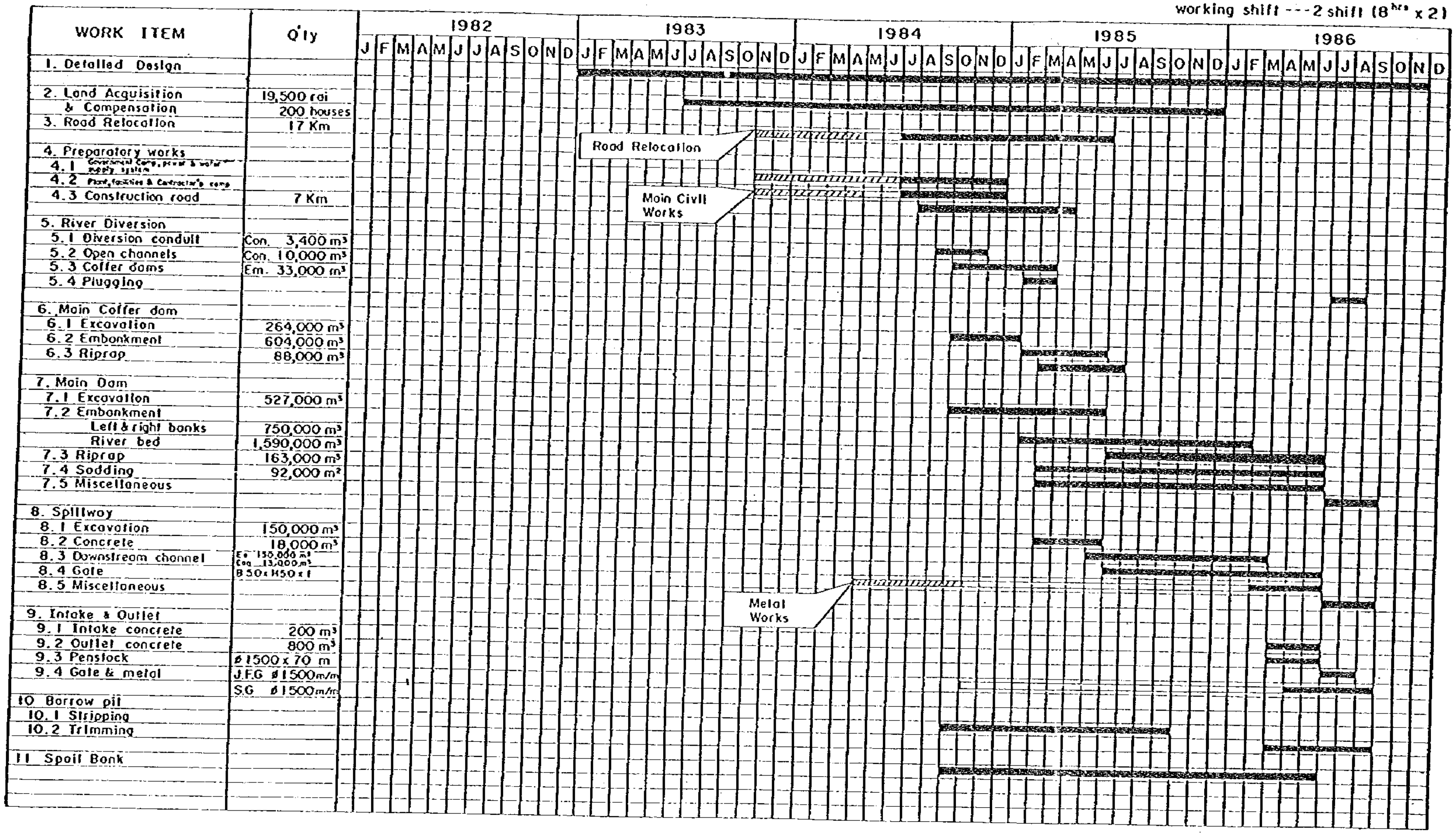


Fig. 1-34 Construction Schedule of Nong PLa Lai Dam

working shift ---2 shift (8 hrs x 2)



Legend

Tender call, evaluation etc

Field work

Note ; government Camp, power & water supply system will be constructed

Fig. 2-1 Comparison of Dam Axis (Plan)

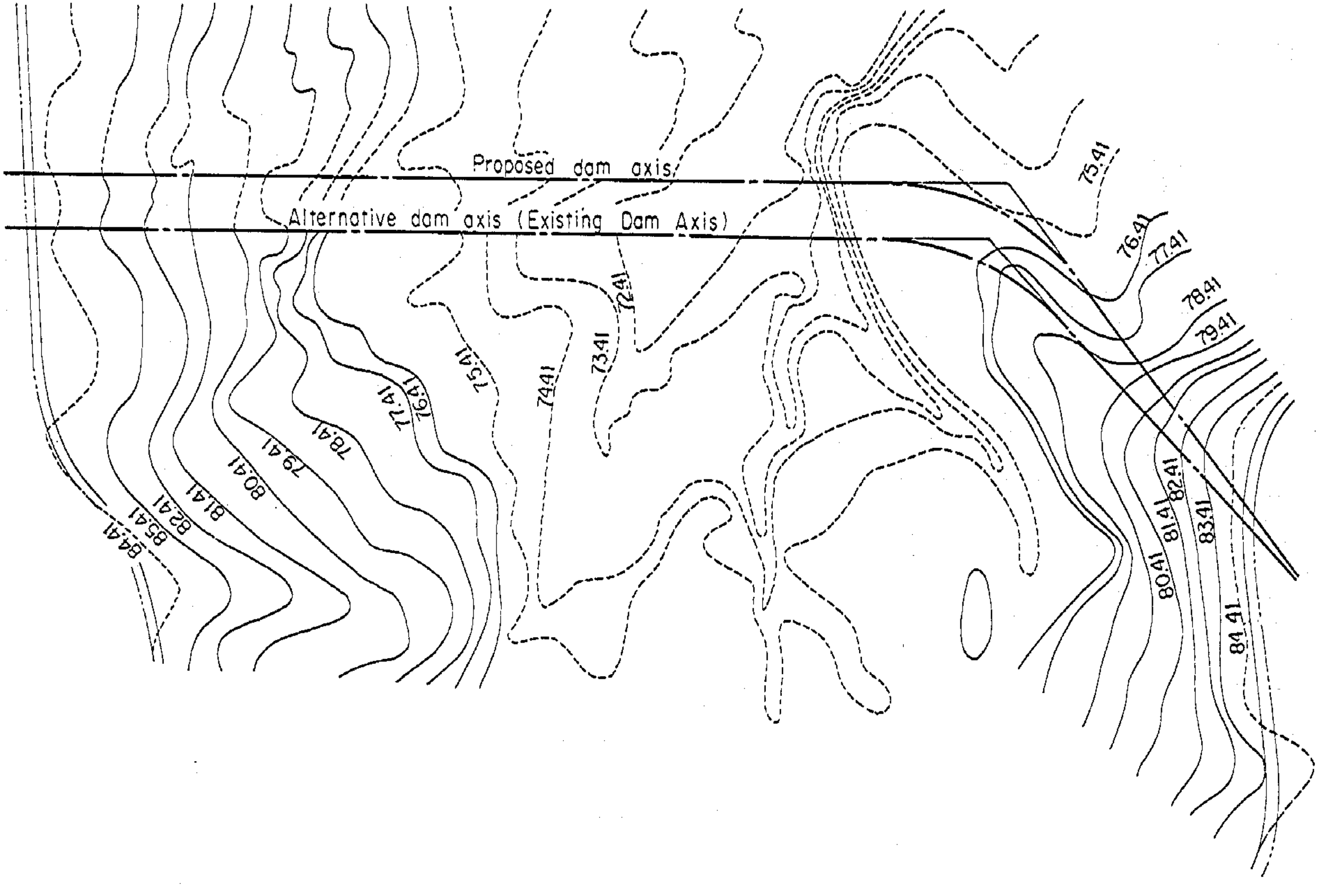
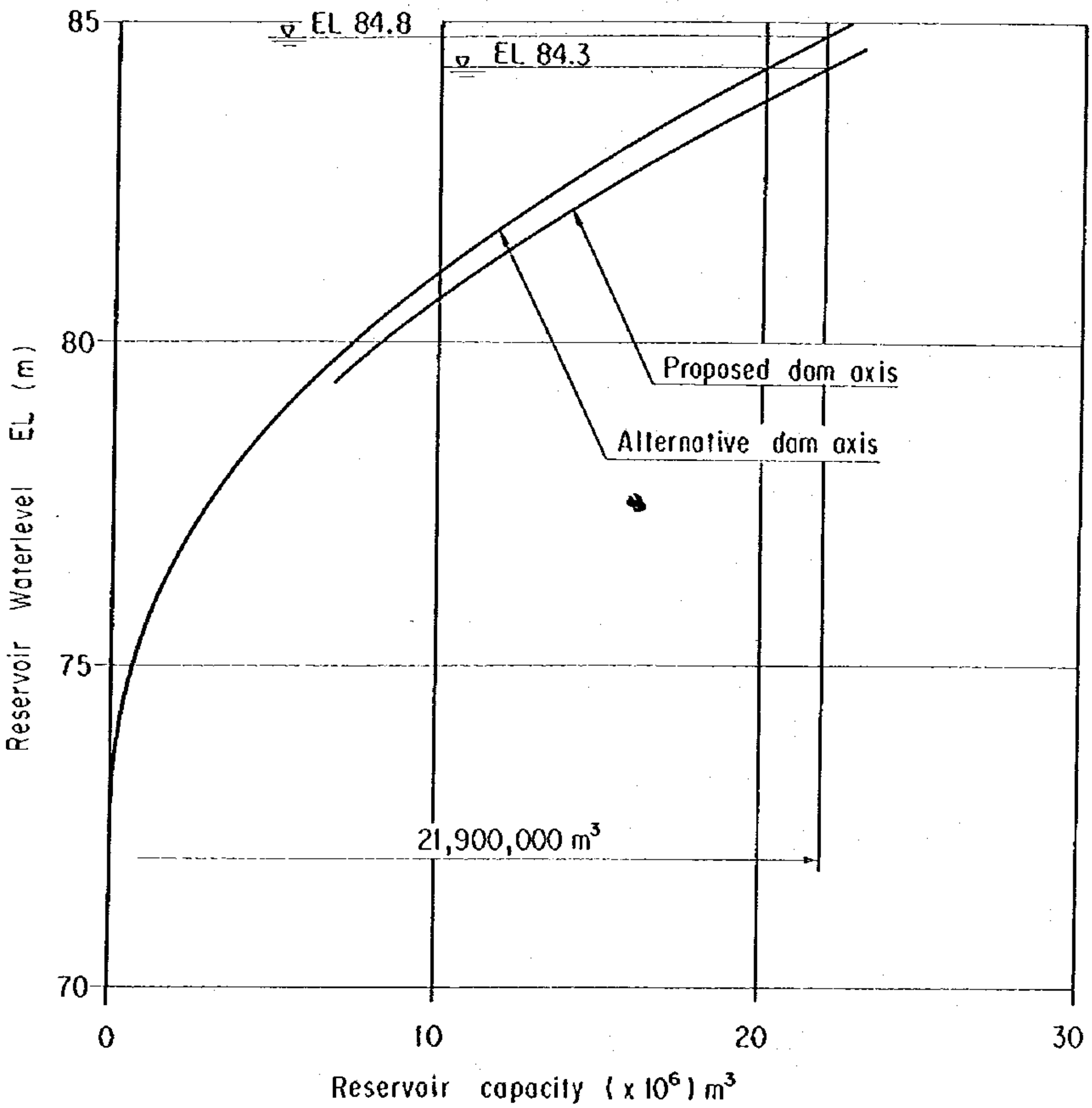
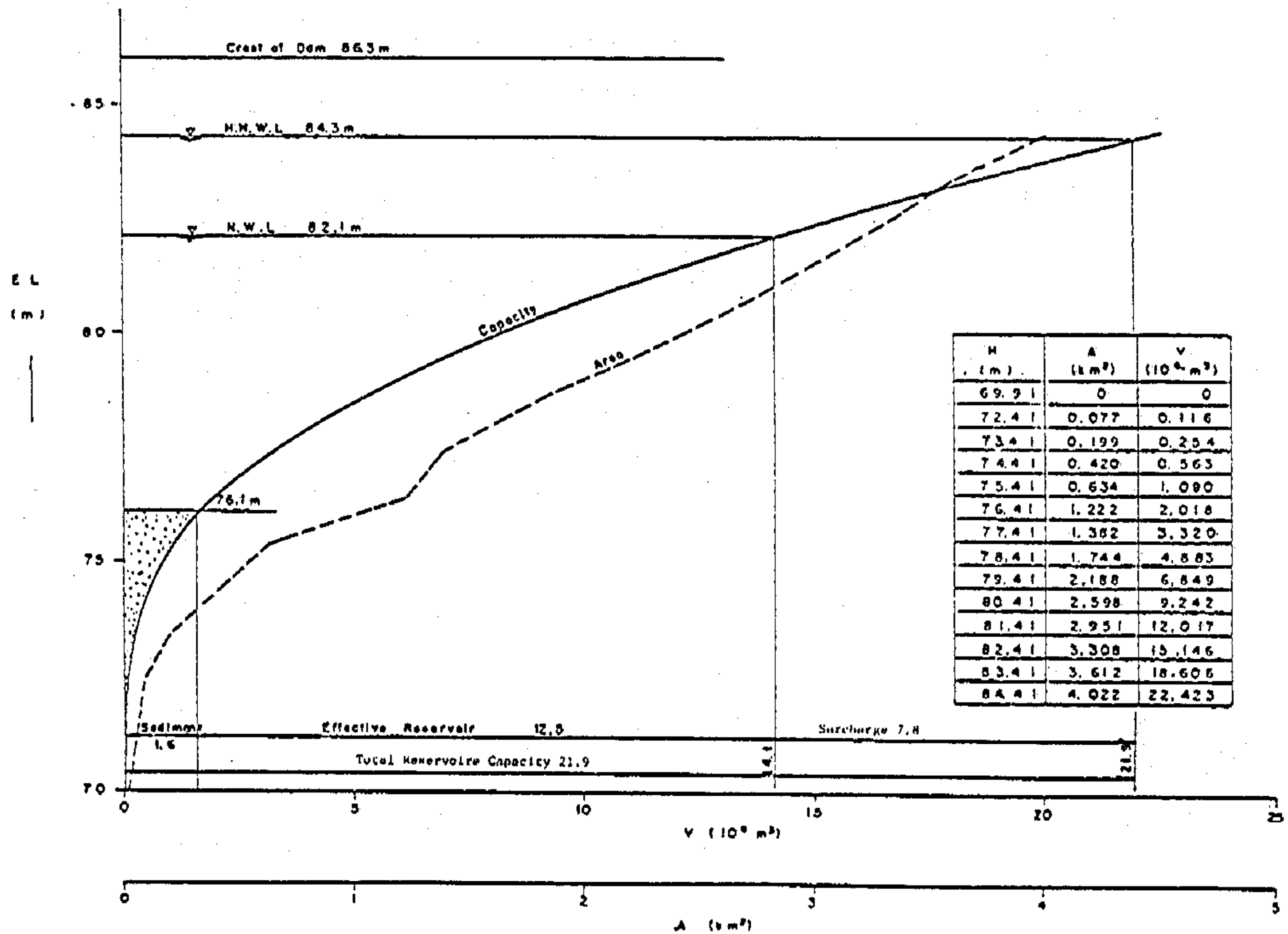


Fig. 2-2 Comparison of Dam Axis (Reservoir Capacity Curve)



Note) Proposed dam axis is 100m downstream of and in parallel to the existing dam axis. Alternative dam axis is the existing one.

Fig.2-3 Reservoir Capacity and Area
(Ban Bung Reservoir)



H (m)	A (km²)	V (10⁶ m³)
69.91	0	0
72.41	0.077	0.116
73.41	0.199	0.254
74.41	0.420	0.563
75.41	0.634	1.090
76.41	1.222	2.018
77.41	1.382	3.320
78.41	1.744	4.883
79.41	2.188	6.849
80.41	2.598	9.242
81.41	2.951	12.017
82.41	3.308	15.146
83.41	3.612	18.606
84.41	4.022	22.423

Fig. 2-4 Geological Map of Ban Bung Dam Site and Reservoir (Scale 1:50000)

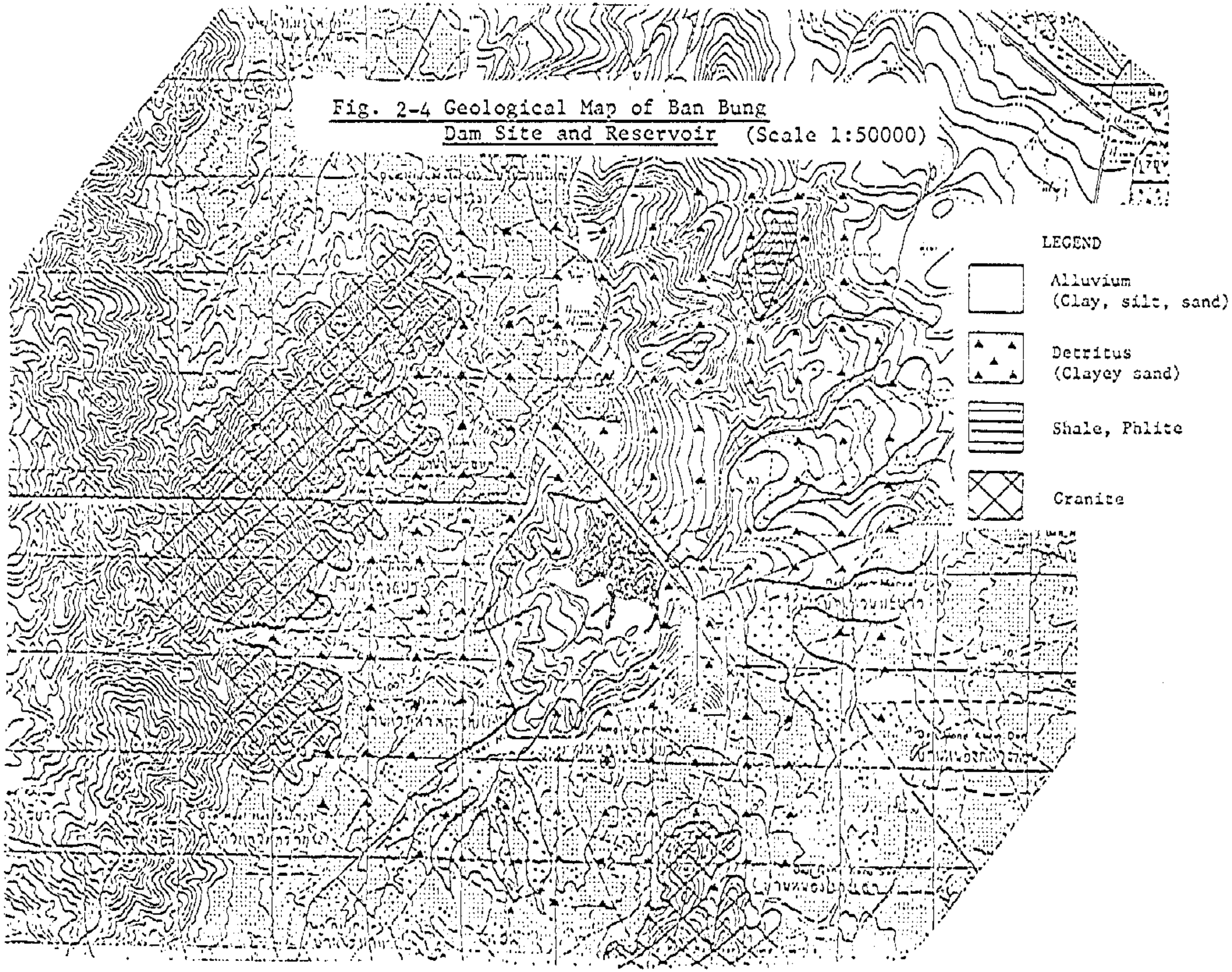


Fig. 2-5 Geological Cross Section of Ban Bung Dam Site

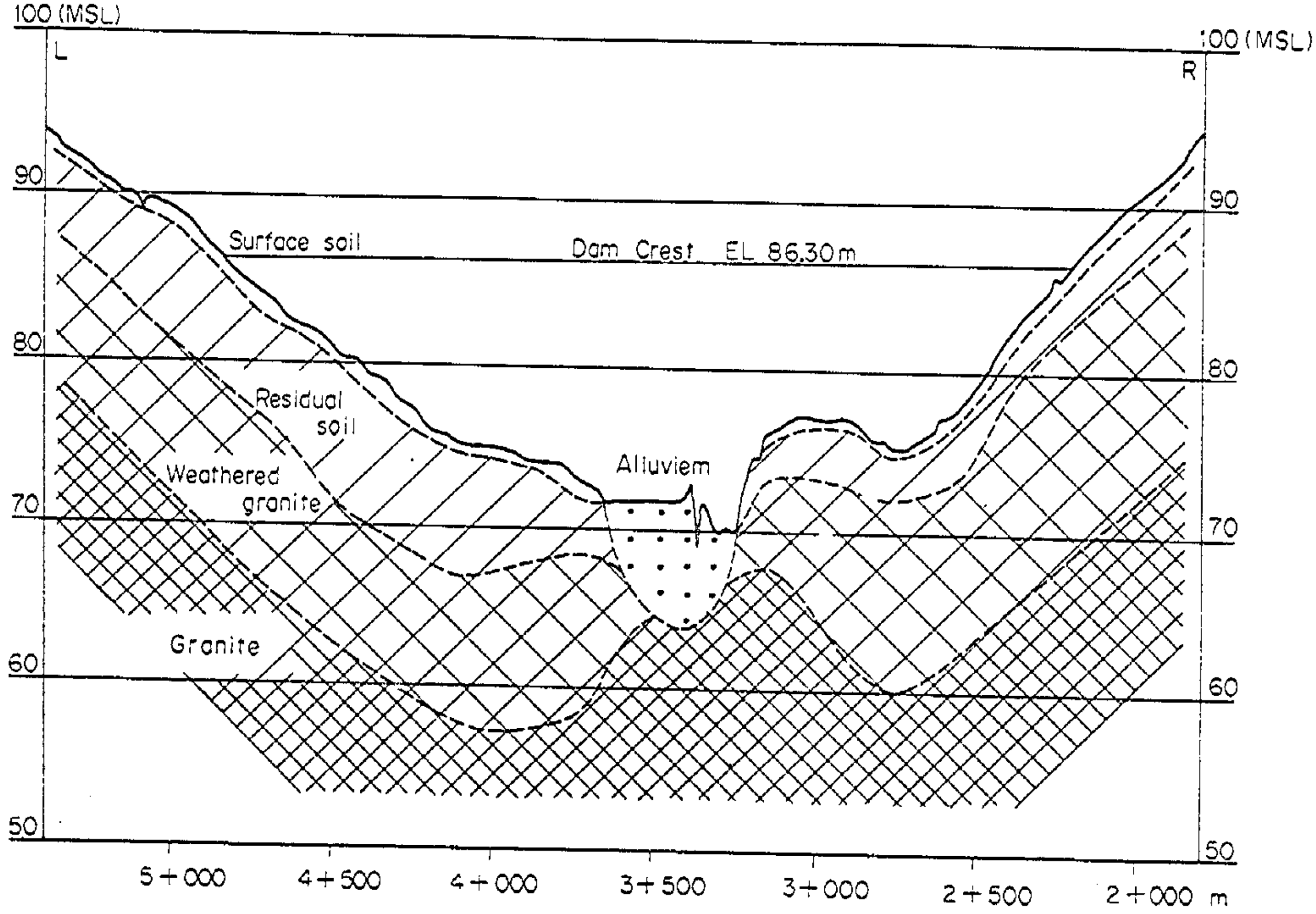
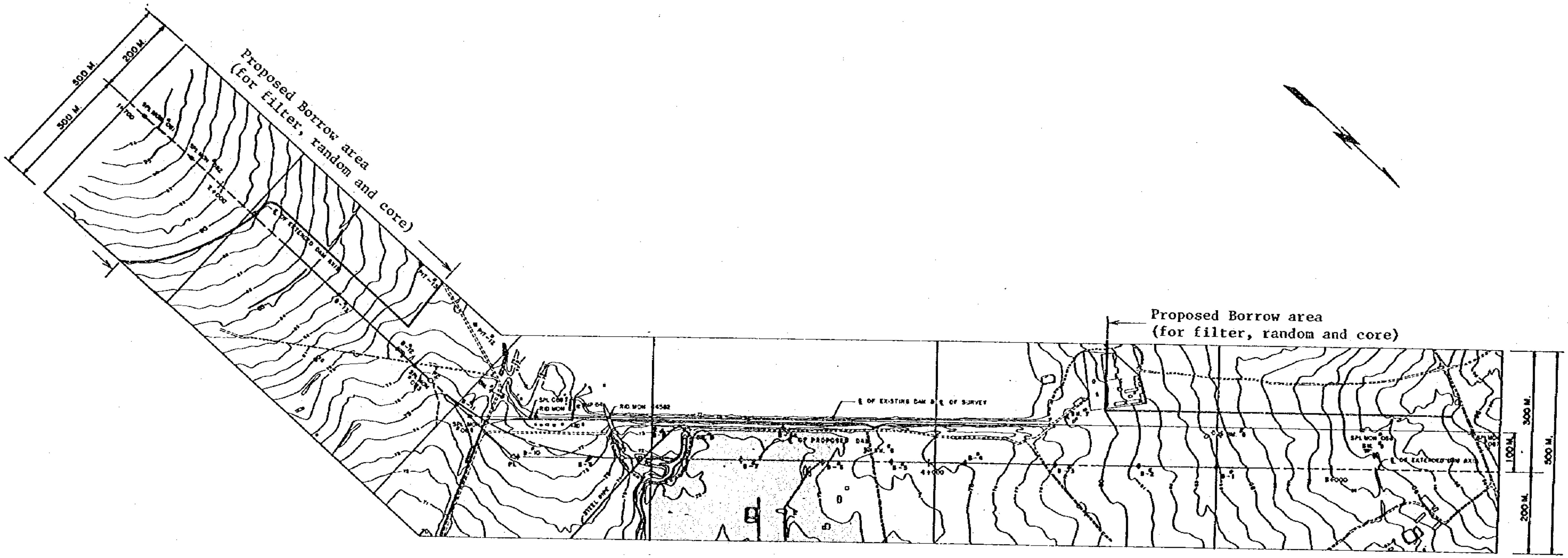


Fig. 2-6 Geological Map of Ban Bung Dam Axis



LEGEND

- clay silt sand
- clayer sand (Decomposed Granite and residual Soil)

GRAPHIC SCALE

Fig. 2-7 Geological Profile along the Ban Bung Dam Axis

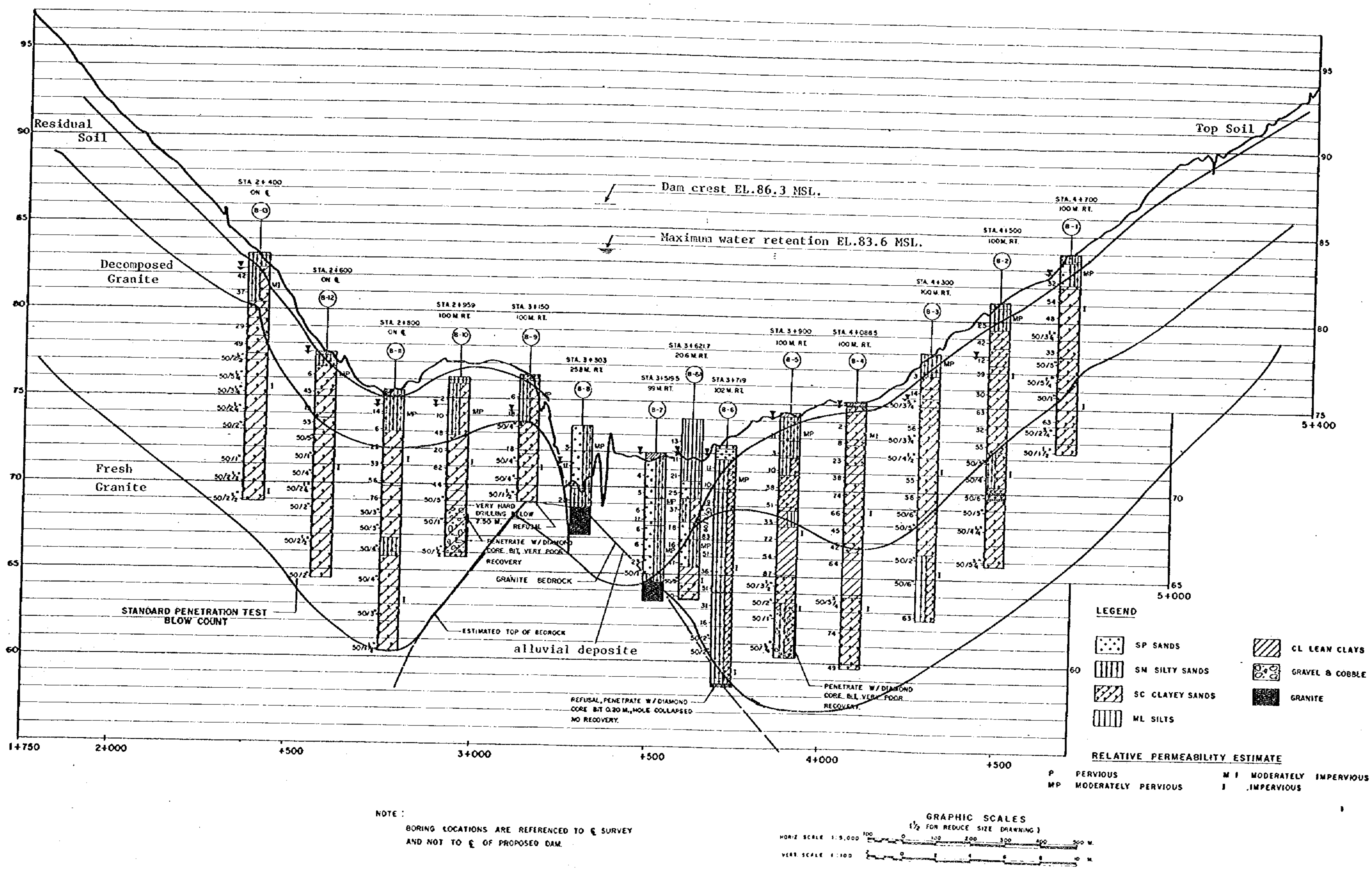


Fig. 2-8 Ban Bung Borrow Pit Gradation Test

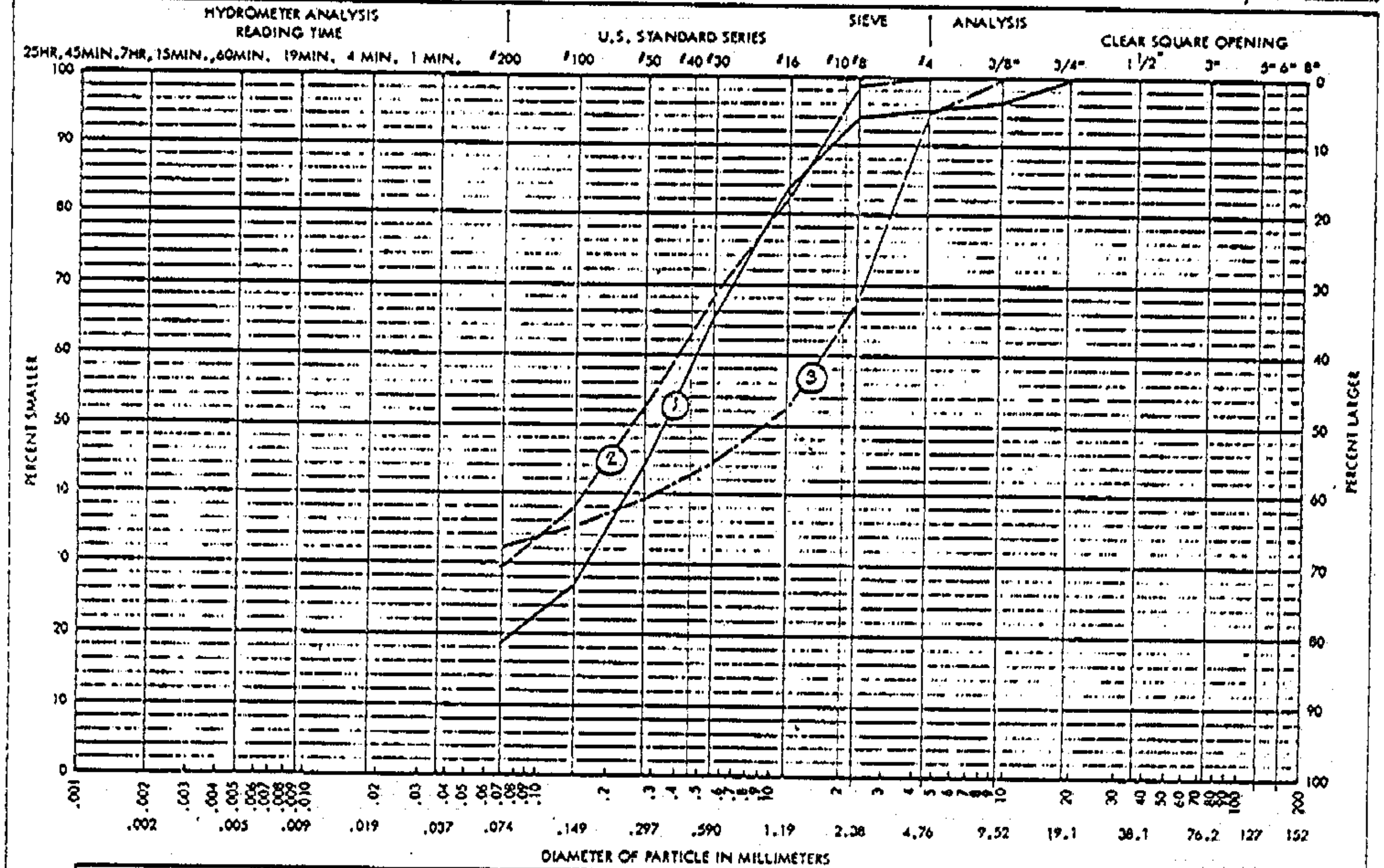
Technical Division
Royal Irrigation Department

Project The East Coast Water Resources Development

GRADATION TEST

ว.ท. 4-38 (พ.ศ.2517)

Memo. 25/2524



CLAY (plastic) TO SILT (non-plastic)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Notes :

No.	Samples From	Location	Elevation (m.)	Atterberg Limits L.L.	P.L.	P.I.	Unified Soil Classification	Nat. Moisture Content
1	Ban Bung	R U/S Pit # 13	1.90 - 2.00	Non - Plastic			SM	12.09 %
2	" — "	R U/S Pit # 12	1.90 - 2.00	" — "			SM	6.00 %
3	" — "	R U/S Pit # 12	3.30 - 3.40	37.7	19.9	17.8	SC	8.14 %

Drawn ..... RT ..... Checked ..... SR ..... Date ..... April 23, 1981 ..... Sheet 4 of 5

Fig. 2-9 Ban Bung Borrow Pit Gradation Test

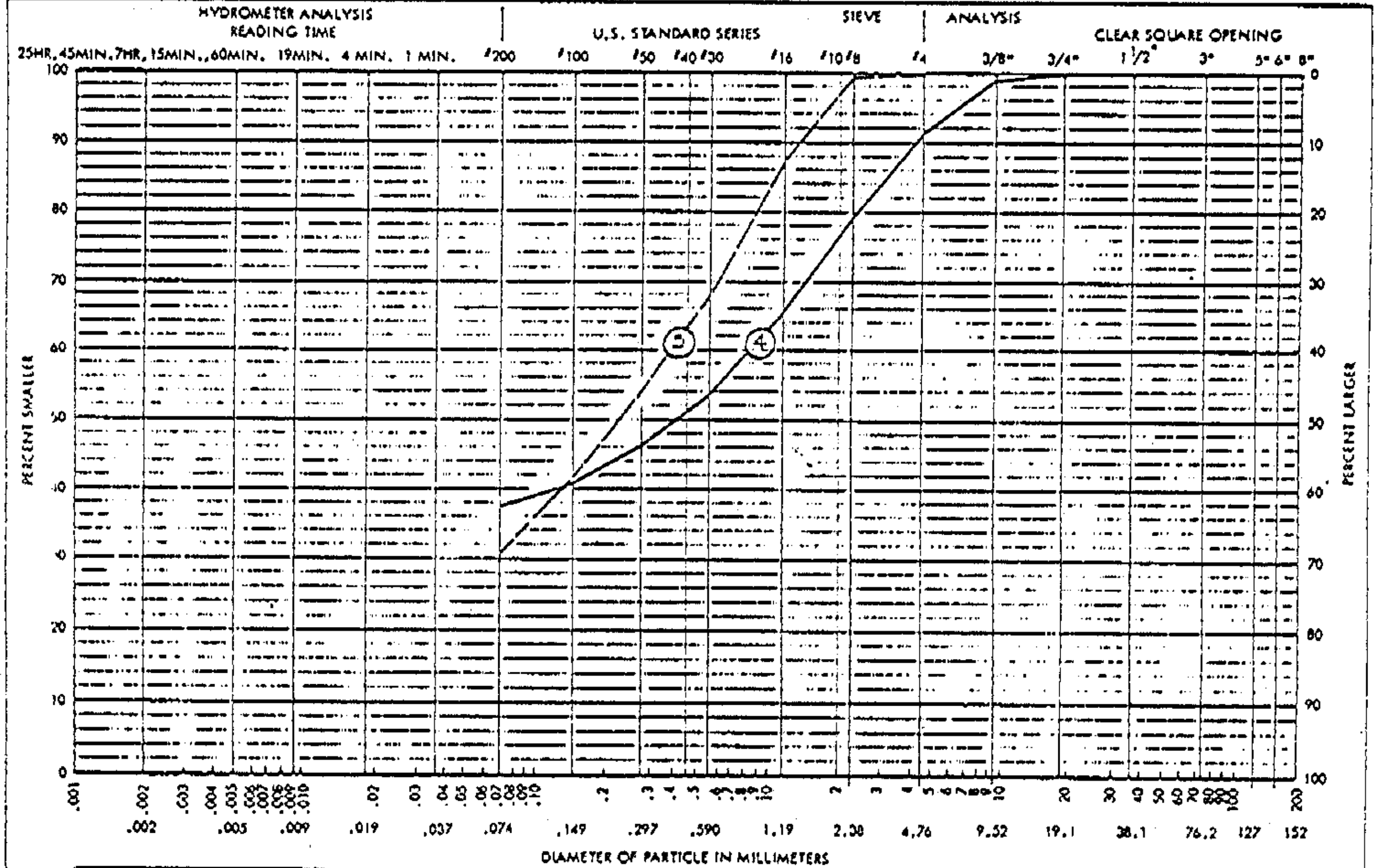
Technical Division
Royal Irrigation Department

GRADATION TEST

รท.4-36
(พ.ศ.2517)

Project The East Coast Water Resources Development

Memo. 20/2524



CLAY (plastic) TO SILT (non-plastic)			SAND			GRAVEL		COBBLES
			FINE	MEDIUM	COARSE	FINE	COARSE	

Notes:

No.	Samples From	Location	Elevation (m.)	Atterberg Limits L.L.	P.L.	P.I.	Unified Soil Classification	Nat. Moisture Content
(4)	Ban Bung	R U/s Pit #1e	4.40 - 4.50	54.3	25.2	29.1	SC	15.45 %
(5)	" —— "	L (4+750) U/s 250m	2.10 - 2.20	Non - Plastic			SM	8.96 %

Drawn R.T. Checked SR. Date April 23, 1981. Sheet 5 of 5

Fig. 2-10 Summary of Test Result (Ban Bung)

SUMMARY OF TEST RESULTS PROJECT: BAN BUNG

BOR. NO.	SAMPLE NO	DEPTH m	DESCRIPTION	1½"	1"	3/4"	3/8"	NO 4	NO 10	NO 40	NO 200	LL	PL	PI	SOIL CLASS	NAT MOIST %	UNIT WT DRY	POCKET PENETROMETER TEST	DIRECT SHEAR C-T/M²	DIRECT SHEAR φ-DEG	PERMEABILITY	OTHER
				GRADATION - PERCENT PASSING								ATTERBERG LIMITS										
B-1	DS-2	2.00-2.45	GRAY CLAYEY SAND					100	98	62	36				SC			2.0				
	DS-4	4.00-4.50	GRAY CLAYEY SAND					100	99	62	33	30	13	17	SC			4.5				
	DS-5	5.00-5.40	MOTTLE CLAYEY SAND					100	97	63	40	32	14	18	SC			3.5				
	DS-9	9.00-9.45	GRAY CLAYEY SAND					100	94	65	48	33	19	14	SC			>4.5				
	DS-11	11.00-11.18	GRAY CLAYEY SAND					100	95	52	28				SC			4.75				
B-2	DS-1	1.00-1.45	GRAYISH BROWN SILTY SAND				100	87	85	58	21				SM							
	DS-2	2.00-2.45	GRAY CLAYEY SAND					100	97	61	37				SC			4.0				
	US-3	2.60-3.00	GRAY CLAYEY SAND			100	94	91	85	62	42	33	14	19	SC	18	2.0	4.5			5.2×10^{-8}	
	DS-5	5.00-5.45	GRAY CLAYEY SAND									24	13	11	SC			4.5				
	DS-8	8.00-8.45	GRAY CLAYEY SAND					100	89	67	48				SC			>4.5				
	DS-10	10.00-10.40	GRAY CLAYEY SILTY SAND				100	99	88	65	53	18	11	7	SM-SC			>4.5				
	DS-12	12.00-12.28	GRAY CLAYEY SAND					100	90	42	26	31	13	18	SC			4.5				
	DS-14	15.00-15.28	GRAY CLAYEY SAND					100	81	44	26				SC			>4.5				
B-3	DS-2	2.00-2.45	GRAY CLAYEY SAND					100	91	55	43				SC			4.25				
	DS-4	4.00-4.45	GRAY CLAYEY SAND				100	99	81	45	26				SC			>4.5				
	DS-7	7.00-7.45	GRAY CLAYEY SAND				100	96	78	54	45				SC			4.5				
	DS-9	9.00-9.45	GRAY CLAYEY SAND				100	98	84	51	34	31	16	15	SC			>4.5				
	DS-12	13.00-13.45	GRAY CLAYEY SILTY SAND					100	95	71	45	18	14	4	SM-SC			2.75				
B-4	US-1	2.60-3.00	GRAY CLAYEY SAND					100	89	32	22	47	17	30	SC	10.6	1.89	3.75	6.2	22.5°	6.5×10^{-5}	
	DS-4	4.00-4.45	GRAY CLAY & SAND					100	87	81	67	58	18	40	CL			4.25				
	DS-6	6.00-6.45	GRAY CLAYEY SAND					100	97	52	21				SC			>4.5				
	DS-9	9.00-9.45	GRAY CLAY & SAND					100	98	58	54	24	15	9	CL			>4.5				
	DS-11	13.00-13.45	GRAY CLAYEY SAND					100	99	44	34	31	18	13	SC			>4.5				
B-5	US-1	2.60-3.00	GRAY CLAYEY SILTY SAND				100	98	88	46	28	17	13	4	SM-SC	7.6	2.18	0.75			4.9×10^{-5}	
	DS-4	4.00-4.45	GRAY CLAYEY SAND					100	86	55	33				SC			4.0				
	DS-6	6.00-6.45	GRAY CLAY & SAND				100	92	85	65	51	17	13	4	CL-ML			2.0				
	DS-9	9.00-9.45	MOTTLE CLAY & SAND				100	98	88	68	53	24	16	8	CL			>4.5				
B-6	US-1	2.60-3.00	GRAY CLAYEY SILTY SAND				100	95	62	44	27	19	14	5	SM-SC	8.5	2.02		3.8	34.0°	6.0×10^{-5}	
	DS-4	4.00-4.45	MOTTLE CLAYEY SAND				100	98	82	44	26				SM-SC			>4.5				
	DS-6	6.00-6.45	GRAY CLAYEY SAND				100	94	75	48	27	22	15	7	SM-SC			>4.5				
	DS-9	9.00-9.45	GRAY CLAYEY SILTY SAND				100	94	82	66	28				SM-SC			0.5				
B-6A	DS-2	2.00-2.45	DARK BROWN SILT & SAND					100	96	87	58				ML			1.5				
	DS-3	3.00-3.45	DARK BROWN SILT & SAND						100	88	60		NP		ML			3.0				
	DS-5	5.00-5.45	MOTTLE CLAYEY SILTY SAND				100	95	72	48	29	21	15	6	SM-SC			4.5				
	DS-7	7.00-7.45	GRAY SILT SAND				100	88	80	38	12				SP-SM			3.5				
	DS-8	8.00-8.45	DARK GRAY CLAY & SAND					100	89	84	61				CL			1.25				
B-7	US-1	2.60-3.00	DARK GRAY SILTY SAND				100	97	75	25	12		NP		SP-SM	14.5	1.94		3.0	32.8°	5.5×10^{-5}	CONSOLIDATION TEST
	DS-6	6.00-6.45	GRAY SILTY SAND					100	93	58	8				SP-SM							
B-8	DS-3	3.00-3.45	GRAY SILTY SAND				100	96	68	38	10				SP-SM							
	DS-4	4.00-4.45	GRAY SILTY SAND				100	96	90	35	13				SW							
B-9	DS-3	3.00-3.10	MOTTLE CLAYEY SAND			100	97	82	65	40	25				SC			>4.5				
	DS-6	6.00-6.10	MOTTLE CLAYEY SAND				100	97	85	36	25				SC			>4.5				

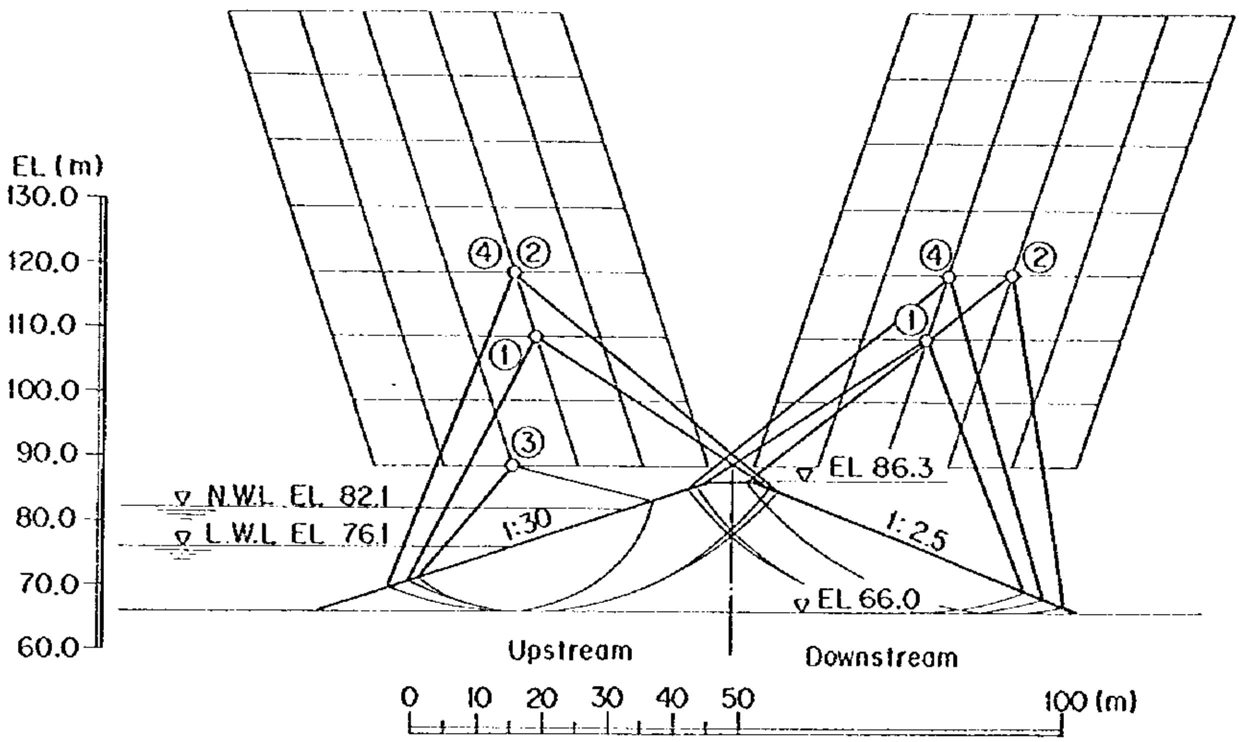
Fig. 2-11 Summary of Test Result (Ban Bung)

SUMMARY OF TEST RESULTS PROJECT BAN BUNG

BOR. NO.	SAMPLE NO	DEPTH M	DESCRIPTION	GRADATION – PERCENT PASSING 1½"	1"	¾"	⅜"	NO 4	NO 10	NO 40	NO 200	ATTERBERG LIMITS LL	PL	PI	SOIL CLASS	NAT MOIST %	UNIT AT DRY g/cc	POCKET PENETROMETER	DIRECT SHEAR C-T/SM	φ-DEG	PERMEABILITY K cm/sec	OTHER
B-10	DS-3	3.00 - 3.45	MOTTLE CLAYEY SILTY SAND				100	97	94	51	28				SM-SC			4.5				
	DS-4	4.00 - 4.45	MOTTLE CLAYEY SAND									56	19	37	SC			>4.5				
	DS-5	5.00 - 5.45	MOTTLE CLAYEY SAND			100	98	86	71	44	33				SC			>4.5				
	DS-6	6.00 - 6.45	MOTTLE CLAYEY SAND				100	89	71	40	26	47	27	20	SC			>4.5				
	DS-7	7.00 - 7.28	MOTTLE CLAYEY SAND			100	92	79	58	32	19				SC			>4.5				
B-11	DS-2	2.00 - 2.45	BROWNISH RED SILTY SAND					100	58	34	30				SM			1.0				
	DS-3	3.07 - 3.52	MOTTLE CLAYEY SAND				100	95	68	47	40				SC			>4.5				
	DS-4	4.00 - 4.45	MOTTLE CLAYEY SAND									43	27	36	SC			>4.5				
	DS-8	6.00 - 6.45	MOTTLE CLAYEY SAND				100	93	73	43	31	64	27	37	SC			>4.5				
	DS-9	9.00 - 9.40	MOTTLE CLAYEY SILTY SAND				100	98	85	49	33	40	31	17	SM			>4.5				
B-12	DS-1	1.00 - 1.45	GRAY CLAYEY SAND					100	96	47	21	37	18	21	SC			1.0				
	DS-2	2.00 - 2.45	GRAY CLAYEY SAND					100	72	45	37	51	18	33	SC			>4.5				
	US-1	3.60 - 3.79	MOTTLE CLAYEY SAND				100	99	87	54	40	54	23	31	SC	20.6	1.54	4.25	3.2	27.0°	2.6×10⁻⁹	
	DS-6	6.00 - 6.17	MOTTLE CLAYEY SAND			100	89	81	68	43	28	30	17	13	SC			>4.5				
	DS-9	9.00 - 9.05	MOTTLE CLAYEY SAND				100	90	78	57	40				SC			>4.5				
B-13	DS-1	1.00 - 1.45	BROWNISH RED SILTY SAND			100	96	95	92	51	16				SM-SC							
	DS-3	3.00 - 3.38	MOTTLE CLAYEY SILTY SAND					100	68	42	27	18	13	5	SM-SC			>4.5				
	DS-5	5.00 - 5.45	MOTTLE CLAYEY SAND				100	95	76	47	35	75	31	42	SC			>4.5				
	DS-7	7.00 - 7.28	MOTTLE CLAYEY SAND				100	90	75	44	28				SC			>4.5				
	DS-10	10.00 - 10.05	MOTTLE CLAYEY SAND				100	85	64	35	20				SC							
																	STD COMPACT OPT MOIST %	MAX DRY DENS T/CM	DIRECT SHEAR C-T/SM	φ DEG		
PIT 1	Bag-1	0.20 - 3.65	RED BROWN CLAYEY SANDY GRAVEL	100	88	86	79	60	58	27	25	45	26	19	GC	9.7	10.8	2.01	6.0	36.5°	K = 4.8×10⁻⁹ cm/sec	
PIT 2	Bag-1	0.20 - 2.65	RED BROWN CLAYEY SANDY GRAVEL	91	85	82	66	49	32	22	18	36	19	17	GC						NOTE 100% PASSING 3" SIEVE	
PIT 3	Bag-1	0.00 - 2.00	RED BROWN CLAYEY SAND			100	98	93	65	43	34	27	17	10	SC		9.8	2.03	0.5	41.5°	K = 8.3×10⁻⁶ cm/sec	
	Bag-2	2.00 - 2.80	MOTTLE CLAYEY SAND			100	98	98	80	44	35	21	15	6	SM-SC							
PIT 4	Bag-2	2.00 - 3.00	BROWN YELLOW CLAYEY SAND				100	97	87	38	25	28	22	6	SM-SC							
PIT 5	Bag-1	0.00 - 2.00	RED BROWN CLAYEY SAND			100	95	75	53	35	25	20	14	6	SM-SC	9.2	9.4	2.09	1.7	43.0°	K = 6.5×10⁻⁶ cm/sec	
	Bag-2	2.00 - 2.60	MOTTLE CLAYEY SANDY GRAVEL	100	91	77	57	44	35	25	18	23	16	7	GM-GC							
PIT 6	Bag-1	0.20 - 1.50	RED BROWN CLAYEY SANDY GRAVEL		100	93	75	53	33	22	20	34	17	17	GC							
PIT 7	Bag-1	0.20 - 2.00	RED BROWN CLAYEY SANDY GRAVEL		100	95	71	48	27	20	18	23	14	9	GC	8.7	7.2	2.02	4.2	41.5°	K = 3.1×10⁻⁶ cm/sec	
PIT 8	Bag-1	0.00 - 2.50	RED BROWN CLAYEY SAND			100	96	74	42	31	27	37	20	17	SC							
PIT 9	Bag-1	0.00 - 4.00	RED BROWN CLAYEY GRAVELLY SAND			100	96	69	46	37	34	37	16	21	SC							
	Bag-2	4.00 - 8.00	MOTTLE GRAVELLY SANDY CLAY			100	96	88	78	64	57	46	20	26	CL							
PIT 10	Bag-1	4.00 - 6.00	MOTTLE SANDY CLAYEY SILT				100	96	98	52	88	35	29	6	ML	15.5	16.0	1.57	2.0	38.0°	K = 4.1×10⁻⁶ cm/sec	
PIT 11	Bag-1	0.00 - 2.50	BROWN SILTY SAND					100	56	38	22		NP		SM							
PIT 12	Bag-1	0.00 - 3.00	BROWN SILTY SAND					100	99	63	22		NP		SM							
PIT 13	Bag-1	0.00 - 1.50	BROWNISH RED SILTY SAND					100	99	53	12		NP		SP-SM							
PIT 14	Bag-1	0.00 - 1.50	RED BROWN CLAYEY SAND				100	99	87	61	38	34	17	17	SC		11.8	1.95				
PIT 15	Bag-1	0.00 - 2.00	RED BROWN CLAYEY SAND			100	98	88	52	38	30	45	21	24	SC							

NOTE:
1. PIT #1 THRU #10 ARE AT KHAO DIN BORROW AREA, ABOUT 2 KMS. D/S FROM DAM SITE
PIT #11 THRU #13 ARE AT RIGHT ABUTMENT AREA.
PIT #14 & #15 ARE AT COMMERCIAL SOURCE ABOUT 8 KMS EAST OF DAM SITE.
2. SAMPLE ARE COMPACTED TO 98% OF STD DENSITY AND 2% WET OF OPTIMUM MOISTURE FOR DIRECT SHEAR & PERMEABILITY TEST.
3. K = COEFFICIENT OF PERMEABILITY

Fig. 2-12 Results of Stability Analysis of Ban Bung Dam



Design value

Item	Value
γ_t	1.8 t/m^3
γ_{sut}	2.0 t/m^3
ϕ	25°
C	3.0 t/m^2

	Condition	Softy Factor	
		Upstream Slope	Downstream Slope
①	Just after completion of embankment	1.55	1.45
②	N.W.L of Reservoir	3.16	2.23
③	Rapid drawdown of water level of Reservoir (N.W.L EL 82.1~L.W.L EL 76.1)	2.07	——
④	N.W.L of Reservoir Horizontal seismic coefficient Ek = 0.05	2.36	1.91

Fig. 2-13 Inflow and Outflow Hydrograph for Extaordinary Flood

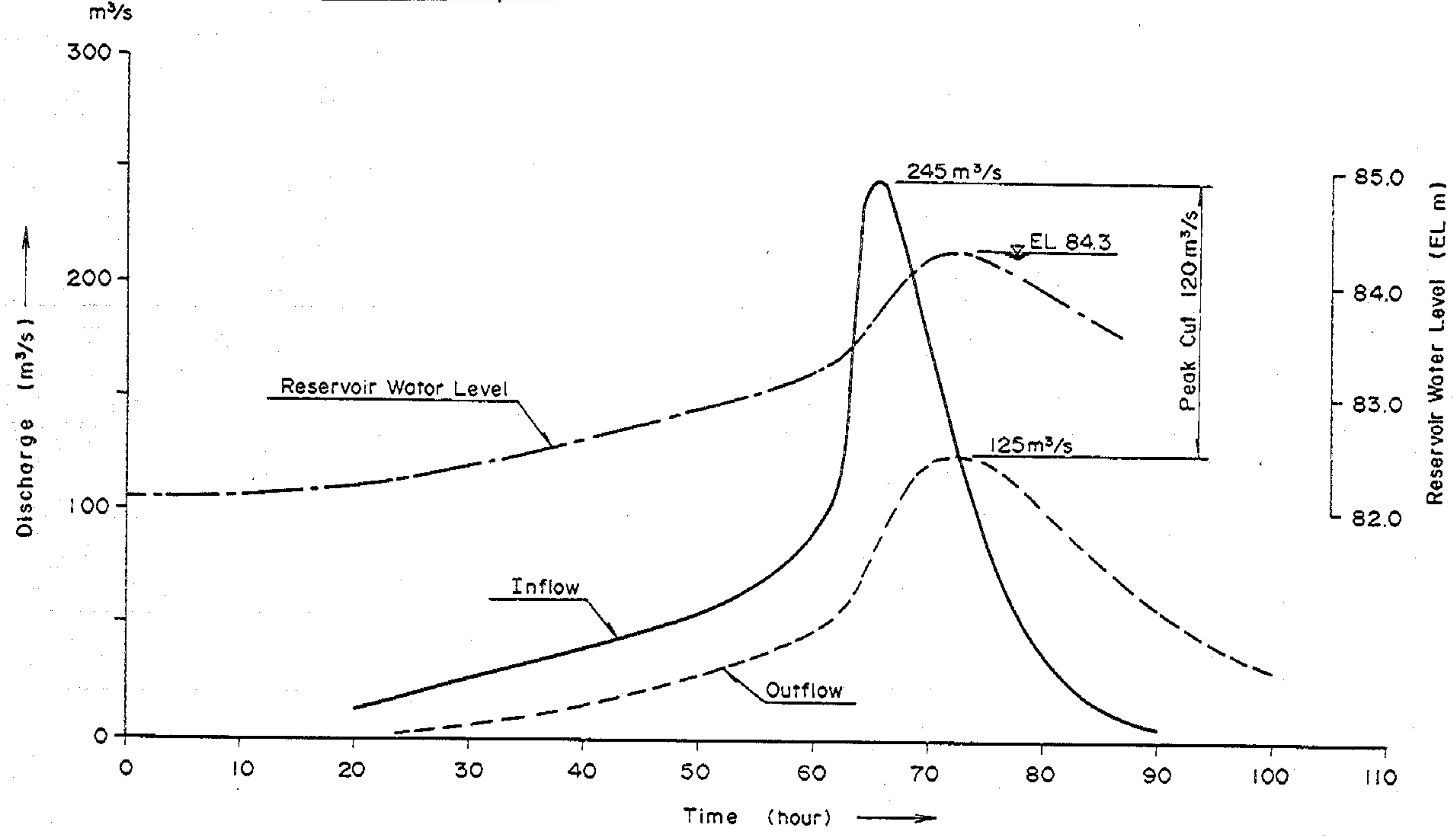


Fig. 2-14 Inflow and Outflow Hydrograph for 30 Year Flood
(Ban Bung Dam)

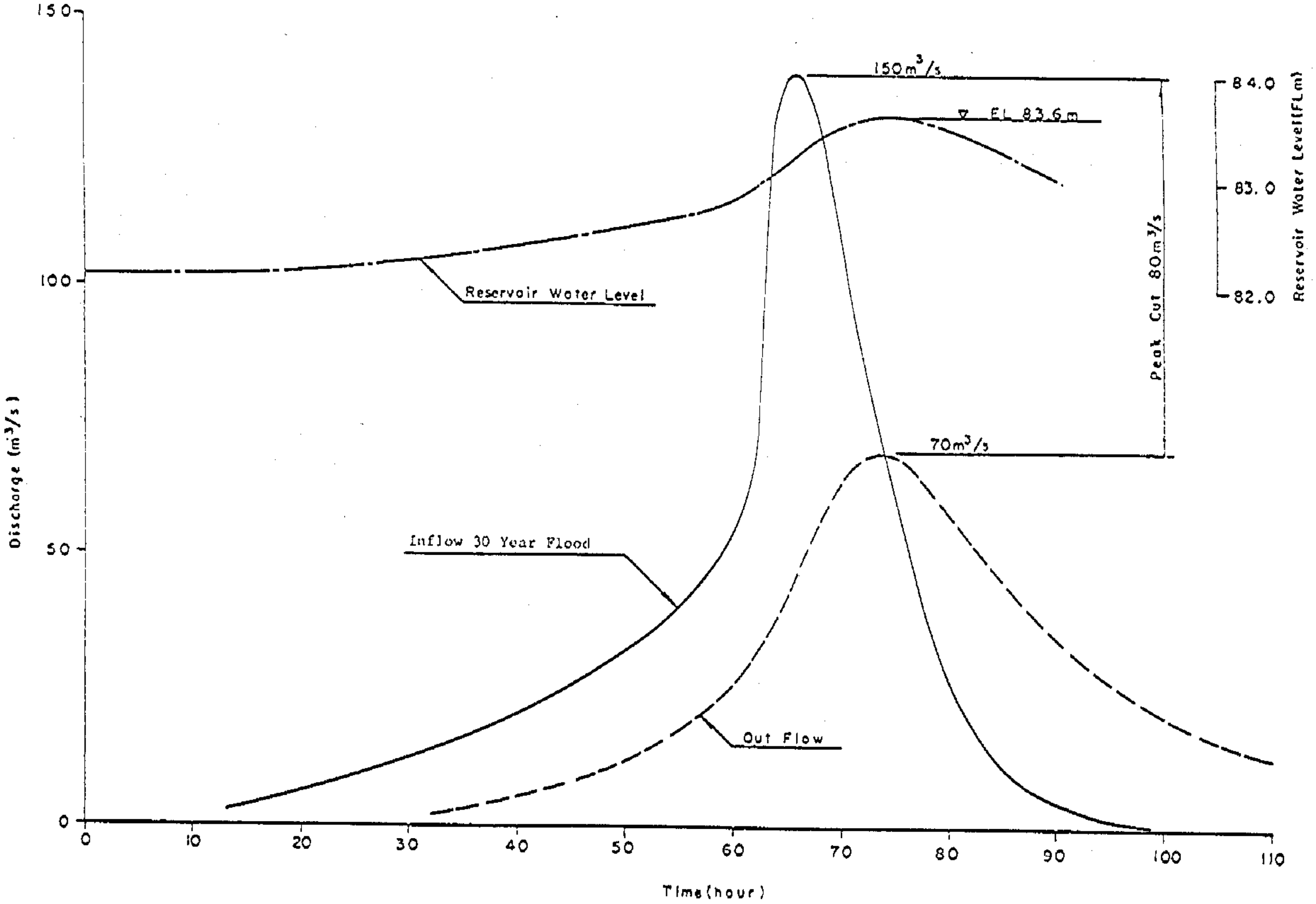


Fig. 2-15 Road Relocation

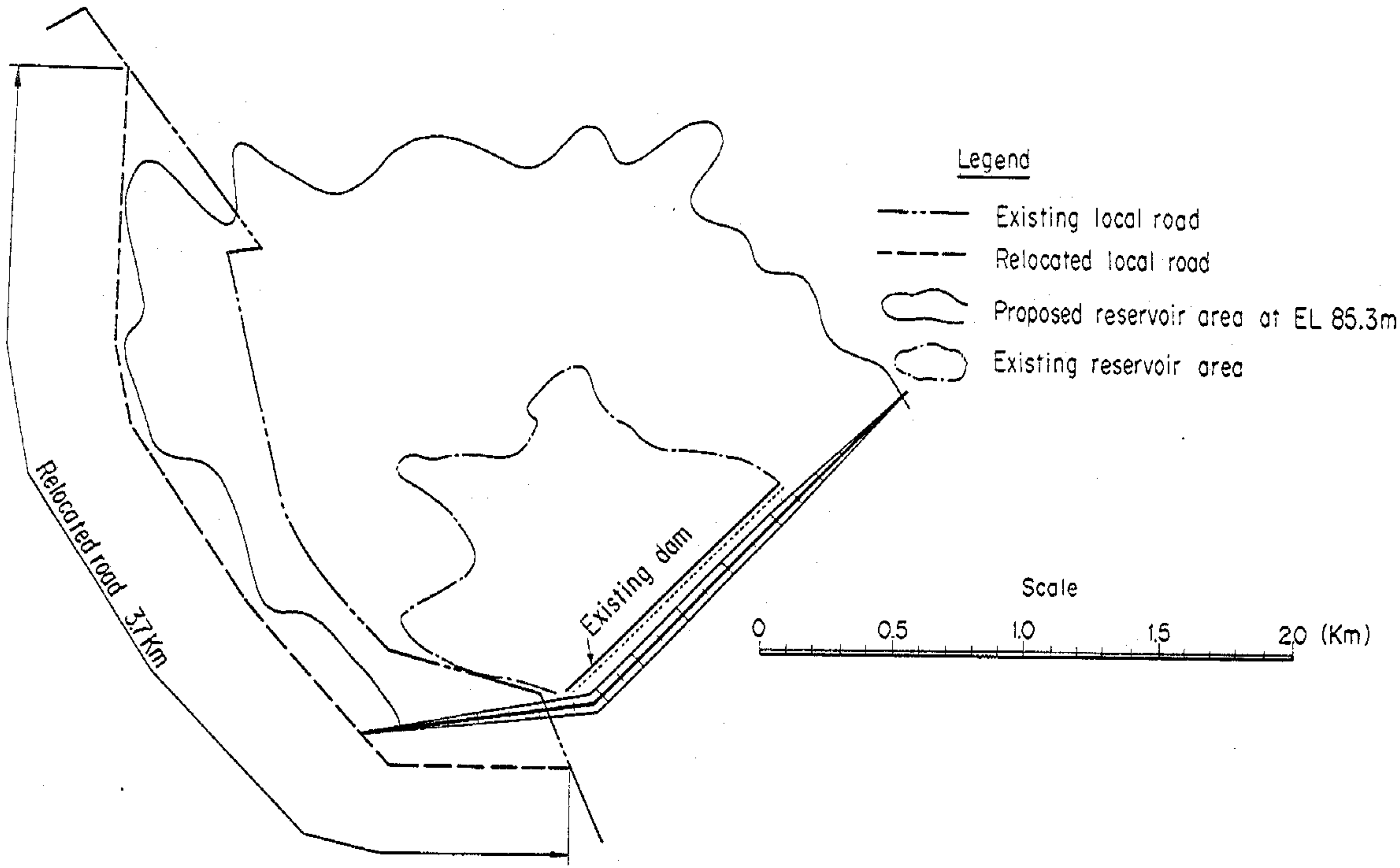


Fig. 2-16 General Plan of Ban Bung Dam

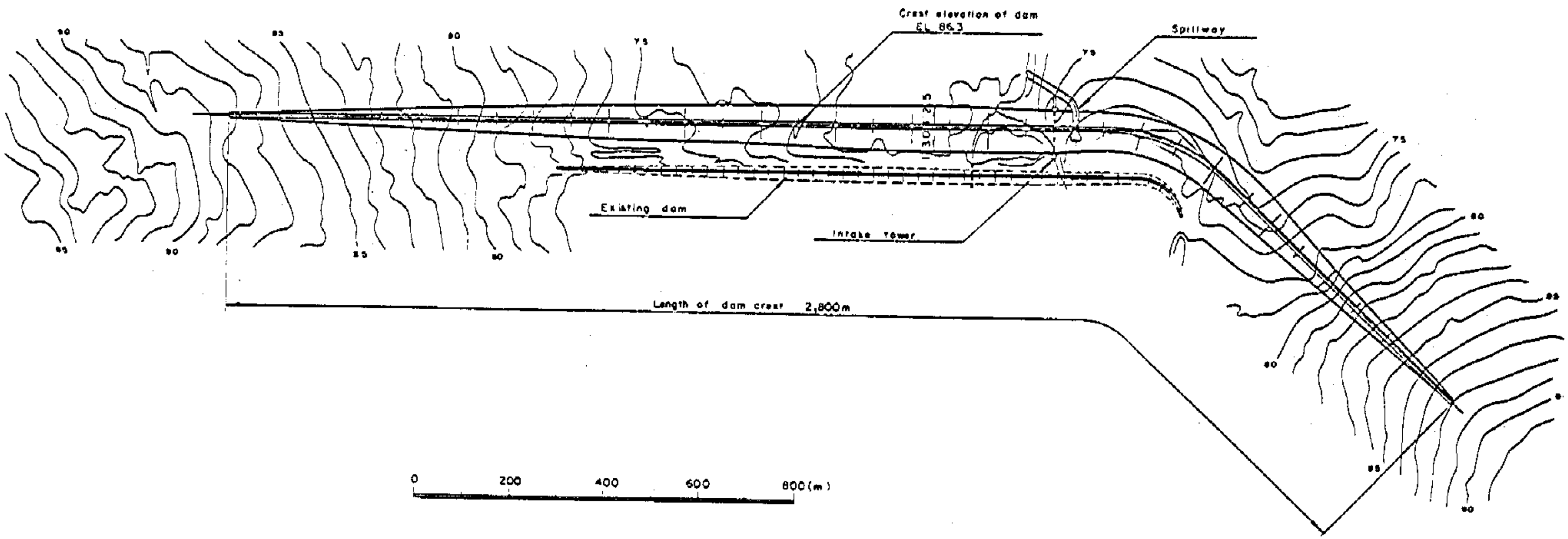
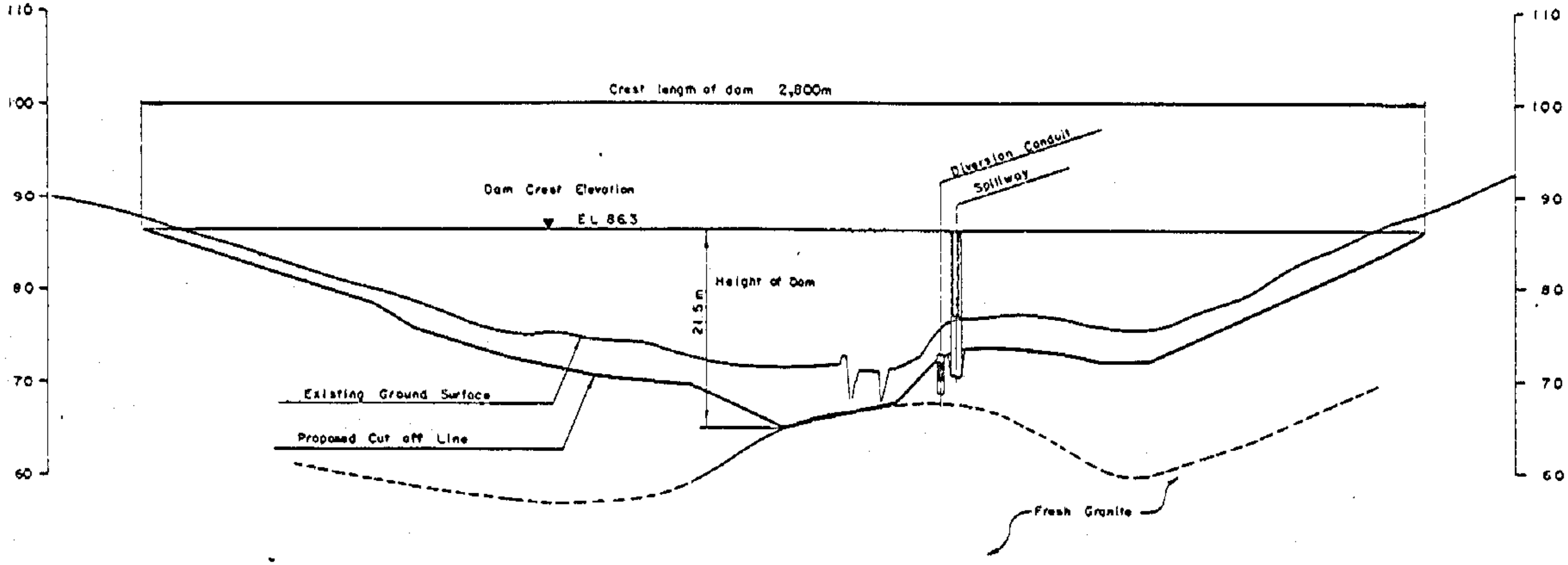


Fig. 2-17 Longitudinal Profile of Ban Bung Dam



CROSS SECTION NO	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PROPOSED CUT OFF LINE	86.3	84.3	83.1	81.4	80.0	78.5	75.5	74.0	72.5	71.5	70.5	70.0	69.5	67.5	65.0
ORIGINAL GROUND SURFACE	88.1	85.8	84.6	82.9	81.5	80.0	78.5	76.7	75.3	75.2	74.4	74.2	72.5	71.6	71.3
ACCUMULATED DISTANCE (m)	0	100	200	300	400	500	600	700	800	900	1.000	1.100	1.200	1.300	1.400

CROSS SECTION NO	15	16	17	18	19	20	21	22	23	24	25	26	27	28
PROPOSED CUT OFF LINE	66.5	68.0	70.5	73.5	73.5	73.0	72.0	72.0	74.0	76.5	79.0	81.0	83.5	86.3
ORIGINAL GROUND SURFACE	71.8	71.1	72.5	76.7	77.0	76.8	75.6	75.4	77.2	78.8	82.0	84.3	86.5	88.3
ACCUMULATED DISTANCE (m)	1.500	1.600	1.700	1.800	1.900	2.000	2.100	2.200	2.300	2.400	2.500	2.600	2.700	2.800

Fig. 2-18 Standard Cross Section of Ban Bung Dam

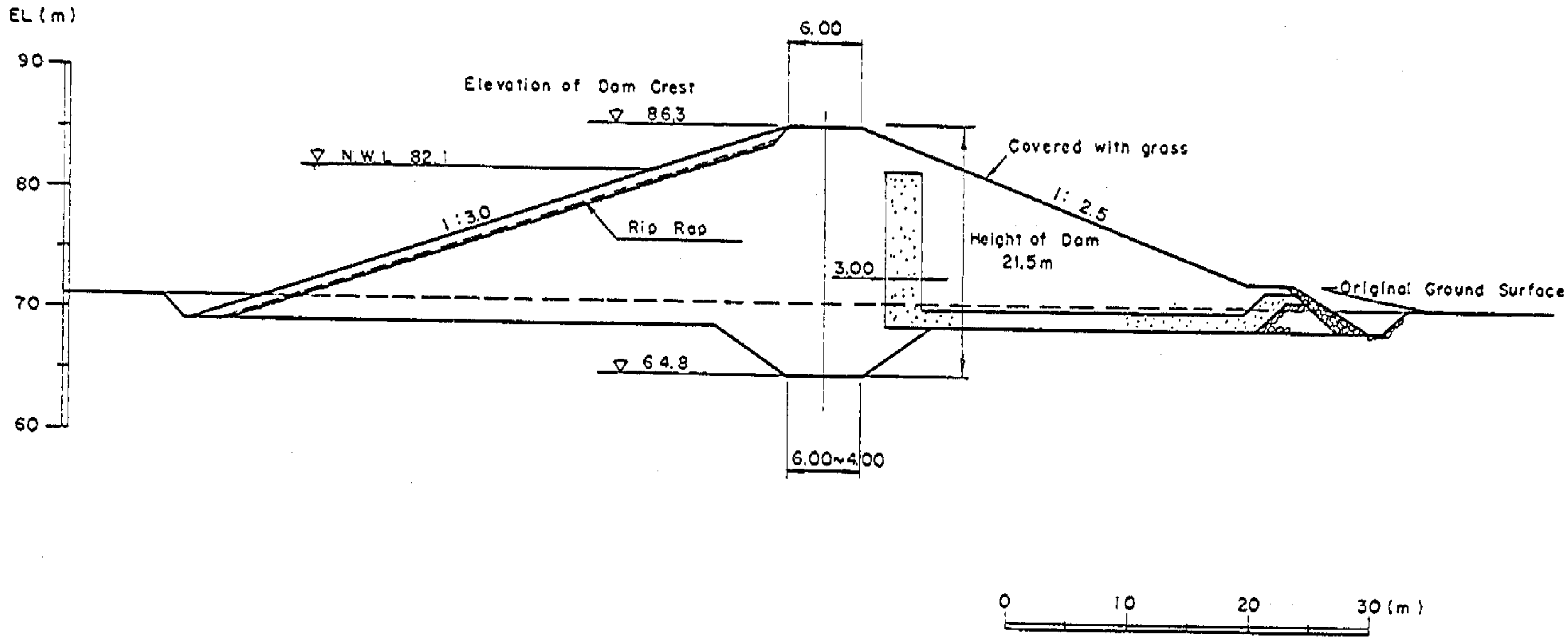


Fig. 2-19 Plan of Spillway and Waterway of Ban Bung Dam

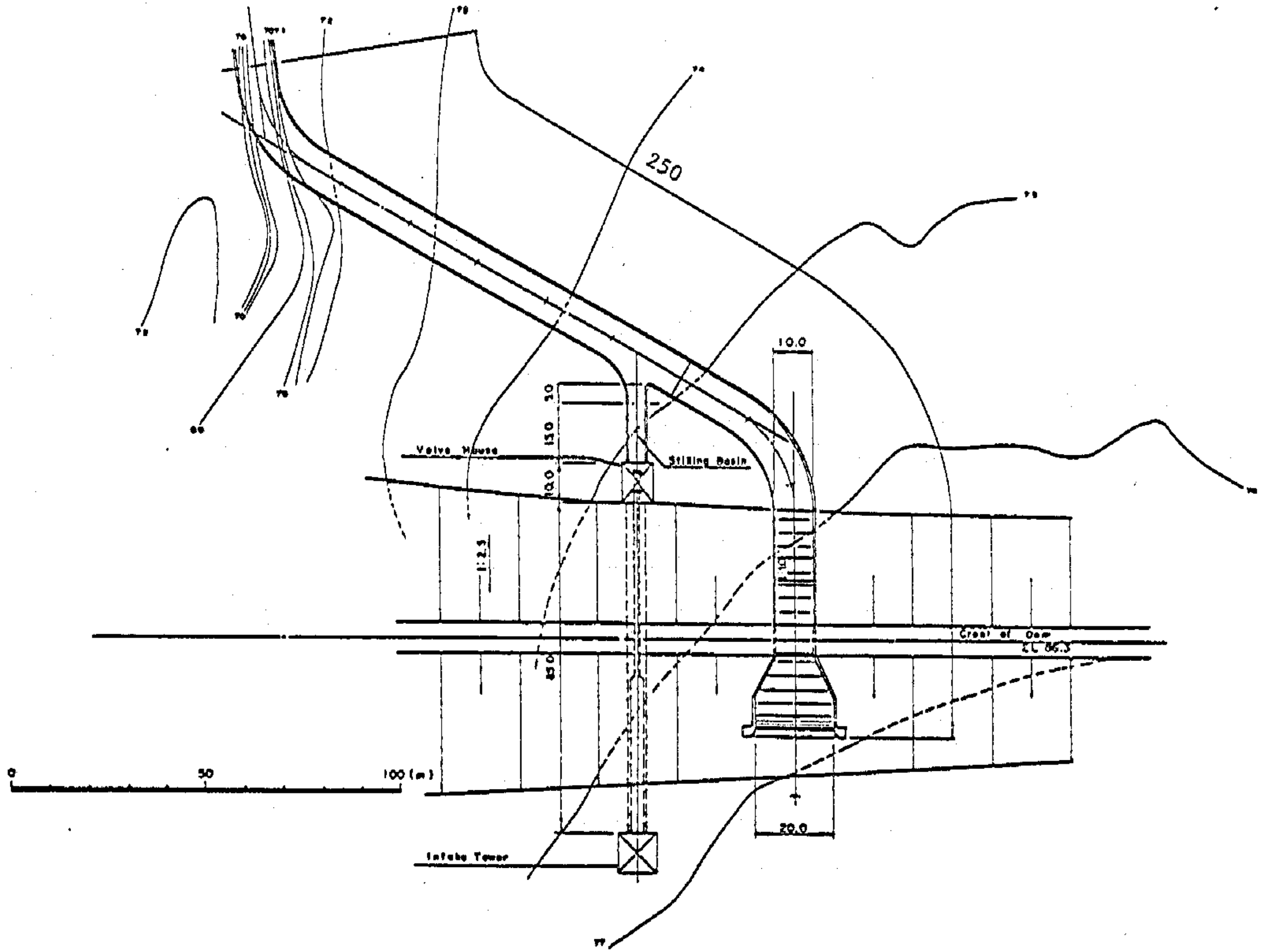


Fig. 2-20 Details of Spillway of Ban Bung Dam

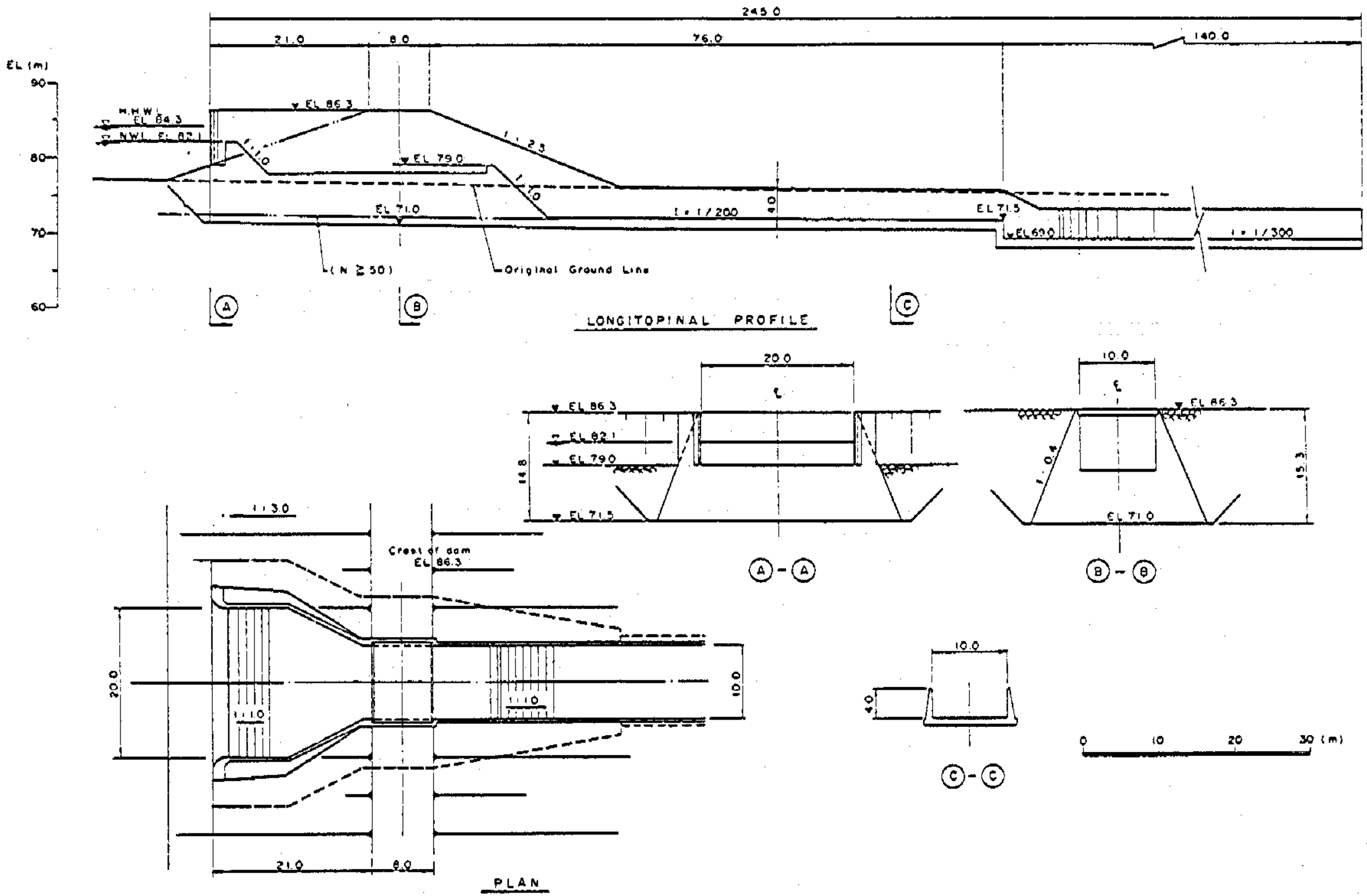


Fig. 2-21 Longitudinal Profile of Waterway of Ban Bung Dam

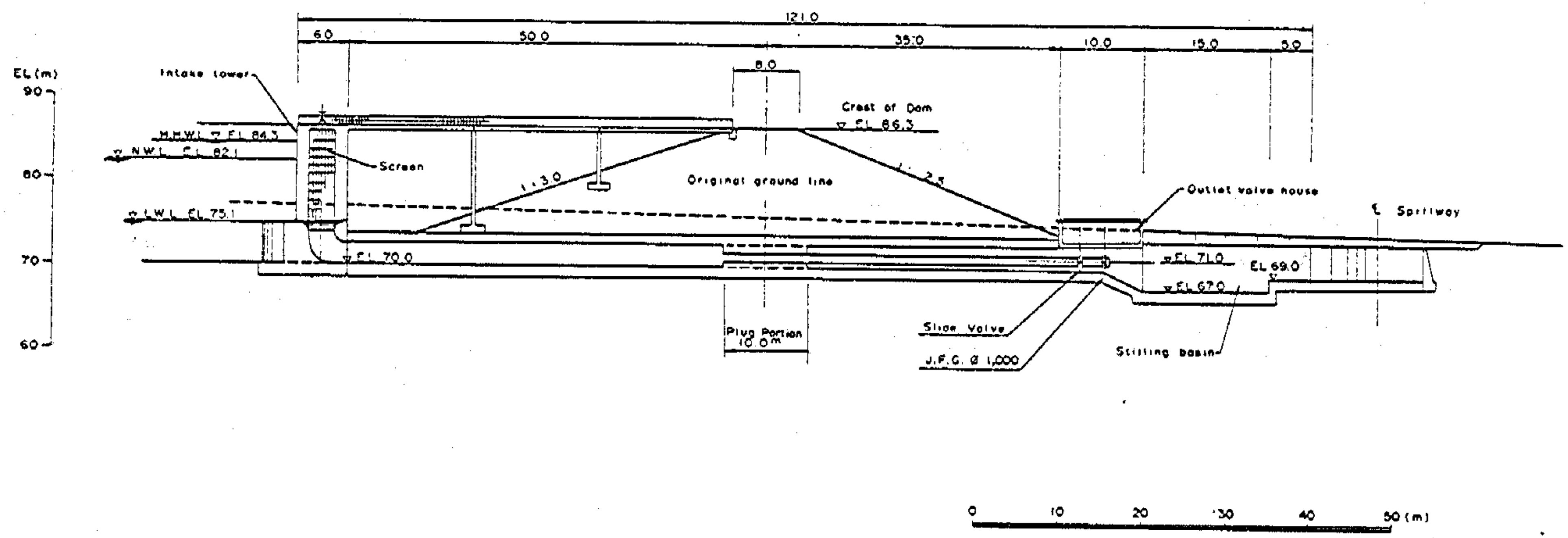
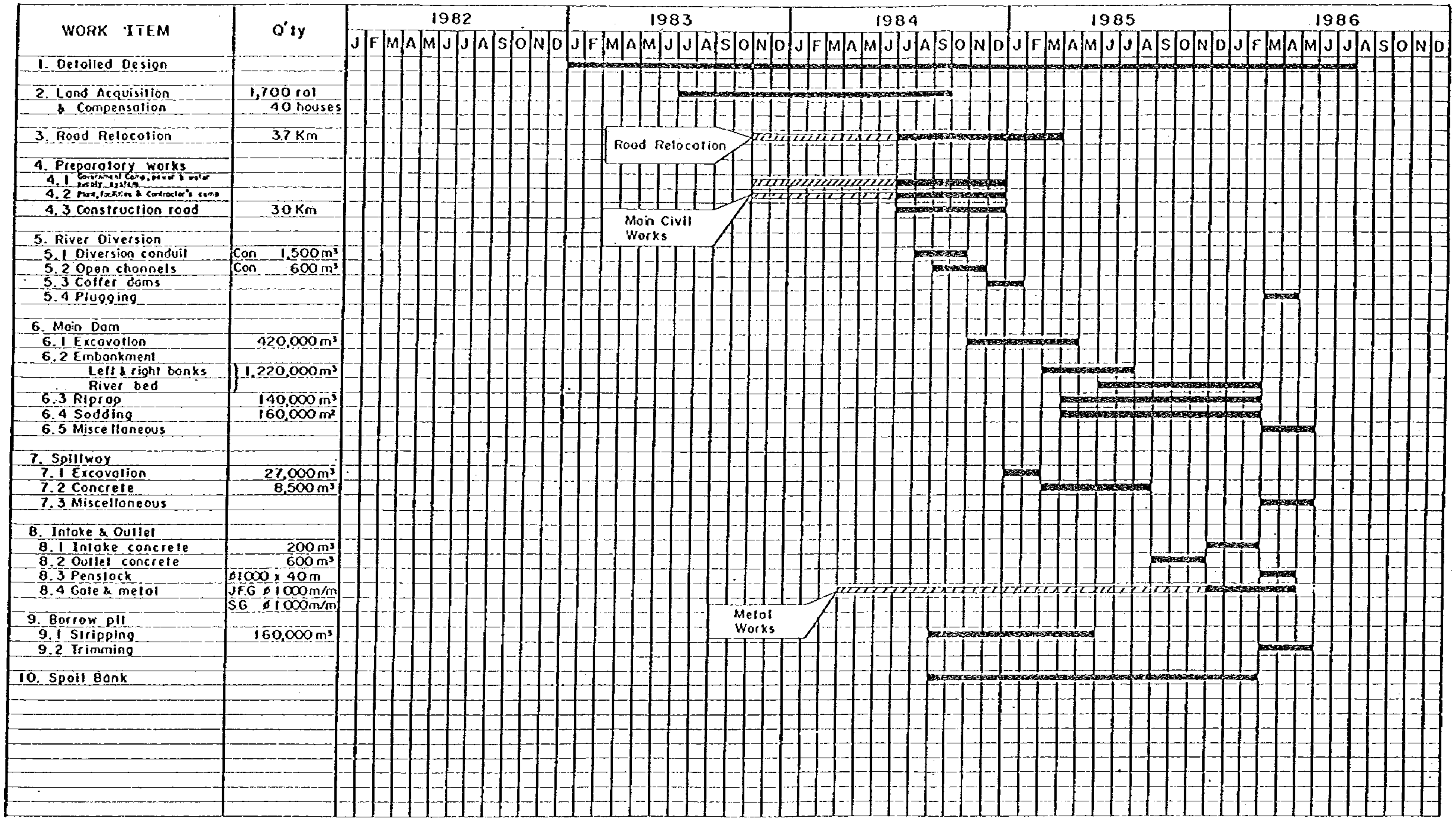


Fig. 2-22 Construction Schedule of Ban Bung Dam

working shift ---2 shift (8^{hrs} x 2)



Legend

Tender call, evaluation etc

Field work

Note ; government Camp, power & water supply system will be constructed

VII. FLOOD CONTROL

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1. FLOOD CONTROL

In general, such flood control measures as the construction of dam and levee, the widening of channel, the equipment of flood diversion channel and of retarding basin and other relevant facilities are employed.

The flood control of this project is to be done only by dam with consideration to the present land use pattern and the extent of inundation in the project area. The priority has been given to the development of urgently required water supply. The other measures of flood control will be carried forward into the future projects.

Free over-flow method has been preferred for ease of operation & maintenance hence no gate will be equipped to the dam.

The flood control capacity, therefore, would be equal to the surcharge volume in excess of the spillway crest height.

Inflow volume being designed at 1.2 times the 200-year return period flood, the smallest admissible dimension to minimize the number of submergible houses, the height of the dam is decided by the scale of spillway, on one hand, and the surcharge volume, on the other.

2. NONG PLA LAI DAM

2.1 RIVER BASIN

The Rayong River system with its main stream called by the name of the Nong Pla Lai in the upper reaches and by the name of the Rayong River after joining the Khlong Yai (left tributary) and the Dok Krai (right tributary), has a length of 85 km and catchment area of 1,800 km^2, in total.

The river, during its southward journey to the Gulf of Thailand, is joined by other tributaries including the Khlong Thap Ma which flows into the Rayong River in the northern suburbs of Rayong city. The river channel is generally left in natural condition as it has not received any improvement work except for some section; the limited flow capacity has been causing inundation of the adjoining areas.

In its downstream after crossing the Highway No. 3, the river starts meandering to a remarkable extent. This, coupled by estuary closure, makes the flow capacity very small. To cope with such condition, three (3) floodways having a combined flow capacity of 130 m^3/s were constructed about 20 years ago.

Dok Krai Dam, located at 10 km upstream of the Khlong Dok Krai's confluence with the Rayong River, has a gross storage capacity of 58 MCM. The proposed Nong Pla Lai Dam will be located at 7 km upstream of the Nong Pla Lai's confluence with the Dok Krai. The Nong Pla Lai's catchment area is 426 km^2.

2.2 PROBABLE RAINFALL

The location of and data recorded by the rainfall gaging stations in and around the project area are as shown in Fig. 2-1. Out of these, nine (9) representative stations were selected by their topographic condition as well as their availability of recorded data. The maximum discharge of any one river can be assumed by dealing with rainfall during a short period of time required for its arrival at the very river. When one is faced with the problem of flood-control by means of a dam, however, rainfall during flooding period needs to be studied rather carefully. Judging from the available rainfall data in the vicinity of the project area, a majority of the rainfall during flooding period has been resultant to 3-day rainfall; hence 3-day has been assumed to stand for the total rainfall. The probable rainfall is based on the data from the said nine stations (refer to Table 2-1) which have been statistically processed and presented in Figs. 2-2-(1) to (9).

From the above analysis, the data with longer observation period from Ban Khai (No. 48022) and Si Racha (No. 09042) stations were selected for obtaining probable rainfall to be used for analytical studies called for Nong Pla Lai Dam and Ban Bung Dam, respectively. The summary of probable rainfalls are shown in Table 2-2.

If the design probability is assumed as 1/30, the design rainfall would correspond to the biggest or the second biggest. As for the design flood discharge of dam, however, the discharge which corresponds to 1.2 times the 200-year return period would be employed.

Table 2-2 Probable Rainfall

Project	Nong Pla Lai	Ban Bung
Rainfall Station	Ban Khai	Si Racha
1/2 probability	115 mm	140 mm
1/5	200	185
1/10	230	230
1/30	273	290
1/100	310	350
1/200	340	390
1/200x1.2	410	470

Since the data so far available did not warrant statistical analysis of hourly distribution of rainfall in and around the project area, that appearing in the "Huai Saphan Hin Project Feasibility Report, 1977" for Changwat Chantaburi which was prepared by NEA has been adopted. Inspite of a certain distance in between, the pattern of hourly distribution of rainfall has been assumed to be more or less the same.

Run-off analysis of the basin has revealed that flood arrival time is in the range of 4-9 hours, and the unit time difference of 2 hours is applied to run-off calculation.

The design rainfall will be derivable by putting each scale of probable rainfall given into the rainfall mass curve (in percent) of Fig. 2-3. The hour-rainfall of 30-year is shown in Table 2-3.

2.3 FLOOD DISCHARGE

2.3.1 Run-off Calculation Method

Numerous data relating to actual rainfall and discharge need to be reviewed in selecting run-off calculation method by which to convert rainfall into run-off. Since such data are limited for this particular study, the run-off function method which has been widely accepted for its adoptability is employed. The basic formula is as below.

In a given short time period of the run-off (specific discharge) at some later time would be represented as:

$q = ate^{-\alpha t}$ .... (1)

where q : run-off (specific discharge) at time t
t : time elasped after start of rainfall
α : 1 / Tp.

Assuming there is no loss between rainfall and run-off,

$$\int_0^\infty q\,dt = \int_0^\infty ate^{-\alpha t} = 1\ d\tau$$

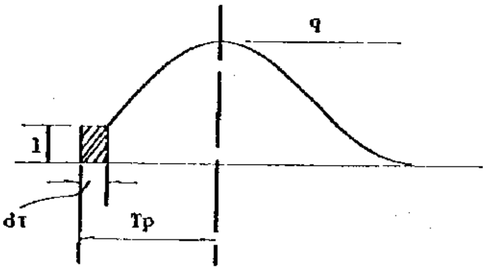
therefore $a = \alpha^2 d\tau$

Likewise, where run-off rate is f, specific discharge in m^3/skm^2, and rainfall in mm/hr,

$$a = 0.2778\ \alpha^2 f d\tau$$

therefore $q = 0.2778\ \alpha^2 f t e^{-\alpha t} d\tau$ ..... (2)

When the catchment area (AKm^2) and hour-rainfall are given to the above formula, each scale of probable discharge is obtained.



2.3.2 Run-off Model

In the past studies by RID the Rayong River basin has been divided into five sub basins, namely, the existing Dok Krai Dam, the proposed Nong Pla Lai Dam, Khlong Yai dam, Thap Ma dam and the residual basin and this division reviewed and found was reviewed and found appropriate through this study. Accordingly, the basin division and run-off model shown in Figs. 2-4-(1) and (2) were adopted.

2.3.3 Feature of the Divided Basin

In line with the river basin division as discussed in the above, the features obtained as pertinent to each river basin are given in Table 2-4 below.

Table 2-4 Features of Divided Basin

No.	Basin	C.A(Km^2)	L (Km)	I	Tp(hr)	f
I	Nong Pla Lai Dam	426.0	46	1/90	8.5	0.7
II	Dok Krai Dam	291.0	42	1/380	9.2	0.7
III	Khlong Yai R.	222.5	25	1/170	7.3	0.7
IV	Tap Ma R.	154.0	26	1/170	7.4	0.7
V	Residual Basin	694.5	15	1/240	6.1	0.7
Total		1,788.0				

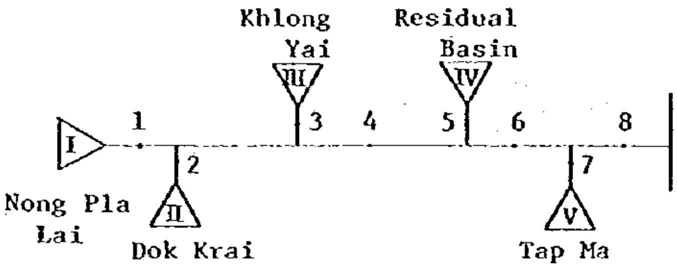
2.3.4 Results of Run-off Analysis

Using the rainfall data and the features of the divided basins mentioned above, the run-off calculation was conducted for each scale of probable discharge. The peak discharge at each location point in the river system is summarized in Table 2-5

Table 2-5 Peak Discharge

Unit: m^3/s

Return period / Point No.	2 yrs	5	10	30	100	200	200x1.2
1	400	515	595	695	800	875	1,050
2	255	330	380	445	515	565	675
3	235	300	345	405	465	510	615
4	890	1,145	1,315	1,545	1,775	1,945	2,335
5	820	1,060	1,215	1,425	1,640	1,795	2,155
6	1,700	2,190	2,520	2,995	3,395	3,725	4,465
7	160	205	240	280	320	350	420
8	1,855	2,395	2,755	3,235	3,715	4,070	4,855



2.4 FLOOD CONTROL

For flood control of a river, the optimum choice must be made in allocating discharge to dam on one part and river channel, on the other.

The present condition of the river is such that even minor floods cause inundation to riparian areas because of limited flow capacity due to back-log in river improvement work. The measures for mitigation of such inundation damages is subject to analysis from the viewpoint of its economic performance in the future.

The flood control under the present project involves a natural over-flow system dam. The surcharge volume flown down through its spillway corresponds to the flood control volume. The storage volume curve of the dam is shown in Fig. 2-5.

The water utilization volume of 144.4 MCM and the sediment volume of 12.8 MCM (300 m^3/km^2/year), which form the total 157.2 MCM, would require the crest elevation of the spillway to be set at EL. 45.0 m.

2.4.1 Spillway and Reservoir Stage of Nong Pla Lai Dam

The reservoir stage is subject to the scale of spillway. In this particular project, the storage water is not to exceed the elevation which may inflict damage to Amphoe Pluak Daeng, a local community with 200 houses, located between elevations 47 and 54 m as shown in Fig. 2-6.

The scale of spillway for the design flood discharge of the dam which is 1.2 times the 200-year probability flood has been conducted by the following formula:

$$Q = CB\,(H-45.0)^{3/2}$$

where C : coefficient of overflow (C=2.0)
B : crest length of spillway (m)
H : reservoir stage (m)

2.4.2 Flood Control Effect of Nong Pla Lai Dam

The formula given in the above resulted at the crest width of 120 m to keep the reservoir stage below EL. 47 m so as to avoid inundation of Amphoe Pluak Daeng.

When the crest width is determined at 120 m, the discharge would be controlled for each scale of probability as shown in Tables 2-6-(1) and (2).

Table 2-6-(1) Performance of Spillway (1)

Case	Return period	R (mm)	Qp In (m^3/s)	Qp Out (m^3/s)	V (MCM)	H (EL m)
1	2	155	398	239	177.4	45.998
2	5	200	514	315	182.1	46.200
3	10	230	591	369	185.1	46.330
4	30	270	694	471	190.6	46.567
5	100	310	797	514	191.8	46.661
6	200	340	874	570	195.6	46.780
7	200x1.2	408	1,049	702	201.7	47.043

Table 2-6-(2) Performance of Spillway (2)

	Inflow Peak Discharge	Outflow Peak Discharge	Storage Volume
30-year Flood	695 m^3/s	475 m^3/s	34.5.MCM
Extraordinary Flood (200 years x 1.2)	1,050	700	43.5

Fig. 2-7 shows the flood control effect by spillway for 30-year flood.

2.4.3 Flood Control Effect of Dok Krai Dam

Flood control operation of the existing Dok Krai Dam has been simulated by using the conditions as shown below.

$$H_1 = 50.6 \text{ m} \;.....\; V = 50.8 \text{ MCM}$$

$$H_2 = 52.6 \text{ m} \;.....\; V = 72.0 \text{ MCM}$$

$$Q_1 = CB\,(H - 50.6)^{3/2} \;.....\; H \leq 53.989$$

$$Q_2 = \sqrt{2g\,(H-34.35)}\cdot A \;.....\; H \geq 53.989$$

where H: reservoir stage (m)
V: storage
B: crest length of spillway (B=26.4 m)
C: coefficient of overflow (C=2.0)
g: 9.8
A: 16.79 m^2

Table 2-7 shows the flood control effect of Dok Krai Dam for the probable floods.

Table 2-7 Flood Control by Dok Krai Dam

Case	Return period	R (mm)	Qp In (m^3/s)	Qp Out (m^3/s)	V (MCM)	H (EL m)
1	2	155	255	119	68.060	52.309
2	5	200	330	163	72.163	52.715
3	10	230	380	193	74.787	52.975
4	30	270	445	235	78.144	53.307
5	100	310	512	279	81.387	53.628
6	200	340	561	312	83.746	53.862
7	200x1.2	408	674	334	90.339	54.515

The regulation effect of dam, together with discharge expected from each river basin, are considered in flood control calculation. The distribution of discharge in the river system for each probability scale is shown in Fig. 2-8. In this figure, the Case 1 is without dam, Case 2 only with Dok Krai Dam, and Case 3 is the combination of Dok Krai Dam and the proposed Nong Pla Lai Dam.

2.5 MITIGATION OF FLOOD DAMAGE

The Rayong River inundates into the riparian areas even in case of small scale flood, due to the poor flow capacity of the river channel. Relatively large flooding occurs every other year. The inundated area between the river mouth and Ban Khai is used to be around 160 km^2. The estuary closure also has an adverse effect on the limited flow of the river channel, while existing floodways can not mitigate the inundation in the area to the upstream of the river's crossing with Highway No. 3. Although lacking in detailed record, direct interview of the inhabitants of the area has revealed that big flooding took place twice in the last 10 years, viz 1974 and 1976 when inundation lasted for several weeks in the middle reaches and for a few months in the lower reaches. (see Fig. 2-9)

As indicated in Fig. 2-8 Discharge Allocation, the combined effect of flood control in reducing the flood damage area by the proposed Nong Pla Lai Dam and the existing Dok Krai Dam would bring down the peak discharge in down-stream area, thus contributing to the net benefit of flood control.

Table 2-8 shows the damage area and value at respective return period flood. As the in undated area mostly consists of paddy field, its flood damage of the area is expressed in that of its paddy. The price of paddy is used to estimate the value as follows:

Yield	1,440 kg/ha	792 thousand Baht/km^2
Unit Price	5.5 Baht/kg	

Table 2-8 Flood Damage Reduction

Return Period (Years)	Damage Area (km^2)		Damage Value (million ฿)	
	Dok Krai Dam only	Dok Krai + Nong Pla Lai	Dok Krai Dam only	Dok Krai + Nong Pla Lai
2	73.5	66.7	58.2	52.8
5	83.8	74.2	66.4	58.8
10	89.5	78.9	70.9	62.5
30	96.0	85.2	76.0	67.5
100	104.0	90.1	82.4	71.4
200	108.0	93.2	85.5	73.8
200x1.2	115.5	104.4	91.5	82.7

Tables 2-9-(1) and (2) show the average annual damage reduction by flood control either by Dok Krai Dam alone or together with Nong Pla Lai.

Table 2-9-(1) Annual Damage Reduction (1 dam)

Return Period	Exceeding Probability	Occurrence Probability	Damage Value	Average Damage	Annual Average
2	0.500	0.500	58.2	58.2	29.1
5	0.200	0.300	66.4	62.3	18.7
10	0.100	0.100	70.9	68.7	6.9
30	0.033	0.067	76.0	73.5	4.9
100	0.010	0.023	82.4	79.2	1.8
200	0.005	0.005	85.5	84.0	0.4
200x1.2	0.001	0.005	91.5	88.5	0.4

(Total 62.2 million Baht)

Note: Damage value in million Baht

Table 2-9-(2) Annual Damage Reduction (2 dams)

Return Period	Exceeding Probability	Occurrence Probability	Damage Value	Average Damage	Annual Average
2	0.500	0.500	52.8	52.8	26.4
5	0.200	0.300	58.8	55.8	16.7
10	0.100	0.100	62.5	60.7	6.1
30	0.033	0.067	67.5	65.0	4.4
100	0.010	0.023	71.4	69.5	1.6
200	0.005	0.005	73.8	72.6	0.4
200x1.2	0.001	0.005	82.7	78.3	0.4

(Total 56.0 million Baht)

Note: Damage value in million Baht

As is clearly known from the above Tables, the average annual damage reduction would be:

62.2 - 56.0 = 6.2 million/฿

Thus, flood damage will be mitigated by the control function of dam and/or but not completely until the flooding will be stopped through river improvement work.

2.6 RIVER IMPROVEMENT PLAN

Except for some sections in the urbanized area, the Rayong River has not received any improvement work and its limited flow capacity, for example 330 m^3/sec (including three floodways) at the river mouth, have been causing overflow even by small floods. The situation is worse in the area to the upstream of its crossing with Highway No. 3, where inundation period is often extended. Three floodways with 130 m^3/s in total were constructed in view of mitigating such damage. This discharge capacity together with that of the main river course, however, is not yet sufficient and the situation has been made even worse due to frequent river mouth clogging.

For the future flood control, improvement measures such as the construction of a training dike for prevention of river mouth clogging and further enlargement of the diversion channel will be required.

Tables 2-10-(1) and (2), Figs. 2-10, 2-11 and 2-12-(1) through (4) show the general plan as well as the longitudinal profile and cross sections of the Rayong River. Its discharge capacity is limited with much fluctuation between several tens to hundreds of cubic meters per second.

Fig. 2-13 shows a simplified example of the design cross section (near Ban Khai) which has a cross-section area about four times that of the existing channel.

However, the river improvement work based on a specific design flood discharge and undertaken with the corresponding norms and standards would not warrant prevention of extraordinary flood which might accompany discharge beyond the design flood discharge from making havoc.

In case of such an extraordinary flood, the river water overtopping the embankment(s) would flow down along the latter to inflict inundation damages towards the economically advanced areas within the valley.

In view of protecting the area invested with valuable assets in the downstream, retarding basin and other countermeasures need to be provided for such an extraordinary flood. In demarcating the retarding basin, good consideration should be made in identifying the area to be made flood-proof and that which might be used for retarding purpose.

3. BAN BUNG DAM

3.1 RIVER BASIN

Ban Bung Dam is located in the upper reaches of the Ban Bung River. Being a secondary tributary to the Bang Pa Kong River, the Ban Bung River originates in Mt. Khao Khieo with an elevation of 660 m. The existing Ban Bung Dam, multi-purpose dam with height of 18.5 m and storage capacity of 1.9 MCM, has not fullfilled its expected role since its completion in 1958, due mainly to its limited capacity. The present project is meant to construct another dam, 100 m directly downstream of the existing one, so that storage capacity may be augmented.

3.2 PROBABLE RAINFALL

As discussed in regards to Nong Pla Lai Dam, the hourly distribution of rainfall (Time unit - 2-hour) of Ban Bung Dam basin is to be derived by rainfall mass curve (Fig. 2-3, in percent) on the basis of three-day rainfall at Si Racha as a total rainfall. For example, Table 2-3 shows 1/30 probability rainfall.

3.3 FLOOD DISCHARGE

Run-off model has been drawn up for the section to the upstream of Ban Nong Yae area, which is subject to discharge regulation effect of dam. Fig. 3-1-(1) and (2) show the basin division and run-off model.

The estimate of run-off was done by run-off calculation method, with full account of the basin division discussed previously. The features of each basin in the river system are as listed in Table 3-1.

Table 3-1 Features of Divided Basin

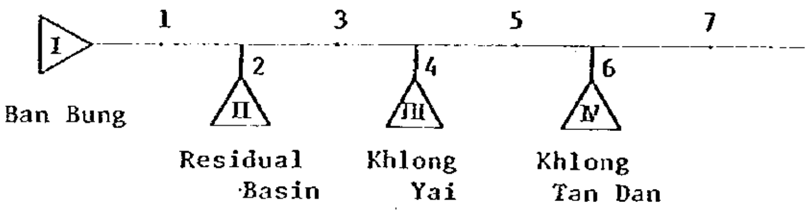
No.	Basin	C.A(Km^2)	L (Km)	I	Tp(hr)	f
I	Ban Bung Dam	53.0	11.0	1/14	4.7	0.7
II	Residual Basin	43.8	5.8	1/90	4.3	0.7
III	Khlong Yai	293.9	31.0	1/177	7.9	0.7
IV	Khlong Tan Dam	127.7	27.0	2/267	7.8	0.7
Total		518.4				

With rainfall and the features of the divided basin arrived at in the aforementioned studies, the design flood of respective return period was calculated. The peak discharges at each location point are as shown in Table 3-2.

Table 3-2 Peak Discharge

Unit: m^3/s

Return period / Point No.	2 yrs	5	10	30	100	200	200x1.2
1	75	105	120	150	185	205	245
2	60	85	100	125	150	170	200
3	135	185	220	275	335	370	445
4	265	365	430	545	655	730	875
5	385	535	635	795	960	1,201	1,285
6	115	160	190	240	290	320	385
7	495	690	815	1,025	1,380	1,380	1,665



3.4 FLOOD CONTROL

Flood control under the present project is to be realized by the dam, employed by means of natural over flow through spillway corresponding to the flood control volume. The reservoir capacity and area is shown in Fig. 3-2.

The previous studies have found the utilization volume of dam to be 12.5 MCM and sediment volume 1.6 MCM (at 300 m^3/km^2/year), with total 14.1 MCM. To meet this volume the elevation of crest would have to be EL. 82.1 m.

The reservoir stage is subject to the scale of spillway. In case of Ban Bung Dam, no submersion of village is expected. The study results of Nong Pla Lai Dam is taken into account and such scale of spillway width was accepted that would give the same ratio of out-flow discharge flood control capacity at design flood discharge of 200-year x 1.2.

The width of the spillway was determined to be 20 m. The flood control effect by spillway at respective return period floods are as listed in Tables 3-3-(1) and (2). Fig. 3-3 shows the flood control by spillway for 30-year flood.

Table 3-3-(1) Performance of Spillway (1)

Case	Return period	R (mm)	Qp In (m^3/s)	Qp Out (m^3/s)	V (MCM)	H (EL.m)
1	2	140	73	31	17.4	82.943
2	5	195	101	46	17.9	83.202
3	10	230	119	57	18.4	83.358
4	30	290	150	74	19.3	83.601
5	100	350	182	91	20.2	83.833
6	200	390	202	104	20.8	83.983
7	200x1.2	468	243	128	21.9	84.266

Table 3-3-(2) Performance of Spillway (2)

	Inflow Peak Discharge	Outflow Peak Discharge	Storage Volume
30-year Flood	150 m^3/s	70 m^3/s	5.20 MCM
Extraordinary Flood (200 years x 1.2)	245	125	7.80

The regulation effect of dam, together with discharge expected from each river basin, are considered in flood control calculation. The distribution of discharge in the river system for respective return period is shown in Fig. 3-4. In the same Figure, the Case 1 is without dam and Case 2 with dam.

3.5 MITIGATION OF FLOOD DAMAGE

The limited flow capacity of the Ban Bung River has been causing inundation of its riparian areas even in case of minor flood. The area isolated by roads in the downstream is inundated every year. The proposed Ban Bung Dam has such flood control effect (see Fig. 3-4) that the discharge in lower reaches will be diminished, resulting in mitigation of flood area and damage value.

Table 3-4 shows the flood damage reduction at respective return period flood. The following price of paddy is used to estimate the value:

Yield .... 1,440 kg/ha ⎤ 292 thousand Baht/km^2
Unit Price ... 5.5 Baht/kg ⎦

Table 3-4 Flood Damage Reduction

Return Period (years)	Damage Area (Km^2)		Damage Value (million ฿)	
	Without Dam	With Dam	Witout Dam	With Dam
2	16.2	16.0	12.83	12.67
5	18.4	17.7	14.57	14.02
10	19.7	18.9	15.60	14.92
30	21.1	20.4	16.71	16.16
100	22.9	21.6	18.14	17.11
200	23.8	22.3	18.85	17.66
200x1.2	25.4	23.9	20.12	18.93

Tables 3-5-(1) and (2) show the annual damage reduction by flood control either with Ban Bung Dam or without Dam.

Table 3-5-(1) Annual Damage Reduction (without Dam)

Return Period years	Exceeding Probability	Occurrence Probability	Damage Value million ฿	Average Damage million ฿	Annual Average million ฿
2	0.500	0.500	12.83	12.83	6.42
5	0.200	0.300	14.57	13.70	4.11
10	0.100	0.100	15.60	15.09	1.51
30	0.033	0.067	16.71	16.16	1.08
100	0.010	0.023	18.14	17.43	0.40
200	0.005	0.005	18.85	18.50	0.09
200x1.2	0.0001	0.005	20.12	19.49	0.09

(Total 13.70 million Baht)

Table 3-5-(2) Annual Damage Reduction (with Dam)

Return Period years	Exceeding Probability	Occurrence Probability	Damage Value million ฿	Average Damage million ฿	Annual Average million ฿
2	0.500	0.500	12.67	12.67	6.34
5	0.200	0.300	14.02	13.35	4.00
10	0.100	0.100	14.97	14.50	1.45
30	0.033	0.067	16.16	15.57	1.04
100	0.010	0.023	17.11	16.64	0.38
200	0.005	0.005	17.66	17.39	0.09
200x1.2	0.0001	0.005	18.93	18.30	0.08

(Total 13.38 million Baht)

As it is clear from the table, the average annual damage reduction would be:

13.70 - 13.38 = 0.32 million Baht

3.6 RIVER IMPROVEMENT PLAN

The proposed Ban Bung dam is located in the tributary of the Huai Khlong river, which is one of the tributaries of the Bang Pakong river. The present river channel to the downstream of the proposed dam-site has been left almost intact and its flow capacity is estimated at 10 to 150 m^3/s.

It is apparent that the present flooding is caused not only by the limited flow capacity of the river course but the clogging of drain-pipe crossing roads as well. Although the long-range goal of a total river improvement inclusive of the main course channel widening and construction of retarding basin is required, flood control by means of a dam is proposed as an initial stage plan.

Tables 3-6-(1) and (2), Figs. 3-5, 3-6, 3-7-(1) and (2) show the general plan, longitudinal profile and cross-section of the Ban Bung river. The cross-section area is limited, being estimated at 10 to 150 m^3/s, and unbalanced.

Fig. 3-8 shows an example of cross-section (near Ban Ang Wian) which is approximately twice as large as the present section. When the above flood control plan is put into implementation, the diminished flooding of the riparian area will enhance an extensive use of land along the river.

Table 2-1 Maximum Rainfall Precipitation

Unit: mm

Station	09013	09022	09032	09042	09052	09062	48012	48022	48121
Year									
1952	187.3		97.7	163.6	61.5	164.1	226.6		
1953	123.0		210.1	96.1	147.6	116.5	120.3		
1954	143.1	154.3	148.9	206.2	131.3	113.4	142.5		
1955	133.0	122.3	70.0	97.1	144.1	84.5	118.8		
1956	103.1	90.6		122.1	121.9	110.9	145.7	376.8	
1957	191.1	102.5		200.6	266.5	181.5	168.6	144.4	
1958	138.2	177.8	134.1	122.4	102.0	136.8	162.2	186.8	
1959	95.0	87.5	136.5	79.5	159.8	132.0	142.4	161.5	
1960	166.3	157.8	106.9	255.6	223.9	172.0	172.5	240.8	
1961	122.1	131.1	171.4	125.3	196.9	87.1	116.1	94.4	
1962	90.9	116.1	132.0	130.0	165.0	80.7	155.7	160.0	
1963	231.4	191.5	153.7	195.7	193.4	175.2	208.1	231.9	
1964	130.6	146.4	249.3	189.3	98.4	123.6	101.2	96.4	
1965	81.7	51.7	89.5	138.6	148.4	136.7	125.3	114.0	
1966	180.0	95.3	93.7	126.5	163.3	125.8	194.5	159.7	
1967	72.6	124.0	110.7	72.4	131.9	127.8	170.5	137.8	110.7
1968	98.8	124.4	119.0	70.0	104.2	165.3	170.7	208.1	217.6
1969	131.1	55.2	100.6	113.5	92.3	130.6	310.2	174.0	95.5
1970	87.6		94.8	145.4	169.3	94.7	200.5	145.0	86.2
1971	158.7		101.3	128.9	94.8	91.7	117.8	145.9	83.2
1972	163.2	148.6	93.5	115.1	159.0	153.5	127.7	182.1	212.0
1973	157.5	96.5	108.3	89.2	134.2	99.4	94.1	136.6	141.9
1974	200.7	187.1	130.2	293.5	299.1	149.2	159.1	172.8	157.8
1975	91.8	103.8	94.7	101.5	66.0	56.7	233.0	117.6	110.0
1976	138.0	107.9	136.1	329.7	129.2	90.4	113.0	155.7	142.5
1977	90.9	131.5	34.4	116.1	82.9	74.1	143.6	118.8	130.2
1978	185.6	78.4	74.1	132.3	100.2	80.7	80.0	154.5	102.9
1979	102.6	89.0	68.9	85.0	110.5			112.5	86.4
1980									170.5

Table 2-3 Hour-rainfall of 30-year (2-hour increments)

hour	Percent 2-hour rainfall		Nong Pla Lai	Ban Bung
	Accumulative	Incremental	2 hour rainfall	2 hour rainfall
	%	%	mm	mm
0	0	0	0	0
2	39.0	0	105.3	113.1
4	46.4	7.4	20.0	21.5
6	52.5	6.1	16.5	17.7
8	57.1	4.6	12.4	13.3
10	61.2	4.1	11.1	11.9
12	65.0	3.8	10.3	11.0
14	68.0	3.0	8.1	8.7
16	70.8	2.8	7.6	8.1
18	73.5	2.7	7.3	7.8
20	76.1	2.6	7.0	7.5
22	78.4	2.3	6.2	6.7
24	80.6	2.2	5.9	6.4
26	82.6	2.0	5.4	5.8
28	84.6	2.0	5.4	5.8
30	86.4	1.8	4.9	5.2
32	88.0	1.6	4.3	4.6
34	89.5	1.5	4.1	4.4
36	91.0	1.5	4.1	4.4
38	92.5	1.5	4.1	4.4
40	93.8	1.3	3.5	3.8
42	95.0	1.2	3.2	3.5
44	95.9	0.9	2.4	2.6
46	96.7	0.8	2.2	2.3
48	97.5	0.8	2.2	2.3
50	98.2	0.7	1.9	2.0
52	98.7	0.5	1.4	1.5
54	99.1	0.4	1.1	1.2
56	99.4	0.3	0.8	0.9
58	99.6	0.2	0.5	0.6
60	99.8	0.2	0.5	0.6
62	99.9	0.1	0.3	0.3
64	100.0	0.1	0.3	0.3
66	100.0	0	0	0
68	100.0	0	0	0
70	100.0	0	0	0
72	100.0	0	0	0

Table. 2-10-(1) Feature of Rayong River (1)

Section No.	Distance	Total distance	River-bed height	Ground height (left)	Ground height (right)
	km	km	m	m	m
0	0	0	-4.83	2.00	2.60
(1)	(1.5)		(-0.15)	(1.30)	(3.41)
2	2.1	2.1	-1.93	2.70	1.40
3	1.6	3.7	-0.96	1.30	2.00
4	1.5	5.2	-0.93	1.00	1.02
5	1.2	6.4	-1.02	0.85	1.00
6	2.6	9.0	-0.88	1.01	1.21
7	1.8	10.8	-1.68	1.90	2.46
8	0.4	11.2	-0.48	2.50	1.90
9	0.7	11.9	-0.84	2.82	1.60
10	2.3	14.2	-0.18	2.39	2.52
11	2.0	16.2	1.00	3.13	3.14
12	3.2	19.4	2.12	4.73	4.81
13	1.0	20.4	2.73	5.04	5.12
14	2.7	23.1	3.72	5.81	6.35
15	2.0	25.1	4.26	7.40	7.70
16	2.0	27.1	5.00	8.46	9.13
17	2.0	29.1	6.20	10.22	9.97
18	1.9	31.0	6.29	10.93	11.07
19	1.6	32.6	7.41	12.86	12.84
20	1.4	34.0	9.10	11.47	13.20
21	1.7	35.7	8.98	14.32	13.49
22	1.7	37.4	10.88	15.80	14.69
23	2.8	40.2	16.00	20.36	20.46
24	2.1	42.3	14.28	17.11	18.31
25	0.7	43.0	15.64	20.02	19.42
26	2.1	45.1	21.60	24.79	24.70
27	1.6	46.7	22.44	24.20	25.25
28	1.0	47.7	22.18	25.62	25.86
29	1.1	(48.8)	26.16	28.20	28.21
29'	1.0		24.69	27.13	28.75

29 ; Dam axis (Right)
29'; Dam axis (Left)

Table 2-10-(2) Feature of Rayong River (2)

No.	G.H	A	B	R	I	n	Q
	EL m	m^2	m	m			m^3/s
0	2.5	313.6	121.0	2.59	1/14,000	0.035	196
1						"	
2	2.0	320.0	127.0	2.52	"	"	195
3	2.0	237.6	135.0	1.76	"	"	101
4	1.0	97.6	82.5	1.18	"	"	23
5	1.0	96.0	80.0	1.20	"	"	28
6	1.0	75.2	63.5	1.18	"	"	21
7	2.0	91.2	50.0	1.82	1/4,200	"	73
8	2.0	98.4	68.5	1.44	"	"	63
9	2.0	41.6	35.0	1.19	"	"	22
10	2.5	60.0	35.0	1.69	"	"	48
11	3.0	59.2	37.5	1.58	1/3,100	"	48
12	4.5	72.8	36.0	2.02	"	"	75
13	5.0	81.0	50.0	1.62	1/2,800	"	71
14	5.5	84.0	54.5	1.54	"	"	70
15	7.5	128.0	58.5	2.19	1/2,300	"	147
16	8.0	98.4	38.5	2.56	"	"	150
17	10.0	141.6	47.0	3.01	"	"	254
18	11.0	134.4	44.0	3.05	1/1,560	"	297
19	13.0	140.0	51.5	2.72	"	"	275
20	12.5	44.0	35.0	1.26	"	"	40
21	14.0	86.4	30.0	2.88	1/1,140	"	211
22	15.0	74.4	27.5	2.71	"	"	171
23	20.5	84.8	29.0	2.92	1/820	"	246
24	18.0	45.6	22.5	2.03	"	"	92
25	20.0	51.2	20.5	2.50	"	"	128
26	24.5	51.2	34.5	1.48	1/630	"	86
27	25.5	24.0	20.5	1.17	"	"	32
28	26.0	40.0	16.0	2.50	"	"	114

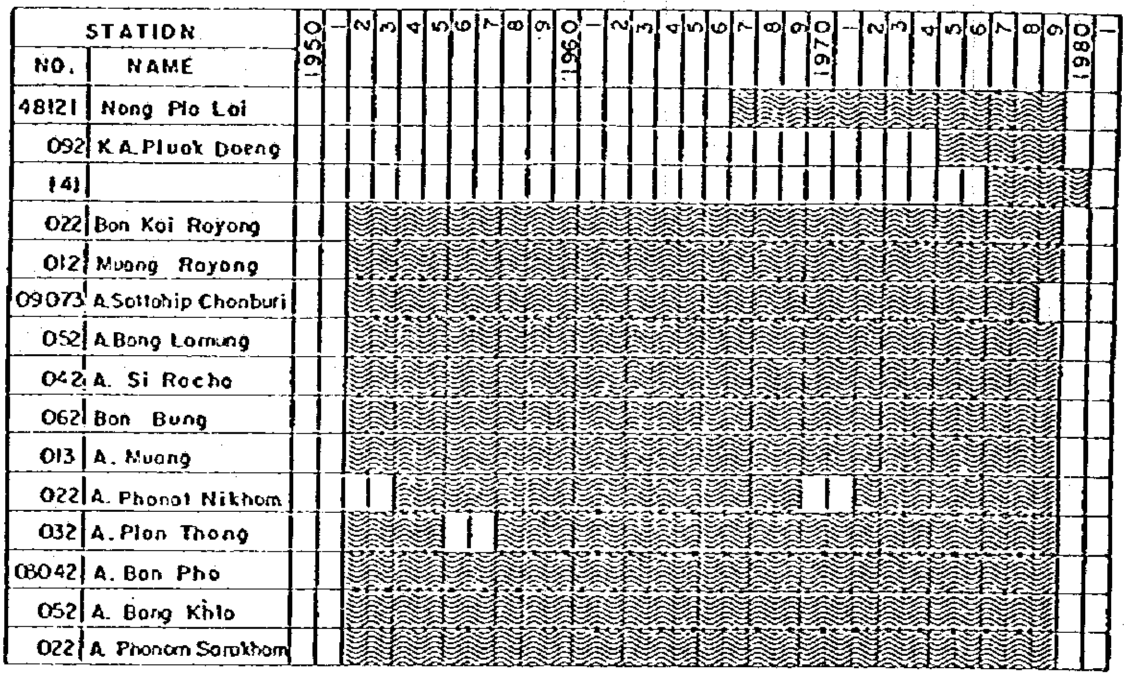
Table 3-6-(1) Feature of Ban Bung River (1)

Section No.	Distance	Total distance	River-bed height	Ground height (left)	Ground height (right)	Q
	km	km	m	m	m	
1	0	0	7.02	8.5	7.8	
2	1.7	1.7	4.27	9.1	8.2	
3	1.2	2.9	6.84	10.9	10.6	
4	2.6	5.5	8.80	12.1	12.5	
5	1.4	6.9	10.78	12.5	12.4	
6	1.8	8.7	13.16	15.0	14.8	
7	1.7	10.4	13.55	16.4	17.0	
8	1.4	11.8	14.90	17.5	17.0	
9	2.3	14.1	17.34	20.7	21.8	
10	1.2	15.3	18.68	22.8	22.2	
11	1.4	16.7	18.77	22.1	22.0	
12	1.8	18.5	21.46	24.6	24.0	
13	1.7	20.2	24.29	27.9	27.5	
14	2.5	22.7	27.54	30.9	31.6	
15	2.3	25.0	33.44	36.5	35.5	
16	2.6	27.6	42.45	47.6	45.4	
17	2.7	30.2	47.31	50.0	51.0	
18	3.4	33.6	59.44	61.7	62.5	
19	0.9	34.5	64.01	65.7	65.7	
20	1.7	36.2	68.14	71.6	72.3	

Table 3-6-(2) Feature of Ban Bung River (2)

No.	G.H	A	B	R	I	n	Q
	EL m	m^2	m	m			m^3/s
1	7.0	6.4	24.0	0.27	1/1090	0.035	2
2	4.3	24	13.5	1.78	"	"	31
3	6.8	40	20.3	1.97	"	"	54
4	8.8	24	16.3	1.47	"	"	27
5	10.8	13	14.0	0.93	"	"	11
6	13.2	10	8.7	1.15	"	"	9
7	13.5	18	12.0	1.50	"	"	20
8	14.9	22	17.7	1.24	"	"	22
9	17.3	26	29.5	0.66	"	"	17
10	18.7	68	26.0	2.62	1/1000	"	117
11	18.8	45	56.5	0.80	"	"	35
12	21.5	30	19.0	1.58	1/910	"	39
13	24.3	60	30.5	1.97	1/710	"	101
14	27.5	26	18.5	1.41	1/530	"	41
15	33.4	19	20.5	0.93	1/400	"	26
16	42.5	28	27.7	1.01	1/360	"	42
17	47.3	32	17.7	1.81	1/330	"	75
18	59.4	16	11.3	1.42	1/270	"	35
19	64.0	23	18.0	1.28	"	"	47
20	68.1	45	21.5	2.09	1/230	"	139

Fig. 2-1 Rainfall Observatory Stations & Period of Availability



RAINFALL STATIONS

East Coast Area

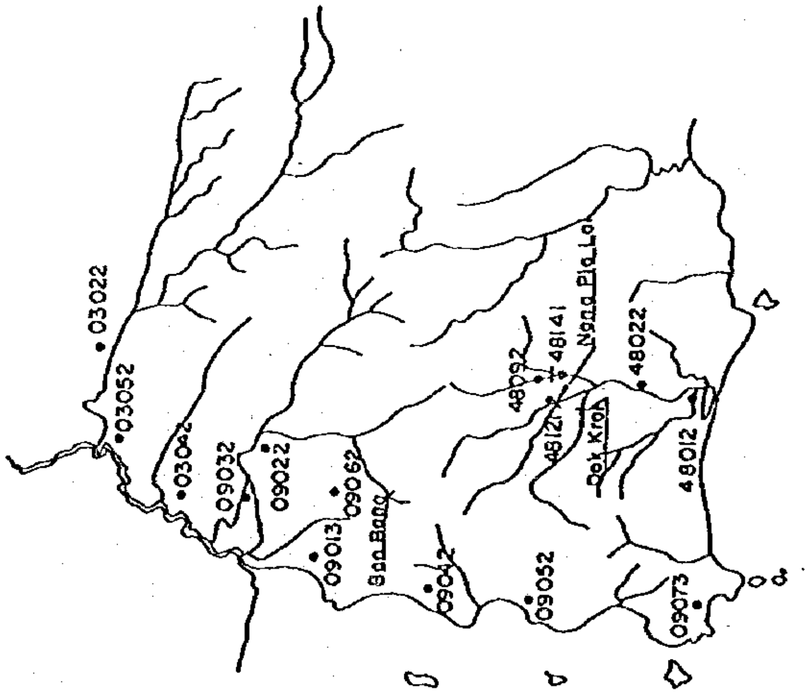
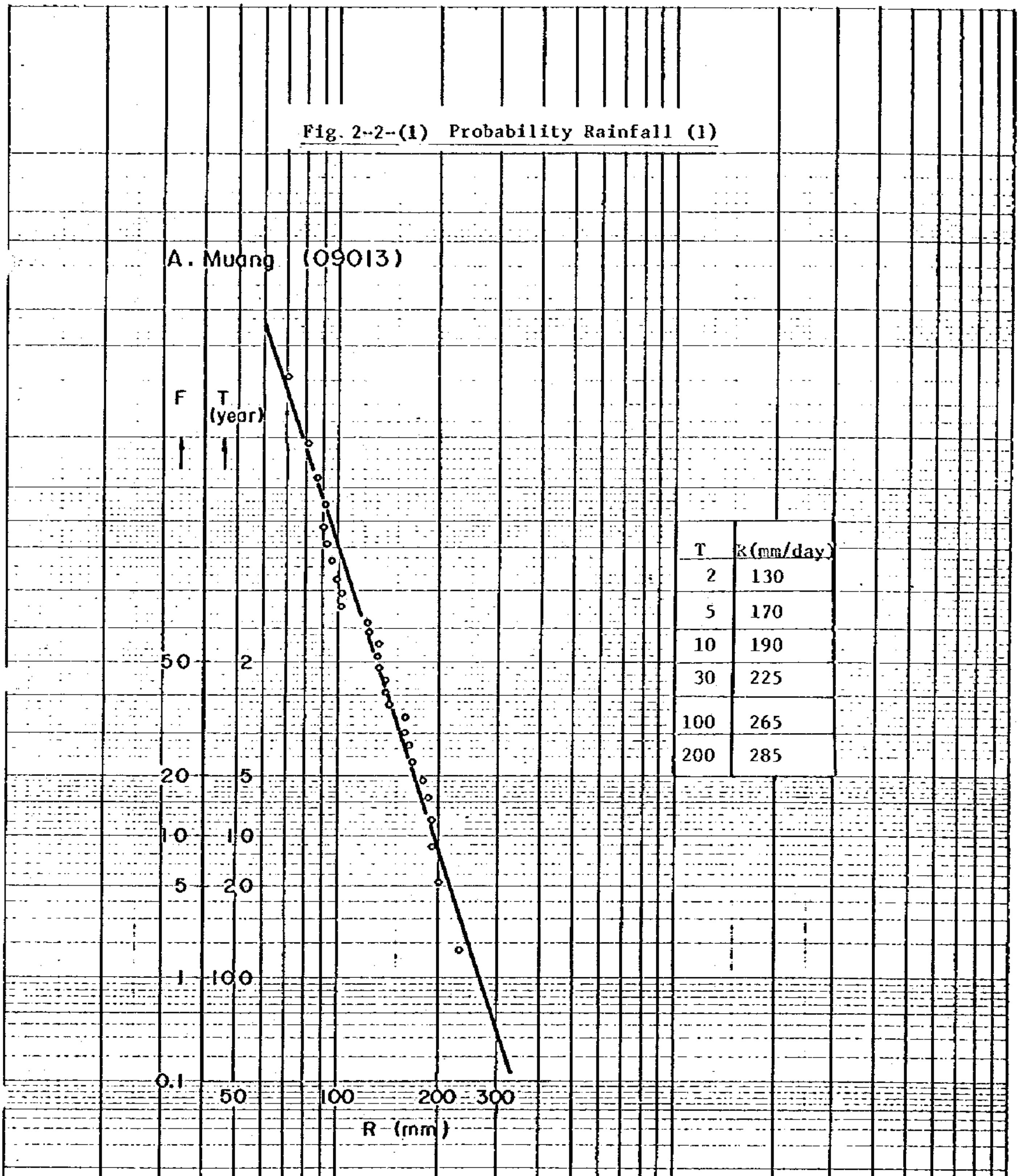
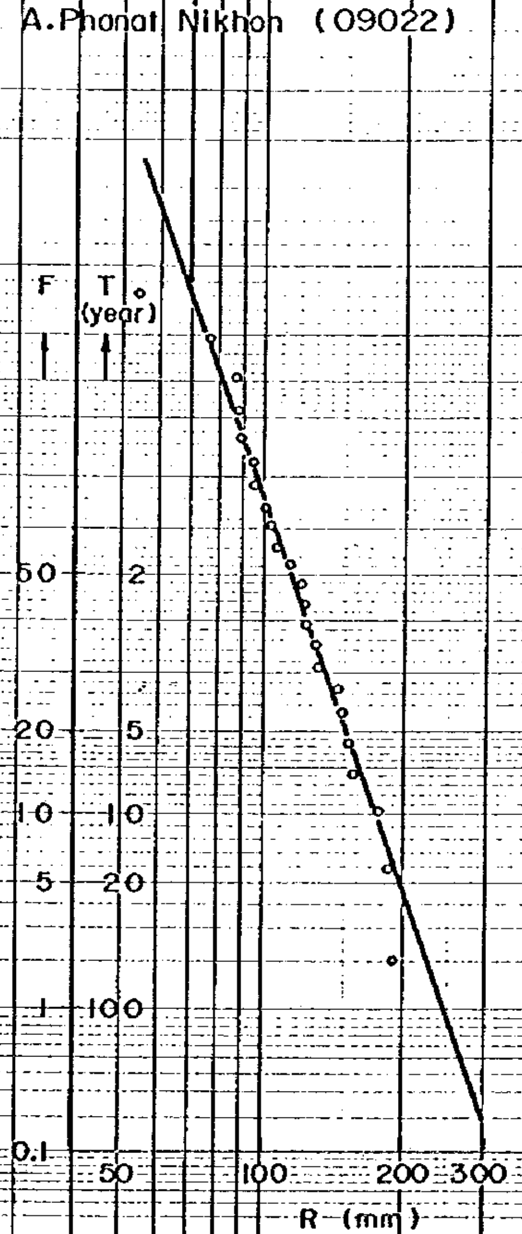


Fig. 2-2-(1) Probability Rainfall (1)



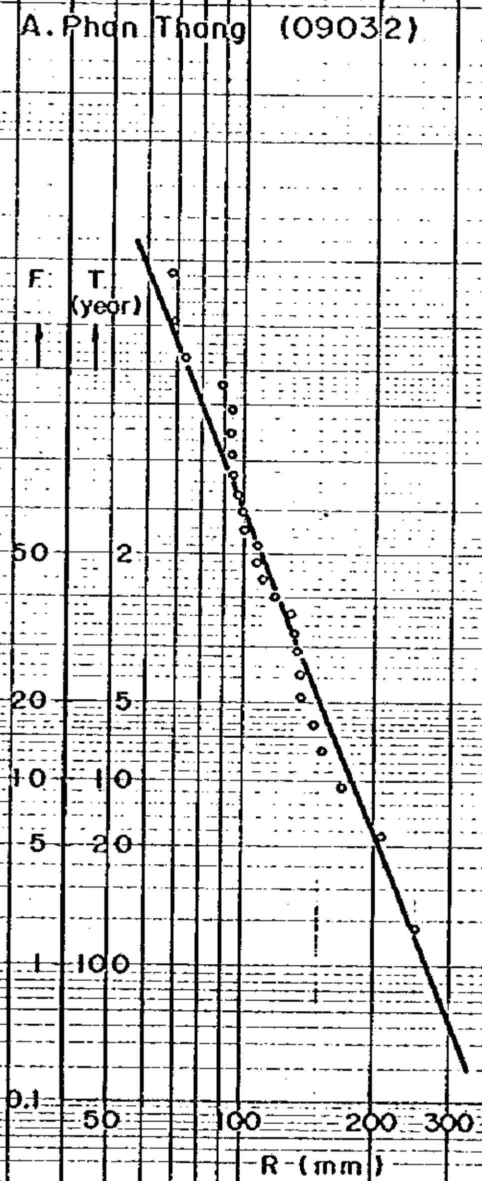
T	R(mm/day)
2	130
5	170
10	190
30	225
100	265
200	285

Fig. 2-2-(2) Probability Rainfall (2)



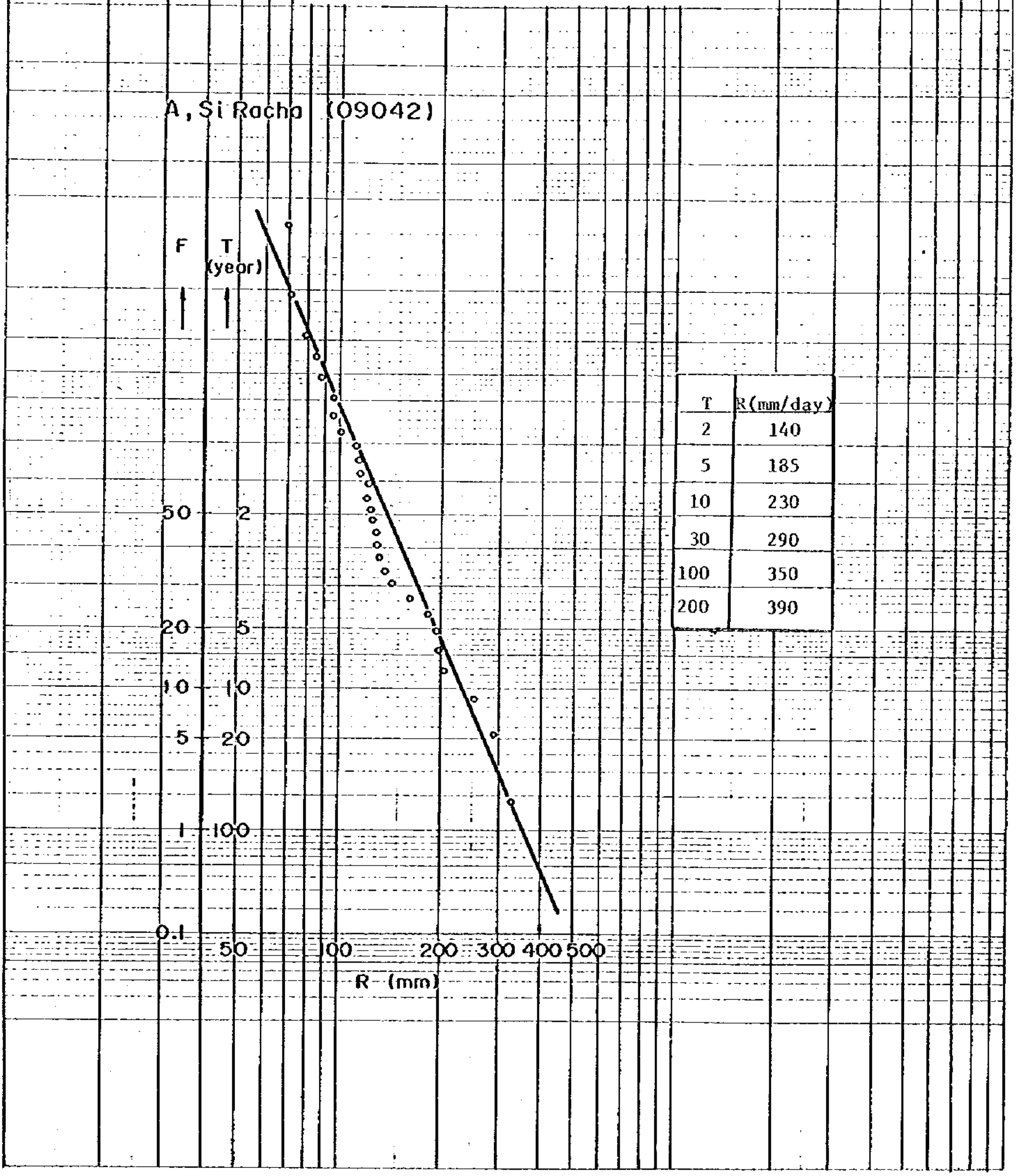
T	R(mm/day)
2	115
5	150
10	175
30	210
100	245
200	270

Fig. 2-2-(3) Probability Rainfall (3)



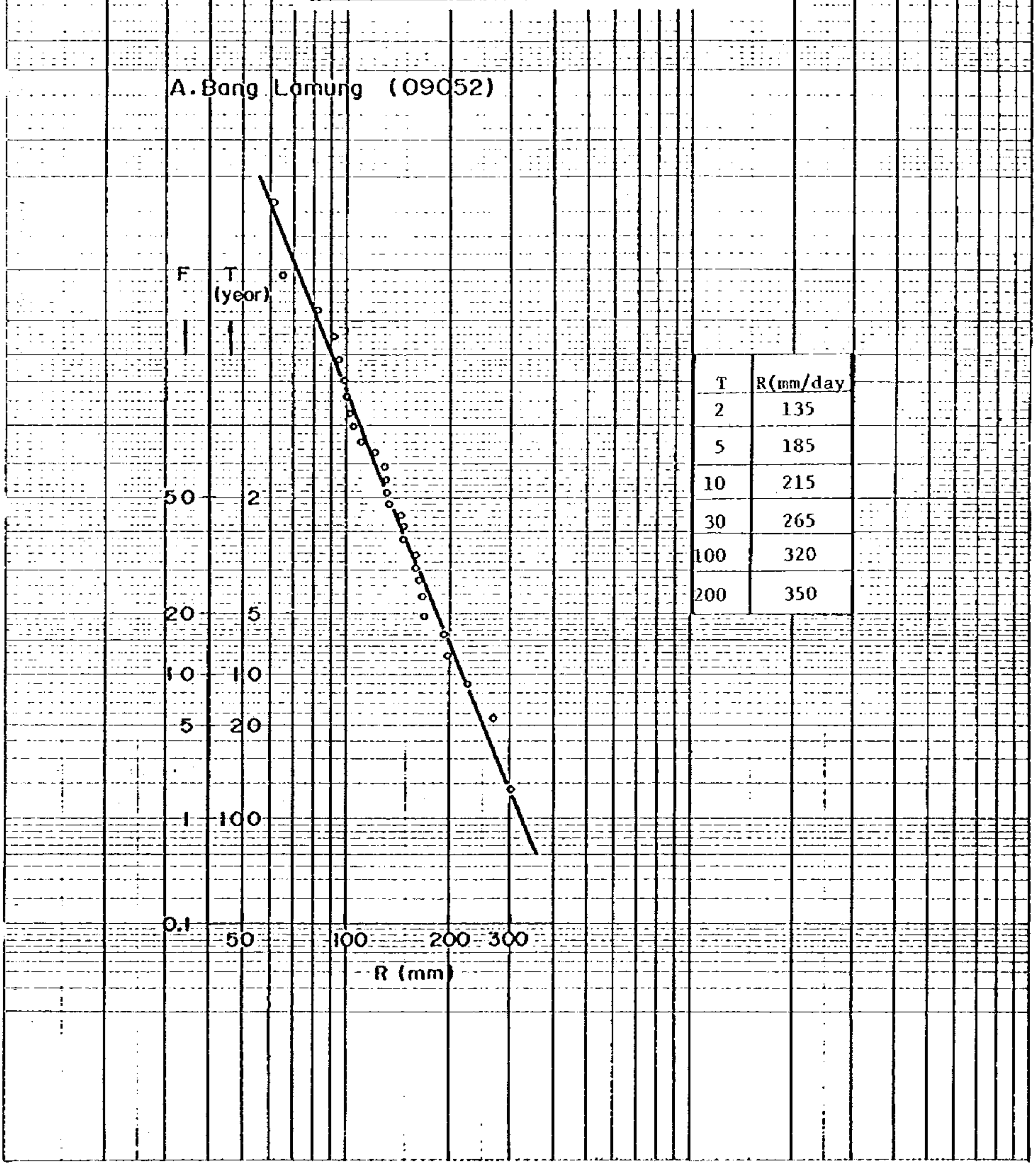
T	R(mm/day)
2	110
5	150
10	180
30	220
100	265
200	290

Fig. 2-2-(4) Probability Rainfall (4)



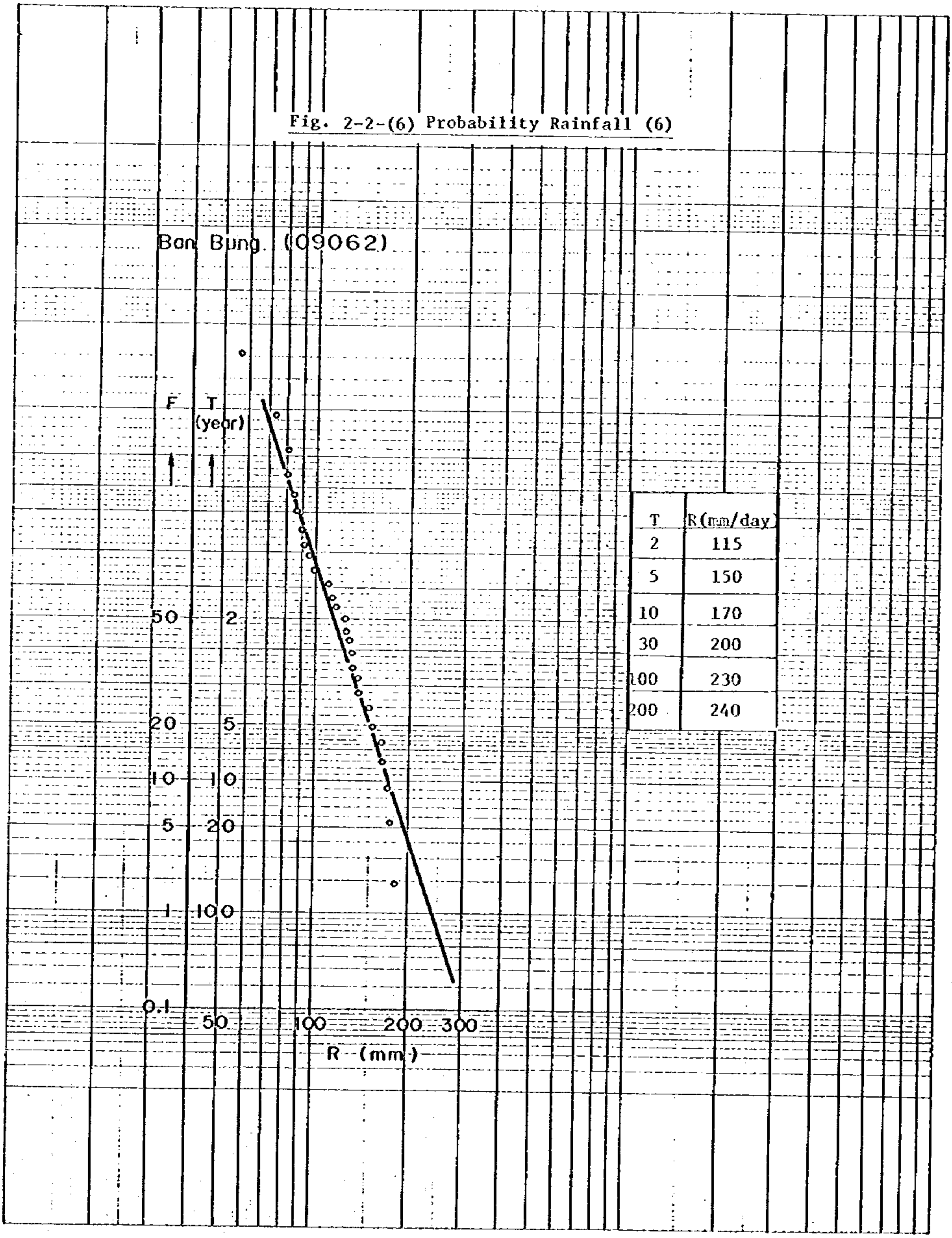
T	R(mm/day)
2	140
5	185
10	230
30	290
100	350
200	390

Fig. 2-2-(5) Probability Rainfall (5)



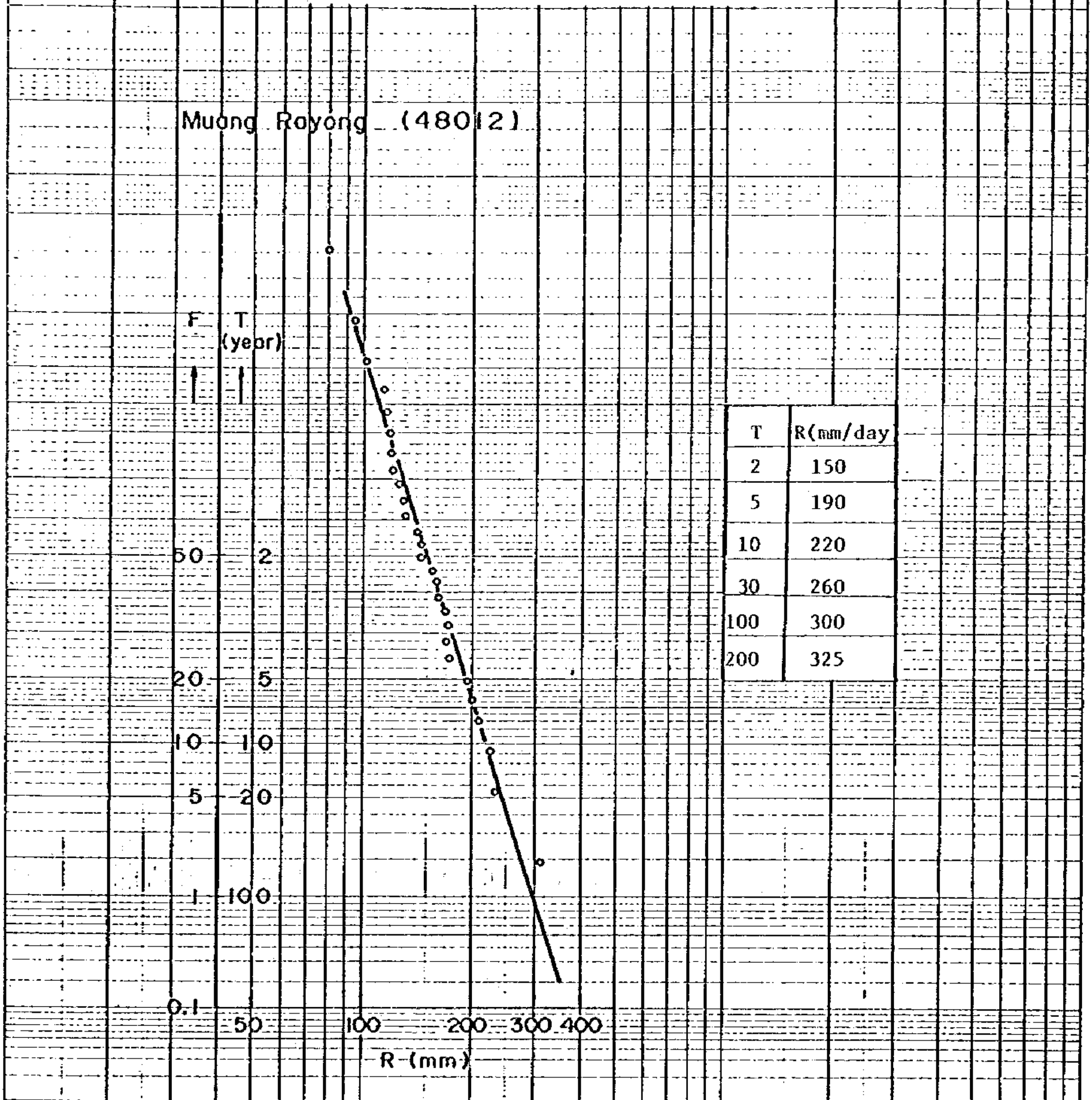
T	R(mm/day)
2	135
5	185
10	215
30	265
100	320
200	350

Fig. 2-2-(6) Probability Rainfall (6)



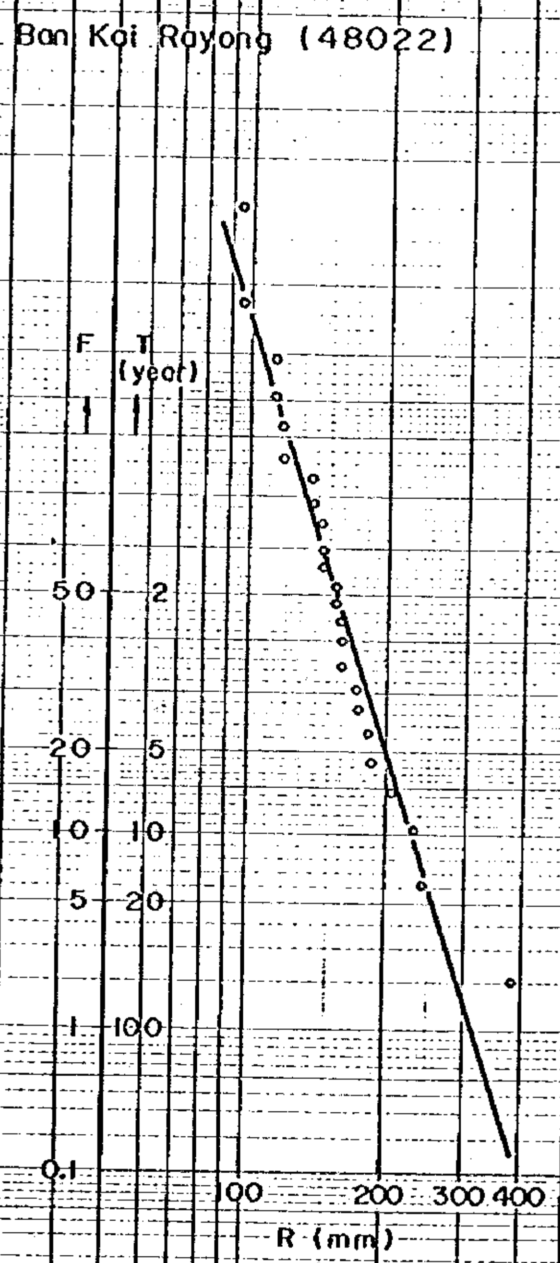
T	R(mm/day)
2	115
5	150
10	170
30	200
100	230
200	240

Fig. 2-2-(7) Probability Rainfall (7)



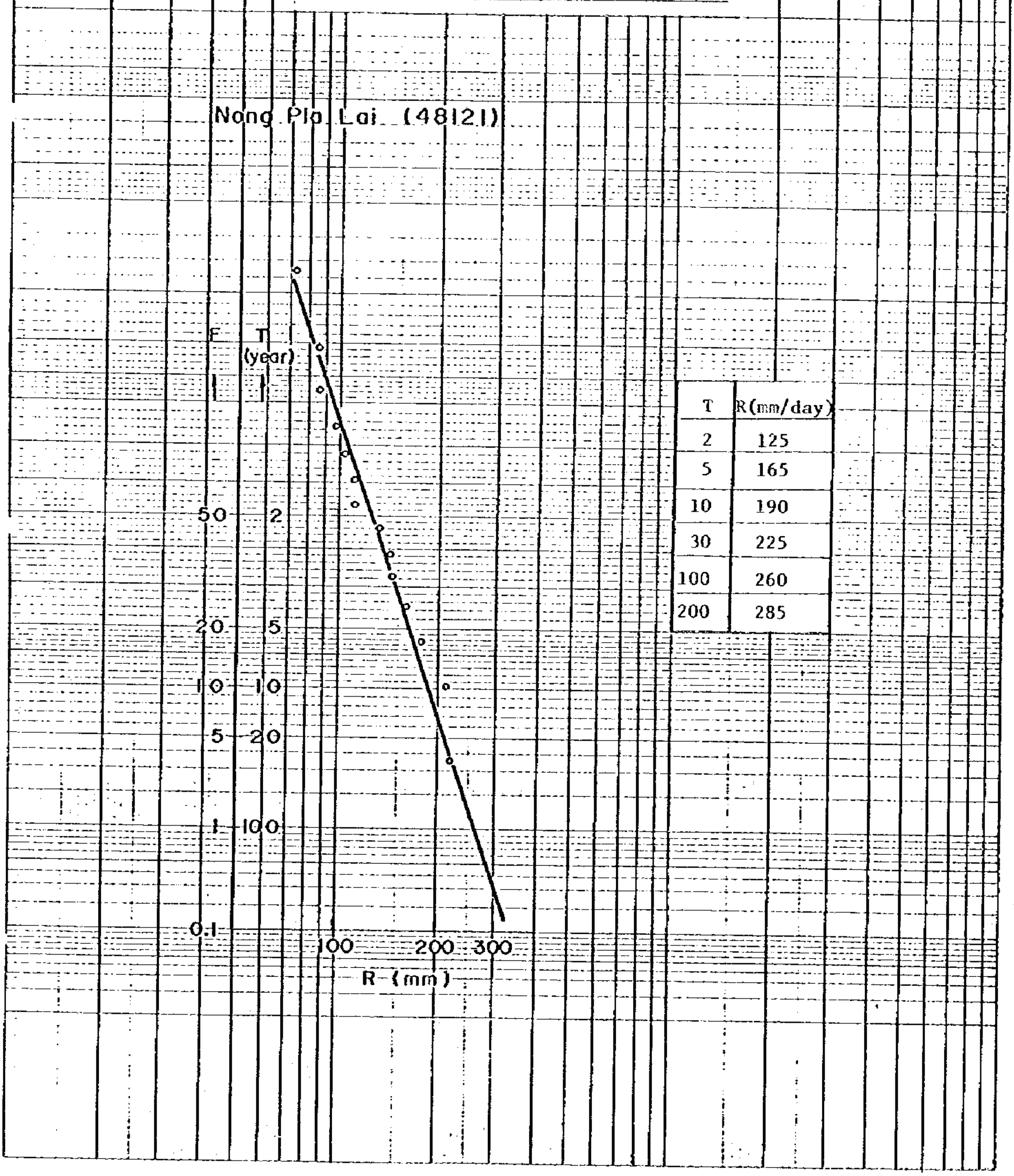
T	R(mm/day
2	150
5	190
10	220
30	260
100	300
200	325

Fig. 2-2-(8) Probability Rainfall (8)



T	R(mm/day)
2	155
5	200
10	230
30	270
100	310
200	340

Fig. 2-2-(9) Probability Rainfall (9)



T	R(mm/day)
2	125
5	165
10	190
30	225
100	260
200	285

Fig. 2-3 Rainfall Mass Curve

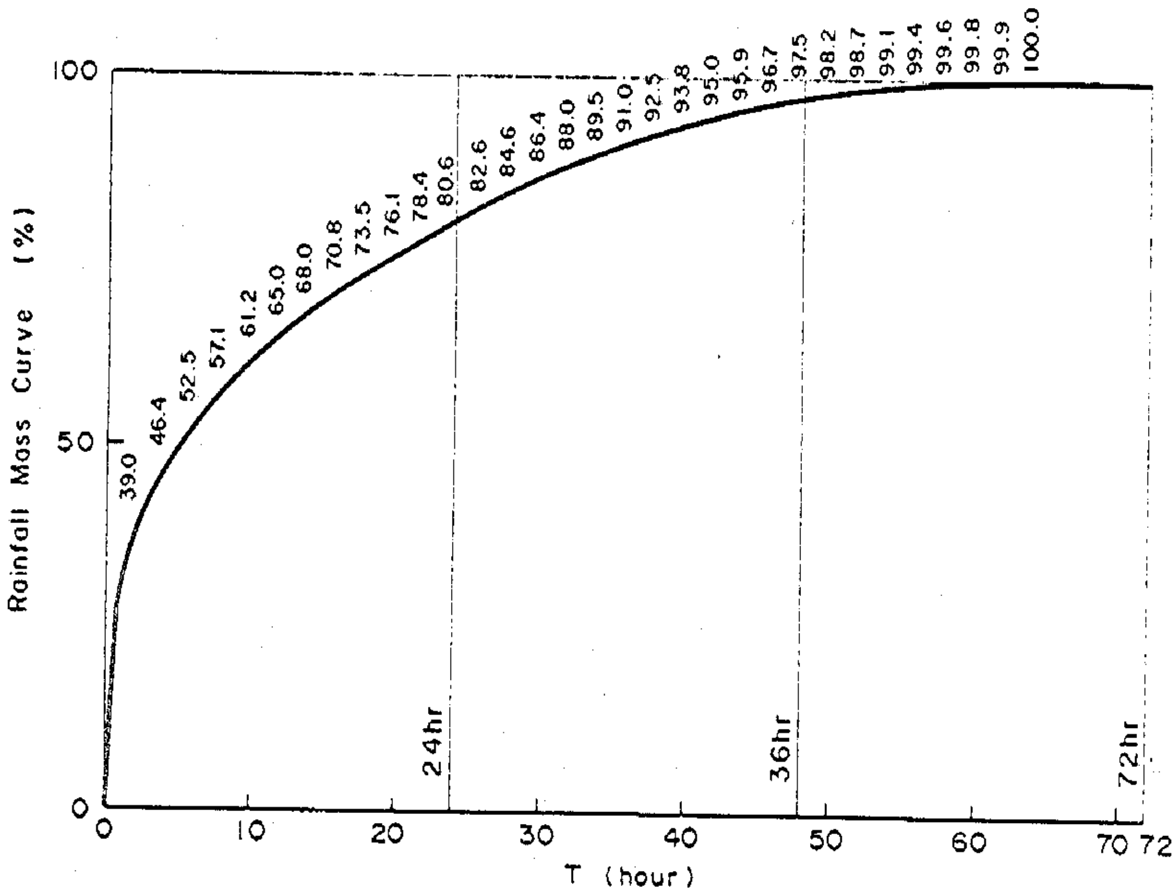


Fig. 2-4-(1) General Map of Rayong River

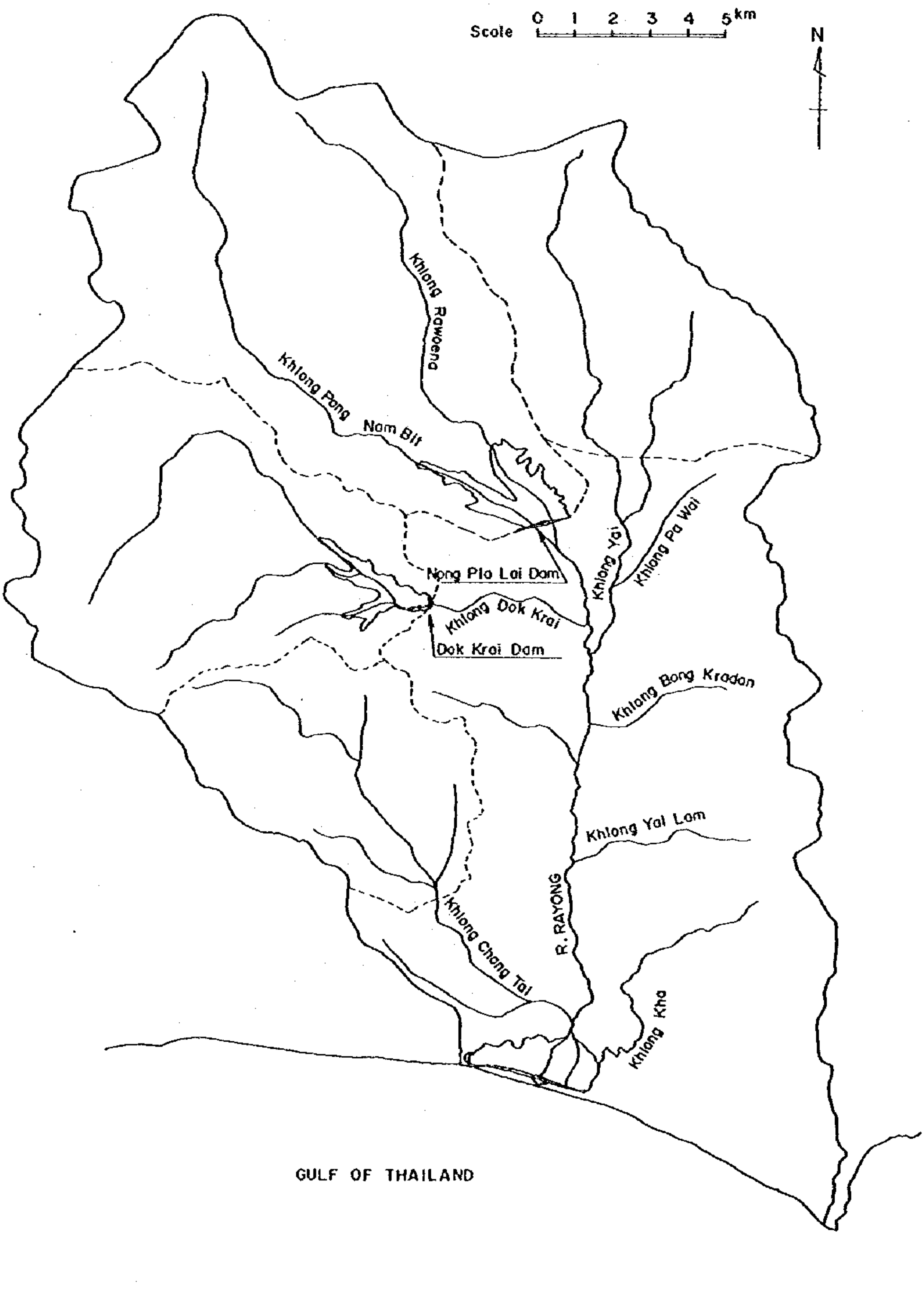
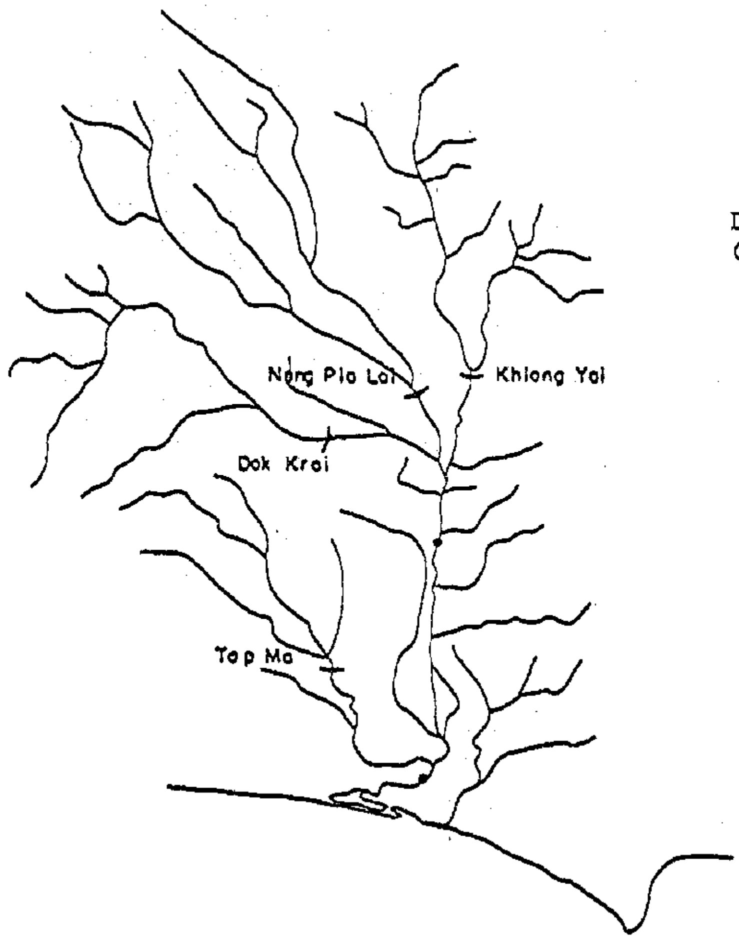


Fig. 2-4-(2) Run-off Model (Nong Pla Lai)



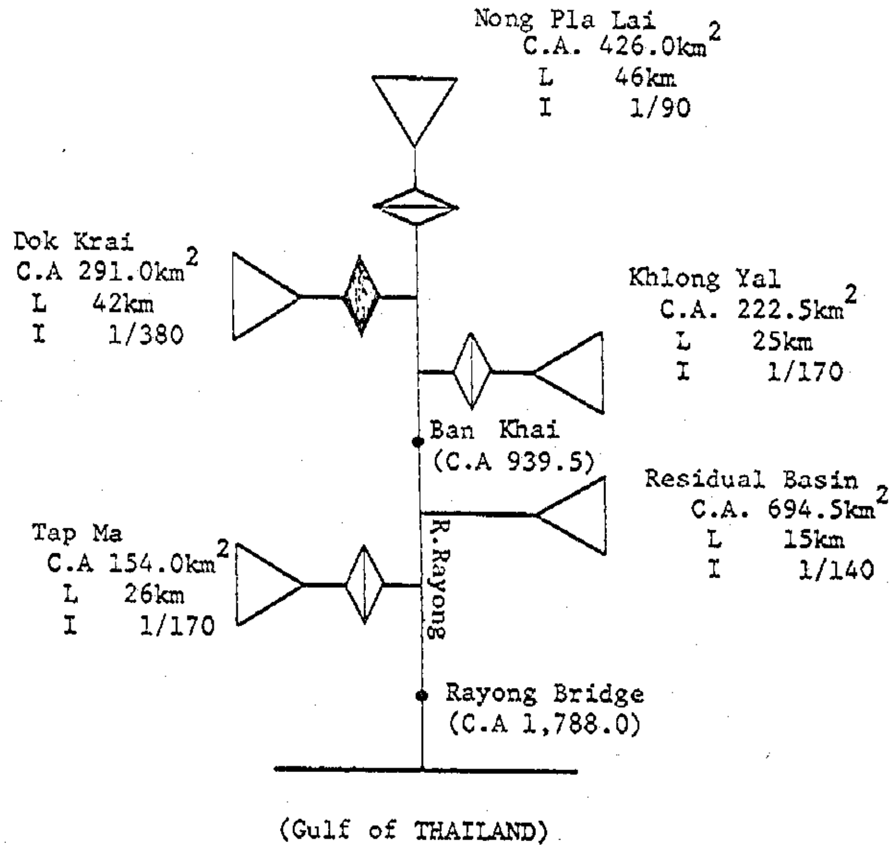
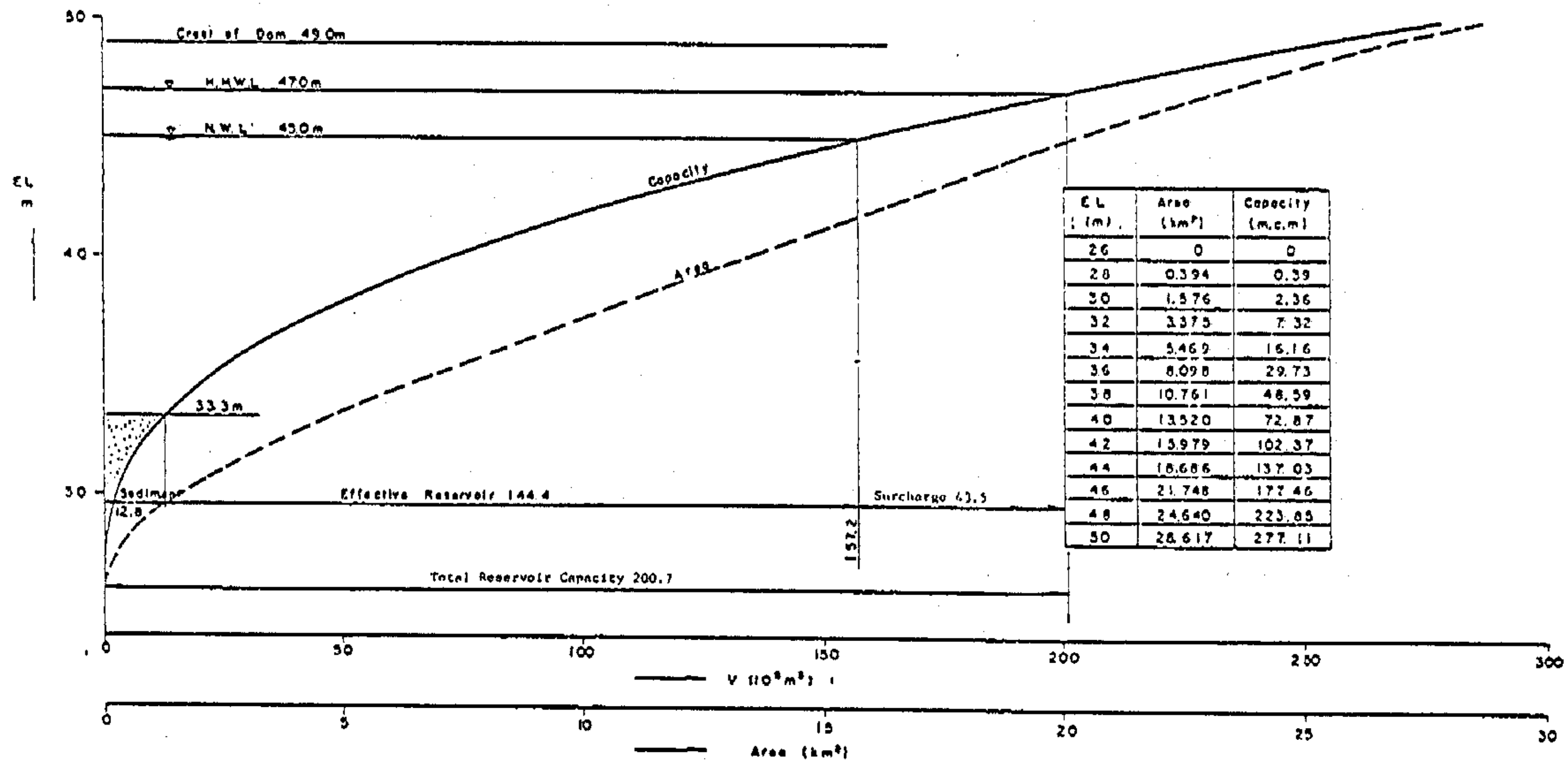


Fig.2-5 Reservoir Capacity and Area
(Nong Pla Lai Reservoir)



E.L. (m)	Area (km²)	Capacity (m.c.m)
26	0	0
28	0.394	0.39
30	1.576	2.36
32	3.375	7.32
34	5.469	16.16
36	8.098	29.73
38	10.761	48.59
40	13.520	72.87
42	15.979	102.37
44	18.686	137.03
46	21.748	177.46
48	24.640	223.85
50	28.617	277.11

Fig. 2-6 Pluak Daeng

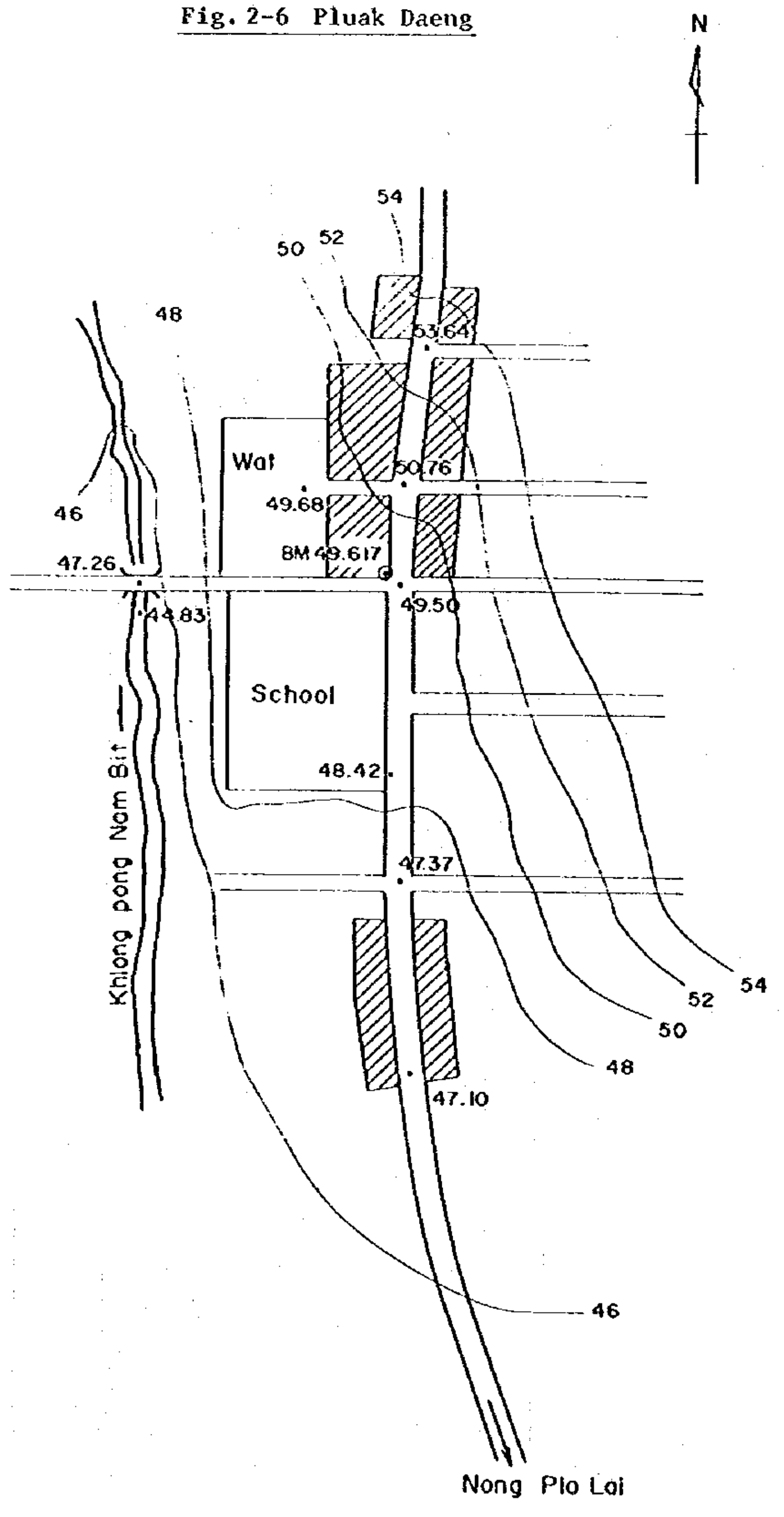


Fig. 2-7 Inflow and Outflow Hydrograph for 30 Year Flood
(Nong Pla Lai Dam)

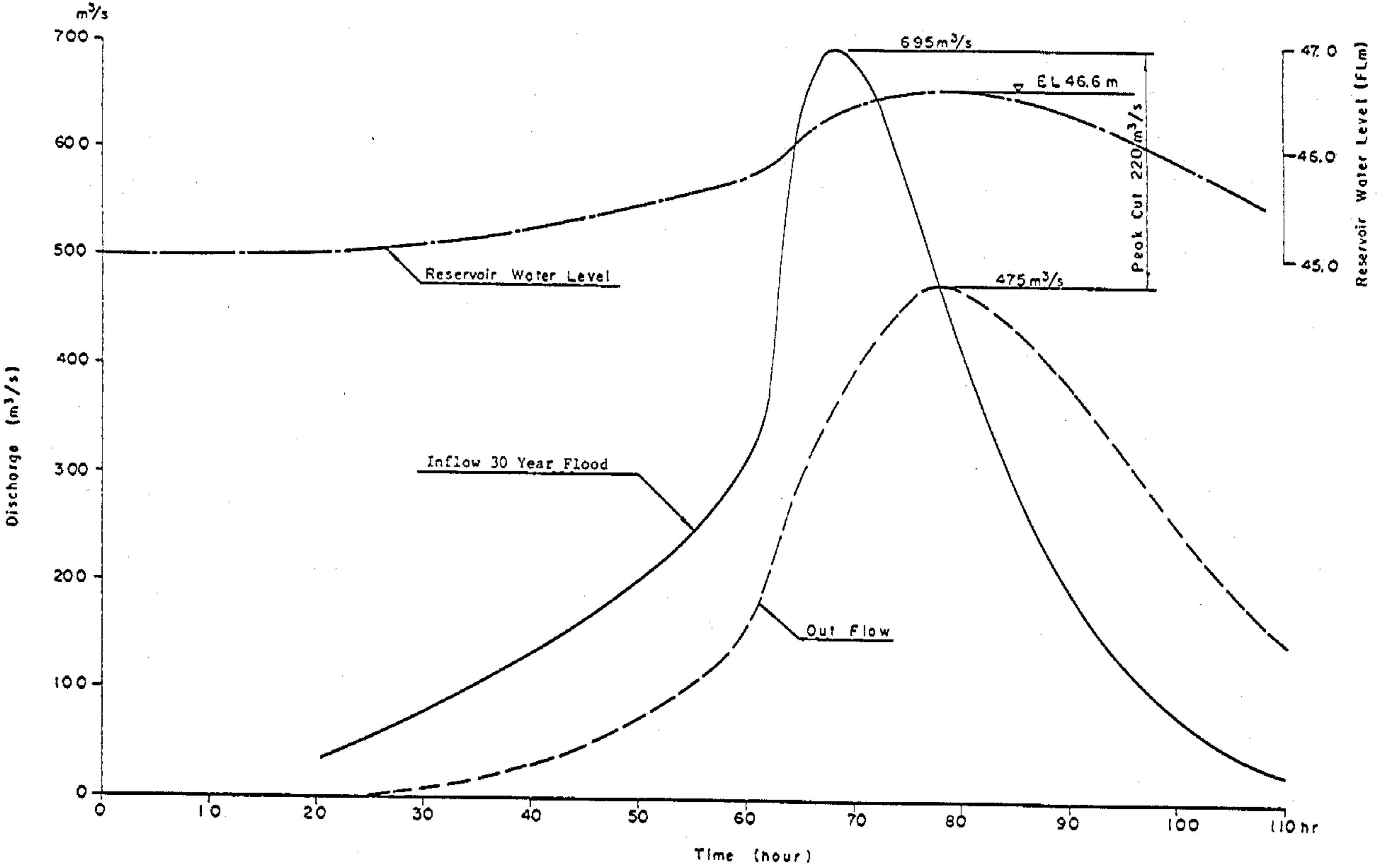
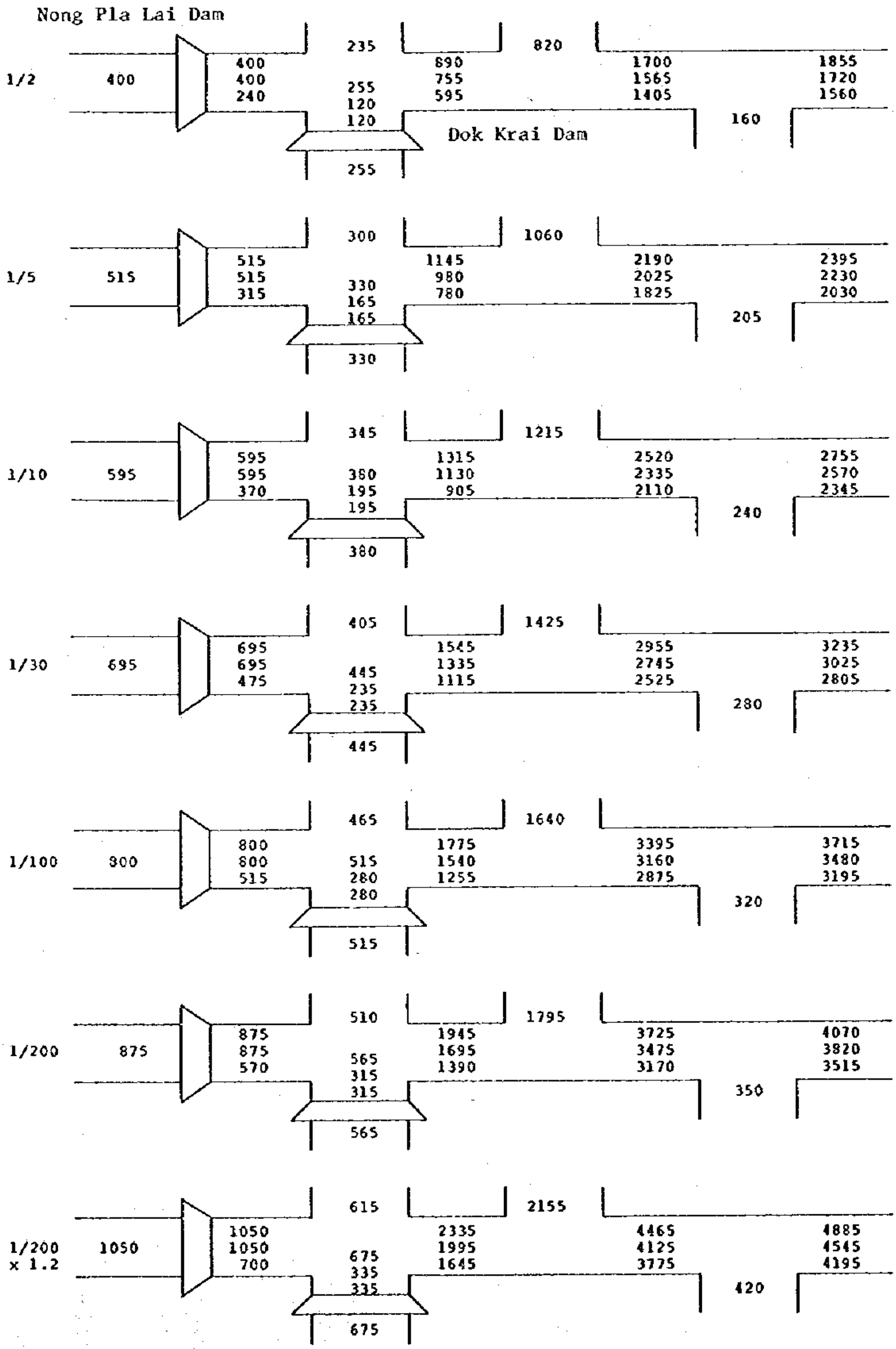


Fig. 2-8 Discharge Distribution (Nong Pla Lai)



Note: upper - natural flood
middle - after regulation by Dok Krai only
lower - after regulation by Dok Krai & Nong Pla Lai

Fig. 2-9 Inundation Area of Rayong River

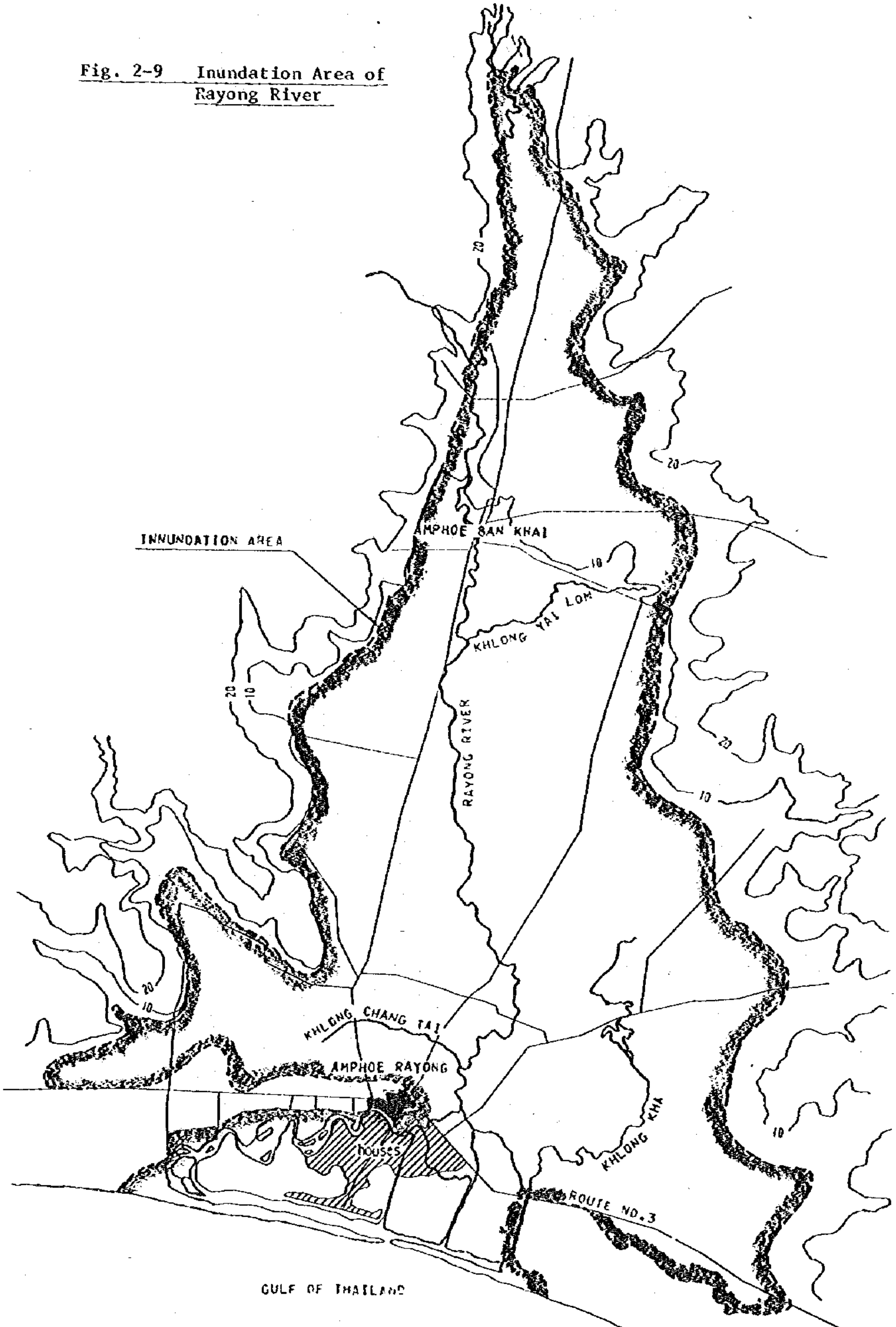


Fig. 2-10 River Cross Section Point (Rayong River)

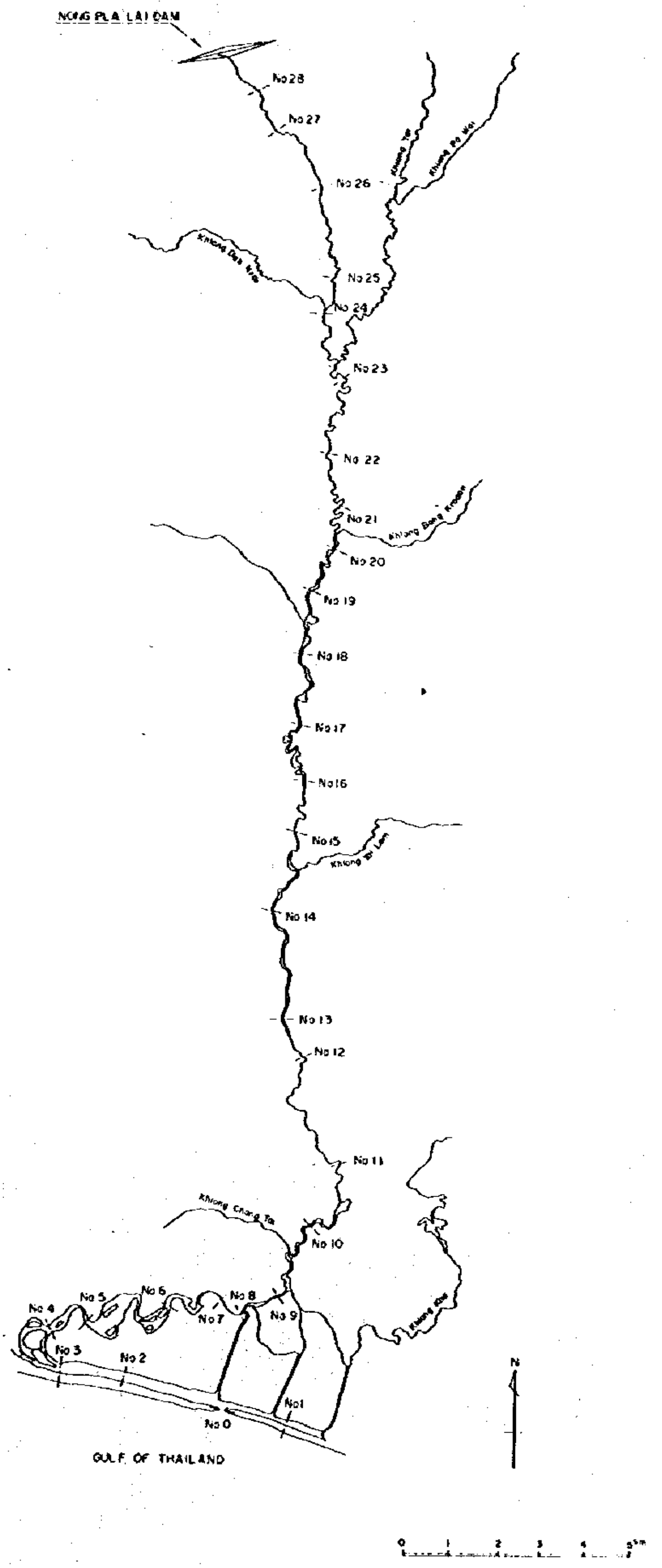


Fig. 2-11 Longitudinal Profile and Stream Flow Capacity (Rayong River)

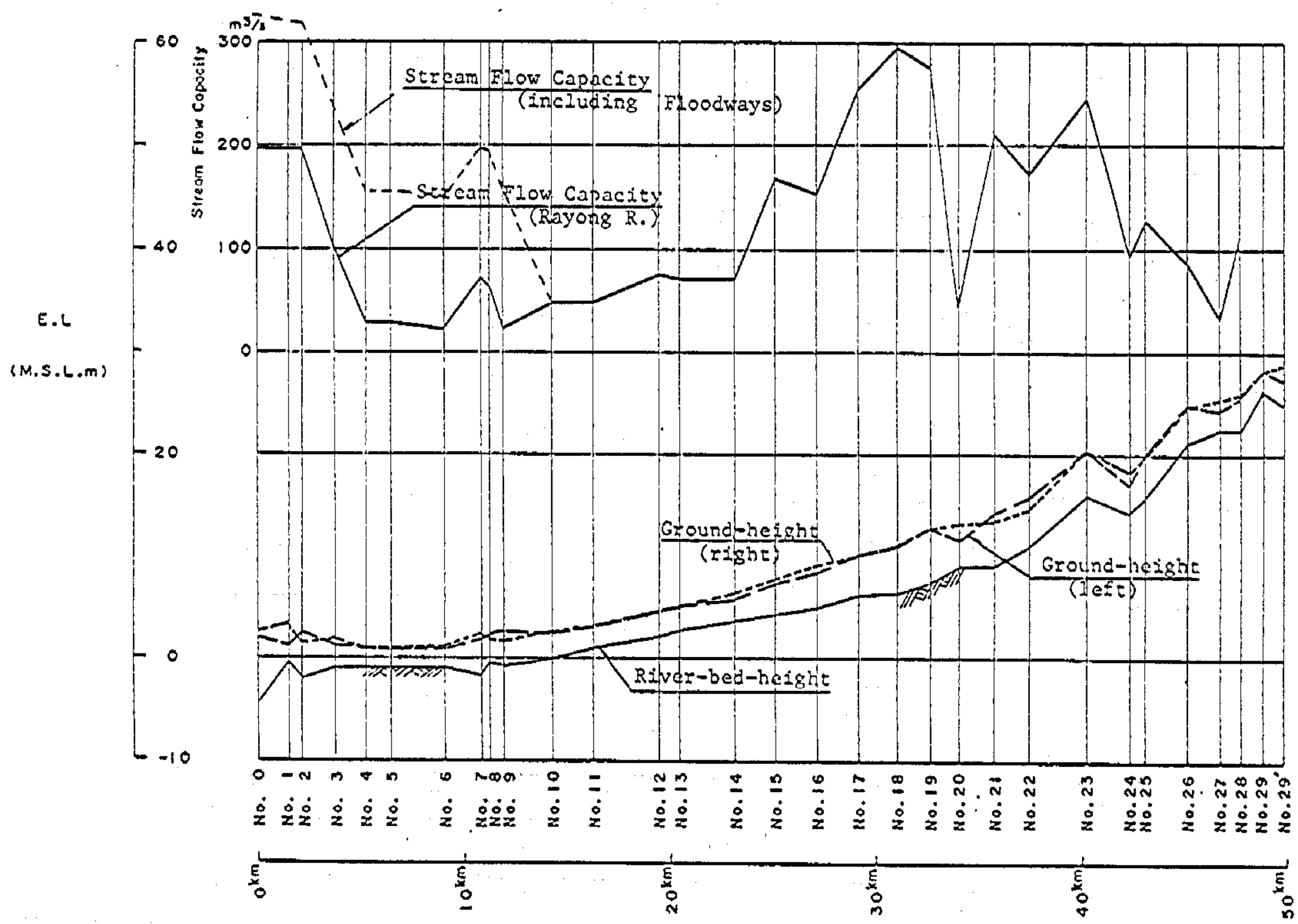


Fig. 2-12-(1) Cross-Section (R.Rayong - 1)

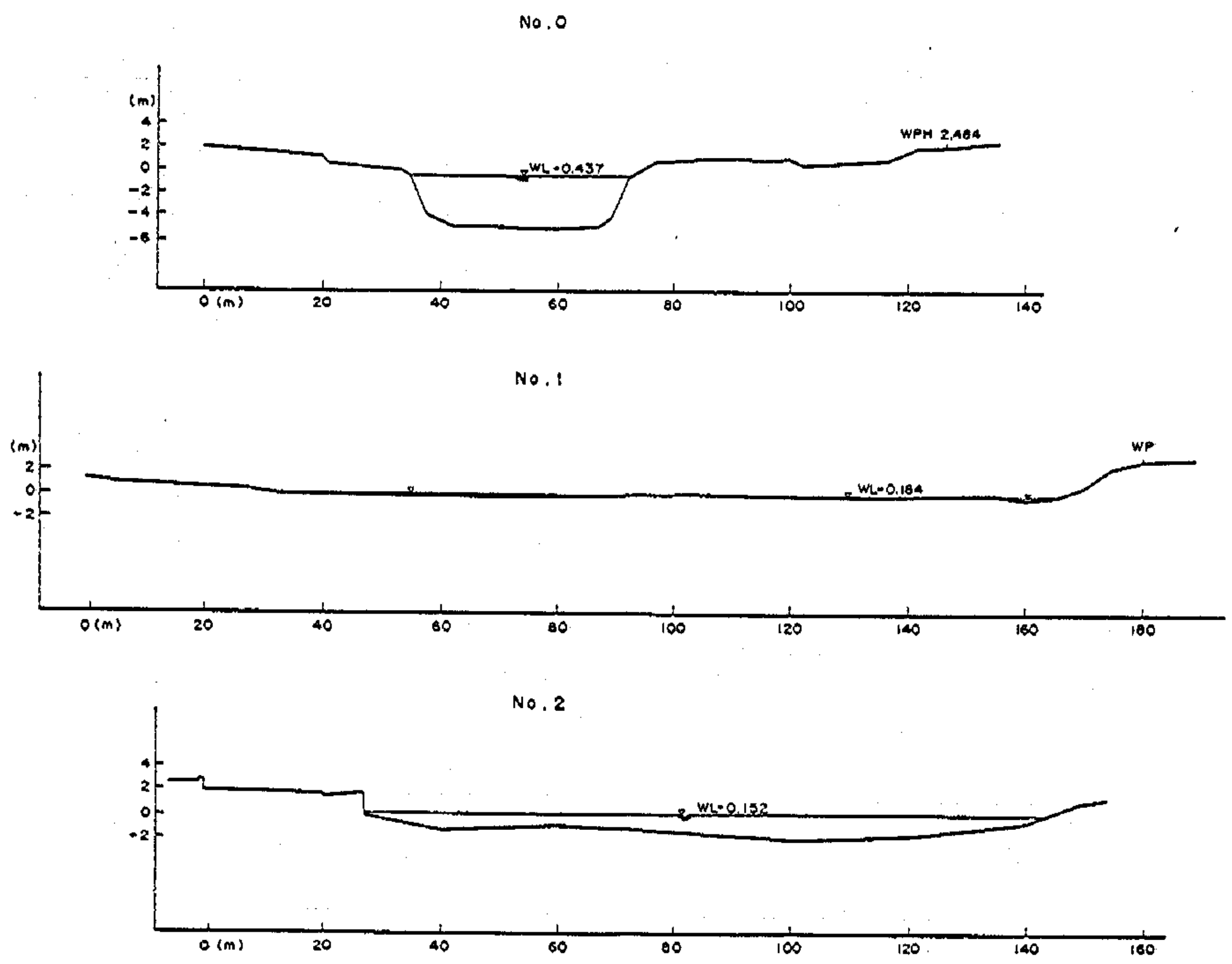


Fig. 2-12-(2) Cross-Section (R.Rayong - 2)

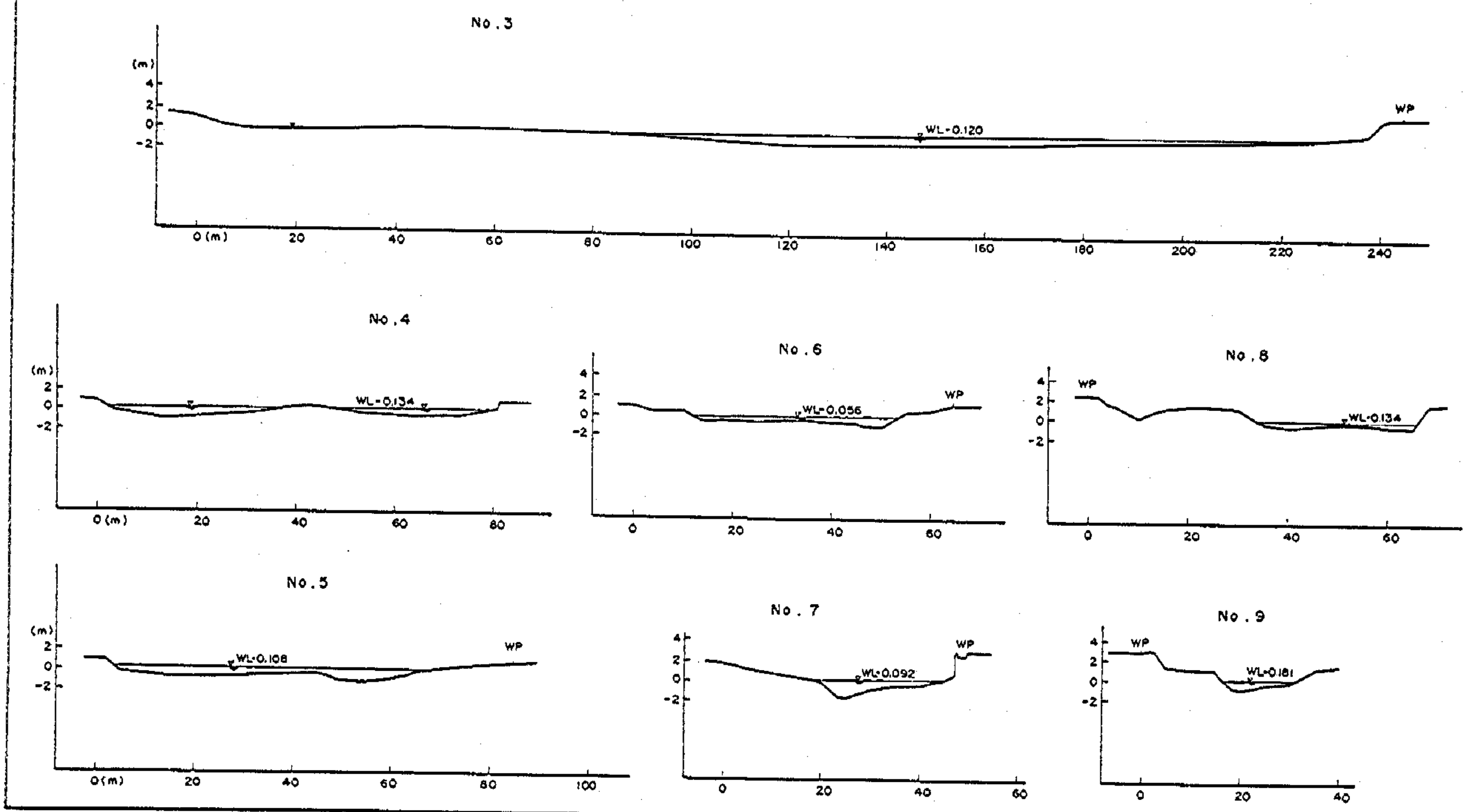


Fig. 2-12-(3) Cross-Section (R.Rayong - 3)

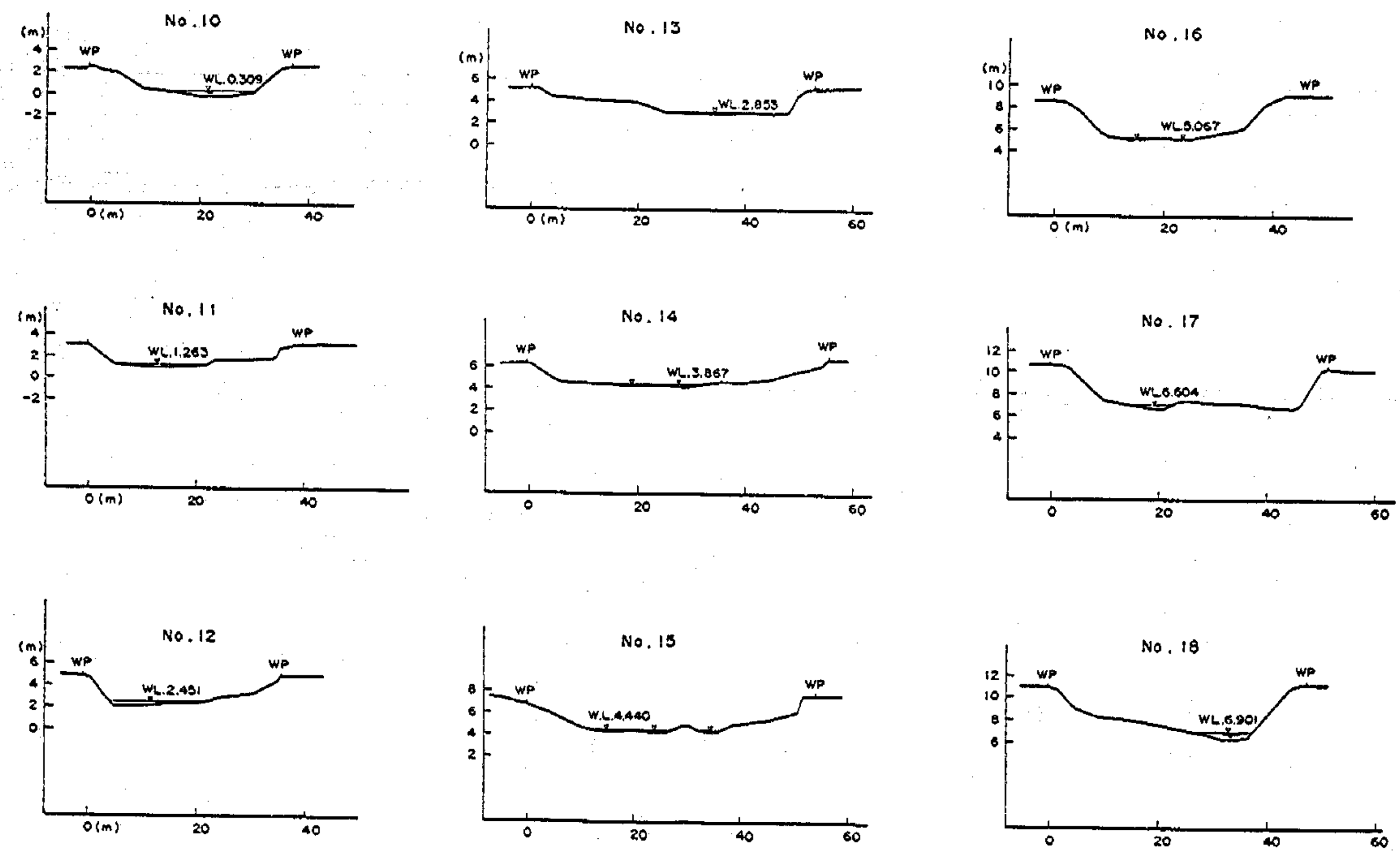


Fig. 2-12-(4) Cross-Section (R.Rayong - 4)

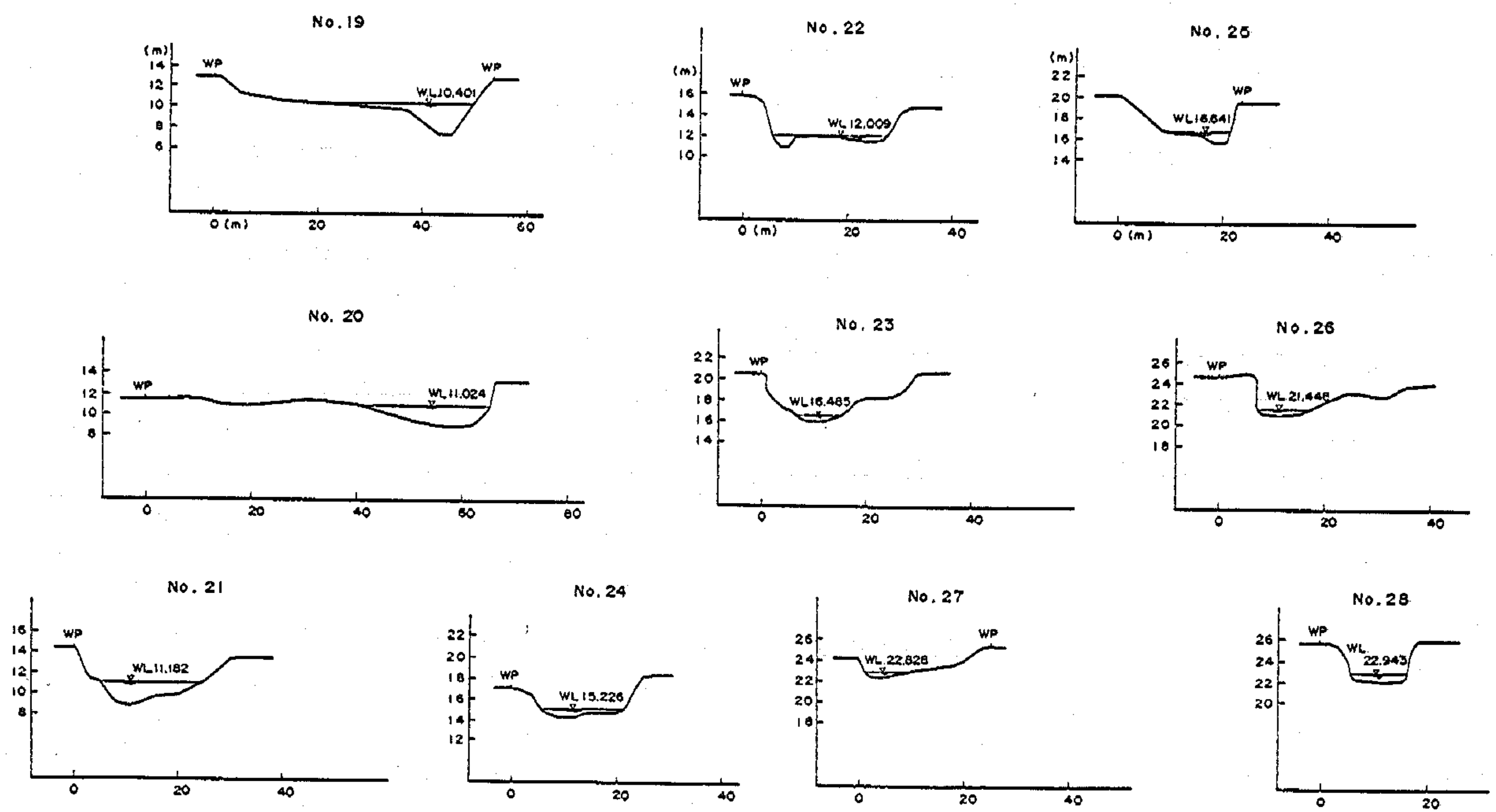


Fig. 2-13 Standard Section
(Rayong River)

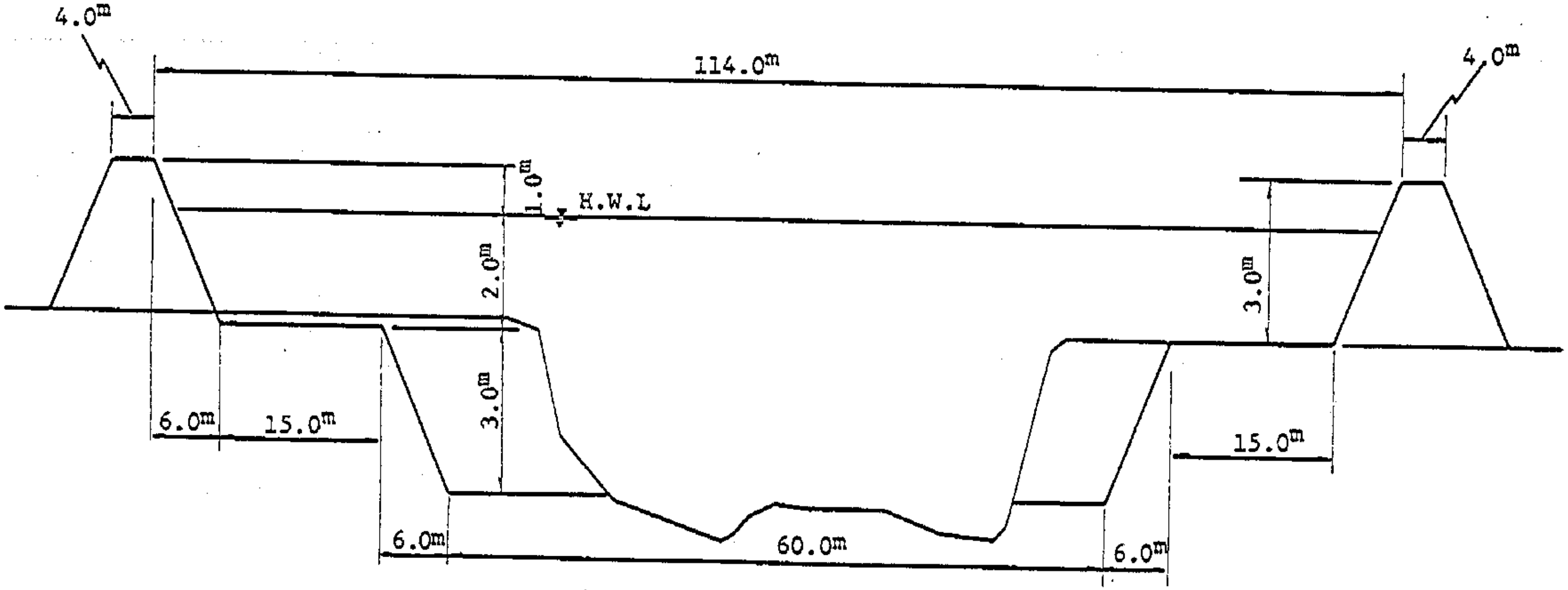


Fig. 3-1-(1) General Map of Ban Bung River

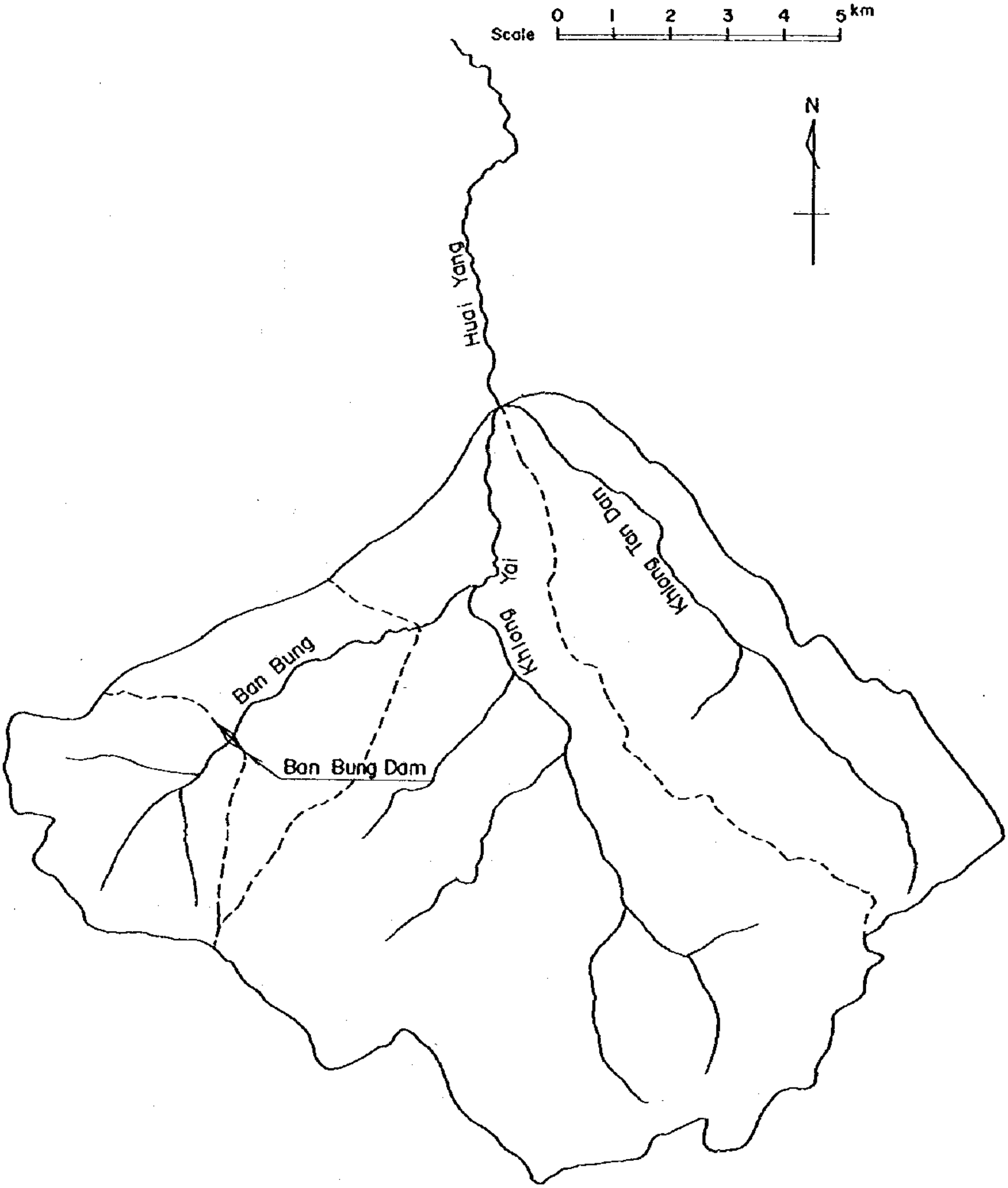
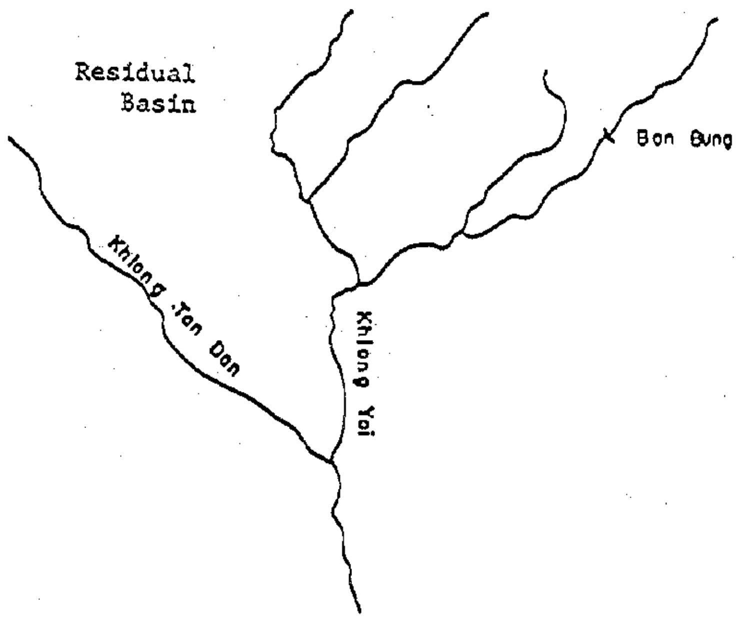


Fig. 3-1-(2) Run-off Model (Ban Bung)



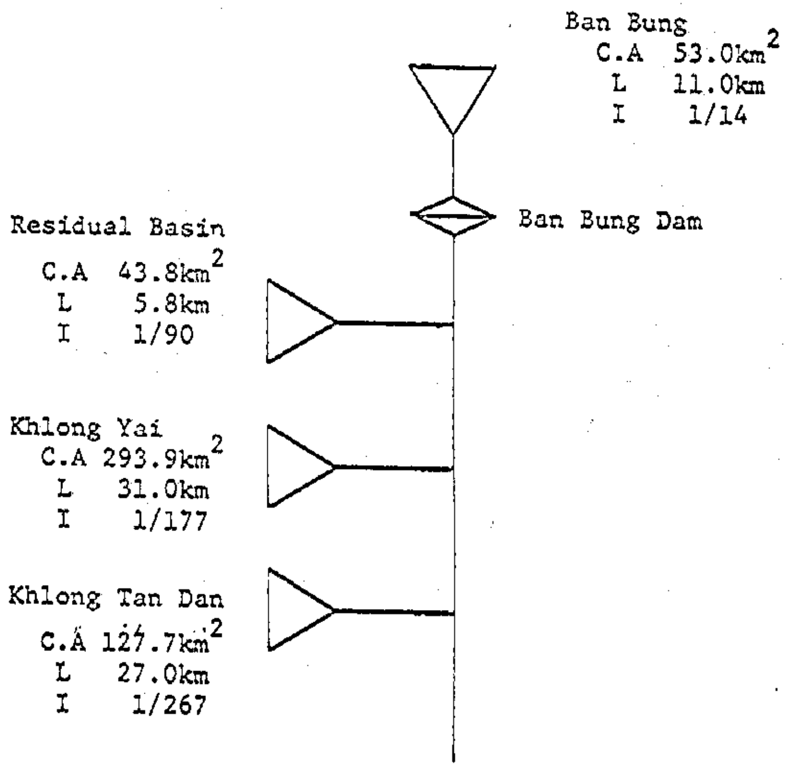
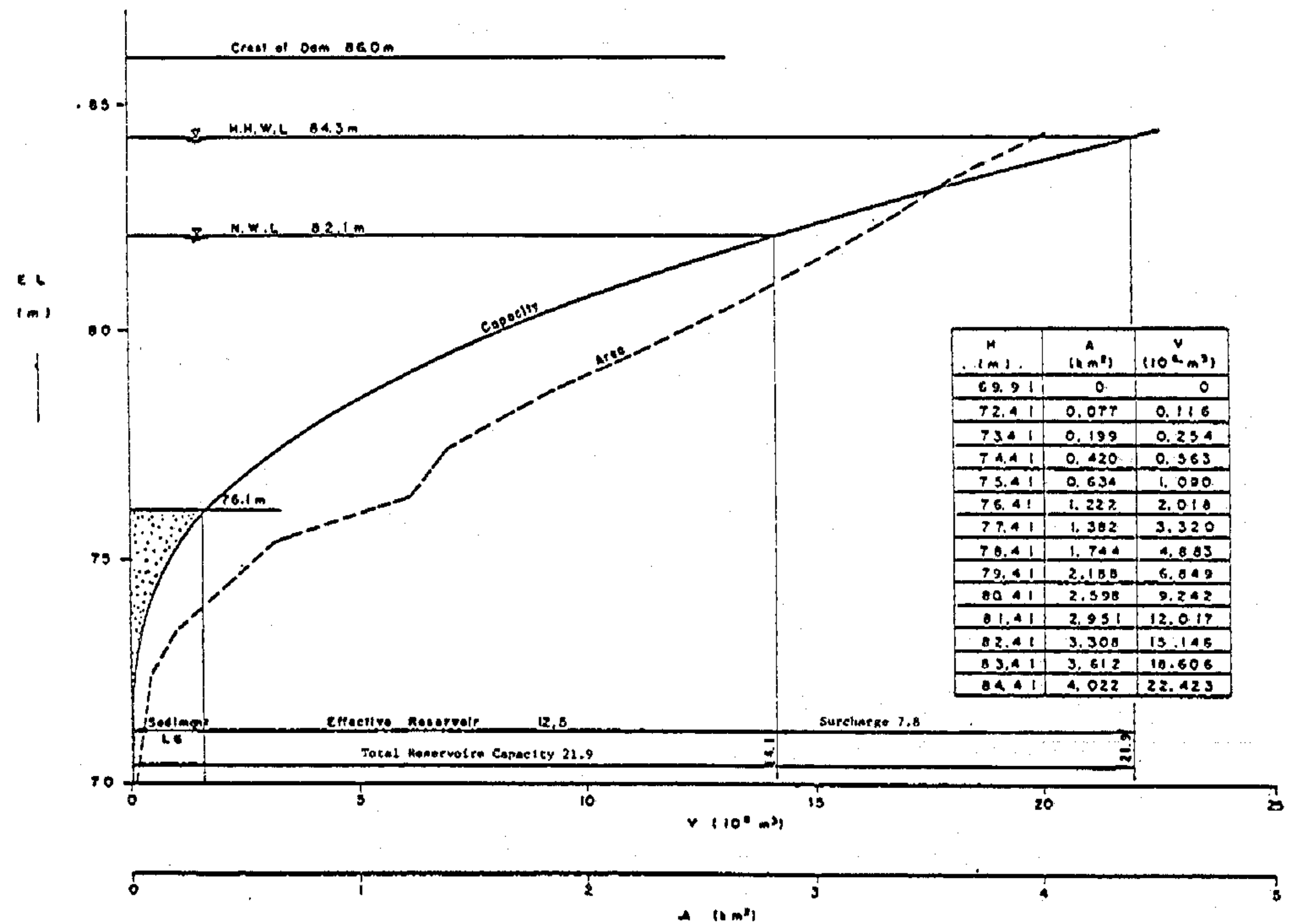


Fig.3-2 Reservoir Capacity and Area (Ban Bung Reservoir)



H (m)	A (km²)	V ($10^6 m^3$)
69.91	0	0
72.41	0.077	0.116
73.41	0.199	0.254
74.41	0.420	0.563
75.41	0.634	1.090
76.41	1.222	2.018
77.41	1.382	3.320
78.41	1.744	4.883
79.41	2.188	6.849
80.41	2.598	9.242
81.41	2.951	12.017
82.41	3.308	15.146
83.41	3.612	18.606
84.41	4.022	22.423

Fig. 3-3 Inflow and Outflow Hydrograph for 30 Year Flood
(Ban Bung Dam)

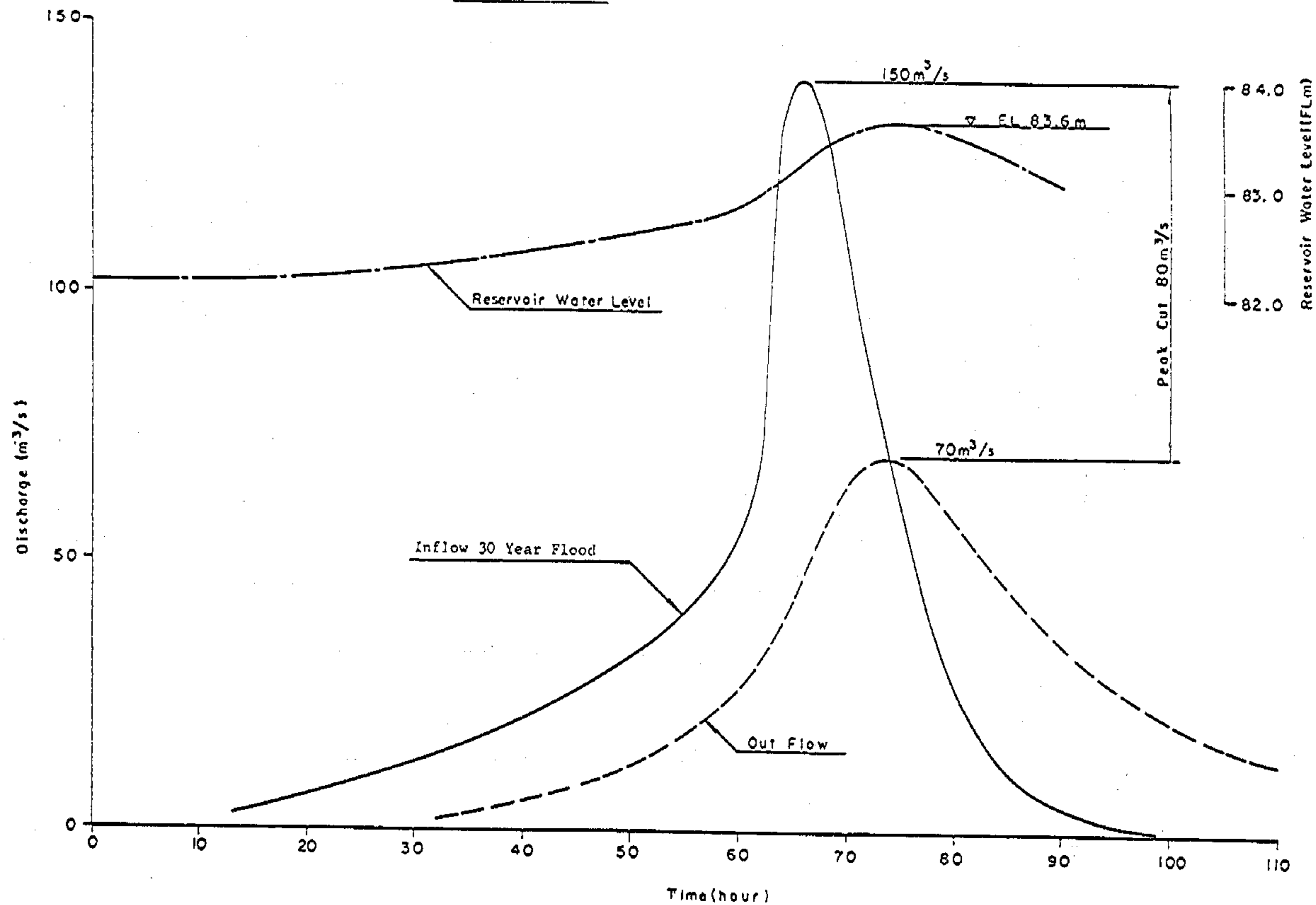
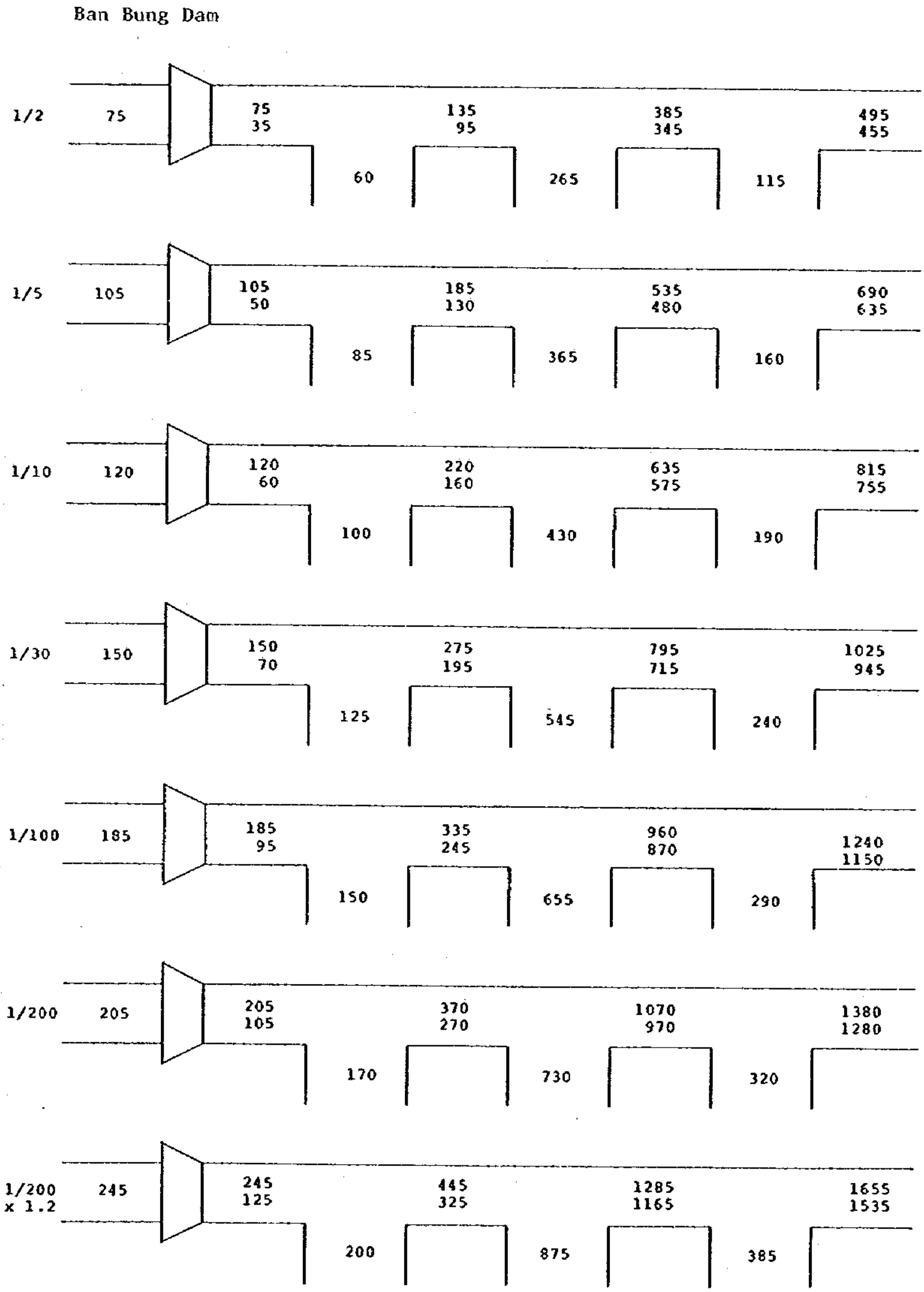


Fig. 3-4 Discharge Distribution (Ban Bung)



Note: upper - natural flood
lower - after regulation by dam

Fig. 3-5 River Cross Section Point
(Ban Bung River)

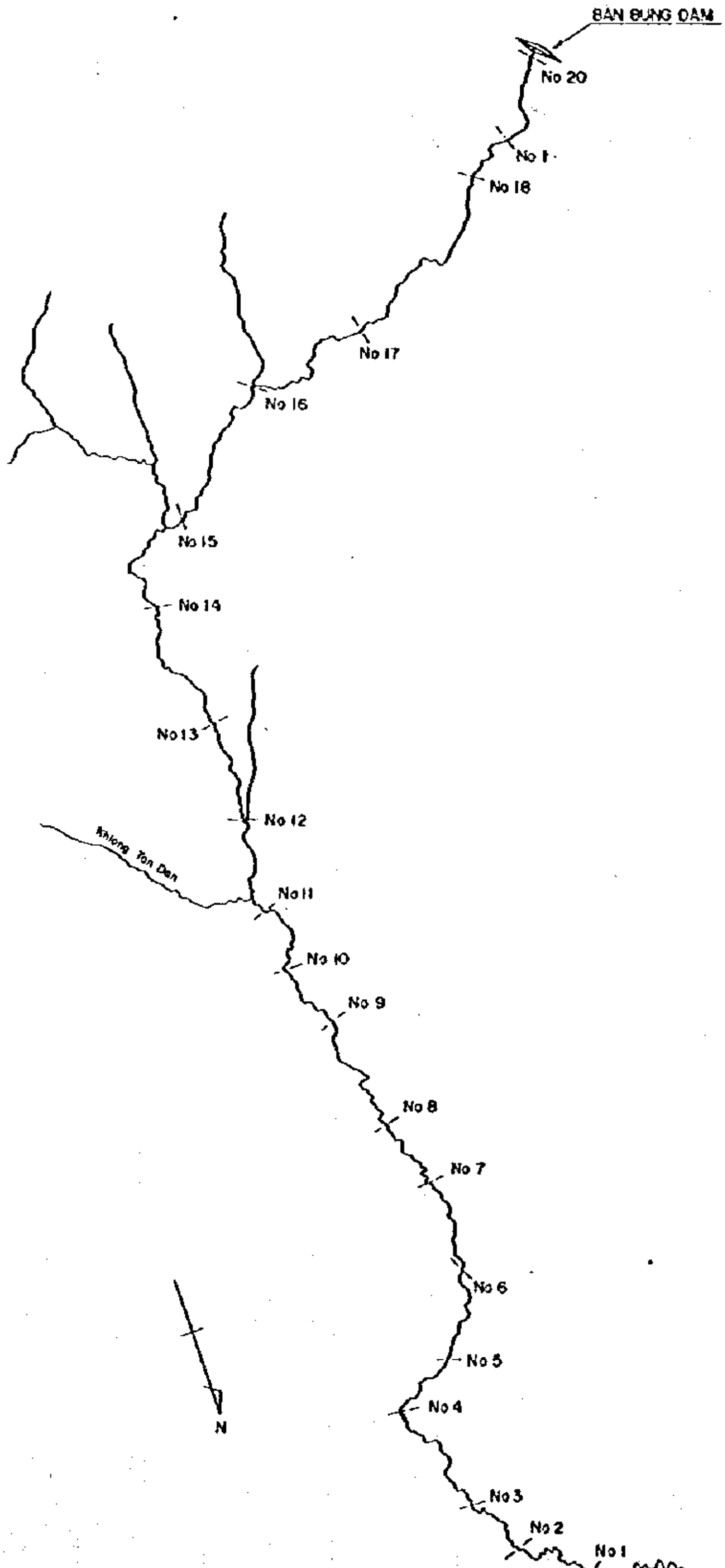


Fig. 3-6 Longitudinal Profile and Stream Flow Capacity (Ban Bung River)

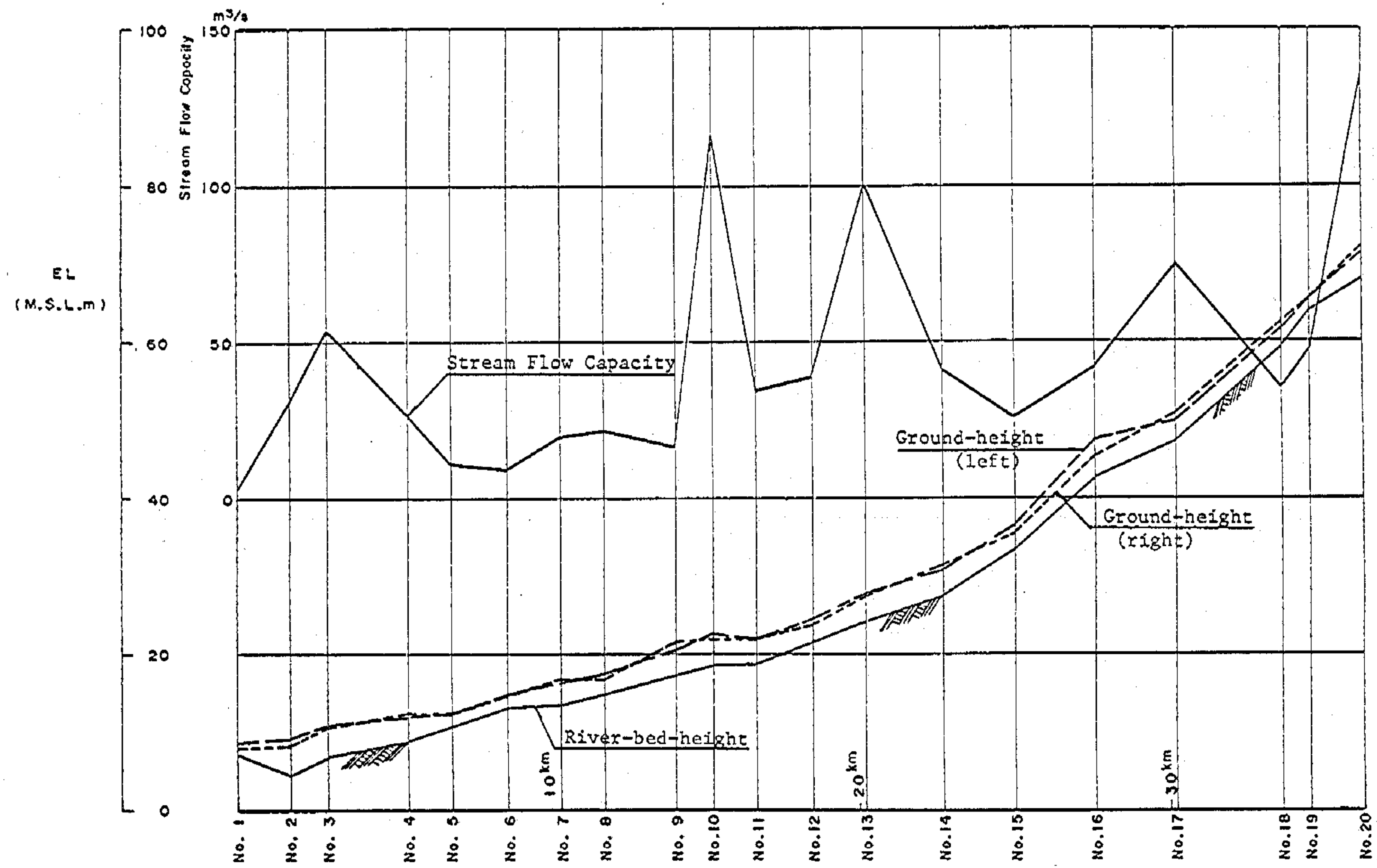


Fig. 3-7-(1) Cross-Section (R.Ban Bung - 1)

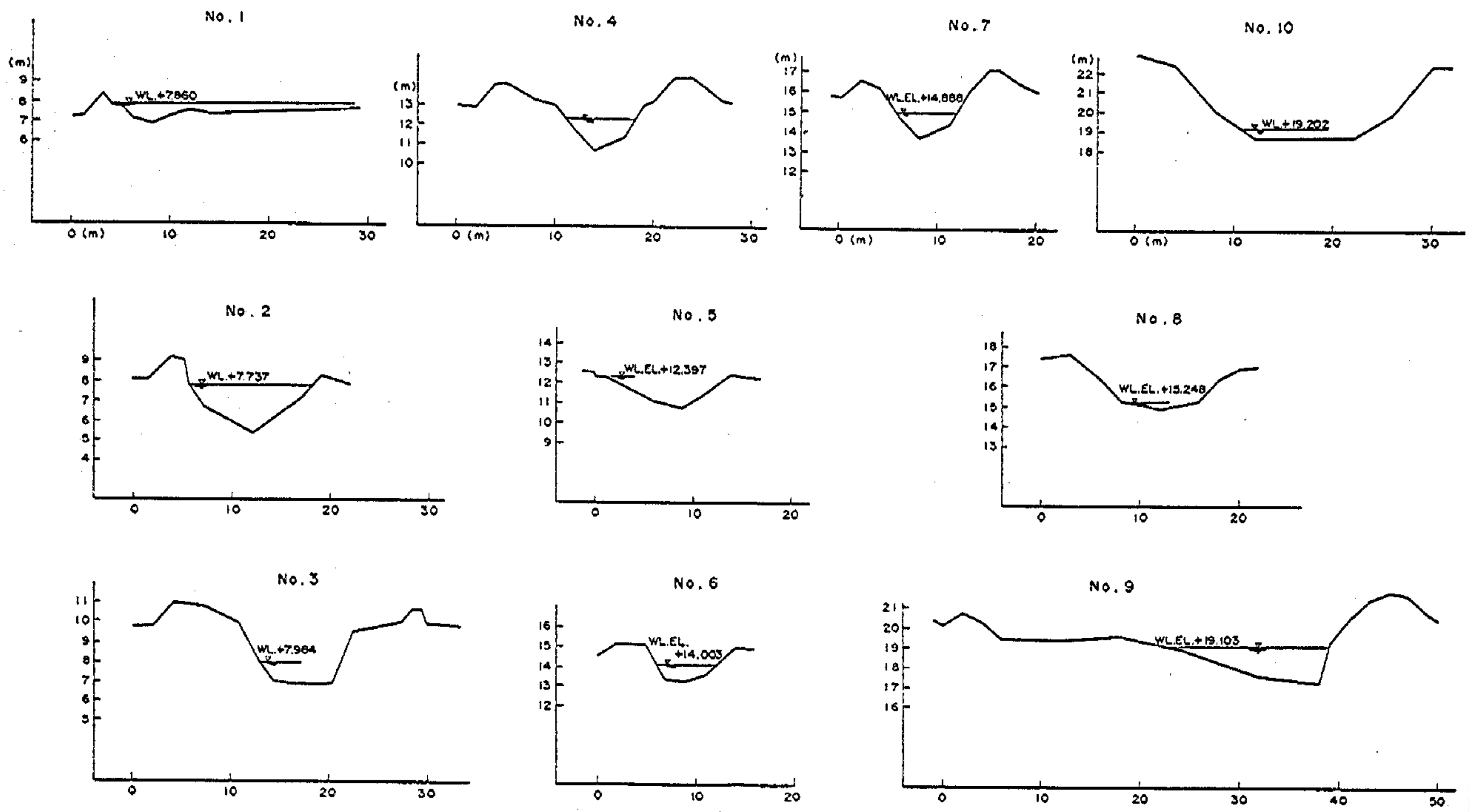


Fig. 3-7-(2) Cross Section (R.Ban Bung - 2)

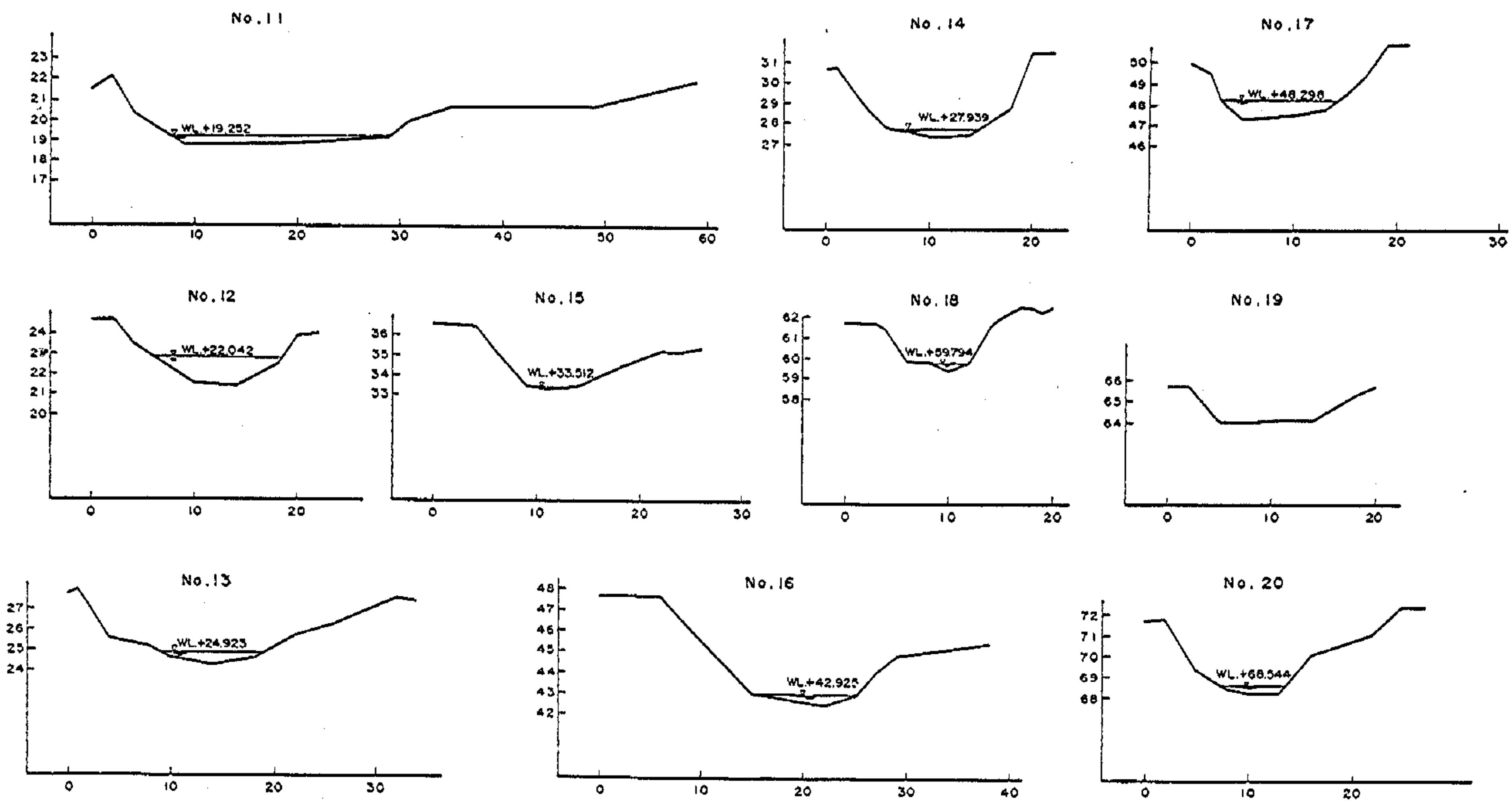
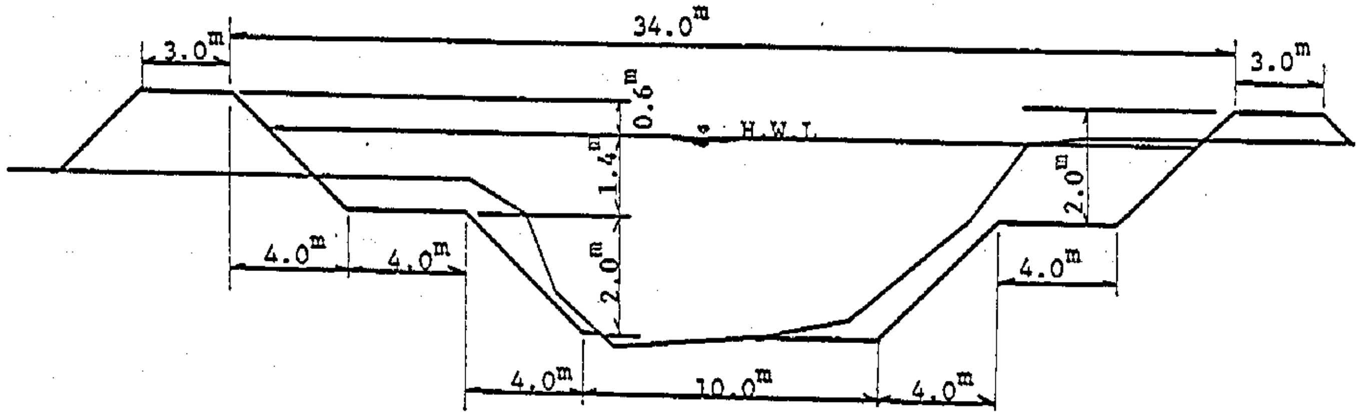


Fig. 3-8 Standard Section (Ban Bung River)



VIII. PIPELINE

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1. GENERAL

As a component of the Nong Pla Lai sub-project, the water transmission system is aimed at conveying a volume of water from Dok Krai reservoir.

PRELIMINARY STUDY:

The service area assumed in the preliminary study are Rayong, Mab Ta Pud, Sattahip and Laem Chabang, that is, all the area that would benefit from receiving municipal-industrial water from Dok Krai reservoir through the water transmission system. Study was made on possible alternatives of trasmission system components, as follows.

- Water transmission routes
- Water transmission conduit
- Pipeline (material and number of lines)
- Pumping station (location and type)
- Head tanks, and other facilities

The principal difference between the priliminary study and PLAN I and PLAN II is that Rayong is excluded as the service area in PALN I and II, while the design themselves are very similar in the three plans. Consequently, the dimensions of facilities for PLAN I and II are decided on the basis of the preliminary study.

PLAN I : Service area is limited to Mab Ta Pud, Sattahip and Laem Chabang areas. Municipal water supply for Rayong will be tapped directly from Rayong river after being released from Dok Krai reservoir.

PLAN I is the same as PLAN I in Main Report of WATER RESOURCES DEVELOPMENT.

PLAN II : The area to be served are Mab Ta Pud and Sattahip regions, municipal-industiral water for Rayong will be tapped from Rayong river after released from Dok Krai reservoir. Because supply to Laem Chabang is avoided, the developed volume of Nong Pla Lai sub-project can satisfy the water demand up to the final target year 2000.

PLAN II is the same as PLAN II in Main Report of WATER RESOURCES DEVELOPMENT.

The plan of the PLAN I serving widespread area would call for further water resources development. The development of Thap Ma Dam and Khong Yai dam is assured for the water supply plan formulated for the final target of the year 2000. In other words, the design discharge of the pipeline system is fixed in compliance with the developed volume of Nong Pla Lai sub-project, which is 80 MCM/yr. The study of Laem Chabang route, although lacking in minute details compared to other routes, has revealed that rather high cost of conveyence is attributable to long distance and difficulty caused from topography of the route. This led to formulation of PLAN II which excludes Laem Chabang Route.

In this subject study, purification and distribution of water are not included and are considered to be studied and implemented by the beneficiaries. Sites of purification plant is temporarily proposed.

I. PRELIMINARY STUDY

Water demand in the East Coast Area are mainly industrial water and its related newly developed municipal water, but it is forecasted that the future additional water demand will occur in the municipalities scattered in this area.

In PRELIMINARY STUDY, it is premised that the industrial water, its related municipal water and the other municipal water supply to Rayong, Sattahip, Laem Chabang regions and their surrounding areas will be conveyed and supplied by the pipeline.

2. GENERAL CONDITIONS

2.1 WATER DEMAND AND WATER SUPPLY

Water demand in Rayong, Sattahip and Laem Chabang areas are shown in Fig. 2-1 and Table 2-1. Water to be developed by construction of the Nong Pla Lai dam will be 80 MCM/year. Water transmission system will be designed for the coping with water demand in the respective areas in 1995.

2.2 NATURAL CONDITIONS AND INFRASTRUCTURE

2.2.1 Topography

General topography of the proposed area is divided into two features. One is a coastal plain developed along the coast near Laem Chabang and Sattahip. The altitude of this plain is 10 meters above the M.S.L. The other is gently rolling hilly area developed in inland near Dok Krai Reservoir, Mab Ta Pud and, etc. The altitude of this hilly area is 100 meters above the M.S.L. Some small hills are observed near the southeast of Dok Krai Reservoir and small rivers flow through these hilly areas.

Most of hilly areas are casava fields and are found in the low laying areas along the small rivers. Coastal plain is utilized for palm and casava plantation.

2.2.2 Geology

General

The geology along the proposed pipeline routes are consisted of granite, palaeozoic sedimentary rocks and alluvial deposites.

Palaeozoic sedimentary rocks are mainly consisted of slate, limestone, and phyllite. Surface soils around this area are mainly consisted of loose sandy clay and clayey sand. And also below these surface soils, residual soil is developed. The thickness of these layers are 1.0 to 3.0 meters, and 1.0 to 5.0 meters respectively. Below these layers, decomposed granite and decomposed sedimentary rocks are observed especially in hilly area. Some of the small rivers, which across the proposed pipeline route, alluvial deposite are observed in riverbeds. The thickness of these layers are 1.0 to 5.0 meters which consisted of fine to coarse loose sand and loose clayey sand. Ground water level in hilly area is generally between 3.0 to 7.0 meters from surface. During the dry season the ground water level falls 2.0 to 3.0 meters below that of the wet seasons.

Subsurface Investigation

Subsurface investigation was done by surface exploration and by using a dynamic corn tester at 6 points.

Ground water levels were checked at wells along the proposed pipeline route. Geological maps include geological profiles along the proposed pipeline routes are shown on Fig. 2-6 to 2-9. Dynamic corn test logs are shown on Fig. 2-10 to 2-15.

1) Intake and Pumping Station

Intake and pumping station site is proposed on down stream of Dok Krai Dam or in Dok Krai Reservoir. The location map is shown on Fig. 2-2. The geological profile of each site is presumed in Fig. 2-3 to 2-5 according to the geological survey and existing boring data on Dok Krai reservoir. Basement of these alternative sites are granite, and above the basement, sand, silty sand and clayey sand layers are developed.

At the site of type A which is mentioned below, the total thickness of these surface layers is 3 to 8 meters. N value (blow count) of S.P.T. in these surface layers has 3 to more than 50, which depends on a soil condition, but N value shows about 20, below 3 meter from the ground surface. The N value of basement is more than 50.

At the below-mentioned Type B and C sites, the total thickness of surface layer is presumed 4 to 10 meters by geological condition shown on Fig. 2-4 and Fig. 2-5. During the detail design work, some more boring tests are required to decide the foundation of the structures.

2) Pipeline

The geology of proposed pipeline routes show on Figs. 2-4 and 2-9 as geological maps and geological profiles. Most part of proposed pipeline routes, the basement is granite. Near Sattahip and Laem Chabang, however, the geology changes to palaeozoic sedimentary rocks. As for the granite area, loose sand and clayey sand which comprise top soil layer and residual soil layer cover decomposed granite. The thickness of these layer is 1.0 to 3.0 meters. The residual soil layer consisted of sand and clayey sand is developed under top soil layer. The thickness of this residual soil layer is about 1.0 to 5.0 meters. Under these layers decomposed granite layer is observed. The thickness of this decomposed granite is more than 10 meters, and fresh granite could not observed along the proposed pipeline routes, except proposed Head Tank site, 1.5 km northeast from Ban Nikhom.

As for the palaeozoic sedimentary area, loose sandy layer called as top soil layer and residual soil layer covered the weathered palaeozoic sedimentary rocks. The total thickness of these layer is 1.0 to 3.0 meters. Weathered or decomposed layer is observed under the top soil and residual soil layer. The thickness of this layer is more than 5 meters. Fresh basement is not observed along the proposed pipeline routes.

Alluvial deposites are also developed in river-beds across the proposed pipeline routes. Alluvial deposite consisted of loose sand, sandy clay, and clayey sand. The thickness of alluvium deposite is 1.0 to 5.0 meters.

Dynamic cone tests were done at six points along the proposed pipeline routes. According to the test, N value increases gradually proportional to the depth from the surface. Around 3 meters below the surface, N value shows more than 20, except Test No. 7.

Main two rivers cross the pipeline route on a way from Mab Ta Pud to Sattahip. Dynamic test No. 7 and No. 8 were done at the river-bed of these two rivers. According to the logs the thickness of alluvial deposite on these rivers are more than 4 meters and 3 meters respectively. N value at the bottom of these holes are 20 at 4 meters, and more than 50 at 5 meters.

3) Head Tank

The main head tank is proposed on a hill, located 1.5 km northeast from the Ban Nikhom. The geology of this area consists of granite and surface soil condition is shown in Fig. 2-6. Around the hill, there are many out crops of granite, and granite basement is also observed on a hill. Therefore, as for the foundation of Head Tank, no problems are found geologically.

4) Other Construction Sites

According to the pipeline design, several head tanks are proposed from Dok Krai Reservoir to Laem Chabang and along Route No. 3. All of the head tanks are located on a small hill. And the basement of these hills are granite or decomposed granite. Around these hills, granite out crops, and thin surface layer are observed. These sites will be a good basement for foundation.

Along the pipeline route from Dok Krai to Laem Chabang, 9.0 km long tunnel is proposed. Except the surface layer and decomposed granite zone, most part of the tunnel will be constructed in fresh granite zone.

2.2.3 Water Quality of Dok Krai Reservoir

There is a wide range in standards of water quality required by the end use purposes.

Presented here in this Report, is a part of the data for the water quality analysis which is performed for the purpose of site location of the proposed purification plant. Also included here is data of monthly water quality analysis. (Refer to Tables 2-2 and 2-3).

The related Water Quality Standards are presented in Table 2-4 Water Quality Standards (for drinking), Table 2-5 Japanese Industrial Water Quality Standards and Table 2-6 Water Quality Standards, WHO.

Check-out with the Standards shows the Dok Krai reservoir water is relatively better in quality required for industrial purposes, so that no damage will be caused in water transmission facilities on route.

As Fe and Mn contents are relatively small, practically no damage to the water transmission facilities is anticipated.

It is recommended to locate the purification plant near to the demand area so that raw water is transmitted to the purification plant by pipeline.

As the quality of water has a mighty effect not only on the water transmission facilities but also on the design of purification plant, collection of more detailed data is required.

2.2.4 Existing Conditions of Related Major Facilities

Road

For the construction and administration of the pipeline, construction and administration roads are required, and usually one road serves for the both purposes. If a marginal strip of the existing road is readily available, it will contribute to easier construction, maintenance and administration of the pipeline, and also to lower the time and cost required for the construction.

It is fortunate that the main highways mentioned below is able to serve the purpose.

Section	Route No.
Dok Krai - Mab Ta Pud	3191 & 3
Mab Ta Pud - Sattahip	3
Dok Krai - Laem Chabang	3191, 36 & 3

Power Transmission

There is a fair chance to rely on the existing 22 kv power line, running along Route 36, from Ao Phai substation to Rayong substation, and from there, running along Route 3, to Ban Chang and running along Route 3191 to Dok Krai Damsite, for the power source for the pipeline construction and pumping station. The thermal power station at Bang Pakong is now in partial operation.

The transmission line 230 kv, from Bang Pakong thermal station will be extended to reach Rayong III substation via Ao Phai before October 1983. Taking the receiving from the two sources mentioned above into consideration, the receiving from existing power transmission line and Rayong III is available.

Fig. 2-16 shows the proposed power grid.

Gas Pipeline

A part of the underground gas pipeline between the Natural Gas Plant at Mab Ta Pud and Bang Pakong is laid along Routes 3191 and 36. As the proposed water pipeline runs close parallel with the existing gas pipeline, a special consideration with respect to prevention of adverse effects on the gas pipeline during construction and of corrosion later on. If electrolytic corrosion proof treatment is applied to the gas pipe, the water pipe should receive the same, otherwise, the water pipe will be heavily damaged by the resulted from electrolytic corrosion.

Fig. 2-17 is a layout map and Fig. 2-18 is a standard cross section of the proposed pipeline.

3. PROJECT FORMULATION

3.1 GENERAL DESCRIPTIONS OF THE SYSTEM

3.1.1 General Conditions of the Required Facilities

Puming-up system

Closed type and open type may be considered for the required pumping system but open type pumping-up system is to be used because of the reasons as below

- As for the closed type system, there is no free water surface on the pipeline route, so water-hammer problem is inevitable.
- In the closed type system, control of the system is very difficult because pipeline length is very long.
- In the open type system, there is free water surface in a head tank and boosted water flows down to

recieving end by gravity flow. Water hammer problem will be reduced between head tank and recieving end.

- On behalf of the stored water in the head tank, it is easy to control flow rate difference between supply head and recieving end.

Pumping Station

Two pumping stations are required. One is a pumping station to deliver the reservoir storage and/or water from outlet works of the Dok Krai dam to the receiving ends, and the other is booster pumping station to be located on the midway of the route for compensation of head loss.

Water Transmission Facilities

1) Water transmission conduit

The purpose of transmission conduit is to convey required water to the destinations safely.
As natural flow is considered for the conduit, adoption of an open type conduit is practical and there are a number of types considered as suitable.

However, for the channel, due to the reasons below, an embedded conduit may have to be specified.
- Keep off soil, dust and garbage from outside
- Prevent loss during transmission such as evaporation loss and unauthorized use of water
- Prevent disturbance from outside

2) Head tank

In the open type pumping-up system, head tanks are necessary for storage of the pumped-up water. The evaluation of the head tank varies with the elevation of the receiving well and the pipe diameter of the pipeline.

Purification Plant

Though the purification plant project is not within the scope of the present study, the location and scale of the proposed purification plant is too important to be neglected in location of the receiving well. As the water quality of Dok Krai reservoir has not been fully investigated yet, therefore, the location study here at present is mostly limited to the location of the proposed purification plant based on the data of similar capacity plants in operation.

As described in 2.2.3 in the foregoing, the water quality of Dok Krai reservoir is relatively good, the purification plant shall be located near the demand areas because of the reasons as mentioned below.