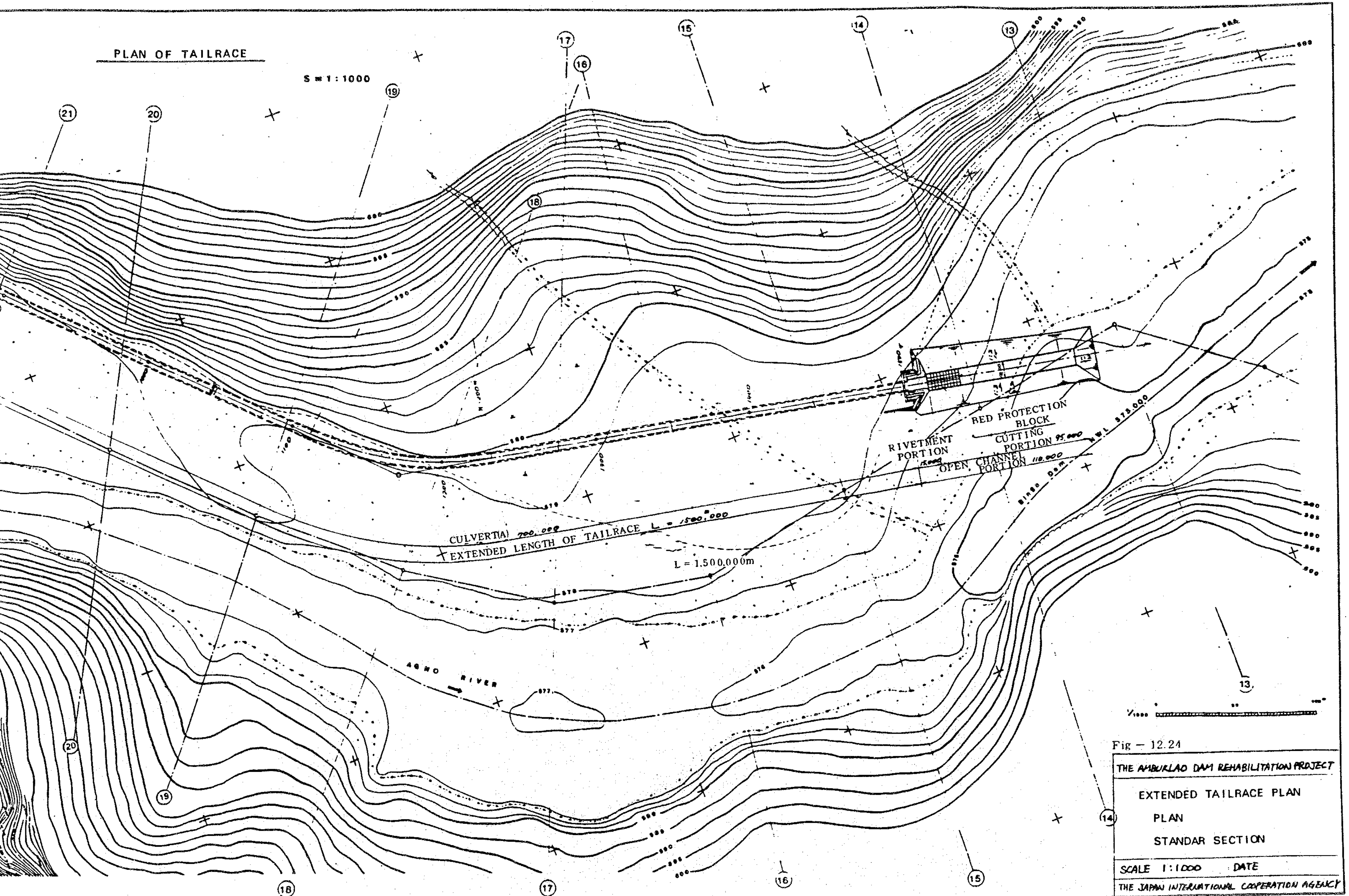


Fig — 12.24

THE AMBURLAO DAM REHABILITATION PROJECT

EXTENDED TAILRACE PLAN

PLAN

STANDAR SECTION

SCALE 1:1000 DATE

THE JAPAN INTERNATIONAL COOPERATION AGENCY

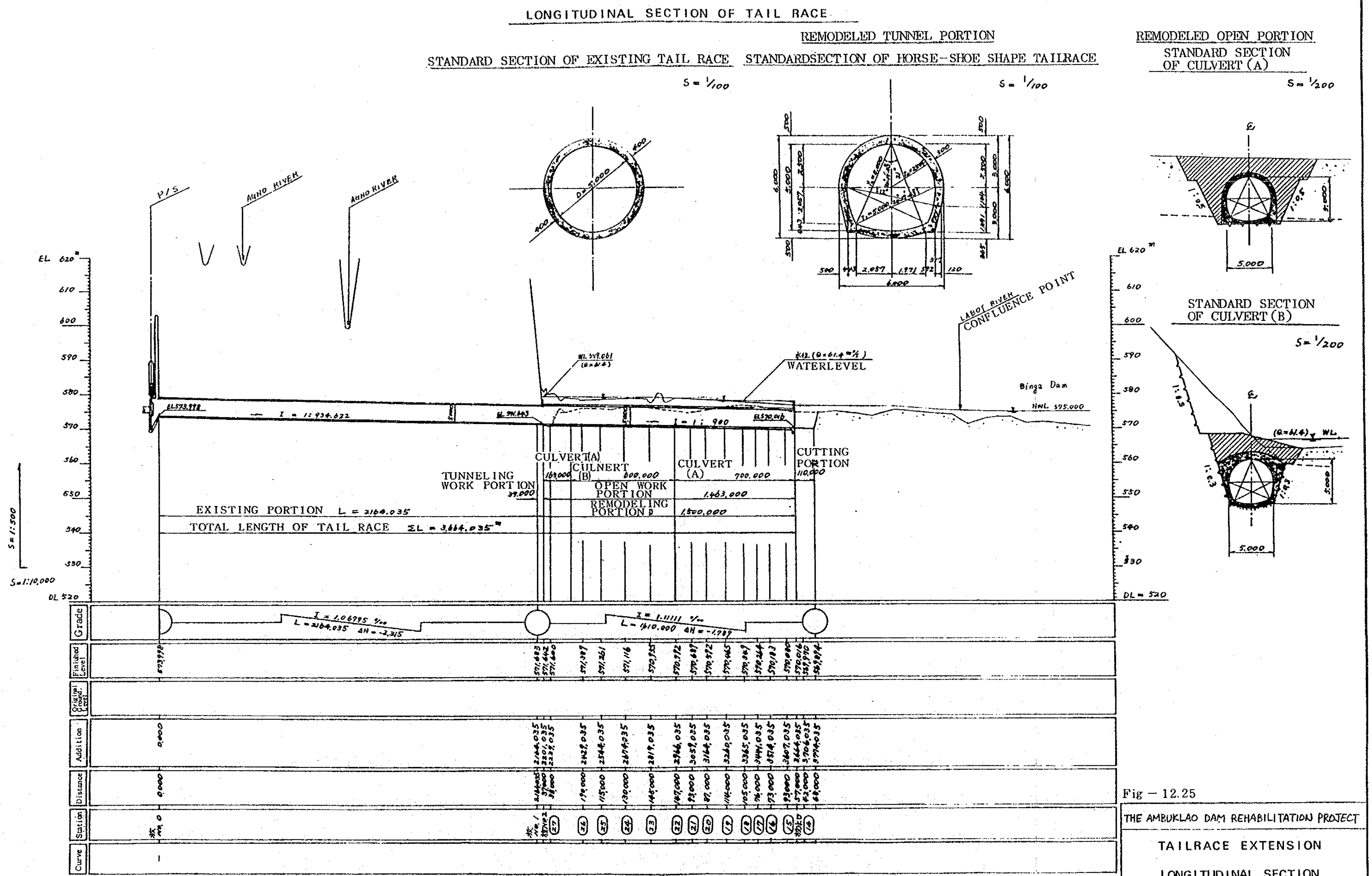


Fig — 12.25

THE AMBUKLAO DAM REHABILITATION PROJECT

TAILRACE EXTENSION

LONGITUDINAL SECTION

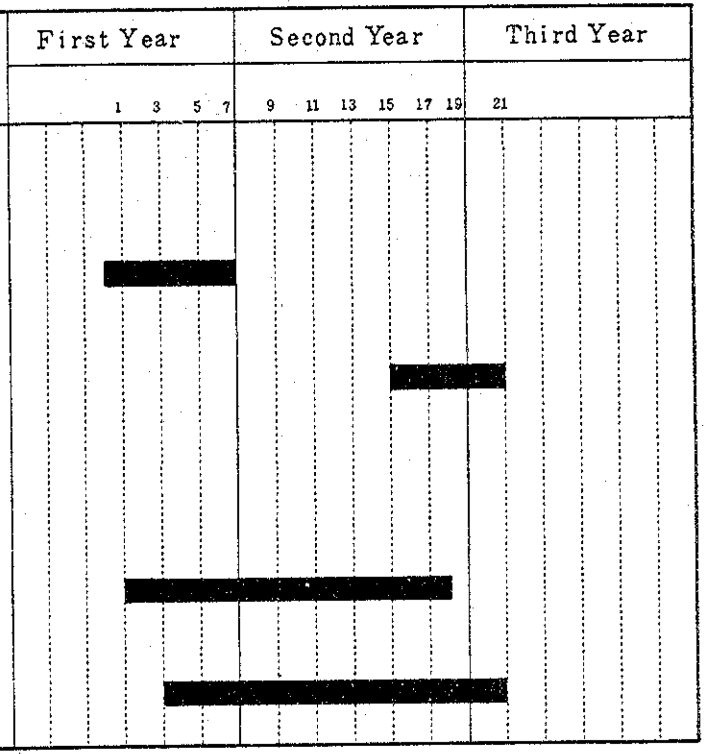
STANDARD SECTIONS

SCALE As shown | DATE

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Fig — 12.26 Scheme H Extended Tailrace Plan

Work Item	Quantity
A. Temporary Work	
1. Access Road	L=2,500m
B. Tunneling Work	L= 37m
C. Open Excavation Work	
1. Culvert Work	L=1,463m
2. Open-Cut Work	L= 110m



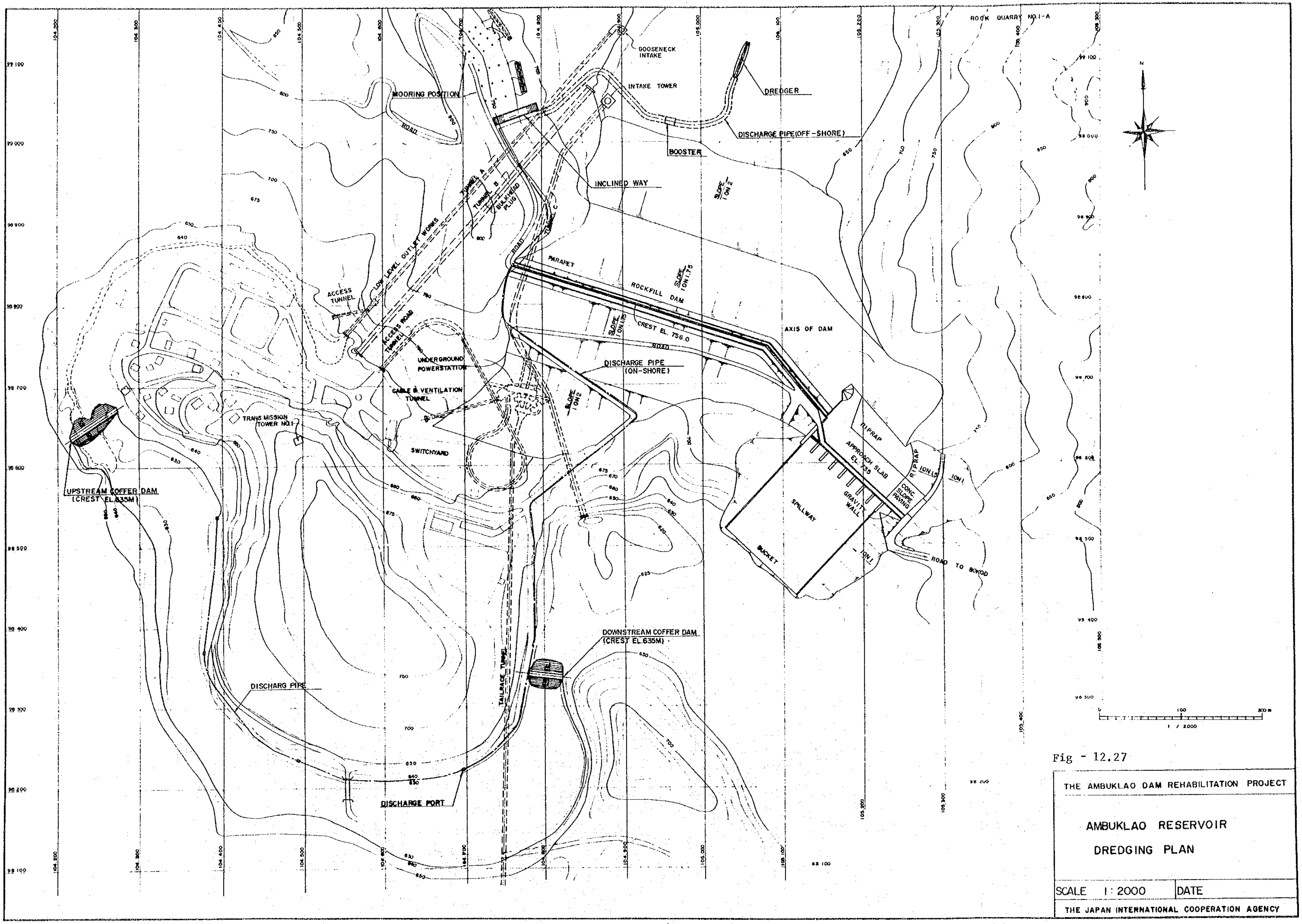


Fig - 12.27

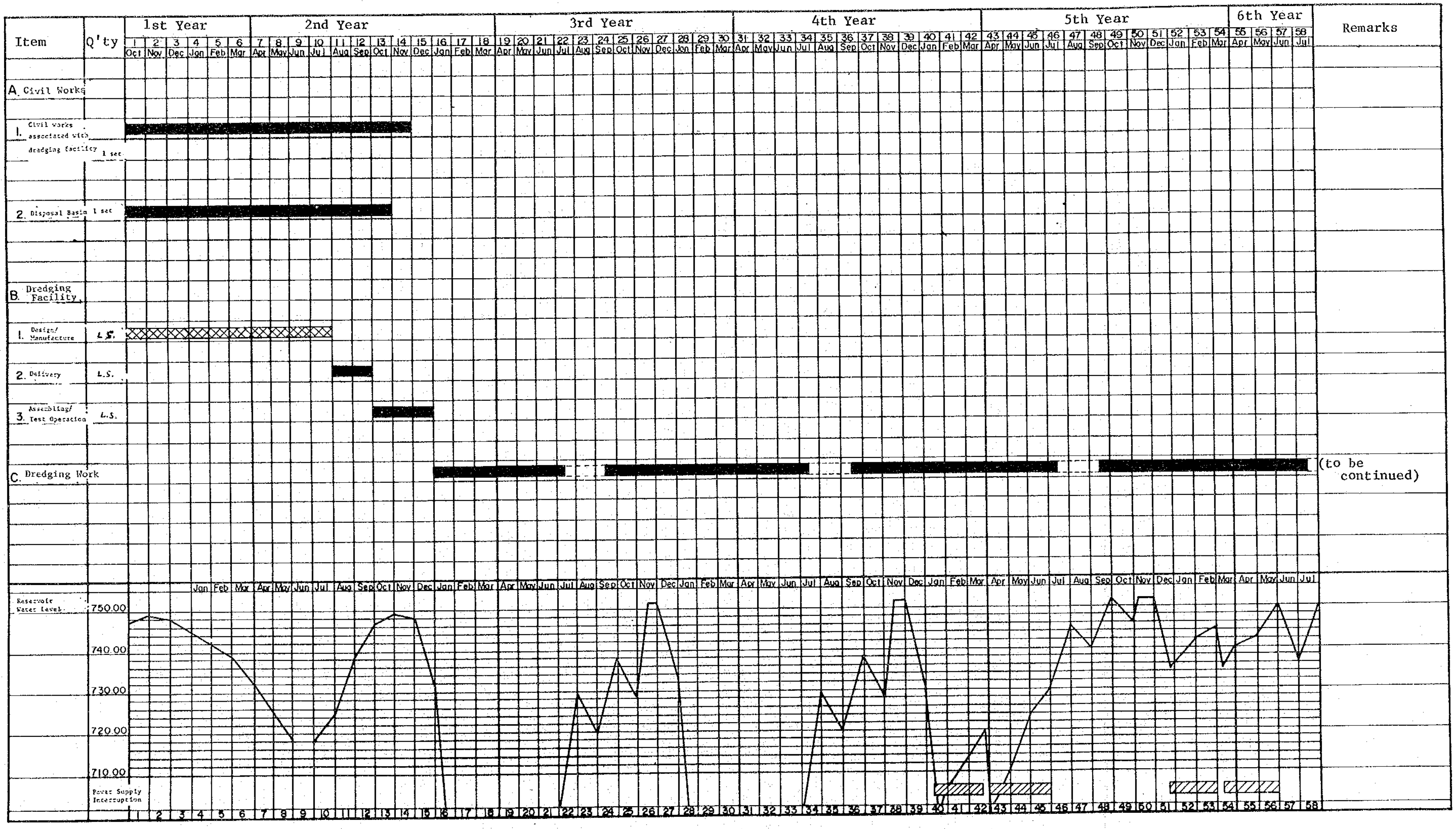
THE AMBUKLAO DAM REHABILITATION PROJECT

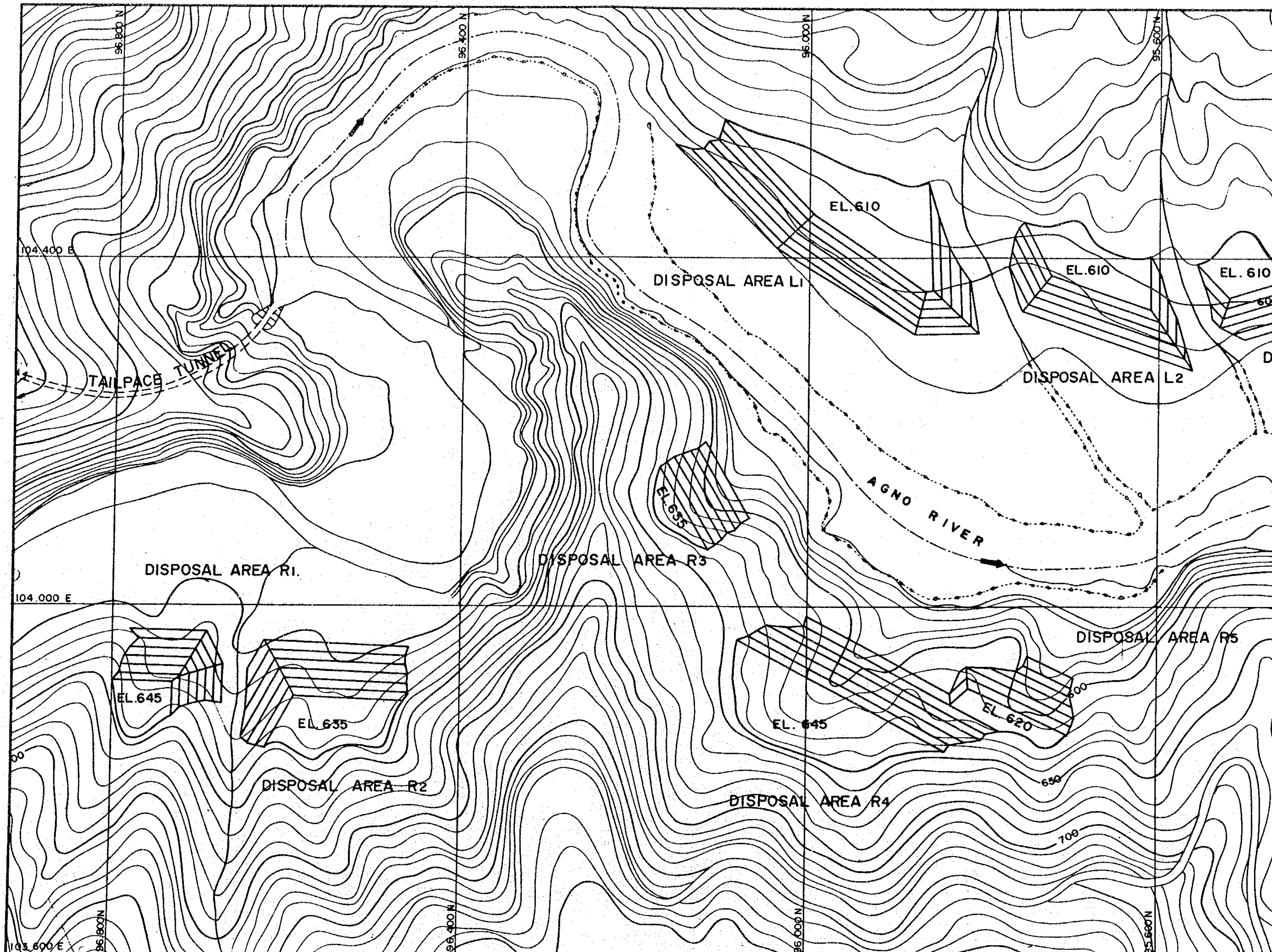
AMBUKLAO RESERVOIR
DREDGING PLAN

SCALE 1 : 2000 | DATE

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. - 12.28 Scheme 0 : Dredging Around Intake Tower

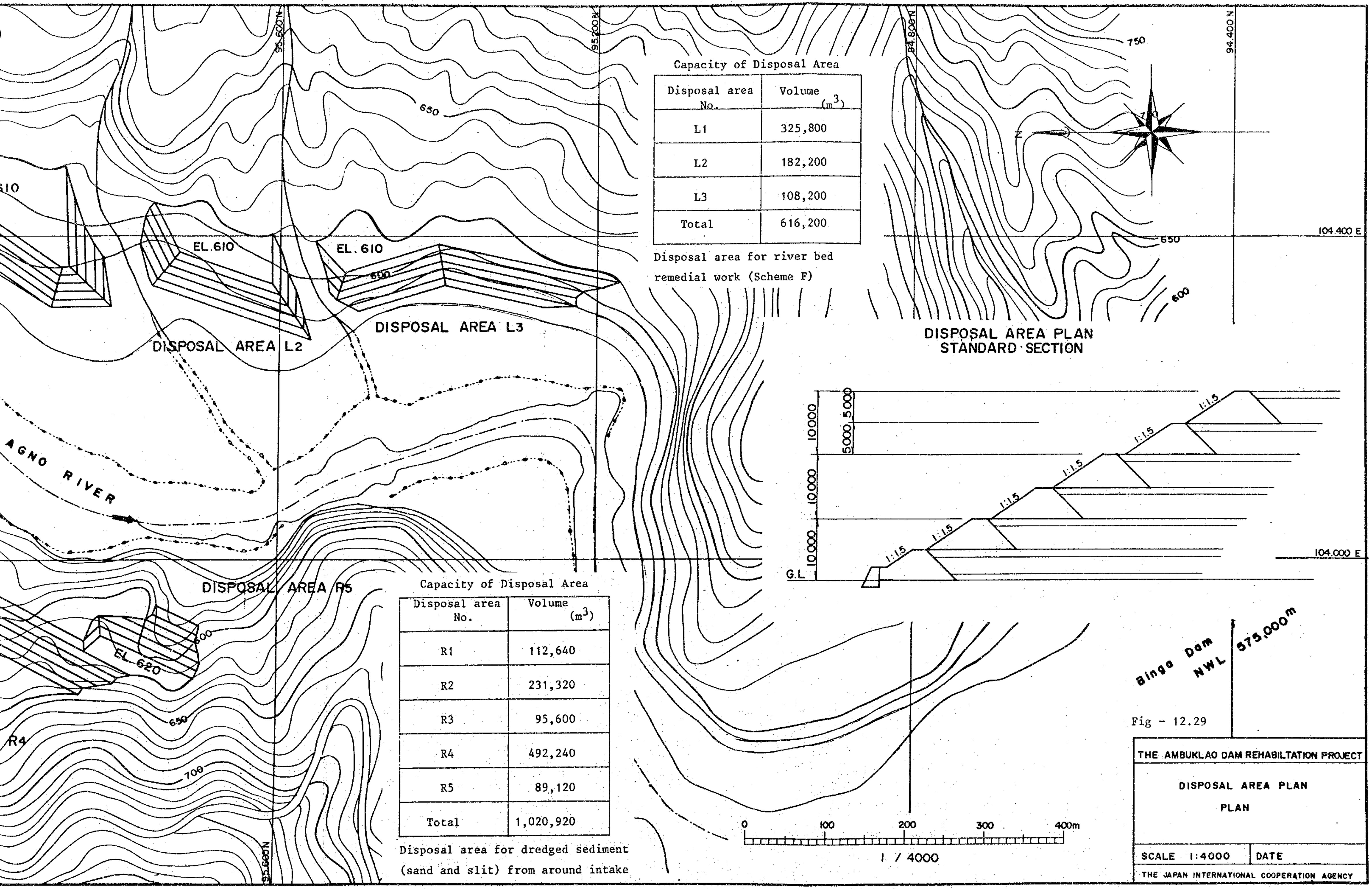




Capacity of

Disposal are No.
R1
R2
R3
R4
R5
Total

Disposal area
(sand and sli



Capacity of Disposal Area

Disposal area No.	Volume (m^3)
L1	325,800
L2	182,200
L3	108,200
Total	616,200

Disposal area for river bed remedial work (Scheme F)

Capacity of Disposal Area

Disposal area No.	Volume (m^3)
R1	112,640
R2	231,320
R3	95,600
R4	492,240
R5	89,120
Total	1,020,920

Disposal area for dredged sediment (sand and slit) from around intake

Fig - 12.29

THE AMBUKLAO DAM REHABILTATION PROJECT

DISPOSAL AREA PLAN

PLAN

SCALE 1:4000 | DATE

THE JAPAN INTERNATIONAL COOPERATION AGENCY

12.3. Construction Cost

The construction costs for Schemes A, B, C, D, E, F and H were computed and are shown in Table 12.3 through 12.9. The most economical alternatives were selected by making a comparative study of various schemes investigated.

Economic comparison of schemes A, B, D, E, F and H is given in Table-12.10.

The economic studies were made using the following assumptions:

Period	:	14 years from 1992 to 2005
Discount rate	:	10, 12, 14, 16%
Exchange rate	:	US$1 = ₱21 = ¥150
Unit cost for evaluation of generated energy	:	16 Wh = 26.071 x $$10^3$

This value was obtained by calculating only the variable costs based on oil fired powerplants, now in operation, which have relatively poor thermal efficiency.

Fuel Price	14.311 $/bbl
Heat content	6.21 MBTU/MWh
Heat Rate	10.753 MBTU/MWh
	(corresponding to thermal efficiency 31.74%)
Variable O/M Ratio	1 %
Station Use Rate	4 %

The costs were calculated after converted to 1991 values by the following three classifications:

(a) Initial construction cost
(b) Maintenance cost thereafter
(c) Cost for evaluation of generated energy

The calculation results are summarized in Table-12.11. The most economical scheme is Scheme (E) among Plans (A), (B), (D) and (F). The additional work for Schemes (F) and (H) produce less additional generated energy as compared with the construction cost involved, and, therefore they are considered to be uneconomical.

Table—12.3 Scheme A: Removal of Sediments by Big Dredging Boat

Unit : US$ 1,000

Work Item	Quantity	Amount	Unit Price	1992	1993	1994	1995	1996	1997
1. Associated Work for Dredging	1 LS	400		160	240				
2. Disposal Pond	1 LS	1,000		400	600				
3. Dredging Equipment	1 LS	22,640		6,792	15,848				
4. Dredging Work	$2{,}250 \times 10^3$ m^3/year	18,000				4,500	4,500	4,500	4,500
Total		42,040		7,352	16,688	4,500	4,500	4,500	4,500

Table – 12.4 Scheme B : Heightening of the Existing Intake Tower

Unit : US$ 1,000

Work Item	Quantity	Amount	Unit Price	1992	1993	1994	1995	1996	1997
1. Construction Road	L= 500m	640		640					
Crusher-run	15,000m³								
Slope Protection	500m³								
Concrete Pavement	700m³								
2. Excavation		2,910		700	750	750	710		
Cutting									
Steel Pile Foundation	5m×80PCS								
3. Piling Work		17,950		950	5,000	5,000	5,000	2,000	
Steel Pile	80m×80PCS								
Concrete	3,620m³								
4. Reinforcement of Intake Tower		2,500						2,500	
5. Removal of Top of Intake Tower	1 LS	1,550					1,550		
6. Manufacture of Ring	1 LS	850					500	350	
7. Installation of Ring	1 LS	9,170						4,430	4,740
8. Disassenbly of Barge	1 LS	300							300
Total		35,870		2,290	5,750	5,750	7,760	9,280	5,040

Table — 12.5 Scheme C : Provision of a Large Capacity Sediment Removal Facility

Unit : US$ 1,000

Work Item	Quantity	Amount	Unit Price	1992	1993	1994	1995	1996	1997
I. Civil Work		32,550		2,177	9,271	12,525	8,577		
1. Tunneling Work		8,400		519	3,007	2,593	2,281		
Temporary Facility	1 LS								
Excavation	65,100m³								
Concrete	9,700m³								
2. Inlet		903		205	452	246			
Concrete	2,580m³								
3. Discharge-zone Work		23,247		1,453	5,812	9,686	6,296		
Temporary Facility	1 LS								
Excavation	223,330m³								
Concrete	71,800m³								
Embankment & Disposal of Sediment	223,330m³								
II. Gate Work		17,150		507	6,724	1,344	6,019	2,556	
1. Temporary Work	1 LS	1,762			881		176	705	
2. Manufacture of Gate	940t	9,118		507	4,052		4,052	507	
3. Transport & Installation Cost	1 LS	6,270			1,791	1,344	1,791	1,344	
Total		49,700		2,684	15,995	13,869	14,596	2,556	

Table − 12.6 Scheme D : Provision of a New Intake Tower (Inclined Type)

Unit : US$ 1,000

Work Item	Quantity	Amount	Unit Price	1992	1993	1994	1995	1996	1997
1. Construction Road	L= 500m	640		640					
Crusher−run	15,000m³								
Slope Protection	500m³								
Concrete Pavement	700m³								
2. Excavation		1,200		600	600				
Cutting									
Steel Pile Foundation	5m×33PCS								
3. Piling Work		6,000			2,500	3,500			
Steel Pile	60m×33PCS								
Concrete	1,300m³								
4. Concreting of Support		2,480			200	1,670	610		
Under Water						1,500	610		
On the Water					200	170			
5. Removal of Top of Intake Tower	250m³	1,550					1,550		
6. Slide Gate	1 LS	13,940			7,510	1,780	3,820	830	
7. Disassenbly of Barge	1 LS	300						300	
Total		26,110		1,240	10,810	6,950	5,980	1,130	

Table – 12.7 Scheme E : Provision of a New Intake (Vertical Type)

Unit : US$ 1,000

Work Item	Quantity	Amount	Unit Price	1992	1993	1994	1995	1996	1997
1. Construction Road	L= 500m	970		970					
Crusher-run	26,000m²	820							
Slope Protection	500m²	80							
Concrete Pavement	700m²	70							
2. Work shop									
Cutting	25,000m³	200		200					
3. Pneumatic Caisson		1,700			1,000	700			
Excavation	5,000m³	325							
Concrete	1,100m³	198							
Temporary Facility	1 LS	1,177							
4. Shaft		3,910				3,300	610		
Drilling	7,000m³	280							
Concrete	3,100m³	775							
Temporary Facility	1 LS	2,855							
5. Plugging Work	550m³	350					350		
6. Intake Tower	8 gates	520					520		
7. Sylinder Gate	1 LS	11,700			5,637	3,283	2,410	370	
Total		19,350		1,170	6,637	7,283	3,890	370	

Table — 12.8 Scheme F : Rever—bed Excavation

Unit : US$ 1,000

Work Item	Quantity	Amount	Unit Price	1992	1993	1994	1995	1996	1997
1. Access Road	L= 2,500 m	152						152	
Excavation	4,000 m^3								
Slope Protection	500 m^2								
Pavement Work	400 m^2								
2. Riverbed Arrangement Work		1,181						1,181	
Temporary Work	1 LS								
Excavation	75,000 m^3								
Disposal of Sediment	75,000 m^3								
Others	1 LS								
Total		1,333						1,333	

Table — 12.9 Scheme H: Tailrace Extension

Unit: US$ 1,000

Work Item	Quantity	Amount	Unit Price	1992	1993	1994	1995	1996	1997
I. Temporary Work									
1. Construction Road	L= 2,500 m	640				640			
Excavation	75,000 m³								
Slope Protection	3,500 m²								
Pavement Work	700 m²								
II. Tunneling Work		360					160	200	
Temporary Work	1 LS								
Excavation	2,143 m³								
Concrete	360 m³								
Plugging Work	245 m³								
III. Open Excavation Work		10,900				3,500	7,300	100	
1. Culvert Work		10,300				3,500	6,800		
Temporary Work	1 LS								
Excavation	152,600 m³								
Concrete	20,544 m³								
2. Open-cut Work		600					500	100	
Temporary Work	1 LS								
Excavation	19,250 m³								
Concrete	622 m³								
Total		11,900				4,140	7,460	300	

Table − 12.10 Yearly Construction Cost & Generated Energy Comparison

Unit : US$ 1,000

		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2005	2010	2015	2020	2025	2030	2035
Generated Energy Estimate (GWH) (Potential)		352.2	358.7	358.3	358.0	357.6	357.3	357.0	356.8	356.5	356.2	355.9	355.4	355.1	354.7	354.2	351.3	345.7	339.2	325.1	315.7	314.5
Scheme / Description	Item \ Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2005	2010	2015	2020	2025	2030	2035
A Removal of Sediments by Big Dredging Boat 213,040	Generated Energy (GWH)	352.2	358.7	358.3	358.0	357.6	357.3	357.0	356.8	356.5	356.2	355.5	355.2	355.1	354.7	354.2	351.3	345.7	339.2	325.1	315.7	314.5
	Construction Cost						7352	16688	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
	Suspension of Current (S/C)						—	—	—	—	—	—	—	—	—							
	Energy to be used (GWH)	—	—	—	—	—	—	—	—	27.0 —	27.0 —	27.0 —	27.0 —	27.0 —	27.0 —	27.0	27.0	27.0	27.0	27.0	27.0	27.0
B Heightening of the Existing Intake Tower 51,281	Generated Energy (GWH)	352.2	358.7	358.3	358.0	357.6							355.2	354.9	354.6	352.5	350.4	345.7	339.8	325.1	316.4	314.5
	Construction Cost						2290	5750	5750	7760	9280	5040				5137		5137		5137		
	Suspension of Current (S/C)						S/C	S/C	S/C	S/C	S/C	S/C										
	Energy to be used (GWH)	—	—	—	—	—	—	—	—	—	—	—	—	—	—							
C Provision of a Large Capacity Sediment Removal Facility 49,700	Generated Energy (GWH)	352.2	358.7	358.3	358.0	357.6						355.5	355.2	354.9	354.6	352.5	350.4	345.7	339.8	325.1	316.4	314.5
	Construction Cost						2684	15995	13869	14596	2556											
	Suspension of Current (S/C)																					
	Energy to be used (GWH)																					
D Provision of a New Intake Tower (Inclined Type) 26,110	Generated Energy (GWH)	352.2	358.7	358.3	358.0	357.6						355.5	355.2	354.9	354.6	352.5	350.4	345.7	339.8	325.1	316.4	314.5
	Construction Cost						1240	10810	6950	5980	1130											
	Suspension of Current (S/C)							S/C	S/C	S/C	S/C											
	Energy to be used (GWH)																					
E Provision of a New Intake Tower (Vertical Type) 19,350	Generated Energy (GWH)	352.2	358.7	358.3	358.0	357.6	391.7	342.9	342.0	339.1	333.6	355.5	355.2	354.9	354.6	352.5	350.4	345.7	339.8	325.1	316.4	314.5
	Construction Cost						1170	6637	7283	3890	370											
	Suspension of Current (S/C)						Plant Operated at LWL	〃	〃	S/C	〃											
	Energy to be used (GWH)						Jan~Mar	Apr~Jun Jan~Mar	Apr~Jun Jan~Mar	Apr~Jun Jan~Mar	Apr~Jun											
F Rever-bed Excavation 13,800	Generated Energy (GWH)							3.0	3.0	2.7	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.5	2.4	2.4
	Construction Cost										1333		733		733		3667		3667		3667	
	Suspension of Current (S/C)																					
	Energy to be used (GWH)																					
H Tailrace Extension 11,900	Generated Energy (GWH)											1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.0	1.0
	Construction Cost								4140	7460	300											
	Suspension of Current (S/C)									Jan~Mar	Apr~May											
	Energy to be used (GWH)																					

Table − 12.11

Calculation Result (1)

Scheme	Cost	Discount Rate (%)			
		10	12	14	16
A	(a)	3,317.00	3,186.95	3,064.47	2,948.98
	(b)	5,435.16	4,707.29	4,099.27	3,588.26
	Total	8,752.16	7.894.24	7,163.74	6,537.24
	(10^6 $)	(65.12)	(58.74)	(53.30)	(48.64)
B	(a)	3,759.18	3,520.80	3,303.71	3,105.58
	(b)	202.92	157.68	123.07	96.48
	Total	3,962.10	3,678.48	3,426.78	3,202.06
	(10^6 $)	(29.48)	(27.37)	(25.50)	(23.82)
D	(a)	3,010.33	2,866.99	2,733.64	2,609.38
	(10^6 $)	(22.40)	(21.33)	(20.34)	(19.42)
E	(a)	2,284.92	2,179.35	2,080.94	1,989.05
	(10^6 $)	(17.00)	(16.22)	(15.48)	(14.80)
F	(a)	287.27	282.14	277.19	272.41
	(b)	1,420.67	1,261.77	1,127.47	1,013.20
	Total	1,707.94	1,543.91	1,404.66	1,285.61
	(10^6 $)	(12.71)	(11.49)	(10.45)	(9.57)
	(c)	(0.465)	(0.414)	(0.371)	(0.334)
H	(a)	1,258.80	1,178.69	1,105.07	1,037.29
	(10^6 $)	(9.37)	(8.77)	(8.22)	(7.72)
	(c)	(0.112)	(0.095)	(0.080)	(0.069)

〔Note〕 Unit : 100 Million Yen, However Unit in parenthesis is US $ 10^6

Calculation Result (2) …… Cost for evaluation of generated energy in plan (A)

Scheme	Cost	Discount Rate (%)			
		10	12	14	16
A	(10^6 $)	(3.43)	(2.97)	(2.59)	(2.27)

12.4. Total Cost and Further Investigation for Rehabilitation Work

12.4.1. Estimate of Total Cost for Rehabilitation Work

The total cost for the proposed rehabilitation work including the rehabilitation work required for the intake tower, Scheme E, is shown in Table 12.12. The cost of the construction work in foreign and local currencies and the associated yearly expenses are summarized in Tables-12.13 through 12.19.

12.4.2. Further Investigation for Rehabilitation Work

It is essential to undertake additional survey and investigation prior to the implementation of the rehabilitation program as mentioned below, so as to ensure a smoother progress of the detailed design work. Such survey and investigation should be commenced from 1989 and completed by the end of 1990 at the latest. (See Table-12.20)

(1) Topographic Survey

A considerable area was covered by the additional topographic survey work done for this report, but further survey will be needed to confirm the adequacy of the proposed sites for the new intake tower and dredging facilities, and the proposed quarry site and spoil bank. Also additionally needed is sounding survey of the upstream side slope of the dam and route survey for the construction of access roads to the tailrace.

(2) Boring Tests

A series of additional geological survey will be needed to support the study of designing and construction methodology of structures. To be covered by the survey is the geology of the proposed site for the new intake tower, particularly for the vertical shaft and its connection to the existing headrace tunnel, and the distribution of base rock masses at the quarry site. Boring tests will also be needed for clarifying the geology and soil properties of the proposed spoil bank and two sedimentation basins for dredging. Some 20 bores with a total length of about 800 m will be required for the purpose.

(3) Geophysical Prospecting

Upon confirmation to some extent of the geology of the quarry site by boring tests, further detailed investigation by means of seismic prospecting and exploratory drilling should be done to clarify the distribution of rock masses. Field rock tests should also be done, utilizing a drain adit installed on the left bank of the spillway.

(4) Other Tests

Laboratory tests of soil and rock materials for the dam embankment and the spoil bank foundation should be done on the samples taken from the boring tests and other geological investigations to support the design work. Soil and rock materials in the fault zone in the vicinity of the left bank of the spillway should also be tested for future design work. It may also be useful for the future dredging program to make laboratory tests on the samples of sand silts in the reservoir, including among others congulation test, sedimentation test and consolidation test.

Besides, it may be necessary to check the state of the turbine inlet valves to support the planning of repair and replacement. Chances of repairing turbines should be utilized for the check. It may also be necessary to check the state of the inlet of the existing intake tower to prepare for the future design work and the planning of work schedules. The check may be done in detail by sending a diver down to the inlet at the time when the reservoir water level comes down and the plant can be taken out of service.

Table - 12.12 Summary of Rehabilitation Cost for Ambuklao Dam

Unit : US$ 1Million

Work Item	Foreign Portion	Local Portion	Total
1. Cost for Rehabilitation Work			
Improvement of Intake Tower	12.522	6.828	19.350
Improvement of Turbine Inlet Valve	1.800	0.333	2.133
Riverbed Arrangement at Tailrace Outlet	0.347	0.986	1.333
Dredging around Intake Tower	3.180	2.276	5.456
Dam Upstream Face Rehabilitation	1.907	5.426	7.333
Subtotal	19.756	15.849	35.605
2. Cost for Investigation			
Boring	—	0.113	0.113
Physical Prospecting	—	0.020	0.020
Survey	—	0.180	0.180
Tests	—	0.057	0.057
Subtotal		0.370	0.370
3. Right of way Cost	—	0.500	0.500
4. Engineering Fee	1.800	—	1.800
5. NAPOCOR Administration Fee	—	0.600	0.600
6. Contingency	1.941	1.620	3.561
7. Total	23.497	18.939	42.436

Table — 12.13 Yearly Expenses for Rehabilitation Work

Unit : US $ 1,000

Work Item		Total Cost	1989	1990	1991	1992	1993	1994	1995	1996
		1,000 $								
1. Rehabilitation Cost										
Intake Tower		19,350.0				1,170.0	6,636.7	7,283.3	3,890.0	370.0
Turbine Inlet Valve		2,133.0								2,133.0
Tailrace Outlet Area		1,333.0								1,333.0
Intake Tower Area	☆	(5,456.0)		406.6	1,346.6	1,426.7	357.3	357.8	357.3	357.3
	★	3,705.3			133.3	524.0	404.7	404.7	404.7	404.7
Dam Upstream Face		7,333.0					200.0	2,200.0	2,666.7	2,266.3
Subtotal	☆	(35,605.0)		(406.6)	(1,479.9)	(3,120.7)	(7,241.4)	(9,888.0)	(6,961.4)	(6,507.0)
	★	33,854.3			133.3	1,694.0	7,598.7	10,245.3	7,318.7	6,864.3
2. Investigation Cost		370.0	200.0	170.0						
3. Right-of-way Cost		500.0			166.7	166.6	166.7			
4. Engineering Fee		1,800.0	466.6	466.7	466.7	400.0				
5. NAPOCOR Administration Fee		600.0		66.7	66.7	93.3	93.3	93.3	93.3	93.4
6. Contingency		(3,561.0)								
		3,561.0		40.7	148.0	312.1	724.1	988.8	696.1	651.2
7. Total	☆	(42,436.0)	(666.6)	(1,150.7)	(2,328.0)	(4,092.7)	(8,225.5)	(10,970.1)	(7,750.8)	(7,251.6)
	★	40,685.3	666.6	744.1	981.4	2,666.0	8,582.8	11,327.4	8,108.1	7,608.9

☆ : ▨ + ▦ , ★ : ▩ + ▦

Table-12.14(a) Scheme E (Vertical Intake Tower) Construction Cost (№1)

Unit: US $ 1

Work Item	Specification	Q'ty	Unit	Unit Price	F.C.	L.C.	Total
A. Civil Work							
1. Construction Road						970,000	970,000
Excavation		5,000	m³	8		40,000	40,000
Crusher-run		26,000	m³	30		780,000	780,000
Slope Protection		500	m²	160		80,000	80,000
Concrete Pavement		700	m²	100		70,000	70,000
2. Working Area							
Excavation	Cutting	25,000	m³	8		200,000	200,000
3. Pneumatic Caisson					470,800	1,229,200	1,700,000
Temporary Facility					470,800	655,200	1,126,000
Excavation		5,000	m³	65		325,000	325,000
Concreting		1,100	m³	180		198,000	198,000
Re-bar		51	ton	1,000		51,000	51,000
4. Shaft					1,091,200	2,818,800	3,910,000
Temborary Facility		1	LS		1,091,200	1,518,800	2,610,000
Excavation		7,000	m³	75		525,000	525,000
Concreting		3,100	m³	250		775,000	775,000
5. Plugging Work					74,000	276,000	350,000
Temporary Facility		1	LS		74,000	102,950	176,950
Removal of Concrete		70	m³	115		8,050	8,050
Concreting		550	m³	300		165,000	165,000
6. Stop log					353,000	167,000	520,000
Setting of log		1	LS		115,000	142,000	257,000
Setting Equipment		1	LS		160,000	—	160,000
Others		1	LS		78,000	25,000	103,000
Total					1,989,000	5,661,000	7,650,000

Table－12.14(b) Scheme E (Vertical Intake Tower) Construction Cost (No.2)

Unit : US $ 1

Work Item	Specification	Q'ty	Unit	Unit Price	F.C.	L.C.	Total
B. Intake Tower Construction							
1. Temporary Facility	Tower Crane etc	1	L S		467,000	133,000	600,000
2. Embedded Portion					867,000	367,000	1,234,000
Manufacture		F.C70 L.C70	ton ton	7,640.00 3,330.00	534,800	233,100	767,900
Installation		1	L S		332,200	133,900	466,100
3. Intake Tower					6,246,000	267,000	6,513,000
Manufacture		600	ton	7,640.00	4,584,000	—	4,584,000
Installation		1	L S		1,662,000	267,000	1,929,000
4. Sleeve Gate					1,140,000	67,000	1,207,000
Manufacture		110	ton	7,640.00	840,400	—	840,400
Installation		1	L S		299,600	67,000	366,600
5. Hoisting Winch					1,813,000	133,000	1,946,000
Manufacture		180	ton	7,640.00	1,375,200	—	1,375,200
Installation		1	L S		437,800	133,000	570,800
6. Bridge					—	200,000	200,000
Manufacture		40	ton	3,330.00	—	133,200	133,200
Installation		1	L S		—	66,800	66,800
Total					10,533,000	1,167,000	11,700,000
Grand Total					12,522,000	6,828,000	19,350,000

Table − 12.15 Cost for Turbine Inlet Valve

Unit : US $ 1

Work Item	Specification	Q'ty	Unit	Unit Price	F.C.	L.C.	Total
1. Civil Work					−	11,000	11,000
Temporary Facility		1	L S		−	4,100	4,000
Foundation Work for Accessory Equipment					−	2,400	2,400
Removal of Old Foundation		5	m³	120	−	600	600
Concreting for New Foundation		6	m³	300	−	1,800	1,800
Foundation Work for Valve					−	4,500	4,500
Removal of Old Foundation		10	m³	120	−	1,200	1,200
Concreting for New Foundation		11	m³	300	−	3,300	3,300
2. Construction Work for Valve							2,122,000
Cost of Manufacture		90	ton	10,700	963,000	−	963,000
Removal of Old Valve		60	ton	5,350	321,000	−	321,000
Installation	Removal of Old Valve, Transport & Installation of New Valve				516,000	322,000	838,000
Total					1,800,000	333,000	2,133,000

Table — 12.16 Scheme F : Riverbed Arrangement Cost

Unit : US $ 1

Work Item	Specification	Q ty	Unit	Unit Price	F.C.	L.C.	Total
1. Access Road						152,000	152,000
Excavation		4,000	m³	8		32,000	32,000
Slop Protection		500	m³	160		80,000	80,000
Concrete Pavement		400	m³	100		40,000	40,000
2. Reverbed Arrangement					347,000	834,000	1,181,000
Temporary Work		1	L S		35,000	30,000	65,000
Excavation		75,000	m³	11.0	248,000	577,000	825,000
Disposal of Sediment		75,000	m³	3.2	64,000	176,000	240,000
Others		1	L S			51,000	51,000
Total					347,000	986,000	1,333,000

Table — 12.17 Dredging Cost Around Intake Tower

Unit : US $ 1

Work Item	Specification	Q ty	Unit	Unit Price	F.C.	L.C.	Total
A. Civil Work					0	374,000	374,000
1. Associated Work for Dredging Equipment					0	170,000	170,000
Pipe Foundation	Reinforced Concrete	430	points	132	0	56,760	56,760
Inclined Way	ditto	1	L S		0	33,300	33,300
Mooring Facility		1	L S		0	26,7 00	26,700
Working Base, Road		1	L S		0	26,7 00	26,700
Others		1	L S		0	26,540	26,540
2. Disposal Pond					0	204,000	204,000
Drainage Work	50cm×50cm	800	m	34	0	27,200	27,200
Embankment	Core Type	1	L S		0	75,000	75,000
Inside Embankment		1	L S		0	90,000	90,000
Others					0	11,800	11,800
B. Dredging Equipment					2,653,333	283,334	2,936,667
Dredger	Steel-made 150 ton	1	Unit	1,727,000	1,586,334	140,666	1,727,000
Booster	125 KW	1	L S		316,000	21,000	337,000
Pipe Line	land 1,300m	1	L S		376,666	11,334	388,000
	on water 500m	1	L S				
Electric Facility	700 KVA	1	L S		124,000	24,600	148,600
Transmission Facility	700 KVA	1	L S		0	83,000	83,000
Tugboat	long 12m, 150 PS	1	Unit		179,333	197	179,530
Other Accessory	Dredger Cable 750 m	1	L S		71,000	2,537	73,537
C. Design Cost		1	L S		526,667	0	526,667
D. Dredging Cost		1	L S		0	1,618,667	1,618,667
Total					3,180,000	2,276,000	5,456,000

Table-12.18

Breakdown of Rehabilitation Cost on Dam Upstream Face

Unit: US $

Work Item	Spec.	Qty	Unit	Unit Price	F.C.	L.C.	Total
1. Direct Construction Cost					1,254,800	3,678,400	4,933,200
Clearing of Quarry Site		50,000	m^2	0.20$	0	10,000	10,000
Removal of Surface Soil		200,000	m^3	3.6 $	200,000	520,000	720,000
Land Grading of Disposal Area		100,000	m^3	0.6 $	0	60,000	60,000
Excavation - Cutting and leveling		35,000	m^3	8.0 $	65,000	215,000	280,000
Collection, Transport and Embankment of Rock Materials		30,000	m^3	10.1 $	86,000	217,000	303,000
Riprap		110,000	m^3	8.5 $	266,000	669,000	935,000
Excavation - Cutting and leveling under water level		25,000	m^3	31.0 $	224,000	551,000	775,000
Riprap-Under water level		90,000	m^3	20.0 $	413,800	1,386,200	1,800,000
Others		1	LS		0	50,200	50,200
2. Common Temporary Facilities					348,900	884,400	1,233,300
3. Site Operation Cost					129,900	369,600	499,500
4. Overhead					173,400	493,600	667,000
Total					1,907,000	5,426,000	7,333,000

Table-12.18

Table-12.19 Breakdown of Rehabilitation Cost on Dam Upstream Face (Slope Gradient 1 : 1.75)

Unit : US $

Work Item	Qty	Unit	Unit Price	F.C.	L.C.	Total
1. Direct Construction Cost				1,025,200	3,030,300	4,055,500
Clearing of Quarry Site	50,000	m^2	0.2	0	10,000	10,000
Removal of Surface Soil	200,000	m^3	3.6	200,000	520,000	720,000
Land Grading of Disposal Area	100,000	m^3	0,6	0	60,000	60,000
Excavation - Cutting and leveling	49,000	m^3	8.0	91,000	301,000	392,000
Collection, Transport and Embankment of Rock Materials	8,000	m^3	10.1	23,000	57,800	80,800
Riprap	115,000	m^3	8.5	278,000	699,500	977,500
Excavation - Cutting and leveling under water level	15,000	m^3	31.0	134,400	330,600	465,000
Riprap-Under water level	65,000	m^3	20.0	298,800	1,001,200	1,300,000
Otehrs	1	LS		0	50,200	50,200
2. Common Temporary Facilities				286,800	727,100	1,013,900
3. Site Operation Cost				106,800	303,800	410,600
4. Overhead				142,500	405,500	548,000
Total				1,561,300	4,466,700	6,028,000

Table-12.19

Table - 12.20 Further Investigation for Rehabilitation Work

	Bed Rocks of the Left Bank of the Spillway	Quarry Site	Spoil Bank (R)	Spoil Bank (L)	Upstream Side Slope	Dredging	Intake Tower	Tailrace	Valve Chamber
Surveying		Topographical survey 50,000 m^2	Topographical survey 600,000 m^2	Topographical survey 500,000 m^2	Sounding on 21 sections down to EL 680 m	Topographical survey for mooring facilities and slipway covering 20,000 m	Topographical survey 15,000 m^2	Longitudinal and cross-sectional leveling for the access road of 2,500 m	
Boring Test		50 m x 6 = 300 m	10 m x 7 = 70 m	10 m x 5 = 50 m		Sedimentation basin dam 15 m x 2 x 2 places = 60 m	Vertical shaft 100 m x 2 + 50 m x 2 = 300 m		
Geophysical Prospecting		3,000 m							
Rock Properties Test		Embankment material							
Soil Properties Test	Fault material		Foundation Soil	Foundation Soil		Silty adimixture			
Field Rock Test	4 x 2 kinds Rock shearing test using drain adit								
Investigation of the Existing Intake Tower							Visual Check of Inlet (Diver - one day)		
Valve Inspection							Turbine inlet valve		Damage inspection of value butterfly 3 spherical 3

12.5. Economical Analysis

12.5.1. Method of Analysis

As a result of the screening test, and as explained in Paragraph 12.1.1, above, it was found that, of the five schemes studied for the problem of the reservoir sedimentation, Scheme E was the most advantageous.

An economic analysis on a system wide basis was made to determine whether an overall rehabilitation of the Ambuklao Project as described in Section 12.4, above, was economically more suitable, or substitution of the Ambuklao by another power source could be more advantageous. The above analysis was based on the data given in the "Power Development Program, 1987 to 2000", a study of power requirements made by NAPOCOR and issued in June 1987.

The above study includes energy and demand forecasts, data on the power expansion program, outputs of various power sources,and economic conditions for fixed and variable cost computations.

The basis of the analysis and its results are described below.

12.5.2. Purpose of the Analysis

In accordance with the findings of the Power Development Program of NAPOCOR (NAPOCOR Program), the expected year of retirement for the Ambuklao powerplant is 2006 or 2007, counting from its commissioning year. Loss or decrease of generation by the Ambuklao powerplant according to the program is not anticipated until after 2000.

However, the studies presented in this Report indicate that, if no measures against sedimentation are taken, loss or decrease of power generation by the Ambuklao powerplant will occur no later than 1996.

In order to prevent the above from happening, two basic alternative measures were studied. They were:

(a) <u>Alternative "A"</u> - Rehabilitation of the Ambuklao Project, as described in Section 12.1, above, Items (1) thru (4).

(b) <u>Alternative "B"</u> - Instead of the above, construction of a new geothermal plant (1 x 55 MW) with the same production capability as that of the Ambuklao powerplant. Include this in the NAPOCOR Program.

The analysis was made to determine which of the above two alternatives was more economical from point of view of the overall power system operation.

In addition to the above, a third alternative was also studied. This alternative was based on the assumption that no measures will be taken for the rehabilitation of the Ambuklao Project, but, the loss of power at the Ambuklao would be supplemented by additional power generation from the other existing plants.

This alternative is to assume no rehabilitation of the Ambuklao dam to be done and the resultant losses in capability (kW) and energy (kWH) to be made up by those attainable from the employment of the system's reserve marging capacity at the cost of the system reliability.

12.5.3. Assumptions

(1) Load demand forecast

The load demand forecast used in this analysis was in accordance with the NAPOCOR program.

(2) Power development program

Based on the NAPOCOR Program for the 1987 to 2000 period, the following alternatives were considered.

(a) Alternative "A" - Rehabilitation of the Ambuklao Project, no change to the NAPOCOR Program.

(b) Alternative "B" - No rehabilitation of the Ambuklao Project, but add a geothermal plant (1 x 55 MW) to the NAPOCOR Program.

(c) Alternative "C" - No rehabilitation of the Ambuklao Project and no change to the NAPOCOR Program.

This alternative is to assume a scenario in which the demand and energy needs would be met by placing the system's reserve margin capacity into service as a temporary measure, and should be considered as a case for reference only.

The operation and maintenance costs for the above three alternatives were taken into consideration. They were combined as required with the construction costs discussed in Section 12,3, above, and used in the economic evaluation of the above alternatives. As discussed further below, for economic comparison, the Internal Rate of Return for each alternative was computed and comparison made.

(3) Period of analysis and cost computation

The power demand forecast and the required power development given in the NAPOCOR's Program cover the period to year 2000.

Reduction in generation of the Ambuklao powerplant will start in 1990, if no rehabilitation work is carried out, and its operation will be discontinued in or after 1996. Therefore, the system wide analysis was made for five years covering the period from 1996 to 2000. The cash flow from 2001 to 2050 was calculated assuming that 90 percent of the initial investment cost will be reinvested at every depreciation period of the powerplant, and there would be no change in the O/M cost.

The cost for the Ambuklao Dam rehabilitation was assumed to be disbursed from 1992 to 1996.

(4) Measures for shortage of power generation during rehabilitation

The work on the dam rehabilitation will be carried out during the dry seasons, from 1992 to 1994, by lowering the reservoir water level. During the dry seasons from 1995 to 1996, the generation will have to be suspended intermittently. However, since dead discharge is not considered during the above period, the influence of the decrease in generation of the Ambuklao powerplant on the whole system could be ignored from point of view of system wide analysis as the decrease could be supplemented by the operation of other plants.

Therefore, no investment was considered for measures against shortage of power generation during rehabilitation. The power demand-supply balance for the period of no operation of the Ambuklao powerplant is covered in the following Section.

(5) Evaluation of the output decrease after completion of the rehabilitation

Even after the completion of the rehabilitation of the Ambuklao Project, the power output may decrease due to the increase in sediment. The annual output at normal water level in 1996 is estimated at 356.2 GWh, and for 2000, at 354.6 GWh. Since the estimated decrease will be only 1.6 GWh (0.45%), the output for each year between 1996 and 2000 was assumed for the system wide analysis the same as that for 2000.

(6) Cost calculation

To calculate the cost for each alternative, the investment cost for Alternative "A" consists of the investment cost provided in the NAPOCOR's Program plus rehabilitation work cost. For Alternative "B", the investment cost consists of the one shown in the NAPOCOR's Program plus the cost of a new geothermal plant, and for Alternative "C", the investment cost is assumed to be the same as that in the NAPOCOR's Program.

For calculation of operation and maintenance cost (O/M), a system wide analysis for each alternative was made to determine the optimum load sharing by each power source. After that, the cost for each type of fuel was calculated. The results are shown in Table-12.5.21.

12.5.4. Outline of the Results

The Internal Rate of Return (IRR) of Alternative "A" with regard to Alternative "B" was 42.84 percent, and that of Alternative "A" to Alternative "C", 17.78 percent.

Therefore, or the basis of the above, it is judged that the rehabilitation of the Ambuklao Project as described in Section 12.1, and specified as Alternative "A", above, is the most advantageous solution.

12.5.5. Procedure used for the Analysis

The procedure used in the analysis was as follows:

(1) Energy and demand forecast

Table-12.5.1 shows the energy and demand forecasts given in the NAPOCOR Program. For these studies, the values at the sending end were used. The sent out energy and demand at the sending end were regarded to be 96% of the generation level value.

Normally, generation level values are not used for this type of studies, as the evaluation of the station used portion is considered to be difficult.

The above rate of 96% was roughly determined, but it is considered to be adequate, as the purpose of the studies is comparison of alternatives.

Table-12.5.2 shows the analysis of the actual records of hourly demand for 1986. A year is divided into following four periods:

Designation	Period
I	January - March
II	April - June
III	July - September
IV	October - December

In Figs.-12.5.1-7, the values of Table-12.5.2 are presented graphically. Each figure indicates the load factor for the period.

Table-12.5.3 shows the modified load duration curve for each period (P.U.).

Table-12.5.4 shows the maximum MW ratio for the period so that the yearly load factor is 70% when the ratio of the load factor to the generated energy for the period does not change.

As the yearly load factor for the future is estimated to be 70%, as shown in Table-12.5.1, the duration curve for each future year is assumed to show the same pattern as that in 1986. The load demand for each period of each year is calculated using the demand at the sending end shown in Table-12.5.1, modified load duration, given in Table-12.5.3, and the tabulated data for load demand, shown in Table-12.5.4.

(2) Installed capacity and output at the sending end

A list of installed capacities of the existing powerplants is given in Table-12.5.5.

Table-12.5.6 shows installed capacities, classified by plant type, as given in the NAPOCOR Program for the period from 1986 to 2000 and considering the power expansion program.

The output at the sending end for 1995 classified by plant type are given in Table-12.5.7.

Table-12.5.8 shows output at the sending end of the reservoir type hydro powerplants which are expected to be developed after 1996.

Table-12.5.9 shows the total output at the sending end of the run-of-river type hydro powerplants.

Table-12.5.10 shows the output of the reservoir type hydro powerplants from 1996 to 2000, classified by alternative.

Table-12.5.11 shows the output of the geothermal power-plants sending end from 1996 to 2000, classified by alternative.

The output of the geothermal powerplants to be developed after 1996 is calculated using the condition of geo-thermal plants shown in Table-12.5.7. The output of Coal "A" (2 x 150 MW) and Coal "B" (2 x 55 MW) plants are calculated, using the condition for Isabela plant shown in Table-12.5.7.

Table-12.5.12 shows the output at the sending end of Alternative "A" from 1996 to 2000, classified by plant type.

(3) Average generation

Table-12.5.13 shows the average monthly generation by hydro powerplants. The values are calculated, based on the NAPOCOR's actual and planning data, however, those of the Ambuklao powerplant are estimated.

Tables-12.5.14 and 15 show the average generation (at the sending end) of the reservoir type hydro and run-of-the river type hydro powerplants, respectively, for each period.

Table-12.5.16 shows the average generation (at the sending end) of the reservoir type hydro powerplants, for each alternative.

(4) Unit cost calculation

Table-12.5.17 shows the annual fixed costs ($/kW-year) for the Ambuklao Project, and the geothermal (1 x 55 MW) powerplant.

The Table-12.5.18 shows the variable costs ($/MWh), classified by plant type. All these values are unit costs/kW and MWh at the sending end.

With regard to the data shown in Table 12.5.18, the following should be noted:

The variable cost of gas-turbine powerplants is highest, followed by oil-fired (Manila, Sucat, Malaya), oil fired (Bataan), coal-fired (Isabela) and coal-fired (Calaca) powerplants.

Assuming that the pumping-up efficiency is 70%, the variable cost for pumping-up of coal-fired (Calaca) is lower than that at oil-fired (Manila, Sucat, Malaya) powerplants. The variable costs for pumping-up of oil-fired and coal-fired powerplants are lower than that of gas-turbine powerplants.

(5) Loading order of thermal power plants

On the basis of the above variable cost comparison, it is judged that the loading order of thermal powerplants should be as follows:

(1) Coal-fired (Calaca).
(2) Coal-fired (Isabela and Equivalent).
(3) Oil-fired (Bataan).
(4) Coal-fired (Calaca) for pumping up.
(5) Oil-fired (Manila, Sucat, Malaya).
(6) Coal-fired (Isabela and Equivalent) for pumping up.
(7) Oil-fired (Bataan) for pumping up.
(8) Oil-fired (Manila, Sucat, Malaya) for pumping up.
(9) Gas-turbine.

The criteria for the optimum operation of the powerplants should be as follows:

Most power generation should be made by operating to the maximum possible extent the available geothermal and coal-fired plants. If surplus energy generated is made available during the off-peak time, it should be used for pumping up. By operating the pumped storage plants, power generation by oil-fired plants (Manila, Sucat, Malaya) should be reduced as much as possible.

When the output at the sending end does not meet the system peak demand, although the oil-fired plants (Manila, Sucat, Malaya) are fully operated, it should be supplemented by pumped storage energy made possible by the use of the off-peak available energy.

If additional energy is required during peak demand, gas-turbine plants should be operated.

(6) Optimum output and generation mix by plant type

The optimum output and generation mix by plant type are computed for each alternative in accordance with load orders and summarized in Tables 12.5.19 (1) to (3) and Tables-12.5.20 (1) - (3), respectively. In these computations, Min./Max. Ratio, shown in Table-12.5.7, were considered.

In Table-12.5.21, the O/M costs of each alternative for the period from 1996 to 2000 are listed. This was obtained by multiplying the variable O/M cost of each plant by the generated energy, based on the computation results shown in Tables-12.5.20 (1) to (3). The coal-fired (300 MW/unit) were assumed to be in full operation for each alternative.

The data shown in Table 12.5.21 include pumping up energy shown in parenthesis in Tables 12.5.20(1) to (3).

(7) Calculation of Internal Rate of Return (IRR)

Based on the investment and operation and maintenance costs, a cash flow was developed to calculate the IRR, assuming the Ambuklao Rehabilitation, Alternative "A", as COST, and Alternatives "B" and "C", as BENEFIT.

The results of the above are shown in Tables-12.5.22 & 23 and in Fig.-12.5.8. & 9.

(8) Balance of power demand and supply caused by interruption of power generation by Ambuklao during rehabilitation

Intermittent suspension of power generation at the Ambuklao Project during rehabilitation will be necessary during the periods January - March and April - June 1995, and April - June 1996. The balance of power demand and supply for the period April - June 1996 was examined.

In such cases, the power demand and supply balance is normally adjusted by rearranging the regular repair program for thermal plants, or by changing the reservoir utilization program of other hydro powerplants as required for covering the above balance.

The worst case of when none of the above measures have been taken at the time of suspension of the Ambuklao powerplant operation is presented below.

Alternative "C" studied above is a case for which the operation of the Ambuklao powerplant has been suspended since rehabilitation of the project has not been carried out. The situation for Period II in 1996 shown in Table-12.5.19 (3) is almost the same as that at the time of suspension of plant operation due to rehabilitation.

In Table-12.5.24, the above situation is shown again with the potential capacity at that time. The parenthesis in Table-12.5.24 shows the potential capacity disregarding economic considerations. This table shows the system still has sufficient reserve margin even when the consumption for forced outage, maintenance and station use, have been taken into account.

Therefore, even without any special provisions for additional power supply during suspension of power generation, the rehabilitation work carried out on the Ambuklao Project is not expected to adversely affect the balance of power demand and supply.

12.5.6. Conclusion

The economic justification for the Ambuklao Rehabilitation Project was evaluated by a system wide analysis covering the entire Luzon Grid of NAPOCOR.

The benefit of attaining the increased capability (kW) and energy (kWH) by the rehabilitation of the Ambuklao dam is by far the most advantageous, as clearly indicated by the above study. The IRR of the measure is found to be as high as 42.24% when compared with the Alternative "B", and 17.69% even against the Alternative "C". The Alternative "B" is to assume the addition of a geothermal capacity (1 x 55 MW) as a substitute power source. The Alternative "C" is to assume no addition of such substitute power source and any output requirements to be met only by putting the reserve margin capacity into service with the resultant degradation of the system reliability. In this scenario, the required system output would be obtained by increasing the capacity factor of power sources with relatively high variable costs, which could in turn result in the increment of variable costs in operating the whole system.

The comparison of the alternatives for the economic analysis should be made under the equal condition in the system reliability. The Alternative "C" is an exceptional case in which the demand would be met by employing the reserve margin capacity at the cost of the system reliability.

Since development of substitute resources do not increase the energy generated by the existing powerplants with high variable cost, the above leads to the increase of the variable cost for the whole system.

Table — 12.5·1 Energy and Demand Forecast in Luzon Grid

F. Y	Sales level (GWh)	Generation level (GWh)	Generation level (MW)	Sentout Energy (GWh)	Demand at Sending End (MW)	Load factor (%)
1986	13,461	14,756	2,435	14,169	2,338	69.18
1987	13,908	15,362	2,505	14,747	2,405	70.00
1988	14,564	16,004	2,610	15,367	2,506	70.00
1989	15,226	16,732	2,729	16,066	2,620	70.00
1990	15,974	17,553	2,863	16,851	2,748	70.00
1991	16,810	18,472	3,012	17,734	2,892	70.00
1992	17,829	19,592	3,195	18,807	3,067	70.00
1993	18,931	20,803	3,393	19,972	3,257	70.00
1994	20,129	22,120	3,607	21,235	3,463	70.00
1995	21,392	23,508	3,834	22,572	3,681	70.00
1996	22,693	24,937	4,067	23,939	3,904	70.00
1997	24,041	26,419	4,308	25,362	4,136	70.00
1998	25,453	27,970	4,561	26,852	4,379	70.00
1999	26,862	29,519	4,814	28,336	4,621	70.00
2000	28,352	31,156	5,081	29,912	4,878	70.00

Note : Demand at Sending End ≒ Generation level (MW) × 0.96

Table — 12.5·2 Load Duration (by NAPOCOR'S Data : from Jan. to Dec. 1986)

Period / Month / MW	I					II					III					IV					Yearly	
	Jan	Feb	Mar	*	Duration (%)	Apr	May	Jun	*	Duration (%)	Jul	Aug	Sep	*	Duration (%)	Out	Nov	Dec	*	Duration (%)	*	Duration (%)
2400																	4		4	0.18	4	0.05
2300			3	3	0.14	14	14	10	38	1.74						4	11	14	33	1.49	74	0.84
2200	2	3	14	22	1.02	34	54	43	169	7.74	8	13	22	43	1.95	28	34	17	112	5.07	346	3.9
2100	11	16	39	88	4.07	111	97	85	462	21.15	51	54	57	205	9.28	60	66	29	267	12.09	1,022	11.7
2000	40	31	74	233	10.79	89	88	79	718	32.88	89	114	103	511	23.14	101	113	67	548	24.82	2,010	22.9
1900	56	71	73	433	20.05	60	57	73	908	41.58	91	82	80	764	34.60	78	56	82	764	34.60	2,869	32.8
1800	85	84	61	663	30.69	51	56	59	1,074	49.18	76	49	51	940	42.57	44	52	39	899	40.72	3,576	40.8
1700	90	52	62	867	40.14	55	56	41	1,226	56.14	57	55	51	1,103	49.95	50	42	55	1,046	47.37	4,242	48.4
1600	59	50	51	1,027	47.55	53	70	74	1,423	65.16	56	61	48	1,268	57.43	60	60	65	1,231	55.75	4,949	56.5
1500	73	73	72	1,245	57.64	85	101	105	1,714	78.48	83	75	74	1,500	67.93	75	65	71	1,442	65.31	5,901	67.4
1400	58	62	93	1,458	67.50	105	103	115	2,037	93.27	104	90	91	1,785	80.84	100	95	92	1,729	78.31	7,009	80.0
1300	70	88	89	1,705	78.94	51	34	34	2,156	98.72	81	101	89	2,056	93.12	87	79	102	1,997	90.44	7,914	90.3
1200	105	82	68	1,960	90.74	7	14	2	2,179	99.77	31	43	43	2,173	98.41	28	34	71	2,130	96.47	8,442	96.4
1100	69	47	34	2,110	97.69	1	0	0	2,180	99.82	5	2	11	2,191	99.23	13	9	34	2,186	99.00	8,667	98.7
1000	26	13	11	2,160	10,000	4	0	0	2,184	100.00	12	5	0	2,208	100.00	16	0	6	2,208	100.00	8,760	100.0
Max. MW	2,217	2,240	2,342	2,342		2,357	2,375	2,365	2,375		2,261	2,275	2,265	2,274		2,363	2,412	2,361	2,412		2,412	
Min. MW	1,032	1,004	1,058	1,004		1,007	1,214	1,217	1,007		1,001	1,041	1,151	1,001		1,026	1,130	1,071	1,026		1,001	
Load factor (%)	68.187					75.596					75.120					70.551					70.515	
	71.441										70.689											

Note : * are cumulative total hours.

Table — 12.5·3 Modified Load Duration (P.U)

I		II		III		IV	
X	Y	X	Y	X	Y	X	Y
0.0000	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000	1.0000
0.0014	0.9821	0.0174	0.9684	0.0195	0.9675	0.0018	0.9950
0.0102	0.9394	0.0774	0.9263	0.0928	0.9235	0.0149	0.9536
0.0407	0.8967	0.2115	0.8842	0.2314	0.8795	0.0507	0.9121
0.1079	0.8540	0.3288	0.8421	0.3460	0.8355	0.1209	0.8706
0.2005	0.8113	0.4158	0.8000	0.4257	0.7916	0.2482	0.8292
0.3069	0.7686	0.4918	0.7579	0.4995	0.7476	0.3460	0.7877
0.4014	0.7259	0.5614	0.7158	0.5743	0.7036	0.4072	0.7463
0.4755	0.6832	0.6516	0.6737	0.6793	0.6596	0.4737	0.7048
0.5764	0.6405	0.7848	0.6316	0.8084	0.6157	0.5575	0.6633
0.6750	0.5978	0.9327	0.5895	0.9312	0.5717	0.6531	0.6219
0.7894	0.5551	0.9872	0.5474	0.9841	0.5277	0.7831	0.5804
0.9074	0.5124	0.9977	0.5053	0.9923	0.4837	0.9044	0.5390
0.9769	0.4697	0.9982	0.4632	1.0000	0.4402	0.9647	0.4975
1.0000	0.4287	1.0000	0.4240	1.0000	0.0000	0.9900	0.4561
1.0000	0.0000	1.0000	0.0000			1.0000	0.4254
						1.0000	0.0000

Table – 12.5·4 Tabulated Data for Load Demand

Period	I	II	III	IV	Yearly
Load factor (%)	0.68187	0.75596	0.75120	0.70551	0.70
Hours	2,160	2,184	2,208	2,208	8,760
Max. MW Ratio (P.U)	0.95655	0.97003	0.94285	1.00000	1.00000

Table − 12.5·5 Existing Power Plant (Luzon Grid, as of June 1987)

Plant name	Installed Capacity (MW)	Remarks (Units × MW)
(Hydro)		
Reservoir Type		
Caliraya	32.00	4 × 8
Ambuklao	75.00	3 × 25
Binga	100.00	4 × 25
Angat	228.00	4 × 50, 3 × 6, 1 × 10
Pantabangan	100.00	2 × 50
Magat	360.00	4 × 90
Kalayaan	300.00	2 × 150
Subtotal	1,195.00	
Run of River Type		
Botocan	16.96	2 × 8, 0.96
Buhi−Barit	1.80	
Cawayan	0.40	
Masiway	12.00	
Subtotal	31.16	
Total	1,226.16	
(Oil−fired)	(MW)	(Units × MW)
Manila	200.00	2 × 100
Sucat	850.00	1 × 150, 2 × 200, 1 × 300
Bataan	225.00	1 × 75, 1 × 150
Malaya	650.00	1 × 300, 1 × 350
Total	1,925.00	
(Coal−fired)	(MW)	
Calaca	300.00	1 × 300
(Geothermal)	(MW)	
Tiwi	330.00	6 × 55
Mak−Ban	330.00	6 × 55
Total	660.00	
Grand Total	4,111.16	

Table – 12.5·6 Installed Capacity (MW) by Plant type in Luzon Grid

F.Y	Oil-fired	Gasthermal	Sub-total	Pumped Storage	Run of River	Reservoir	Sub-total	Coal-fired	Geo-thermal	Total	Expansion Program
1986	1,925	–	1,925	300	31	895	1,226	300	660	4,111	Rehab.Malaya 1 (300)
1987	1,925	–	1,925	300	31	895	1,226	300	660	4,111	Rockwell (180)
1988	1,925(180)	–	1,925	300	31	895	1,226	300	660	4,111	
1989	1,925(180)	150	2,075	300	31	895	1,226	300	660	4,261	Gas-T. (3×50), Rehab. Sucat 1 (150)
1990	1,925(180)	350	2,275	300	31	895	1,226	300	660	4,461	Gas-T. (4×50), Rehab. Sucat 4 (300)
1991	1,925(180)	350	2,275	300	31	895	1,226	300	770	4,571	Geo (2×55)
1992	1,925	350	2,275	300	31	895	1,226	600	770	4,871	Calaca Ⅱ (300), Retire Rockwell(△180)
1993	1,925	350	2,275	300	54	895	1,249	600	990	5,114	Pantay H. (23), Geo (4×55)
1994	1,925	350	2,275	300	54	895	1,249	600	1,210	5,334	Geo (4×55)
1995	1,925	350	2,275	300	54	895	1,249	900	1,210	5,634	Isabela (2×150)
1996	1,925	350	2,275	300	54	1,285	1,639	900	1,210	6,024	San Roque H. (390)
1997	1,925	350	2,275	300	54	1,553	1,907	900	1,210	6,292	Casecnan H. (268)
1998	1,925	350	2,275	300	54	1,728	2,082	900	1,320	6,577	Binongan H. (175), Geo (2×55)
1999	1,925	350	2,275	300	54	1,728	2,082	1,200	1,320	6,877	Coal A (2×150)
2000	1,925	350	2,275	300	54	1,728	2,082	1,500	1,320	7,177	Coal B (2×150)

Table − 12.5·7 Tabulated Data for MW Capacity (in 1995)

Plant	Installed Capacity (MW)	Max. Limit (MW)	Min. Limit (MW)	Min./Max.	EFOR (%)	SMD (days/year)	SUR (%)	Decrease factor (P.U)	Output at Sending End (MW)
Gas−turbine	7×50	7×40	−		8	0	1	0.911	255.1
Hydro	249	1,249	−		0.5	−	0.3	0.992	1,239.0
Oil−fired									
Bataan 1	75	70	50		10	49	4	0.748	52.4
2	150	150	80		10	49	4	0.748	112.2
Sub−total	225	220	130	0.591					164.6
Manila 1	100	100	30		10	49	4	0.748	74.8
2	100	100	30		10	49	4	0.748	74.8
Sucat 1	150	150	40		10	49	4	0.748	112.2
2	200	160	120		14	49	4	0.715	114.4
3	200	140	120		14	49	4	0.715	100.1
4	300	300	120		16	56	4	0.683	204.9
Malaya 1	300	300	120		16	56	4	0.683	204.9
2	350	350	150		14	56	4	0.699	244.7
Sub−total	1,700	1,600	730	0.456					1,130.8
Total	1,925	1,820	860						1,295.4
Coal−fired									
Calaca	2×300	2×300	2×230	0.767	17	56	8.5	0.643	385.8
Isabela	2×150	2×150	2×115	0.767	12	49	8.5	0.697	209.1
Geothermal	22×55	22×50	22×30	0.600	4	35	10.0	0.781	859.1

Note : EFOR = Equivalent forced outage rate, SMD = Scheduled maintenance days, SUR = Station use rate,

Decrease factor = $(1-\text{EFOR})\times(1-\frac{\text{SMD}}{365})\times(1-\text{SUR})$, Output at sending End = Max. Limit × Decrease factor.

Table — 12.5·8 Output of Reservoir Type Hydro (MW)

～ at Sending End ～

Plants	Output (MW)
Existing (Ambuklao)	1,185.46 (74.40)
San Roque	386.89
Casecnan	211.30
Binongan	173.60
Total	1,957.25

Table — 12.5·9 Output of Run of River Type Hydro (MW)

～ at Sending End ～

Plants	Output (MW)
Existing	53.73

Table – 12.5·10 Output of Reservoir Type Hydro at Sending End (MW)

F.Y \ Alternatives	(a)	(b) (c)
1996	1,572.4	1,498.0
1997	1,783.7	1,709.3
1998	1,957.3	1,882.9
1999	1,957.3	1,882.9
2000	1,957.3	1,882.9
Remarks	With Ambuklao	Without Ambuklao

Table – 12.5·11 Output of Geothermal Power Plant at Sending End (MW)

F.Y \ Alternatives	(a) (c)	(b)
1996	859.1	898.2
1997	859.1	898.2
1998	937.2	976.3
1999	937.2	976.3
2000	937.2	976.3
Remarks		+ Geothermal (1×55MW)

Table − 12.5·12 Output at Sending End (MW)

F.Y	Gas−turbine	Oil−fired		Pumped Storage	Run of River (in May)	Reservoir (a)	Coal−fired (a)	Geothermal	Total (a)
		(Bataan)	(Others)						
1996	255.1	164.6	1,130.8	297.6	24.4	1,572.4	594.9	859.1	4,898.9
1997	255.1	164.6	1,130.8	297.6	24.4	1,783.7	594.9	859.1	5,110.2
1998	255.1	164.6	1,130.8	297.6	24.4	1,957.3	594.9	937.2	5,361.9
1999	255.1	164.6	1,130.8	297.6	24.4	1,957.3	804.0	937.2	5,571.0
2000	255.1	164.6	1,130.8	297.6	24.4	1,957.3	1,013.1	937.2	5,780.1

Note : Alternative (a) ; With Ambuklao

Table − 12.5 ·13 Average monthly Generation (GWh)

	Installed Capacity (MW)	I			II			III			IV			Total 365
		Jan 31	Feb 28	Mar 31	Apr 30	May 31	Jun 30	Jul 31	Aug 31	Sep 30	Oct 31	Nov 30	Dec 31	
Reservoir Type														
Caliraya	32	8.19	8.31	4.92	5.22	4.63	4.99	4.63	5.83	6.24	6.47	9.18	8.15	76.76
Ambuklao	75	12.09	10.69	11.59	10.95	11.54	10.71	52.77	54.30	53.29	54.50	53.80	18.33	354.56
Binga	100	18.21	21.96	17.94	19.27	26.30	27.96	43.59	65.97	75.02	55.68	49.29	29.33	450.52
Angat	228	39.14	42.95	32.37	28.06	15.92	31.92	39.75	36.09	44.32	46.62	70.92	58.36	486.42
Pantabangan	100	25.21	28.54	25.43	22.17	6.48	2.16	6.18	7.28	6.02	7.91	5.55	9.95	152.88
Magat	360	54.30	53.16	38.03	27.39	64.92	89.29	86.56	136.90	139.31	128.15	168.50	83.34	1,069.85
Sub-total	1,195(1,185.5)	157.14	165.61	130.28	113.06	129.79	167.03	233.48	306.37	324.20	299.33	357.24	207.46	2,590.99
		453.03(451.67)			409.88(408.65)			864.05(861.46)			864.03(861.44)			
San Roque	390	38.26	28.43	29.37	32.08	59.15	103.44	155.55	182.77	182.31	152.34	83.58	51.91	1,099.19
Casecnan	213	107.64	62.46	63.77	65.60	92.77	115.70	133.16	143.89	152.36	162.38	166.05	148.45	1,414.23
Binongan	175	40.79	30.36	24.62	22.06	36.62	64.31	89.39	105.05	99.03	82.61	66.92	59.19	720.95
Sub-total	778(771.8)	186.69	121.25	117.76	119.74	188.54	283.45	378.10	431.71	433.70	397.33	316.55	259.55	3,234.37
		425.70(424.42)			591.73(539.96)			1,243.51(1,239.78)			973.43(970.51)			
Total	1,973(1,957.2)	878.73(876.09)			1,001.61(998.61)			2,107.56(2,101.24)			1,837.46(1,831.95)			
Run of River Type														
Botocan	16.96	4.45	3.66	5.17	4.78	2.82	6.39	6.37	4.97	5.60	5.57	10.64	10.20	70.62
Buhi-Barit	1.80	1.14	1.12	0.70	0.63	0.36	0.35	0.61	0.74	0.79	0.89	1.05	1.09	9.47
Cawayan	0.40	0.23	0.23	0.18	0.19	0.13	0.11	0.28	0.27	0.13	0.14	0.14	0.18	2.21
Masiway	12.00	4.95	5.30	5.22	5.24	2.34	0.46	1.46	1.59	1.58	1.70	1.30	2.60	33.74
Pantay	23.00	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	12.50	150.00
Total	54.16(53.7)	23.27	22.81	23.77	23.34	18.15	19.81	21.22	20.07	20.60	20.80	25.63	26.57	266.04
		69.85(69.64)			61.30(61.12)			61.89(61.70)			73.00(72.78)			

Note : ( ) shows Sending End Values.

Table — 12.5・14 Average Generation of Reservoir Type Hydro (GWh)

～ at Sending End ～

Plants \ Period	I	II	III	IV
Existing (Ambuklao)	451.67 (34.27)	408.65 (33.10)	861.46 (159.88)	861.44 (126.25)
San Roque	95.77	194.09	519.07	286.97
Casecnan	233.17	273.25	428.12	475.45
Binongan	95.48	122.62	292.59	208.09
Total	876.09	998.61	2,101.24	1,831.95

Table — 12.5・15 Average Generation of Run of River Type Hydro (GWh)

～ at Sending End ～

Plants \ Period	I	II	III	IV
Existing	69.64	61.12	61.70	72.78

Table − 12.5·16 Average Generation of Reservoir Type Hydro at Sending End (GWh)

Alternatives	(a) with Ambuklao				(b) and (c) without Ambuklao			
F.Y \ Period	I	II	III	IV	I	II	III	IV
1996	547.44	602.74	1,380.53	1,148.41	513.17	569.64	1,220.65	1,022.16
1997	780.61	875.99	1,808.65	1,623.86	746.34	842.89	1,648.77	1,497.61
1998	876.09	998.61	2,101.24	1,831.95	841.82	965.51	1,941.36	1,705.70
1999	876.09	998.61	2,101.24	1,831.95	841.82	965.51	1,941.36	1,705.70
2000	876.09	998.61	2,101.24	1,831.95	841.82	965.51	1,941.36	1,705.70

Table – 12.5.17 Fixed O/M Cost

Plants	Type	Installed Capacity (MW)	Construction Cost(c) ($/KW)	Construction Period(k) (year)	Life Time (n) (year)	Residual Value Rate (z)	Forced Outage Rate (%)	Maintenance days/year (days)	Station Use Rate (P.U)	Fixed O/M Cost(m) $/KW–month	Annual Fixed Cost ($/KW–year)
Ambuklao	Hydro	75	542.47	8	30	0.1	0.5	–	0.003	0.45633	5.520
Coalfired(2)		300	1,162.10	4	30	0.1	12.0	49	0.085	1.28475	22,116
Geothermal	–	*100	624.60	4	30	0.1	4.0	35	0.100	0.47000	7.220

Note : Annual Fixed O/M Cost ($/KW – year) = $[m \times 12] \div [(1-\frac{\text{Forced Outage Rate}}{100})(1-\frac{\text{Maintenance days}}{365})(1-\text{Station Use Rate})]$

* Max.Limit

Disbursement Ratio (Rk) of Construction Cost

Plants	R_6	R_5	R_4	R_3	R_2	R_1	R_0	R_{-1}
Ambuklao	1.638	1.829	2.412	6.553	21.096	27.842	19.929	18.702
Coalfired(2)	–	–	–	$\frac{100}{4}$	$\frac{100}{4}$	$\frac{100}{4}$	$\frac{100}{4}$	–
Geothermal	–	–	–	$\frac{100}{4}$	$\frac{100}{4}$	$\frac{100}{4}$	$\frac{100}{4}$	–

Total Construction Cost (unit : 10^6)

Plants	L.C ₱	F.C US$	Equivalent US$
Ambuklao	381.234	22.531	40.685
Coalfired(2)	1,563.0	274.2	348.63
Geothermal	347.8	45.9	62.46

Table − 12.5.18 Variable

Plant Type	Fuel Cost	Heat Content	Fuel Cost ($/MBTU)	Heat Rate (MBTU/MWh)	(Thermal Efficiency) (%)	Variable O/M Ratio (%)	Station use Rate (%)	Variable Cost ($/MWh)
Gas − turbine	−		3.00	14.841	23.00	1	1.0	45.422
Oil − fired								
(1) Manila, Sucat, Malaya	14.311 $/bbl	6.21 MBTU/bbl	2.3045	10.753	31.74	1	4.0	26.071
(2) Bataan	13.831 $/bbl	6.248 MBTU/bbl	2.2136	9.484	35.98	1	4.0	22.087
Coal − fired								
(Calaca)	35.63 $/t	21.630 MBTU/t	1.6472	9.484	35.98	1	8.5	17.244
(Isabela)	35.74 $/t	18.739 MBTU/t	2.0673	9.484	35.98	1	8.5	21.642
Geothermal			*0.2526				10.0	13.365

Note : Variable Cost at Sending End ($/MWh) = $\dfrac{\text{Fuel Cost (\$/MBTU)} \times \text{Heat Rate (MBTU/MWh)} \times (1 + \text{Variable O/M Ratio} \times 10^{-2})}{1 - \text{Station Use rate} \times 10^{-2}}$

Variable Cost for Pumping up = Variable Cost ÷ Pumping up Efficiency (0.7)

Plants	Variable cost for Pumping up ($/MWh)
Oil − fired (Manila, Sucat, Malaya)	37.244
Oil − fired (Bataan)	31.553
Coal (Calaca)	24.634
Coal (Isabela)	30.917
Geothermal	19.093

* P/kwh

Table − 12.5・19(1) Output at Sending End by Plant Type (Alternative (a)) (MW)

F．Y	1995				1996				1997			
Period / Plants	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ
Gasturbine												
Pumped Storage					297.6	105.3	64.3	162.7	297.6	69.1	12.7	78.7
Reservoir					983.7	945.9	1,463.3	1,411.0	1,213.3	1,226.5	1,771.0	1,705.3
Oil−fired (1)					802.2	1,089.2	506.7	678.7	794.5	1,069.8	469.3	700.4
Oil−fired (2)					164.6	〃	〃	〃	〃	〃	〃	〃
Coal−fired (150MW units)					209.1	〃	〃	〃	〃	〃	〃	〃
Coal−fired (300MW units)					385.8	〃	〃	〃	〃	〃	〃	〃
Geothermal					859.1	〃	〃	〃	〃	〃	〃	〃
Run of River					32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0
Total					3,734.3	3,787.0	3,680.8	3,904.0	3,956.2	4,012.0	3,899.5	4,136.0

F．Y	1998				1999				2000			
Period / Plants	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅰ	Ⅱ	Ⅲ	Ⅳ
Gasturbine												
Pumped Storage	297.6	68.7	0.8	54.0	297.6	78.8	28.9	115.0	297.6	90.6	60.2	183.2
Reservoir	1,337.6	1,352.3	1,956.5	1,903.4	1,393.9	1,382.8	1,928.5	1,843.0	1,453.0	1,412.8	1,897.4	1,775.9
Oil−fired (1)	824.5	1,102.1	446.7	691.9	790.6	1,087.1	465.7	724.2	768.3	1,085.5	498.7	771.0
Oil−fired (2)	164.6	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Coal−fired (150MW units)	209.1	〃	〃	〃	418.2	〃	〃	〃	627.3	〃	〃	〃
Coal−fired (300MW units)	385.8	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Geothermal	937.2	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Run of River	32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0
Total	4,188.6	4,247.8	4,128.6	4,379.0	4,420.1	4,482.5	4,356.8	4,621.0	4,666.0	4,731.8	4,599.1	4,878.0

Note : Oil−fired (1) are Oil−fired (Manila, Sucat, Malaya), Oil−fired (2) are Oil−fired (Bataan).

Table — 12.5·19(2) Output at Sending End by Plant Type (Alternative (b)) (MW)

F . Y	1995				1996				1997			
Plants \ Period	I	II	III	IV	I	II	III	IV	I	II	III	IV
Gasturbine												
Pumped Storage					297.6	121.0	91.4	217.4	297.6	75.5	37.8	126.8
Reservoir					956.4	902.7	1,352.6	1,283.0	1,189.0	1,196.4	1,671.6	1,583.4
Oil-fired (1)					790.3	1,077.5	551.1	712.9	779.6	1,054.4	504.5	735.1
Oil-fired (2)					164.6	〃	〃	〃	〃	〃	〃	〃
Coal-fired (150MW units)					209.1	〃	〃	〃	〃	〃	〃	〃
Coal-fired (300MW units)					385.8	〃	〃	〃	〃	〃	〃	〃
Geothermal					898.2	〃	〃	〃	〃	〃	〃	〃
Run of River					32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0
Total					3,734.2	3,786.9	3,680.7	3,904.0	3,956.1	4,012.0	3,899.5	4,136.0

F . Y	1998				1999				2000			
Plants \ Period	I	II	III	IV	I	II	III	IV	I	II	III	IV
Gasturbine												
Pumped Storage	297.6	74.1	22.8	100.5	297.6	85.9	53.9	166.9	297.6	100.6	85.2	241.0
Reservoir	1,313.8	1,324.4	1,860.1	1,782.9	1,369.8	1,352.3	1,829.2	1,717.5	1,428.5	1,378.8	1,798.2	1,645.1
Oil-fired (1)	809.2	1,085.5	482.0	726.8	775.6	1,071.4	500.9	758.7	753.7	1,070.4	533.7	804,9
Oil-fired (2)	164.6	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Coal-fired (150MW units)	209.1	〃	〃	〃	418.2	〃	〃	〃	627.3	〃	〃	〃
Coal-fired (300MW units)	385.8	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Geothermal	976.3	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Run of River	32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0
Total	4,188.6	4,247.8	4,128.6	4,379.0	4,420.1	4,482.5	4,356.8	4,621.0	4,666.0	4,731.8	4,599.0	4,878.0

Note : Oil-fired (1) are Oil-fired (Manila, Sucat, Malaya), Oil-fired (2) are Oil-fired (Bataan).

Table — 12.5・19(3) Output at Sending End by Plant Type (Alternative (c)) (MW)

F . Y	1995				1996				1997			
Plants \ Period	I	II	III	IV	I	II	III	IV	I	II	III	IV
Gasturbine												
Pumped Storage					297.6	111.1	81.7	197.9	297.6	70.9	28.1	107.4
Reservoir					954.4	912.4	1,367.6	1,302.0	1,188.1	1,201.0	1,681.3	1,602.5
Oil－fired (1)					831.5	1,116.9	585.0	752.5	819.7	1,093.5	543.6	774.5
Oil－fired (2)					164.6	〃	〃	〃	〃	〃	〃	〃
Coal－fired (150MW units)					209.1	〃	〃	〃	〃	〃	〃	〃
Coal－fired (300MW units)					385.8	〃	〃	〃	〃	〃	〃	〃
Geothermal					859.1	〃	〃	〃	〃	〃	〃	〃
Run of River					32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0
Total					3,734.3	3,787.0	3,680.8	3,904.0	3,956.2	4,012.0	3,899.5	4,136.0

F . Y	1998				1999				2000			
Plants \ Period	I	II	III	IV	I	II	III	IV	I	II	III	IV
Gasturbine												
Pumped Storage	297.6	70.5	13.1	82.6	297.6	80.8	44.3	145.8	297.6	93.8	75.6	218.8
Reservoir	1,313.1	1,327.9	1,869.8	1,800.6	1,368.9	1,357.3	1,838.8	1,738.2	1,427.3	1,385.5	1,807.8	1,666.6
Oil－fired (1)	849.0	1,124.7	521.1	766.1	815.6	1,110.6	540.0	798.2	794.0	1,109.6	572.9	844.7
Oil－fired (2)	164.6	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Coal－fired (150MW units)	209.1	〃	〃	〃	418.2	〃	〃	〃	627.3	〃	〃	〃
Coal－fired (300MW units)	385.8	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Geothermal	937,2	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃	〃
Run of River	32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0	32.2	28.0	27.9	33.0
Total	4,188.6	4,247.8	4,128.6	4,379.0	4,420.1	4,482.5	4,356.8	4,621.0	4,666.0	4,731.8	4,599.1	4,878.0

Note : Oil－fired (1) are Oil－fired (Manila, Sucat, Malaya), Oil－fired (2) are Oil－fired (Bataan).

Table – 12.5・20(1) : Generation Mix at Sending End by Plant Type (Alternative (a)) (GWh)

F.Y	1995					1996					1997				
Plants	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total
Gasturbine															
Pumped Storage						15.4	1.8	0.7	2.4	20.3	4.6	0.7	0.0	0.6	6.0
Reservoir						547.4	602.7	1,380.5	1,148.4	3,679.0	780.6	876.0	1,808.6	1,623.9	5,089.1
Oil-fired (1)						1,426.1	2,059.3	1,092.0	1,295.0	5,872.4	1,498.8	2,153.5	1,024.8	1,176.2	5,853.3
Oil-fired (2)						334.2	355.7	361.8	358.4	1,410.1	344.9	358.5	362.7	360.8	1,426.9
Coal-fired (150MW units)						440.7	455.5	460.8	459.1	1,816.1	446.4	456.3	461.4	460.7	1,824.8
Coal-fired (300MW units)						(13.4) 819.9	(1.4) 841.2	(0.9) 850.9	(2.6) 849.2	(18.3) 3,361.2	(4.8) 828.5	(0.4) 842.2	(0.0) 851.8	(0.7) 851.1	(5.9) 3,373.6
Geothermal						(8.6) 1,847.1	(1.2) 1,875.1	(0.1) 1,896.8	(0.8) 1,896.1	(10.7) 7,515.1	(2.0) 1,853.7	(0.6) 1,875.7	1,896.9	(0.0) 1,896.9	(2.6) 7,523.2
Run of River						69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2
Total						(22.0) 5,500.4	(2.6) 6,252.4	(1.0) 6,105.2	(3.4) 6,081.4	(29.0) 23,939.5	(6.8) 5,827.2	(1.0) 6,624.0	(0.0) 6,467.9	(0.7) 6,443.0	(8.5) 25,362.1

F.Y	1998					1999					2000				
Plants	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total
Gasturbine															
Pumped Storage	3.9	0.7	0.0	0.3	4.9	6.2	0.8	0.1	1.0	8.1	9.0	1.0	0.5	2.5	13.0
Reservoir	876.1	998.6	2,101.2	1,832.0	5,807.9	876.1	998.6	2,101.2	1,831.9	5,807.8	876.1	998.6	2,101.2	1,832.0	5,807.9
Oil-fired (1)	1,574.3	2,249.3	939.4	1,172.9	5,935.9	1,478.1	2,181.6	857.8	1,093.4	5,610.9	1,408.9	2,139.2	800.4	1,040.9	5,389.4
Oil-fired (2)	346.3	358.7	362.9	361.6	1,429.5	341.6	358.1	362.3	359.4	1,421.4	335.6	356.9	361.6	356.4	1,410.5
Coal-fired (150MW units)	447.3	456.4	461.6	461.0	1,826.3	890.1	912.3	922.4	919.9	3,644.7	1,328.8	1,367.5	1,382.5	1,376.4	5,455.2
Coal-fired (300MW units)	(4.0) 829.3	(0.4) 842.2	(0.0) 851.8	(0.3) 851.5	(4.7) 3,374.8	(5.7) 827.6	(0.4) 842.2	(0.1) 851.7	(1.3) 850.5	(7.5) 3,372.0	(7.8) 825.5	(0.5) 842.1	(0.6) 851.2	(2.4) 849.4	(11.3) 3,368.2
Geothermal	(1.6) 2,022.8	(0.5) 2,046.3	2,069.3	2,069.3	(2.1) 8,207.7	(3.2) 2,021.2	(0.7) 2,046.1	2,069.3	(0.1) 2,069.2	(4.0) 8,205.8	(5.1) 2,019.3	(0.9) 2,045.9	(0.0) 2,069.3	(1.1) 2,068.2	(7.1) 8,202.7
Run of River	69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2
Total	(5.6) 6,169.6	(0.9) 7,013.3	(0.0) 6,847.9	(0.3) 6,821.4	(6.8) 26,852.2	(8.9) 6,510.5	(1.1) 7,400.8	(0.1) 7,226.5	(1.4) 7,198.1	(11.5) 28,335.9	(12.9) 6,872.8	(1.4) 7,812.3	(0.6) 7,628.4	(3.5) 7,598.6	(18.4) 29,912.1

Note : ( ) shows Pumping up Energy.

Table − 12.5・20(2) Generation Mix at Sending End by Plant Type (Alternative (b)) (GWh)

F . Y	1995					1996					1997				
Plants	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total
Gasturbine															
Pumped Storage						20.7	2.3	1.5	4.5	29.0	7.0	0.9	0.2	1.4	9.5
Reservoir						513.2	569.6	1,220.6	1,022.2	3,325.6	746.3	842.9	1,648.8	1,497.6	4,735.6
Oil−fired (1)						1,384.7	2,009.6	1,166.6	1,339.2	5,900.1	1,453.1	2,101.8	1,099.1	1,218.5	5,872.5
Oil−fired (2)						330.4	354.0	361.4	355.9	1,401.7	342.8	358.2	362.3	359.6	1,422.9
Coal−fired (150MW units)						438.0	454.8	460.5	458.2	1,811.5	445.0	456.1	461.2	459.9	1,822.2
Coal−fired (300MW units)						(16.6) 816.7	(1.8) 840.8	(1.4) 850.4	(4.3) 847.5	(24.1) 3,355.4	(6.8) 826.5	(0.5) 842.1	(0.3) 851.5	(1.7) 850.1	(9.3) 3,370.2
Geothermal						(12.9) 1,927.2	(1.6) 1,960.1	(0.6) 1,982.6	(2.2) 1,981.1	(17.3) 7,851.0	(3.2) 1,936.9	(0.8) 1,960.9	1,983.2	(0.3) 1,982.9	(4.3) 7,863.9
Run of River						69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2
Total						(29.5) 5,500.5	(3.4) 6,252.3	(2.0) 6,105.3	(6.5) 6,801.4	(41.4) 23,939.5	(10.0) 5,827.2	(1.3) 6,624.0	(0.3) 6,468.0	(2.0) 6,442.8	(13.6) 25,362.0

F . Y	1998					1999					2000				
Plants	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total
Gasturbine															
Pumped Storage	5.8	0.8	0.1	0.8	7.5	8.7	1.0	0.4	2.2	12.3	12.1	1.3	1.0	4.3	18.7
Reservoir	841.8	965.5	1,941.4	1,705.7	5,454.4	841.8	965.5	1,941.4	1,705.7	5,454.4	841.8	965.5	1,941.4	1,705.7	5,454.4
Oil−fired (1)	1,528.1	2,197.4	1,013.5	1,214.7	5,953.7	1,434.2	2,130.0	932.3	1,136.6	5,633.1	1,367.6	2,088.8	875.2	1,087.0	5,418.6
Oil−fired (2)	344.4	358.5	362.6	360.5	1,426.0	338.9	357.8	361.9	358.2	1,416.8	332.7	355.7	361.3	354.0	1,403.7
Coal−fired (150MW units)	446.0	456.3	461.3	460.4	1,824.0	887.5	911.9	921.9	918.4	3,639.7	1,324.1	1,366.9	1,381.8	1,373.4	5,446.2
Coal−fired (300MW units)	(5.5) 827.8	(0.4) 842.2	(0.1) 851.7	(1.1) 850.7	(7.1) 3,372.4	(7.8) 825.5	(0.5) 842.1	(0.5) 851.3	(2.2) 849.6	(11.0) 3,368.5	(10.1) 823.2	(0.7) 841.9	(1.0) 850.8	(3.7) 848.1	(15.5) 3,364.0
Geothermal	(2.7) 2,106.1	(0.6) 2,131.6	2,155.7	(0.1) 2,155.6	(3.4) 8,549.0	(4.6) 2,104.2	(0.9) 2,131.3	(0.1) 2,155.6	(0.9) 2,154.8	(6.5) 8,545.9	(7.2) 2,101.6	(1.1) 2,131.1	(0.4) 2,155.3	(2.4) 2,153.3	(11.1) 8,541.3
Run of River	69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2
Total	(8.2) 6,169.6	(1.0) 7,013.4	(0.1) 6,848.0	(1.2) 6,821.2	(10.5) 26,852.2	(12.4) 6,510.4	(1.4) 7,400.7	(0.6) 7,226.5	(3.1) 7,198.3	(17.5) 28,335.9	(17.3) 6,872.7	(1.8) 7,812.3	(1.4) 7,628.5	(6.1) 7,598.6	(26.6) 29,912.1

Note : ( ) shows Pumping up Energy.

Table – 12.5·20(3) Generation Mix at Sending End by Plant Type (Alternative (c)) (GWh)

F.Y	1995					1996					1997				
Plants	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total
Gasturbine															
Pumped Storage						17.3	2.0	1.2	3.6	24.1	5.5	0.7	0.1	1.0	7.3
Reservoir						513.2	569.6	1,220.6	1,022.1	3,325.5	746.3	842.9	1,648.8	1,497.6	4,735.6
Oil-fired (1)						1,463.8	2,093.3	1,252.6	1,423.7	6,233.4	1,534.6	2,186.8	1,185.1	1,303.8	6,210.3
Oil-fired (2)						332.7	355.1	361.5	357.1	1,406.4	344.2	358.4	362.5	360.1	1,425.2
Coal-fired (150MW units)						439.6	455.3	460.6	458.5	1,814.0	445.9	456.3	461.3	460.2	1,823.7
Coal-fired (300MW units)						(14.6) 818.7	(1.5) 841.1	(1.2) 850.6	(3.6) 848.2	(20.9) 3,358.6	(5.4) 827.9	(0.4) 842.2	(0.1) 851.7	(1.3) 850.5	(7.2) 3,372.3
Geothermal						(10.2) 1,845.5	(1.3) 1,875.0	(0.4) 1,896.5	(1.5) 1,895.4	(13.4) 7,512.4	(2.4) 1,853.3	(0.7) 1,875.6	1,896.9	(0.1) 1,896.8	(3.2) 7,522.6
Run of River						69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2
Total						(24.8) 5,500.4	(2.8) 6,252.5	(1.6) 6,105.3	(5.1) 6,081.4	(34.3) 23,939.6	(7.8) 5,827.3	(1.1) 6,624.0	(0.1) 6,468.1	(1.4) 6,442.8	(10.4) 25,362.2

F.Y	1998					1999					2000				
Plants	I	II	III	IV	Total	I	II	III	IV	Total	I	II	III	IV	Total
Gasturbine															
Pumped Storage	4.5	0.7	0.0	0.6	5.8	7.0	0.9	0.3	1.7	9.9	10.1	1.1	0.8	3.5	15.5
Reservoir	841.8	965.5	1,941.4	1,705.7	5,454.4	841.8	965.5	1,941.4	1,705.7	5,454.4	841.8	965.5	1,941.4	1,705.7	5,454.4
Oil-fired (1)	1,609.9	2,282.5	1,099.6	1,300.3	6,292.3	1.514.5	2,215.0	1,018.3	1,221.6	5,969.4	1,446.2	2,172.9	961.0	1,170.8	5,750.9
Oil-fired (2)	345.6	358.7	362.7	360.9	1,427.9	340.8	358.0	362.0	358.8	1,419.6	334.6	356.6	361.4	354.9	1,407.5
Coal-fired (150MW units)	446.8	456.4	461.4	460.7	1,825.3	889.2	912.2	922.1	919.0	3,642.5	1,327.1	1,367.3	1,382.1	1,374.7	5,451.2
Coal-fired (300MW units)	(4.5) 828.8	(0.4) 842.2	(0.0) 851.8	(0.8) 851.0	(5.7) 3,373.8	(6.4) 826.9	(0.5) 842.1	(0.4) 851.4	(1.8) 850.0	(9.1) 3,370.4	(8.6) 824.7	(0.6) 842.0	(0.9) 850.9	(3.2) 848.6	(13.3) 3,366.2
Geothermal	(2.0) 2,022.4	(0.5) 2,046.3	(0.0) 2,069.3	(0.0) 2,069.3	(2.5) 8,207.3	(3.7) 2,020.7	(0.8) 2,046.0	(0.0) 2,069.3	(0.5) 2,068.8	(5.0) 8,204.8	(5.8) 2,018.6	(1.0) 2,045.8	(0.2) 2,069.1	(1.8) 2,067.5	(8.8) 8,201.0
Run of River	69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2	69.6	61.1	61.7	72.8	265.2
Total	(6.5) 6,169.4	(0.9) 7,013.4	(0.0) 6,847.9	(0.8) 6,821.3	(8.2) 26,852.0	(10.1) 6,510.5	(1.3) 7,400.8	(0.4) 7,226.5	(2.3) 7,198.4	(14.1) 28,336.2	(14.4) 6,872.7	(1.6) 7,812.3	(1.1) 7,628.4	(5.0) 7,598.5	(22.1) 29,911.9

Note : ( ) shows Pumping up Energy.

Table - 12.5·21 Total O & M Cost

Units : 1,000 US$

Alternaitives / F.Y.	Original Plan + Rehab. Ambuklao (a)	Original Plan + Geothermal (b)	No Change O.P. (c)
1996	398,809.1	403,587.7	407,636.6
1997	400,220.9	404,978.2	409,038.2
1998	413,143.8	417,897.7	421,954.9
1999	443,804.2	448,570.1	452,629.2
2000	476,911.1	481,706.0	485,739.6

Table - 12.5.22 I.R.R. and Present Value
Case : (a) - (b)

AMBUKULAN

CASE = A-B

TABLE INTERNAL RATE OF RETURN

	COST			BENEFIT			PRESENT VALUE		I.R.R.
YEAR	INVESTMENT	O & M	TOATAL	INVESTMENT	O & M	TOATAL	COST	BENEFIT	DISC.FAC.
1987	26646.	0.	26646.	26646.	0.	26648.	26648.	26648.	1.0000
1988	167526.	0.	167526.	167526.	0.	167526.	117769.	117769.	0.7030
1989	239513.	0.	239513.	238847.	0.	238847.	118365.	118036.	0.4942
1990	306150.	0.	306150.	305406.	0.	305406.	106360.	106101.	0.3475
1991	421665.	0.	421665.	420704.	0.	420704.	102986.	102767.	0.2443
1992	352904.	0.	352904.	358046.	0.	358046.	60589.	61472.	0.1717
1993	313756.	0.	313756.	313011.	0.	313011.	37872.	37779.	0.1207
1994	300262.	0.	300262.	296762.	0.	296762.	25478.	25179.	0.0849
1995	296456.	0.	296456.	296157.	0.	296157.	17683.	17665.	0.0597
1996	316365.	398809.	715174.	308756.	403588.	712344.	29988.	29869.	0.0419
1997	238704.	400221.	638925.	238704.	404978.	643682.	18833.	18974.	0.0295
1998	173105.	413144.	586249.	173105.	417898.	591003.	12148.	12247.	0.0207
1999	86553.	443804.	530357.	86553.	448570.	535123.	7726.	7795.	0.0146
2000	0.	476911.	476911.	0.	481706.	481706.	4884.	4933.	0.0102
2001	0.	476911.	476911.	0.	481706.	481706.	3433.	3468.	0.0072
2002	0.	476911.	476911.	0.	481706.	481706.	2414.	2438.	0.0051
2003	0.	476911.	476911.	0.	481706.	481706.	1697.	1714.	0.0036
2004	0.	476911.	476911.	0.	481706.	481706.	1193.	1205.	0.0025
2005	0.	476911.	476911.	0.	481706.	481706.	838.	847.	0.0018
2006	0.	476911.	476911.	0.	481706.	481706.	589.	595.	0.0012
2007	23983.	476911.	500894.	23983.	481706.	505689.	435.	439.	0.0009
2008	55804.	476911.	532715.	55804.	481706.	537510.	325.	328.	0.0006
2009	31821.	476911.	508732.	31821.	481706.	513527.	218.	221.	0.0004
2010	0.	476911.	476911.	0.	481706.	481706.	144.	145.	0.0003
2011	0.	476911.	476911.	0.	481706.	481706.	101.	102.	0.0002
2012	0.	476911.	476911.	0.	481706.	481706.	71.	72.	0.0001
2013	0.	476911.	476911.	0.	481706.	481706.	50.	51.	0.0001
2014	0.	476911.	476911.	0.	481706.	481706.	35.	36.	0.0001
2015	0.	476911.	476911.	0.	481706.	481706.	25.	25.	0.0001
2016	0.	476911.	476911.	0.	481706.	481706.	17.	18.	0.0000
2017	0.	476911.	476911.	0.	481706.	481706.	12.	12.	0.0000
2018	83078.	476911.	559989.	83078.	481706.	564784.	10.	10.	0.0000
2019	112317.	476911.	589228.	111717.	481706.	593423.	7.	8.	0.0000
2020	141065.	476911.	617976.	140395.	481706.	622101.	5.	6.	0.0000
2021	200061.	476911.	676972.	199178.	481706.	680884.	4.	4.	0.0000
2022	138158.	476911.	615069.	142786.	481706.	624492.	3.	3.	0.0000
2023	114844.	476911.	591755.	114146.	481706.	595852.	2.	2.	0.0000
2024	102690.	476911.	579601.	99522.	481706.	581228.	1.	1.	0.0000
2025	99248.	476911.	576160.	98978.	481706.	580684.	1.	1.	0.0000
2026	176696.	476911.	653608.	169848.	481706.	651554.	1.	1.	0.0000
2027	193831.	476911.	670742.	193831.	481706.	675537.	1.	1.	0.0000
2028	211599.	476911.	688510.	211599.	481706.	693305.	0.	0.	0.0000
2029	109719.	476911.	586630.	109719.	481706.	591425.	0.	0.	0.0000
2030	0.	476911.	476911.	0.	481706.	481706.	0.	0.	0.0000
2031	0.	476911.	476911.	0.	481706.	481706.	0.	0.	0.0000
2032	0.	476911.	476911.	0.	481706.	481706.	0.	0.	0.0000
2033	0.	476911.	476911.	0.	481706.	481706.	0.	0.	0.0000
2034	0.	476911.	476911.	0.	481706.	481706.	0.	0.	0.0000
2035	0.	476911.	476911.	0.	481706.	481706.	0.	0.	0.0000
2036	0.	476911.	476911.	0.	481706.	481706.	0.	0.	0.0000
TOTAL	5034592.	19301689.	24336281.	5016629.	19498155.	24514783.	698963.	698963.	

AMBUKULAN

CASE = A-B

*** I.R.R. = 42.24 % ***

TABLE PRESENT VALUE

DISC. RATE(%)	(5)	(10)	(12)	(20)	(25)	(30)	(35)	(40)
COST								
INVEST.	2761465.	1965716.	1768739.	1250489.	1044561.	889611.	769804.	675188.
O & M	5429341.	2084547.	1510046.	514439.	293546.	176970.	111198.	72199.
TOTAL	8190826.	4050263.	3278787.	1764928.	1338107.	1066580.	881001.	747387.
BENEFIT								
INVEST.	2753977.	1961301.	1765013.	1248394.	1043022.	888443.	768890.	674451.
O & M	5485394.	2106421.	1525994.	519993.	296751.	178921.	112434.	73008.
TOTAL	8239371.	4067722.	3291007.	1768387.	1339773.	1067364.	881324.	747459.
B/C	1.0059	1.0043	1.0037	1.0020	1.0012	1.0007	1.0004	1.0001
B-C	48545.	17459.	12220.	3460.	1666.	783.	323.	72.

Table - 12.5.23 I.R.R. and Present Value

Case : (a) - (c)

AMBUKULAC

CASE - A-C

TABLE INTERNAL RATE OF RETURN

	COST			BENEFIT			PRESENT VALUE		I.R.R.
YEAR	INVESTMENT	O & M	TOATAL	INVESTMENT	O & M	TOATAL	COST	BENEFIT	DISC.FAC.
1987	26646.	0.	26643.	26643.	0.	26646.	26648.	26648.	1.0000
1988	167526.	0.	167525.	167526.	0.	167526.	142338.	142338.	0.8497
1989	239513.	0.	239513.	238847.	0.	238847.	172904.	172423.	0.7220
1990	306156.	0.	306156.	305406.	0.	305406.	187780.	187323.	0.6135
1991	421685.	0.	421685.	420704.	0.	420704.	219756.	219245.	0.5213
1992	352904.	0.	352904.	350238.	0.	350238.	156260.	155080.	0.4429
1993	313786.	0.	313756.	305203.	0.	305203.	118049.	114820.	0.3764
1994	300282.	0.	300282.	288954.	0.	288954.	95984.	92363.	0.3198
1995	296456.	0.	296455.	288350.	0.	288350.	80514.	78312.	0.2717
1996	316365.	398809.	715174.	308756.	407637.	716393.	165027.	165309.	0.2309
1997	238704.	400221.	638925.	238704.	409039.	647743.	125266.	126995.	0.1962
1998	173105.	413144.	586249.	173105.	421955.	595060.	97657.	99125.	0.1667
1999	86553.	443804.	530357.	86553.	452629.	539182.	75063.	76312.	0.1416
2000	0.	476911.	476911.	0.	485740.	485740.	57350.	58412.	0.1204
2001	0.	476911.	476911.	0.	485740.	485740.	48727.	49629.	0.1023
2002	0.	476911.	476911.	0.	485740.	485740.	41401.	42168.	0.0869
2003	0.	476911.	476911.	0.	485740.	485740.	35176.	35827.	0.0738
2004	0.	476911.	476911.	0.	485740.	485740.	29887.	30441.	0.0627
2005	0.	476911.	476911.	0.	485740.	485740.	25394.	25864.	0.0533
2006	0.	476911.	476911.	0.	485740.	485740.	21576.	21975.	0.0453
2007	23983.	476911.	500894.	23983.	485740.	509722.	19254.	19593.	0.0385
2008	55804.	476911.	532715.	55804.	485740.	541544.	17398.	17686.	0.0327
2009	31821.	476911.	508732.	31821.	485740.	517561.	14117.	14362.	0.0278
2010	0.	476911.	476911.	0.	485740.	485740.	11244.	11452.	0.0236
2011	0.	476911.	476911.	0.	485740.	485740.	9553.	9730.	0.0201
2012	0.	476911.	476911.	0.	485740.	485740.	8117.	8267.	0.0170
2013	0.	476911.	476911.	0.	485740.	485740.	6897.	7024.	0.0145
2014	0.	476911.	476911.	0.	485740.	485740.	5860.	5968.	0.0123
2015	0.	476911.	476911.	0.	485740.	485740.	4979.	5071.	0.0105
2016	0.	476911.	476911.	0.	485740.	485740.	4230.	4308.	0.0089
2017	0.	476911.	476911.	0.	485740.	485740.	3594.	3661.	0.0076
2018	83078.	476911.	559989.	83078.	485740.	568817.	3586.	3642.	0.0064
2019	112317.	476911.	589228.	111717.	485740.	597457.	3206.	3250.	0.0055
2020	141065.	476911.	617976.	140395.	485740.	626134.	2857.	2894.	0.0046
2021	200061.	476911.	676972.	199176.	485740.	684917.	2659.	2690.	0.0039
2022	138158.	476911.	615069.	135759.	485740.	621498.	2052.	2074.	0.0033
2023	114844.	476911.	591755.	107119.	485740.	592859.	1678.	1681.	0.0028
2024	102690.	476911.	579601.	92495.	485740.	578235.	1396.	1393.	0.0024
2025	99248.	476911.	576160.	91951.	485740.	577691.	1179.	1182.	0.0021
2026	176696.	476911.	653606.	169848.	485740.	655588.	1137.	1140.	0.0017
2027	193831.	476911.	670742.	193831.	485740.	679571.	991.	1004.	0.0015
2028	211599.	476911.	688510.	211599.	485740.	697338.	864.	875.	0.0013
2029	109719.	476911.	586630.	109719.	485740.	595458.	626.	635.	0.0011
2030	0.	476911.	476911.	0.	485740.	485740.	432.	440.	0.0009
2031	0.	476911.	476911.	0.	485740.	485740.	367.	374.	0.0008
2032	0.	476911.	476911.	0.	485740.	485740.	312.	318.	0.0007
2033	0.	476911.	476911.	0.	485740.	485740.	265.	270.	0.0006
2034	0.	476911.	476911.	0.	485740.	485740.	225.	229.	0.0005
2035	0.	476911.	476911.	0.	485740.	485740.	191.	195.	0.0004
2036	0.	476911.	476911.	0.	485740.	485740.	163.	166.	0.0003
TOTAL	5034592.	19301669.	24336281.	4957290.	19663624.	24620914.	2052185.	2052184.	

AMBUKULAC

CASE - A-C

I.R.R. = 17.69 %

TABLE PRESENT VALUE

DISC. RATE(%)	(5)	(10)	(12)	(20)	(25)	(30)	(35)	(40)
COST								
INVEST.	2761485.	1965716.	1768739.	1250489.	1044561.	889611.	769804.	675188.
O & M	5429341.	2084547.	1510048.	514439.	293546.	176970.	111198.	72199.
TOTAL	8190826.	4050263.	3278787.	1764928.	1338107.	1066580.	881001.	747387.
BENEFIT								
INVEST.	2726457.	1943525.	1749489.	1238610.	1035461.	882519.	764195.	670693.
O & M	5532664.	2124894.	1539465.	524694.	299467.	180575.	113483.	73694.
TOTAL	8259121.	4068418.	3288957.	1763304.	1334927.	1063094.	877678.	744386.
B/C	1.0083	1.0045	1.0031	0.9991	0.9976	0.9967	0.9962	0.9960
B-C	68294.	18156.	10169.	-1623.	-3179.	-3487.	-3324.	-3000.

Table − 12.5・24 MW Balance in Period II of 1996

Plants	Capacity (MW) at Sending End	
	(c_1)	(c_2)
Gas−turbine	(255.1)	(255.1)
Pumped Storage	111.1 } (1,216.3)	75.0 } (1,245.0)
Reservoir	912.4	1,143.7
Oil−fired (1)	1,116.1 (1,130.8)	1,130.8
Oil−fired (2)	164.6	164.6
Coal−fired (150MW units)	209.1	0
Coal−fired (300MW units)	385.8	385.8
Geothermal	859.1	859.1
Run of River	28.0	28.0
Total	3,787.0 (4,248.8)	3,787,0 (4,068.4)
Reserve Margin after considering Forced Outage, Maintenance and Station use.	461.8 MW 12.2 %	281.4 MW 7.4 %

Note : ( ) shows Potential Capacity at Sending End

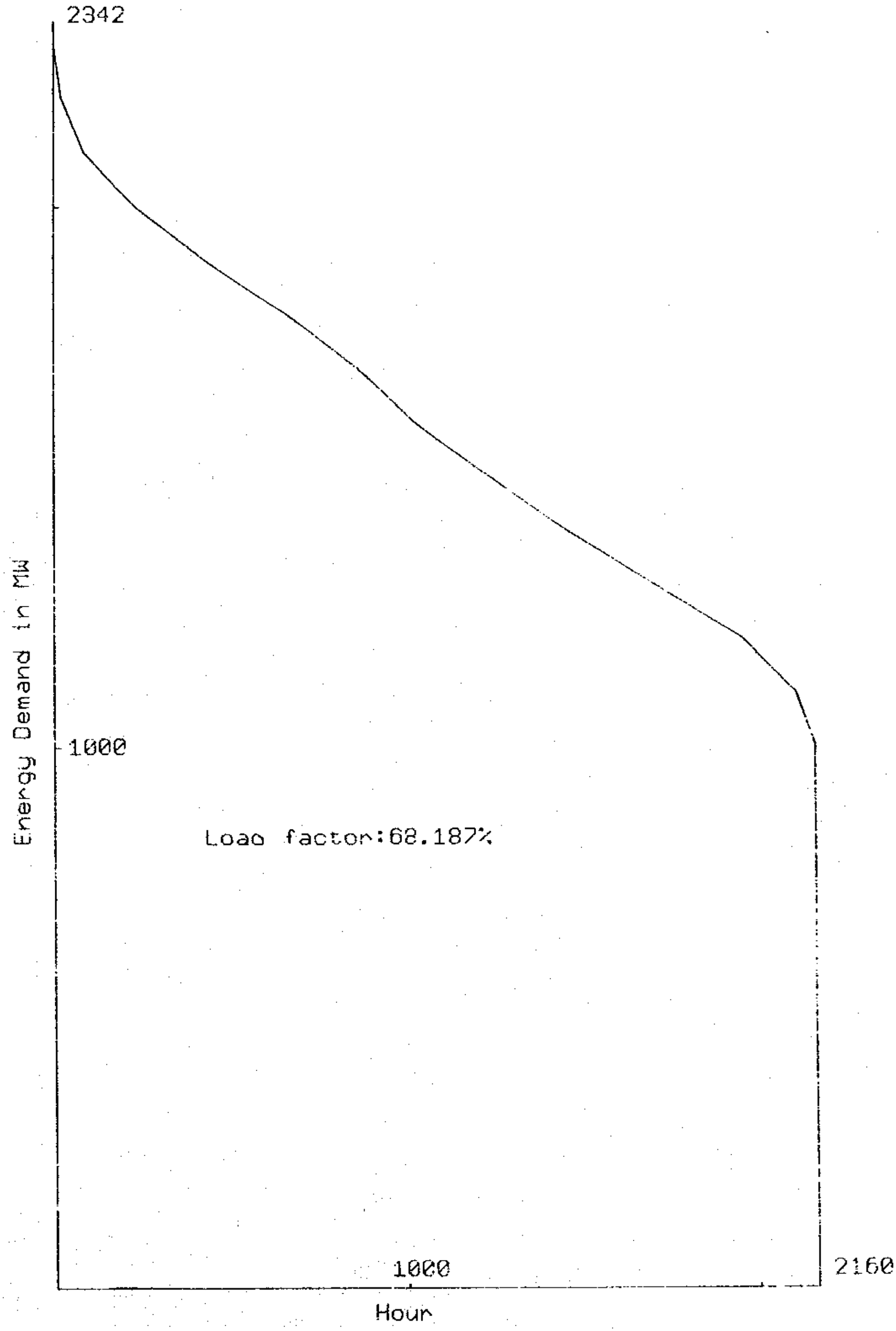


Fig — 12.5·1 Duration Curve I (from Jan, to Mar. 1986)

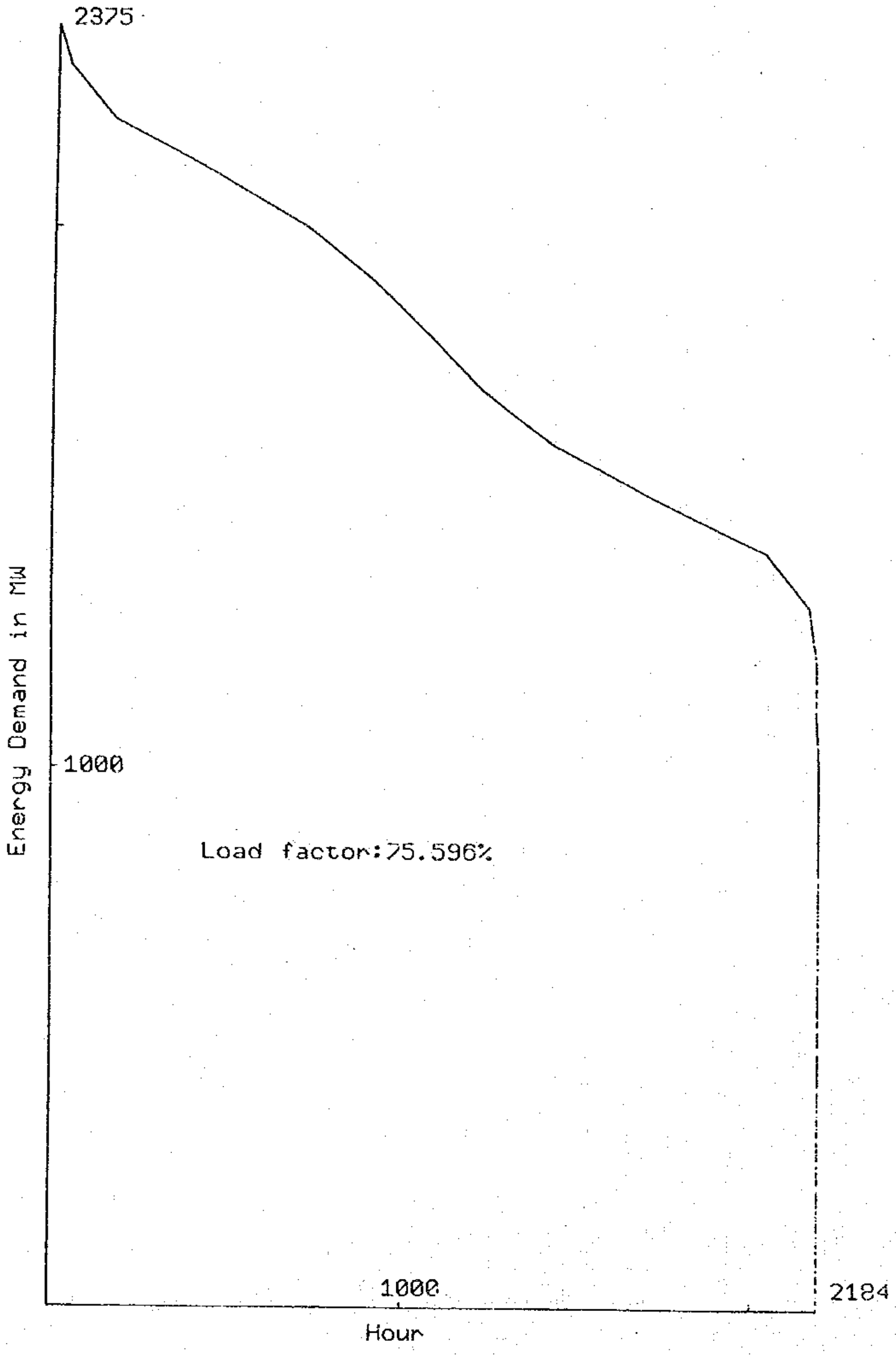


Fig — 12.5·2 Duration Curve II (from Apr. to Jun. 1986)

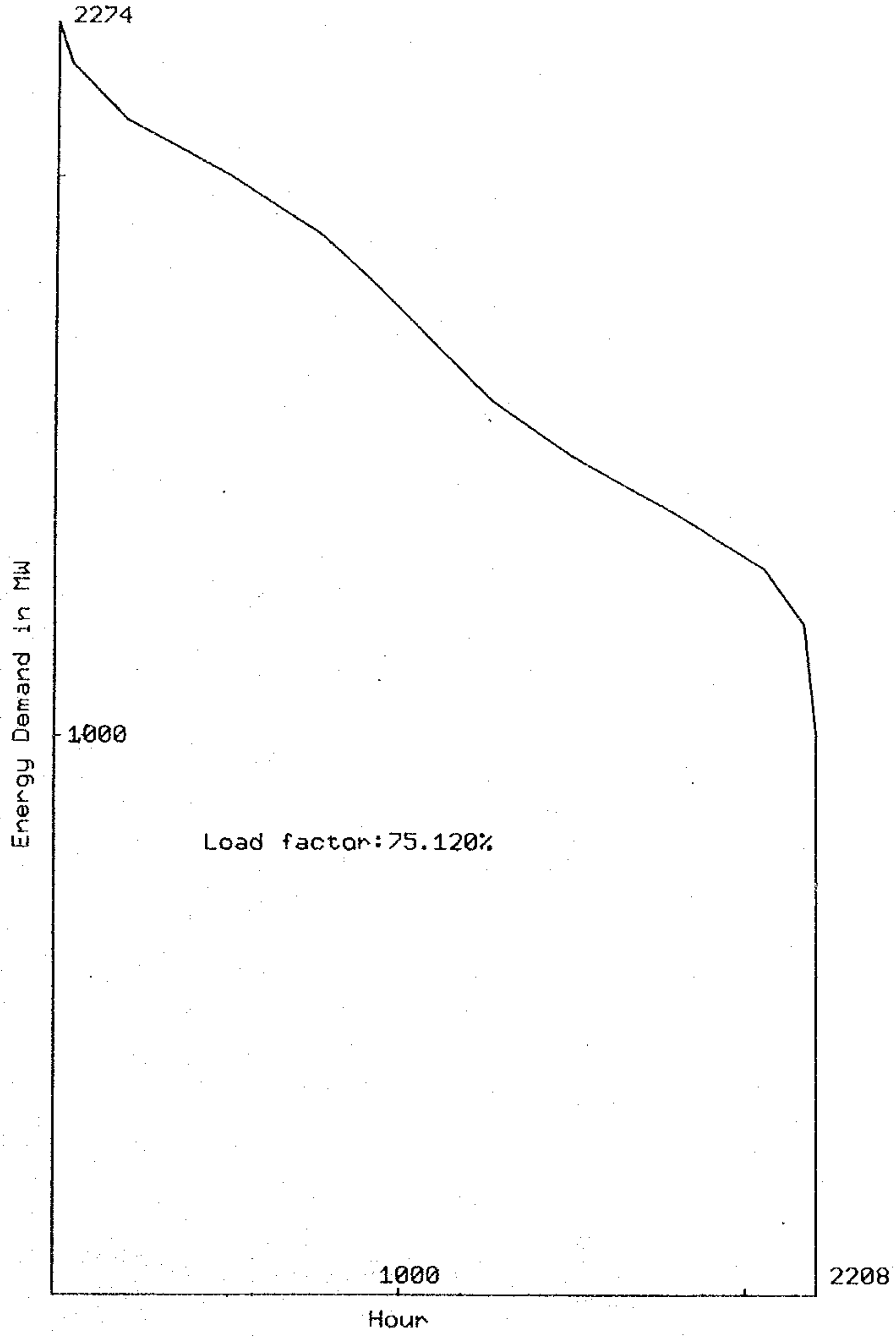


Fig — 12.5·3 Duration Curve ▮ (from Jul. to Sep. 1986)

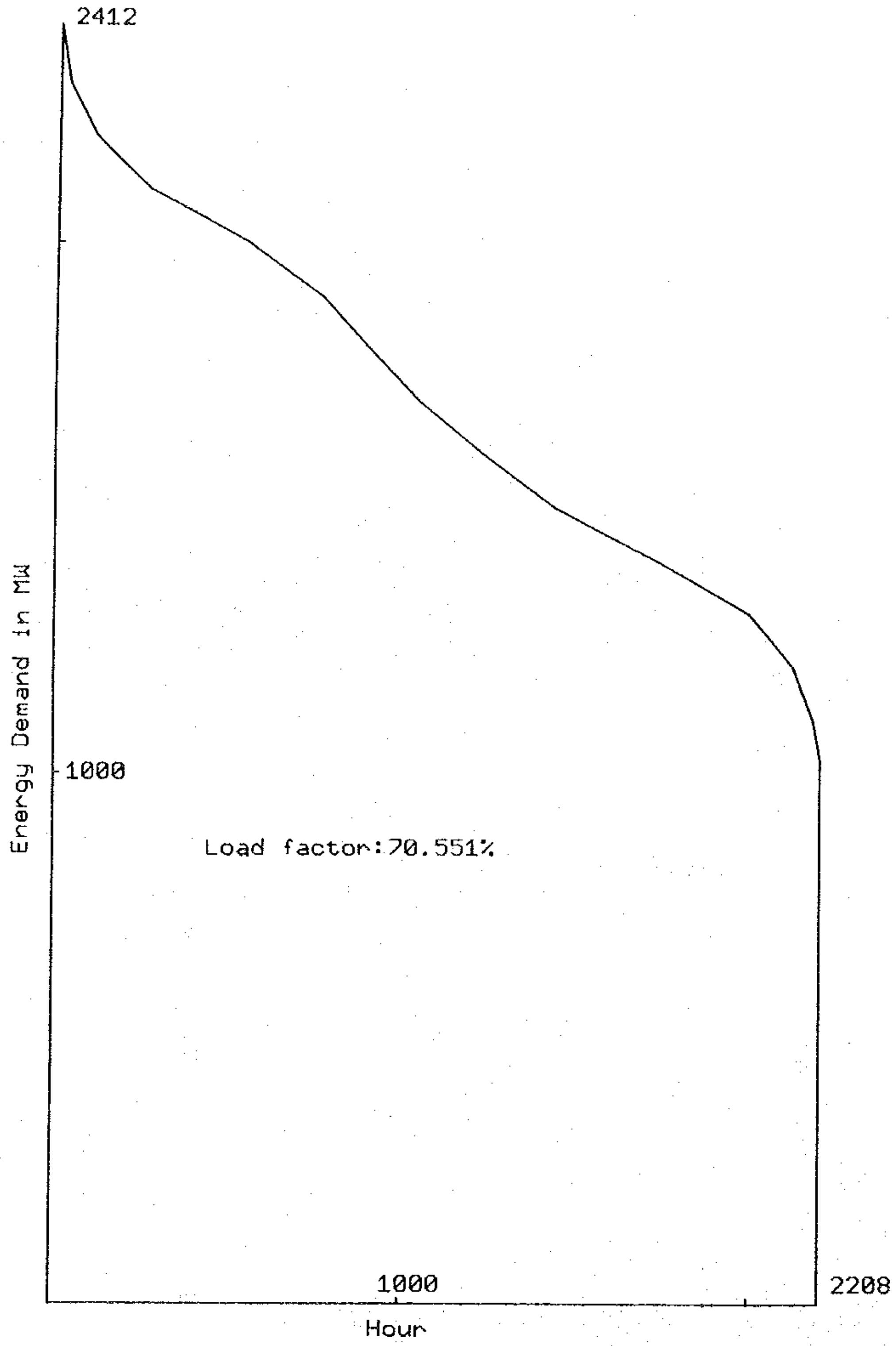


Fig — 12.5·4 Duration Curve Ⅳ (from Oct. to Dec. 1986)

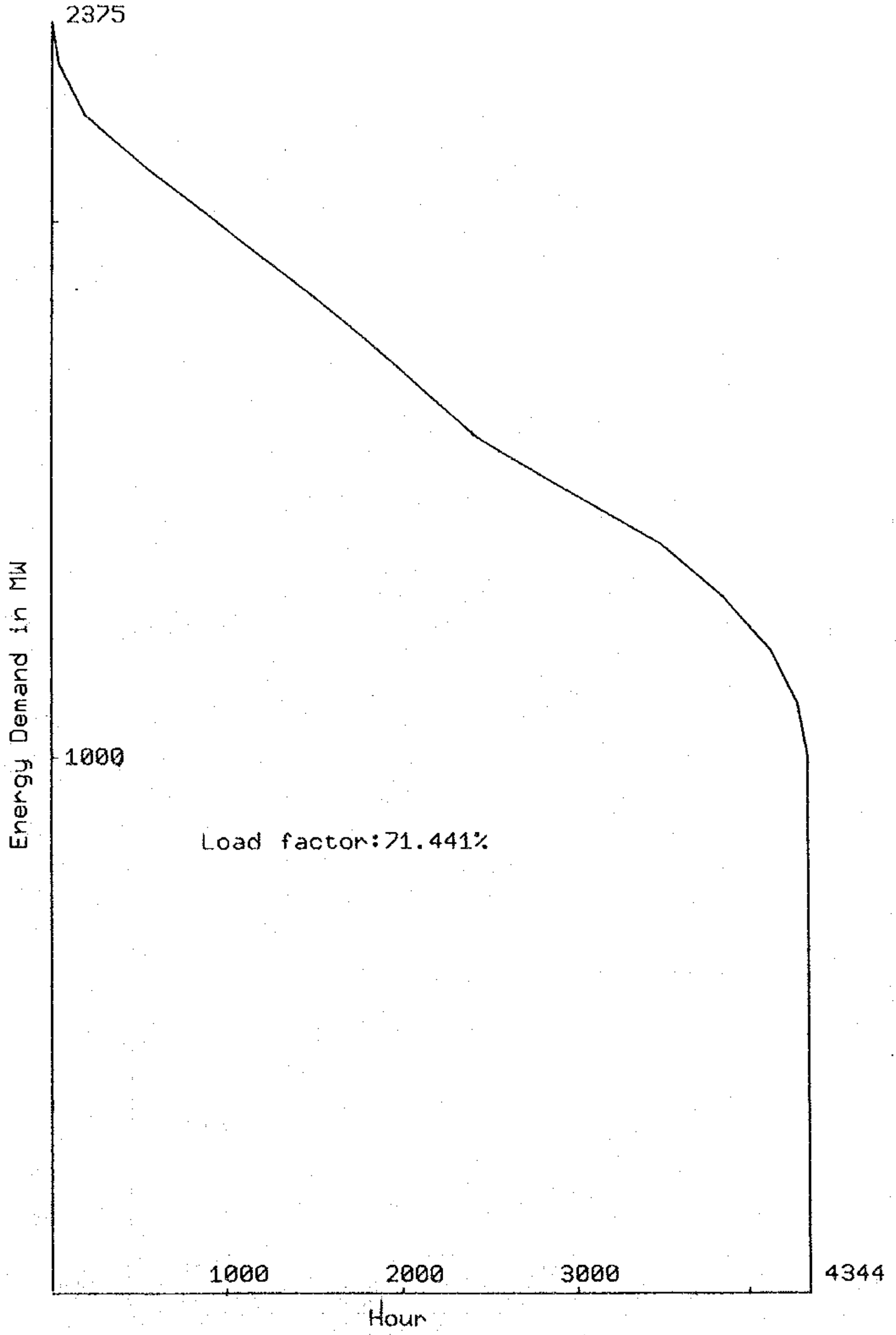


Fig — 12.5·5 Duration Curve (from Jan. to Jun. 1986)

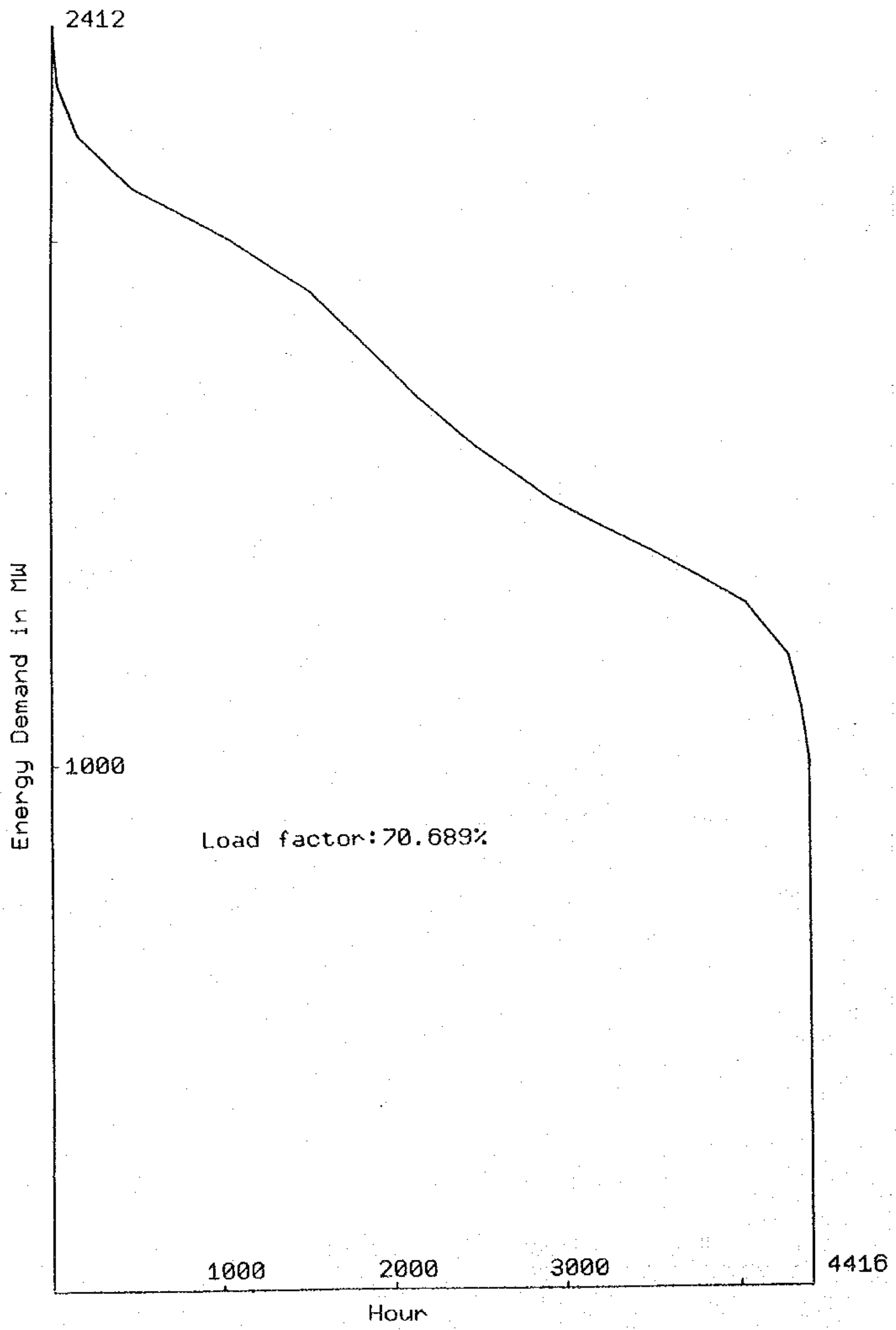


Fig — 12.5·6 Duration Curve (from Jul. to Dec. 1986)

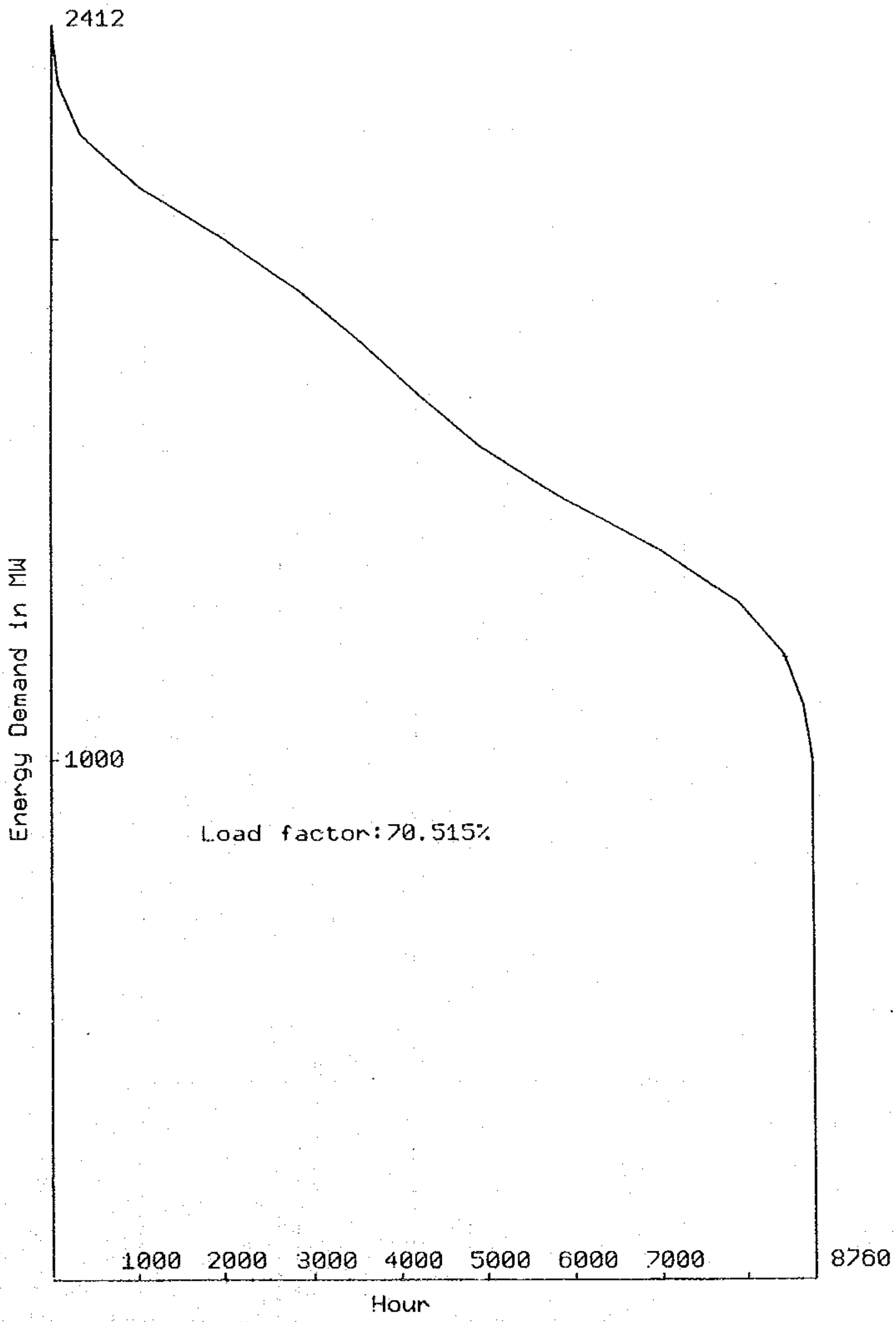


Fig — 12.5·7 Duration Curve (from Jan. to Dec. 1986)

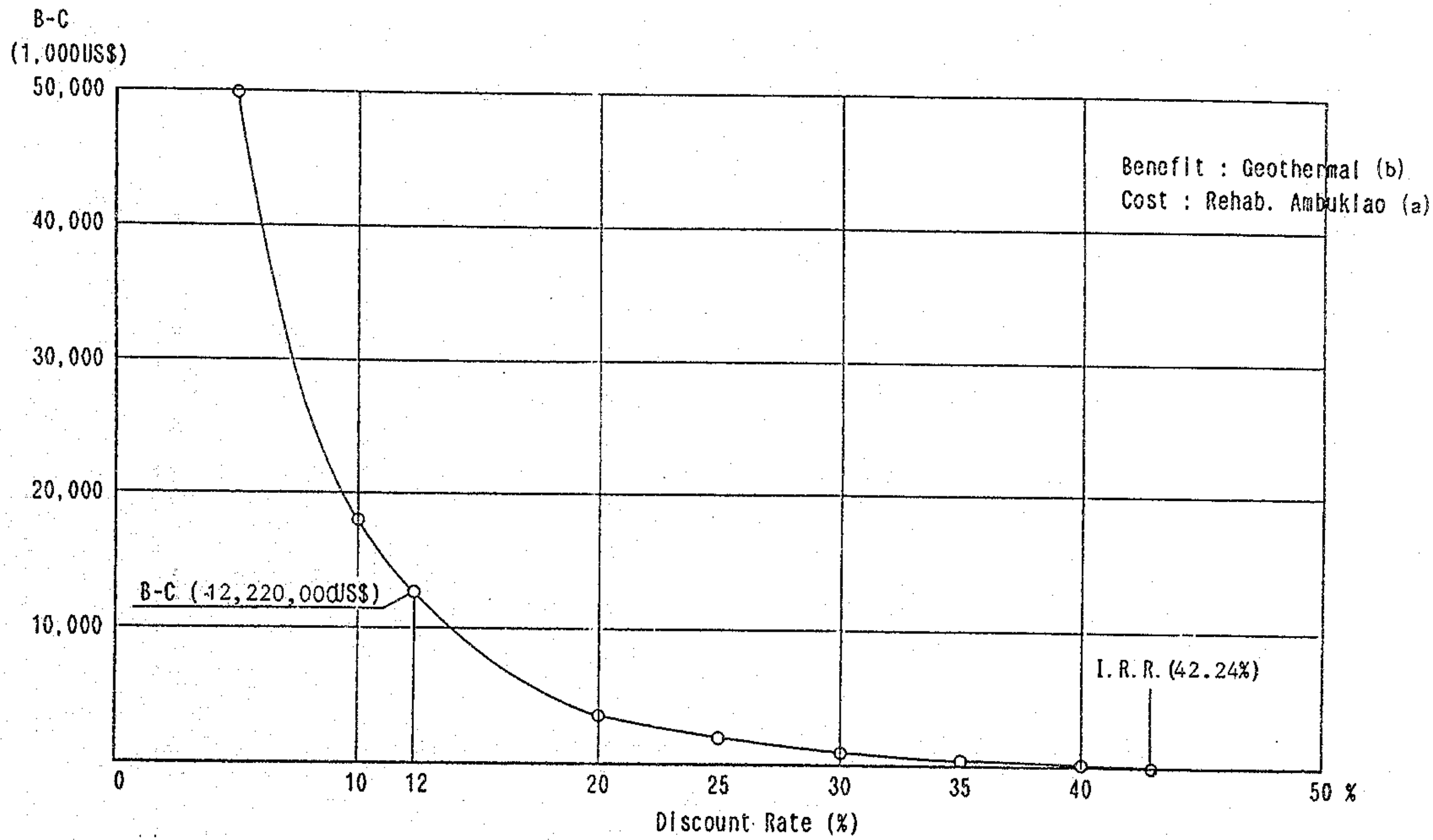
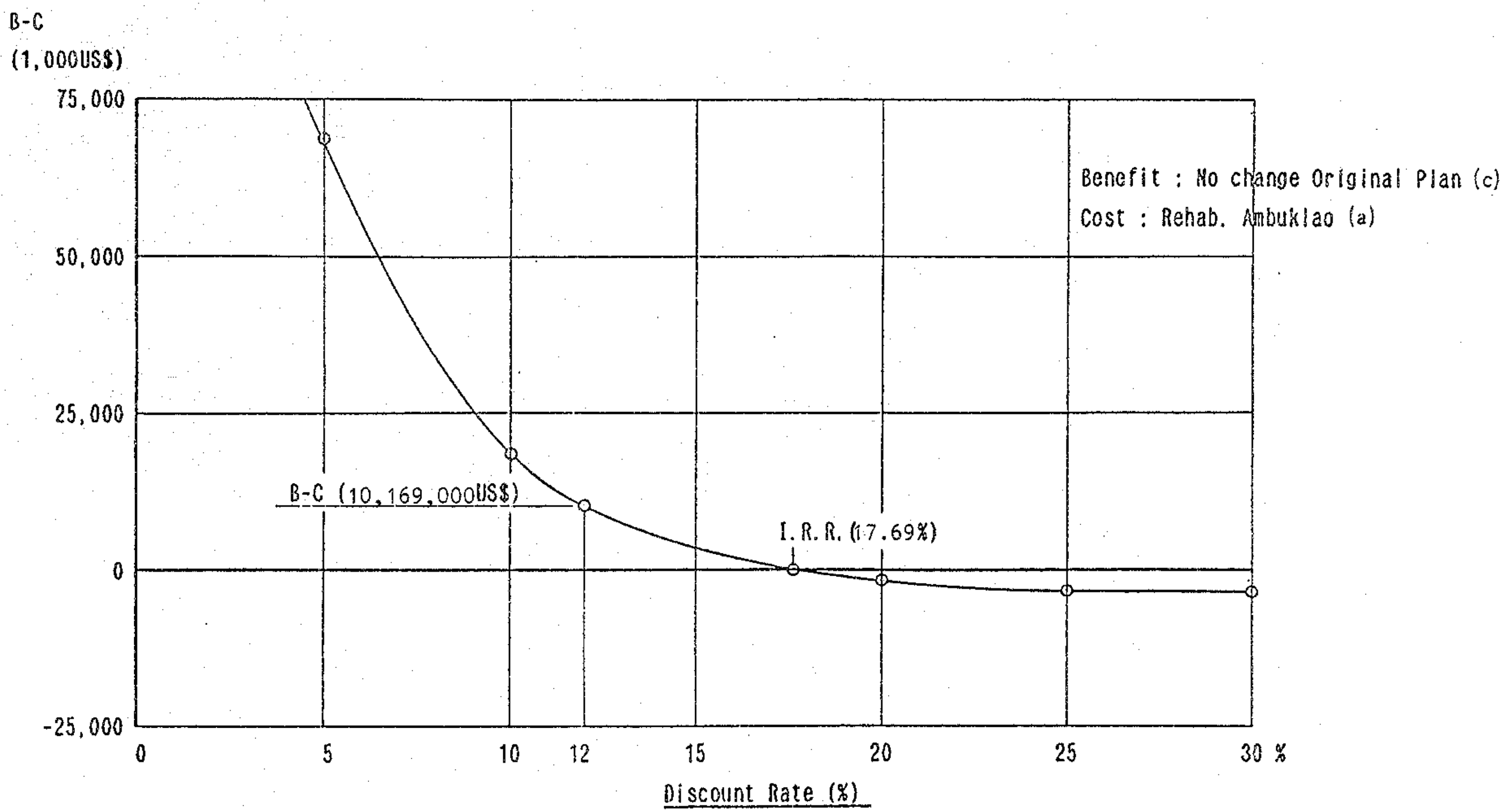


Fig-12.5.8 B-C, Discount Rate Curve (a-b)



Fig－12.5.9　B－C, Discount Rate Curve (a－c)

13. Dam Safety Control System

13. Dam Safety Control System

13.1. General

The general safety control requirements for the Ambuklao Project were discussed in Chapters 4 and 10, above.

The safety control of hydropower facilities cover wide area, such as safety against landslides at or near the project structures and around the reservoir, safety against floods and sedimentation, safety of the dam and its foundations, underground structures, generating equipment and facilities, and environmental conservation.

In this Section, safety control for the rockfill dam is discussed in greater detail, taking into account the effects which the earthquake of April 1985 had on the stability of the dam.

For safety of rockfill dams, prevention of the following is important:

(1) Flow over the top of the dam
(2) Seepage through the dam or its foundations
(3) Collapse of face of the dam caused by large earthquakes.

Inspection, surveillance and maintenance of the dam and its auxiliary structures are, therefore, very important, for the safety of the project.

For this, the following measures are required:

(1) Monitoring
(2) Inspection and surveillance
(3) Detail inspection and further investigations
(4) Maintenance

13.2. Monitoring

It is proposed to change the existing monitoring system in accordance with the proposed three stages described below. As over 30 years have passed since the completion of the Ambuklao Dam, it will be natural to assume that the Ambuklao Project should be placed in the third stage. However, considering the earthquake of April 1985 and the installation of boring holes for underground water observations, it is proposed that the second stage be applied. The second stage should be modified as required. Table-13.1 shows the proposed monitoring items and frequency of monitoring.

Description of the monitoring systems follows.

(1) First Stage

This is the stage which covers the initial reservoir filling period. The water pressure load acts on the dam for the first time. The dam shows variable reactions until the water reaches the maximum reservoir level. This first stage of observations is, no doubt, the most important for the safety of the dam. Monitoring, therefore, must be carried out carefully and frequently. The monitoring results must be analyzed quickly in order to evaluate the behaviour of the dam and its safety and to decide the mode and sequence of further water level rises.

(2) Second Stage

During the period of this stage, monitoring is performed in order to determine whether the operating conditions of the dam could be judged to be normal, including the conditions of seepage through the foundation rock. This period could cover 3 to 5 years.

(3) Third Stage

This stage covers the period during which monitoring of the dam is done with a purpose of maintaining the proper function of the dam through its lifetime. The period of this stage is the longest of the three stages.

The following table describes the frequency and type of monitoring normally used for embankment dams:

Table-13.1
Embankment Dams
Type of Monitoring and Frequency

Stage	Dam type	Monitoring Items		
		Seepage	Deformation	Seepage line
1	U/S* facing	everyday	once a week	
	zoned	ditto	ditto	
	homogenious	ditto	ditto	once a week
2	U/S facing	once a week	once a month	
	zoned	ditto	ditto	
	homogenious	ditto	ditto	once a month
3	U/S facing	once a week	once 3 months	
	zoned	once a week	once 3 months	
	homogenious	once a week	once 3 months	once 3 months

U/S: Upstream

For the Ambuklao Dam, the following specific type of monitoring and respective frequencies are proposed:

Table-13.2

Ambuklao Dam

Type of Monitoring and Frequency

Monitoring Items	Frequency	Remarks
Precipitation	once a day	
Reservoir Water Level	once a day	
Seepage at the Dam	once a week	
Seepage at the Powerstation	once a day	to be reduced in the future
Water Level at the Openpipe Piezometer	once a month	to be reduced in the future
Water Level at the Openpipe Piezometer on the Dam Crest	once a week	
Water Level at the Inclinometer Hole	once a week	
Water Level at the Spillway Left Abutment	once a week	to be reduced in the future
Dam Displacement, Alignment-1	once a month	to be reduced in the future
Dam Displacement, Alignment-2	once a month	to be reduced in the future
Inclinometer	once a month	

13.3. Inspection

Inspection of structures is very important for prevention of problems and, failures. Inspection of the dam on a regular basis and in accordance with some predetermined pattern can be very effective in preventing major problems or even failures from developing. In addition to the regular inspections, inspections to be performed after occurrence of a major event, such as large floods or earthquakes, are also highly desirable.

The above inspections and their frequencies are presented in the following tabulation:

Table-13.3

Type of Inspections and their Frequency

Type of Inspection	Frequency	Activity
Periodic inspection	Once a month	Measurement and surveillance reading
Inspection after earthquake	If stronger than .... on the Richter Scale	ditto
Inspection after flood	If bigger than 3-year return period	ditto
Inspection after heavy rain	If bigger than 3-year return period	ditto

13.4. Detail Inspection and Further Investigations

If abnormal behaviour or conditions are detected during the periodic inspection or from the collected monitoring data, a detail investigation must be undertaken to determine the causes for the above.

The extent of the investigation will depend on the importance of the problem or the structure.

For the Ambuklao Dam, the abnormal flood of December 1976 or the earthquake of April 1985, belong to the events for which further investigation would be required.

As reported such proper measures were actually taken at the time of the occurrence of the above flood and earthquake.

13.5. Maintenance

When it is found, as a result of the routine inspection or inspection after the occurrence of a big flood or earthquake, or simply from the monitoring data, that the dam or certain parts of the dam require to be maintained and repaired, such work should be carried out immediately and without any delay.

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