3.5.2 R-2 Hydropower Project

R-2 Regulating Dam, while regulating the discharge of R-1 Power Station, at the same time has the function of diverting the water to R-2 Power Station and El Chorro Power Station.

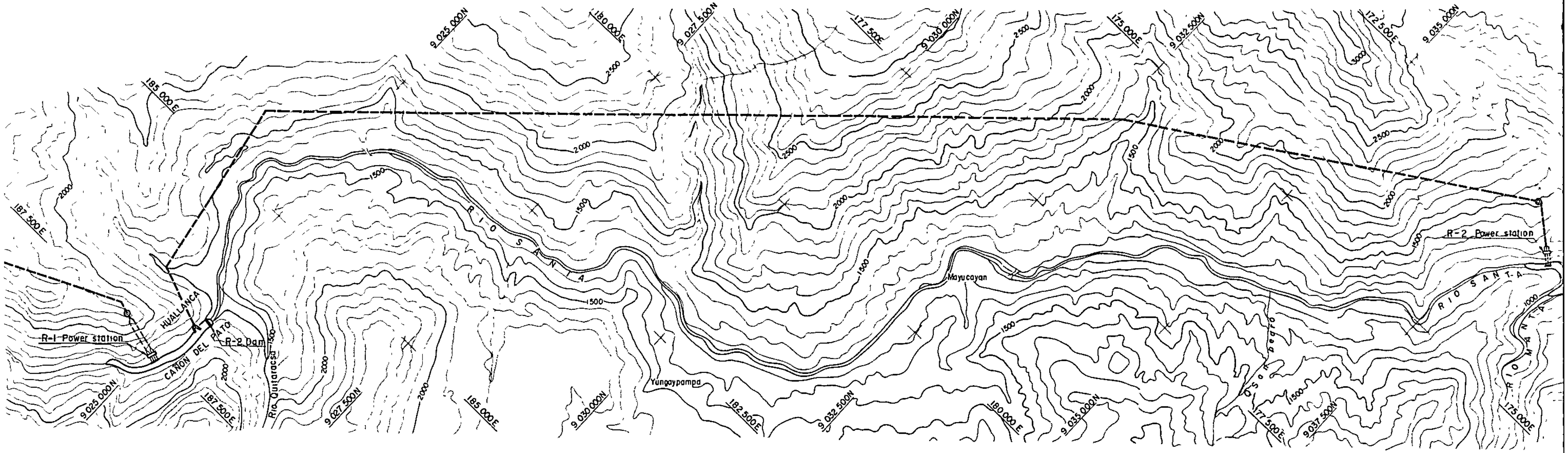
A concrete gravity dam of height of 74 m and crest length of 115 m is to be constructed immediately downstream of the R-1 Power Station outlet to obtain available drawdown of 55 m and effective storage capacity of 4.2×10^6 m^3.

The intake is to be provided at the left bank immediately upstream of the dam. It is to be a diagonal-type concrete structure of 15.0 m wide and 76.0 m high with two intake gates provided. The water taken in is to be conducted to a surge tank by a pressure tunnel of inside diameter of 6.20 m and length of 21.5 km. This surge tank will be located at the El Chorro site at the left-bank side of the Santa river 500 m upstream from the confluence of the Santa and the Manta rivers. The surge tank is to be a chamber-type of inside diameter of 7.8 m and height of 180 m. This surge tank is connected to 1 to 3 penstocks of 900 m in length. The powerhouse is to be of underground type of 20.0 m wide, 45.0 m high and 77.0 m long, and is to be of reinforced concrete structure.

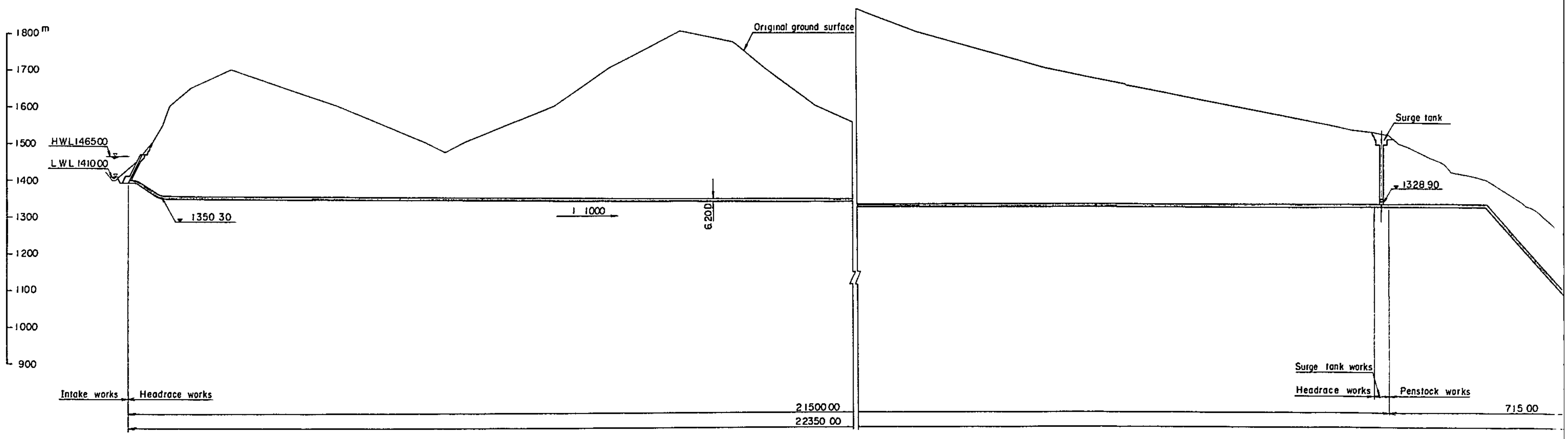
The standard effective head of this power station will be 440 m, and the maximum available discharge 132 m^3/sec, with the maximum turbine discharge per unit being 44 m^3/sec. The turbine which matches such conditions would be a vertical-shaft Francis turbine. The output per turbine is to be 169,000 kW and the output per generator 182,000 kVA with generator voltage 16.5 kV, and rated power factor 0.9 (lagging). With these, a maximum output of 490 MW will be obtained. The energy production will be an annual average of $1,717.0 \times 10^6$ kWh, and $1,297 \times 10^6$ kWh in a dry year.

The plans and cross sections of the structures of R-2 Power Station are indicated in Fig.-IV.3.7 through IV.3.10.

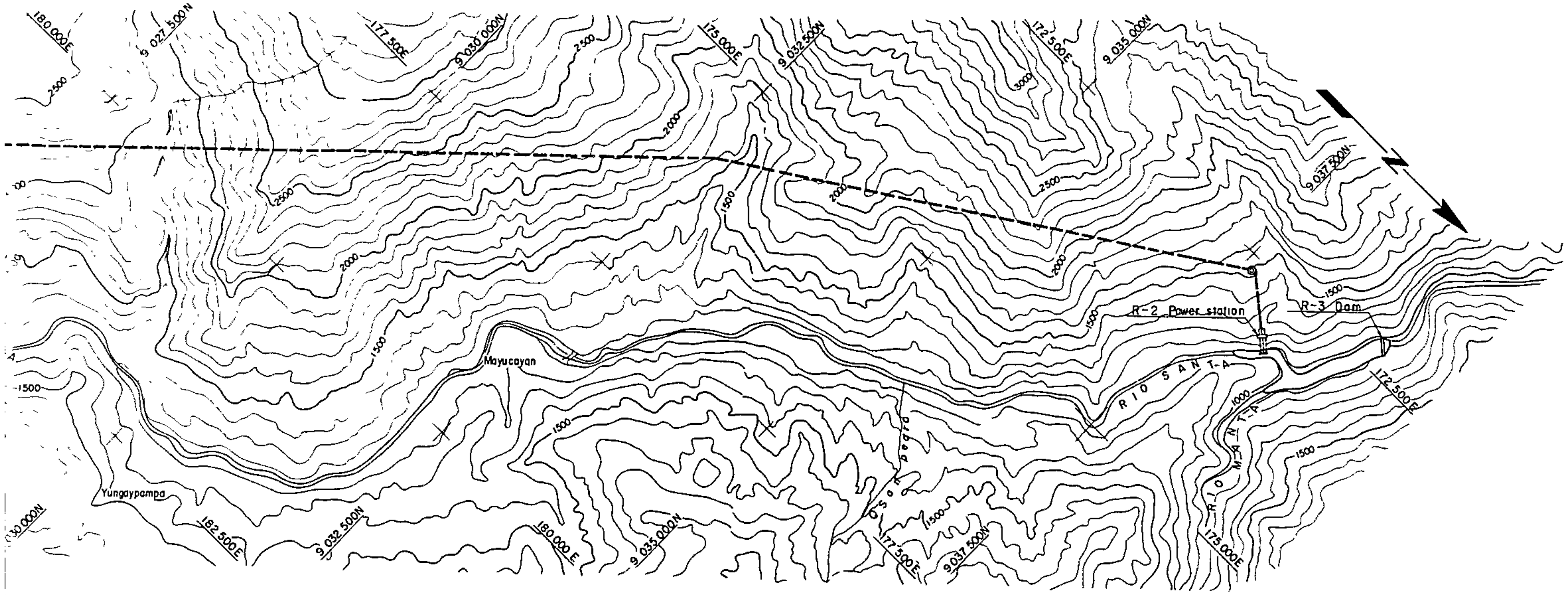
PLAN



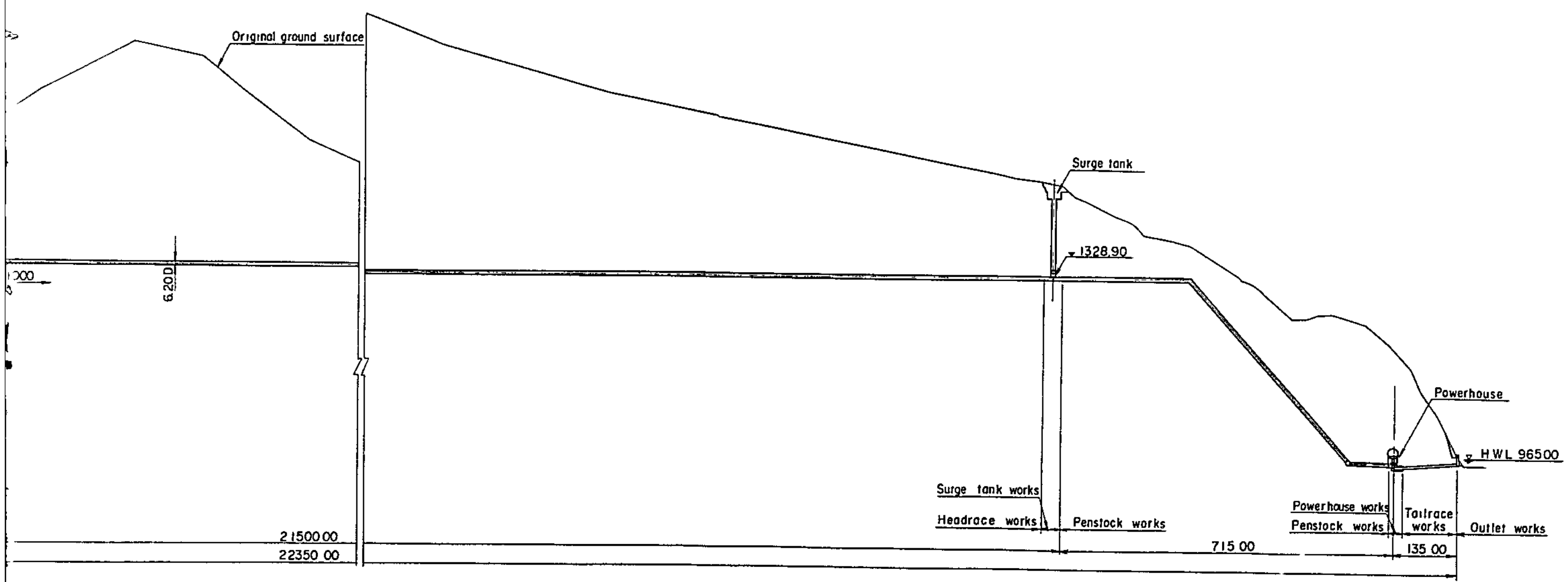
PROFILE



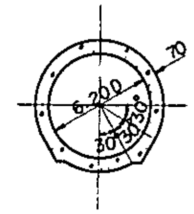
PLAN



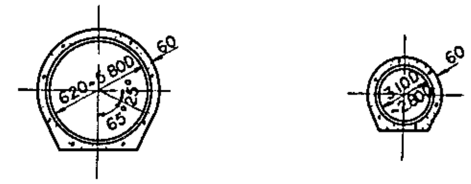
PROFILE



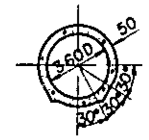
TYPICAL SECTION OF HEADRACE TUNNEL



TYPICAL SECTION OF PENSTOCK



TYPICAL SECTION OF TAILRACE TUNNEL



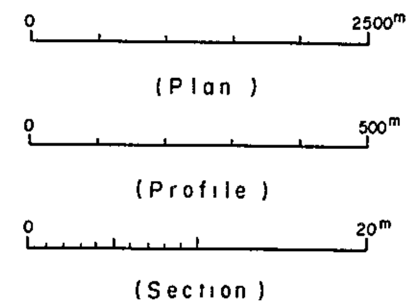
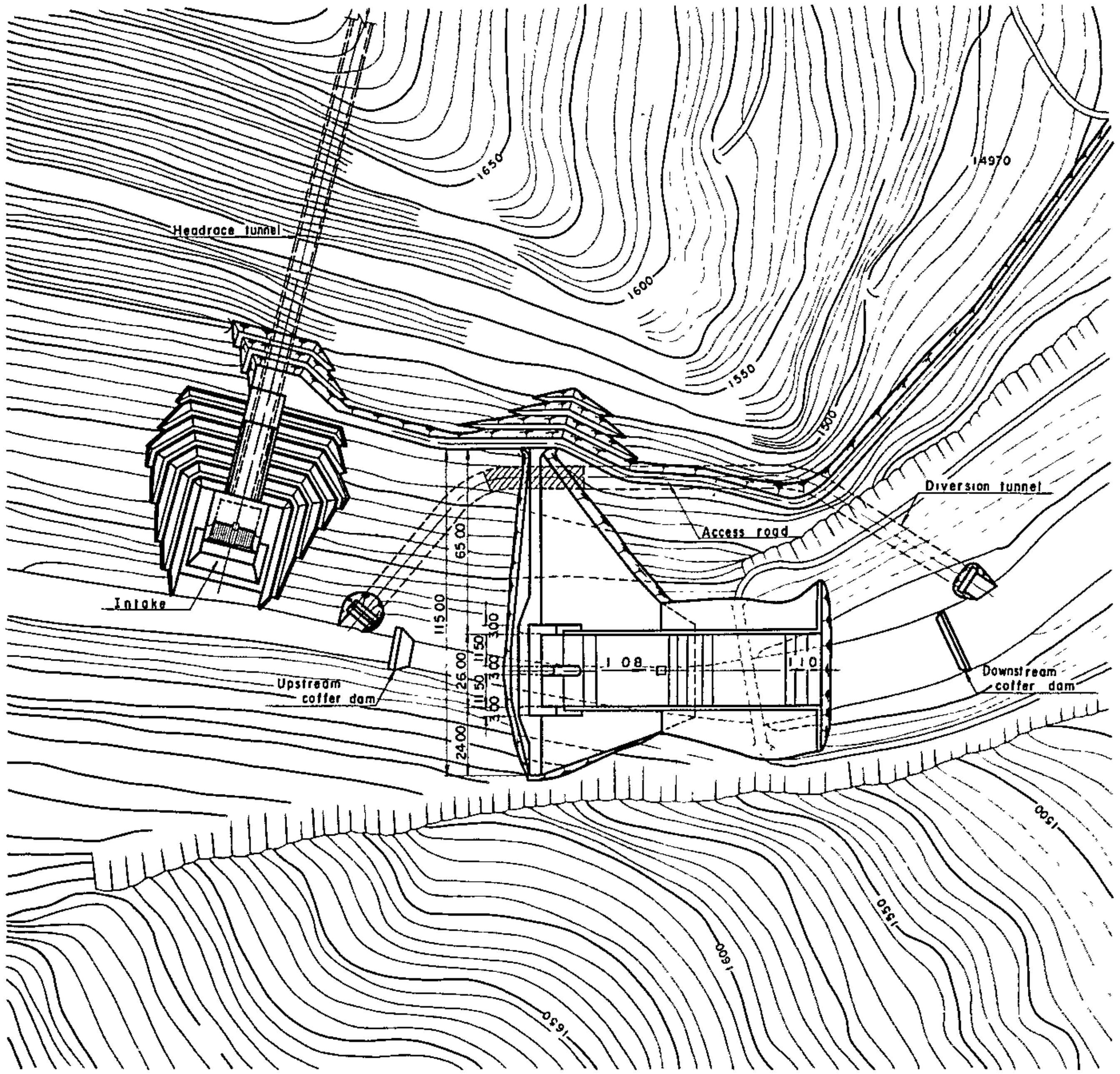
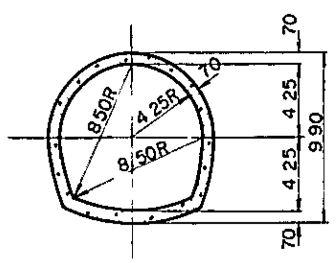


Fig.-IV.3.7 General Plan and Water Conductor (R-2) Longitudinal Profile

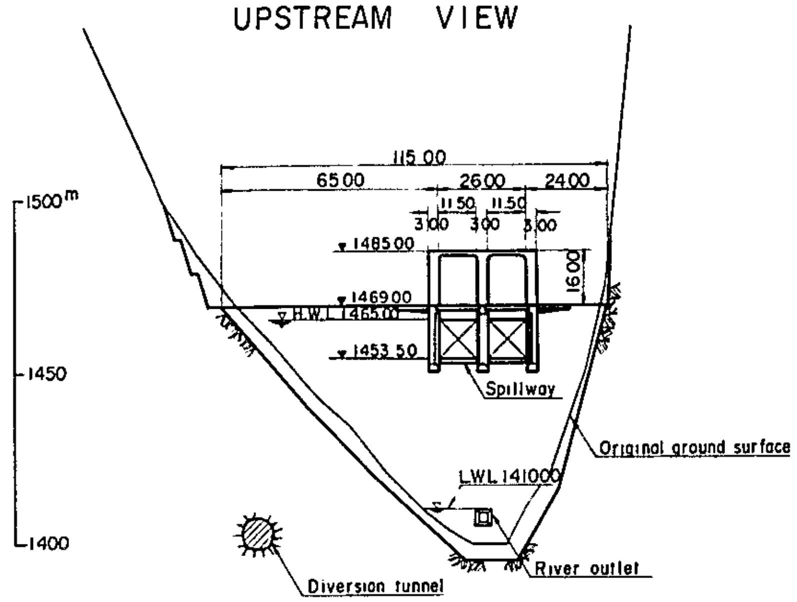
PLAN



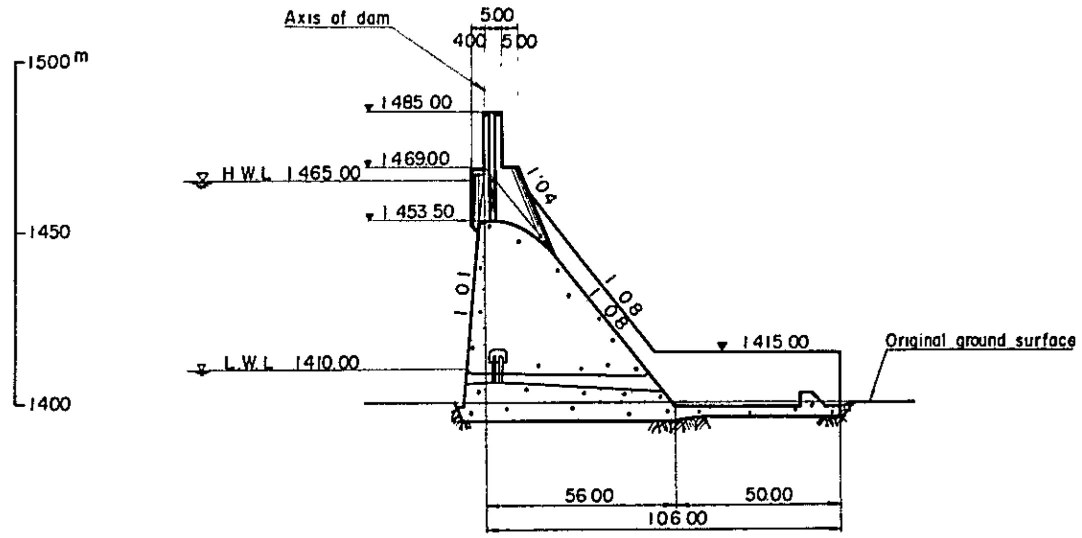
TYPICAL SECTION OF DIVERSION TUNNEL



UPSTREAM VIEW



OVERFLOW SECTION



NON-OVERFLOW SECTION

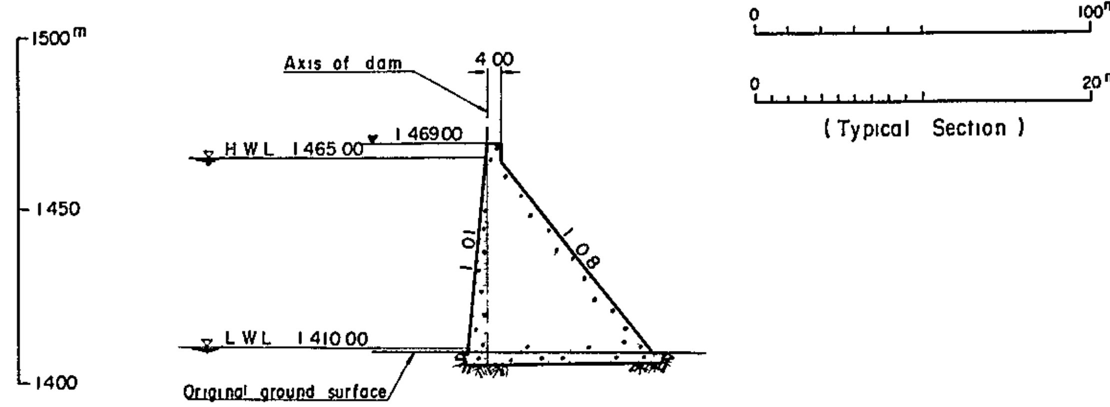


Fig-IV.38 Dam (R-2)
Plan, Profile and Section

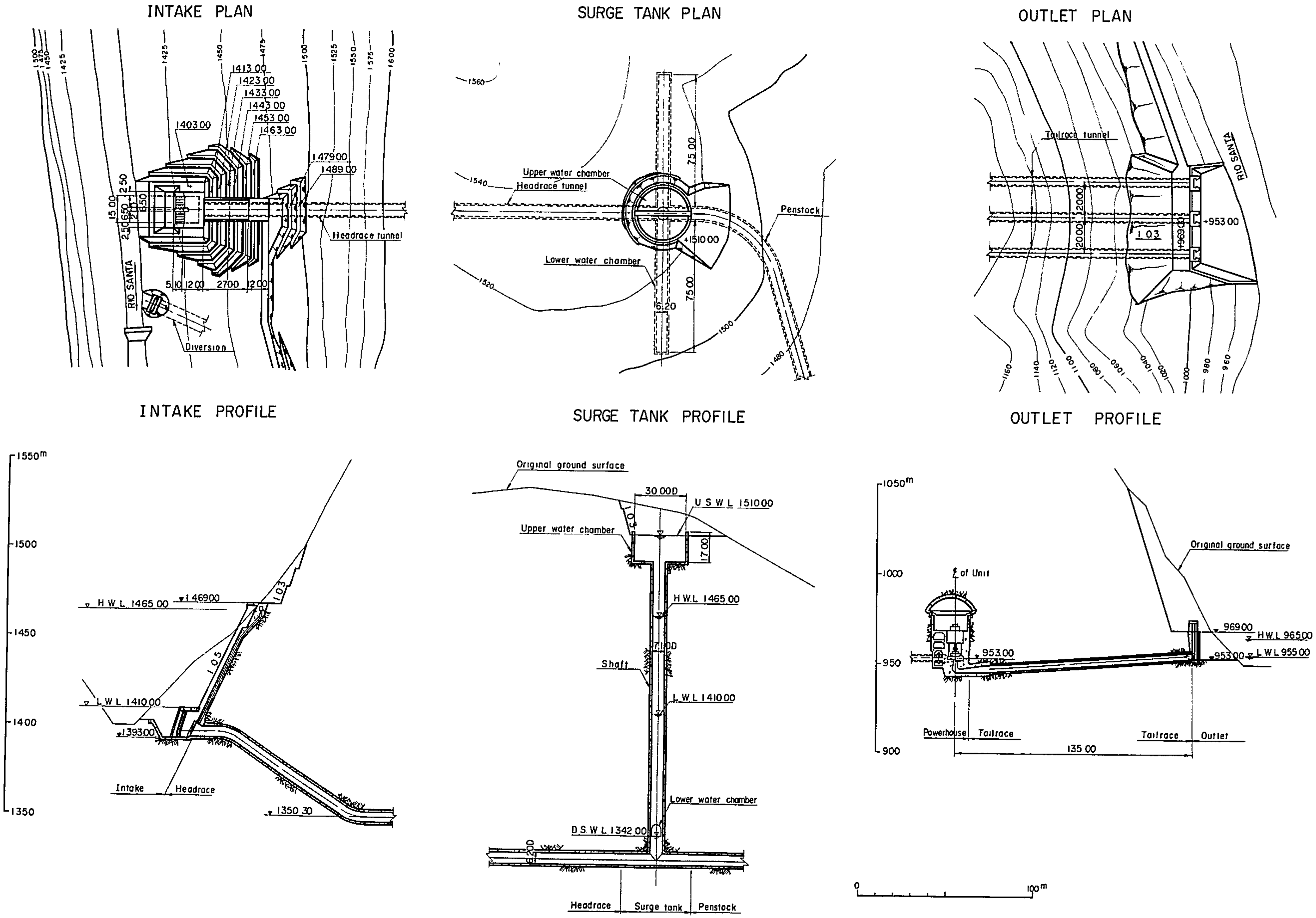
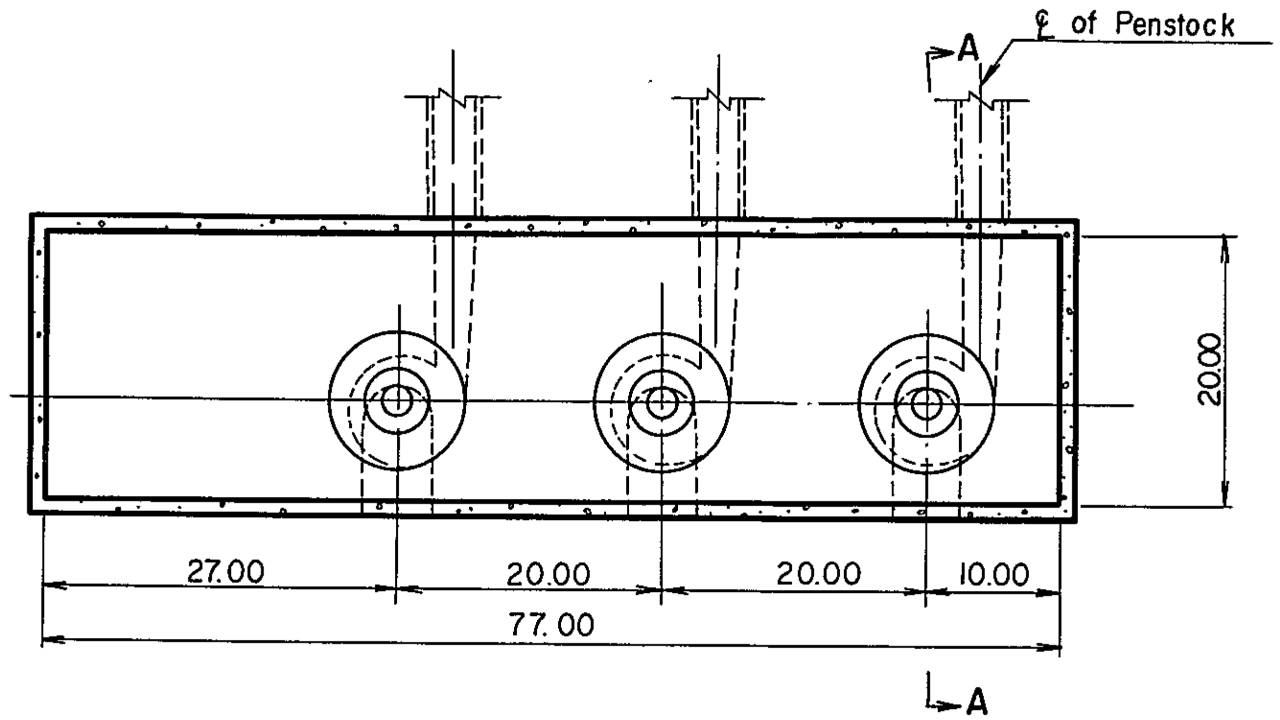
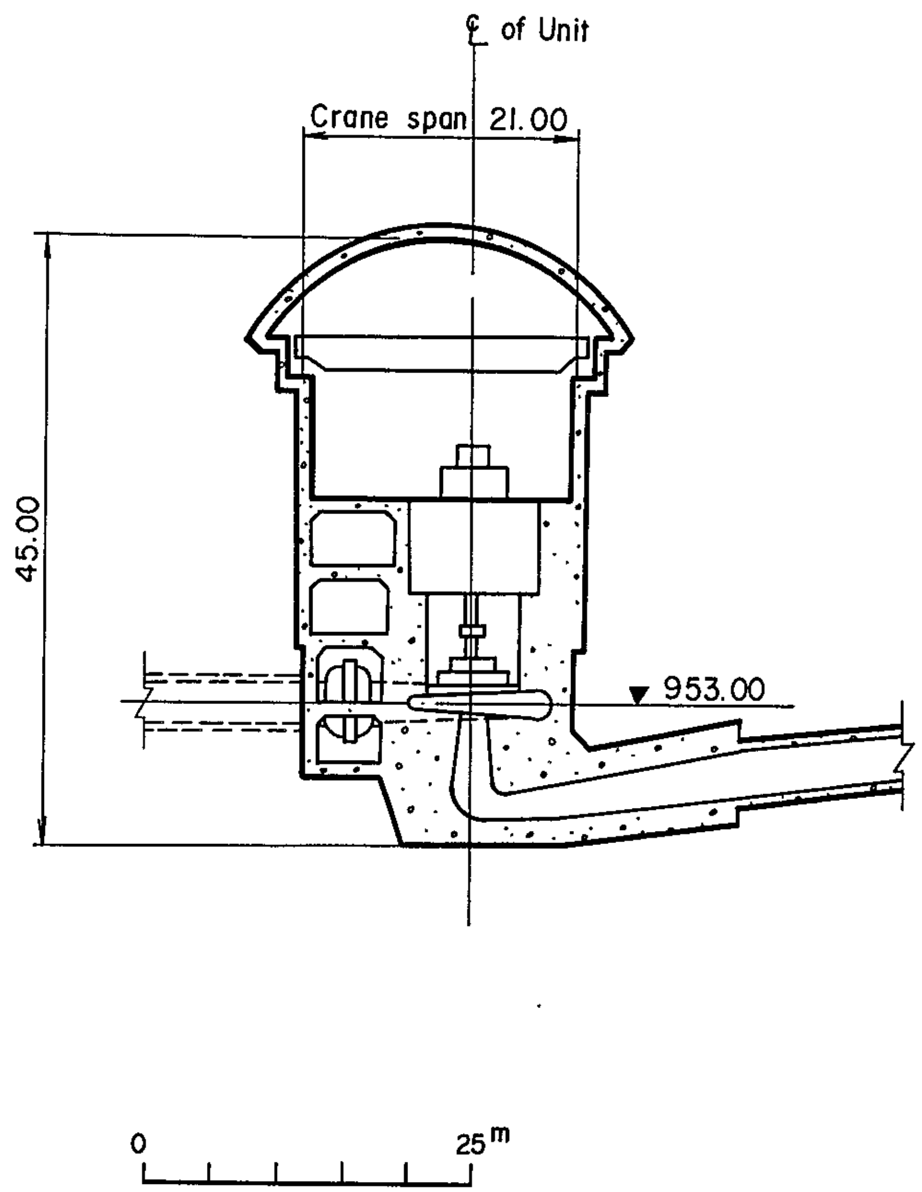


Fig.-IV.3.9 Intake, Surge Tank and Out let (R-2) Plan and Profile

PLAN



SECTION A - A



LONGITUDINAL SECTION

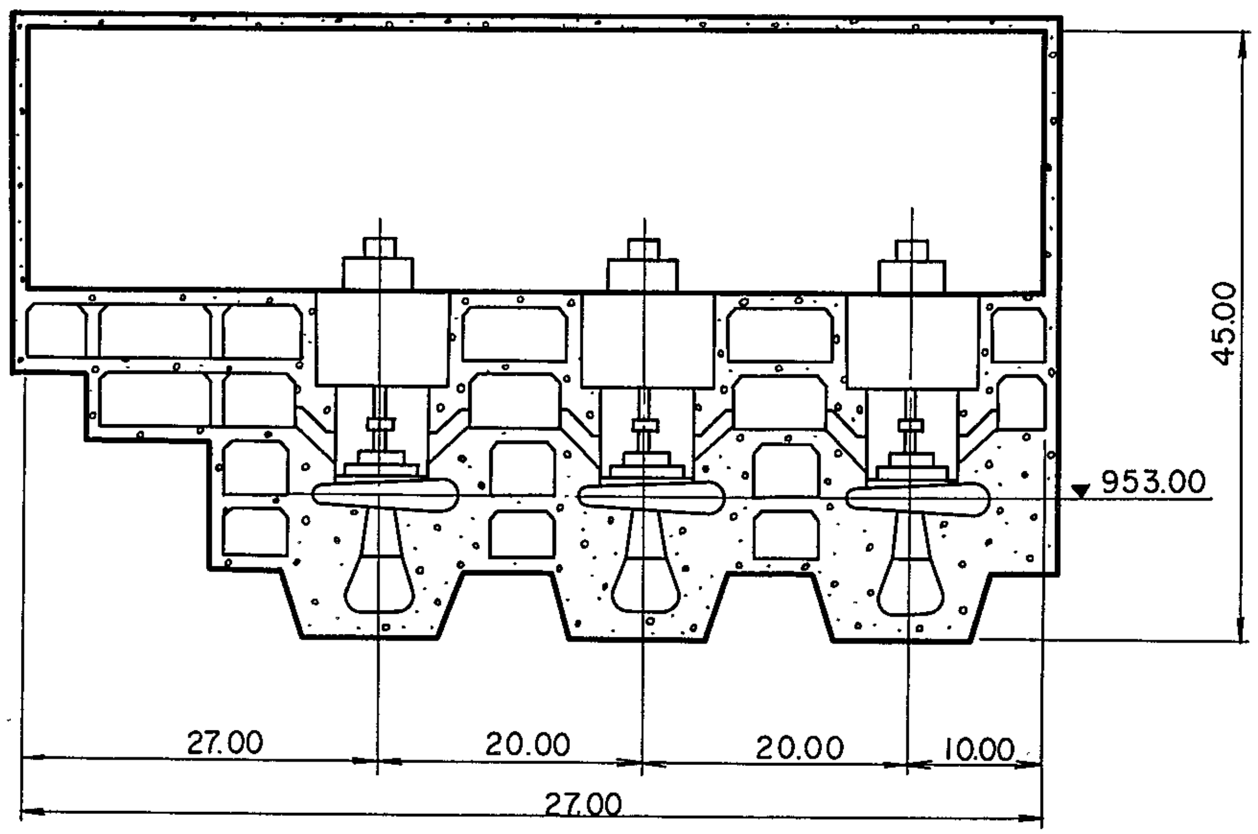


Fig.-IV.3.10 Power house (R-2)
Plan, Profile and Section

3.5.3 R-3 Hydropower Project

R-3 Regulating Pondage is to be made by constructing a concrete gravity dam of height of 55.0 m and crest length of 100 m at a site approximately 1.5 km downstream of the R-2 Power Station outlet for available drawdown of 10 m and effective storage capacity of 1.0 x 10^6 m^3.

The intake is to be provided at the left bank immediately upstream of the dam. It is to be a diagonal-type concrete structure of 15.0 m wide and 33.0 m high with two intake gates provided.

The water taken in is to be conducted by a pressure tunnel of inside diameter of 6.6 m and length of 33.3 km to a surge tank provided on the left-bank side upstream of the intake dam of the Chao-Viru Irrigation Project. This surge tank is to be a chamber type of inside diameter of 7.6 m and height of 160 m. From this surge tank the water is to be conducted to the powerhouse by 1 to 3 penstocks each of inside diameter 6.60 to 3.20 m and length of 700 m to the powerhouse. The powerhouse is to be an underground type of 20.0 m wide, 45.0 m high and 77.0 m long, and is to be a reinforced concrete structure.

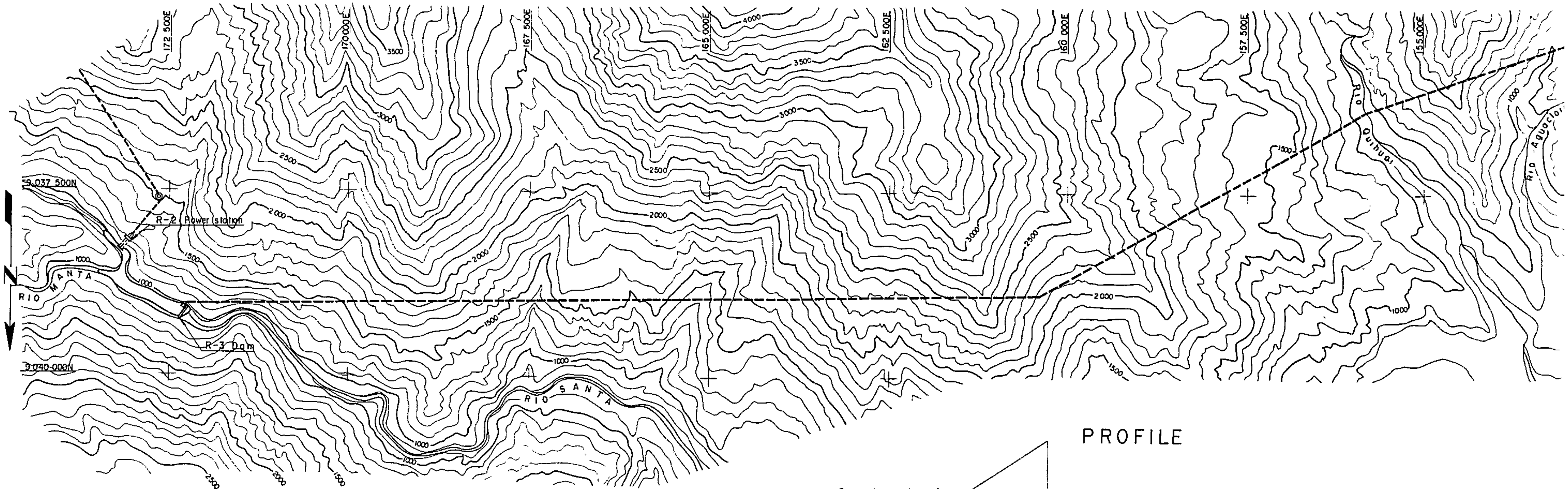
The standard effective head of this power station will be 453.5 m, the maximum available discharge 130 m^3/sec, and the maximum turbine discharge per unit 43.3 m^3/sec. The turbine matching these conditions is a vertical-shaft Francis turbine. The output per turbine is to be 171,000 kW, and that per generator 184,000 kVA, the generator voltage being 16.5 kV and rated power factor 0.9 (lagging).

With the above, a maximum output of 540 MW will be obtained. The energy production would be an annual average of 2,067.0 x 10^6 kWh, and 1,433.0 x 10^6 kWh in a dry year.

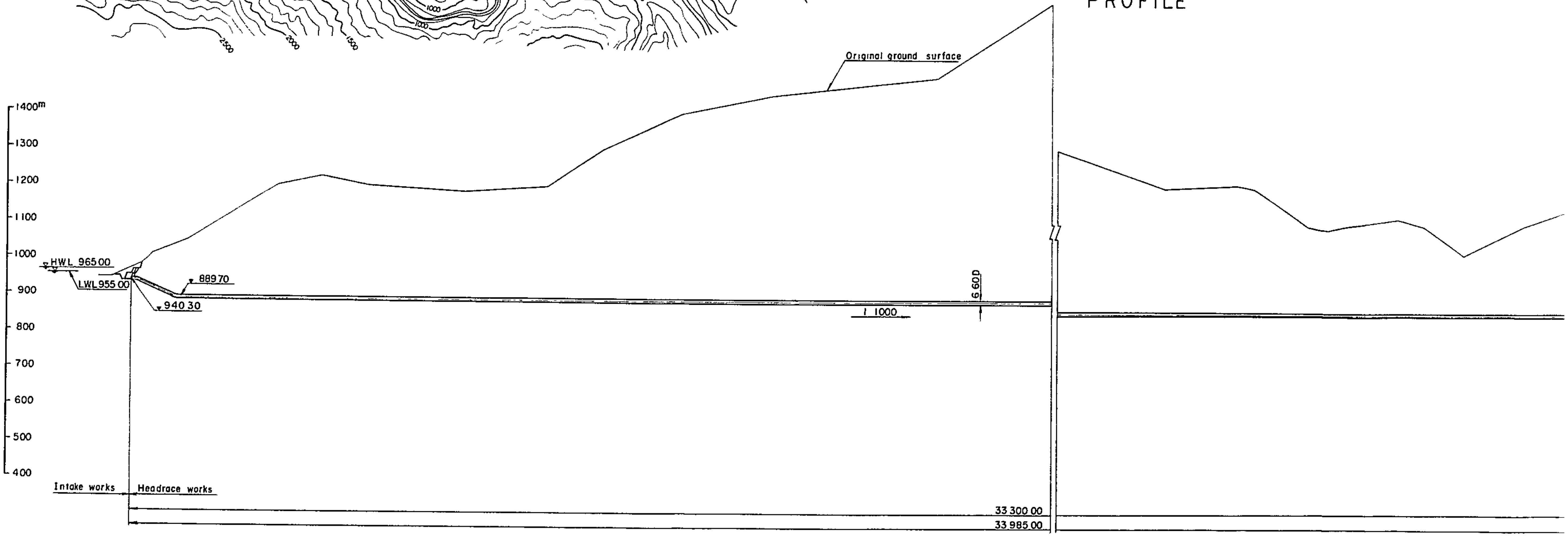
The plans and cross sections of the structures of R-3 Power Station are indicated in Fig.-IV.3.11 through IV.3.14.

Although the available discharge of the R-1, R-2 and R-3 Power Stations have been determined based on standard heads, considerations have been given so that there would be no trouble even when the available discharges are increased so that maximum installed capacities can be secured at minimum water level of reservoirs and regulating ponds. Consequently, the maximum installed capacity may be said to be effective power generating capacity.

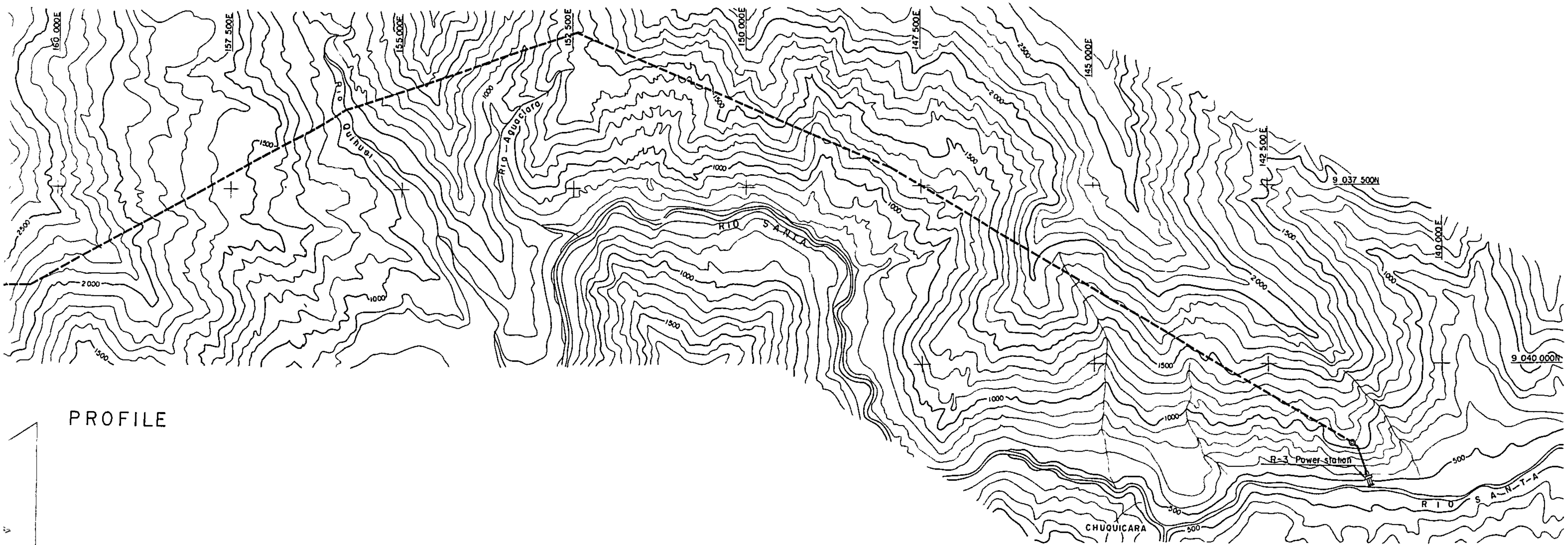
PLAN



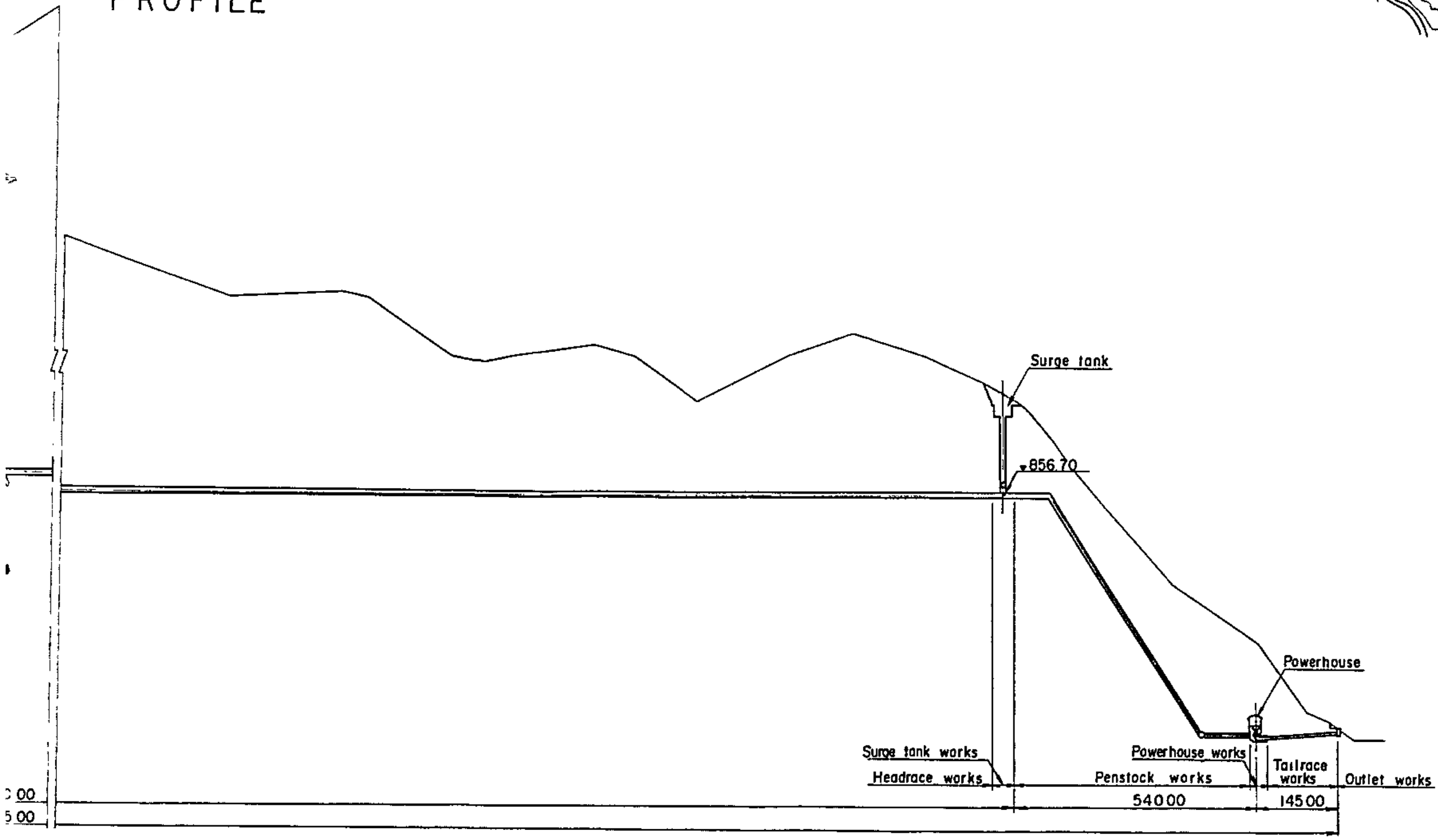
PROFILE



PLAN



PROFILE



TYPICAL SECTION OF HEADRACE TUNNEL

TYPICAL SECTION OF PENSTOCK

TYPICAL SECTION OF TAILRACE TUNNEL

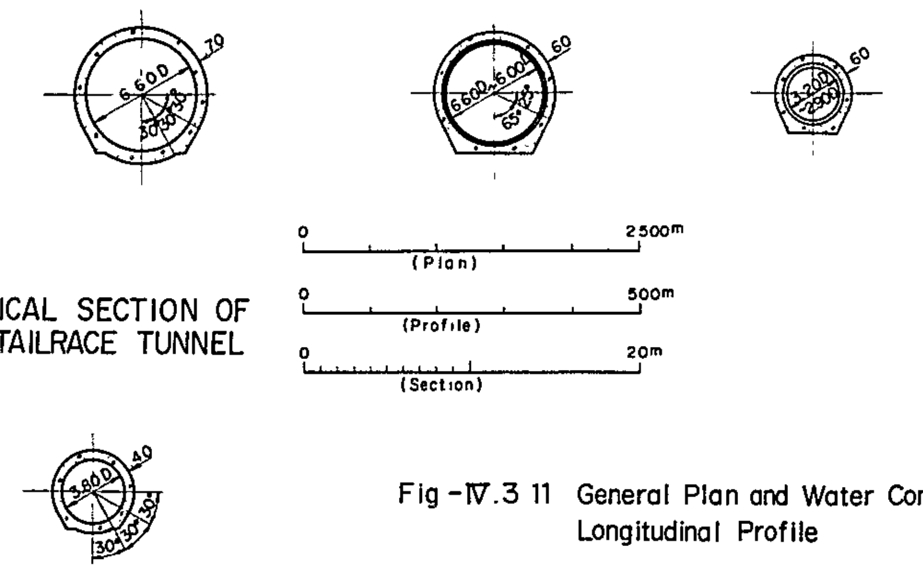


Fig-IV.3 11 General Plan and Water Conductor (R-3) Longitudinal Profile

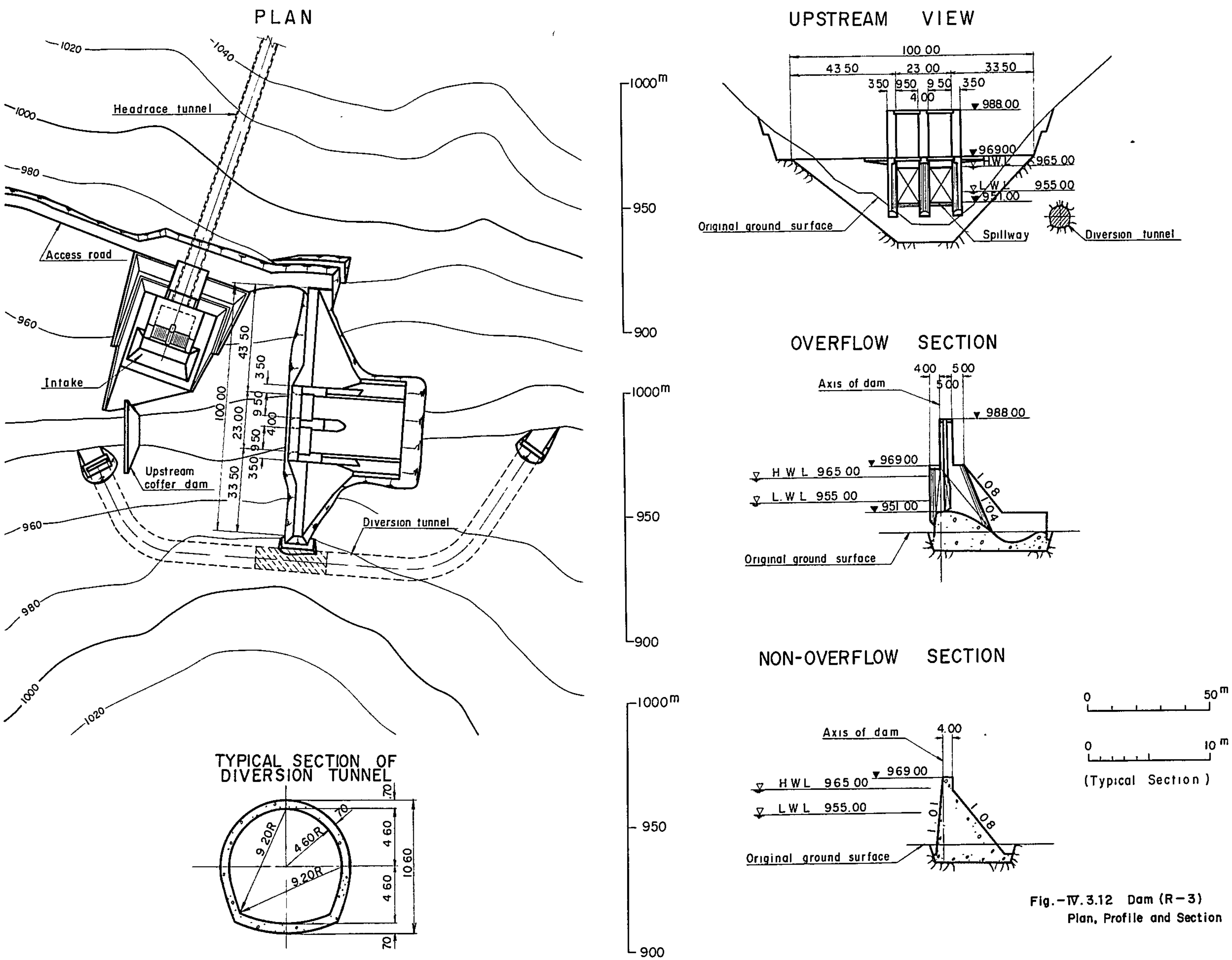


Fig.-IV.3.12 Dam (R-3)
Plan, Profile and Section

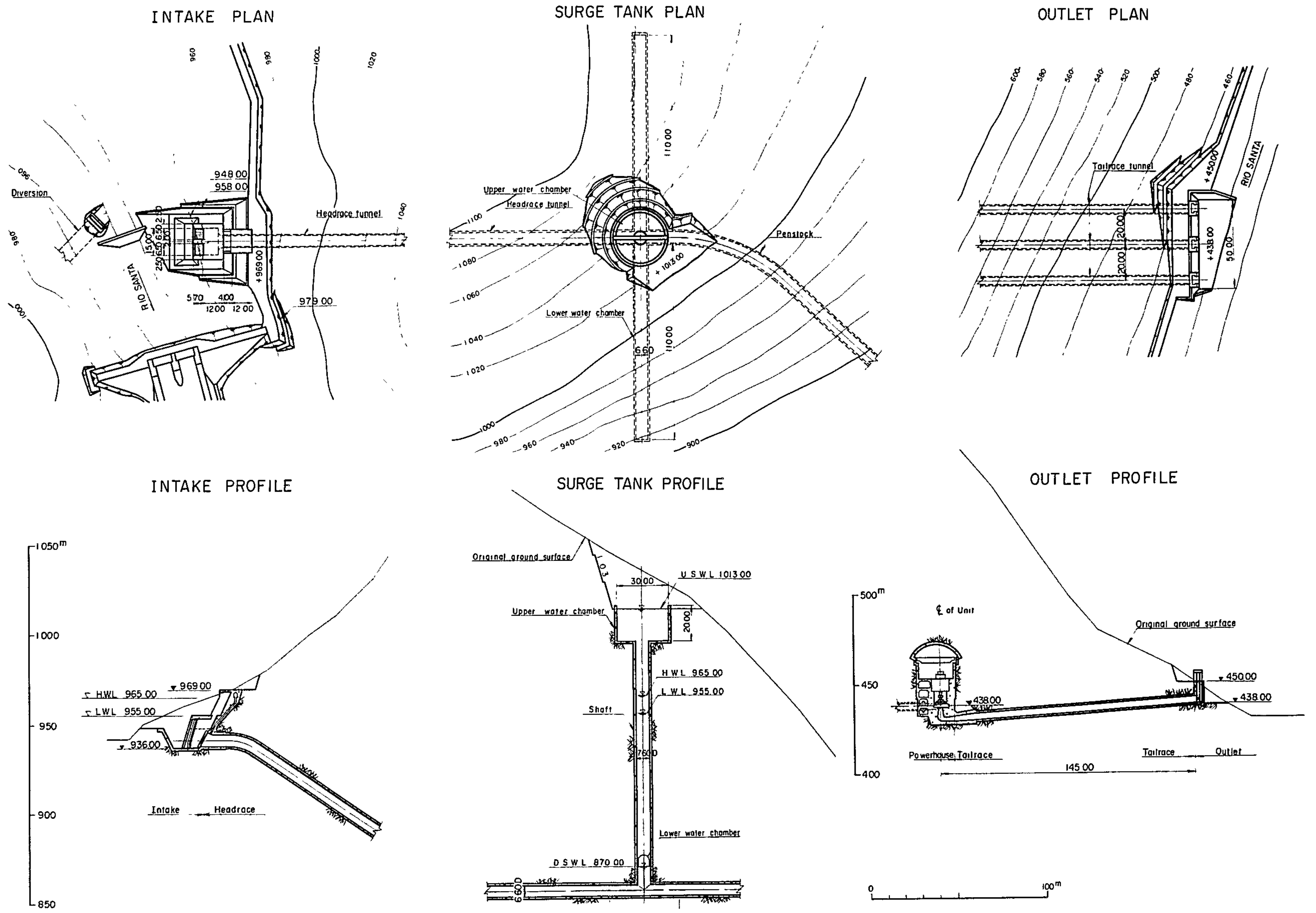


Fig -IV 3 13 Intake, Surge Tank and Out let (R-3) Plan and Profile

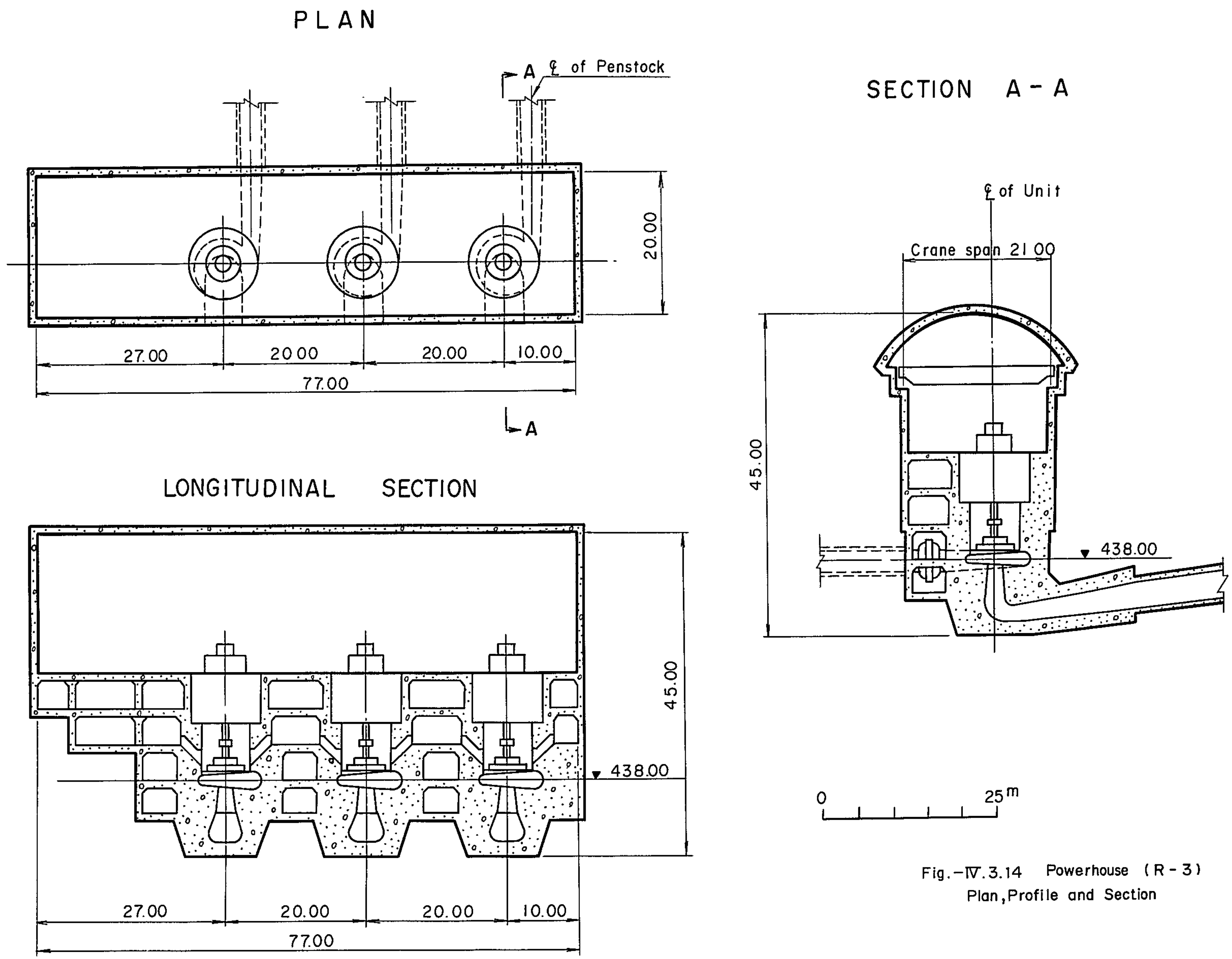


Fig.-IV.3.14 Powerhouse (R-3)
Plan, Profile and Section

3.5.4 Transmission and Switchyard Plan

(1) Transmission Line

The power stations of the R Series Hydropower Project will be developed in sequence from 1995, and the scale is a total of 2,350 MW. The power flow distribution of the Central and North Regions after 1999 when all of the R Series Hydropower Project will have been developed is as indicated in Fig.-IV.3.15, and the power generated at the power stations of the R Series Hydropower Project will be transmitted to the Central System in the Lima Area and load areas of the North System such as Trujillo, Chiclayo and Piura.

The transmission line to the Central System would lead directly to Lima Substation, and the transmission distance in this case will be long, while the power transmitted will be large, so that the transmission line is to be a new one of extra-high voltage of 500 kV and double circuit.

On the other hand, the transmission line to the North System is to match the existing transmission line and is to be 220 kV, 3 cct, connected to the existing buses of Chimbote No. 1 Substation.

In realization of the extra-high voltage 500 kV transmission facilities, thorough investigations and studies should be made of corona phenomena at places of high elevation, and heavy salt contamination at areas close to the coast, and countermeasures should be provided.

(2) Switchyard

The powerhouse sites of the R Series Hydropower Project are located at steep gorges of the Santa river, and it is difficult to secure sufficient areas to provide switchyards on the surface.

Consequently, the switchyards are to be provided underground, while it is thought advisable to adopt the GIS (Gas Insulated Switchgear) System using SF6 gas. The site area for the GIS System will be less compared with conventional outdoor switchyard because of extremely more compact and light weight equipment, and since there will be equipment which will already have been assembled, there will be less work in the field, making possible labor-saving and shortening of construction schedules in construction work, and it is thought this is suitable for the Project.

3.6 CONSTRUCTION COST AND CONSTRUCTION SCHEDULE

(1) Construction Cost

In estimation of construction cost of the R-1, R-2 and R-3 Hydropower Projects, considerations are given to the following conditions.

(i) The construction cost is to be estimated on the basis of preliminary design as indicated in Fig.-IV.3.2 through IV.3.14.

(ii) Unit costs are to be calculated taking into account performance records of hydroelectric power projects in Peru and the regional conditions of the project area.

Estimated construction costs calculated based on the above mentioned conditions are shown in Table-IV.3.2, IV.3.3 and IV.3.4. The construction cost in implementation of R-1 Hydropower Project would require US$ 1,234.9 x 10^6, R-2 Hydropower Project US$ 440.9 x 10^6 and R-3 Hydropower Project US$ 517.8 x 10^6. However, these estimated construction cost should be modified more or less depending on the results of further investigations.

(2) Construction Schedule

The construction periods of R-1, R-2 and R-3 Hydropower Projects, taking into consideration quantities of work, arrangement of structures and regional conditions such as topography and climate, will be 9.5, 6 and 6.5 years, respectively.

The construction schedules including the investigation of work and design are shown in Fig.-IV.3.16.

Fig. IV.3.15 Forecast of Power Flow in 1999

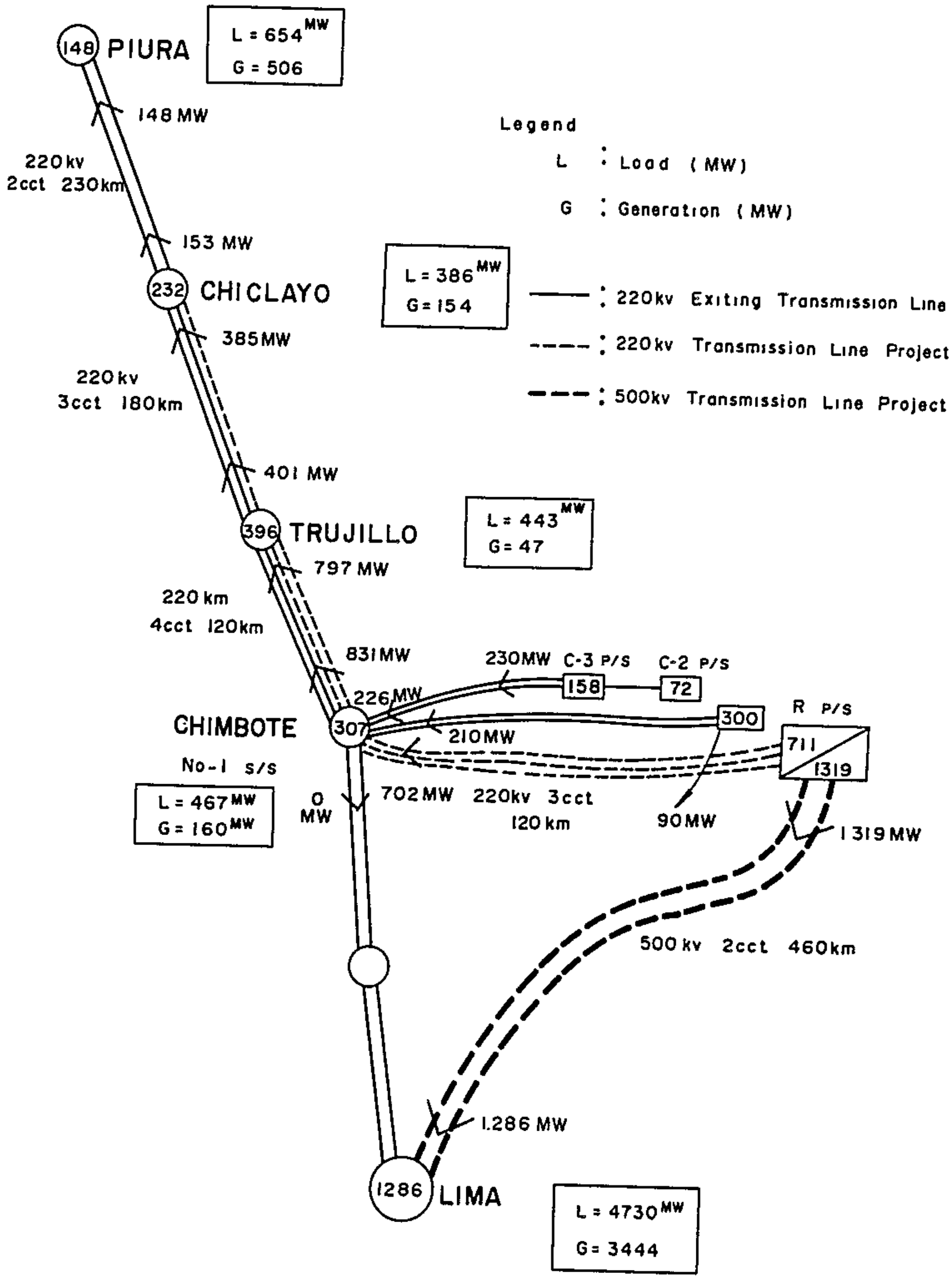


Fig - IV.3.16 Construction Schedule of R Series Hydropower Project

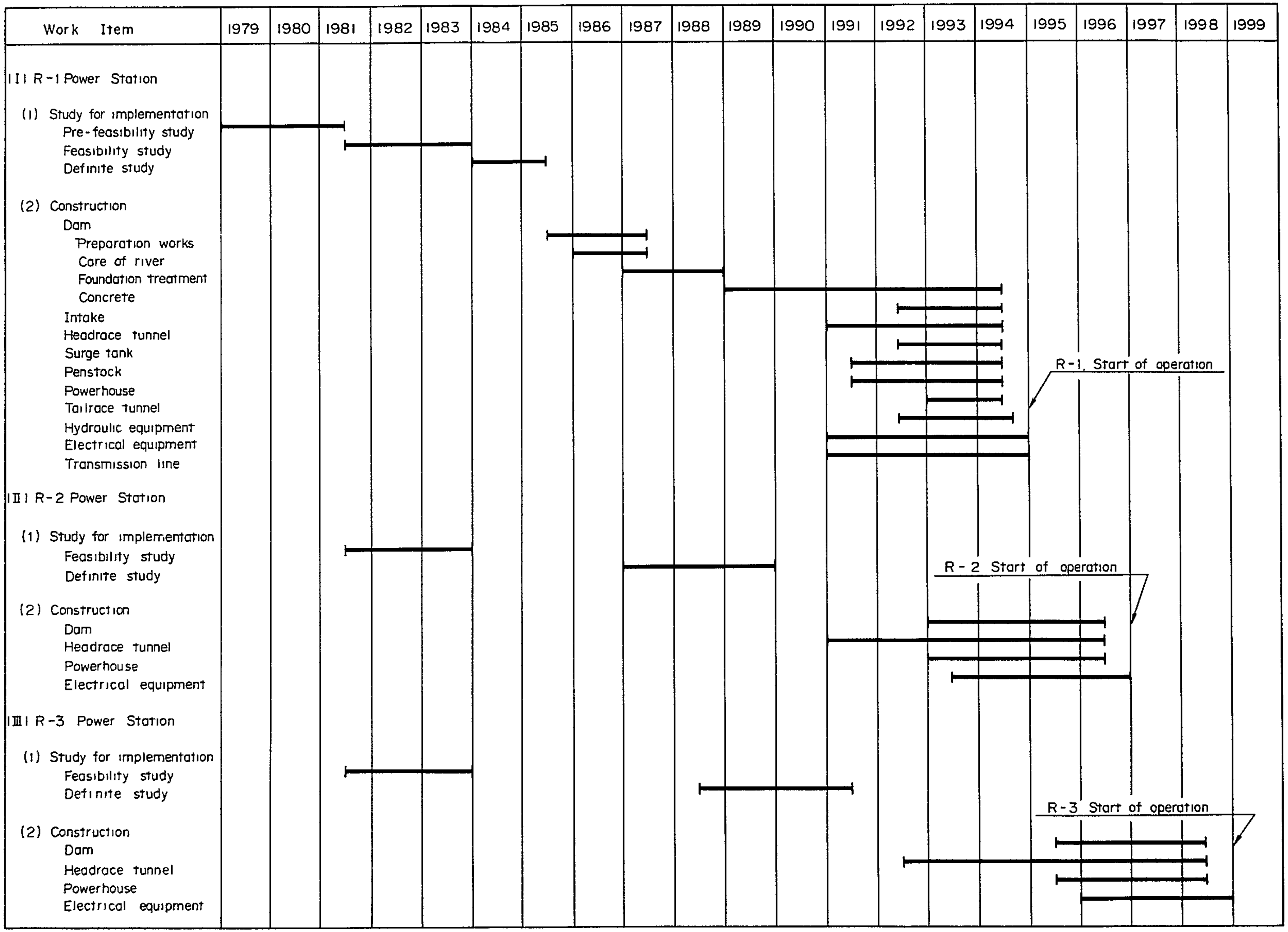


Table-IV.3.2 Summary of Estimated Construction Cost of R-1 Power Station

	Work Item	Cost US$
1)	Care of River	6,338,000
2)	Dam	365,981,000
3)	Intake	21,388,000
4)	Headrace Tunnel	37,140,000
5)	Surge Tank	6,699,000
6)	Penstock	67,362,000
7)	Powerhouse	18,324,000
8)	Tailrace Tunnel	2,760,000
9)	Outlet	6,391,000
10)	Access Tunnel	1,928,000
11)	Under-ground Switchyard	6,460,000
12)	Sub-total	540,771,000
13)	Over Head	243,347,000
14)	Electrical Equipment	118,330,000
15)	Transmission Line	180,618,000
16)	Total	1,083,066,000
17)	2ndary Sub-station	151,800,000
18)	Grand Total	1,234,866,000

Item R-1 (1) Dam

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Open excavation	m^3	4,629,000	10	46,290.0	Rock
2. Concrete in dam	"	5,430,700	45	244,381.5	
3. Concrete in pier	"	19,500	200	3,900.0	
4. Reinforcement	t	560	800	448.0	
5. Others	L.S			59,004.5	
Total				354,024.0	
Appurtenant Works					
1. Spillway gate	t	138	6,000	828.0	
2. Outlet gate	"	84	6,000	504.0	
3. Outlet tube	"	130	2,500	325.0	
4. Grouting	m	103,000	100	10,300.0	
Total				11,957.0	
Grand Total				365,981.0	

Item R-1 (2) Intake

	Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost						
1.	Open Excavation	m^3	596,100	10	5,961.0	Rock
2.	Concrete in structure	"	23,130	200	4,626.0	
3.	Concrete in wall	"	30,660	160	4,905.6	
4.	Reinforcement	t	1,157	800	925.6	
5.	Others	L.S	1		3,283.8	
	Total				19,702.0	
Appurtenant Works						
1.	Gate	t	226	6,000	1,356.0	
2.	Screen	"	110	3,000	330.0	
	Total				1,686.0	
	Grand Total				21,388.0	

Item R-1 (3)   Headrace Tunnel

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Tunnel excavation	m^3	362,140	40	14,485.6	
2. Concrete in lining	"	96,370	160	15,419.2	
3. Reinforcement	t	2,887	800	2,309.6	
4. Others	L.S	1		3,221.6	
Total				35,436.0	
Appurtenant Works					
1. Grouting	m	17,040	100	1,704.0	
Total				1,704.0	
Grand Total				37,140.0	

Item R-1 (4) Surge Tank

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Open excavation	m^3	54,500	10	545.0	
2. Excavation in chamber	"	16,230	40	649.2	
3. Shaft excavation	"	20,970	80	1,677.6	
4. Tunnel excavation	"	3,820	40	152.8	
5. Concrete in chamber	"	5,000	160	800.0	
6. Concrete in shaft	"	6,200	160	992.0	
7. Concrete in lining	"	1,320	160	211.2	
8. Reinforcement	t	578	800	462.4	
9. Others	L.S			1,098.8	
Total				6,589.0	
Appurtenant Works					
1. Grouting	m	1,100	100	110.0	
Total				110.0	
Grand Total				6,699.0	

Item R-1 (5) Penstock

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Tunnel excavation	m^3	75,540	80	6,043.2	
2. Fill-up Concrete	"	24,870	140	3,481.8	
3. Reinforcement	t	50	800	40.0	
4. Others	L.S	1		957.0	
Total				10,522.0	
Appurtenant Works					
1. Penstock	t	20,300	2,800	56,840.0	
Total				56,840.0	
Grand Total				67,362.0	

Item R-1 (6) Powerhouse

Work		Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost •						
1.	Excavation in arch	m^3	25,330	60	1,519.8	
2.	Excavation in body	"	80,560	40	3,222.4	
3.	Concrete in arch	"	6,000	200	1,200.0	
4.	Concrete in wall	"	8,620	200	1,724.0	
5.	Concrete in base	"	1,160	160	185.6	
6.	Concrete in foundation	"	13,290	200	2,658.0	
7.	Concrete in slab	"	8,470	200	1,694.0	
8.	Reinforcement	t	3,000	800	2,400.0	
9.	Others	L.S	1		2,920.2	
	Total				17,524.0	
Appurtenant Works						
1.	Grouting	m	8,000	100	800.0	
	Total				800.0	
	Grand Total				18,324.0	

Item R-1 (7) Tailrace Tunnel

Work	Unit	Quantity	Unit Cost US$	cost 10^3US$	Remarks
Direct Cost					
1. Tunnel Excavation	m^3	17,270	55	949.85	
2. Concrete in lining	"	6,720	181	1,216.32	
3. Reinforcement	t	202	800	161.6	
4. Others	L.S	1		233.23	
Total				2,561.0	
Appurtenant Work					
1. Grouting	m	1,990	100	199.0	
Total				199.0	
Grand Total				2,760.0	

Item R-1 (8) Outlet

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Open excavation	m^3	100,660	10	1,006.6	
2. Concrete in structure	"	7,610	200	1,522.0	
3. Concrete in wall	"	13,700	160	2,192.0	
4. Reinforcement	t	381	800	304.8	
5. Others	L.S			1,005.6	
Total				6,031.0	
Appurtenant Works					
1. Gate	t	60	6,000	360.0	
Total				360.0	
Grand Total				6,391.0	

Item R-1 (9) Access Tunnel

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Tunnel excavation	m^3	13,890	49	680.61	
2. Concrete in lining	"	4,720	172	811.84	
3. Reinforcement	t	142	800	113.6	
4. Others	L.S	1		321.95	
Total				1,928.0	

Item R-1 (10) Under-ground Switchyard

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1. Excavation	m^3	70,320	40	2,812.8	
2. Concrete	"	14,040	200	2,808.0	
3. Others	L.S			839.2	
Total				6,460.0	

Item R-1 (11) Electrical Equipment (Including Transportation and Installation)

	Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1.	Turbine	Unit	4	5,720,000	22,880.0	
2.	Generator	Unit	4	8,125,000	32,500.0	
3.	Others	L.S	1		43,228.0	
	Total				98,608.0	
1.	Over Head	L.S	1		19,722.0	
	Total				19,7220.0	
	Grand Total				118,330.0	

Item R-1 (12) 500KV Transmission Line

	Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1.	Transmission Line	Km	460	300,000	138,000	
2.	Contingencies	L.S			13,800	
3.	Engineering Fee and Maintenance	"			10,626	
4.	Interest during construction	"			18,192	
	Total				180,618	

Item R-1 (13)   2ndary Sub-station

	Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1.	Construction Cost	L.S			120,000	
2.	Contingencies	"			12,000	
3.	Engineering Fee and Maintenance	"			6,000	
4.	Interest during construction	"			13,800	
	Total				151,800	

Table-IV.3.3 Summary of Estimated Construction Cost of R-2 Power Station

	Work Item	Cost US$
1)	Care of River	3,279,000
2)	Dam	16,287,000
3)	Intake	5,824,000
4)	Headrace Tunnel	131,389,000
5)	Surge Tank	6,144,000
6)	Penstock	29,327,000
7)	Powerhouse	12,669,000
8)	Tailrace Tunnel	1,183,000
9)	Outlet	2,630,000
10)	Access Tunnel	805.000
11)	Repair of Intake Structure	532,000
12)	Under-gound Switchyard	5,060,000
13)	Sub-total	215,129,000
14)	Over Head	86,052,000
15)	Electrical Equipment	62,556,000
16)	Transmission Line	42,592,000
17)	Total	406,329,000
18)	2ndary Sub-station	34,606,000
19)	Grand Total	440,935,000

Item R-2 (1) Dam

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Rock excavation	m^3	50,900	10	509.0	
2. Concrete in dam	"	149,000	50	7,450.0	
3. Concrete in pier	"	3,130	200	626.0	
4. Concrete in guidewall	"	15,950	169	2,552.0	
5. Reinforcement	t	1,111	800	888.8	
6. Others	L.S	1		2,405.7	
Total				14,431.5	
Appurtenant Works					
1. Spillway gate	t	136	6,000	816.0	
2. Sand flush gate	"	12	6,000	72.0	
3. Steel pipe	m	27	2,500	67.5	
4. Grouting	"	9,000	100	900.0	
Total				1,855.5	
Grand Total				16,287.0	

Item R-2 (2) Under-ground Switchyard

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Excavation	m^3	56,256	40	2,250.0	
2. Concrete	"	11,232	200	2,246.0	
3. Others	L.S	1		564.0	
Total				5,060.0	

Item R-2 (3) Electrical Equipment (Including Transportation and Installation)

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1. Turbine	Unit	3	4,004,000	12,012.0	
2. Generator	Unit	3	5,460,000	16,380.0	
3. Others	L.S	1		23,738.0	
Total				52,130.0	
4. Over Head	L.S	1		10,426.0	
Total				10,426.0	
Grand Total				62,556.0	

Item R-2 (4) 220KV Transmission Line and 2ndary Sub-station

	Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1.	Transmission Line Constraction Cost	Km	320	100,000	32,000.0	
2.	Contingencies	L.S	1		3,200.0	
3.	Engineering Fee and Maintenance	"	1		3,520.0	
4.	Interest during construction	"	1		3,872.0	
	Total				42,592.0	
1.	2ndary Sub-station Construction Cost	L.S	2	13,000	26,000.0	
2.	Contingencies	"	1		2,600.0	
3.	Engineering Fee and Maintenance	"	1		2,860.0	
4.	Interest during construction	"	1		3,146.0	
	Total				34,606.0	
	Grand Total				77,198.0	

Table-IV.3.4 Summary of Estimated Construction Cost of R-3 Power Station

	Work Item	Cost US$
1)	Care of River	3,305,000
2)	Dam	5,888,000
3)	Intake	3,082,000
4)	Headrace Tunnel	211,309,000
5)	Surge Tank	6.485.000
6)	Penstock	26,602,000
7)	Powerhouse	12,669,000
8)	Tailrace Tunnel	1,047,000
9)	Outlet	1,232,000
10)	Access Tunnel	805,000
11)	Under-ground Switchyard	5,060,000
12)	Sub-total	277,484,000
13)	Over Head	110,994,000
14)	Electrical Equipment	64,651.000
15)	Transmission Line	30,037,000
16)	Total	483,166,000
17)	2ndary Sub-station	34,606,000
18)	Grand Total	517,772,000

Item R-3 (1) Dam

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Open excavation	m^3	30,500	10	305.0	
2. Concrete in dam	"	27,660	60	1,659.6	
3. Concrete in pier	"	4,170	200	834.0	
4. Concrete in guidewall	"	3,820	160	611.2	
5. Reinforcement	t	608	800	486.4	
6. Others	L.S	1		779.8	
Total				4,676.0	
Appurtenant Works					
1. Spillway gate	t	142	6,000	852.0	
2. Grouting	m	3,600	100	360.0	
Total				1,212.0	
Grand Total				5,888.0	

Item R-3 (2) Under-ground Switchyard

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Excavation	m^3	56,256	40	2,250.0	
2. Concrete	"	11,232	200	2,246.0	
3. Others	L.S	1		564.0	
Total				5,060.0	

Item R-3 (3) Electrical Equipment (Including Transportation and Installation)

Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1. Turbine	Unit	3	3,850,000	11,550.0	
2. Generator	Unit	3	6,020,000	18,060.0	
3. Others	L.S	1		24,266.0	
Total				53,876.0	
1. Over Head	L.S			10,775.0	
Total				10,775.0	
Grand Total				64,651.0	

Item R-3 (4) 220KV Transmission Line and 2ndary Sub-station

	Work	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
1.	Transmission Line construction cost	Km	100	100,000	10,000.0	2 circuit
	" "	Km	180	70,000	12,600.0	1 circuit
2.	Contingencies	L.S	1		2,260.0	
3.	Engineering Fee and Maintenance	"	1		2,443.0	
4.	Interest during construction	"	1		2,734.0	
	Total				30,037.0	
5.	2ndary Sub-station Construction Cost		2	13,000	26,000.0	
6.	Contingencies	L.S	1		2,600.0	
7.	Engineering Fee and Maintenance	"	1		2,860.0	
8.	Interest during construction	"	1		3,146.0	
	Total				34,606.0	
	Grand Total				64,643.0	

CHAPTER 4 ECONOMIC ANALYSIS

4.1 METHOD OF ECONOMIC ANALYSIS

Similarly to the cases of the C-2 and C-3 Hydropower Projects described in 7.1, Chapter 7, Part III, converting the cost of an exclusively oil-burning thermal power generation facility to benefit and comparing with the cost of the power generating facilities of the R-1, R-2 and R-3 power stations, the benefit-cost ratio and the surplus benefit are sought.

4.2 ANNUAL COST

The annual cost of this Project is to be determined based on the following conditions:

(i) Interest rate: 8.0% per annum for both foreign and domestic currencies.

(ii) Depreciation method: Sinking fund method

(iii) Operation and maintenance cost, administrative cost:

R-1 Power Station	1.6%
R-2 and R-3 Power Stations,	2.0%

The annual costs of R-1, R-2 and R-3 Power Stations determined based on the above conditions are as indicated in Table-IV.4.1.

4.3 ANNUAL BENEFIT

The annual benefits are to be the same as in the case of C-2 and C-3 Power Stations described in 7.3, Chapter 7, Part III, and US$ 84 per kW and US$ 0.022 per kWh.

The annual energy production is as indicated in Table-IV.4.2. For this energy production, the following two cases were studied since the existing Cañón del Pato Power Station will become unable to take in water from the Santa river because of construction of R-1 Power Station and will generate power with only the water of the Quitaracsa river.

(1) Case of not considering compensation for existing Cañón del Pato Power Station since it will have approximately reached its service life of 50 years in the year 2000 when construction of the R Series is completed.

(2) Case of considering Cañón del Pato Power Station generating 150,000 kW of power with only the annual average discharge of 11 m^3/sec, dry-season discharge of 6 m^3/sec of the Quitaracsa river (assuming that a reservoir will have been

constructed upstream according to INIE plans) to become a power station of 3-hour peak in the dry season and an average of 5.5-hour peak so that the entire amount of reduction compared with the present energy production is to be calculated as minus benefit of the R Series Hydropower Project. Also, considering the equipment cost required to make it possible for Cañón del Pato Power Station to have a peak capacity of 150,000 kW to be borne by the R Seires Hydropower Project, this is calculated as minus benefit.

The effects in irrigation, flood prevention, avalanche damage prevention, etc. will be very great, but these were considered as allowances and were not included in calculations.

4.4 RESULTS OF ECONOMIC ANALYSIS

Considering only electric power the benefit cost ratio (B/C) and surplus benefit (B - C) of the R Series Hydropower Project are as indicated in Table-IV.4.2, and its economic efficiency compared with a thermal power plant is more advantageous by 1.56 to 1.69 times, and expenditures will be US$ 111 x 10^6 to US$ 136 x 10^6 less annually than the case of a thermal plant. Further, irrigation water for 100,000 ha will be secured, and when the effects of avalanche and flood disaster prevention are considered, the economic effects will be very great.

Table-IV.4.1 Annual Cost of R Hydropower Plants

(Unit : US$ 10^6)

Item	R-1		R-2		R-3	
	Investment cost	Annual cost	Investment cost	Annual cost	Investment cost	Annual cost
I. Interest and Depreciation	1,083.07	89.43	406.33	33.53	483.17	39.76
I-1. Civil work and Hydraulic Equipment	784.12	63.96	301.18	24.57	388.48	31.69
I-2. Electrical Equipment	118.33	10.08	62.56	5.33	64.65	5.51
I-3. Transmission Line	180.62	15.39	42.59	3.63	30.04	2.56
II. Maintenance, Operation and Administration Expenses	1,083.07	17.33	406.33	8.13	483.17	9.66
III. Total Annual Cost	-	106.76	-	41.66	-	49.42
IV. Annual Cost of Secondary Sub-station	151.80	15.97	34.61	3.64	34.64	3.64
IV-1. Interest and Depreciation	-	12.93	-	2.95	-	2.95
IV-2. Maintenance, Operation and Administration Expenses	-	3.04	-	0.69	-	0.69
Grand Total	1,234.87	122.73	440.94	45.3	517.81	53.06

Table-IV.4.2 Economic Evaluation of R Hydropower Plants

Item	Unit	R-1	R-2	R-3	Total
Installed Capacity	MW	1,320	490	540	2,350
Available Capacity	MW	1,320	490	540	2,350
Load Factor (Average)	%	35.6	39.7	43.4	38.1
" (Minimum)	%	30.0	30.0	30.1	30.0
Energy Production (Average)	10^6 kWh	4,062	1,717	2,067	7,846
" (Minimum)	10^6 kWh	3,468	1,288	1,424	6,180
Construction Cost	10^6 US$	1,083.07	406.33	483.17	1,972.57
Construction Cost per kW	US$	821	829	895	839
Construction Cost per kWh (Annual Average)	US$	0.267	0.237	0.234	0.251
Annual Cost	10^6 US$	106.76	41.66	49.42	197.84
Benefit	10^6 US$	184.03	70.50	79.57	334.10
Benefit Cost Ratio (B/C)		1.72	1.69	1.61	1.69
Annual Surplus Benefit (B - C)	10^6 US$	77.27	28.84	30.15	136.26
* Decrease of Annual Benefit	10^6 US$	14.0	5.20	5.80	25.00
Benefit Cost Ratio (B/C)		1.59	1.57	1.49	1.56
Annual Surplus Benefit (B - C)	10^6 US$	63.27	23.64	24.35	111.26

* These values were calculated based on the reduction in benefit of Cañón del Pato Power Station due to reduction in kWh caused by completion of R-1 Power Station.

CHAPTER 5 FURTHER INVESTIGATIONS

The feasibility of development of the R Series power stations (total capacity, 2,350 MW) will depend entirely on the technical feasibility of constructing R-1 Dam and estimation of the sediment inflow at the reservoir. Consequently, the investigations required hereafter first of all are regarding the R-1 Hydropower Project and are as described below.

5.1 HYDROLOGICAL INVESTIGATIONS

(1) It will be necessary to provide meteorological observation stations in the Project Area for observations regarding temperature, humidity and evaporation which will influence R-1 Reservoir. As locations, it is thought the existing intake of Cañón del Pato Power Station and Caraz will be suitable considering the aspects of maintenance and administration.

(2) Estimation and investigation of suspended load and bed load of the Santa river.

(3) Collection of data on avalanches (huayco) from the Cordillera Blanca and estimation of sediment brought down.

(4) As methods of investigating bed load due to avalanches, the following are conceivable:

(i) Bury carbon in the river bed and investigate its washing out and movement after floods have occurred.

(ii) Investigations by aerial photographs.

5.2 TOPOGRAPHICAL AND GEOLOGICAL INVESTIGATIONS

The investigation works necessary hereafter are the following:

(1) Preparation of 1/5,000 and 1/25,000 topographical maps and of geological maps by surface reconnaissance of the R-1 Dam site.

(2) Preparation of 1/1,000 topographical maps of the vicinity of the dam site by aerial photography.

(3) Estimation of interior geology through physical prospecting .... 4 km.

(4) Investigation of possibility of landsliding in R-1 Reservoir.

(5) Construction of paths for carrying out the above investigation works.

5.3 EARTHQUAKE INVESTIGATIONS

5.3.1 Earthquake-proof Design

In recent years, the technique of investigating the vibration properties and strength of a structure, the dynamic properties of structural properties, etc., for comprehensive evaluation of the earthquake proof of that structure has been proposed as a method of earthquake-proof design. The basic principle can be applied to R-1 Dam without modification, but at present, there are practically no necessary data obtained as yet so that these must be clarified through future investigations. Particularly, it will be necessary to start earthquake observation in the field as soon as possible.

Further, in studying the stability of a dam during earthquake, not only the dam proper, but also the stabilities of the foundation bed of the dam and slopes around the reservoir must be investigated. Since stresses in the ground, ground water levels, and pure water pressures at the reservoir bottom and the surroundings will vary as a result of dam construction and water impoundment, it is necessary for thorough investigations to be made whether disadvantageous conditions such as liquefaction of ground, sliding and collapse of slopes, etc. will be newly produced.

5.3.2 Earthquake Observations

It is thought suitable for earthquake observations to be made in the vicinity of the dam axis, in which case it is desirable for places where earthquake observation facilities are to be installed to satisfy the following:

(1) That the location is not at a steep cliff, near the mountain peak, or on soft ground of great thickness.

(2) That the location is distant from roads of heavy vehicle traffic, airfields, and paths for cattle, horses and sheep.

(3) That the location is not easily influenced by vibratory machines and equipment such as electric motors, engines, compressors, etc.

(4) That locations of high temperature, low temperature and high humidity liable to adversely influence stability of equipment, locations with risk of inundation, and locations susceptible to effects of strong winds and gusts are avoided.

(5) That the location can be safely approached for maintenance and inspection, and alternating-current power supply can be easily secured.

(6) That the location is distant from power lines and transformers where strong electric currents flow in order to avoid trouble caused by induction currents and from places where there is risk of lightning strokes.

Taking the above into account, it is thought that within the Project Area, the underground settling basin of Cañón del Pato Power Station will be suitable for installing seismometers. Also, if possible, it would be desirable to install one set each of seismometers at the left and right banks at an elevation which will be close to the crest of the dam for a total of 3 sets including the set at the underground settling basin.

The equipment to be installed would be one electromagnetic transducer for each of the east-west, north-south and vertical directions in order to detect earthquake motions of two components in the horizontal direction and one component in the vertical direction, a total of three components.

APPENDIX

APPENDIX-A.1 STUDY OF AVAILABLE DISCHARGES FOR C SERIES HYDROPOWER PROJECT

(1) Cañón del Pato Power Station

(i) Maximum Available Discharge ($Q_{CP.max}$)

$$Q_{CP\cdot max} = 48 \ m^3/sec$$

(Maximum water intake is 48.5 m^3/sec, but 0.5 m^3/sec is for sand flushing from sedimentation basin.)

(ii) Firm Available Discharge ($Q_{CP.95}$)

$$Q_{CP.95} = 47.2 \ m^3/sec$$

$Q_{CP.95}$: 95 % dry-season runoff of Cañón del Pato Power Station

(See Table-III.2.12)

(iii) Dry-season Available Discharge ($Q_{CP.100}$)

$$Q_{CP.100} = 38.8 \ m^3/sec$$

$Q_{CP.100}$: 100 % dry-season discharge of Cañón del Pato Power Station

(See Table-III.2.12)

(iv) Average Available Discharge (Q_{CPm})

$$Q_{CPm} = \frac{Q_{CP}}{T} - 0.5 \ m^3/sec = 47.8 \ m^3/sec$$

Q_{CP} : cumulative total of daily average intake

= 405,657.5 m^3/sec

T : number of days = 23 yr

(2) El Chorro Power Station

El Chorro Power Station will use the discharge of Cañón del Pato Power Station as is, and the available discharge will be the same.

(3) C-2 Power Station

(i) Maximum Available Discharge ($Q_{C2P.max}$)

$$Q_{C2P.max} = Q_{CP.max} + Q_M = 50 \ m^3/sec$$

Q_M : dry-season discharge of Manta River

$= 2.0 \ m^3/sec$

(ii) Firm Available Discharge (Q_{C2P95})

$$Q_{C2P95} = Q_{CP95} + Q_{M95} = 49.6 \ m^3/sec$$

Q_{M95} : 95 % dry-season discharge of Manta River

$= 2.4 \ m^3/sec$

(iii) Dry-season Available Discharge (Q_{C2P100})

$$Q_{C2P100} = Q_{CP100} + Q_{M100} = 39.8 \ m^3/sec$$

Q_{M100} : 100 % dry-season discharge of Manta River

$= 1.0 \ m^3/sec$

(iv) Average Available Discharge (Q_{C2Pm})

$$Q_{C2Pm} = Q_{CPm} + Q_{Mm} = 49.8 \ m^3/sec$$

Q_{Mm} : average intake quantity from Manta River

$= 2.0 \ m^3/sec$

(4) C-3 Power Station

(i) Maximum Available Discharge ($Q_{C3P.max}$)

$$Q_{C3P.max} = Q_{C2P.max} + Q_{TP} = 80 \ m^3/sec$$

Q_{TP} : 6-hr peak discharge of 95 % dry-season discharge of Tablachaca River

$= 30 \ m^3/sec$

(ii) Firm Available Discharge (Q_{C3P95})

$$Q_{C3P95} = Q_{C2P95} + Q_{T95} = 57.1 \ m^3/sec$$

Q_{T95} : 95 % dry-season discharge of Tablachaca River

$= 7.5 \ m^3/sec$

(iii) Dry-season Available Discharge (Q_{C3P100})

$$Q_{C3P100} = Q_{C2P100} + Q_{T100} = 45.5 \text{ m}^3/\text{sec}$$

Q_{T100} : 100 % dry-season discharge of Tablachaca River

$= 5.7 \text{ m}^3/\text{sec}$

(iv) Average Available Discharge (Q_{C3Pm})

$$Q_{C3Pm} = Q_{C2Pm} + Q_{Tm} = 67.7 \text{ m}^3/\text{sec}$$

Q_{Tm} : average intake quantity of Tablachaca River

$= 17.9 \text{ m}^3/\text{sec}$

APPENDIX-A.2 STUDY OF REGULATING CAPACITY REQUIRED FOR C-2 POWER STATION

The available discharge of C-2 Power Station is 50 m^3/sec adding the dry-season discharge of 2.0 m^3/sec of the Manta river to the available discharge of 48.0 m^3/sec of El Chorro Power Station.

The available discharge of El Chorro Power Station when Recreta Reservoir is considered will be 47.2 m^3/sec in firm discharge (95 %) and 38.8 m^3/sec in minimum dry-season discharge (100 %). When Recreta Reservoir is not considered, the firm discharge will be 37 m^3/sec.

Assuming that the load variation is 50 % of the difference between average available discharge and maximum available discharge, and that the velocity of water flowing down the tailrace is 3 m/sec, the regulating capacity required is calculated as follows:

(i) Case of Firm Discharge 47.2 m^3/sec

$$V = (48.0\ m^3/sec - 47.2\ m^3/sec) \times 1/2 \times 1500\ m \div 3\ m/sec$$

$$= 200\ m^3$$

(ii) Case of Minimum Dry-season Discharge 38.8 m^3/sec

$$V = (48.0\ m^3/sec - 38.8\ m^3/sec) \times 1/2 \times 1500\ m \div 3\ m/sec$$

$$= 2{,}300\ m^3$$

(iii) Case of Firm Discharge 37.0 m^3/sec when not Considering Recreta Reservoir

$$V = (48.0\ m^3/sec - 37.0\ m^3/sec) \times 1/2 \times 1500\ m \div 3\ m/sec$$

$$= 2{,}750\ m^3$$

Consequently, it will be sufficient to have a regulating capacity of 3,000 m^3/sec.

APPENDIX-A.3 SELECTION OF TYPES AND NUMBER OF UNITS OF TURBINES

1. OUTLINE

The Santa river has much siliceous suspended load (rainy season, 1.0 - 8.7 g/l; annual average, 0.87 g/l) in its water flow and adequate sedimentation cannot be looked forward to even when settling basins are provided. Consequently, it is expected that abrasion of turbines by such sediment will be severe, the abovementioned abrasion conditions being considered in selection of the turbine types and number of units for C Series Hydropower Project, and since there are available records of abrasion by sediment of Francis turbines in the Republic of Peru at Cahua Power Station (head 215 m, available discharge 11 m^3/sec) and Machupichu Power Station (head 350 m, available discharge 7 m^3/sec), the types and number of units were selected upon comparisons with these power stations and in consideration of economic efficiency.

As for the R Series Hydropower Project, since it will have a large reservoir of 1,500 x 10^6 m^3, roughly complete sedimentation can be looked forward to so that it was considered the problem of abrasion by sediment would be eliminated, and selections were made taking into account heads, economic efficiencies, system operation and manufacturing performances at factories of turbines and generators.

As a result of the studies, it was decided that turbine types and their numbers for the C and R Series Hydropower Projects should be 3 Francis turbines for C-2 Power Station, 3 Pelton turbines for C-3 Power Station, 4 Francis turbines for R-1 Power Station, and 3 Francis turbines each for R-2 and R-3 Power Stations because of the reasons given below.

2. SELECTION OF TURBINE TYPE AND NUMBER FOR C-2 POWER STATION

The turbine type for C-2 Power Station must be decided on examining the two points of abrasion by sediment inflow and economic efficiency mentioned above. C-2 Power Station will have a head of 167 m and maximum available discharge of 50 m^3/sec, and if there were no problem of abrasion by sediment, the Francis type of turbine would be advantageous from aspects such as economy.

A Pelton turbine, because of its structure, causes loss of approximately 3 m of head between the turbine center and the tailrace water level (in this Project the loss would correspond to 1.8 % of total head), in addition to which the maximum turbine efficiency will be 2 to 3 % lower compared with a Francis turbine. Consequently, in terms of identical-capacity turbine and generator facilities there will be loss of approximately 4 % (turbine efficiency 2 % + head loss 1.8 %), converted into output, a reduction of 3,000 kW. Further, the equipment and installation price of the turbine and generator will be US$ 6,900 x 10^3 higher. (See Table-A.3.1)

However, the Pelton turbine requires less repair cost compared with a Francis turbine, while further, there is little reduction in turbine efficiency during light loads, but regarding turbine efficiency in the case of the Francis type, if there were to be 3 or more units, the efficiency reduction during light loads can be countered through combined operation of the turbines. The examination of whether practical operation of Francis turbines can be carried out against abrasion in comparison with the abrasion of turbines at Cahua and Machupichu Power Stations is as described in 2.1 below.

2.1 COMPARISONS WITH ABRASION AT CAHUA AND MACHUPICHU POWER STATIONS

2.1.1 Calculation Formula for Abrasion of Turbine by Sediment

It has been indicated by many turbine model tests that abrasion rate of turbine materials by sediment inflow may be expressed by the formula below, where relative velocity of flowing water is v (m/sec).

$$W \propto \rho a v^3 \qquad (1)$$

where

W : abrasion rate
ρ : sediment content in water (g/l)
a : gradation of sand

The parts in a turbine where water flows in the highest velocity are the runner sides of guide vanes and near the upper and lower liners. The velocities (v) in these vicinities become close to π DN/60.

where

π : 3.142
D : turbine inlet diameter (m)
N : revolving speed (rpm)

The parts of next highest velocity are the vicinities of runner outlets, and the velocity v_e is expressed by $v_e = \sqrt{v_1^2 + v_2^2}$, where v_1 is the velocity in the vertical direction inside the runners, and v_2 is the relative velocity between turbine and flowing water in the horizontal direction.

2.1.2 Comparisons of Turbine Abrasion between C-2 Power Station and Cahua and Machupichu Power Stations

(1) Case of Assuming Water Qualities of Power Stations to be Identical (See Table-A.3.2)

(i) The abrasion rates in the vicinities of the guide vanes and upper and lower liners in case Cahua is considered as 100 are the following for C-2 and Machupichu.

	v^3	%
Cahua	91,125	100
C-2, 3 units	65,646	72
C-2, 4 units	64,868	71
Machupichu	178,754	196

(ii) The abrasion rates in the vicinities of runner outlets are the following:

	V^3	%
Cahua	48,991	100
C-2, 3 units	41,111	84
C-2, 4 units	39,750	81
Machupichu	71,084	145

(2) Comparison of Abrasion in Case of Considering Water Qualities of the Rivers

When the water qualities of these rivers are considered, the gradings, contents, and components of the suspended loads will be the items of concern. Here, it is assumed that the gradings are identical for three power stations and the components are silica (SiO_2) and iron (Fe). This is because the analyses for Cahua and Machupichu Power Stations are for these two only and these were judged to have serious effects on abrasion. However, it will be necessary to investigate and study further before the stage of a definite study.

The annual sediment inflows of the rivers based on data obtained this time are estimated as indicated below.

	Annual average sediment (g/l)	Sio + Fe
Santa	0.87	65 %
Machupichu	0.32	84 %
Cahua	0.58	86 %

The ratios of sediment content in water ρ of the Santa and the Machupichu when that of Cahua is taken to be 100 will be as indicated below.

	Ratios of sediment factors (ρ)
Cahua	100 %
Santa	113 %
Machupichu	54 %

To compare abrasion rates considering the above sediment content in water ρ :

(i) For abrasion at guide vanes and upper and lower liners, the ratios for C-2 and Machupichu in case of 100 for Cahua are the following:

Cahua	100 %
C-2, 3 units	81.4 %
C-2, 4 units	80.2 %
Machupichu	105.8 %

(ii) Abrasion in the vicinities of runner outlets will be the following:

Cahua	100 %
C-2, 3 units	95 %
C-2, 4 units	92 %
Machupichu	78 %

Although it will be necessary for further investigation and comparisons to be carried out on the above examination results and actual, and modifications to be made, according to information received in the present investigations, in case of Machupichu Power Station, the abrasion at guide vanes and upper and lower liners is severe requiring repairs in one year, with large vibrations produced in the turbines in two years.

As for Cahua Power Station, replacement repairs of guide vanes, upper and lower liners, and runners are being carried out once in 0.5 to 1 year, the time required for such repairs being approximately 30 hours.

Taking these situations into account and making economic comparisons, the plan for 3 units will be the most economical as shown in Table-A.3.1 and it was decided to adopt the plan for 3 Francis units.

3. SELECTION OF TURBINE TYPE AND NUMBER FOR C-3 POWER STATION

C-3 Power Station will have an effective head of 235 m and maximum available discharge of 80 m^3/sec. The turbine type suitable for these conditions will be Francis, but in case the Francis turbine is adopted, even if the speed were to be held low (N_S = 100 or lower), the index v indicating abrasion speed in the vicinities of guide vanes and upper and lower liners would be 112,000 as shown in Table-A.3.3, which would be 170 % in comparison with C-2 Power Station. Further, when the characteristics of the sediment of the river is considered, abrasion will be about 30 % greater compared with Cahua and Machupichu. Considering that Cahua and Machupichu are at the limit of abrasion, it was decided that Pelton turbines should be adopted.

It should be noted that the turbine specifications (head 260 m, available discharge 96 m^3/sec) of Restitution Power Station presently planned (scheduled for start of construction shortly) by INIE are similar to those of C-3 Power Station, and that Pelton turbines have been adopted in the definite study in spite of the fact that the water quality is better than in the case of C-3.

The number of units was taken to be 3 in consideration of the aspects of operation and maintenance and repair.

4. SELECTION OF TURBINE TYPE AND NUMBER FOR R-1 POWER STATION

R-1 Power Station will have an effective head of 622.5 m and maximum available discharge of 260 m^3/sec. Both the Francis and Pelton type turbines will fit these conditions, but adopting the Pelton type for such large available discharge will naturally mean that the available discharge per unit will be restricted so that the number of turbine units will be increased, and the cost will therefore be increased. Also, since this power station has a large-capacity reservoir, it is thought that suspended load in the flowing water will be settled in the reservoir so that the water will be cleared and abrasion of turbines will be reduced. Consequently, the Francis type with which specific speed (N_S) can be raised and generator cost will be lower is to be adopted.

At present, it is possible for Francis-type turbines to be manufactured up to effective head of about 900 m. Further, manufacture is possible if casing plate thickness is within 100 mm and stay vane thickness within 250 mm. However, there are some restrictions on repair and forming work of the number. In effect, at present, when the orifice height (B) at the inlet sides of runners becomes 30 cm or less, it will become difficult for repair and forming work in the runner flow paths in case of integrated runners, and it will be necessary for orifice height on the runner inlet side to be 30 cm or more. Since there will be restrictions in transportation, a large capacity cannot be adopted.

Therefore, the number of units was selected keeping the above in mind.

Regarding generators, there are limits to possibility of manufacture which have been determined as below, and these points were checked.

Manufacturing Limit of Generator

(i) n x MVA = 2.8×10^5 (water-cooled type)

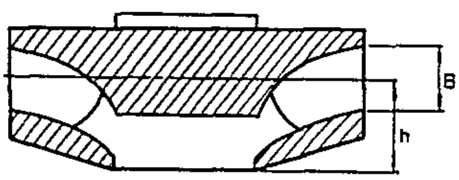
(ii) Stator core laminated thickness L = 3.8 m

(iii) Rotor peripheral speed V = 130 m/sec

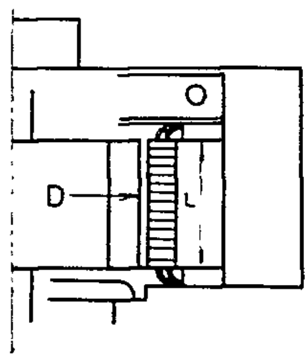
The results of studies of turbines and generators according to the above conditions are as given in Tables-A.3.4 and A.3.5 so that if a plan for 5 units were to be adopted, the orifice height (B) on the inlet side would be 27 cm, while with a plan for 3 units, the stator core laminated thickness (L) would be 3.76 m, and these are limits. Therefore, from the standpoint of operation of a large peak-load power station of 1,400 MW, a plan for 4 units is to be adopted.

Runner Dimensions

Francis Type



Generator Dimensions



5. SELECTION OF TURBINE TYPES AND NUMBERS FOR R-2 AND R-3 POWER STATIONS

R-2 Power Station will have an effective head of 440 m and maximum available discharge of 132 m^3/sec, while R-3 Power Station will have an effective head of

453.5 m and maximum available discharge of 141 m^3/sec. The most suitable turbine type matching these conditions is a vertical-shaft Francis turbine.

In selection of number of units, the limits to manufacture were examined with plans for 3 units and 4 units for R-2 Power Station, and 3 units for R-3 Power Station, and as a result, 3 units were found to be suitable for both R-2 and R-3 Power Stations as shown in Table-A.3.6. The 3-units plan is suitable in consideration of system operation also.

Further, with regard to the problem of turbine abrasion by sediment inflow, this was not considered assuming that sediment would be settled at R-1 Reservoir.

Table-A.3.1 Economical Comparison for Selection of Turbine Type in C-2 Power Station

Type of Turbine / Items	Pelton	Francis	
	3 units	3 units	4 units
(1) Price of Turbines and its Installation Costs (10^6US$)	8.40	4.50	4.80
(2) Price of Generators and its Installation Costs (10^6US$)	8.10	5.10	5.20
(3) Repair Days per annum	4	10	11.3
(4) Present Worth of Repair Cost (10^6US$)	0.42	1.80	1.92
(5) Loss energy (by repair and maintenace) (10^6kWh)	2.3	5.8	4.9
(6) Incremental Energy (10^6kWh)	0	23.97	23.97
(7) Present Worth of kWh Benefit (10^6US$)	0.51	-4.01	-4.20
(8) Increase of Construction Cost (10^6US$)	0	0	1.01
Total ((1)+(2)+(4)+(7)+(8)) (10^6US$)	17.43	7.39	8.73
Ratio (%)	100	42	50

Table -A.3.2 Study on Flow Velocity in Turbine for C-2 Power Station

P-S / Items		Cahua	Machu pichu	C-2	
				3 units	4 units
Discharge (m^3/sec)		11.0	7.0	16.7	12.5
Effective Head	(m)	217	350	168	168
Turbine Output	(kW)	20,000	20,000	24,600	18,400
Specific Speed	(m-kW)	103	85.1	116.7	115
Revolving Speed	(rpm)	600	900	450	514
V	(m/sec)	45	56	40.3	40.2
V^3		91,125	178,754	65,646	64,868
Ve	(m/sec)	36.60	41.42	34.51	34.13
Ve^3		48,991	71,084	41,111	39,750

Table -A.3.3 Study on Flow Velocity in Francis Turbine for C-3 Power Station

unit / Items		3	4	5
Discharge (m^3/sec)		26.7	20.0	13.3
Effective Head	(m)	235	235	235
Turbine Output	(kW)	54,000	40,500	27,000
Specific Speed	(m-kW)	101	98	92
Revolving Speed	(rpm)	400	450	514
V	(m/sec)	48.15	48.18	48.18
V^3		111,632	111,840	111,840

Table -A.3.4 Study on Manufacturing Limit of Turbine for R-1 Power Station

Items \ unit	3	4	5
Discharge (m^3/ s)	84.0	63.0	50.5
Effectibe Head (m)	622.5	622.5	622.5
Turbine Output (kW)	456,000	342,000	274,000
Height of Runner at inlet (m)	0.34	0.31	0.27

Table -A.3.5 Study on Manufacturing Limit of Generator for R-1 Power Station

Items \ unit	3	4	5
Generator Capacity(MVA)	507	369	304
n ×MVA	1.47×10^5	1.32×10^5	1.17×10^5
Height of Stator Core (m)	3.8	3.6	3.6
Diametor of Rotor(m)	7.15	5.75	5.0
Diametor of Rotor (at V=130m/sec)	8.2	7.0	6.2

Table -A.3.6 Study on Manufacturing Limit of Turbine for R-2 and R-3 Power Station

Items \ Power station	R-2		R-3
	3	4	3
Turbine Discharge (m^3/sec)	44	33	43.3
Effective Head (m)	440	440	454
Turbine Output (kW)	169,000	127,000	171,000
Height of Runner at Inlet (m)	0.3	0.25	0.3

APPENDIX-A.4 INDEPENDENT EMERGENCY INTAKE OF C-3 POWER STATION

1. INTRODUCTION

The existing Cañón del Pato Power Station is generating power taking in water from an intake provided at the Santa river. El Chorro, C-2 and C-3 Power Stations are planned to generate power directly taking in the discharge from Cañón del Pato Power Station in stepped form. Consequently, power generation will be possible even though independent intakes are not provided for El Chorro, C-2 and C-3 Power Stations. However, in the case of El Chorro Power Station, it is planned for an independent intake to be provided for emergencies in order to enhance safety of electric power supply.

Taking the above into account, studies will be made of whether or not there will be a necessity to provide independent emergency intakes on the Santa river for C-2 and C-3 Power Stations similarly to the case of El Chorro Power Station

2. CONDITIONS OF STUDY

The cases when independent intakes would be necessary for C-2 and C-3 Power Stations are considered as below.

(i) Case of intakes of Cañón del Pato and El Chorro Power Stations being damaged due to great floods or other causes.

(ii) To supplement reduction in discharge from El Chorro Power Station during periods of inspection and repair of turbines and generators.

(iii) To supplement reduction in intake at El Chorro Power Station due to periodic inspection and repair of civil structures and during repair periods in case of breakdown.

A comparison of the annual average number of days of shutdown for periodic inspection and repairs, and breakdown for hydro and thermal power stations in Japan are as indicated below.

Annual Average Number of Days of Shutdown at Hydro and Thermal Power Stations

	Hydro Power Station	Thermal Power Station
Periodic inspection and repair	7 day/yr	50 day/yr
Breakdown	2 day/yr	18 day/yr
Total	9 day/yr	68 day/yr

According to the performance at Cañón del Pato Power Station,

Periodic inspection and repair (dam, intake)	20 day/2 yr
Periodic inspection and repair (turbine)	7 day/yr
Damage to intake dam due to great floods	120 day/40 yr
Total (average shutdown day/yr)	20 day/yr

Consequently, it may be considered that stoppage of operation at Cañón del Pato Power Station is at a rate of an annual average of 20 days.

Shutdown of 20 day/2 yr for periodic inspection and repair of the dam and intake which will be the independent intake for El Chorro Power Station can be prevented by alternating use of the independent intakes of Cañón del Pato and El Chorro. Therefore, if the average number of days of shutdown at El Chorro Power Station were to be considered to consist of 7 day/yr required for periodic inspection and repair of turbines and the 120 day/40 yr for repair of damage to the intake dam due to great floods, it would be 10 day/yr, and this would be a normal rate of shutdown.

With regard to C-2 and C-3 Power Stations, there will not be much concern about intake from the Santa river if there is an independent intake at El Chorro, in addition to which hindrance to electric power supply can be reduced if periodic inspections and repairs of turbines are done simultaneously at the stations during offpeak hours (Saturdays, Sundays, midnight, etc.).

The power demand around 1990 (2 years after start of operation of C-2 and C-3 Power Stations) will be 3,500,000 kW, of which the Santa System (total of Cañón del Pato, El Chorro, C-2 and C-3 Power Stations) will be 530,000 kW. Of this Santa System, even if there were to be temporary outage of the 382,000 kW being generated with water from the Santa river, this will correspond to only 10.6 % of the entire demand of the Central-North System, and it will be possible for this 382,000 kW to be covered by the reserve capacity (10 %) possessed by the system and by some amount of power conservation.

Consequently, there is no necessity to provide an independent intake especially. However, the installed capacity of C-3 Power Station is 158,000 kW, and in order to enhance safety even more, it is conceivable to provide an independent intake for this power station, and for the sake of reference, its design drawing is indicated in Fig.-A.4.1 and the breakdown of the construction cost in Table-A.4.1.

3. RESULT OF STUDY

As a result of study of the economic natures of independent intakes for El Chorro and C-3 Power Stations, the conclusions below are obtained.

(1) El Chorro Independent Intake

(i) Period of shutdown — 10 day/yr

(ii) Construction cost — US$ 19,000,000

(iii) Power generation reduction — 382,000 kW

(iv) Power loss due to power generation reduction

$$382{,}000 \times \frac{10}{360} = 10{,}556 \text{ kW}$$

(v) Construction cost per kW

$$19{,}000{,}000/10{,}556 = \text{US\$ } 1{,}800/\text{kW}$$

Since it is estimated that the maximum investment amount possible is around US$ 2,000/kW, this plan for an independent intake is feasible.

(2) C-3 Independent Intake

(i) Period of shutdown — 10 day/yr

(ii) Construction cost — US$ 19,000,000

(iii) Power generation reduction — 98,750 kW

(iv) Power loss due to power generation reduction

$$98{,}750 \times \frac{10}{360} = 2{,}743 \text{ kW}$$

(v) Construction cost per kW

$$19{,}000{,}000/2{,}743 = \text{US\$ } 6{,}927/\text{kW}$$

Since it is estimated that the maximum investment amount possible is around US$ 2,000/kW, the plan for an independent intake for C-3 Power Station is not feasible.

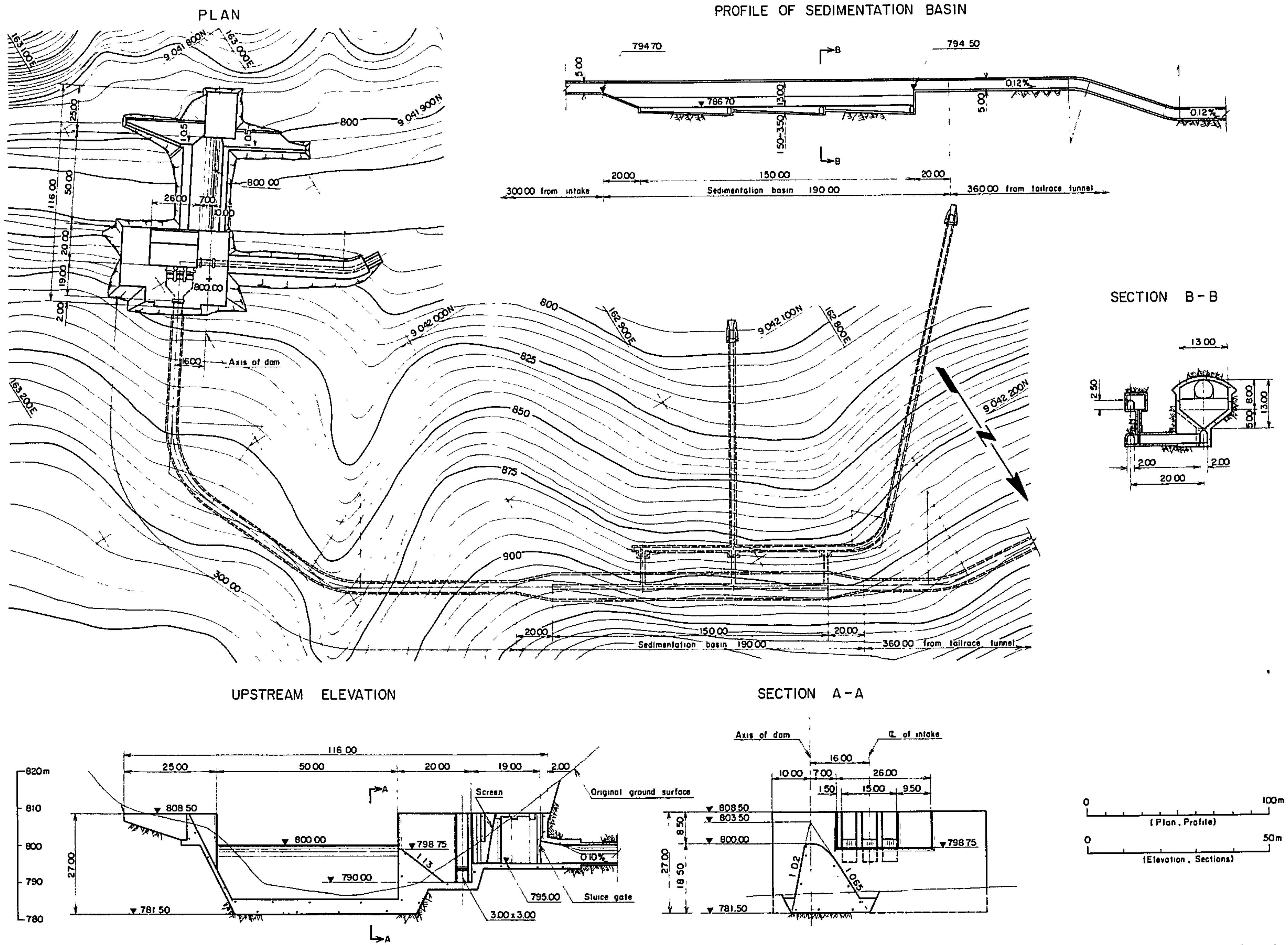


Fig-A.4.1 Independent Intake (C-3)

Table-A.4.1 Estimated Construction Cost of Independent Intake (C-3)

Works	Unit	Quantity	Unit Cost US$	Cost 10^3US$	Remarks
Direct Cost					
1. Open excavation	m^3	58,000	10	580.0	
2. Tunnel excavation	"	31,700	50	1,585.0	B=13.0m, H=13.0m
3. " "	"	21,900	49	1,073.1	B=5.0m, H=5.0m
4. " "	"	5,500	70	385.0	B=2.0m, H=2.5m
5. Concrete in structure	"	43,200	110	4,752.0	
6. Concrete in lining	"	8,400	200	1,680.0	B=13.0m H=13.0m
7. " "	"	7,700	172	1,324.4	B=5.0m, H=5.0m
8. " "	"	2,300	200	450.0	B=2.0m, H=2.5m
9. Reinforcement	t	810	800	648.0	
Total				12,487.5	
Appurtenant Works					
1. Gate	t	5	6,000	30.0	Flushgate B=3.0m H=3,0m
2. "	"	10	"	60.0	Intake gate B=5.0m H=6.0m
3. "	"	21	"	125.0	Gate for sedimentation B=2.0m H=2.50m 3Nos
4. Screen	"	40	3,000	120.0	
Total				335,0	
Contingencies and Others	L.S			6,177.5	Including Cost of Care of river
Grand Total				19,000.0	

APPENDIX-A.5 BASIC DATA

1. Hidrological and Meteorological Data

   1-1 Transporte de sólidos
   Investigación en el Embalse de Tablachaca, Agosto 1976

   1-2 Run-off Records of Santa River Basin-ELECTROPERU-INIE

   1-3 Meteorological Records of Santa River Basin-ELECTROPERU-INIE

2. Geological Informations

   2-1 General Geology of Republic of Peru (1972)-Japan Metal and Mining Promotion Agency

   2-2 Sinopsis de la Geología del Perú, Boletín No.22 (1969)-Servicio de Geología y Minera, República del Perú.

   2-3 Geología de los Cuadrangulos de Mollebamba, Tayabamba, Huaylas, Pomabamba, Carhuaz y Huari, Boletín No 16 (1967)- Servicio de Geología Minera, República del Perú.

   2-4 Geología de los Cuadrangulos de Santiago de Chuca y Santa Rosa, Boletín No.8 (1964)-Carta Geológica Nacional, República del Perú

   2-5 Informe de Geología del Proyecto Hidroeléctrico de Rio Santa escrito por Ing. Orlando Felix de ELECTROPERU-INIE

3. Data for Economic Evaluation

   3-1 Tarifas de Electricidad según Tipos de Consumo y Empresas (vigentes a partir de 25,01,78)

   3-2 Central Térmica de Arequipa (Volumen 1)

4. Data for Load Forcast

   4-1 Información para el Estudio de Planificación Nucleoeléctrica

   4-2 Plan de Electrificación Nacional, Diciembre 1977

   4-3 Anuario de Estadística Eléctrica, 1975

   4-4 Plan de Electrificación Nacional. Segundo Reajuste Período 1978 ~ 1990

   4-5 Evaluación Nacional de la Demanda por Energía Eléctrica

   4-6 Estudio de la Operación Eléctrica del Sistema Interconectado a 220 KV de la Región Central del Perú (1974~1983)

5. Others

5-1 Ampliación C.H. Cañón del Pato Evaluación Preliminar del Potencial Hidroeléctrico de la Cuenca del Rio Santa

5-2 Central Hidroeléctrica el Chorro Actualización del Estudio de Factifilidad-Borrador

5-3 Inventario, Evaluación y Uso Racional de los Recursos naturales de la Costa, Cuencas de los Rios Santa, Lacramarca y Nepeña

I)	Volumen-I	Febrero 1972
II)	Volumen-II	Febrero 1972
III)	Volumen-III	Febrero 1972

5-4 Proyecto de la Irrigación de Chao, Viru, Moche y Chicama

I) Tomo-I
II) Tomo-II

5-5 Mantaro I Tercera Etapa
Central Hidroeléctrica Restitución O.T-024-00

5-6 Central Hidroeléctrica Sheque
Proyecto a Nivel de Licitación

5-7 Diagrama Unifilar Sistema Interconectado
Centro Norte Año 1990

5-8 Linea de Transmisión Chimbote-Trujillo, 220 KV (Volumen I)

6. Topographical Map

6-1 Topographical Map of Manta River (scale: 1/1,000)

6-2 Topographical Map of Confluent Area of Manta River and Santa River (scale: 1/1,000)

6-3 Topographical Map of Santa River Basin (scale: 1/10,000, 1/25,000)

6-4 Topographical Map of Project Area (scale: 1/25,000, 1/100,000)

ADDENDUM

INIE's Observation for the Interim Report

MEMORANDUM N° 7// -78/DI

A : ING. TSUGUO NOZAKI
JEFE MISION TECNICA DEL GOBIERNO DE JAPON

DE : ING. CESAR A. ZAPATA
ENCARGADO DIRECCION INIE

ASUNTO : PROYECTOS DE DESARROLLO HIDROELECTRICO DEL RIO SANTA. CC. HH. C Y R

FECHA : LIMA, 15 DE NOVIEMBRE DE 1978

Tengo el agrado de dirigirme a Ud. para manifestarle que habiendo recibido el Borrador Final del Informe sobre los proyectos de desarrollo hidroeléctrico del río Santa, el mismo está siendo revisado por los especialistas del Instituto.

De acuerdo a las reuniones sotenidas desde su llegada el 7 de Noviembre pasado, se están analizando los planteamientos incluídos en dicho Informe en relación a otros estudios que se han realizado y se vienen realizando en el Instituto, sobre los recursos hidroeléctricos del río Santa. Las observaciones y comentarios finales sobre el estudio las remitiremos a Tokio a fines del presente mes de Noviembre a través de JICA, las mismas que consideramos conveniente deben ser incluídas, luego de las aclaraciones de su grupo técnico, como un anexo al Informe Final de los estudios.

Sin embargo, en líneas generales y teniendo en cuenta las discusiones previas sostenidas en Tokio con los Ings. Romero y Marquina, podemos manifestarle que el Informe presentado se encuentra bien enfocado en los planteamientos generales y contiene valiosa información que debe ser tenida en cuenta para el desarrollo hidroeléctrico futuro de la Cuenca del río Santa.

En relación a algunas observaciones y comentarios generales sobre las Centrales Hidroeléctricas C-2 y C-3, le podemos manifestar lo siguiente :

///

En el Capítulo 2, se considera importante analizar la sensibilidad de los resultados obtenidos para variaciones de la demanda con valores menores que los calculados, haciendo variar también la oferta postergando la puesta en operación de Centrales como Restitución (1983), Alto Chicama (1984), El Chorro (1986) y Sheque (1987), en el período analizado 1978-1990.

En el Capítulo 5, Item 5.1.2 (3), se plantea que el desarenador en caverna ubicado aguas abajo de la Toma, en el Reservorio de Tablachaca de la C. H. C-3, operaría como un conducto a presión. No se conoce experiencias en operación de este tipo de obras. Sería necesario fundamentar mejor su selección y prever las investigaciones de modelo hidráulico necesaria para el siguiente nivel de los estudios.

Capítulo 7, Item 7.2, para efectos del análisis económico, en la evaluación de los costos anuales del Proyecto se utilizó una tasa de descuento del 8%. Sería conveniente estimar la relación B/C y los beneficios incrementales (B-C) para una tasa de descuento del 10%, que es la utilizada en los análisis económicos de los proyectos realizados por el Instituto.

Agradecemos anticipadamente, a través suyo, la magnífica colaboración prestada por el organismo de cooperación del Gobierno del Japón (JICA) para la realización de estos estudios, y esperamos contar con el mismo apoyo para el desarrollo de los niveles subsiguientes de dichos estudios.

Atentamente,

Ing. César A. Zapata López-Aliaga
ENC. DIRECCION

L.Y.Y. . . .

GRS / if
cc. : DI (2)
SD-IC
D.I.H.(2)
Ing. Nakamura -SDIEM
Ing. Marquina
Ing. Olazábal

MEMORUNDUM N°714-78/DI

TO	:	ING. TSUGUO NOZAKI TEAM LEADER OF TECHNICAL MISSION DESPATCHED BY THE JAPANESE GOVERNMENT
FROM	:	ING. CESAR A. ZAPATA SUB-DIRECTOR, INIE
SUBJECT	:	SANTA RIVER HYDRO-POWER DEVELOPMENT PROJECTS (C AND R HYDROELECTRIC POWER STATIONS)
DATE	:	NOVEMBER 15, 1978 LIMA

I am pleased to express that we have received the Final Draft of Report on Santa River Hydro-power Development Projects which has been reviewed by specialists of the Institute.

According to the meetings held from your arrival on November 7, schemes included in the said report have been analyzed in relation with other studies that have been realized and underway in the Institute concerning hydroelectric resources of the Santa River. We will submit observations and final comments concerned with this study to Tokyo through JICA, and the same observation, we consider, should be included as an annex to the Final Report after being clarified by your technical team.

However taking into consideration previous discussions held in Tokyo with Engineers Messrs. Romero and Marquina, we are pleased to state that the Report presented is considered well focused on general plannings and contains valuable information which should be taken into consideration for the hydroelectric development of the Santa River Basin in the future.

In relation to some observations and comments in general regarding Hydroelectric Power Stations C-2 and C-3 we convey to you the following:

In Chapter 2 it is considered important to make an analysis of the influence to be caused by amending the power demand to a small value than that calculated in the report, rescheduling the commissioning dates of projects, such as Restitución (1983), Alto Chicama (1984), El Chorro (1986), Sheque (1987), in the period of analysis from 1978 to 1990.

In Item 5.1.2 (3) of chapter 5 the sedimentation basin of underground type to be provided downstream of the intake of the Tablachaca Regulating Pondage for the C-3 Power Station is planned to be operated as a headrace tunnel. There are no experience of this type of structure in practical operation. It will be necessary to establish superior advantages for this selection and foresee the hydraulic model tests necessary for the next stage of studies.

In Item 7.2 of chapter 7, a discount rate of 8% was employed for the purpose of the economic evaluation in the appraisal of annual costs of these projects. It will be convenient to estimate the benefit-cost ratio (B/C) and the surplus benefits (B - C) assuming a discount rate of 10% which is utilized in economic evaluation of projects realized by the Institute.

In advance we express our thanks through you for the magnificent collaboration extended by Japan International Cooperation Agency (JICA) for the realization of these studies, and we wish to count on the same assisstance for the development of the succeeding stages of the stated studies.

Sincerely yours,

Ing. César A. Zapata López-Aliaga
ENC. DIRECCION

Regarding to the Final Draft of the Report three comments were given by INIE and the results of studies for the comments are made as follows;

I Demand and Supply Balance

The differences in the commissioning dates of power generation projects stated in Part II, Chapter 2, "Demand and Supply Balance," and the previously-mentioned comments of INIE are that the Restitución Project scheduled for start of operation in 1982 has been changed to 1983, and the El Chorro Project scheduled for 1985 has been changed to 1986. Regarding the Alto Chicama Project (simply termed a thermal power station identified as TV-AF in Chapter 2) and the Sheque Project, differences have not arisen with the commissioning dates stated in the Report. Therefore, the influences on the demand and supply balance in connection with the differing commissioning dates of the Restitución and El Chorro Projects will be examined.

With a delay of one year in start of operation of the Restitución Project there will be a shortage of 34,000 kW produced in 1982. This amount of shortage would correspond to 1.9% of the total demand of the Central and North Systems.

Meanwhile, the Republic of Peru was faced with an economic crisis in 1978 resulting in almost zero growth in power demand, and even if there were to be rapid recovery of the economy, it may be assumed that the effects of the economic crisis will remain until 1982, and therefore, the shortage of 1.9% in 1982 will be cancelled out.

As for the delay of one year from the scheduled start of operation in 1985 of the El Chorro Project, reserve capacity will be reduced from 319 MW to 169 MW, but the effects on the Central and North Systems will not be serious.

Consequently, it is thought the delays in the commissioning dates of presently planned hydro development projects pointed out will not adversely affect the power system.

In the report, the same rates as forecast by MEM were adopted regarding future growth in power demand:

1978 - 1985	approx.	6.83 %
1985 and after		6.50 %

Here, however, the influences on the commissioning dates of the C-2, C-3, R-1, R-2 and R-3 power generation projects in the event the growth rates are lower than mentioned above will be examined. Assuming the two cases of the above growth rates being lowered by 1 and 2 per centage points, the situations in 1985, 1986 (C-2 Power Station start-up), 1995 (R-1 Power Station start-up) and 2000 will be as indicated below.

		1978	1985	1986	1995	2000
Presently Planned						
Annual Av. Growth Rate	(%)		6.83	6.50	6.50	6.50
Power Demand	(MW)	1,656	2,629	2,799	4,935	6,761
1 % Reduction						
Annual Av. Growth Rate	(%)		5.83	5.5	5.5	5.5
Power Demand	(MW)	1,656	2,462	2,597	4,205	5,496
2 % Reduction						
Annual Av. Growth Rate	(%)		4.83	4.5	4.5	4.5
Power Demand	(MW)	1,656	2,304	2,407	3,578	4,459

Regarding the commissioning dates for C-2 and C-3 Power Stations it will not be necessary to delay construction in both cases of growth rates lowered by 1 and 2 percentage points so long as construction of thermal power of approximately 200,000 kW scheduled for 1985 is reduced in scale, and by the reduction in size of the thermal power station, it may be considered that even more economical electric power development can be carried out.

Next, regarding the commissioning dates of the R-1 to R-3 power stations, in case of lowering of growth rate by 1 percentage point a possibility will remain for the R Power Generation Project to be carried out as planned in the Report, but with 2 percentage points, it is thought start of construction would need to be delayed by several years.

II Underground Sedimentation Basin

As pointed out, there is no experience with the type of underground sedimentation basin planned to be provided for the C-3 regulating pondage at Tablachaca. This underground sedimentation basin would be subjected to water pressure of 4.2 m (at the end), but since it is estimated there will be practically no difference in sedimentation of the suspended load whether under pressure or no pressure, and since it was judged that from the standpoint of C-3 Power Station operation it would be more advantageous for the sedimentation basin to be made a pressure type, this type was adopted.

However, as stated in the comments of INIE, it is desirable for studies by model experiments to be made at the time of a feasibility study or when carrying out detail design.

III Economic Analysis

In Part III, Chapter 7, the Economic Analysis was made assuming the interest rate of 8%, however in case this rate is to be of 10% the results will be the following:

1. Method of Economic Analysis

same as mentioned in 7.1.

2. Annual Cost

The construction cost and useful life by facility are indicated in Tables A.A.1 and A.A.2, and the annual cost shown in Tables A.A.3 and A.A.4.

3. Annual Benefit

(1) Annual Cost of Alternative Thermal Power Plant

The benefit per kW and the benefit per kWh, as indicated in Table-A.A.6, will be the following:

Benefit per kW	US$ 98
Benefit per kWh	US$ 0.022

(2) Salable Energy

same as described in 7.3.2.

(3) Annual Benefit of C-2 and C-3 Power Stations

The annual benefit, calculated only from effective out put and effective energy will be:

C-2 Power Station

$$68{,}400 \text{ kW} \times \text{US\$}98 + 593 \times 10^6 \text{ kWh} \times \text{US\$}0.022$$
$$\fallingdotseq \text{US\$}19{,}749{,}000$$

C-3 Power Station

$$150{,}100 \text{ kW} \times \text{US\$}98 + 939 \times 10^6 \text{ kWh} \times \text{US\$}0.022$$
$$\fallingdotseq \text{US\$}35{,}368{,}000$$

4. Result of Economic Analysis

(1) The annual cost of C-2 and C-3 Power Stations are US$ 16,633,000 and US$ 34,127,000 as calculated in Tables A.A.3 and A.A.4, and the annual benefits US$ 19,749,000 and US$ 35,368,000 as calculated in 3 (3).

The benefit-cost ratio (B/C) and the surplus benefits (B-C) obtained from these as follows:

	B/C	B - C
C-2 Power Station	1.19	US$ 3,116,000
C-3 Power Station	1.04	US$ 1,241,000
Total	1.09	US$ 4,357,000

From these results it may be said that it will be far better to construct C-2 and C-3 Power Stations than to supply electric power constructing a thermal power plant.

(2) As a reference, on making an economic analysis assuming that 50 % or 100 % of the surplus energy of 210 x 10^6 kWh (without considering loss rate of 5 %) can be used to save fuel at existing thermal power stations with unit cost of fuel as US$0.02/kWh, the results will be the following:

	Salable Surplus Energy (50 %)	B/C	B - C
C-2 Power Station	3 x 10^6 kWh	1.19	$ 3,176,000
C-3 Power Station	97 x 10^6 kWh	1.09	$ 3,181,000
Total	100 x 10^6 kWh	1.13	$ 6,357,000

	Salable Surplus Energy (100 %)	B/C	B - C
C-2 Power Station	6 x 10^6 kWh	1.19	$ 3,236,000
C-3 Power Station	194 x 10^6 kWh	1.11	$ 5,121,000
Total	200 x 10^6 kWh	1.16	$ 8,357,000

(3) The result of Item (1), above mentioned, does not include any influence of inflation. Here as a reference, an economic analysis will be made due to an assumption that the inflation with an annual rate of 6 % will continue on after the commissioning of C-2 and C-3 Power Stations. In case the effective energy is to be primary energy, the benefit cost ratio (B/C) and surplus benefit (B - C) will be calculated in the period of analysis 50 years in order to see the influence of inflation upon the benefits and costs.

(i) Cost Items Influenced by Inflation

(a) Hydropower plant

Replacement costs for electric equipment, transmission lines and substations, operation and maintenance cost, administration cost and others.

(b) Thermal plant

Replacement cost for all facilities, operation and maintenance cost, insurance cost and fuel cost.

The cost items above are assumed to be influenced by an inflation rate of 6 %.

(ii) Annual Benefit and Annual Cost

The uniform equivalent annual benefit and annual cost calculated due to the conditions of Item (i) above mentioned in the period of analysis 50 years are as follows.

Benefit per KW	$138.^{0}$ US$/kW
Benefit per kWh	0.00404 US$/kWh

	C-2 P.S.	C-3 P.S.	Total
Annual Benefit (B)	US$ $33.^{40} \times 10^{6}$	US$ $58.^{65} \times 10^{6}$	US$ $92.^{05} \times 10^{6}$
Annual Cost (C)	US$ $19.^{42} \times 10^{6}$	US$ $34.^{17} \times 10^{6}$	US$ $53.^{59} \times 10^{6}$

(iii) Benefit Cost Ratio (B/C) and Surplus Benefit (B - C)

From the above, the benefit cost ratio (B/C) and surplus benefit (B - C) are calculated as follows.

	C-2 P.S.	C-3 P.S.	Total
Benefit Cost Ratio (B/C)	1.72	1.72	1.72
Surplus Benefit (B- C)	US$ $13.^{98} \times 10^{6}$	US$ $24.^{48} \times 10^{6}$	US$ $38.^{46} \times 10^{6}$

As a result of above, it could be concluded that C-2 and C-3 Power Stations would have much more advantage over the alternative thermal power plant, when the influence of inflation are considered. The reason is that the former has a longer useful life than the latter and the variable cost (mainly fuel cost) of the latter gives a big influence of inflation upon the annual cost.

5. Energy Cost

From the relations between salable energy of C-2 and C-3 Power Stations and the annual costs of C-2 and C-3 Power Stations described in 2, the energy cost of C-2 and C-3 Power Stations delivered at substations at demand areas will become US$ 0.033 per kWh within two years after construction, and US$ 0.029 per kWh when surplus energy should become effective in the future.

Table-A.A.1 Construction Cost and Useful Life (Yrs.) of Facility of C-2 Power Station

(Interest, 10 %) (Unit: 10^3 US$)

Item	Useful Life Years	Total Cost	Foreign Currency	Local Currency
1. Generating Facilities				
Civil Works	50	75,738	15,148	60,590
Hydraulic Equipment	50	2,418	1,814	604
Electrical Equipment	35	15,000	11,250	3,750
Engineering and Administration Cost		8,716	4,216	4,500
Others		6,488	1,995	4,493
Interest during Construction		18,000	18,000	0
Total		126,360	52,423	73,937
2. Transmission Line and Other Facilities				
Transmission Line and Others	35	8,000	5,600	2,400
Engineering and Administration Cost		1,000	500	500
Others		600	300	300
Interest during Construction		1,000	1,000	0
Total		10,600	7,400	3,200
Total Construction Cost		136,960	59,823	77,137

Table-A.A.2 Construction Cost and Useful Life (Yrs.) of Facility of C-3 Power Station

(Interest 10 %) (Unit: 10^3 US$)

Item	Useful Life Years	Total Cost	Foreign Currency	Local Currency
1. Generating Facilities				
Civil Work	50	162,188	32,438	129,750
Hydraulic Equipment	50	5,523	4,142	1,381
Electrical Equipment	35	38,500	28,875	9,625
Engineering and Administration Cost		18,859	9,000	9,859
Others		13,934	4,180	9,754
Interest during Construction		39,595	39,595	0
Total		278,599	118,230	160,369
2. Transmission Line and Other Facilities				
Transmission Line and Others	35	2,000	1,400	600
Engineering and Administration Cost		300	150	150
Others		180	90	90
Interest during Construction		150	150	0
Total		2,630	1,790	840
Total Construction Cost		281,229	120,020	161,209

Table-A.A.3 Annual Cost of C-2 Power Station

(Unit: 10^3 US$)

Item	Investment	Annual Cost
1. Interest and Depreciation	136,960	13,894
1.1 Civil Works 1.2 Hydraulic Equipment	108,560	10,949
1.3 Electrical Equipment	17,800	1,846
1.4 Transmission Line, Sub-station and Communication System	10,600	886
2. Maintenance, Operation and Administration Expense	136,960	2,739
2.1 Generating Facilities	126,360	2,527
2.2 Transmission Line, Sub-station and Communication System	10,600	212
Total Annual Cost (C)		16,633

Table-A.A.4 Annual Cost of C-3 Power Station

(Unit: 10^3 US$)

Item	Investment	Annual Cost
1. Interest and Depreciation	281,229	28,502
1.1 Civil Works 1.2 Hydraulic Equipment	232,890	23,489
1.3 Electrical Equipment	45,709	4,740
1.4 Transmission Line, Sub-station and Communication System	2,630	273
2. Maintenance, Operation and Administration Expense	281,229	5,625
2.1 Generating Facilities	278,599	5,572
2.2 Transmission Line, Sub-station and Communication System	2,630	53
Total Annual Cost (C)		34,127

Table-A.A.5 Alternative Thermal Power Plant

Installed Capacity	(MW)	198
Unit Capacity	(MW x Unit)	66 x 3
Annual Plant Factor	(%)	70
Thermal Efficiency at Generating End	(%)	34
Annual Energy Production	(10^6KWh)	1,214
Present of Powerhouse Service Use	(%)	5
Annual Available Energy	(10^6KWh)	1,153
Annual Energy Consumption	(10^3Kl)	315.6
Construction Cost	(10^6US$)	119.38

Table-A.A.6 Estimated Annual Cost of Alternative Thermal Plant

Item	Unit	Fixed Cost	Variable Cost	Notes
Interest and Depreciation	10^3US$	12,664	-	Serviceable Years; 30 (*1) C.R.F. = 0.10608
Operation, Maintenance and Administration Cost	10^3US$	2,387	597	Construction Cost x 0.025 Fixed Cost 80% Variable Cost 20%
Insurance and Others	10^3US$	860	-	Insurance and Others ; Construction Cost x 0.0072
Fuel Cost	10^3US$	-	24,756	315.6×10^3 (Kl) x 78.44 ($/Kl)
Total	10^3US$	15,911	25,353	
Annual Cost at Sending End				
Cost per KW	US$	98.0	-	$\frac{15,911 \times 10^3}{198,000} \times 1.22^{(*2)}$
Cost per KWh	US$	-	0.022	$\frac{25,353 \times 10^3}{1,214 \times 10^6} \times 1.05^{(*3)}$

(Note) *1 Capital Recovery Factor (i = 10.0%)

*2, *3 KW, KWh, adjustment Factor

Item		Hydro	Steam
Transmission	Loss (%)	1.5	1.5
Station Service	Loss (%)	0.3	5.0
Failure	Loss (%)	0.5	5.0
Repair	Loss (%)	2.0	14.0

KW Adjustment Factor $= \frac{(1-0.015) \times (1-0.003) \times (1-0.005) \times (1-0.02)}{(1-0.015) \times (1-0.05) \times (1-0.05) \times (1-0.14)}$

$= 1.22$

KWh " " $= \frac{(1-0.015) \times (1-0.003)}{(1-0.015) \times (1-0.05)} = 1.05$