193 m^3/s. The results of the study are presented in Table 9-14, 15 and Fig. 9-16 - 21.

These results indicate that the peak duration of 6 hours with the maximum power discharge of 321 m^3/s and the installed capacity of 543 MW is the most advantageous choice. For a longer peak duration, it is advantageous to adopt smaller maximum power discharge and smaller installed capacity.

9.1.4 Artvin Project

(1) Basic Considerations

The site of Artvin Project is situated between the two large reservoirs, Yusufeli and Deriner and this project is planned to make use of the residual head of approximately 110 m between the two projects.

In the site reconnaissance, it was found out that the original dam site of Artvin Dam proposed in the Master Plan may be directly affected by the landslide (Havuzlu) located just upstream at the site, and two alternative dam sites have been selected, one being 3 km upstream from the original dam site (Artvin Upstream Dam Site) and the other 8 km downstream (Artvin Downstream Dam Site).

Artvin Upstream Dam Site is located directly downstream at a confluence of Hev tributary on the left bank of the main river. The catchment area at this site is 15,400 km^2. This site is 9 km downstream from Yusufeli Dam Site, and the residual catchment area is 150 km^2, and the average residual flow is 1.6 m^3/s. The elevation of the river bed at this site is 446 m, and the width of the river bed is approximately 40 m. This site is at the bottom of a "V" shaped valley, with both sides having slopes of 55 to 60 degree gradients. On the left bank, there is a col at an elevation of approximately 530 m. The base rock at the site is very hard, being gabbro, but there exists distribution of faults on the left bank, and remarkable weatherings are observed. Local distributions of slope washes

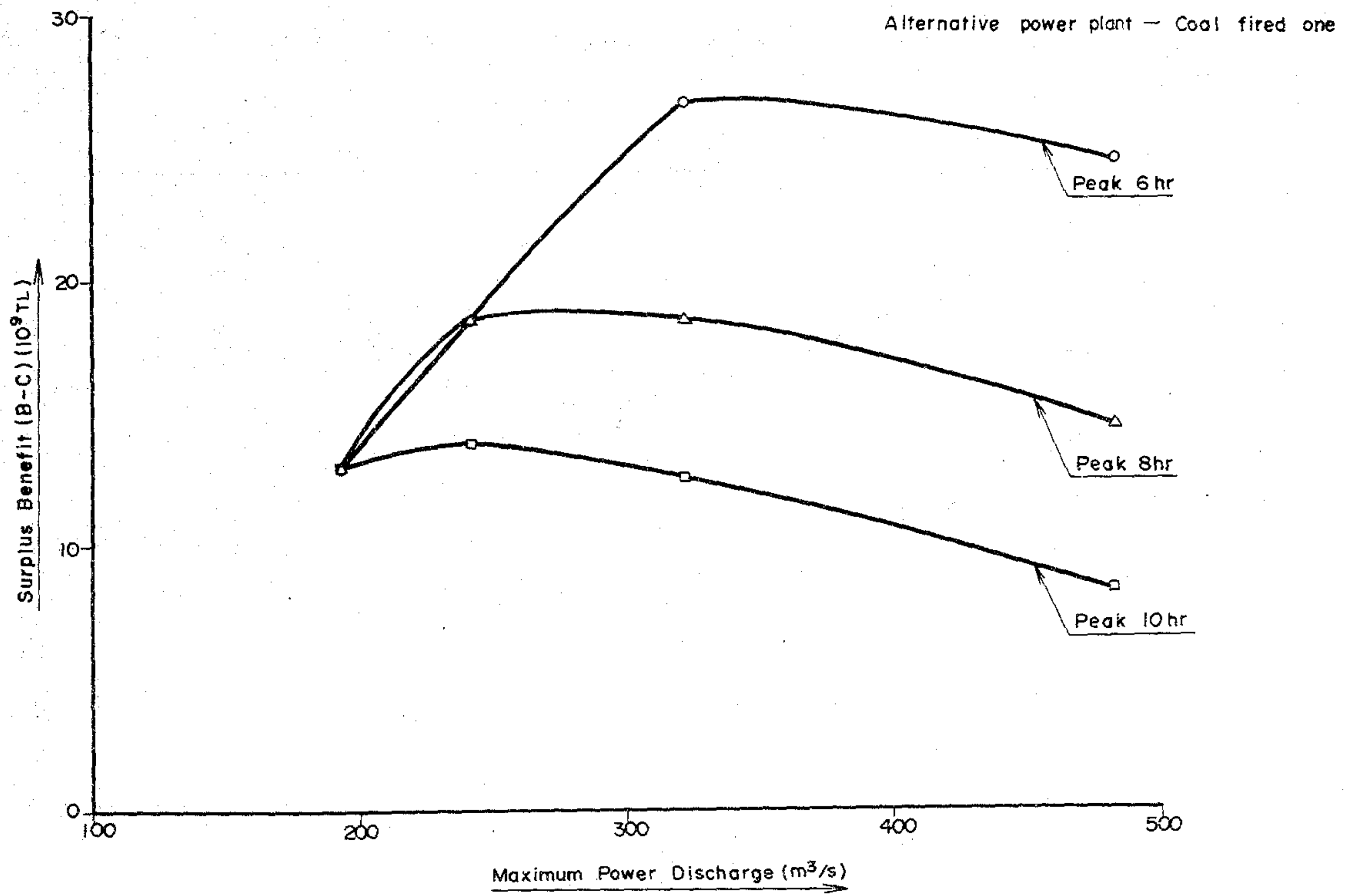


Fig. 9–16 Study on Optimum Power Discharge and Peak Duration (B–C) (1)

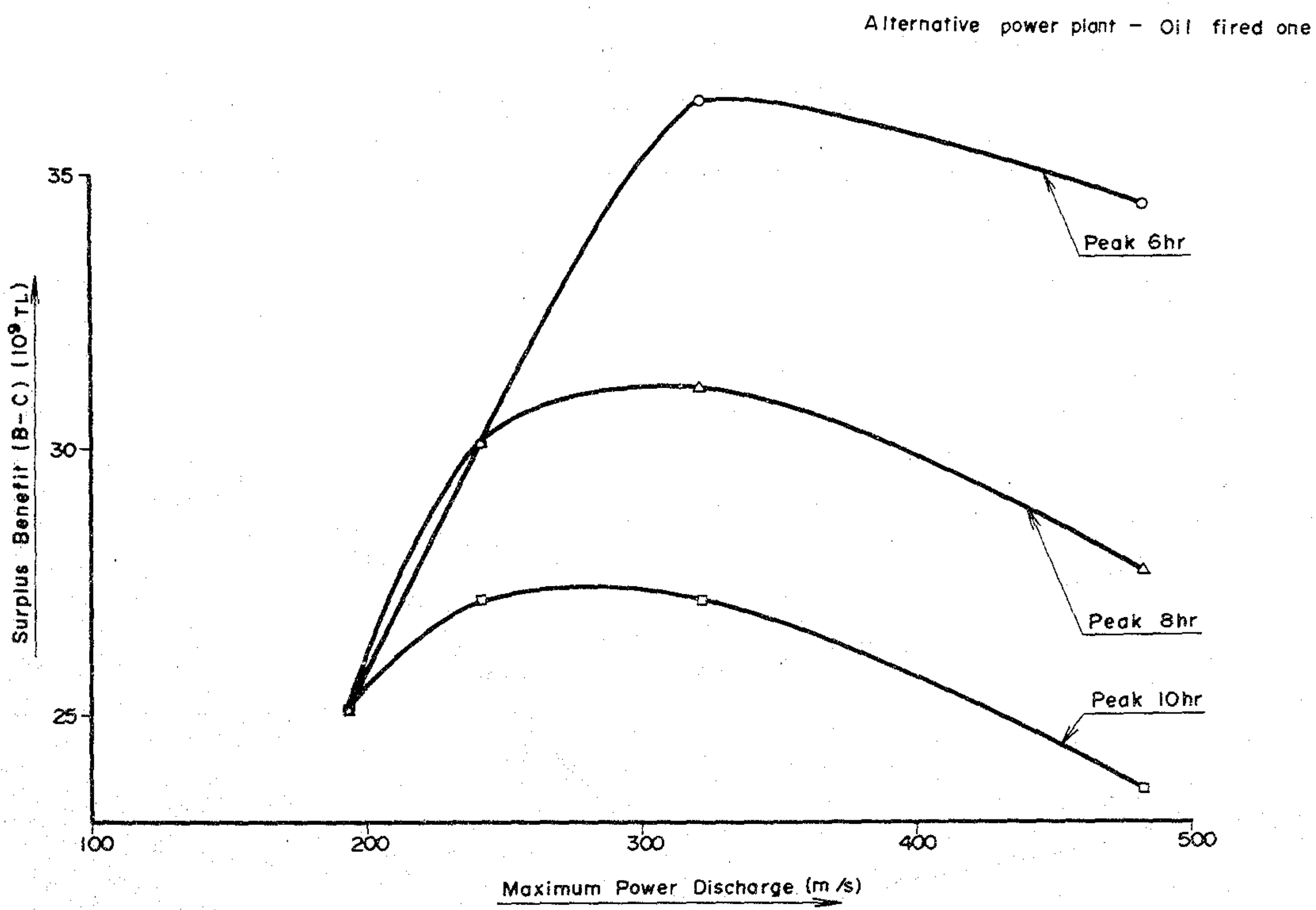


Fig. 9—17 Study on Optimum Power Discharge and Peak Duration (B—C) (2)

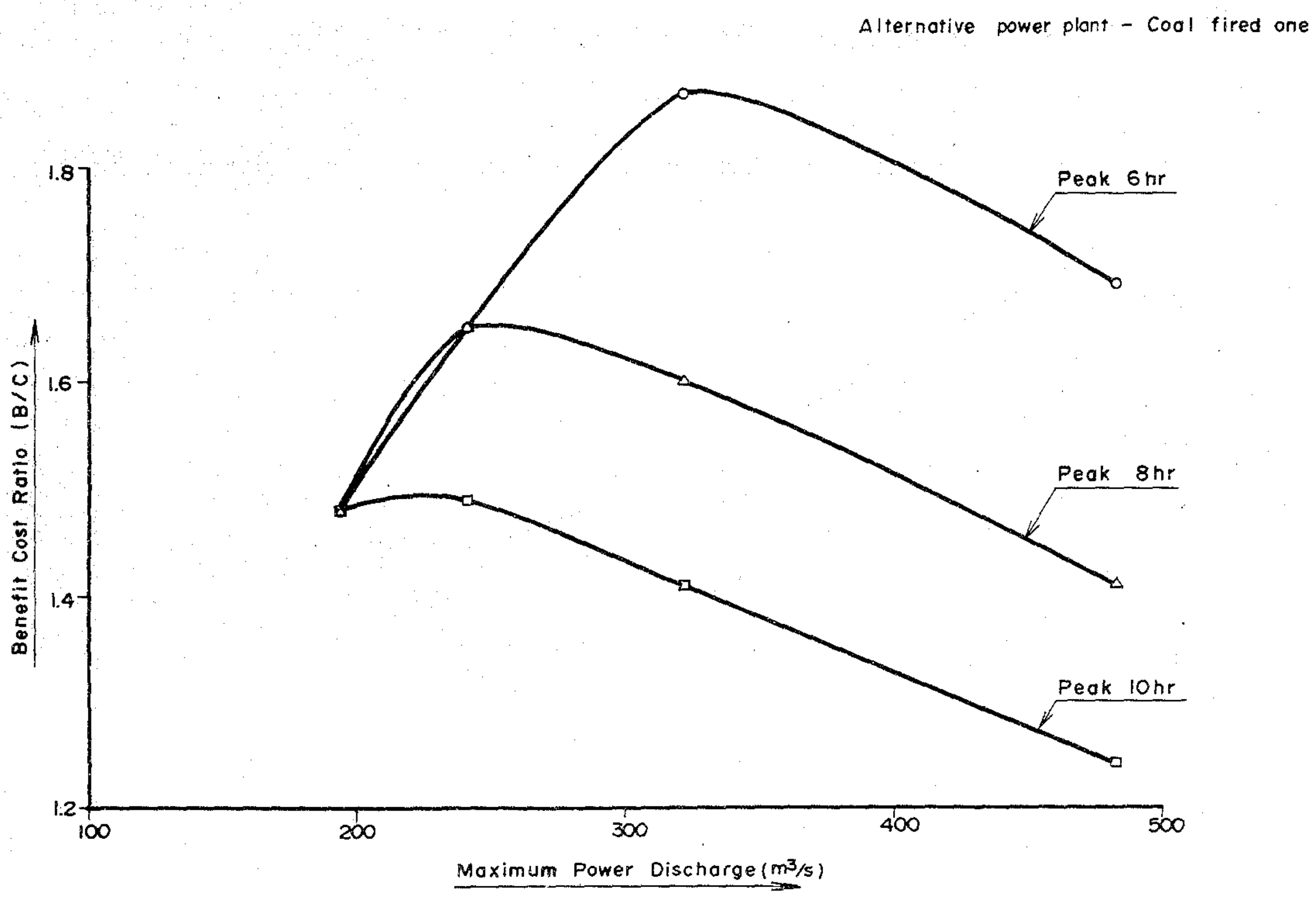


Fig. 9–18 Study on Optimum Power Discharge and Peak Duration (B/C) (1)

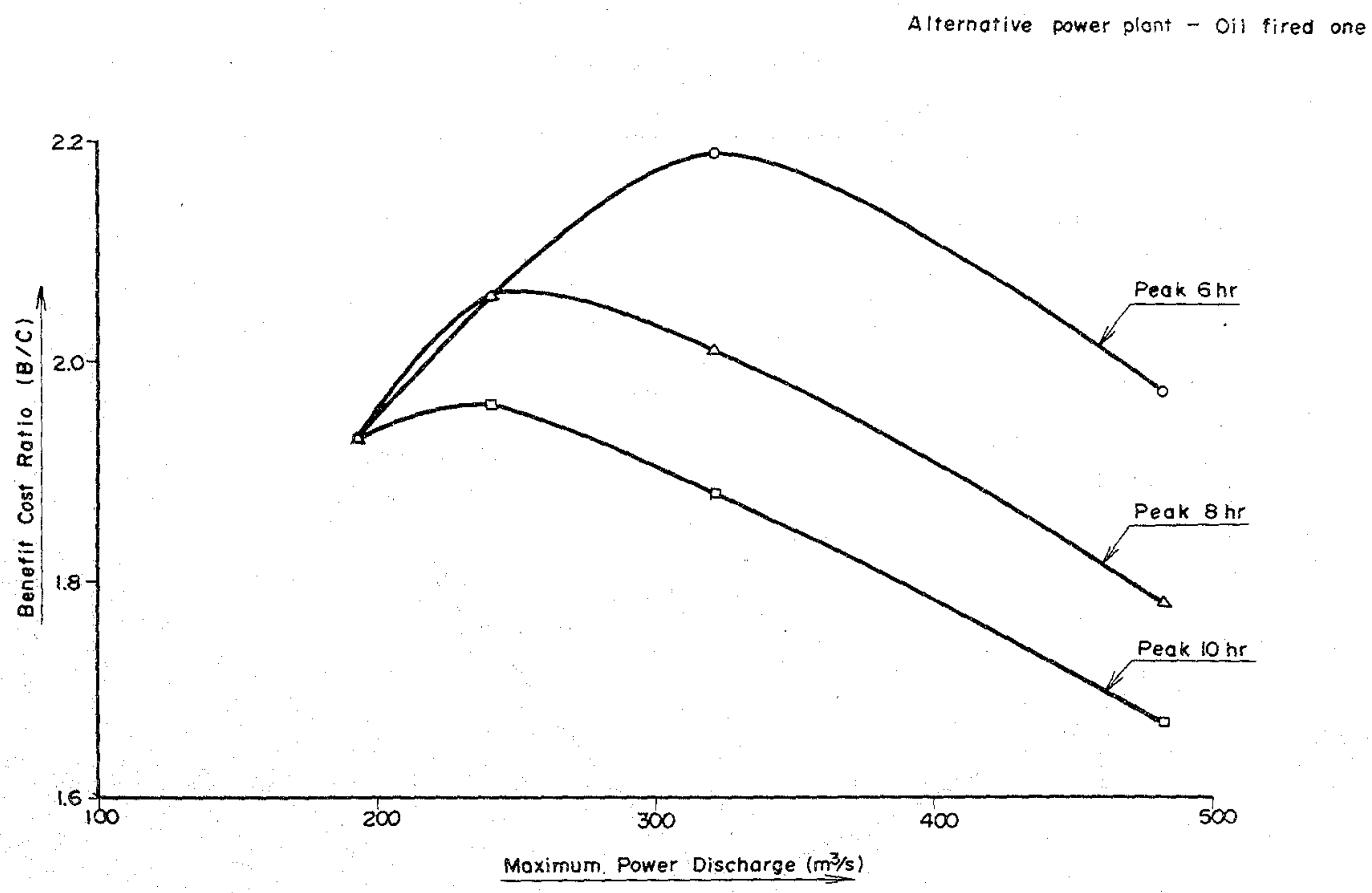


Fig. 9–19 Study on Optimum Power Discharge and Peak Duration (B/C) (2)

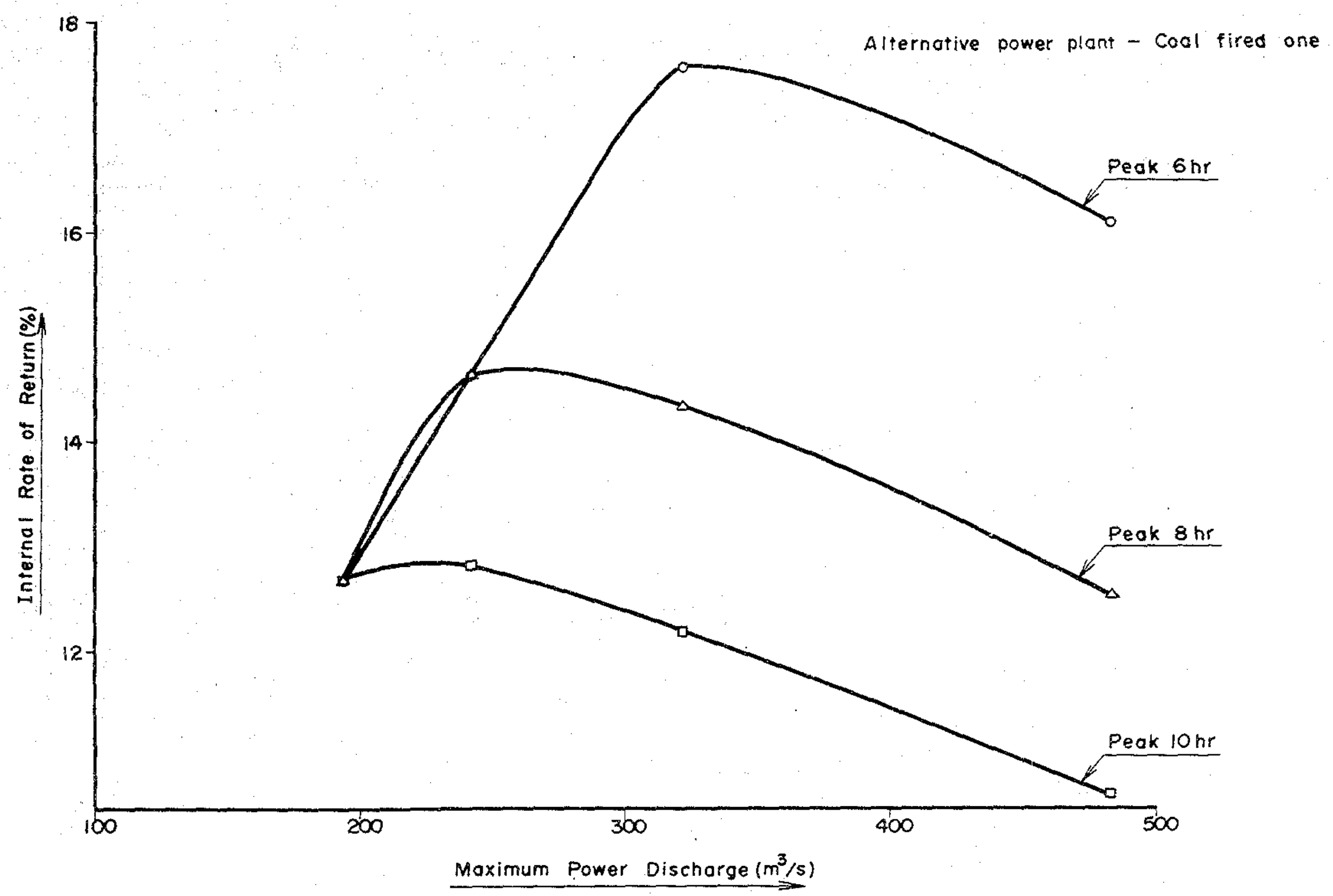


Fig. 9–20 Study on Optimum Power Discharge and Peak Duration (I.R.R.) (1)

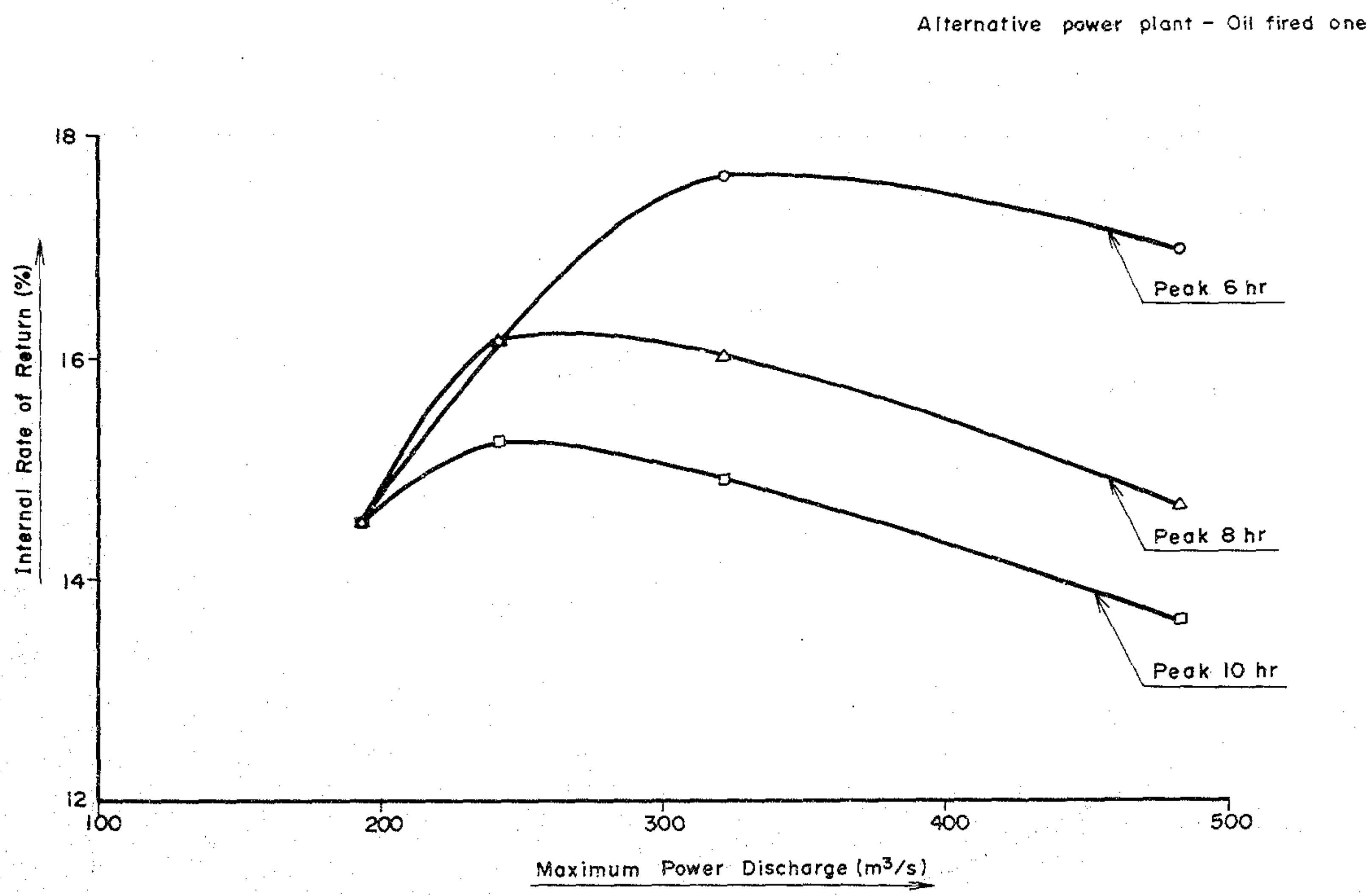


Fig. 9–21 Study on Optimum Power Discharge and Peak Duration (I.R.R.) (2)

Table 9–14 Study on Optimum Power Discharge and Peak Duration (1)

*Alternative Power Plant ....Coal-fired One

Case	H.W.L (m)	Effective Storage Capacity (10^6m^3)	Firm Discharge (m^3/s)	Maximum Discharge (m^3/s)	Effective Head (m)	Installed Capacity (MW)	Peak Duration (hour)	Firm Peak Power (MW)	Annual Energy (GWh)	Investment Cost (10^6TL)	Annual Cost (10^6TL)	Energy Cost (TL/kWh)	I.R.R. (%)	Surplus Benefit (10^6TL)	Benefit-Cost Ratio
1							6	530.5	1,772.2			20.6	16.1	24,530	1.69
2				482		816	8	397.4	1,773.2	342,000	35,340	20.6	12.6	14,450	1.41
3							10	317.0	1,772.6			20.6	10.6	8,350	1.24
4							6	507.3	1,709.2			18.6	17.6	26,720	1.87
5				321		543	8	397.4	1,721.9	299,600	30,700	18.4	14.3	18,530	1.60
6	710	1,080	80.4		191.7		10	318.4	1,724.6			18.4	12.2	12,560	1.41
7							6	380.9	1,617.0			18.1	14.6	18,460	1.65
8				241		408	8	380.9	1,618.2	278,100	28,350	18.1	14.6	18,470	1.65
9							10	317.6	1,629.2			18.0	12.8	13,790	1.49
10							6	305.2	1,520.8			18.4	12.7	12,940	1.48
11				193		326	8	305.2	1,520.8	266,400	27,050	18.4	12.7	12,940	1.48
12							10	304.9	1,522.2			18.4	12.7	12,940	1.48

Table 9-15 Study on Optimum Power Discharge and Peak Duration (2)

*Alternative Power Plant .... Oil-fired one

Case	H.W.L (m)	Effective Storage Capacity ($10^6 m^3$)	Firm Discharge (m^3/s)	Maximum Discharge (m^3/s)	Effective Head (m)	Installed Capacity (MW)	Peak Duration (hour)	Firm Peak Power (MW)	Annual Energy (GWh)	Investment Cost (10^6TL)	Annual Cost (10^6TL)	Energy Cost (TL/kWh)	I.R.R. (%)	Surplus Benefit (10^6TL)	Benefit-Cost Ratio
1							6	530.5	1,772.2			20.6	16.5	34,440	1.97
2				482		816	8	397.4	1,773.2	342,000	35,340	20.6	14.7	27,690	1.78
3							10	317.0	1,772.6			20.6	13.6	23,600	1.67
4							6	507.3	1,709.2			18.6	17.6	36,380	2.19
5				321		543	8	397.4	1,721.9	299,600	30,700	18.4	16.0	31,090	2.01
6	710	1,080	80.4		191.7		10	318.4	1,724.6			18.4	14.9	27,140	1.88
7							6	380.9	1,617.0			18.1	16.2	30,070	2.06
8				241		408	8	380.9	1,618.2	278,100	28,350	18.1	16.2	30,100	2.06
9							10	317.6	1,629.2			18.0	15.3	27,140	1.96
10							6	305.2	1,520.8			18.4	15.0	25,200	1.93
11				193		326	8	305.2	1,520.8	266,400	27,050	18.4	15.0	25,200	1.93
12							10	304.9	1,522.2			18.4	15.0	25,220	1.93

are observed on both banks, and the alluvium of the river bed is presumed to have depth of about 50 meters.

The other alternative site, Artvin Downstream Dam Site is in the inundated area of Deriner Reservoir, and the catchment area at this site is 15,540 km^2. The site is 19 km downstream from Yusufeli Site with residual catchment area of 290 km^2. The average residual flow is 3.0 m^3/s. The elevation of the river bed is 380 m, and the river width is approximately 30 m, having very steep slopes of a "V" shaped valley on both banks, which gradient is partly as high as 70 degrees. The right abutment forms a col having an elevation of about 550 m. The base rock consists of strata of phillite, basic tuff and diabase, which are fresh and hard. The river bed alluvium is approximately 35 m deep, and there are some distributions of slope washes on both banks.

The examiantions of development type and layout were made with 1/5000 topographical maps.

(2) Study on Development Type and Layout

In examining development type and layout, the high water level is determined to be EL. 500 m to utilize the residual head sufficiently.

In the plan for Artvin Upstream Dam Site, a dam and conduit type power plant is planned with the powerhouse located near the end of Deriner Reservoir back water, because of a residual head between high water level of Deriner Reservoir, 392 m and the riverbed elevation of this dam site, 446 m. Two alternatives have been compared for this plan, one having the outlet at the end of Deriner Reservoir back water, and the other having the outlet at an elevation lower than the high water level of Deriner Reservoir taking into account the fluctuation of the water level of Deriner Reservoir.

As for the upstream dam site, a rockfill dam is suitable from geological point of view.

As for the downstream dam site, a concrete dam is recommended judging from the possibility of Havzulu landslide and unavailability nearby of impervious soil material as well as topographical and geological conditions. Regarding the type of concrete dam, two plans of an arch gravity dam in which a powerhouse and a spillway can be incorporated, and an arch dam with a center overflow spillway and an underground powerhouse in the left bank are conceivable. The plan of an arch dam with a chute spillway located at the col of the right bank and a surface powerhouse at the foot of the dam was abandoned from economic point of view. The plan of a concrete gravity dam was eliminated because the dam volume would be large and economically unfavorable.

Comparison studies of basic layout are made among the above 4 cases, as shown in Table 9-16. The outlines of alternative plans are shown in Fig. 9-22.

It is judged that the appropriate operation mode of Artvin Power Plant is to generate peak power, regulating the residual flow in coordination with the operation of Yusufeli Power Plant located upstream. Thus the effective storage capacity of Artvin Reservoir is designed to have sufficient capacity with which the residual flow can be regulated for the peak duration time of Yusufeli Power Plant. The maximum power discharge and the required effective storage capacity of Artvin Power Plant have been studied based on the 42 year flow data, and the results are presented in Fig. 9-23.

The results of the study indicate that the effective storage capacities required for the regulation of the residual flow are 270×10^3 m^3 for the upstream dam site plan, and 300×10^3 m^3 for the downstream dam site plan, which correspond to the drawdown of 0.3 m and 0.1 m respectively.

Finally, the available drawdown is set to be 1.0 m for both plans, making a certain allowance.

The reservoir storage capacity and area curves of Artvin Reservoir are given in Figs. 9-24, 25.

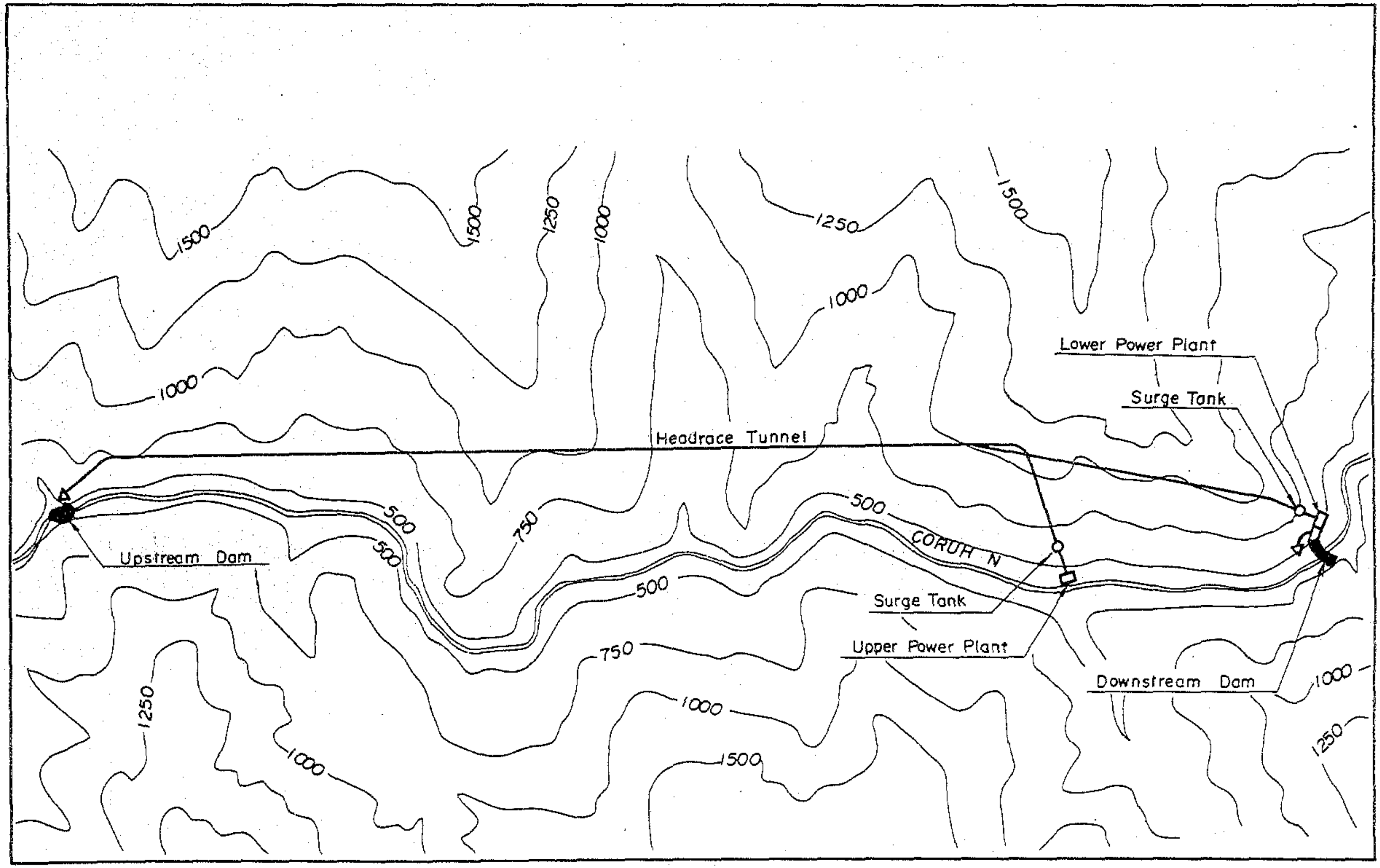


Fig. 9—22 Artvin Alternative Plans

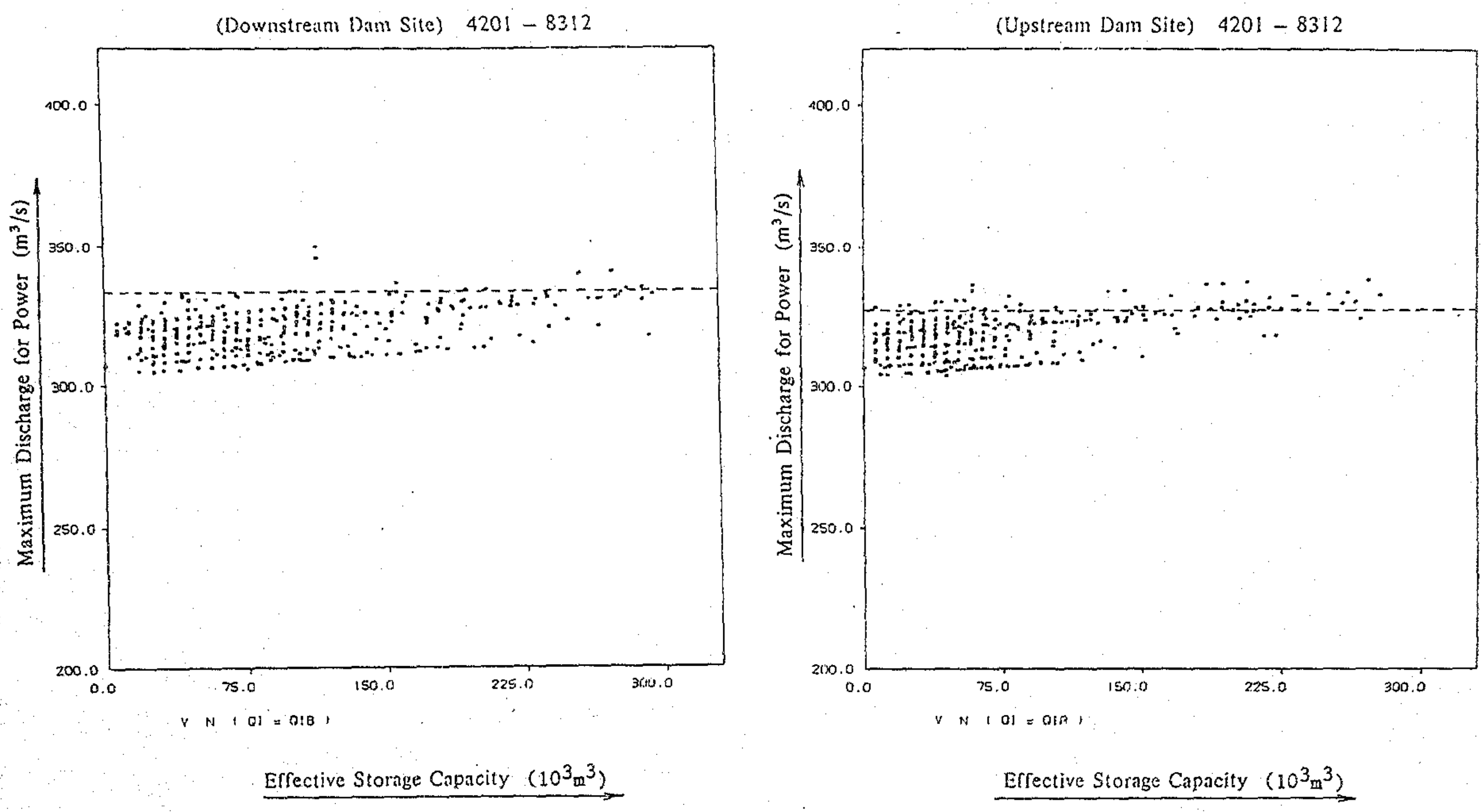
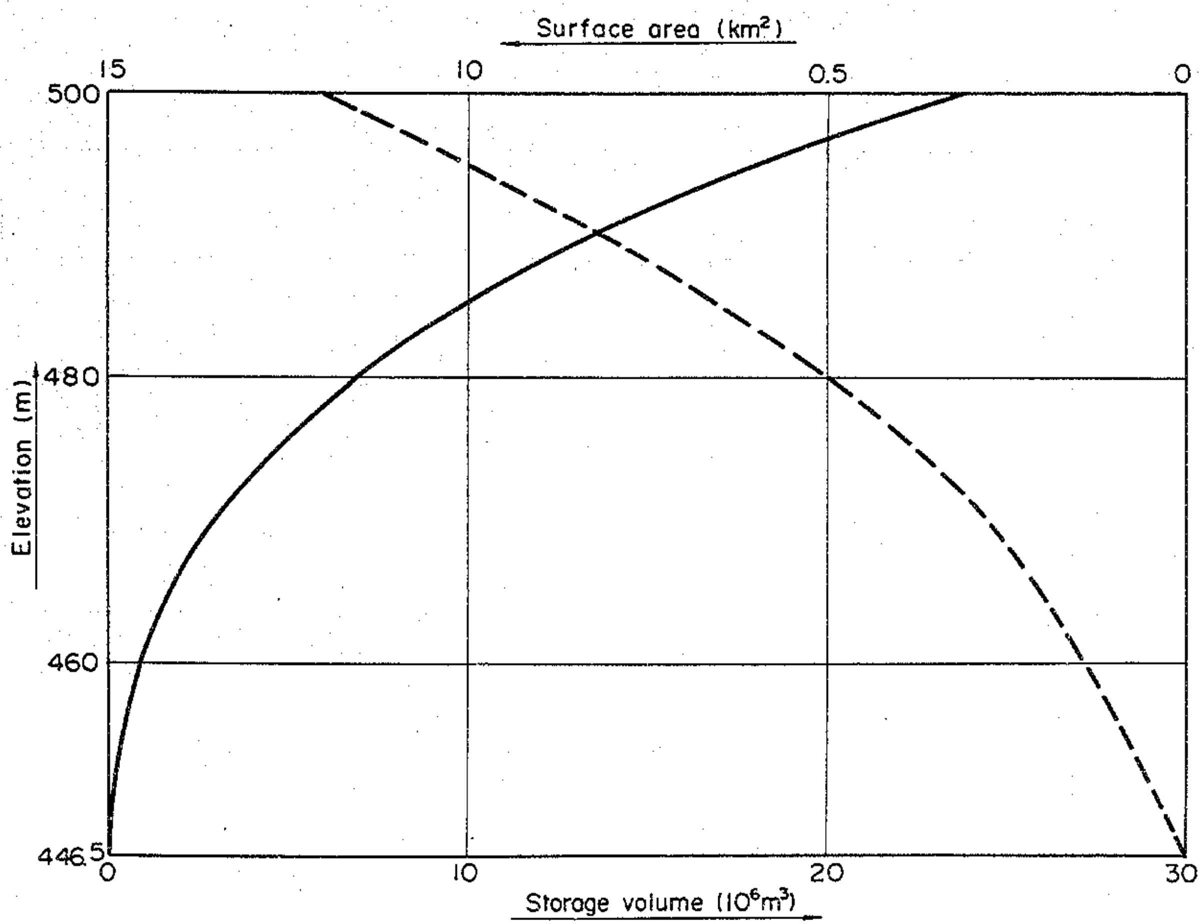
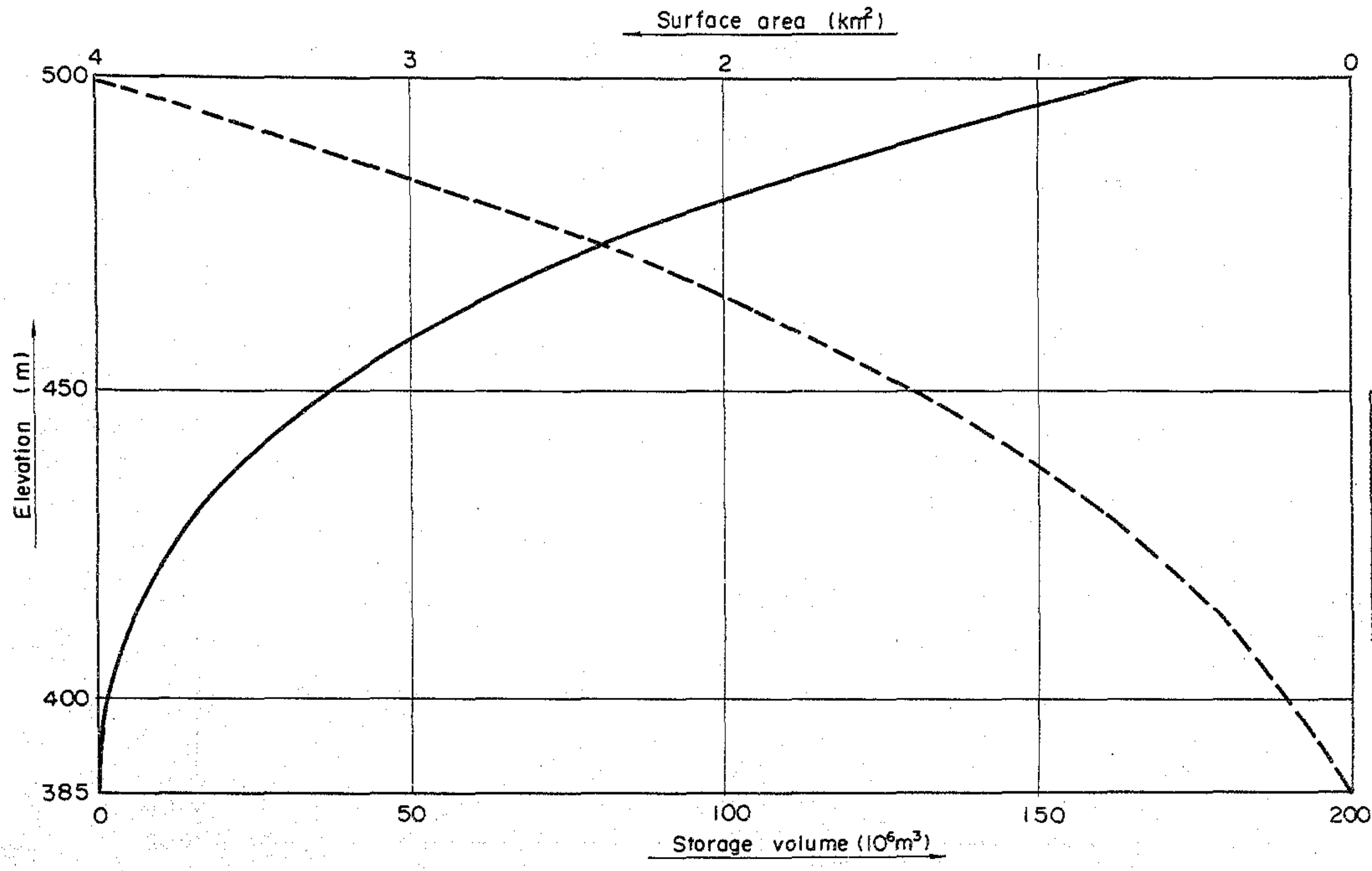


Fig. 9–23 Study on Effective Storage Capacity of Artvin Reservoir



E.L.	Area (km²)	Volume (10⁶m3)
446.5	0.00	0.0
460	0.13	0.9
480	0.50	6.9
500	1.21	23.7

Fig. 9–24 Artvin Reservoir Storage Capacity and Area Curve (Upstram Dam Site)



E.L.	Area (km²)	Volume (10⁶m³)
385	0.00	0.0
400	0.21	1.6
420	0.56	9.0
440	1.07	25.3
460	1.81	53.3
480	2.77	98.6
500	4.08	166.8

Fig. 9–25 Artvin Reservoir Storage Capacity and Area Curve
(Downstream Dam Site)

Table 9–16 Structural Dimension (Artvin Project)

Item	Case	Upstream Dam (Rockfill Dam)		Downstream Dam	
		Upper Power Plant	Lower Power Plant	(Arch Gravity Dam)	(Arch Dam)
Dam	H x L (m)	115 x 125	115 x 125	160 x 188.5	160 x 217
	Top width (m)	12	12	5	8
	Outer slope	1:2.2, 1:1.9	1:2.2, 1:1.9	1:0.55 (Downstream)	25 (Base width)
	Dam volume (10^3 m^3)	1,150	1,150	910	500
Diversion tunnel	D x L x n (m)	9.5 x 627 x 1	9.5 x 627 x 1	10.0 x 510 x 1	10.0 x 549 x 1
Spillway gate	B x H x n (m)	13.5 x 15.0 x 4	13.5 x 15.0 x 4	13.5 x 15.0 x 3 (free-overflow Section B=78)	13.0 x 15.0 x 4 (free-overflow section B=40)
Headrace	D x L x n (m)	9.8 x 7,910	9.8 x 9,200	-	-
Surge tank	D x H x n (m)	Shaft 18.0 x 50 Chamber 18.0 x 20.0 x 120	Shaft 18.0 x 15 Chamber 18.0 x 20.0 x 120	-	-
Penstock	D x L x n (m)	(9.8-8.4-5.3)x195 x(1-2)	(9.8-8.4-5.3)x201 x(1-2)	(6.6-5.3) x 143/135	(6.5-5.2) x 201/239 x 2
Tailrace	D x L x n (m)	7.0 x 103 x 1	7.0 x 103 x 1	-	7.5 x 192/169 x 2
Powerhouse	B x L (m)	23 x 63	23 x 63	23 x 63	23 x 63

The amount of sediment was calculated for the catchment area between Yusufeli Dam and Artvin Dam, and the sediment rate of 400 m^3/km^2/year was considered for 50 years. The total sediment (and the sediment level) amounts to 3.0 x 10^6 m^3 (EL.470 m), and 5.8 x 10^6 m^3 (EL.413 m) for the Artvin Upstream Dam Site Plan and Downstream Dam Site Plan respectively.

In these comparative studies, the maximum power discharge of Artvin Power Plant was determined based on the maximum power discharge of Yusufeli Power Plant, 321 m^3/s, and the residual flow. The increment of the maximum discharge corresponding to the residual flow was designed to produce a 6-hour peak generation for the average residual flow. The maximum power discharges determined on these conditions are 327 m^3/s for the upstream dam plan and 333 m^3/s for the downstream dam plan.

The rated intake water level was selected at EL.500 m, which is equal to high water level. The rated tail water level in each plan was designed based on the water level curves obtained with non-uniform flow calculations according to the measurement data received from EIE. In the upper power plant plan, the water level is little affected by the water level of Deriner Reservoir at maximum power discharge of Artvin Power Station, as shown in Fig. 9-26, and the rated tail water level can be determined to be EL. 393.5 m. In the lower power plant plan, the elevation of the outlet is lower than high water level of Deriver Reservoir, and the effect of the water level of the reservoir must be taken into account.

Although the effect of Yusufeli Project on Deriner Project is described in 9.2.3, the probability distribution of the water level of Artvin Reservoir is as presented in Fig. 9-27, and the water level with 50% probability of exceeding is EL. 382 m.

The outlet water level at maximum power discharge when the water level of Deriner Reservoir is at EL. 382 m is to be the rated tail water level, and EL. 383.2 m is determined.

Similarly, the tail water level is determined to be EL. 384.1 m in the downstream dam plan. The water level curves at the outlets are shown in Fig. 9-28, 29.

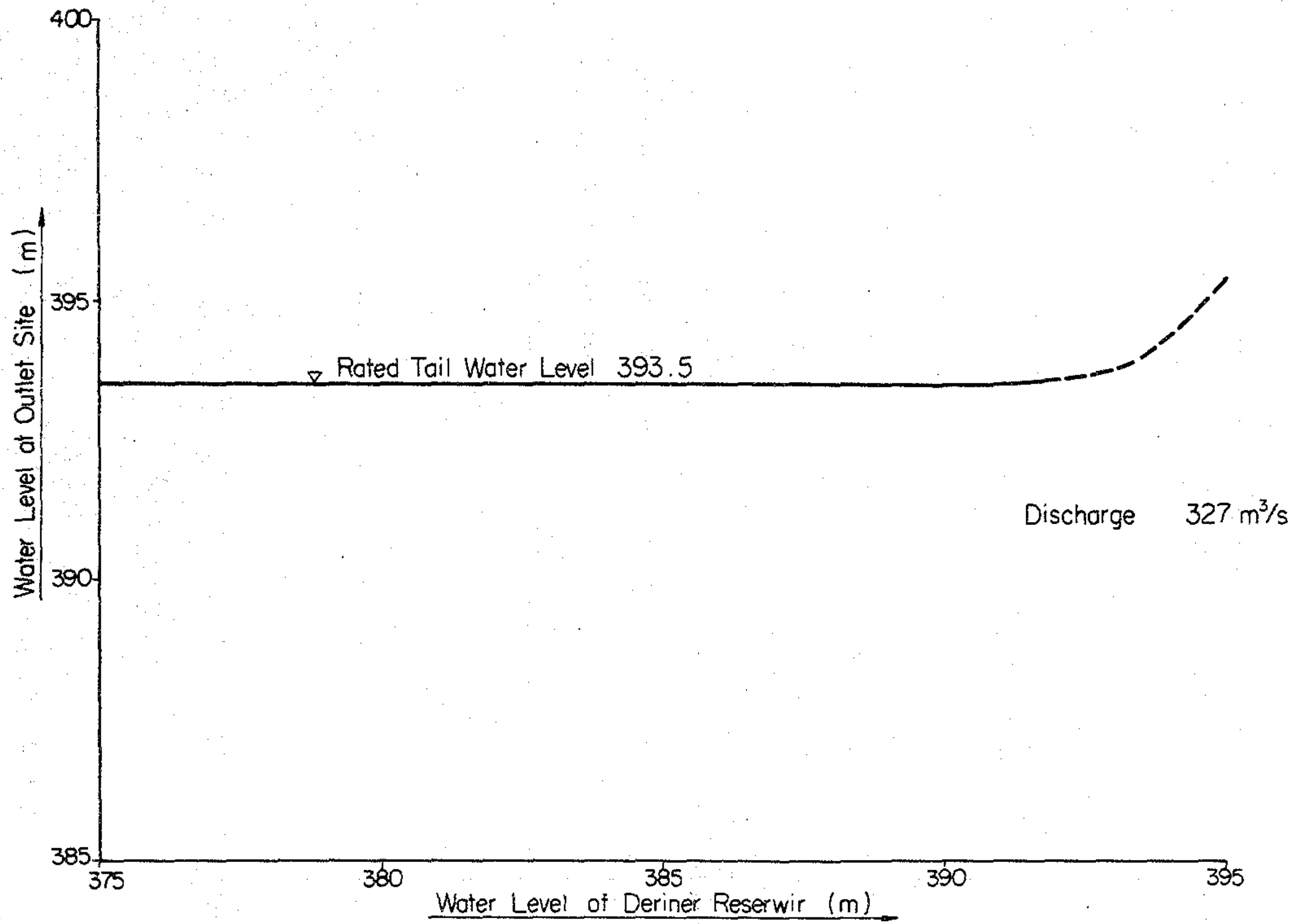


Fig. 9–26 Tail Water Level of Artvin Power Plant
(Upstream Dam Site – Upper Power Plant)

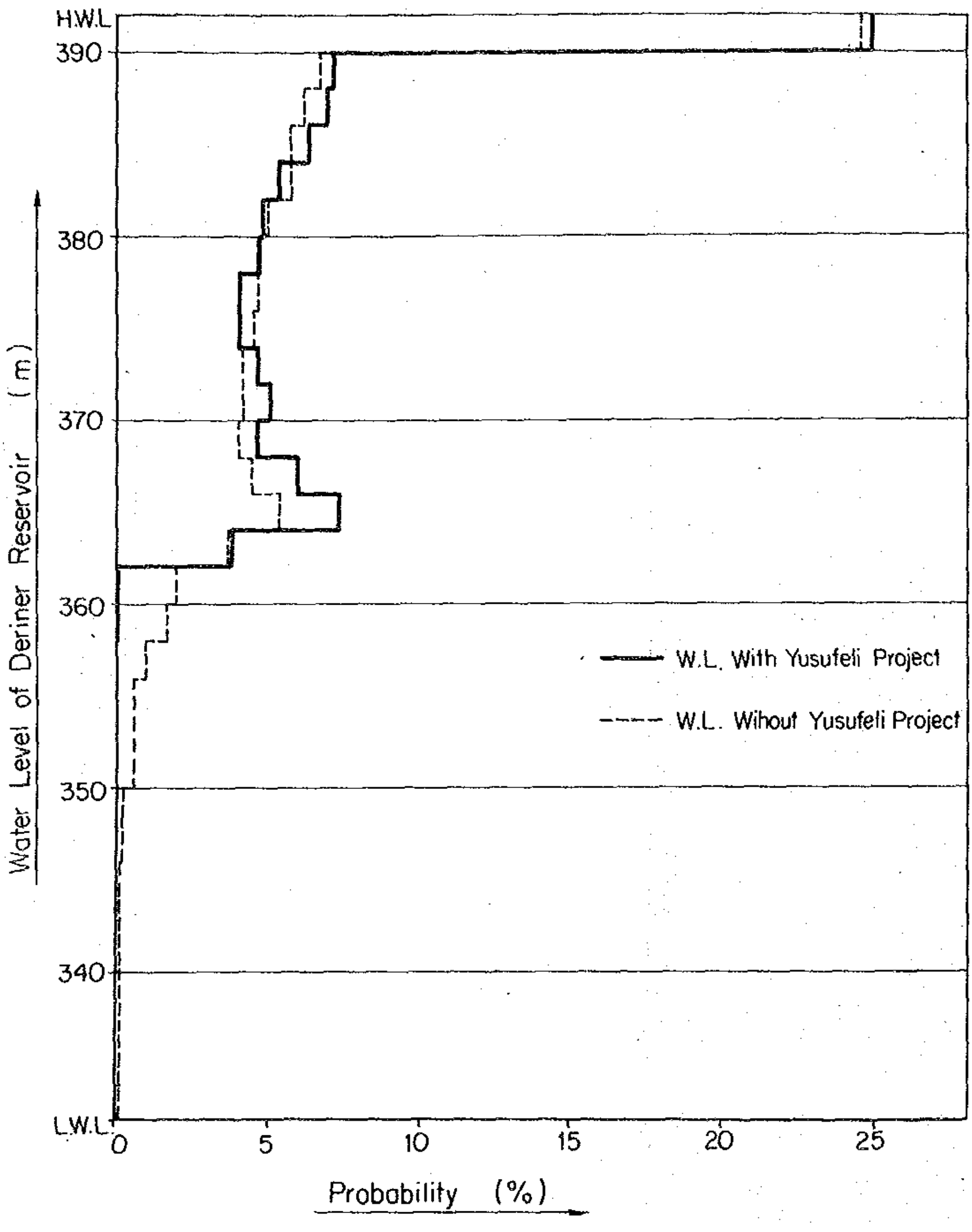


Fig. 9–27 Water Level Frequency of Deriner Reservoir

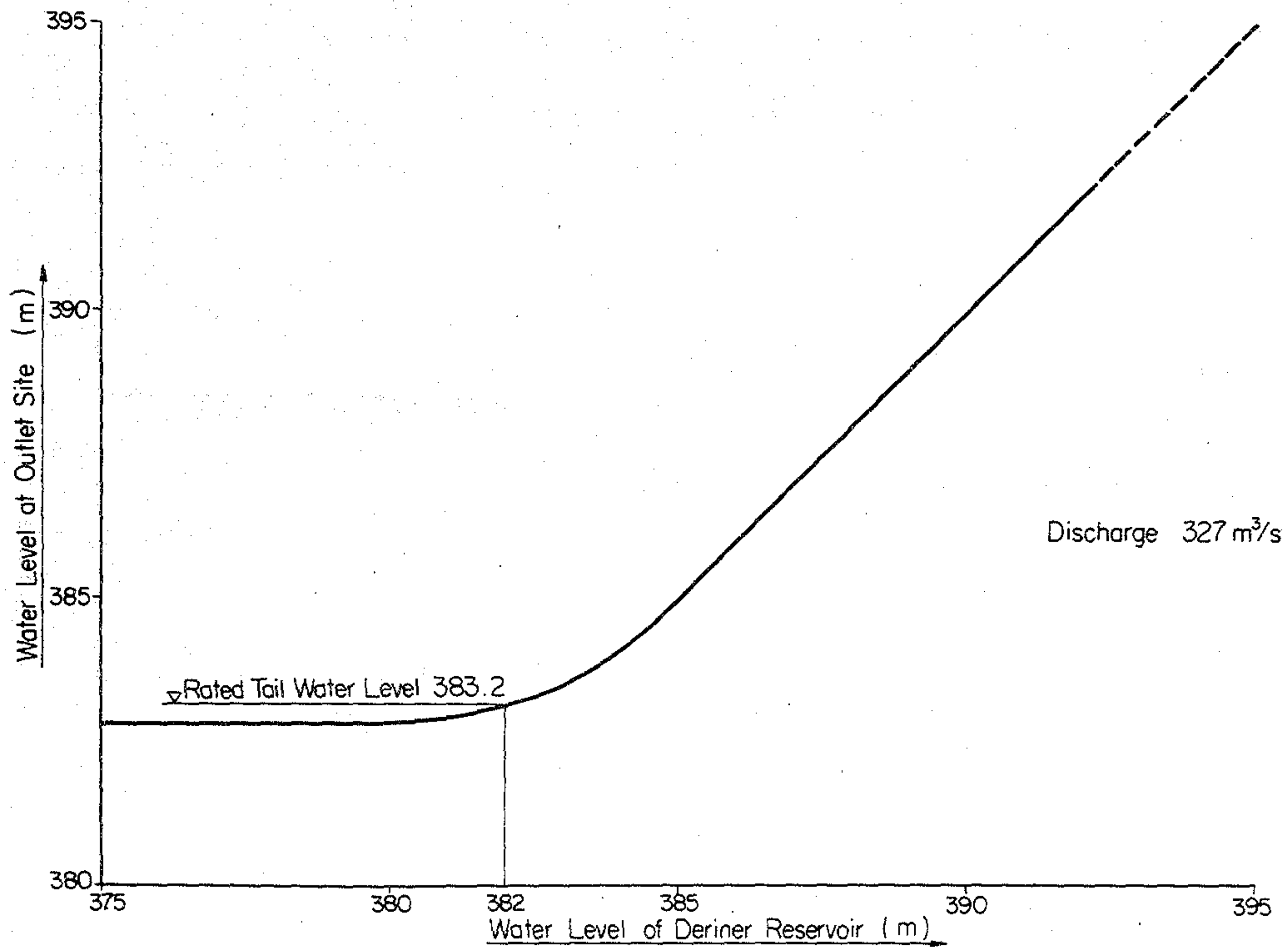


Fig. 9–28 Tail Water Level of Artvin Power Plant (Upstream Dam Site – Lower Power Plant)

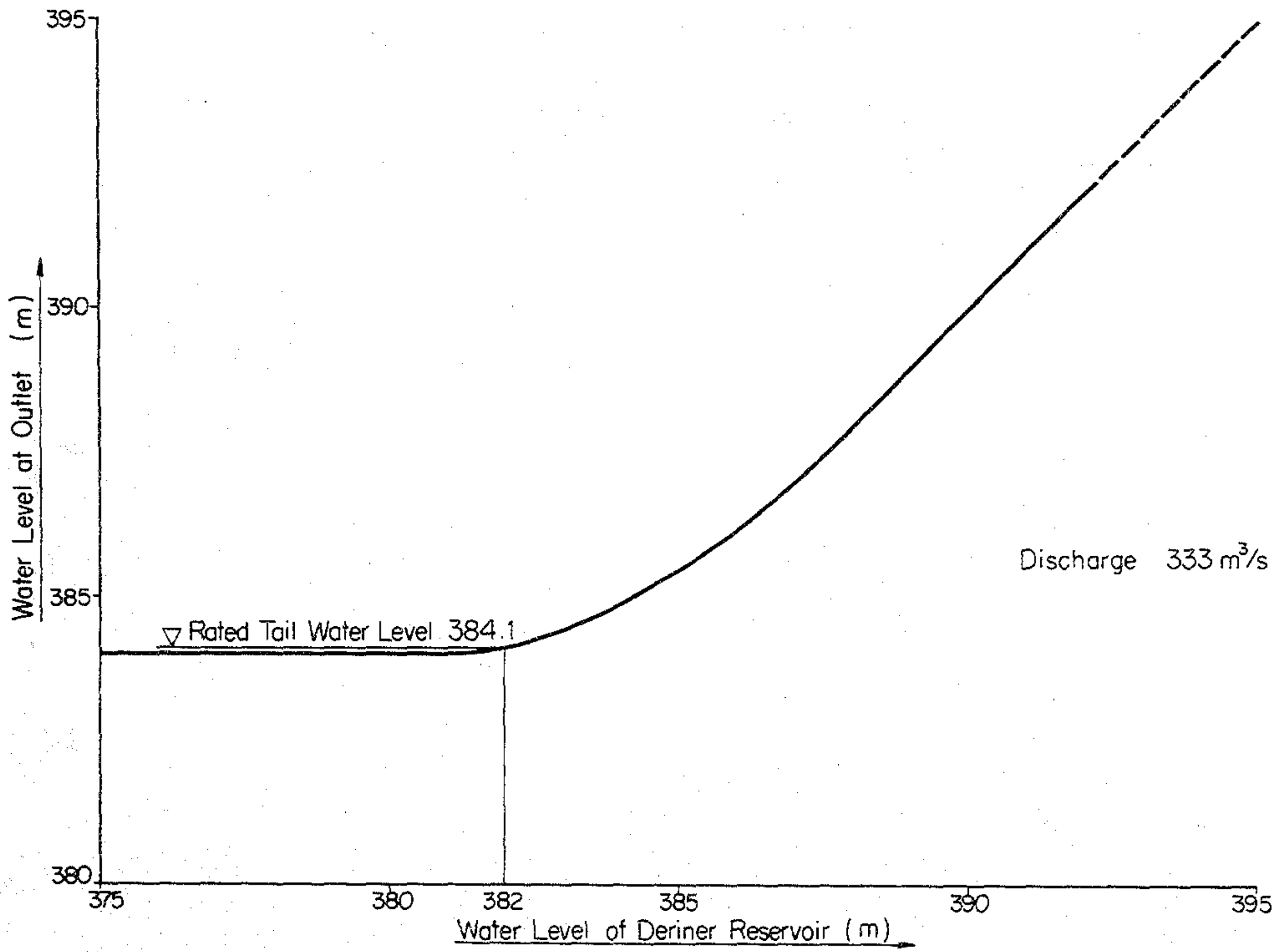


Fig. 9–29 Tail Water Level of Artvin Power Plant (Downstream Dam Site)

As shown in Tables 9-17, 18, the arch dam plan at the downstream dam site would be most favorable economically. Although geological investigations have not been completed, and it is difficult to make faultless judgment at the present time, the arch dam plan is selected in this report.

The investment costs of the 4 plans are presented in Table 9-19, and outlines of basic layout of alternative plan are described as follows.

(a) Rockfill Dam : Upstream Dam Plan

The dam is a rockfill dam of center impervious core with the outer slope of 1 to 2.2 upstream and 1 to 1.9 downstream.

The total embankment volume will amount to about 1.2 x $10^6 m^3$ with the height of 115 m and the crest length of 125 m.

A chute spillway is arranged on the col of the left bank and four radial gates 13.5 m in width and 15.0 m in height are installed. A narrow ridge is to be excavated in order to acquire a necessary approaching channel section to the spillway. Moreover, the flood discharge is designed so as not to affect the stability of the slope wash on the right bank downstream of the chute end.

A power waterway is located in the left bank and consists of power intake, headrace tunnel, surge tank, penstock, underground powerhouse, tailrace tunnel and outlet. The length of the headrace tunnel is 7,910 m and 9,200 m for an upstream outlet plan and for a downstream one respectively. From economic point of view, one line of headrace tunnel 9.8 m in inner diameter is adopted. A surge tank is a restricted orifice type and has an upper surge chamber on the top of the vertical tank 18 m in inner diameter. A part of the access tunnel is utilized for the upper surge chamber by extending the tunnel section. The elevation of the bottom of the surge tank is determined in

Table 9–17 Study on Optimum Layout of Artvin Project (1)

* Alternative Power Plant .... Coal-fired One

Item	Unit	Upstream Dam Site (Rockfill Dam)		Downstream Dam Site	
		Upper Power Plant	Lower Power Plant	(Arch Gravity Dam)	(Arch Dam)
Installed Capacity	MW	262	286	322	320
Maximum Discharge	m^3/s	327	327	333	333
Rated Effective Head	m	95.0	103.8	113.7	112.9
Firm Peak Power	MW	260.7	274.1	305.6	303.6
Annual Energy	GWh	836.2	889.8	995.2	988.8
Investment Cost	10^6TL	148,900	162,600	145,700	139,300
Internal Rate of Return	%	38.2	34.9	39.0	41.7
Surplus Benefit (B-C)	10^6TL	13,710	13,910	19,060	19,480
Benefit Cost Ratio (B/C)	-	1.89	1.83	2.25	2.34
Energy Cost	TL/KWh	19.0	19.5	15.7	15.2

Table 9–18 Study on Optimum Layout of Artvin Project (2)

* Alternative Power Plant .... Oil-fired one

Item	Unit	Upstream Dam Site (Rockfill Dam)		Downstream Dam Site	
		Upper Power Plant	Lower Power Plant	(Arch Gravity Dam)	(Arch Dam)
Installed Capacity	MW	262	286	322	320
Maximum Discharge	m^3/s	327	327	333	333
Rated Effective Head	m	95.0	103.8	113.7	112.9
Firm Peak Power	MW	260.7	274.1	305.6	303.6
Annual Energy	GWh	836.2	889.8	995.2	988.8
Investment Cost	10^6TL	148,900	162,600	145,700	139,300
Internal Rate of Return	%	27.4	26.1	30.0	31.5
Surplus Benefit (B-C)	10^6TL	17,980	18,540	24,250	24,640
Benefit Cost Ratio (B/C)	-	2.17	2.11	2.60	2.70
Energy Cost	TL/KWh	19.0	19.5	15.7	15.2

Table 9–19 Investment Cost of Layout Alternative Plans (Artvin Project)

(unit: 10^6 TL)

Item	Upstream Dam (Rockfill Dam)		Downstream Dam		Remarks
	Upper Power Plant	Lower Power Plant	(Arch Gravity Dam)	(Arch Dam)	
Civil Works	69,200	75,900	53,600	48,900	
Dam	10,900	10,900	32,300	26,200	
Care of River	(3,200)	(3,200)	(2,400)	(2,500)	
Dam	(5,000)	(5,000)	(29,900)	(23,700)	
Spillway	(2,700)	(2,700)	-	-	
Waterway	37,200	42,700	-	2,800	
Powerhouse	6,000	6,000	7,700	6,900	
Access Road	500	800	1,000	1,000	
Camp Facility	5,600	5,600	5,600	5,600	
Physical Contingency	9,000	9,900	7,000	6,400	
Hydraulic Equipment	3,400	3,500	3,400	4,100	
Electromechanical Equipment	28,400	31,000	34,900	34,700	
Total	101,000	110,400	91,900	87,700	
Project Controlling	15,200	16,600	13,800	13,200	
Land Acquisition	200	200	700	700	
Relocation of Road	1,100	1,100	6,300	6,300	
Project Cost	117,500	128,300	112,700	107,900	
Interest during Construction	31,400	34,300	33,000	31,400	
Investment Cost	148,900	162,600	145,700	139,300	

connection with the down surge at the time of the sudden increase of the load.

The diversion tunnel is arranged in the right bank being designed based on the 25 year return period flood, that is 1,350 m^3/s. The tunnel inner diameter is to be 9.5 m with the crest elevation of 485 m for the upstream cofferdam. The bottom outlet is not provided because of the very short period required for the impoundment of the reservoir.

(b) Arch Gravity Dam : Downstream Dam Plan

The dam is an arch gravity type 160 m high, 150 m in radius for the upstream face, 188.5 m in crest length and 1:0.55 for the downstream face slope, and dam volume amounts to about 910 x 10^3 m^3. A bottom outlet is installed at around EL. 450 m in the dam body.

The spillway is a chute type arranged in the center of the dam crest with three radial gates of 13.5 m wide and 15.0 m high. On the both sides, ungated chute spillways are provided.

The design flood dischage is to be 8,200 m^3/s which is obtained by adding the maximum spillway discharge at Yusufeli Dam and the flood discharge of the remaining catchment area. The flood flow after descending will jump by the flip bucket and fall down to the place far from the dam.

The powerhouse is arranged on the left bank just adjacent to the dam under the ungated-overflow section separated from the gated overflow section. Two lines of penstock 6.6 m in inner diameter are contracted to 5.3 m at the entrance of the powerhouse leading directly to two units of vertical Francis turbine respectively.

The diversion tunnel is arranged in the left bank being designed based on the 10 year return period flood, that is

1,120 m^3/s. The tunnel inner diameter is to be 10.0 m with the crest elevation of 406 m for the upstream cofferdam.

(c) Arch Dam : Downstream Dam Plan

The arch dam is of dual-centered, constant thick double curvature, with the height of 160 m and the crest length of 217 m. As a result of the preliminary stress analysis by means of the trial load method, the thickness of the dam is to be 8 m at the top and 25 m at the base and the total concrete volume will amount to 0.5 x $10^6 m^3$.

The spillway is a center overflow type having four radial gates 13.0 m wide and 15.0 m high each, for release of design flood discharge of 8,200 m^3/s. The energy of fallen flood flow will be dissipated in a plunge pool with the bottom elevation of 347 m and the bottom length of 120 m, provided imemdiately downstream of the dam. A bottom outlet is installed at around EL. 450 m in the dam body.

The power waterway and the underground powerhouse are arranged in the left bank. Since the waterway is short, two lines of vertical shaft penstock of inner diameter 6.5 m to 5.2 m are adopted to connect to vertical-shaft Francis turbines each. Two lines of tailrace tunnel will also be short, and lead to the outlet without confluence.

Care of river is planned based on design flood of 1,120 m^3/s that corresponds to 10 years return period flood. The crest elevation of the upstream cofferdam is 406 m, and one line of diversion tunnel of pressure type with the inner diameter of 10.0 m is arranged in the right bank.

9.2 Optimum Development Plan

9.2.1 Yusufeli Project

The optimum development plan selected with the precision of 1/5000 topographical maps is studied in further detail with the precision of 1/1000 topographical maps. The river water levels which are necessary for deciding the project features are recalculated using river profile and cross section measurements furnished by EIE after submittal of the Interim Report. The river profile and cross section data obtained are given in Appendix.

The rated tail water level is regarded as the water level at release of the maximum power discharge when the water level of Artvin Reservoir is EL. 500 m, which is high water level. As a result of non-uniform flow calculations using a roughness coefficient of 0.05, as shown in Fig. 9-30, the rated tail water level is determined to be EL. 500.4 m. The head loss was estimated at 5.5 m based on the preliminary design.

As a result of the abovementioned reexaminations, the optimum development plan of Yusufeli Project would be composed of the installed capacity of 540 MW (180 MW x 3 units) and the annual energy generation of 1,704.6 x 10^6 kWh with the maximum power discharge of 321 m^3/s and the rated effective head of 190.8 m. Yusufeli Reservoir has high water level of 710 m and effective storage capacity of 1,080 x $10^6 m^3$ with available drawdown of 40 m by the rockfill dam 270 m in height.

The power discharge, the amount of evaporation, and the amount of spill of Yusufeli Reservoir, for a simulation of reservoir operation for 42 years from 1942 to 1983, are presented in Table 9-20. The storage, the water supplement and reservoir water level are given in Fig. 9-31, and the energy generation and the monthly minimum peak power of Yusufeli Power Plant are given in Tables 9-21, 22 respectively and Fig. 9-32.

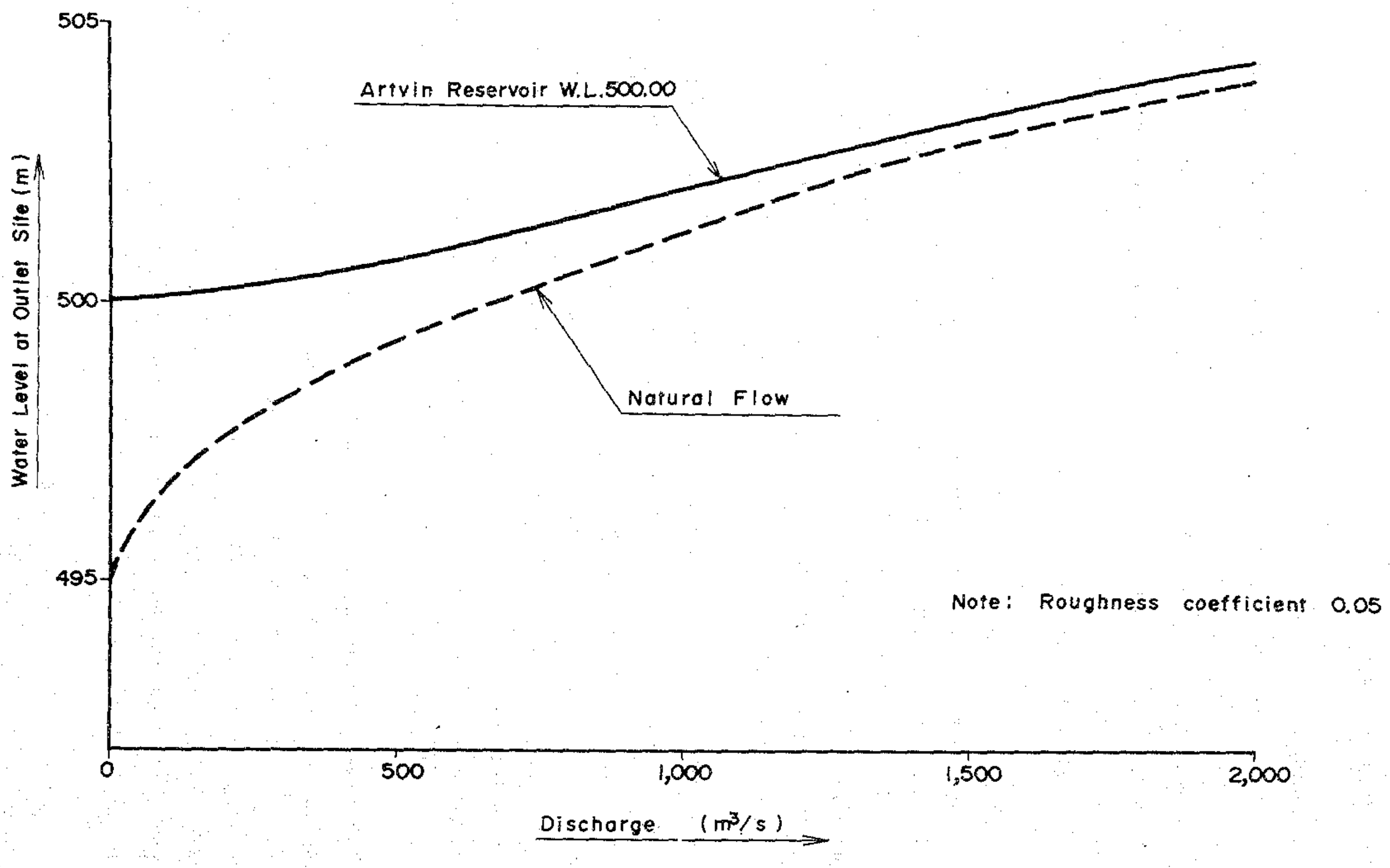


Fig. 9–30 Tail Water Level of Yusufeli Power Plant

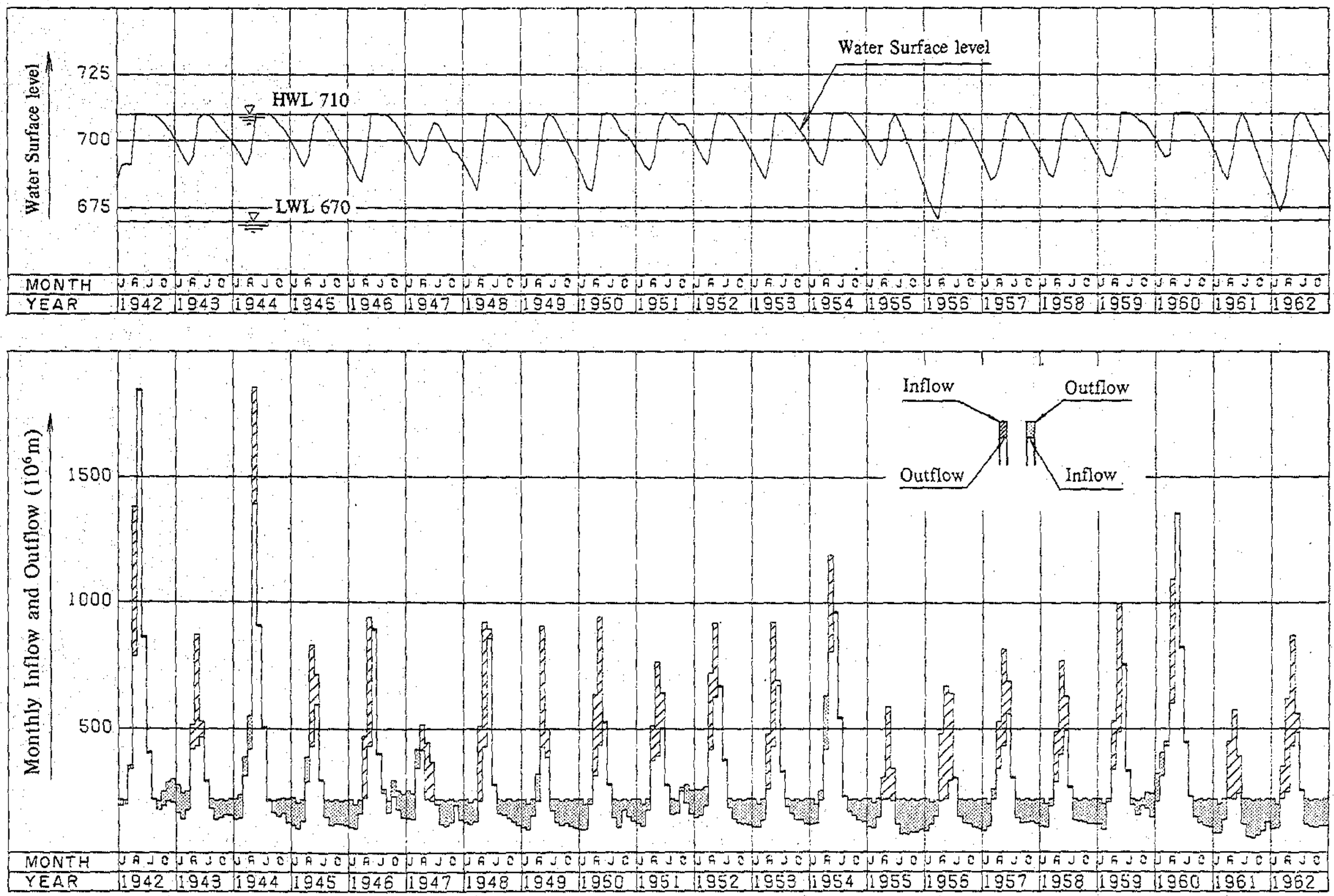
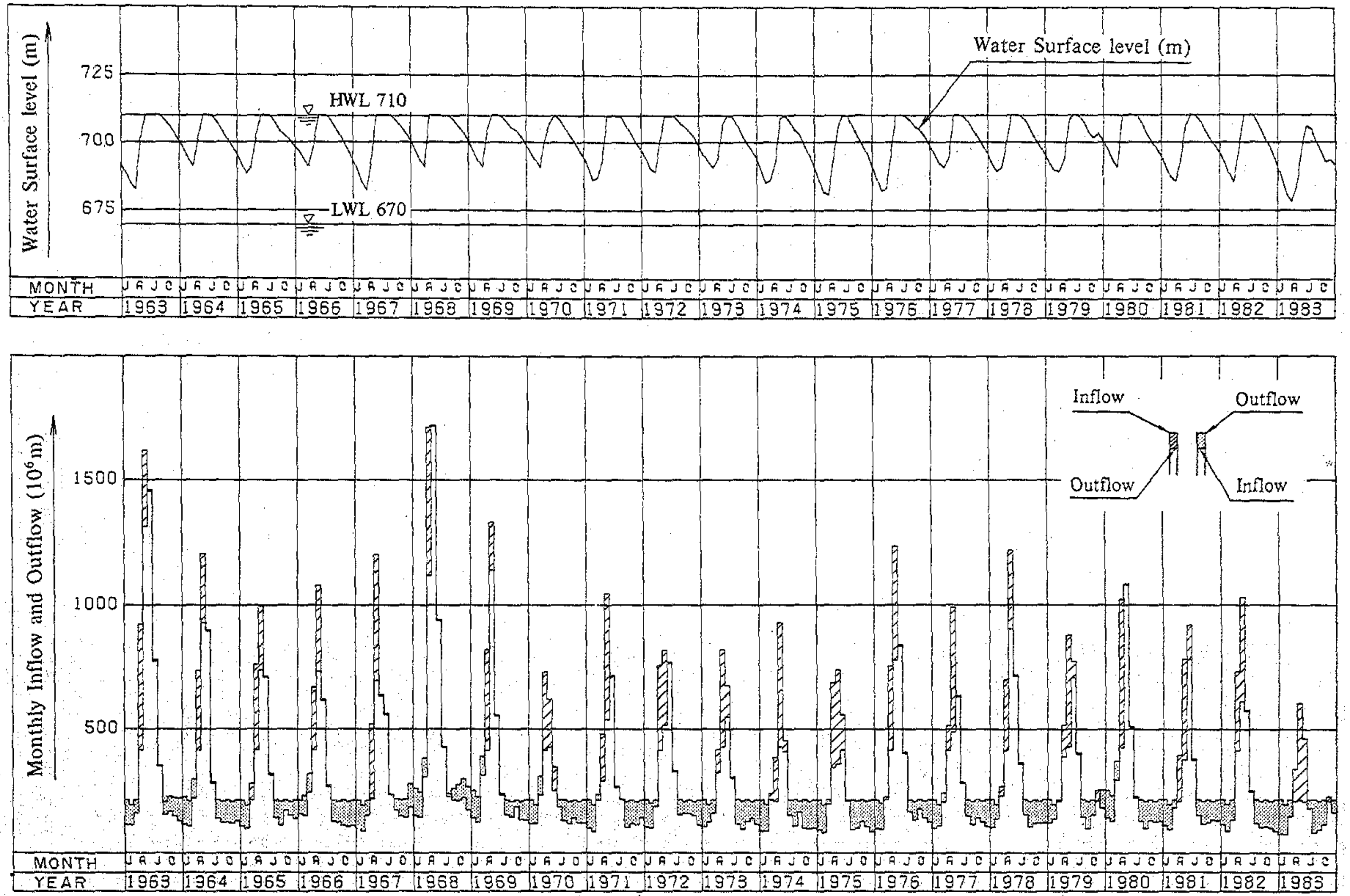


Fig. 9-31 Yusufeli Reservoir Operation (1)



Yusufeli Reservoir Operation (2)

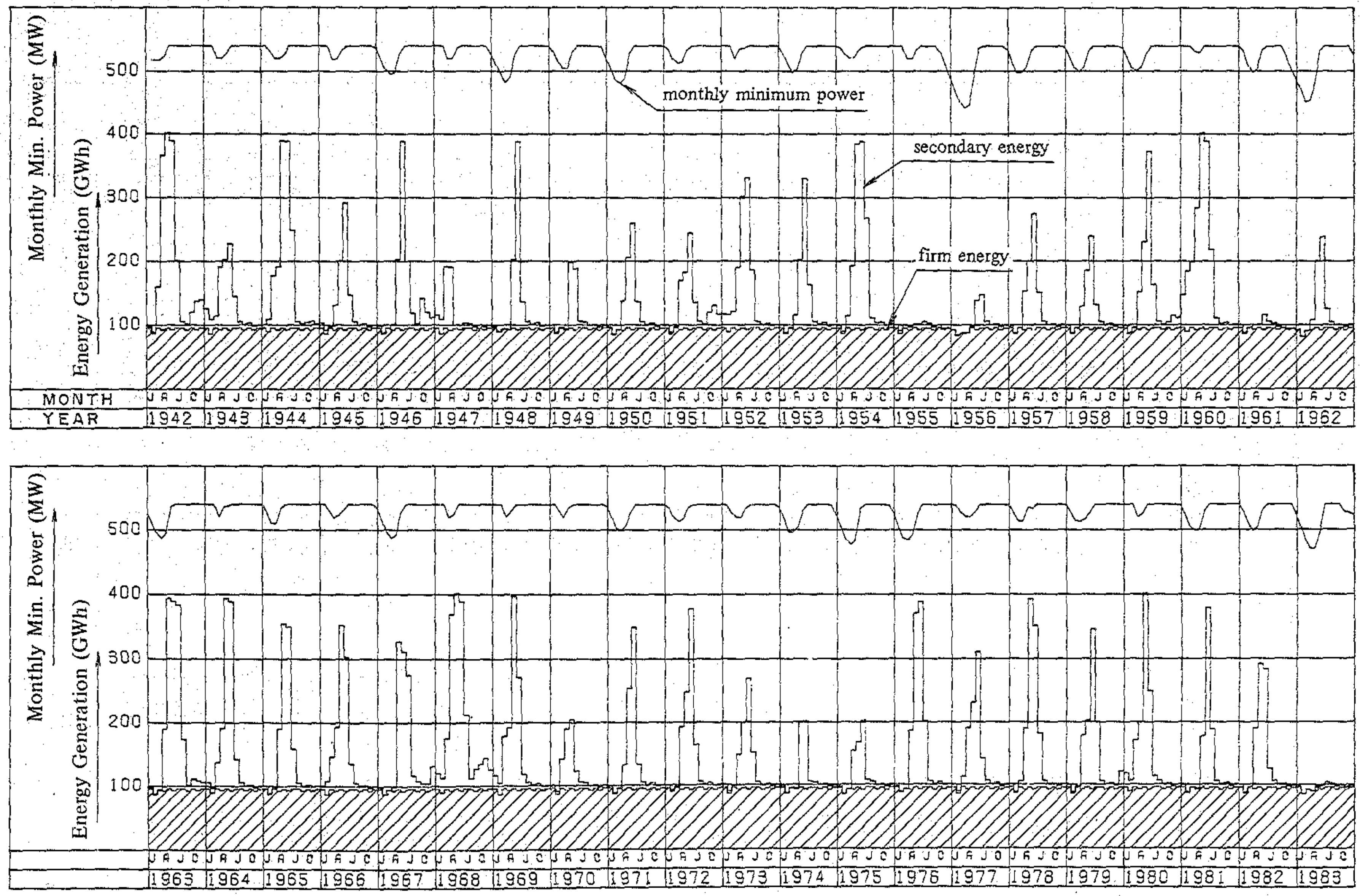


Fig. 9-32 Energy Generation and Monthly Minimum Peak Power of Yusufeli Power Station

Table 9-20 Summary of Operation Study of Yusufeli Reservoir

Year	Inflow (10^6m^3)	Evaporation (10^6m^3)	Discharge for Power (10^6m^3)	Outflow from Spillway (10^6m^3)
1942	6213.1	38.0	4815.5	1091.8
1943	3426.7	37.1	3428.0	0.0
1944	5204.4	37.5	4443.0	685.4
1945	3160.2	36.8	3312.3	0.0
1946	4034.0	37.2	3708.9	99.0
1947	2806.1	35.4	3025.3	0.0
1948	3648.8	36.7	3401.9	66.5
1949	2787.0	36.1	2926.3	0.0
1950	3448.4	36.6	3237.1	0.0
1951	3512.5	37.0	3364.0	0.0
1952	3823.8	37.4	3923.3	0.0
1953	3475.5	37.0	3376.7	0.0
1954	4570.9	37.6	4290.9	169.2
1955	2093.4	35.6	2547.9	0.0
1956	3021.5	35.2	2709.1	0.0
1957	3399.4	36.5	3322.1	0.0
1958	3155.4	36.5	3129.0	0.0
1959	3870.8	37.1	3649.4	0.0
1960	5389.0	38.1	4877.3	564.3
1961	2209.5	35.3	2578.7	0.0
1962	3366.7	36.0	3101.3	0.0
1963	6128.6	37.4	4666.7	1158.8
1964	4209.8	37.2	4117.5	213.1
1965	3991.7	37.2	3873.0	0.0
1966	3769.8	37.1	3870.5	0.0
1967	4151.3	37.2	3899.9	0.0
1968	6473.9	38.1	5064.9	1730.8
1969	4280.6	37.6	3961.8	323.6
1970	2987.8	36.9	3098.1	0.0
1971	3630.5	37.0	3500.1	0.0
1972	3803.7	37.4	3727.9	0.0
1973	3191.6	36.6	3301.3	0.0
1974	2907.2	36.1	2953.4	0.0
1975	3073.3	36.1	3031.6	0.0
1976	4399.3	36.9	4091.3	43.2
1977	3471.1	37.0	3541.5	0.0
1978	4129.3	37.1	4017.4	85.6
1979	3869.4	36.8	3661.6	0.0
1980	4021.6	37.5	3901.6	264.0
1981	3519.0	36.5	3438.7	0.0
1982	3441.6	36.7	3541.9	0.0
1983	2573.9	34.0	2535.5	0.0
Average	3777.2	36.8	3594.4	146.1

Table 9–21 Energy Generation of Yusufeli Power Plant

(unit: GWh)

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL.
1942	98.2	88.6	160.0	366.7	401.8	388.9	201.2	105.5	107.1	120.2	137.1	139.6	2309.8
1943	125.7	109.3	114.1	191.0	202.8	228.6	145.2	105.5	101.1	103.6	98.3	100.6	1625.9
1944	100.5	109.1	177.3	191.6	389.9	388.9	249.0	105.5	102.1	104.5	106.4	102.0	2126.8
1945	103.3	91.8	98.6	131.6	200.9	292.0	147.2	105.5	100.3	101.6	97.4	100.5	1570.6
1946	98.8	87.6	95.4	101.0	203.4	388.9	200.1	118.7	102.2	142.1	120.7	112.0	1771.0
1947	115.9	109.0	191.9	191.1	100.5	99.3	103.6	102.6	97.4	100.5	97.2	99.5	1408.5
1948	97.8	89.9	94.1	93.2	202.8	383.2	136.8	105.5	101.1	103.6	98.3	100.5	1611.8
1949	100.3	88.3	96.7	94.0	198.9	188.4	105.5	104.5	99.3	100.6	97.2	99.2	1373.4
1950	97.0	85.5	93.2	138.5	205.3	260.2	137.0	105.5	100.3	102.6	97.4	100.5	1523.5
1951	100.4	89.1	97.4	169.7	182.7	245.6	135.8	105.5	101.1	120.0	131.4	117.4	1596.1
1952	116.9	116.2	121.1	190.5	302.5	331.0	186.0	105.5	101.1	102.6	98.3	100.5	1872.4
1953	99.8	88.4	96.2	115.6	202.8	330.2	163.1	105.5	101.1	103.6	98.3	100.6	1605.2
1954	100.5	89.8	114.3	192.9	384.6	388.9	268.1	110.8	103.2	104.5	100.3	101.6	2059.5
1955	100.5	91.0	100.3	97.6	100.6	101.1	105.5	102.6	97.4	100.1	94.5	95.2	1186.5
1956	92.5	84.1	87.2	87.7	97.8	138.7	148.0	105.5	100.3	101.6	97.4	100.5	1241.3
1957	98.2	86.8	95.6	153.5	200.9	275.1	150.7	105.5	100.3	101.6	97.4	100.5	1566.0
1958	99.1	87.9	96.0	129.3	185.2	239.5	131.8	105.5	100.3	101.6	97.4	100.5	1474.0
1959	99.0	87.8	96.0	151.9	230.5	373.3	163.4	105.5	101.1	104.5	115.5	111.3	1740.0
1960	147.3	184.2	199.1	284.5	401.8	388.9	218.3	110.3	102.1	103.6	99.3	100.6	2340.7
1961	100.4	88.5	96.1	99.5	100.6	116.5	105.5	102.6	97.2	99.6	94.0	94.8	1195.4
1962	92.6	81.3	90.5	108.1	200.9	238.8	125.1	104.5	100.3	100.6	97.2	99.5	1439.5
1963	97.5	86.4	94.2	189.9	393.6	388.9	383.2	173.8	102.1	111.5	108.6	106.0	2235.7
1964	106.0	96.6	137.3	190.5	393.6	388.9	142.6	105.5	100.3	101.6	97.4	100.5	1960.9
1965	99.5	88.1	97.2	190.5	355.5	350.1	159.2	105.5	100.3	102.6	98.3	100.6	1847.6
1966	100.5	108.7	147.4	193.5	352.8	303.0	135.9	105.5	100.3	101.6	97.2	100.4	1846.9
1967	98.3	86.9	94.4	99.2	327.8	311.7	275.1	117.2	108.6	104.5	104.7	132.6	1861.0
1968	121.0	113.2	176.7	370.1	401.8	388.9	212.6	112.3	128.3	135.4	144.2	126.4	2431.1
1969	117.2	104.5	179.6	192.5	397.5	272.0	119.2	105.5	101.1	103.6	99.3	100.6	1892.7
1970	100.5	90.4	143.0	190.5	204.8	123.5	105.5	104.5	99.3	101.6	97.2	100.5	1461.2
1971	98.8	87.4	95.9	133.8	254.2	350.0	134.1	105.5	101.1	103.6	98.3	100.5	1663.2
1972	100.5	92.2	97.3	193.4	248.8	378.8	165.1	105.5	101.1	103.6	99.3	100.6	1786.5
1973	100.5	89.9	98.4	149.3	200.9	269.3	152.5	104.5	99.3	101.6	97.2	100.5	1564.0
1974	98.4	86.9	95.3	94.1	200.9	201.7	105.5	103.6	99.3	100.6	97.2	99.2	1382.9
1975	97.0	85.4	93.1	155.0	168.8	203.3	107.0	104.5	99.3	100.6	97.2	99.4	1410.7
1976	97.2	88.7	93.8	187.8	371.0	388.9	202.4	105.5	101.1	103.6	99.3	100.6	1940.0
1977	100.5	89.9	111.9	191.0	231.2	311.1	142.8	105.5	100.3	102.6	97.4	100.5	1684.6
1978	99.4	88.3	105.2	190.5	393.6	351.6	181.5	105.5	100.3	101.6	97.4	100.5	1915.4
1979	99.4	88.4	97.3	178.6	202.8	346.3	200.9	105.5	100.3	101.6	98.3	120.5	1740.0
1980	117.7	105.9	171.0	200.3	401.8	249.7	112.8	105.5	100.3	101.6	97.2	100.5	1864.3
1981	99.0	87.8	95.8	94.2	177.3	379.3	183.5	105.5	100.3	102.6	97.4	100.5	1628.3
1982	99.9	88.5	96.1	189.7	291.8	283.5	124.7	105.5	100.3	101.6	97.2	99.5	1678.4
1983	97.0	85.2	92.3	89.9	97.9	98.3	103.6	101.6	97.2	99.9	96.0	98.9	1157.9
AVE	103.1	94.6	114.9	165.3	256.3	288.8	161.5	107.7	101.2	105.0	102.1	104.0	1704.6

Table 9–22 Monthly Minimum Peak Power of Yusufeli Power Plant

(unit: MW)

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVE.
1942	517.8	517.3	517.9	524.7	540.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	533.2
1943	540.1	540.1	520.3	520.3	528.7	540.1	540.1	540.1	540.1	540.1	540.1	540.1	535.8
1944	540.1	530.9	520.3	520.3	526.5	540.1	540.1	540.1	540.1	540.1	540.1	540.1	534.9
1945	540.1	540.1	519.2	519.2	533.6	539.8	540.1	540.1	540.1	540.1	540.1	536.9	535.8
1946	519.6	504.2	495.5	497.8	528.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	527.2
1947	540.1	540.1	520.3	520.3	536.2	540.1	540.1	540.1	540.1	540.1	538.8	527.1	535.3
1948	512.2	497.5	482.2	489.4	526.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	524.0
1949	530.1	516.8	504.4	504.4	530.6	539.8	540.1	540.1	540.1	540.1	538.3	521.2	528.9
1950	502.9	486.6	481.5	488.6	528.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	522.4
1951	535.1	519.9	512.6	515.0	533.6	540.1	540.1	540.1	540.1	540.1	540.1	540.1	533.1
1952	540.1	540.1	520.3	535.5	536.6	540.1	540.1	540.1	540.1	540.1	540.1	540.1	537.8
1953	527.3	512.6	498.1	503.0	528.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	529.1
1954	537.9	527.1	520.5	522.9	534.3	540.1	540.1	540.1	540.1	540.1	540.1	540.1	535.3
1955	540.1	540.1	520.3	520.3	533.6	540.1	539.4	540.1	540.1	528.2	509.7	488.5	528.4
1956	468.1	450.4	440.4	445.2	493.8	536.6	540.1	540.1	540.1	540.1	540.1	534.5	505.8
1957	512.4	497.5	497.6	506.7	533.6	538.8	540.1	540.1	540.1	540.1	540.1	538.3	527.1
1958	521.3	506.2	500.4	505.3	533.6	540.1	540.1	540.1	540.1	540.1	540.1	537.3	528.7
1959	521.4	505.2	501.1	506.1	528.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	528.5
1960	540.1	540.1	531.7	529.6	540.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	538.5
1961	533.2	512.3	497.8	502.9	533.6	540.1	539.7	540.1	540.1	524.5	503.7	488.1	521.3
1962	468.9	450.3	452.8	479.8	533.6	540.1	540.1	540.1	540.1	540.1	539.8	525.9	512.6
1963	509.9	495.7	487.1	496.6	535.5	540.1	540.1	540.1	540.1	540.1	540.1	540.1	525.5
1964	540.1	540.1	520.3	535.5	537.8	540.1	540.1	540.1	540.1	540.1	540.1	540.0	537.9
1965	526.0	510.6	510.8	535.2	539.9	540.1	540.1	540.1	540.1	540.1	540.1	540.1	533.6
1966	540.1	530.9	520.3	522.9	531.3	540.1	540.1	540.1	540.1	540.1	540.1	534.5	535.0
1967	516.4	497.1	487.4	492.0	528.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	525.1
1968	540.1	540.1	520.3	524.7	540.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	537.2
1969	540.1	540.1	520.3	529.7	539.6	540.1	540.1	540.1	540.1	540.1	540.1	540.1	537.5
1970	540.1	530.8	520.3	535.5	540.1	540.1	540.1	540.1	540.1	540.1	540.1	536.8	537.0
1971	519.2	502.4	499.9	507.3	528.1	540.1	540.1	540.1	540.1	540.1	540.1	540.1	528.1
1972	534.9	518.6	513.3	518.1	535.7	540.1	540.1	540.1	540.1	540.1	540.1	540.1	533.4
1973	538.7	528.4	520.0	519.9	533.6	539.2	540.1	540.1	540.1	540.1	540.1	535.6	534.7
1974	516.6	497.0	497.1	504.9	530.5	540.1	540.1	540.1	540.1	540.1	538.7	521.1	525.5
1975	503.0	485.2	477.8	485.0	533.6	540.1	540.1	540.1	540.1	540.1	540.1	524.3	520.8
1976	504.3	487.3	484.9	493.3	526.9	540.1	540.1	540.1	540.1	540.1	540.1	540.1	523.1
1977	538.8	527.1	520.5	520.3	528.9	540.1	540.1	540.1	540.1	540.1	540.1	539.7	534.7
1978	525.1	514.0	514.0	536.3	533.9	540.1	540.1	540.1	540.1	540.1	540.1	538.7	533.5
1979	525.9	514.7	513.9	516.4	527.7	540.1	540.1	540.1	540.1	540.1	540.1	540.1	531.6
1980	540.1	540.1	520.3	524.7	540.1	540.1	540.1	540.1	540.1	540.1	540.1	537.6	537.0
1981	521.1	505.2	499.0	501.5	530.5	540.1	540.1	540.1	540.1	540.1	540.1	540.1	528.2
1982	528.6	512.3	498.1	503.0	530.9	540.1	540.1	539.5	540.1	540.1	540.1	525.0	528.2
1983	502.4	483.6	470.5	470.3	497.9	539.4	540.1	540.1	540.1	528.7	526.2	522.8	513.5
AVE	524.8	513.7	504.1	510.2	531.2	539.9	540.1	540.1	540.1	539.2	538.1	534.2	529.6
MIN	468.1	450.3	440.4	445.2	493.8	536.6	539.4	539.5	540.1	524.5	503.7	488.1	505.8

9.2.2 Artvin Project

1/1000 topographical maps for Artvin Project could not be obtained in time, and therefore, the optimum plan is the same as the plan which was studied on development type and scale with 1/5000 topographical maps.

The optimum development plan of Artvin Project would be composed of the installed capacity of 320 MW (160 MW x 2 units) and the annual energy generation of 988.8 x 10^6 kWh with the maximum power discharge of 333 m^3/s and the rated effective head of 112.9 m. Artvin Reservoir has high water level of 500 m and effective storage capacity of 4 x $10^6 m^3$ with available drawdown of 1 m by the arch dam 160 m in height.

The simulated operation of Artvin Reservoir, for the 42 year records from 1942 to 1983, is indicated in Table 9-23 for its power discharge, evaporation and spill. The energy generation and the monthly minimum peak power of Artvin Power Plant are indicated in Tables 9-24, 25 and Fig. 9-33.

9.2.3 Effect on Deriner Project

The construction of Yusufeli Reservoir will improve the inflow conditions to Deriner Reservoir, and will provide favorable effects on hydroelectric power projects of Deriner, Borcka and Muratli which are being planned downstream.

Concerning Deriner Project, the effect of fluctuation of the water level of its reservoir must have been studied because this can affect the tail water level of Artvin Power Plant. The effect of Borcka and Muratli Projects is not mentioned here, for the effect is small because of their small project scale.

In studying the effect on Deriner Reservoir, the operation rule for this reservoir has been assumed based on the outline plan of the Deriner Project presented in Table 9-26, which provides larger firm discharge for Deriner Reservoir. This operation rule is a provisional one to estimate the power and energy generation of Deriner

Table 9–23 Summary of Operation Study of Artvin Reservoir

Year	Inflow ($10^6 m^3$)	Evaporation ($10^6 m^3$)	Discharge for Power ($10^6 m^3$)	Outflow from Spillway ($10^6 m^3$)
1942	6068.5	4.8	5076.7	980.8
1943	3519.2	4.8	3514.3	0.1
1944	5259.8	4.8	4648.4	606.3
1945	3369.0	4.8	3364.6	0.0
1946	3857.1	4.8	3826.9	25.7
1947	3078.1	4.8	3073.6	0.0
1948	3518.6	4.8	3513.6	0.0
1949	2967.0	4.8	2962.1	0.0
1950	3293.4	4.8	3288.9	0.0
1951	3416.0	4.8	3410.4	0.0
1952	3969.3	4.8	3964.6	0.1
1953	3423.7	4.8	3418.8	0.0
1954	4522.8	4.8	4416.4	102.0
1955	2573.4	4.8	2568.9	0.0
1956	2763.0	4.8	2756.6	0.0
1957	3387.7	4.8	3382.8	0.1
1958	3206.8	4.8	3202.2	0.1
1959	3738.5	4.8	3733.2	0.0
1960	5616.1	4.8	5104.4	501.3
1961	2661.3	4.8	2656.5	0.1
1962	3225.1	4.8	3220.5	0.1
1963	5963.9	4.8	4884.0	1074.6
1964	4426.5	4.8	4324.0	97.9
1965	3998.8	4.8	3993.8	0.0
1966	3966.0	4.8	3961.0	0.2
1967	4017.3	4.8	4012.2	0.0
1968	6689.6	4.8	5319.5	1365.1
1969	4340.2	4.8	4054.7	280.6
1970	3195.1	4.8	3189.8	0.1
1971	3617.5	4.8	3612.6	0.1
1972	3859.4	4.8	3654.5	0.0
1973	3434.0	4.8	3429.0	0.1
1974	3036.8	4.8	3031.9	0.0
1975	3148.2	4.8	3143.6	0.2
1976	4262.5	4.8	4251.7	0.0
1977	3620.0	4.8	3615.1	0.0
1978	4236.3	4.8	4185.9	45.4
1979	3794.2	4.8	3789.3	0.1
1980	4257.2	4.8	4033.6	219.3
1981	3553.5	4.8	3548.9	0.1
1982	3648.5	4.8	3643.7	0.0
1983	2631.8	4.8	2627.3	0.2
Average	3836.5	4.8	3705.0	126.2

Table 9–24 Energy Generation of Artvin Power Plant

(unit: GWh)

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL.
1942	60.5	54.7	98.7	225.4	228.3	220.4	106.5	56.3	54.9	67.2	79.7	82.7	1335.4
1943	74.5	64.8	69.6	116.3	120.1	126.8	77.2	56.3	54.9	58.4	58.0	59.6	936.7
1944	59.5	65.2	109.2	116.3	238.1	221.0	133.0	56.2	54.7	58.0	61.4	60.3	1232.0
1945	61.2	54.4	60.1	80.4	119.0	159.9	77.9	55.3	54.0	57.8	57.3	59.5	898.0
1946	59.8	54.2	60.7	64.1	120.5	229.9	104.9	62.6	54.3	78.8	69.1	65.9	1024.9
1947	68.6	64.6	117.2	116.3	59.5	58.6	59.7	59.8	57.6	59.5	57.6	59.9	839.0
1948	60.0	56.3	60.3	69.1	120.1	228.9	71.8	55.7	54.3	57.9	57.4	59.5	942.3
1949	59.8	54.0	60.5	58.9	117.8	106.9	58.1	56.0	56.4	53.6	57.2	59.8	806.0
1950	59.9	54.0	60.9	87.8	121.9	142.2	72.3	55.8	54.4	58.0	57.5	59.5	854.3
1951	59.5	54.1	60.1	104.0	108.2	138.9	71.5	55.3	54.4	67.6	75.7	69.3	919.1
1952	69.2	68.9	73.9	115.2	175.4	177.5	97.7	55.7	54.3	57.5	57.1	59.5	1062.0
1953	59.5	53.9	59.9	71.8	120.1	182.7	85.9	55.8	54.8	53.0	57.5	59.6	919.4
1954	59.5	54.1	70.0	117.2	227.7	222.1	139.2	57.9	55.0	57.5	57.3	59.7	1177.3
1955	59.5	53.9	61.1	59.5	59.6	58.0	59.9	59.7	57.7	59.5	57.6	59.7	705.9
1956	59.8	56.3	59.6	60.9	61.5	82.2	84.4	59.3	57.6	59.3	57.6	59.4	757.9
1957	59.3	54.0	61.2	95.0	119.2	151.5	79.5	55.8	54.4	57.5	57.1	59.5	904.1
1958	59.6	54.0	61.1	81.3	112.1	133.2	69.7	55.8	54.6	57.6	57.3	59.5	855.9
1959	60.0	54.0	61.2	94.2	136.6	203.3	87.0	55.9	54.4	53.3	66.4	65.6	997.0
1960	87.3	111.2	126.5	172.8	228.3	214.8	116.0	58.3	54.3	58.1	57.6	59.6	1338.9
1961	59.5	54.0	60.6	64.6	63.1	69.0	59.5	58.9	57.1	59.2	57.8	60.7	724.4
1962	60.4	54.8	62.9	72.0	122.0	132.9	66.8	55.9	54.8	58.2	57.6	59.9	858.2
1963	60.5	55.0	61.3	119.2	238.1	221.0	203.6	91.1	54.7	61.5	62.0	62.5	1290.5
1964	62.8	57.3	83.8	116.5	238.1	221.0	75.3	56.0	54.7	59.3	57.7	59.5	1141.9
1965	59.9	54.7	60.5	120.3	210.5	187.0	84.7	55.5	54.3	58.5	58.3	59.6	1063.8
1966	59.5	65.0	88.6	117.4	209.0	161.2	72.0	55.3	54.6	57.3	56.6	59.4	1056.5
1967	59.5	54.3	60.4	64.4	194.5	165.8	145.3	62.3	58.8	57.7	60.5	78.6	1062.1
1968	71.7	67.6	107.3	230.4	228.3	221.0	115.1	60.7	68.8	73.8	80.8	74.1	1399.8
1969	69.4	61.9	106.6	116.0	238.1	142.0	61.7	55.9	55.3	59.1	57.7	59.6	1083.3
1970	59.5	54.1	86.7	116.7	121.3	68.6	57.6	57.6	56.2	59.9	57.6	59.5	855.3
1971	60.2	55.0	61.1	83.5	151.9	191.2	70.9	56.2	54.6	58.9	58.2	59.5	961.2
1972	59.5	56.3	60.5	121.3	147.4	204.3	83.2	55.9	55.1	57.7	57.9	59.6	1024.0
1973	59.5	54.1	60.2	92.9	124.8	151.4	82.0	56.0	54.4	57.7	57.6	59.5	910.2
1974	60.2	54.3	61.2	58.6	122.6	112.1	56.3	56.0	55.5	57.9	57.6	60.0	812.2
1975	60.3	54.5	62.2	103.1	103.6	114.4	56.6	55.9	54.7	58.3	57.6	59.9	841.1
1976	60.3	56.5	61.5	117.6	219.8	218.0	107.5	55.8	54.7	59.1	57.9	59.6	1128.5
1977	59.5	54.1	68.5	116.3	137.0	169.4	75.5	55.9	54.7	58.4	57.7	59.5	966.7
1978	59.9	54.7	65.3	117.2	238.1	189.3	97.0	56.7	54.8	58.1	57.7	59.5	1108.2
1979	59.9	54.7	60.5	110.1	124.7	192.1	106.6	56.3	54.4	57.6	58.0	71.4	1066.4
1980	69.7	62.8	104.4	119.1	238.1	131.4	59.0	55.9	54.7	58.2	57.6	59.5	1070.6
1981	60.2	54.9	61.2	59.7	107.8	213.1	99.8	56.2	55.3	58.5	57.7	59.5	944.0
1982	59.9	54.5	60.5	118.3	172.9	152.3	66.7	56.1	54.8	58.1	57.6	59.9	971.5
1983	60.3	54.4	61.6	61.1	64.4	59.4	59.2	58.4	56.7	59.1	58.3	60.2	713.1
AVE	62.1	58.0	71.7	102.7	152.6	160.6	86.2	57.3	55.5	59.7	59.9	61.9	988.8

Table 9–25 Monthly Minimum Peak Power of Artvin Power Plant

(unit: MW)

YEAR	JAN.	FEB.	MAR.	APR.	MAY.	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVE.
1942	320.0	320.0	320.0	306.9	306.9	306.1	285.9	288.5	287.6	297.1	310.9	320.0	305.8
1943	320.0	320.0	320.0	320.0	320.0	291.6	286.6	288.1	290.2	299.6	315.5	320.0	307.6
1944	320.0	320.0	320.0	320.0	306.9	306.9	288.5	287.9	286.6	295.2	308.5	318.6	306.6
1945	320.0	320.0	319.6	320.0	320.0	286.8	285.0	285.5	291.2	302.6	314.8	320.0	307.1
1946	318.0	315.1	317.5	320.0	320.0	306.9	283.2	284.6	283.9	294.8	306.1	317.3	305.6
1947	320.0	320.0	320.0	320.0	320.0	318.5	311.1	314.7	319.5	320.0	320.0	320.0	318.6
1948	317.5	314.7	312.1	320.0	320.0	306.3	283.3	284.5	288.1	296.8	311.8	320.0	306.3
1949	319.1	317.5	317.9	320.0	320.0	298.1	297.1	299.2	305.6	313.8	315.6	316.9	311.7
1950	314.5	311.3	315.4	320.0	320.0	283.9	284.6	285.1	290.3	300.5	315.5	320.0	305.1
1951	320.0	318.2	318.0	320.0	320.0	289.9	283.6	285.1	288.1	299.5	307.9	312.2	305.7
1952	320.0	320.0	320.0	320.0	306.9	282.1	283.8	284.5	288.0	298.1	310.4	319.1	304.4
1953	317.6	315.6	313.0	320.0	320.0	286.6	283.8	284.8	290.2	297.5	312.6	320.0	305.1
1954	320.0	320.0	320.0	320.0	300.3	306.9	280.5	281.6	295.2	292.8	305.5	316.8	304.1
1955	320.0	320.0	319.5	320.0	320.0	309.8	307.0	314.3	319.9	317.8	315.0	310.6	316.2
1956	307.5	304.7	304.0	320.0	320.0	320.0	305.9	303.3	309.4	315.4	319.4	319.2	312.4
1957	313.4	312.8	320.0	320.0	320.0	289.3	285.0	285.1	290.3	300.9	313.3	320.0	305.8
1958	316.8	314.4	319.3	320.0	320.0	293.4	285.0	284.8	291.5	301.5	314.8	320.0	306.8
1959	318.7	314.4	320.0	320.0	320.0	286.5	287.4	286.1	287.6	296.6	307.5	318.4	305.3
1960	320.0	320.0	320.0	306.9	306.9	298.4	286.9	284.2	284.3	297.8	310.1	320.0	304.6
1961	320.0	316.3	317.8	320.0	320.0	319.2	304.6	309.7	317.2	316.1	312.7	315.1	315.7
1962	310.7	307.2	320.0	320.0	320.0	292.6	288.3	289.1	292.1	307.6	318.1	320.0	307.1
1963	320.0	318.4	319.2	320.0	306.9	306.9	286.9	283.0	286.3	293.0	305.4	318.2	305.3
1964	320.0	320.0	320.0	320.0	306.9	306.9	284.9	286.8	291.4	310.0	318.4	320.0	308.8
1965	320.0	320.0	320.0	320.0	299.9	288.4	287.4	282.4	290.6	304.0	319.5	320.0	306.0
1966	320.0	320.0	315.1	320.0	303.5	287.3	286.1	284.8	291.6	299.8	311.5	319.0	304.9
1967	316.5	314.3	314.0	320.0	306.9	287.3	285.3	287.0	289.2	293.8	308.9	320.0	303.6
1968	320.0	320.0	318.5	306.9	306.9	306.9	292.4	291.6	286.7	289.6	299.8	315.9	304.6
1969	320.0	320.0	311.3	320.0	306.9	281.8	278.3	283.4	293.8	305.7	310.8	320.0	304.3
1970	320.0	320.0	317.9	320.0	320.0	296.4	294.9	297.3	304.8	312.8	320.0	320.0	312.0
1971	320.0	320.0	319.7	320.0	320.0	287.4	285.7	287.8	288.5	301.6	316.2	320.0	307.2
1972	320.0	320.0	320.0	320.0	309.7	287.7	288.6	286.5	291.5	295.8	311.9	320.0	306.0
1973	320.0	320.0	320.0	320.0	320.0	295.8	290.2	289.7	292.7	301.9	318.1	320.0	309.0
1974	320.0	314.3	320.0	320.0	320.0	292.9	288.0	290.9	300.4	305.8	316.6	318.4	309.0
1975	316.7	313.8	320.0	320.0	320.0	296.8	285.3	288.1	295.5	308.3	317.0	320.0	308.5
1976	316.7	314.2	318.6	320.0	304.6	302.8	286.9	285.5	289.4	303.4	311.9	320.0	306.2
1977	320.0	320.0	320.0	320.0	320.0	286.4	285.6	286.1	291.7	302.6	318.4	320.0	307.6
1978	320.0	320.0	320.0	320.0	306.9	290.8	288.7	290.5	291.8	303.7	318.1	320.0	307.5
1979	320.0	320.0	320.0	320.0	320.0	291.8	286.6	288.5	290.1	301.5	315.1	320.0	307.8
1980	320.0	320.0	320.0	320.0	306.9	284.3	282.5	286.1	292.0	304.4	319.6	320.0	306.3
1981	320.0	319.2	320.0	320.0	320.0	295.5	286.0	287.8	294.5	303.0	318.8	320.0	308.7
1982	320.0	318.9	316.3	320.0	310.4	287.4	288.6	287.1	291.8	304.0	316.7	320.0	306.8
1983	316.7	313.1	317.0	320.0	320.0	320.0	307.8	309.4	314.2	315.7	320.0	320.0	316.2
AVE	318.6	317.3	318.1	319.1	314.4	296.7	288.9	289.8	293.9	302.9	313.8	319.1	307.7
MIN	307.5	304.7	304.0	306.9	299.7	281.8	278.3	281.6	283.9	289.6	299.8	310.6	303.6

Table 9–26 Plan Outline of Deriner Reservoir and Power Plant

Item	Unit	Description
Reservoir		
Maximum Water Level	m	395.0
High Water Level	m	392.0
Low Water Level	m	332.6
Available Drawdown	m	59.4
Reservoir Area	km^2	26.3
Gross Storage Capacity	$10^6 m^3$	1,948
Effective Storage Capacity	$10^6 m^3$	1,190
Dam		
Height	m	245
Power Plant		
Gross Head (at H.W.L.)	m	207
Effective Head (at H.W.L.)	m	205
Maximum Discharge (at H.W.L.)	m^3/S	392
Installed Capacity	MW	670

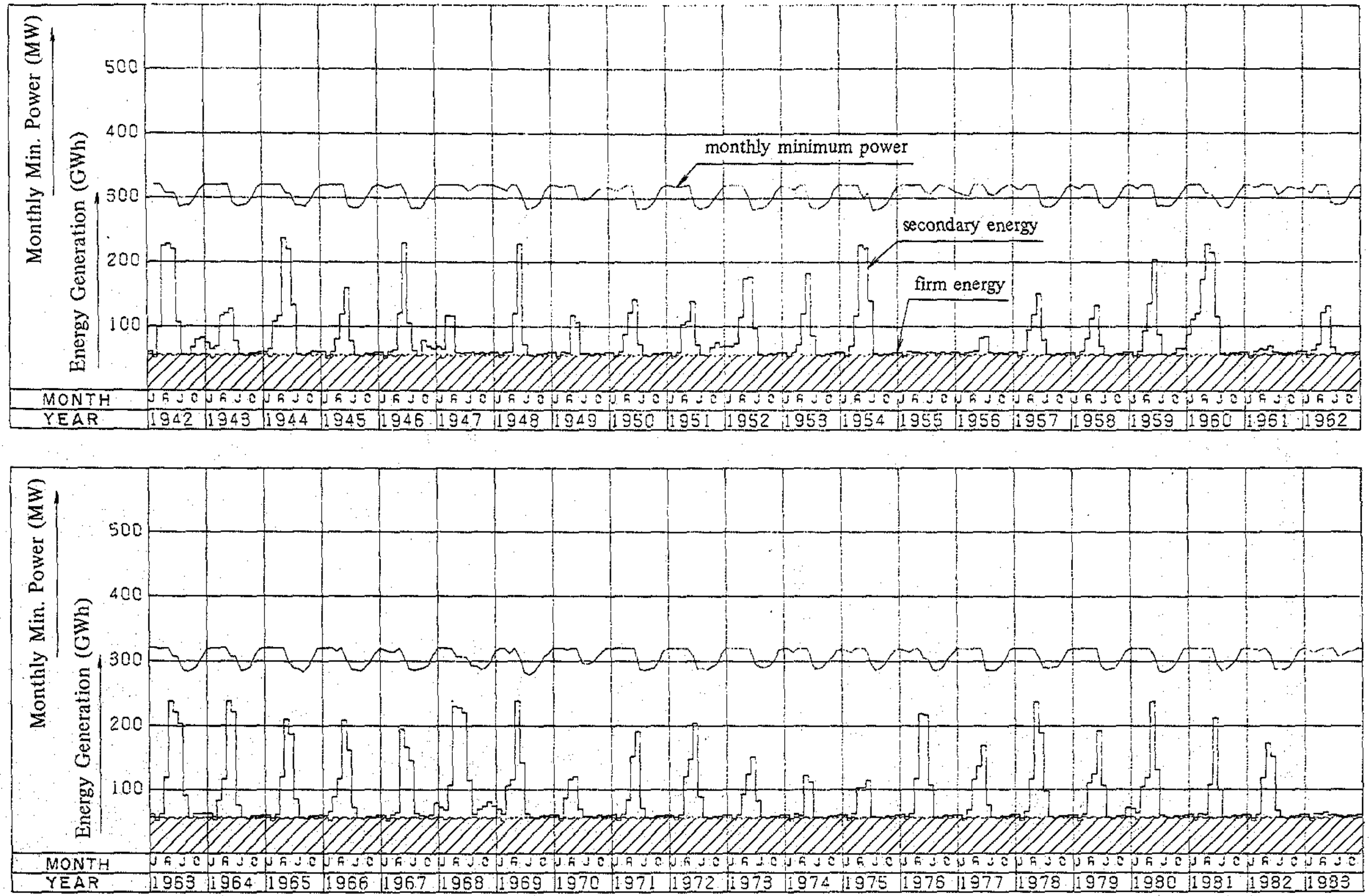


Fig. 9-33 Energy Generation and Monthly Minimum Peak Power of Artvin Power Station

Power Plant, and this is different from that used in the feasibility study of Deriner Project.

The inflow, power discharge and amount of energy generation of Deriner Power Plant have been calculated, for the two cases with and without Yusufeli Project. The energy generation has been simulated for the 42 years from 1942 to 1983, and the results are given in Table 9-27. This simulation indicates that the inflow to Deriner Reservoir is decreased by 0.8% due to the surface evaporation from Yusufeli and Artvin Reservoirs, the improvement of the river discharge increases the available power discharge by 1.7% and the rise of the average water level by approximately 1.0 m. This results in 3.2% increase of the effective power output and 1.4% increase of the effective energy output. Fig. 9-34 indicates that the inflow conditions into Deriner Reservoir is substantially improved.

The reservoir storage capacity and area curves of Deriner Reservoir are presented in Fig. 9-35.

9.2.4 Effect on Karakale Project

According to the Master Plan, the rated tail water level of Karakale Power Plant situated upstream of Yusufeli Reservoir has been set at EL. 700 m to match high water level of Yusufeli Reservoir. Consequently, by changing the high water level of Yusufeli Reservoir from EL. 700 m to EL. 710 m, Karakale Project would be affected by the water level fluctuation of Yusufeli Reservoir. The water level frequency of Yusufeli Reservoir is as shown in Fig. 9-36, and the probability of the water level being higher than EL. 700 m is approximately 55%. The average tail water level of Karakale Power Plant will rise from EL. 700 m to EL. 703.7 m. Considering the water level rise of Yusufeli Reservoir due to the effect of regulation at Karakale Reservoir, the rise of the average tail water level will be even greater, and is thought to reach about 4 m.

An approximate economic comparison was made for the case of changing the power plant site to an EL. 710 m site for the rated tail water level to match high water level of Yusufeli Reservoir. If the

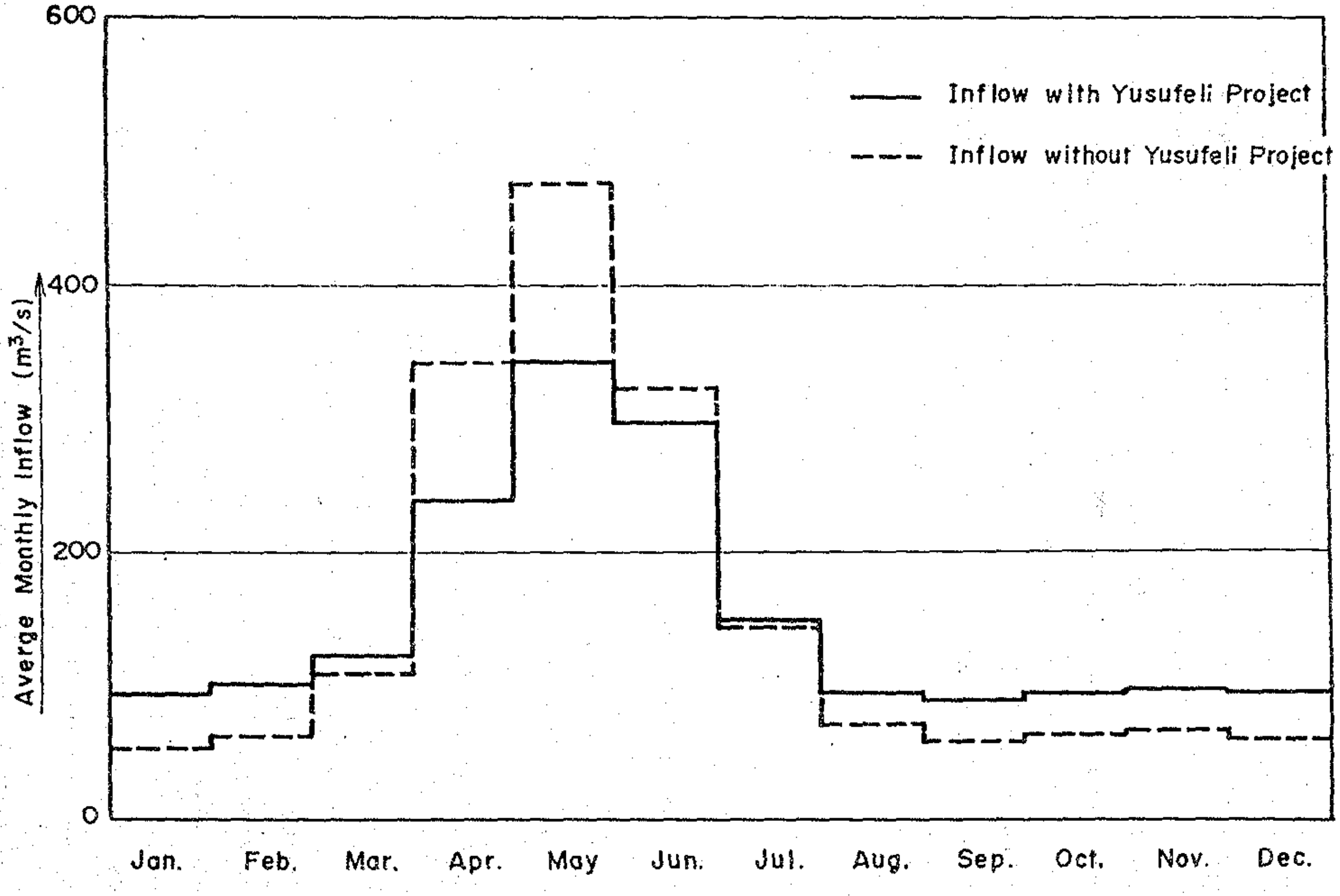
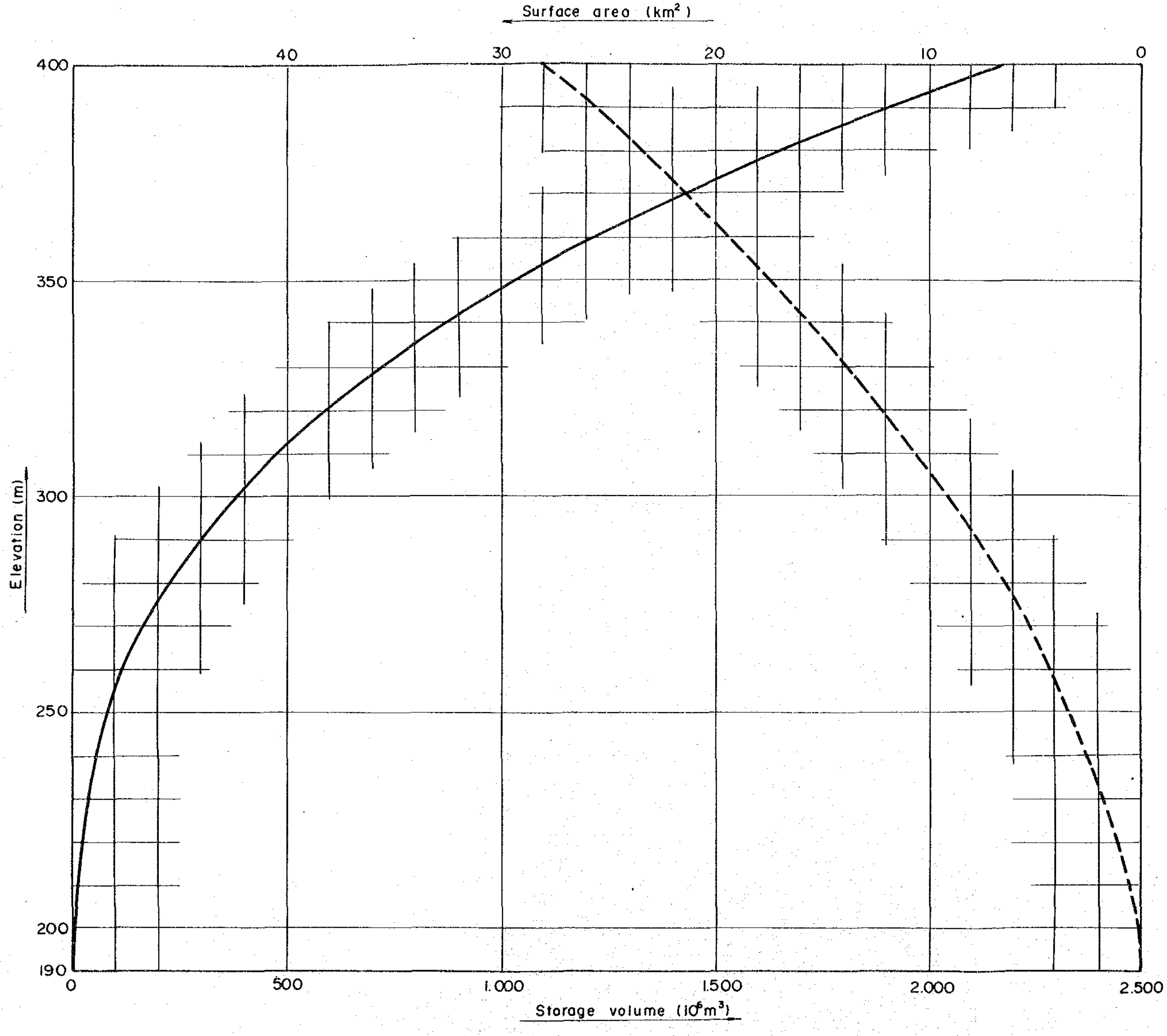


Fig. 9–34 Average Monthly Inflow of Deriner Reservoir



E. L.	Area (km²)	Volume (10⁶m³)
190	0.00	0.0
200	0.10	0.5
225	1.40	19.3
250	3.43	79.7
275	5.75	194.5
300	9.17	381.0
325	12.98	657.8
350	17.49	1038.7
375	22.48	1538.3
400	28.23	2172.3

Fig. 9–35 Deriner Reservoir Storage Capacity and Area Curve

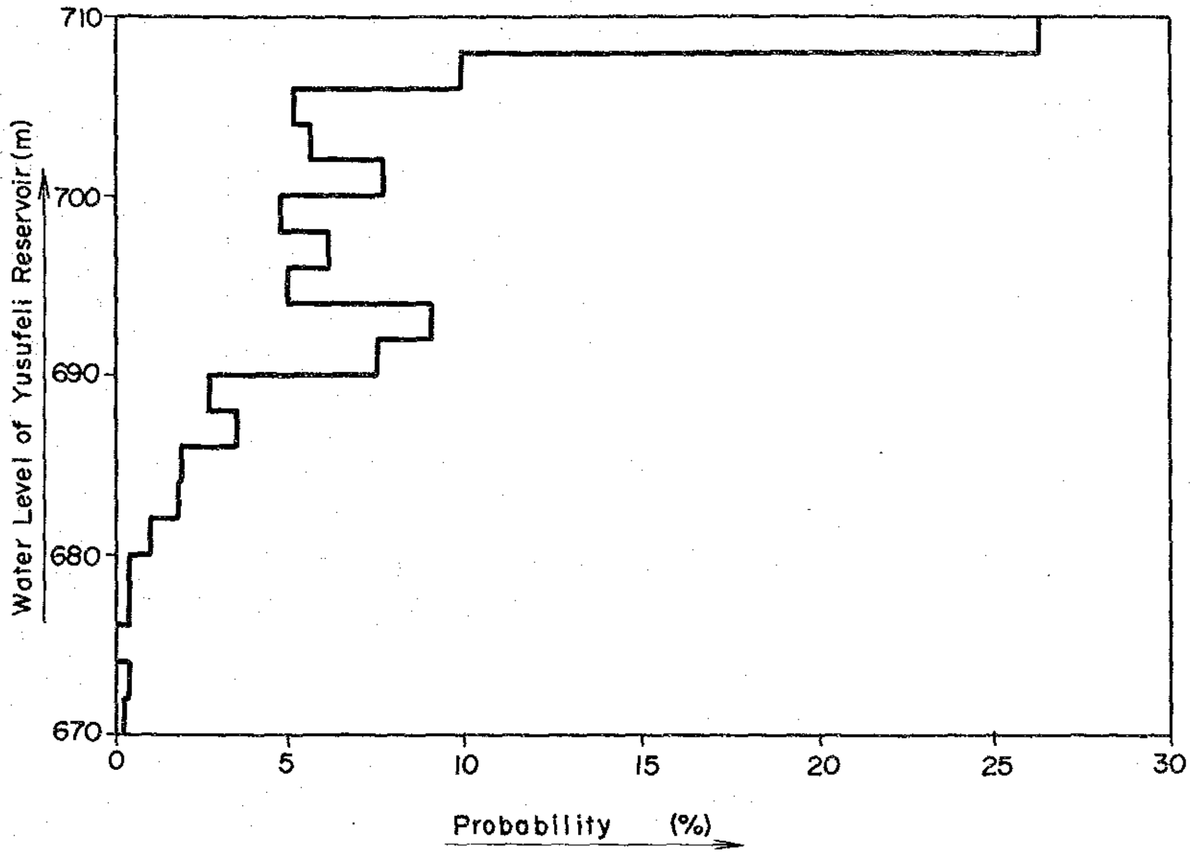


Fig. 9–36 Water Level Frequency of Yusufeli Reservoir.

Table 9-27 Effect on Deriner Project by Yusufeli Project

Item	Unit	Deriner Project without Yusufeli Project	Deriner Project with Yusufeli Project	
Annual inflow	$10^6 m^3$	4,849.0	4,807.9	-41.1
Discharge for power	"	4,567.5	4,647.0	79.5
Spill	"	252.4	132.0	-120.4
Evaporation	"	29.1	29.0	-0.1
Average Water Level	m	379.2	380.2	1.0
Firm Peak Power	MW	551.7	569.2	17.5
Annual Energy	Gwh	2,054.0	2,083.0	29.0

reduction in headrace tunnel length is assumed to be 1500 m from the average river-bed gradient, the head loss due to headrace tunnel length reduction will be approximately 5 m, and as a result, it will be a reduction of approximately 1 m in terms of the average effective head. The annual benefit loss will be approximately 140×10^6 TL when the ratio of firm peak power output to installed capacity is taken to be 0.9 and the average effective head is taken as 160 m. On the other hand, the annual cost reduction due to reduction of headrace tunnel length will be approximately 370×10^6 TL when the headrace construction cost is taken to be 2.5×10^6 TL/m, and the result is a greater advantage through change of the power plant site upstream. Needless to say, the above estimation is based on simplified hypotheses, and the result will greatly depend on topographical and geological characteristics, but the indications are that it will be worthwhile to further study in detail changing Karakale Power Plant to an upstream site.

9.3 Transmission Line Plan

9.3.1 Outline of Power Systems

The main power transmission systems in Turkey consist of 380 kV transmission lines, and the secondary transmission systems consist of 154 kV lines.

While the major load centers of Turkey, such as Ankara, Istanbul and Izmir, are located in the western part of the country, the main power sources, including this Project, are generally located in the eastern part, being 800 Km to 1,000 km away from the load centers. Thus, the power on the 380 kV lines connecting these two areas flow toward west in all sections of the lines.

The existing power system in the Coruh area is composed of 154 kV transmission lines. The plan for expansion of the main power systems, including those in Coruh area, is now being studied by TEK. The 380 kV power transmission systems as of 1985 are illustrated in Fig. 9-37.

9.3.2 Transmission Line Plan

This Project is located 800 km to the northeast of capital city Ankara. The total power output of this project amounts to 860 MW, the output of Artvin Power Plant being 320 MW and that of Yusufeli being 540 MW. It can not be expected that such amount of power is consumed in the vicinity of this project area.

The power demand of Hopa City, which is about 100 km away from the Project site, is estimated to be approximately 100 MW in around year 2000, and most of the power generated by this Project must be consumed in Ankara and areas to the west part of the country.

On the other hand, the power system in the area of this Project is composed of 154 kV lines, which is not capable of transmitting as much as 860 MW.

At present, TEK is studying a plan to expand the main transmission system from Hopa to the Ankara area, and it is expected that the

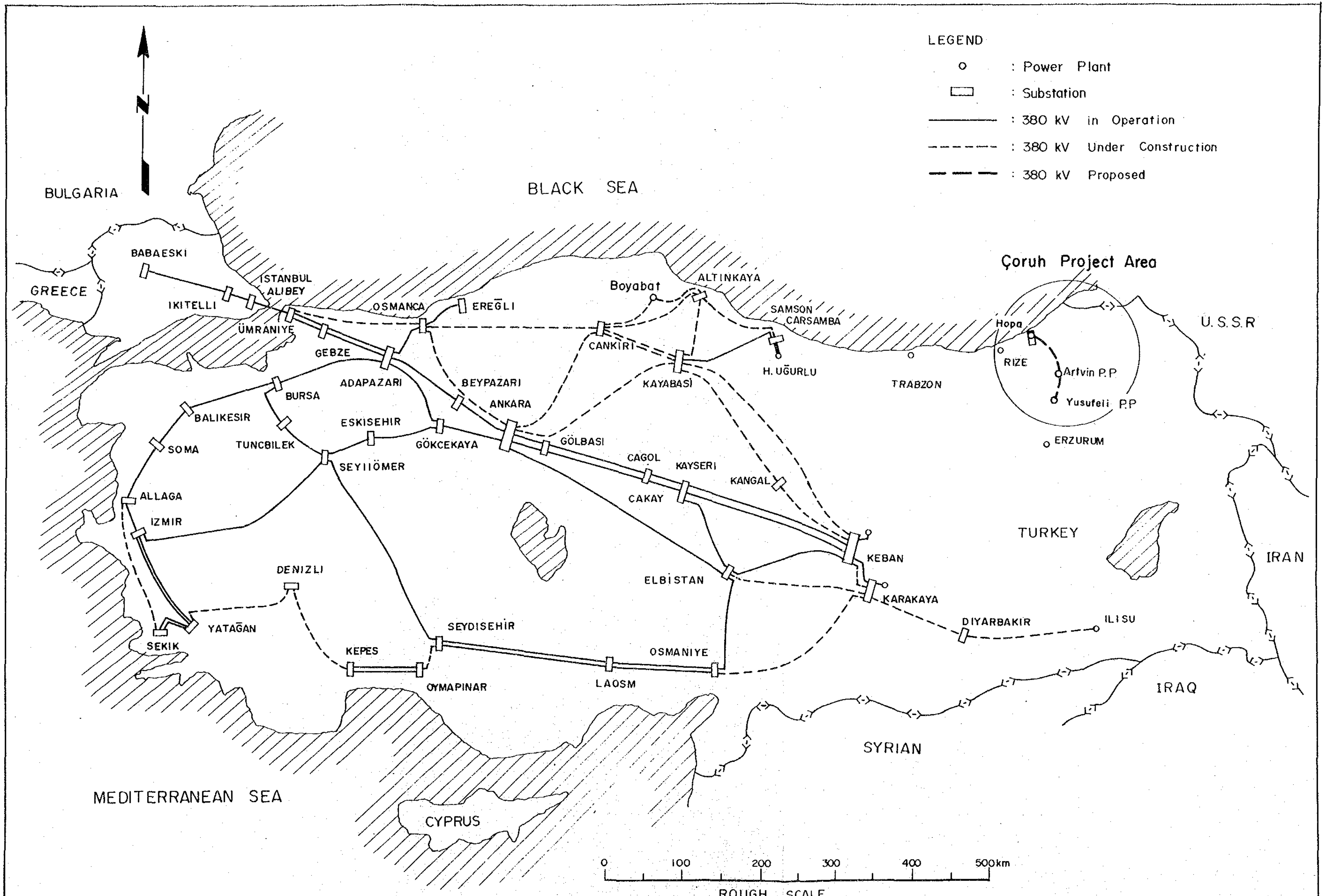


Fig. 9–37 380kV Transmission System in 1985

power system in this area will be reinforced by the year 2000 when this Project will be completed.

Thus, only the transmission line connecting this project site to Hopa City, 93 km in length, has been included in this study, and the transmission line plan was established based on the assumption that Hopa City and the major load centers were interconnected by the main transmission system being planned as mentioned above.

The following factors were taken into consideration in studying transmission line configurations.

- Location of receiving substation
- Transmission line voltage
- Transmission line conductor size
- Number of circuits of transmission line
- Total length of transmission line

(1) Receiving Substation and Connection

A new substation to be constructed in Hopa was selected as the receiving substation. And the transmission route was decided as to start from Yusufeli Power Plant and reach Hopa Substation via Artvin Power Plant. The proposed transmission route and the existing transmission lines are illustrated in Fig. 9-38.

(2) Selection of Transmission Line Voltage

The transmission line voltage was chosen from the existing voltage class. considering the 860 MW power to be transmitted for this Project, and the distance of 93 km to Hopa Substation, the transmission capacity of 154 kV lines is not sufficient. Thus 380 kV was selected as the transmission line voltage.

(3) Selection of Transmission Line Conductor Size

The conductor size was chosen from the sizes already in use in Turkey. The selected size is as below.

954 MCM ACSR x 2 bundles.

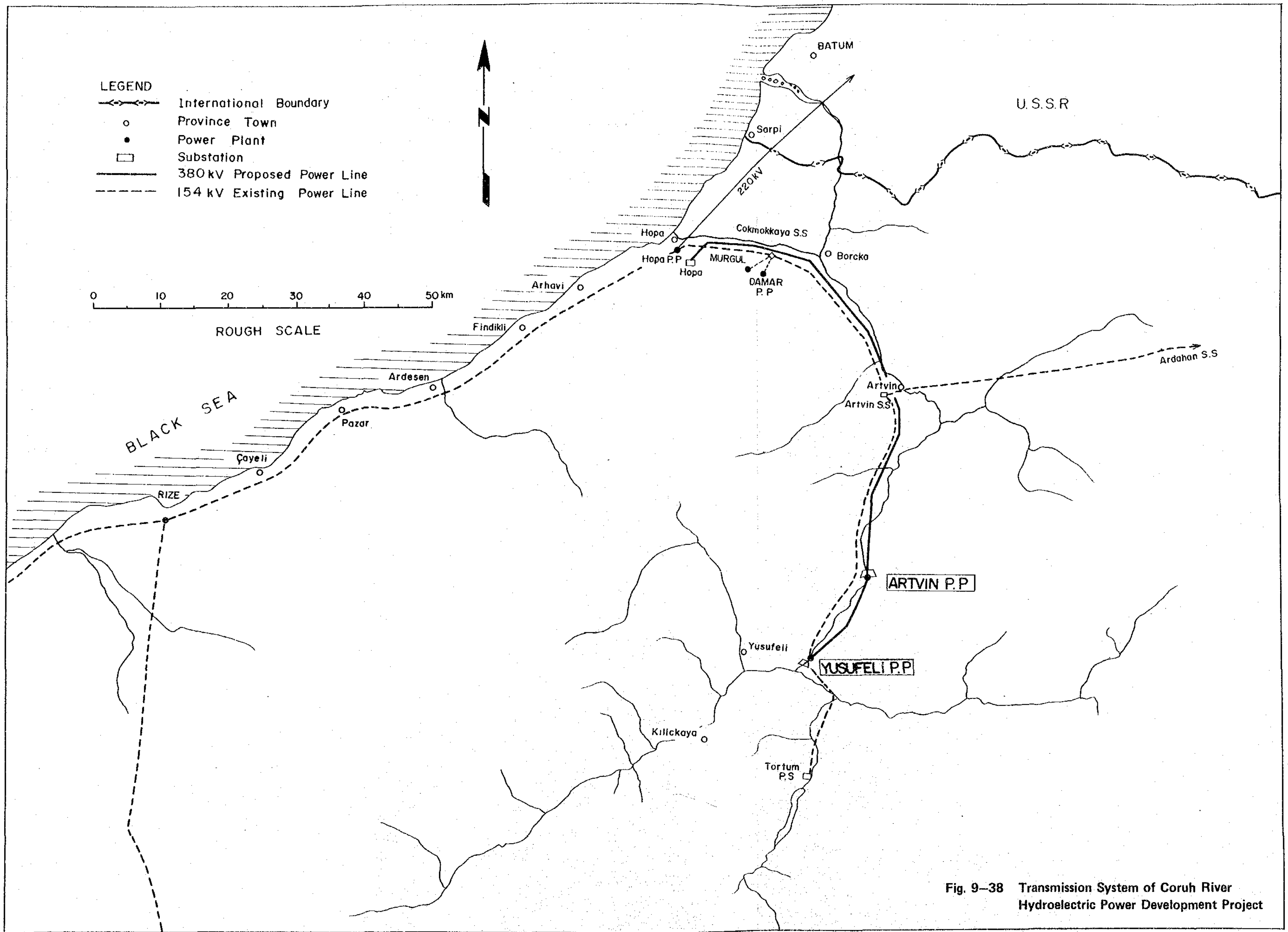


Fig. 9–38 Transmission System of Coruh River Hydroelectric Power Development Project

(4) Number of Circuits

Single circuit and double circuit plans have been studied and compared.

(5) Transmission Line Length

The transmission line length for each section was estimated as below, based on "Coruh Basin Single-Line Diagram" attached to the EIE Master Plan Report and the proposed transmission line route as shown in Fig. 9-38.

1) Yusufeli Power Plant -- Artvin Power Plant : 19 km
2) Artvin Power Plant -- Hopa Substation : 74 km

(6) Transmission Line Configurations

By screening the different combinations of design parameters mentioned above, the following 3 plans were selected for the comparative studies. The line configuration in each plan is given in Table 9-28.

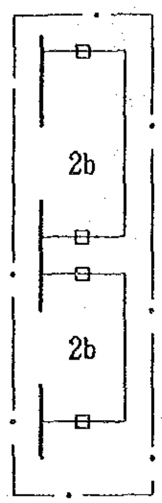
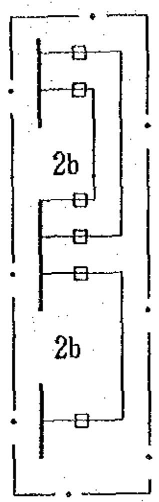
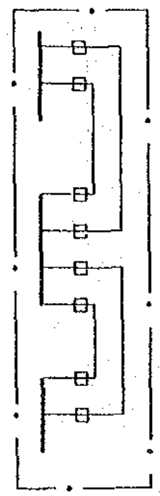
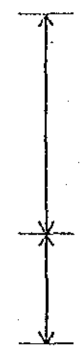
Table 9-28 Alternative Patterns of Transmission Line for Coruh Project

Trans-mission pattern (Case)	Line No.	Voltage (kV)	Conductor (MCMACSR)	Number of Circuits	Length (km)	Lead-in Point
1	Y-A A-H Total	380 380	954 x 2b 954 x 2b	Single Single	19 74 93	Hopa
2	Y-A A-H Total	380 380	954 x 2b 954 x 2b	Single Double	19 74 93	Hopa
3	Y-A A-H Total	380 380	954 x 2b 954 x 2b	Double Double	19 74 93	Hopa

Y : Yusufeli Power Plant
A : Artvin Power Plant
H : Hopa Substation

Note: Transmission System of Each Pattern As shown on Table 9-29.

Table 9-29 Economic Comparison of Transmission for Coruh Project

Transmission Pattern	Case 1	Case 2	Case 3	Reference
Power System Program / Items	 Hopa S.S Artvin P.P (P=320MW) Yusufeli P.P (P=540MW)	 Hopa S.S Artvin P.P (P=320MW) Yusufeli P.P (P=540MW)	 Hopa S.S Artvin P.P (P=320MW) Yusufeli P.P (P=540MW)	 Hopa S.S 74km Artvin P.P 19km
Transmission Line				
Voltage (kV)	380	380	380	
Length to be constructed (km)	(19+74)	(19+74)	(19+74)	
Number of Circuits	1	1/2	2	
Size of Conductor	954MCM 2b	954MCM 2b	954MCM 2b	
Construction Cost (10^6TL)	2,985	4,747	5,199	
Annual Cost (10^6TL)	340	541	593	
Station Equipments				
Switch gear set				
380 kV Outline				
Construction Cost (10^6TL)	1,122	1,686	2,247	
Annual Cost (10^6TL)	128	192	256	
Transmission Losses				
Peak Power Loss	(12.4MW) 1,013	(7.3MW) 597	(6.7MW) 548	
Annual Energy Loss	(26.9GWh) 308	(14.7GWh) 168	(13.5GWh) 155	
Annual Cost (10^6TL)	1,321	765	703	
Total Construction Cost (10^6TL)	4,107	6,433	7,446	
Total Annual Cost (10^6TL)	1,789	1,498	1,552	

Note 1 : [dash-dot box] : Scope of construction cost for economic comparison

2 : Annual cost factor
(a) 11.4% for transmission line
(b) 11.4% for station equipment

3 : Cost for power loss and energy loss
(a) 81.99x10^3 TL/kW/year
(b) 11.45TL/kWh

9.3.3 Economic Comparison Study

The economy of 3 power transmission plans for this Project was compared. The result of the study is given in Table 9-29. In this economic comparison study, the annual expenses were compared based on the construction costs of transmission lines and power plant switching equipments and the transmission losses.

The study result indicated that Case 1 (single circuit 380 kV) has the lowest construction cost, and Case 3 (double circuit 380 KV) has the highest. In comparison of the annual expenses including transmission losses, Case 2 is most economical.

9.3.4 Conclusion

Case 2 is recommended as the transmission plan for this Project. The transmission facilities in Case 2 are as presented below.

° Transmission voltage: 380 kV

° Number of circuits : Single circuit from Yusufeli Power Plant to Artvin Power Plant (19 km).
Double circuit from Artvin Power Plant to Hopa Substation (74 Km).

° Total line length : 93 km

The features of this plan are as below.

° This plan is more economical than other plans.

° As two circuits are present in the section between Artvin Power Plant and Hopa Substation, where the transmission power is heavy, the supply reliability is high. When a 380 kV interconnection is provided from Yusufeli Power Plant ot Erzurm in future, a loop system is formed with the line from Hopa Substation to Ankara, to enhance the system reliability a great deal.

CHAPTER 10 PRELIMINARY DESIGN

CHAPTER 10. PRELIMINARY DESIGN

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CHAPTER 10. PRELIMINARY DESIGN

10.1 Yusufeli Project

10.1.1 Dam and Appurtenant Structures

As described in Chapter 9, "Development Plan", comparisons of concrete gravity, arch gravity, arch and rockfill dams were made regarding the dam type, based on the rough construction costs estimated with the volume of dam and excavation, and arch and rockfill dams were further studied considering the layout of waterways and powerhouses. Consequently, a rockfill dam was selected. As a result of studies of the layout of the open chute type spillway considering the layout of the powerhouse, it was found that the left bank would be more favorable as the volume of excavation will be enormous in case of the right bank. Consequently, it was decided that Yusufeli Dam is to be an impervious core type rockfill dam with high water level of 710 m and available drawdown of 40 m with an open chute type spillway at the left-bank side.

The design flood discharge for Yusufeli Dam is to be 9,000 m^3/s, which is the Probable Maximum Flood, and the discharge for care of river during construction is determined to be 1,330 m^3/s that corresponds to 25-year return period flood taking into consideration the dam type of rockfill.

(1) Care of River

According to the hydrological data of the latest 20 years, the maximum flood discharge at Yusufeli Site is estimated to be about 1,200 m^3/s. The design flood discharge for care of river during construction is determined to be 1,330 m^3/s that corresponds to 25-year return flood taking into consideration the dam type of rockfill.

The diversion tunnel is arranged in the right bank in view of the configuration of the river. In principle, the crest elevation of an upstream cofferdam would be determined in good relation to the inner diameter of the diversion tunnel, but in this case as the upstream cofferdam will make a part of the main embankment, the size of the cofferdam would be decided by its own construction schedule. It is judged to be appropriate to have the upstream cofferdam with the crest elevation of 550 m and the embankment volume of 620 x 10^3 m^3 for construction works in one dry season. One line of the diversion tunnel is adopted from the economic point of view, and with a standard horseshoe shape of inner diameter of 9.2 m, it will be possible to discharge 1,330 m^3/s at water level of 546.0 m.

Furthermore, on studying the discharge capacity of the diversion tunnel considering the storage effect of the upper cofferdam based on 50-year return period flood of 1,510 m^3/s with 10-day inflow of 635 x 10^6 m^3, it will be possible to discharge at water level of 546.6 m.

(2) Dam

Much attention must be paid to settlement of the dam, especially that of the impervious core for the high dam with steeply-sloped abutments at both banks. Accordingly, the rockfill dam of center impervious core, which has higher adaptability to settlement than that of inclined impervious core, is selected.

The outer slope of dam embankment is made 1 to 2.2 upstream and 1 to 1.9 downstream taking account of the study of slip circle based on the assumed physical properties of the available materials and the design seismic coefficient of 0.15. The results of the abovementioned study are shown in Appendix.

Regarding the crest elevation, as described in item "(3) spillway", an examination was made of combinations of the spillway discharge capacity and the dam crest elevation, taking into account freeboard above the maximum water level including wave heights due to wind and earthquake and the maximum water level and the dam crest elevation are determined to be 712.3 m and 715 m respectively. The dam will thus be

270 m in height, and the crest length of 430 m, the total dam volume being approximately 21 x 10^6 m^3.

The core material will be carried directly from the borrow area along the Tortum River. The rock material is to be obtained at the quarry near the dam site, part of which will be provided by the spillway excavation.

The foundation treatment will be done by means of curtain grouting and blanket grouting, and the extent of grouting, spacing and depths of grout holes will be determined carefully taking into account the geological condition of the foundation to be in contact with the impervious soil core, the construction schedule, etc. at the definite design stage. For the lower part of the left abutment, a foundation treatment gallery is planned to be provided, from which grouting would be done.

(3) Spillway

The spillway will be arranged on the left bank, which is an open chute type releasing the discharge straight into the stilling basin at the end of the chute. The study on the spillway discharge capacity is performed based on the Probable Maximum Flood - 9,000 m^3/s at the maximum discharge and 2,810 x 10^6 m^3 in 10-day flood volume-obtained through the hydrological analysis. The radial gates 13.5 m wide and 15.0 m high are adopted in view of the current practice in Turkey. In respective cases of three, four and five gates the spillway discharge capacity and the maximum water levels are estimated, and the case of the minimum construction costs of dam and spillway combination is selected. The results are shown in Table 10-1 and four gate plan is adopted. In this case the surcharge water level will be 2.3 m above high water level giving the maximum spillway discharge of about 8,000 m^3/s, as shown in Fig. 10-1.

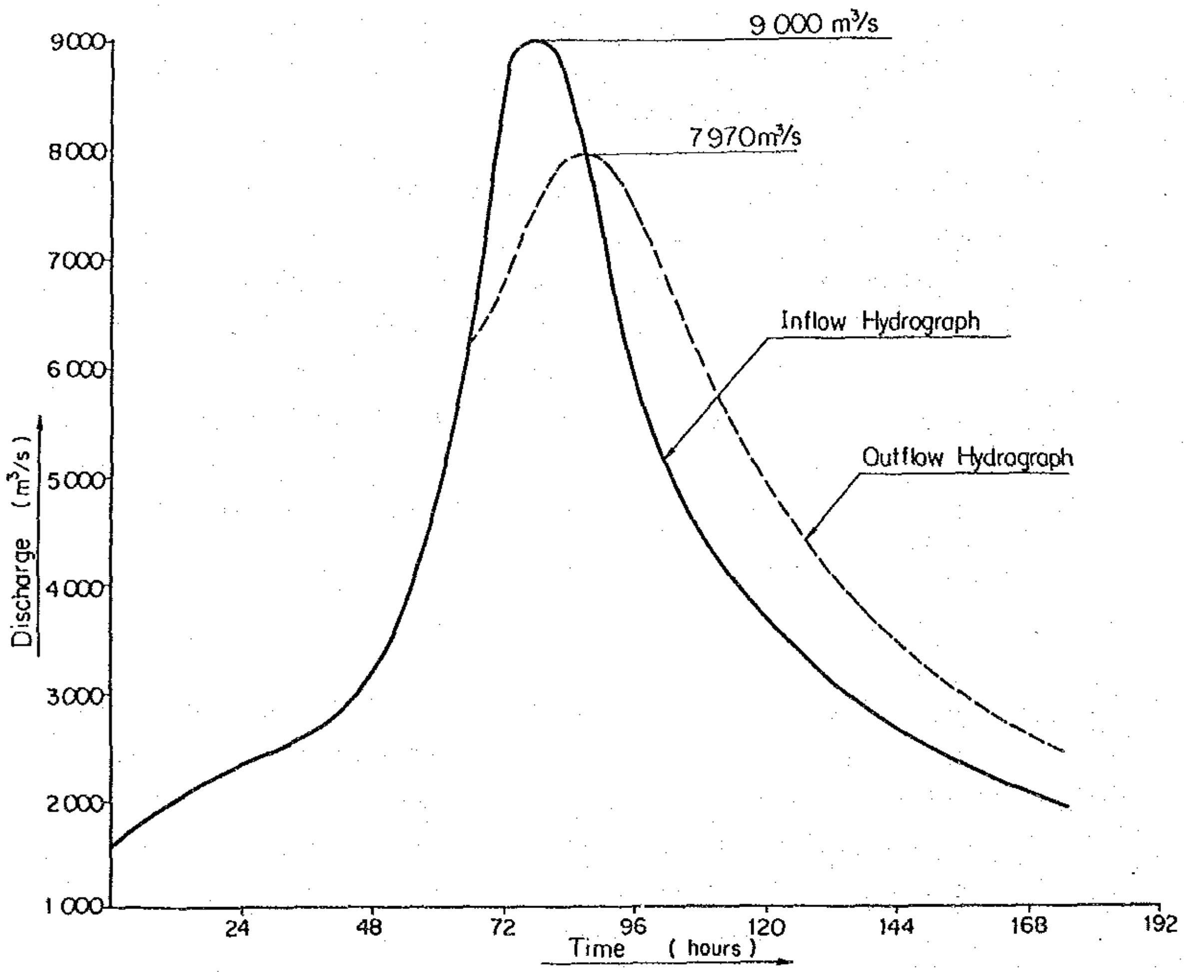


Fig. 10–1 Inflow and Outflow Hydrographs

The excavated stilling basin has a rectangular flat bottom 66 m wide, 160 m long at the elevation of 476 m which will ensure the stable hydraulic jump there. The excavation volume for spillway as a whole will amount to about 8 x 10^6 m^3.

Stoplogs will be provided in case of inspection and repair of the spillway gates.

Table 10-1 Comparative Costs of Spillway-Dam Combinations

Item \ Number of Gate	Unit	3	4	5
Dam & Reservoir				
High Water Level	m	710	710	710
Maximum Water Level	m	715.0	712.3	710.6
Dam Crest Elevation	m	717.7	715.0	713.3
Design Flood	m^3/s	9,000	9,000	9,000
Spillway				
Dimension of Gate	m	13.5 x 15.5	13.5 x 15.5	13.5 x 15.5
Maximum Discharge	m^3/s	7,380	7,970	8,520
Construction Cost				
Dam	10^6 TL	52,380	50,900	49,960
Spillway	10^6 TL	23,570	24,360	31,990
Gate, Stoplog	10^6 TL	830	1,020	1,220
Total	10^6 TL	76,780	76,280	83,170

(4) Bottom Outlet

A bottom outlet will have to be provided to release a certain amount of water required downstream and to control the rate of the reservoir water rise during initial filling of the reservoir. In terms of reservoir scale, it is not practical to give the bottom outlet a function to lower quickly the reservoir water level in an emergency at Yusufeli Dam.

The intake sill elevation of the bottom outlet is 555 m, a little higher than the crest elevation of the upstream cofferdam and the discharge will be done to the diversion tunnel through the connecting inclined shaft downstream of the gate chamber. Release will be possible about one month later than commencement of filling. The tunnel section for the most part will be circular 3.5 m in inner diameter. And the high pressure slide gate 2.0 m in width and height will do for the above purpose.

Two lines of diversion tunnels at different intake elevation are fundamentally preferable for rockfill dam taking into consideration the control of the very initial reservoir water rise during the closure works in the diversion tunnel, for the bottom outlet installed beforehand at a higher diversion tunnel can function immediately after the final closure of the gate.

In conclusion, the proposed plan of one line of diversion tunnel was adopted in pursuit of economy. And this should be further studied at the definite design stage taking account of the reservoir filling plan as well.

10.1.2 Waterway and Powerhouse

With regard to the layout of the waterway and powerhouse, comparison was made between an underground powerhouse to be provided in the right bank and a surface powerhouse to be provided on the left bank for the rockfill dam. In the investment cost, the plan of an underground powerhouse in the right bank is more advantageous. The power waterway and powerhouse are to be provided in the right bank with maximum power discharge of 321 m^3/s, effective head of 190.8 m, and installed capacity of 540 MW.

(1) Power Waterway

The power intake structure will be an inclined type which turned out more economical as compared with a vertical tower type. The sill elevation of the power intake is well below the low water level and above the estimated sediment level in 50 years after the completion of the dam. The whole waterway is provided underground considering topographical conditions, and the penstock tunnel is adopted from the power intake to the powerhouse. From an economical point of view, one line of waterway is preferably adopted. It has inner diameter of 9.0 m at the upper horizontal portion and tri-furcates after the inclined shaft of 8.0 m in inner diameter to be contracted to inner diameter of 4.2 m just before the powerhouse. In the calculation of the thickness of steel penstock, it is assumed that 30% of the internal pressure will be carried by the surrounding rock.

The tailrace is a pressure tunnel having inner diameter of 10.0 m after the confluence. Inner diameter of the tunnel is determined to be most economical as shown in Fig. 10-2. A surge tank in the tailrace could be eliminated because of not so big water hammer with instanteneous valve closure due to the short length of the tunnel and small flow velocity.

(2) Powerhouse and Switchyard

The powerhouse is to be provided underground in the right bank being connected by an access tunnel about 490 m in length.

The 3 units of main generating machine are provided. The turbine is a vertical Francis type and the center of the turbine is 22 m apart from the adjacent one and the whole excavation of powerhouse cavern presents the maximum dimension of 22 m in breadth, 88 m in length and 48 m in height.

A chamber for main transformers and draft gates is arranged underground downstream of the powerhouse and a switchyard is provided at the downstream end of dam embankment. Between them, a connecting bus bar tunnel of 310 m in length is to be required.

A control building is provided next to the switchyard. The access road to the powerhouse and the outdoor switchyard will be connected with the relocated highway along the right bank of the Coruh River, with about 1.2 km in length.

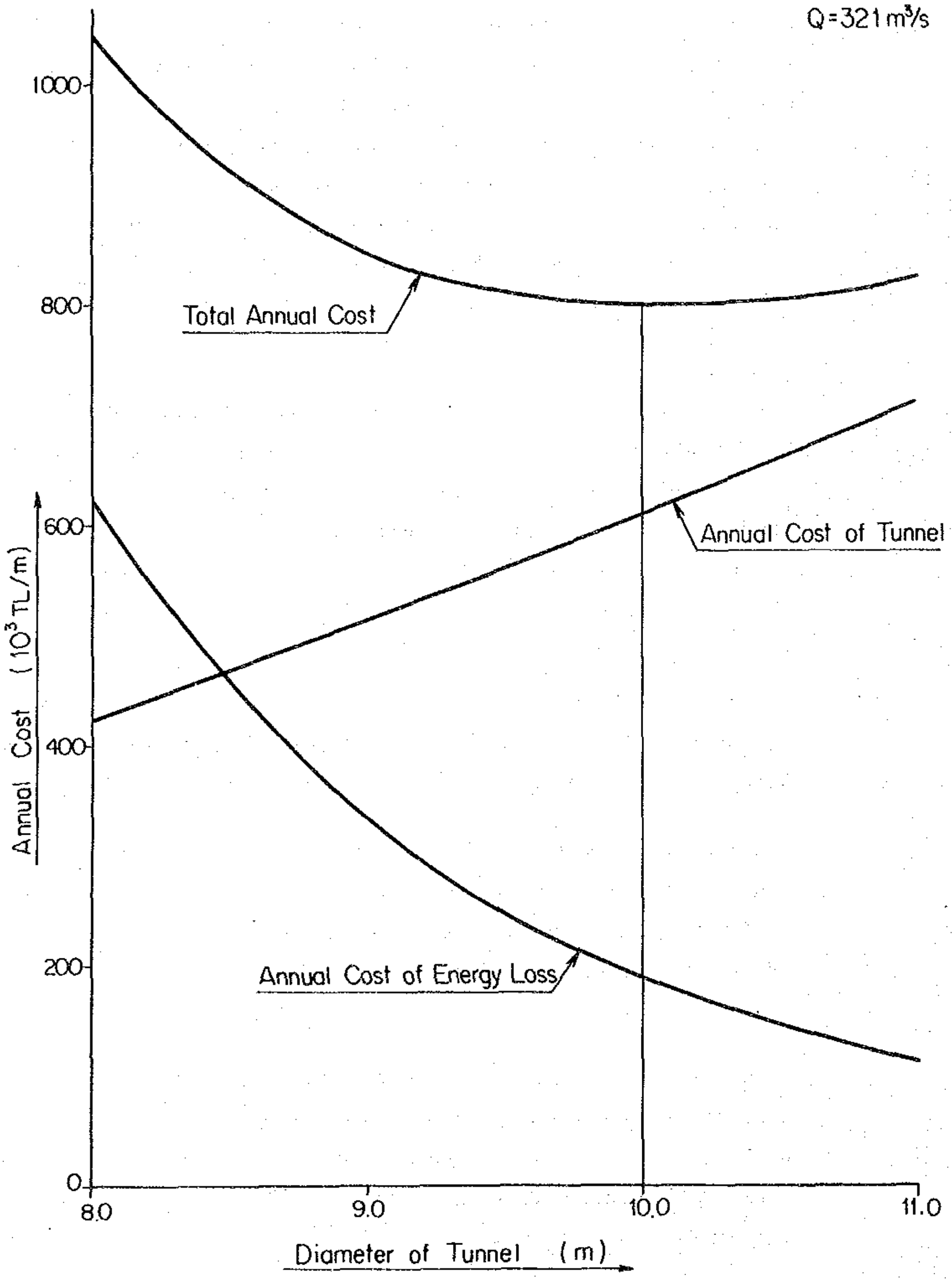


Fig. 10–2 Optimum Diameter of Tailrace Tunnel (Yusufeli Project)

10.1.3 Electro-Mechanical Equipment

(1) Selection of Number of Units

For the maximum output of Yusufeli Power Plant of 540 MW, 2, 3 or 4 units can be contemplated in selecting the number of main equipment.

In the 2 unit design, the advantage of unit size can be reflected in the construction cost. However, technical problems can be expected because the large unit size of 270 MW is practically the technical limit in manufacturing Francis turbines. At the same time, the flexibility in the plant operation is reduced.

In the 4 unit design, there is neither technical nor operational problem. On the other hand, the construction cost is higher than that of the 3 unit design.

In the 3 unit design, the size of the unit is well within the technical limit for Francis turbine, and this design has a distinctive advantage over the 4 unit design in terms of economy, and over the 2 unit design in terms of operational flexibility. With these considerations, the 3 unit design was selected as the most appropriate plan for the plant size.

(2) Selection of Main Equipment

As the vertical type Francis turbine is most suitable in relation to the design parameters of Yusufeli Project, this turbine type has been selected.

Major Design Parameters of Mechanical and Electrical Equipment

<u>Water Turbine</u>:

Type	vertical type Francis Turbine
Number of units	3
Normal effective head	190.8 m
Turbine discharge	107 m^3/s

Normal output	184 MW
Revolving speed	188 rpm

Generator:

Type	3-phase AC synchronous generator
Number of units	3
Output	200 MVA (0.9 lagging power factor)
Frequency	50 Hz

Main Transformer:

Type	indoor, 3-phase, forced oil circulation water cooled
Number of units	200 MVA
Voltage	$380/\sqrt{3}/14.4$ kV

Switchyard:

Type	SF_6 gas insulated switchgear
Number of lines	1

(3) Power Plant

Yusufeli Power Plant is planned to be a underground power house, in which 3 main turbine generators will be installed with 22 meter distances between the units. The overhead traveling crane for assembly and auxiliary equipments will also be installed in the power house.

The power plant layout drawing is presented in Fig. 10-3.

(4) Main Electrical Circuit and 380 kV Switching Station

The main electrical circuit is a unit system in which one main generator is connected to one dedicated main transformer. The main circuit between the generator and transformer is isolated phase bus. The generator terminal voltage of 14.4 kV is stepped up by the main transformer to 380 kV, and the transformer is then connected to the SF_6 gas insulated switchgear in the outdoor switching station by 380 kV CV cables.

The 380 kV switching station is designed to employ the SF_6 gas insulated switchgears (hereinafter called GIS). The reason the GIS has been selected is explained below together with its comparative advantages over the conventional switching stations.

1) Comparison of Equipment Costs and Ground Area Required

	Conventional Equipment	GIS
Equipment Cost	100	170
Ground Area Required	100	14

Note; The cost and space for conventional equipment are taken as 100.

2) Reasons for Selection of GIS

Both banks of the river at the proposed site of Yusufeli Power Plant are very steep ridge having inclination angles of 50 degrees or so.

If a conventional type switching station is to be constructed, the ground area required will amount to 36,000 m^2, and no place is found near the site of Yusufeli Power Plant which is suitable for reclamation of such large area of land. On the other hand, the ground area required for a switching station employing GIS is approximately 5,000 m^2, and this amount of ground area can be easily provided on the slope downstream of the site.

Although the equipment cost for the GIS switching station will amount to 170% of the conventional facility, the GIS can be more economical in terms of the total construction cost including the ground preparation cost.

In the technical aspect, it is almost half a century since the GIS was first placed in commercial use. Thus the GIS can be regarded as well established technology, and there are sufficient performance records of GIS all over the world. Recently, the 750 kV GIS has been applied to a commercial power system with successful operational performance.

The features of GIS are: (a) Equipment deterioration is less likely to occur and high reliability can be maintained for a long time, because the main conductors and insulators are all sealed in the gas atmosphere and the equipment is isolated from outside environment. (b) The space for installation can be drastically reduced from what is needed for the conventional equipment. (c) The major components of GIS is assembled in the factory, to reduce the installation time required at the project site. Together with the sealing system, this results in high equipment reliability, which in turn reduces the labor required in operation and maintenance.

As discussed above, the GIS switching station has a distintive advantage over the conventional equipment in the case of Yusufeli Project, and thus the GIS equipment has been selected for the 380 kV switching station. However, the final decision of whether to adopt conventional switching equipment or GIS should be made after careful study during the detail design stage taking into consideration the experience in Turkey.

The related one-line diagram is presented in Fig. 10-4.

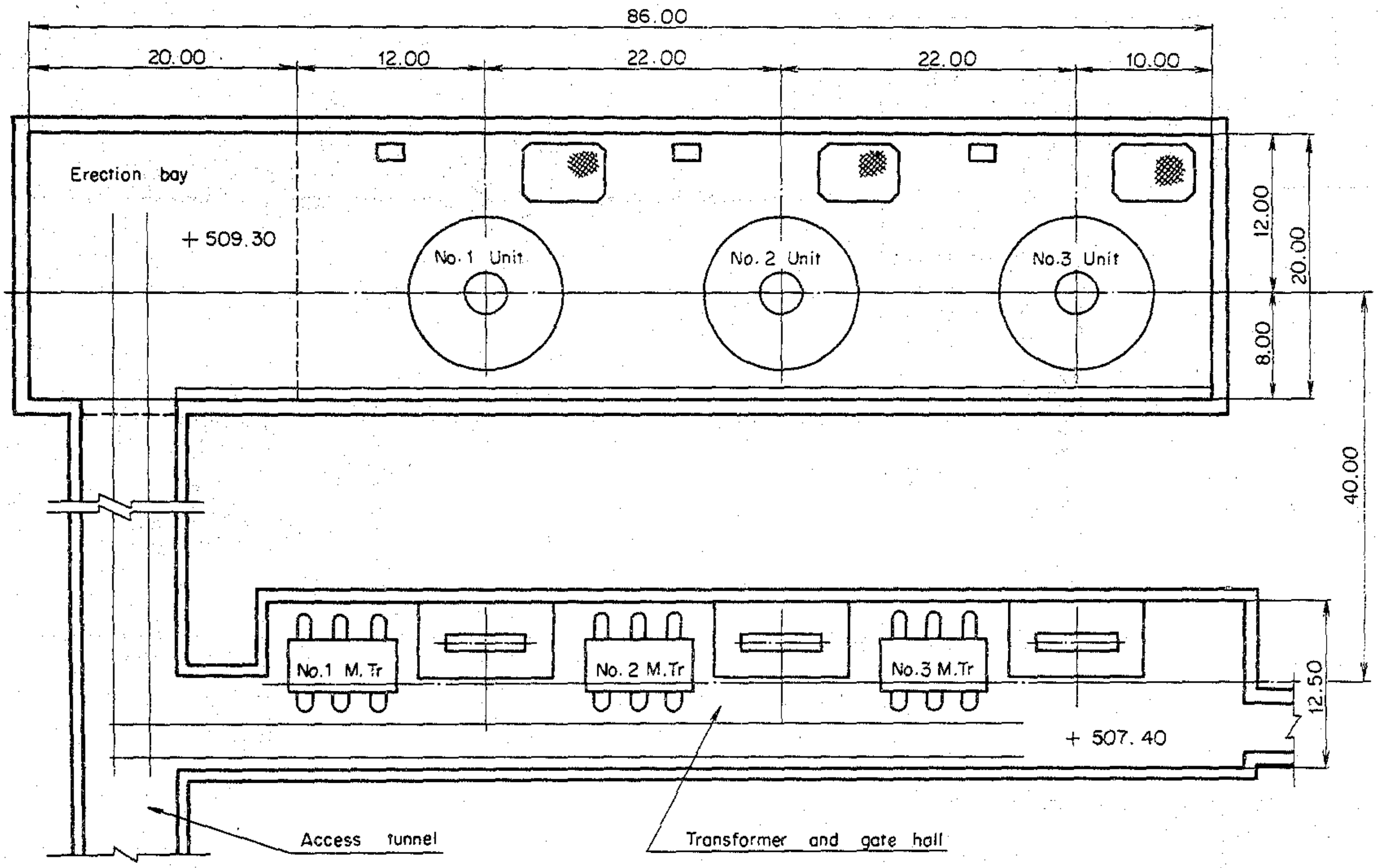


Fig. 10–3 Plan of Power Plant (Yusufeli Project)

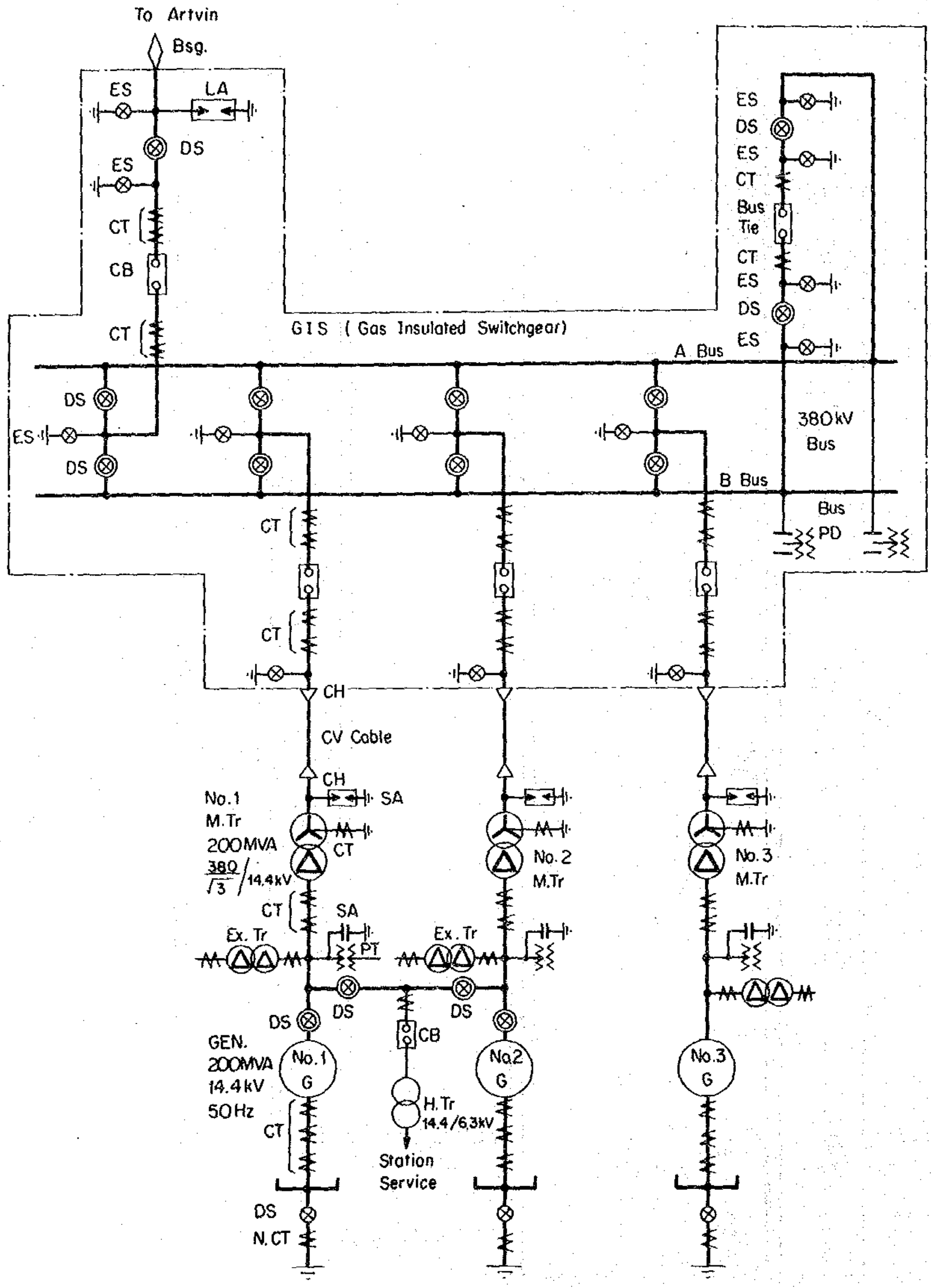


Fig. 10–4 Single Line Diagram (Yusufeli Project)

10.2 Artvin Project

10.2.1 Dam and Appurtenant Structures

As described in Chapter 9, "Development Plan", comparisons were made among a rockfill dam at the upstream dam site, and a concrete gravity dam, an arch gravity dam, and an arch dam at the downstream dam site with regard to the dam type, and as a result, an arch dam at the downstream dam site was selected.

The design flood discharge for Artvin Dam is to be 8,200 m^3/s adding the flood discharge of 200 m^3/s of the remaining catchment area to the release from Yusufeli Dam of 8,000 m^3/s in case of the Probable Maximum Flood.

(1) Care of River

The design flood discharge for care of river during construction is determined to be 1,120 m^3/s that corresponds to 10-year return period flood taking into consideration of the dam type of concrete.

The diversion tunnel is arranged in the right bank, and one line of tunnel is adopted from the economic point of view. The crest elevation of a upstream cofferdam is to be determined by selecting the optimum combination with the inner diameter of the diversion tunnel. As a result of the study, the diversion tunnel is determined to be a standard horseshoe shape with inner diameter of 10.0 m, and the crest elevation of the upstream cofferdam is to be 406 m as shown in Fig.10-5.

(2) Dam

The dam is of double curvature arch with dual-center and constant-thickness. The radii of extrados curve at the crest are 140 m on the right-bank side and 170 m on the left-bank side. The dam body thickness is 8 m at the crest of the dam and 25 m at the base, and the total concrete volume will amount to about 500 x 10^3 m^3. The stress analysis by means of trial load method are shown in the Appendix. The dam crest

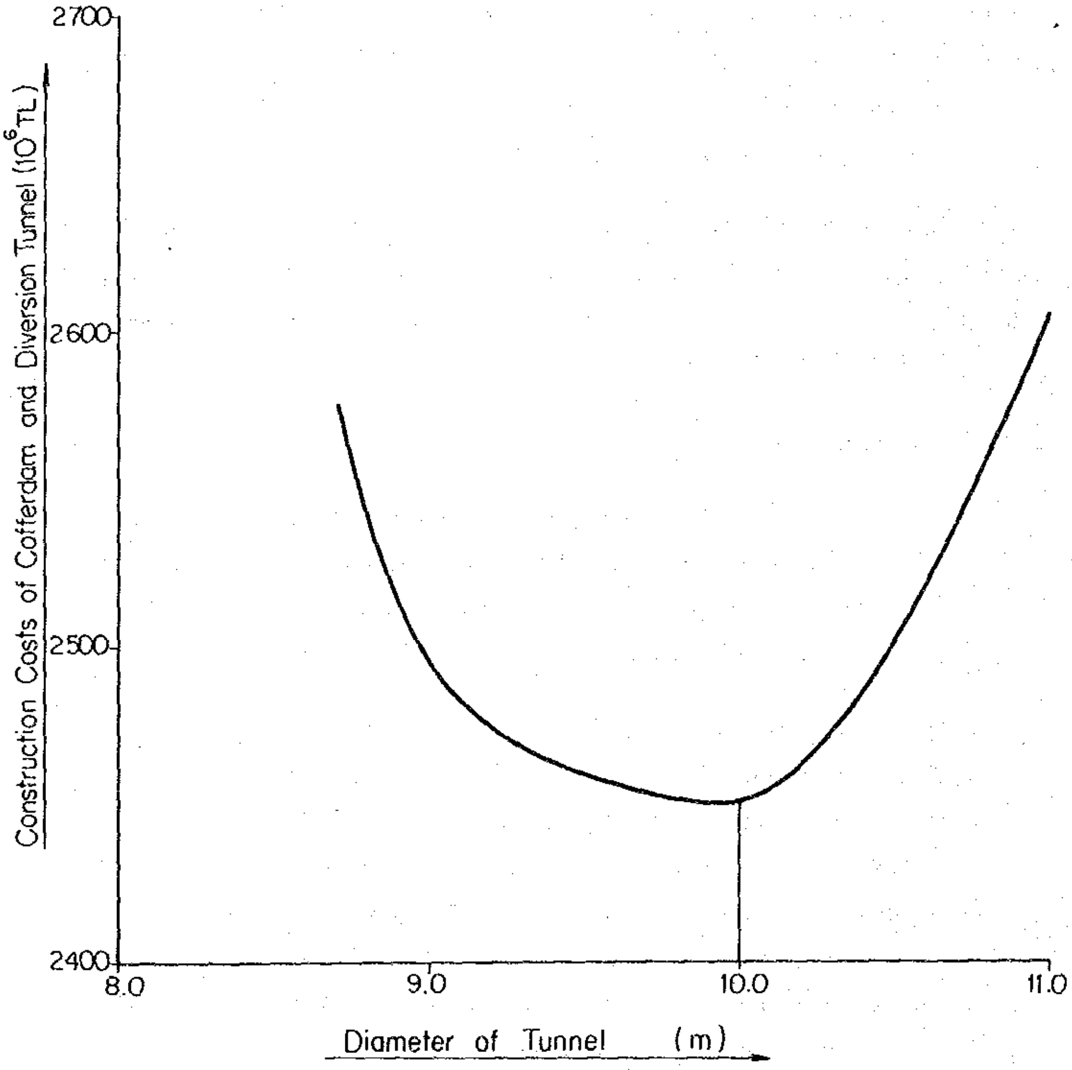


Fig. 10–5 Comparative Costs of Cofferdam – Diversion Tunnel Combinations

elevation is determined to be 505.0 m considering freeboard above the maximum water level of 503.0 m including wave height due to wind and earthquake. A bottom outlet is to be provided in the dam body at around EL. 450 m. With regard to foundation treatment, it is difficult to make faultless judgement at the present time since geological investigations have not yet been completed, but for the col at the right abutment, curtain grouting for water cut-off and prestressed anchoring work to cope with anticipated joints would be planned. The definite design must be carried out carefully, since supplementary fault treatment will be anticipated depending on the results of geological investigations.

(3) Spillway

The spillway is to be a free-fall type at the center of the dam, having four radial gates each 13 m in width and 15 m in height. The design flood of 8,200 m^3/s will be discharged with maximum water level of 503.0 m. Flood control capacity of 12 x 10^6 m^3 above high water level is ignored in this report because of its small quantity. In case a landslide should occur at Havuzlu approximately 9 km upstream of the dam site, the effect at the dam site due to the landslide will be waves of less than 5 m in height. Since the dam has freeboard of 5 m above high water level, the dam crest will not be overflowed. At both sides of the gated section there will be ungated overflow spillways of total width 40 m provided with the crest elevation matching maximum water level. They will increase safety of the dam body against waves due to landsliding. The energy of falling flood water will be dissipated in a plunge pool of bottom elevation 347 m and horizontal length of bottom 120 m provided at the foot of the dam. Following the dissipation it will flow into Deriner Reservoir.

10.2.2 Waterway and Powerhouse

The waterway and underground powerhouse are to be provided in the left-bank, which is thought to be sounder than the right-bank, with maximum power discharge of 333 m^3/s, effective head of 112.9 m, and installed capacity of 320 MW.

(1) Power Waterway

The power intake is to be arranged immediately upstream of the left abutment of the dam, which will be a reinforced concrete structure provided with two roller gates 8.5 m wide and 8.5 m high each. The sill elevation of the power intake is well below the low water level and above the estimated sediment level in 50 years after the completion of the dam. Because of the short length of the waterway there will be two vertical-shaft penstock lines with inner diameter of 6.5 - 5.2 m. In the calculation of the thickness of steel penstock, it is assumed that 30 percent of the internal pressure will be carried by the surrounding rock. The tailraces are to be two pressure tunnels lined with concrete, having inner diameters of 7.5 m. The inner diameter of the tunnel is determined to be most economical as shown in Fig. 10-6.

(2) Powerhouse and Switchyard

The powerhouse is to be provided underground in the left bank being connected by an access tunnel 217 m in length. The generators are to be two units of unit capacity 160 MW. The turbine is to be vertical-shaft Francis type with the spacing between turbine centers of 24 m, and the whole excavation of powerhouse cavern presents the maximum dimension of 25 m in breadth, 65 m in length, and 50 m in height.

A chamber for main transformers and draft gate is to be arranged downstream of the powerhouse connected with a cable head by a bus tunnel of 235 m in length. The cable head will be connected by aerial lines to an outdoor switchyard planned at Yagcilargagligi approximately 2 km downstream of the dam-site. As suitable space cannot be found near the powerhouse by topographic reasons, the switchyard site has been selected at Yagcilargagligi from a topographic map of scale 1:5000.

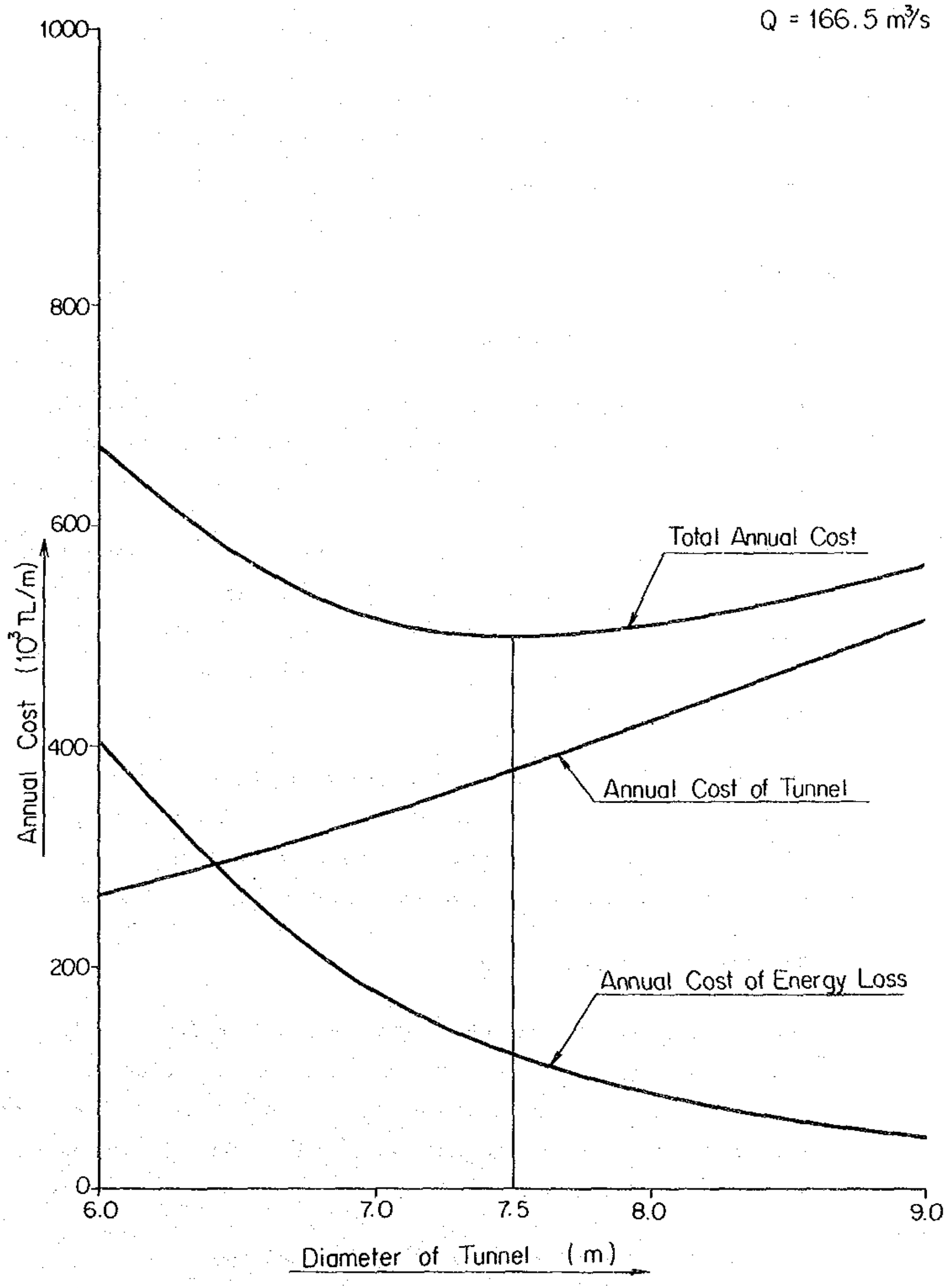


Fig. 10–6 Optimum Diameter of Tailrace Tunnel (Artvin Project)

However, the final location should be decided during the detail design stage after careful study. A control building is to be located adjacent to the outdoor switchyard.

The access road to the powerhouse will be connected with the relocated highway along the left bank of the Coruh river, with about 1.0 km in length.

10.2.3 Electro-Mechanical Equipment

(1) Selection of Number of Unit

For the maximum output of Artvin Power Plant of 320 MW, the number of main electrical equipment studied are 1, 2 and 3 unit designs.

The study result prohibits the selection of the 1 unit design because the turbine for this design is over the limit for manufacturing Francis turbine. The 3 unit design is more expensive than the 2 unit design in terms of the total construction cost.

The 2 unit design was finally selected in the study because the unit capacity in this design is 160 MW, which was well within the limit of manufacture of Francis turbine, and also there is no operational problem involved in this design.

(2) Selection of Main Equipment

The design parameters of Artvin Project stipulate H_{nor} of 112.9 m and Q_{max} of 166.5 m^3/sec, and the selected number of the main equipment is 2. Under these conditions, the vertical type Francis turbine has been selected because it is the most suitable turbine type.

Major Design Parameters of Mechanical and Electrical Equipment

Water Turbine:

Type	vertical type Francis Turbine
Number of units	2
Normal effective head	112.9 m
Turbine discharge	166.5 ^{3}/s
Normal output	167 MW
Revolving speed	150 rpm

Generator:

Type	3-phase AC synchronous generator
Number of units	2
Output	182 MVA (0.9 lagging power factor)
Frequency	50 Hz

Main Transformer:

Type	indoor, 3-phase, forced oil circulation water cooled
Number of units	2
Output	182 MVA
Voltage	$380/\sqrt{3}/14.4$ kV

Switchyard:

Type	SF_6 gas insulated switchgear
Number of lines	3

(3) Power Plant

Artvin Power Plant is planned to be an underground power house in which the main turbine generators are to be installed with a 24 meter distance between the units. The overhead traveling crane for assembly of main units and auxiliary equipments will also be installed in the power house.

The plant layout drawing is presented in Fig. 10-7.

(4) Main Electrical Circuit and 380 kV Switching Station

The main electrical circuit is a unit system in which one main generator is connected to one dedicated main transformer. The main circuit between the generator and transformer is isolated phase bus. The generator terminal voltage of 14.4 kV is stepped up by the main transformer to 380 kV, and the transformer is then connected to the outdoor cable head. Overhead lines run from this cable head to the SF_6 gas insulated switchgears which are in the switching station 2 km downstream.

The employment of the SF_6 gas insulated switchgears for the 380 kV switching station was determined based on the same reason as that of Yusufeli Project. However, the final decision of whether to adopt GIS should be made after careful study during the detail design stage.

The one-line diagram is presented in Fig. 10-8.

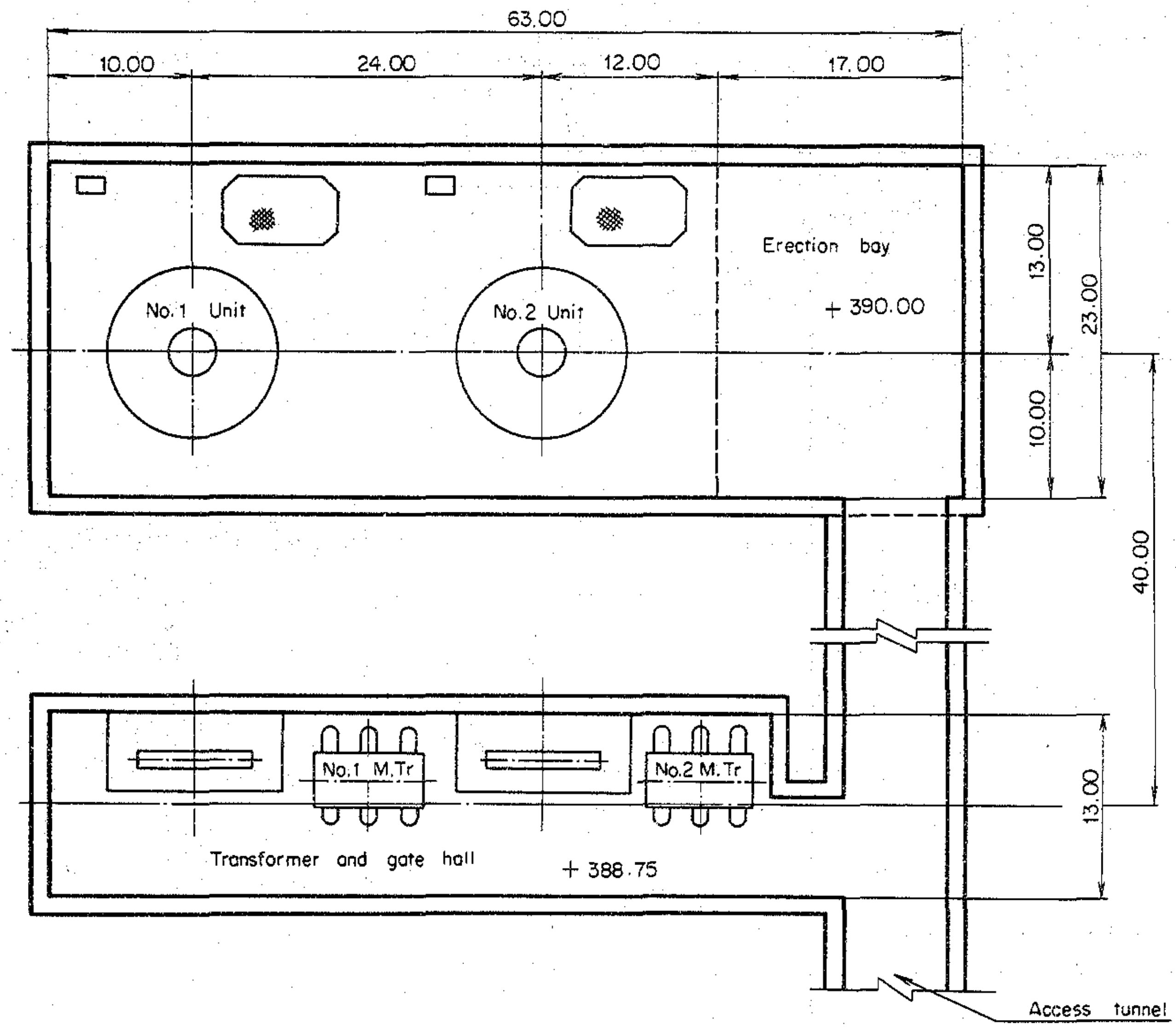


Fig. 10–7 Plan of Power Plant (Artvin Project)

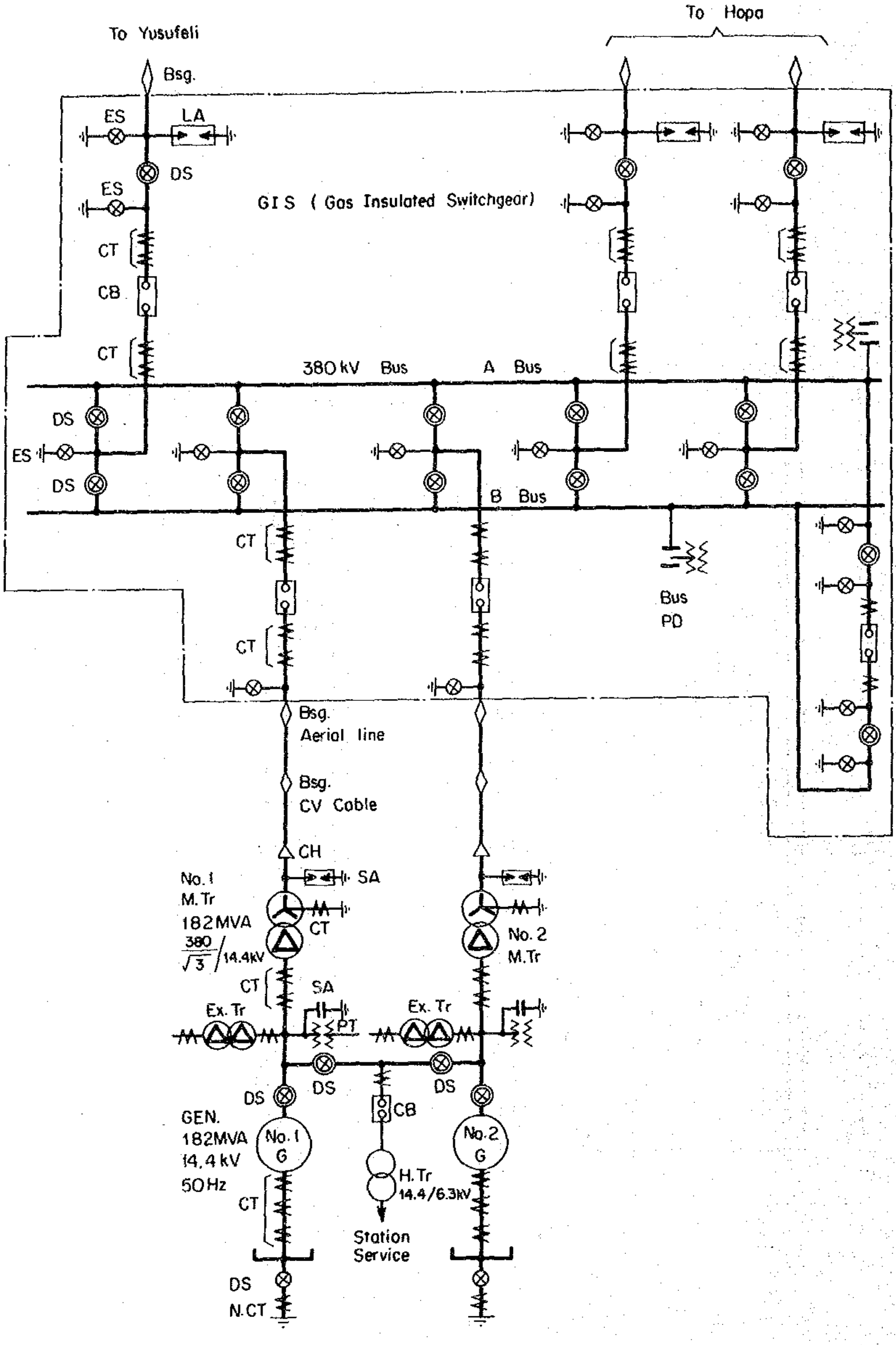


Fig. 10–8 Single Line Diagram (Artvin Project)

10.3 Transmission Line Plan

(1) Transmission Line Route

In constructing a transmission line, the availability of existing road for transportation of material and equipment affects the construction cost substantially. For this reason, the transmission route was selected in the proximity of National Highway No. 950 (from Hopa to Erzurum) that runs along Coruh River. This highway will be re-routed in the section between Artvin Dam and Yusufeli Dam, but the new route will be completed by the time the transmission line construction work is started. The elevations of the power plant sites are below 1,500 m, and there is no problem of transmission line routing.

The construction of the transmission line must be coordinated with the relocation work on an existing 154 kV line (about 35 km) because of the reservoir water of this Project. The transmission line route from Artvin Power Plant to Borcka and Hopa was selected along the national highway mentioned above and the existing 154 kV transmission line by considering the convenience of construction and maintenance.

Hopa Substation was planned in a location minimum 2 km inland from the sea shore to avoid the salt contamination.

(2) Transmission Line Voltage and Number of Circuits

In order to transmit the total output of this Project, amounting about 860 MW for a distance of 93 km from Yusufeli to Hopa, the 154 kV line is insufficient as discussed in 9.3.2 Transmission Line Plan, and at least a circuit of 380 KV transmission line is required.

(3) Conductor

The following conductor type was selected based on considerations on the current capacity required for the output of this Project, the mechanical strength and corona characteristics, as well as the past practice in Turkey.

From Yusufeli Power Plant to Artvin Power Plant :
945 MCM, ACSR x 2 bundles

From Artvin Power Plant to Hopa Substation :
945 MCM, ACSR x 2 bundles

(4) Lightning Protection Design

The IKL (isokeraunic level) observed in the central part of the Black Sea Coast is from 20 to 40, and it can be assumed that the level will be similar in the project area. Thus it has been designed to provide two 90 mm^2 GSW ground wires with the shielding angle of less than 20 degrees, to expect 100% lightning shield.

(5) Insulator type and Number of Insulators per String

The insulation design for the 380 kV transmission line was worked out based on the maximum system voltage of 420 kV and maximum route elevation of 1,500 m, and assuming that the power system is effectively grounded.

The transmission line route mainly runs inland areas.
Although the number of insulators per string is generally decided by the switching surge voltage, some margin was provided in order to coordinate the insulation of existing facility in Turkey, and the insulator string design was determined as 22 insulators per string with 250 mm diameter suspension insulators.

(6) Structure

The transmission tower design standard of Turkey dictates the standard wind pressure of 68 kg/m^2 for wires and 90 kg/m^2 for towers. Considering the meteorological data and past operation record, this standard is regarded as appropriate.

The drawing of standard suspension tower is presented in Fig. 10-9.

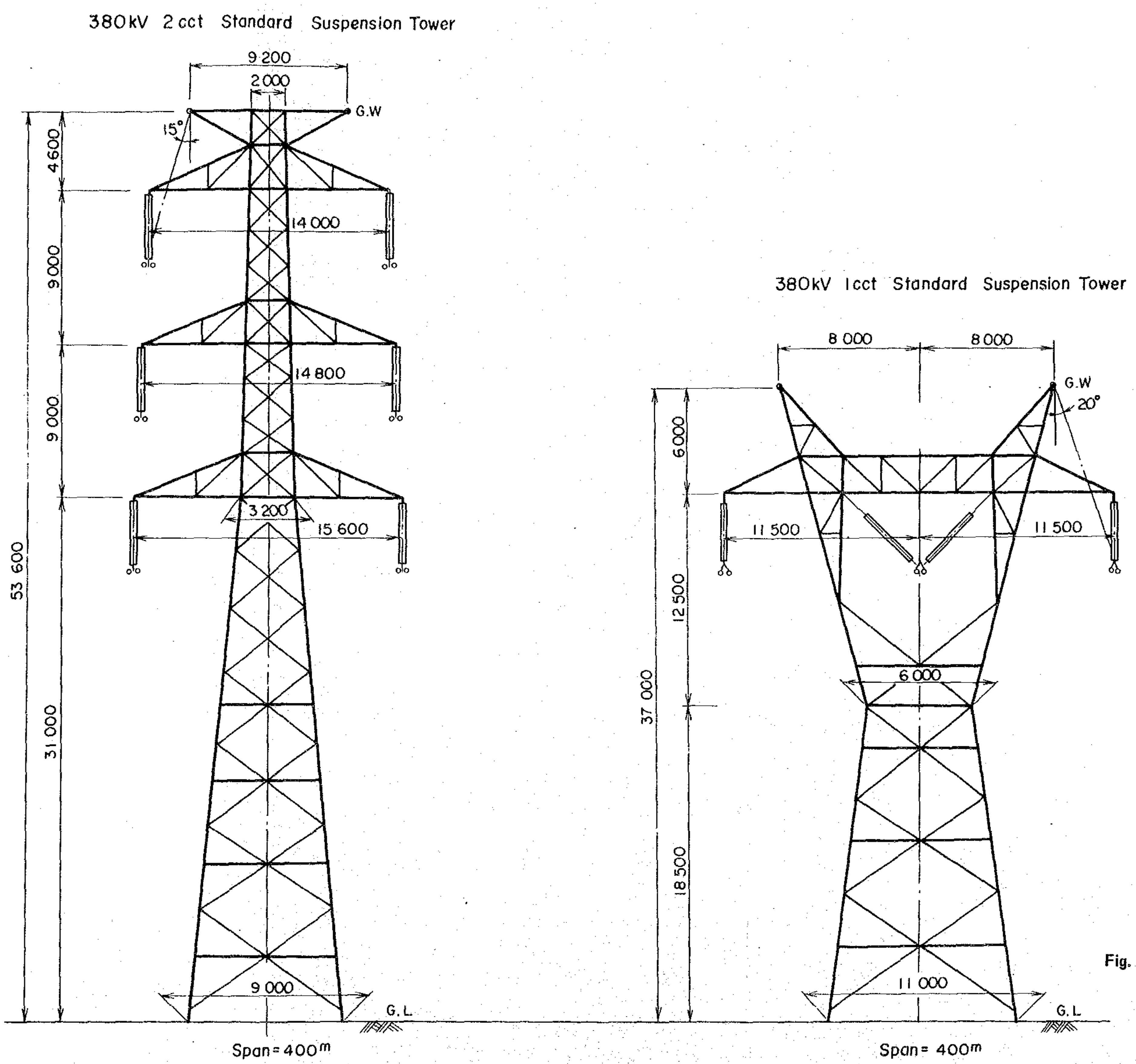
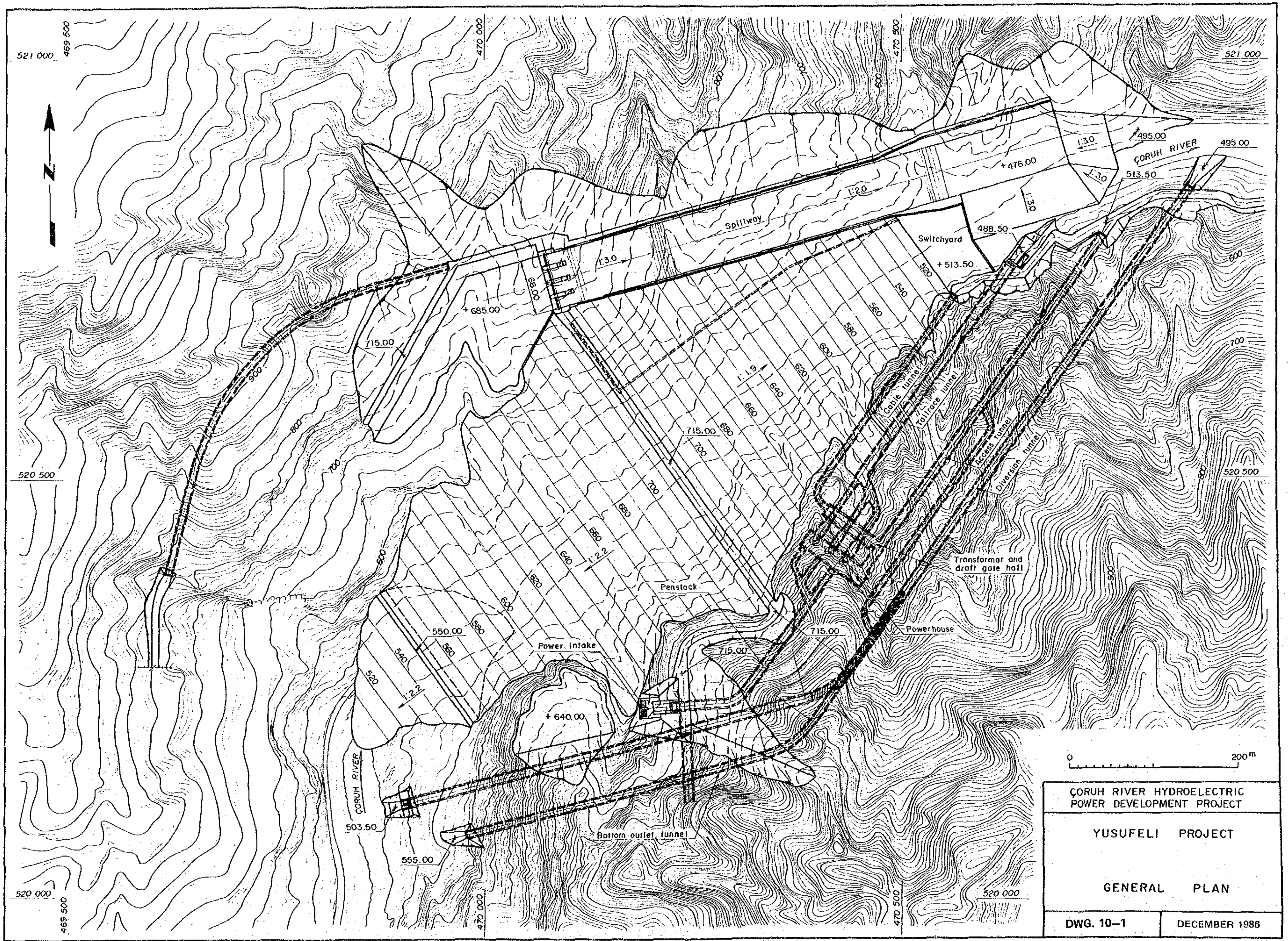
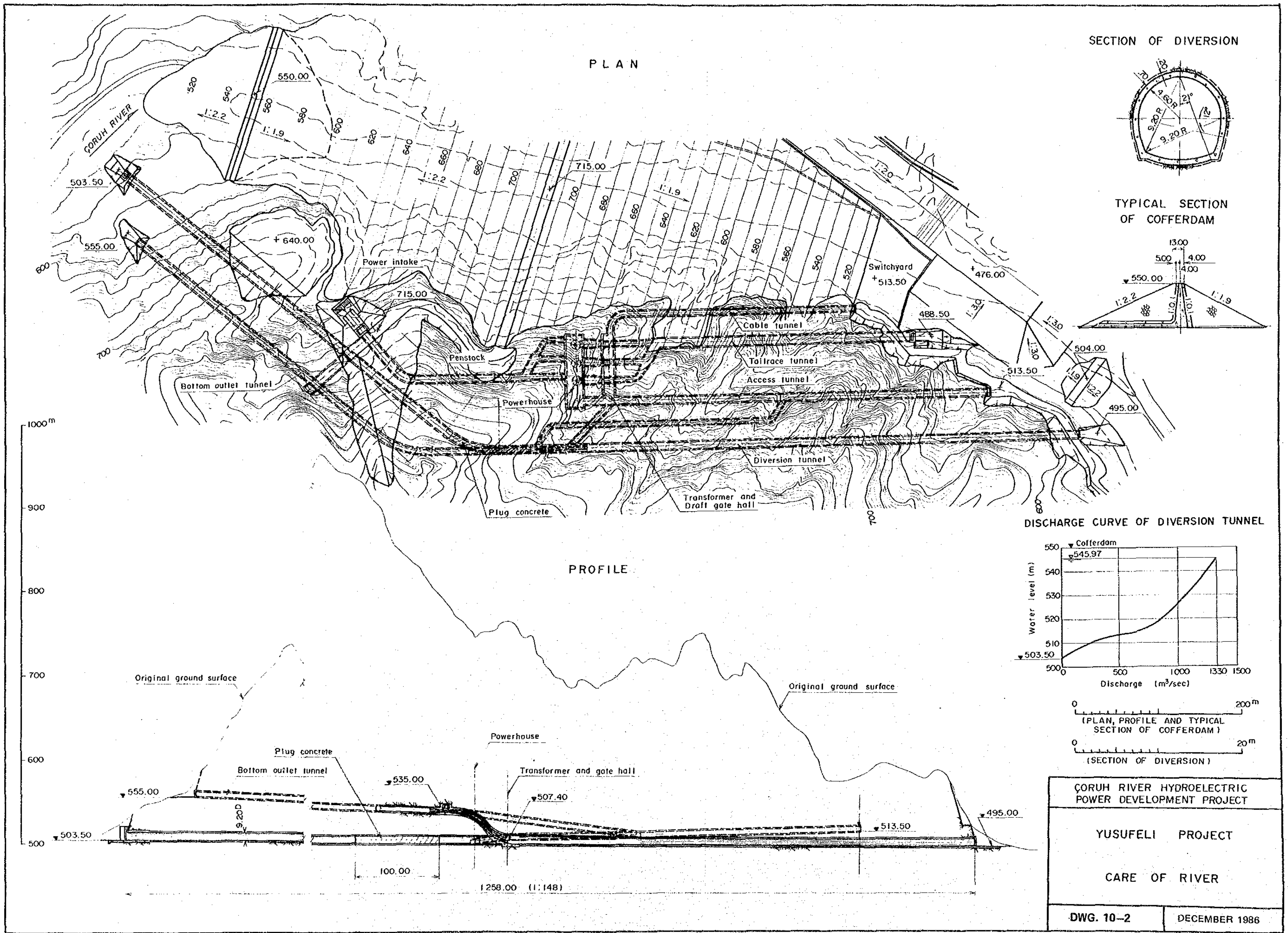
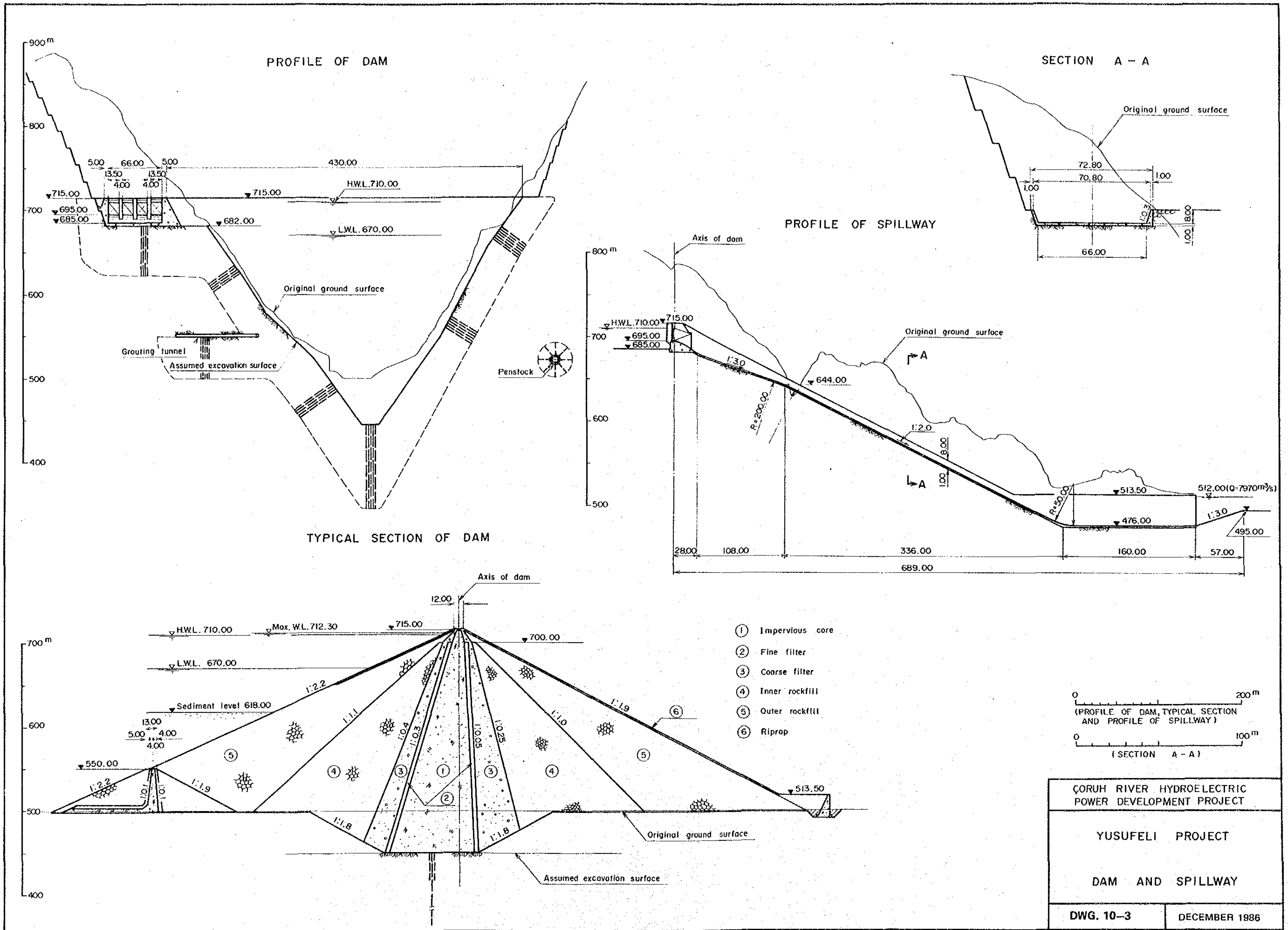


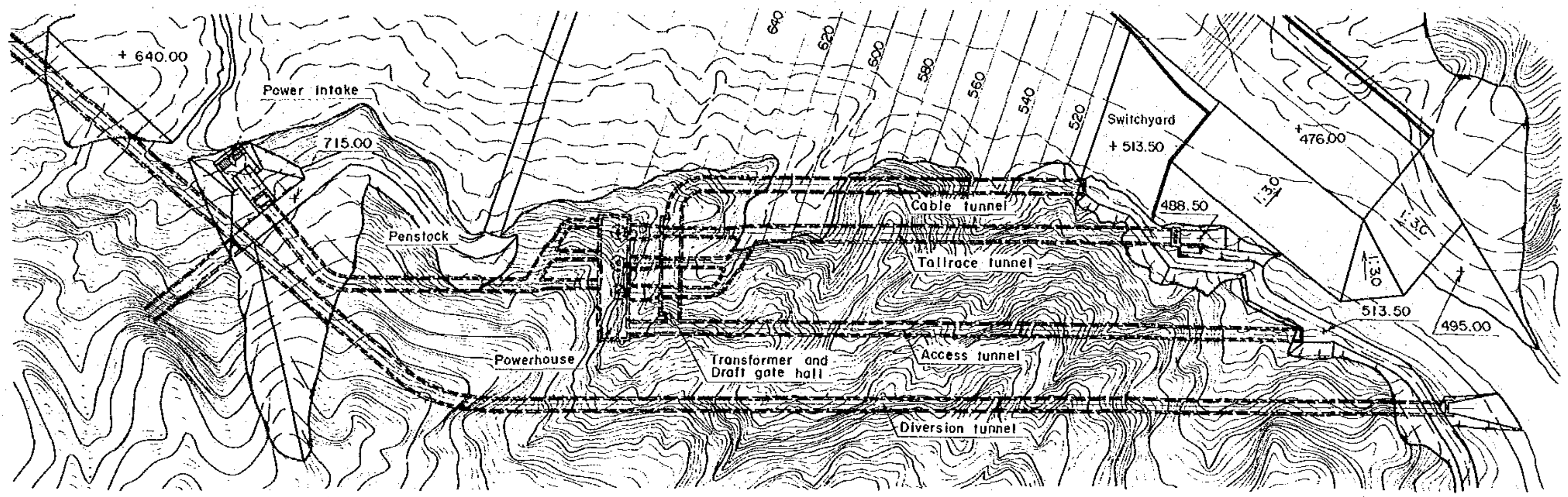
Fig. 10–9 Standard Suspension Tower for Coruh Project


ÇORUH RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT
YUSUFELI PROJECT
GENERAL PLAN
DWG. 10–1
DECEMBER 1986
N
Spillway
Switchyard
ÇORUH RIVER
Cable tunnel
Tailrace tunnel
Access tunnel
Diversion tunnel
Transformer and draft gate hall
Powerhouse
Penstock
Power intake
Bottom outlet tunnel
+476.00
+513.50
+685.00
+640.00
715.00
550.00
503.50
555.00
488.50
495.00
513.50
1:30
1:20
1:3.0
1:1.9
1:2.2
521 000
520 500
520 000
469 500
470 000
470 500
0
200m

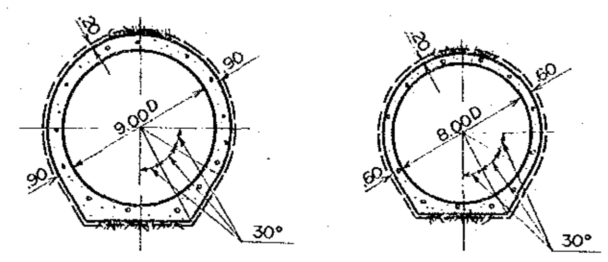

PLAN
ÇORUH RIVER
503.50
555.00
550.00
715.00
+640.00
Power intake
Penstock
Powerhouse
Bottom outlet tunnel
Cable tunnel
Tailrace tunnel
Access tunnel
Diversion tunnel
Transformer and Draft gate hall
Plug concrete
Switchyard
+513.50
+476.00
488.50
504.00
513.50
495.00
1:2.2
1:1.9
1:2.0
1:3.0
SECTION OF DIVERSION
4.60R
9.20R
TYPICAL SECTION OF COFFERDAM
13.00
5.00
4.00
550.00
DISCHARGE CURVE OF DIVERSION TUNNEL
Cofferdam
545.97
503.50
Water level (m)
Discharge (m³/sec)
1330
PROFILE
Original ground surface
Plug concrete
Bottom outlet tunnel
Powerhouse
Transformer and gate hall
555.00
535.00
507.40
513.50
495.00
503.50
9.20D
100.00
1258.00 (1:148)
1000 m
900
800
700
600
500
0
200 m
(PLAN, PROFILE AND TYPICAL SECTION OF COFFERDAM)
0
20 m
(SECTION OF DIVERSION)
ÇORUH RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT
YUSUFELI PROJECT
CARE OF RIVER
DWG. 10–2
DECEMBER 1986


PROFILE OF DAM
900 m
800
700
600
500
400
5.00
66.00
5.00
430.00
13.50
13.50
4.00
4.00
715.00
H.W.L. 710.00
695.00
685.00
682.00
L.W.L. 670.00
Original ground surface
Grouting tunnel
Assumed excavation surface
Penstock
SECTION A – A
Original ground surface
72.80
70.80
1.00
1.00
8.00
1.00
66.00
PROFILE OF SPILLWAY
Axis of dam
800 m
700
600
500
H.W.L. 710.00
715.00
695.00
685.00
1:3.0
644.00
R=200.00
1:2.0
8.00
1.00
R=50.00
513.50
512.00(Q=7970m³/s)
476.00
1:3.0
495.00
28.00
108.00
336.00
160.00
57.00
689.00
TYPICAL SECTION OF DAM
Axis of dam
12.00
H.W.L. 710.00
Max. W.L. 712.30
715.00
700.00
L.W.L. 670.00
Sediment level 618.00
550.00
13.00
5.00
4.00
4.00
1:2.2
1:1.1
1:0.4
1:0.3
1:0.05
1:0.25
1:1.0
1:1.9
1:1.8
1:1.8
1:0.1
513.50
Original ground surface
Assumed excavation surface
700 m
600
500
400
(1) Impervious core
(2) Fine filter
(3) Coarse filter
(4) Inner rockfill
(5) Outer rockfill
(6) Riprap
0
200 m
(PROFILE OF DAM, TYPICAL SECTION AND PROFILE OF SPILLWAY)
0
100 m
(SECTION A – A)
ÇORUH RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT
YUSUFELI PROJECT
DAM AND SPILLWAY
DWG. 10–3
DECEMBER 1986

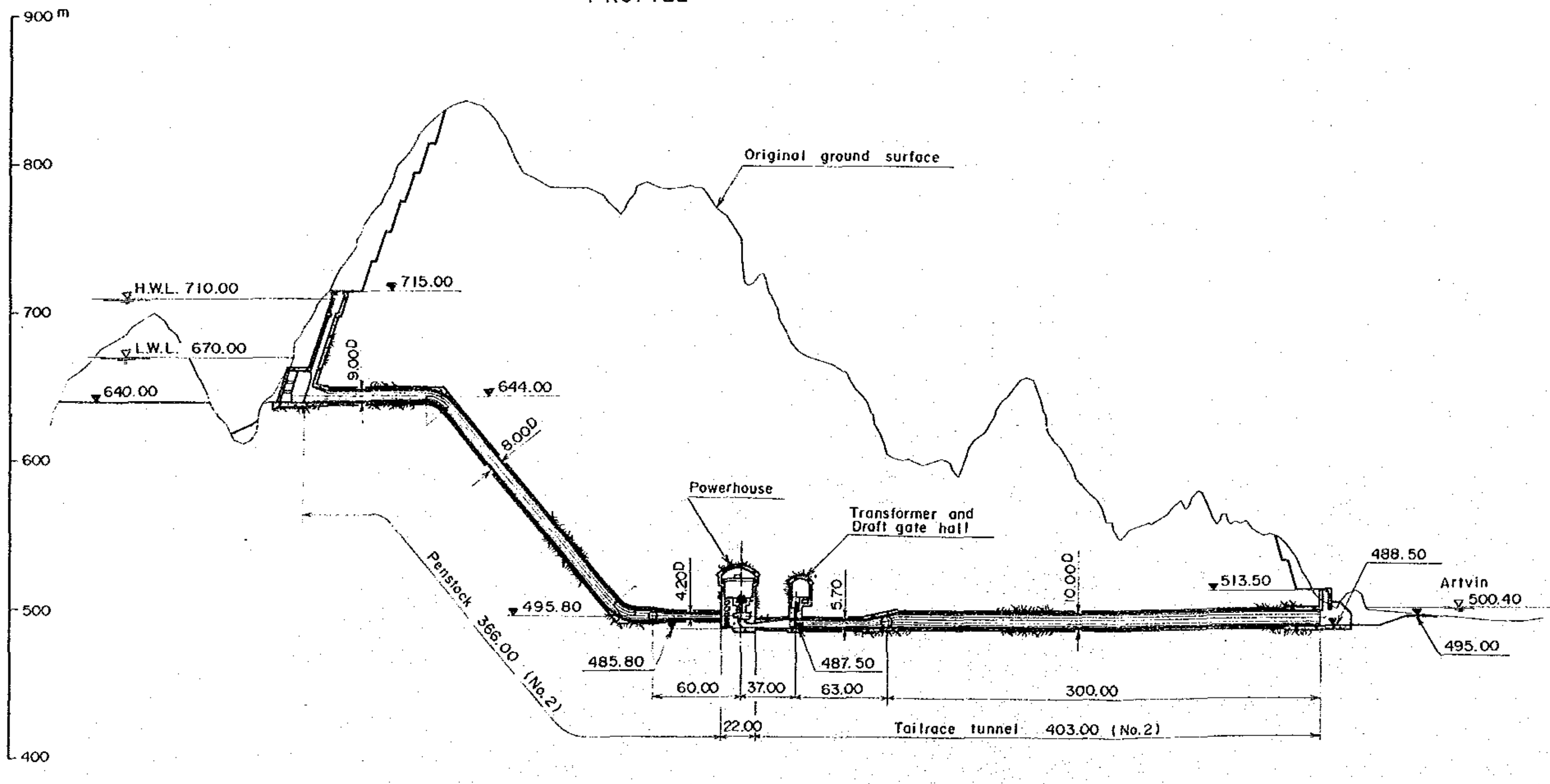
PLAN



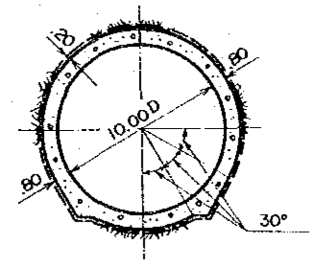
SECTION OF PENSTOCK

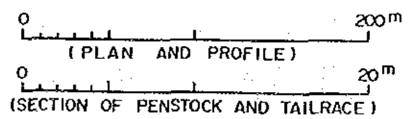


PROFILE



SECTION OF TAILRACE



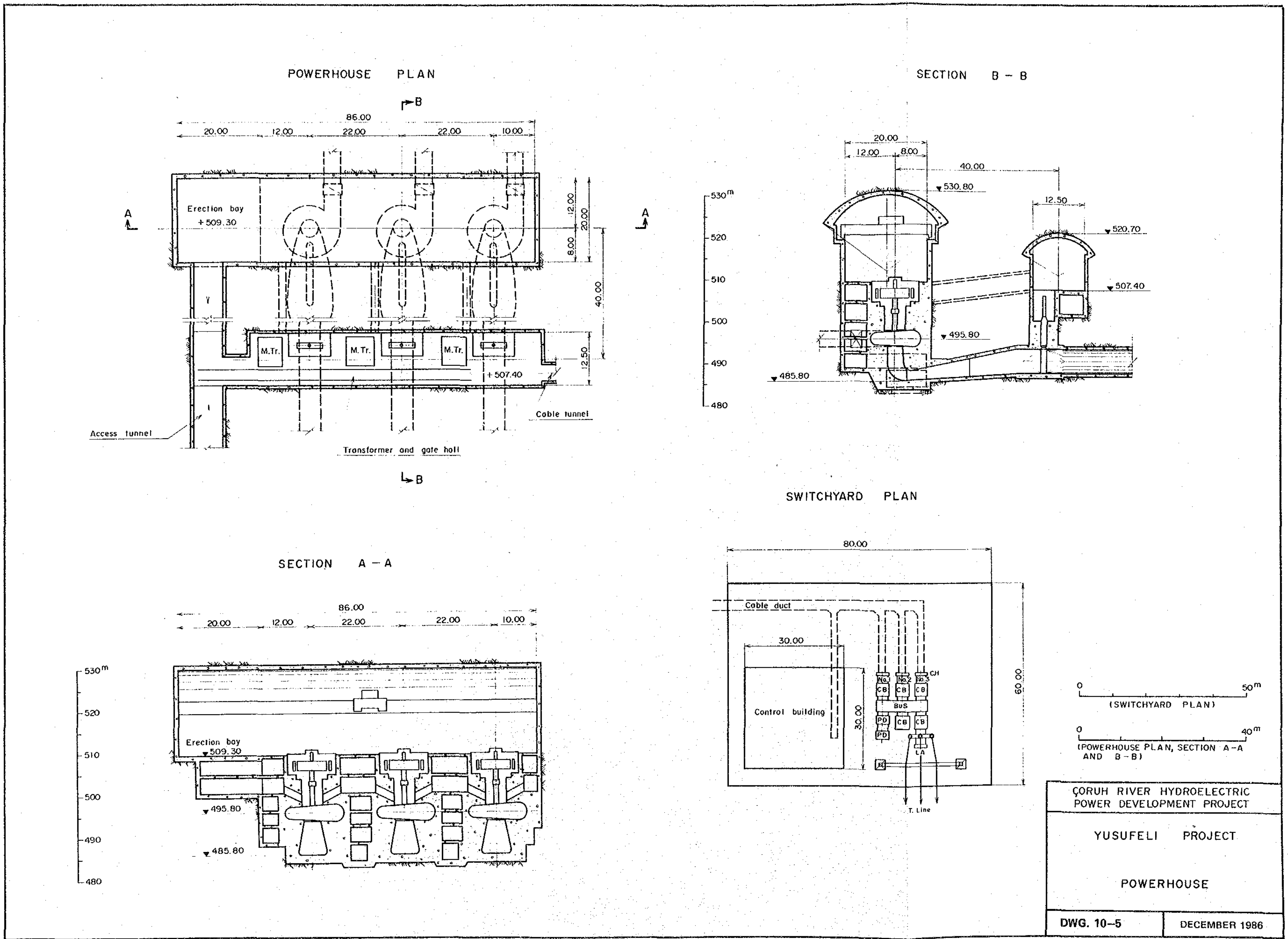


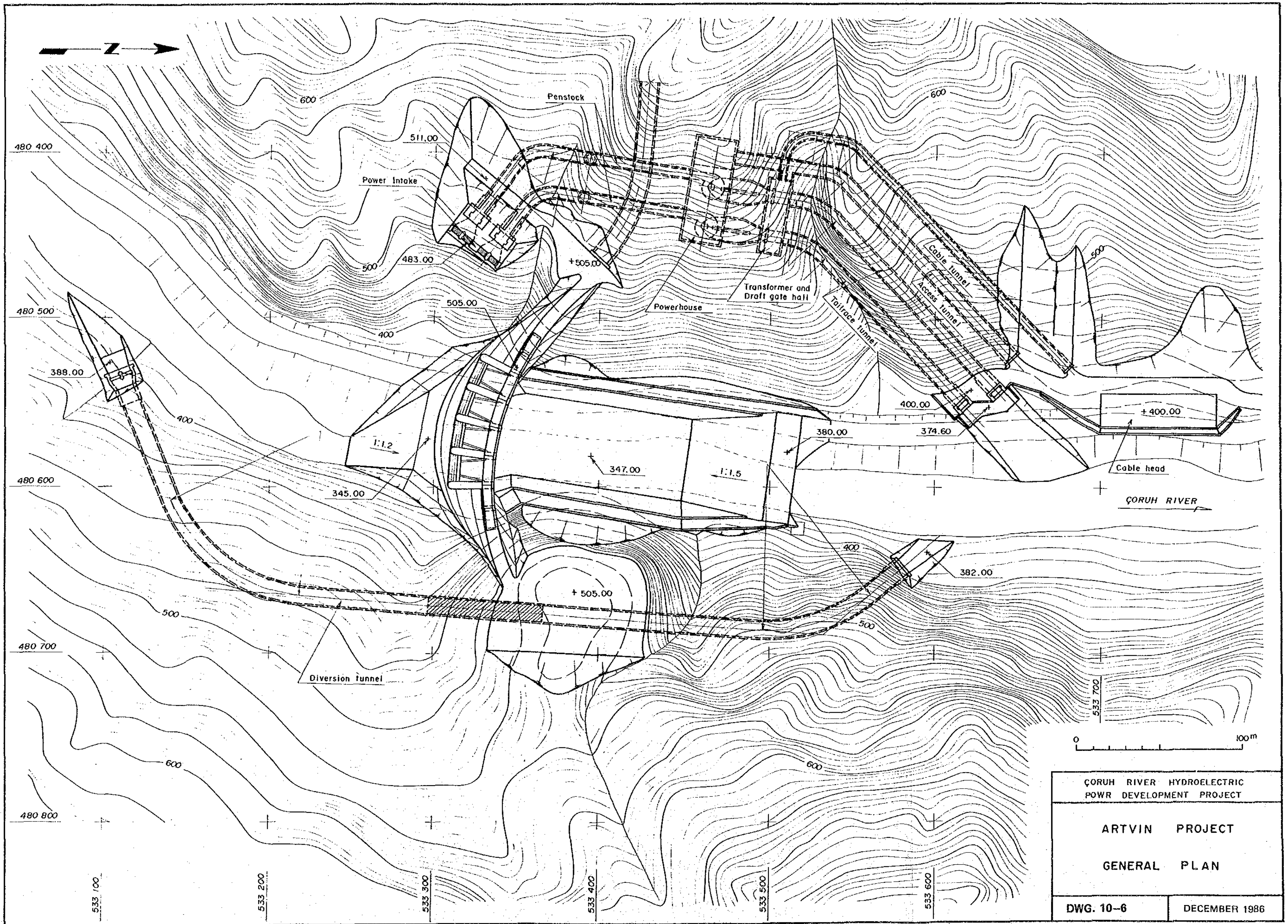
ÇORUH RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

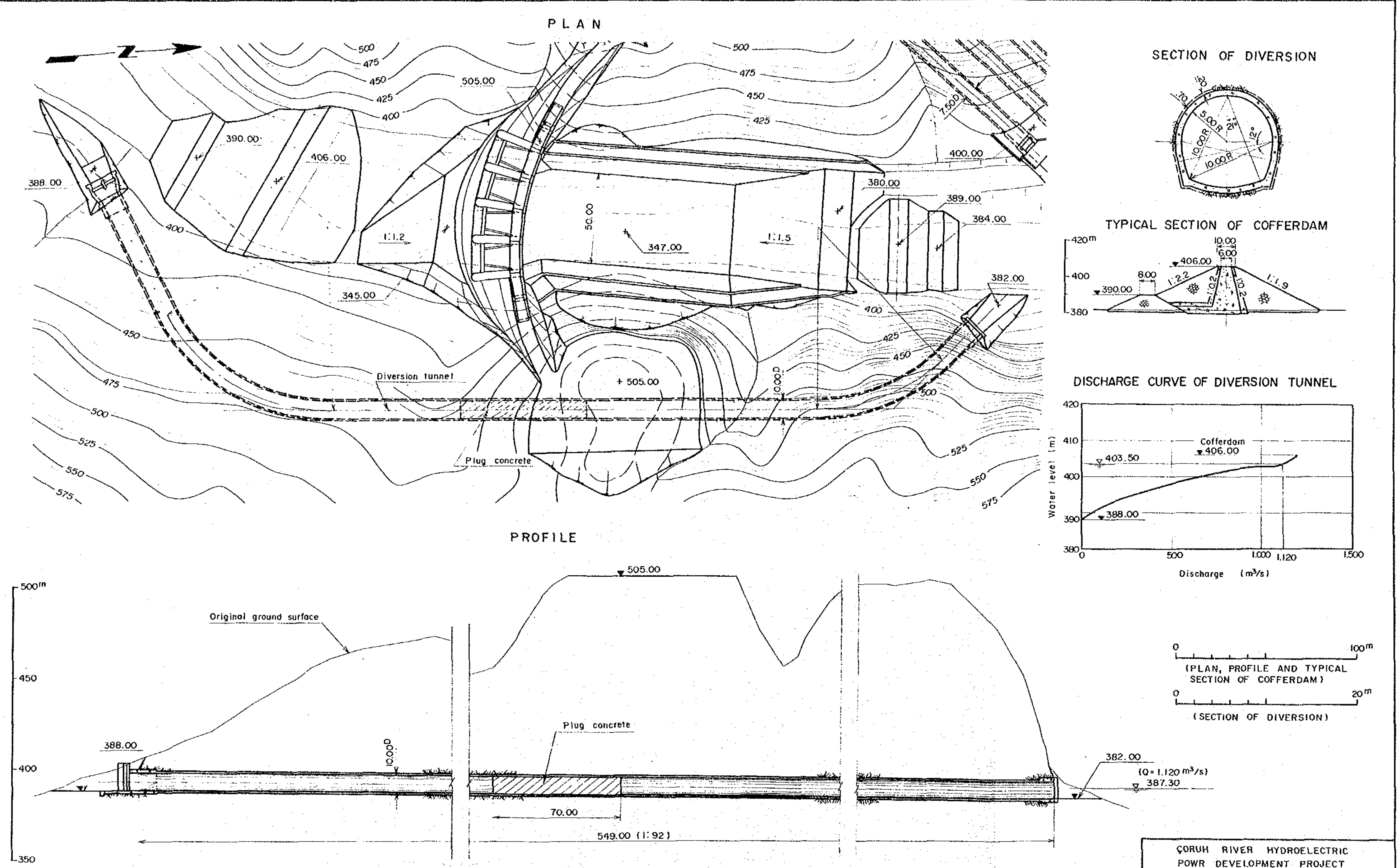
YUSUFELI PROJECT

WATERWAY

DWG. 10-4 | DECEMBER 1986


POWERHOUSE PLAN
86.00
20.00
12.00
22.00
22.00
10.00
Erection bay
+509.30
M.Tr.
M.Tr.
M.Tr.
+507.40
12.00
20.00
8.00
40.00
12.50
Access tunnel
Cable tunnel
Transformer and gate hall
SECTION B – B
20.00
12.00
8.00
40.00
12.50
530.80
520.70
507.40
495.80
485.80
530m
520
510
500
490
480
SWITCHYARD PLAN
80.00
Cable duct
30.00
Control building
30.00
60.00
CB
BUS
PD
LA
T. Line
SECTION A – A
86.00
20.00
12.00
22.00
22.00
10.00
Erection bay
509.30
495.80
485.80
530m
520
510
500
490
480
0
50m
(SWITCHYARD PLAN)
0
40m
(POWERHOUSE PLAN, SECTION A–A AND B–B)
ÇORUH RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT
YUSUFELI PROJECT
POWERHOUSE
DWG. 10–5
DECEMBER 1986


Z
Penstock
511.00
Power Intake
483.00
+505.00
505.00
Transformer and Draft gate hall
Powerhouse
Tailrace tunnel
Access tunnel
Cable tunnel
388.00
400.00
374.60
+400.00
380.00
347.00
1:1.2
1:1.5
345.00
Cable head
ÇORUH RIVER
382.00
+505.00
Diversion tunnel
480 400
480 500
480 600
480 700
480 800
533 100
533 200
533 300
533 400
533 500
533 600
533 700
0
100m
ÇORUH RIVER HYDROELECTRIC
POWR DEVELOPMENT PROJECT
ARTVIN PROJECT
GENERAL PLAN
DWG. 10-6
DECEMBER 1986



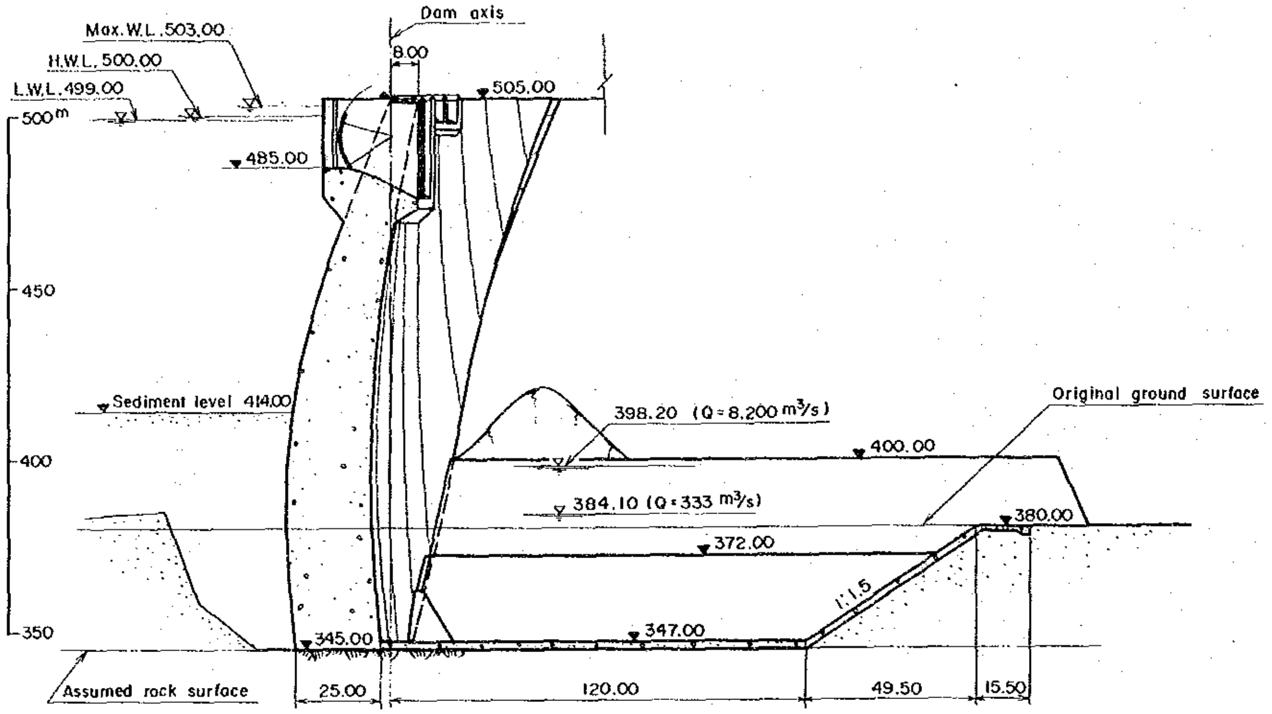
ÇORUH RIVER HYDROELECTRIC POWR DEVELOPMENT PROJECT

ARTVIN PROJECT

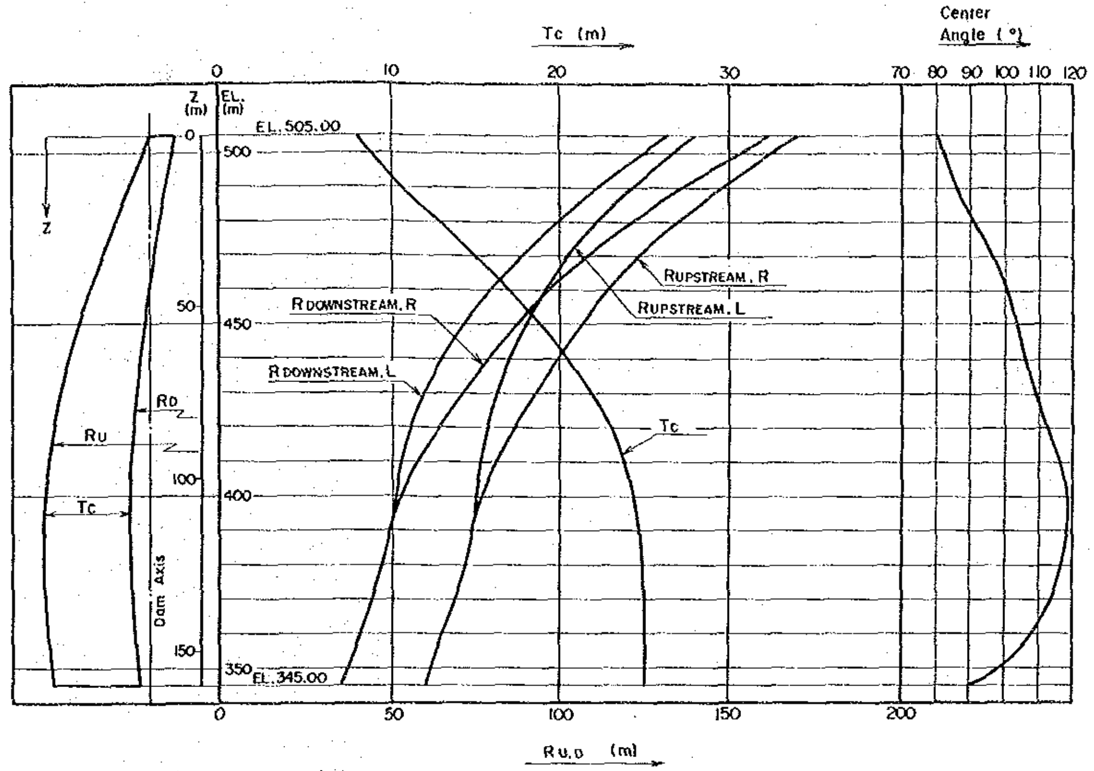
CARE OF RIVER

DWG. 10–7	DECEMBER 1986

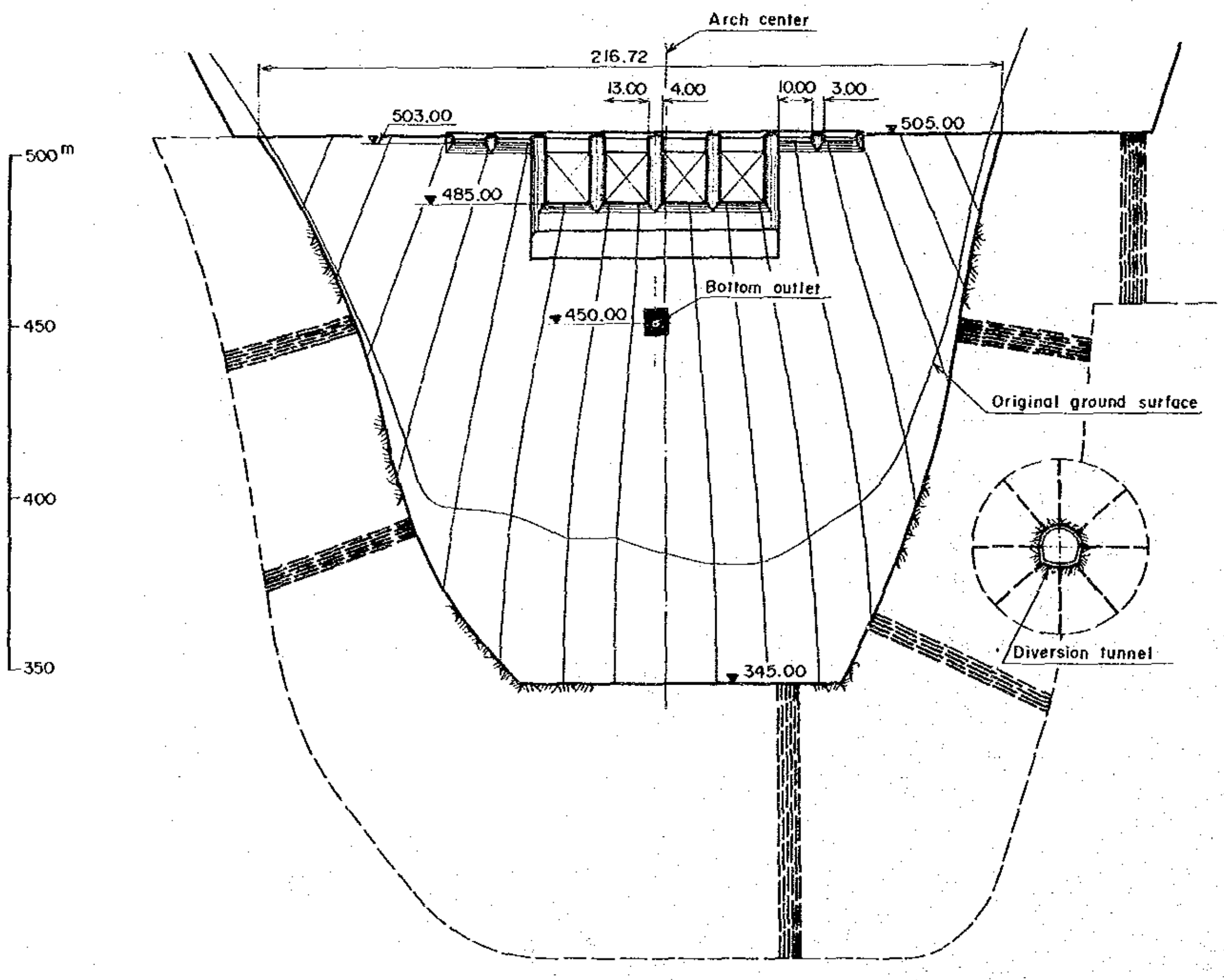
SECTION OF ARCH CROWN



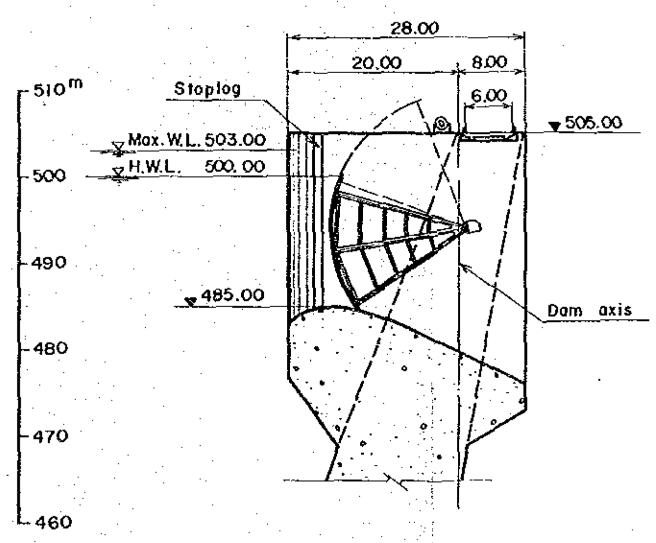
ARCH GEOMETRY

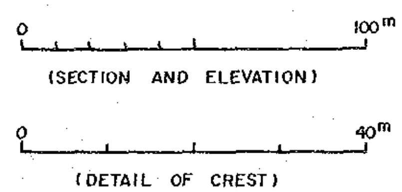


DEVELOPED ELEVATION (UPSTREAM)



DETAIL OF CREST



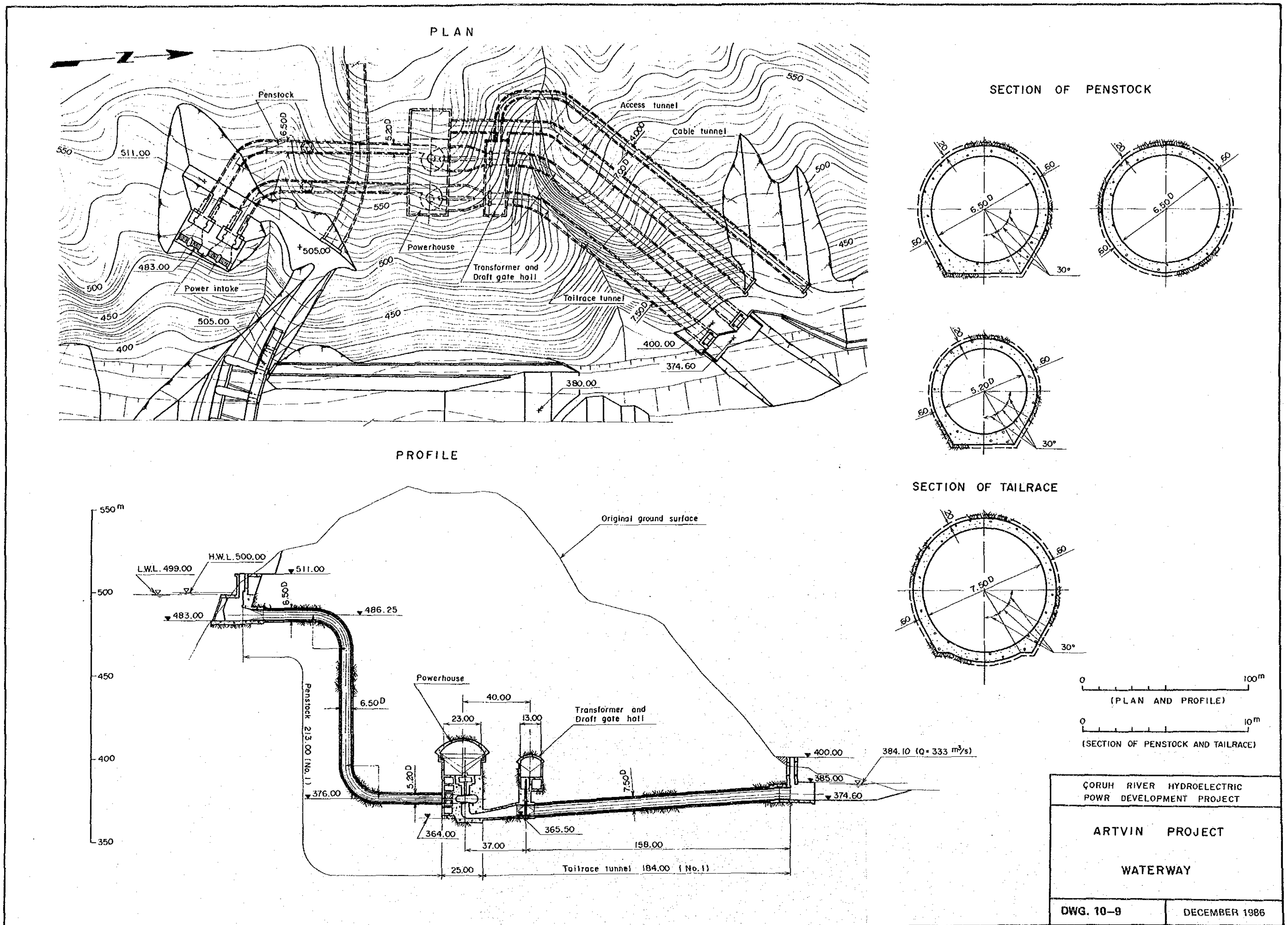


ÇORUH RIVER HYDROELECTRIC POWR DEVELOPMENT PROJECT

ARTVIN PROJECT

DAM AND SPILLWAY

DWG. 10-8	DECEMBER 1986



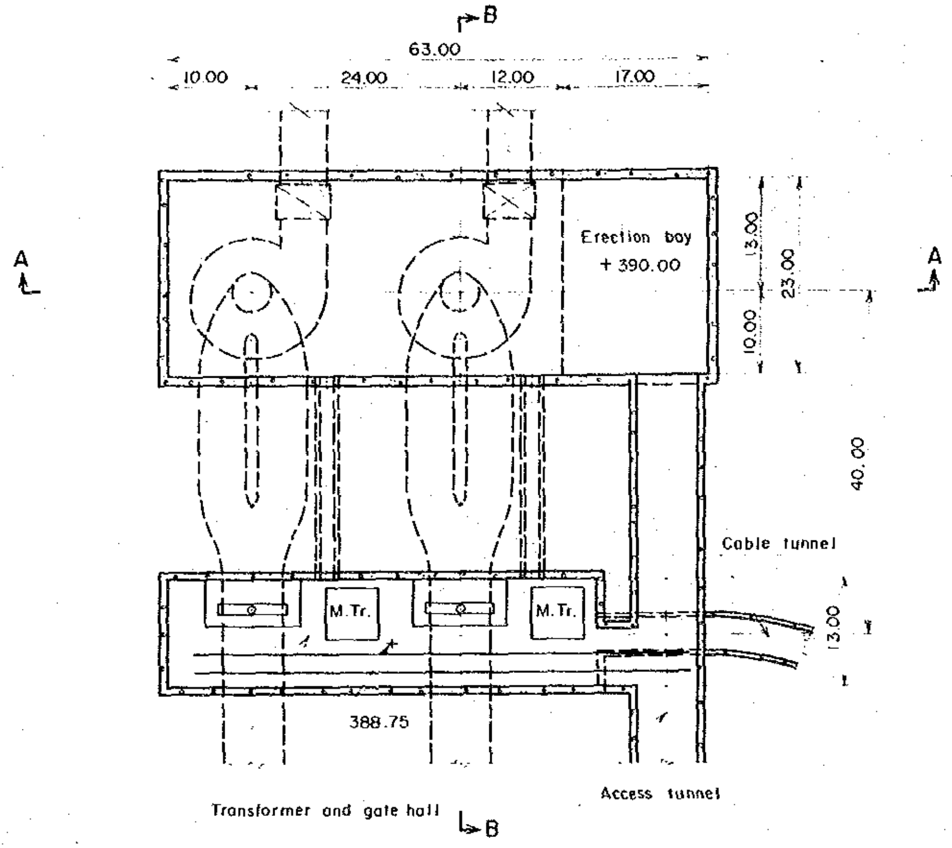
ÇORUH RIVER HYDROELECTRIC
POWR DEVELOPMENT PROJECT

ARTVIN PROJECT

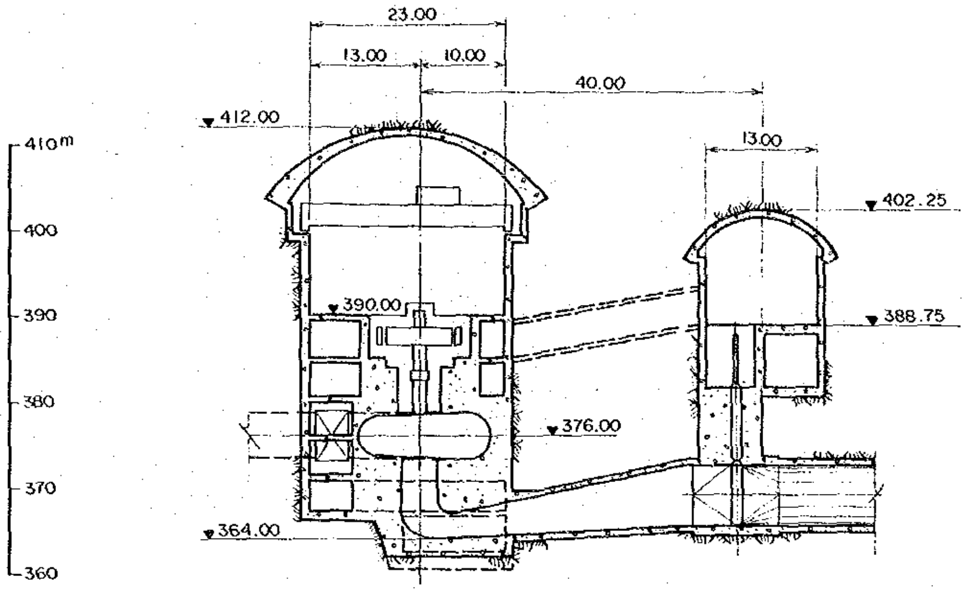
WATERWAY

DWG. 10–9 | DECEMBER 1986

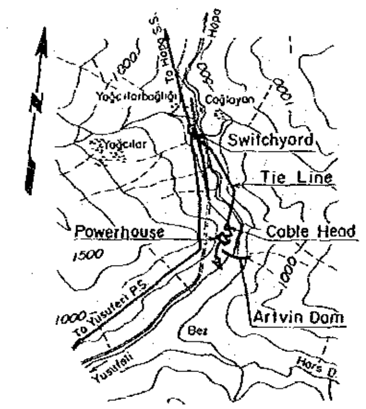
POWERHOUSE PLAN



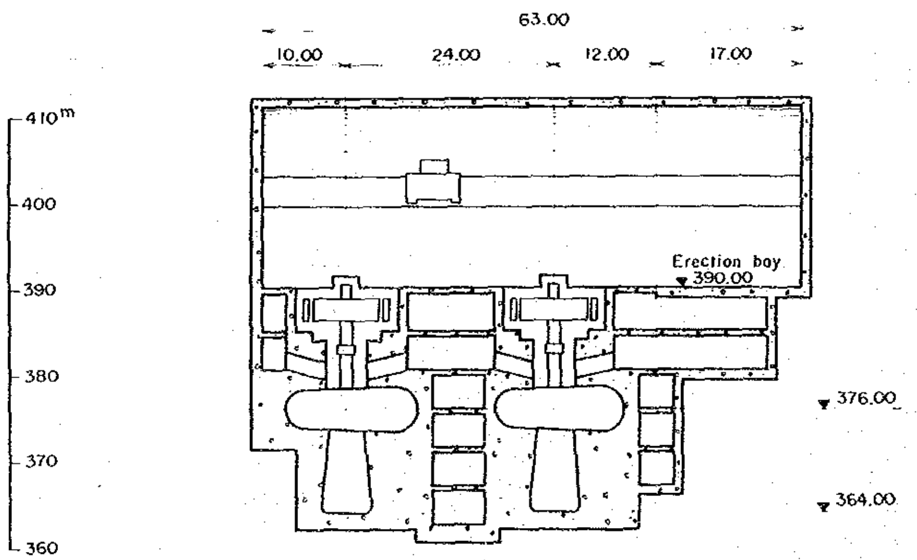
SECTION B - B



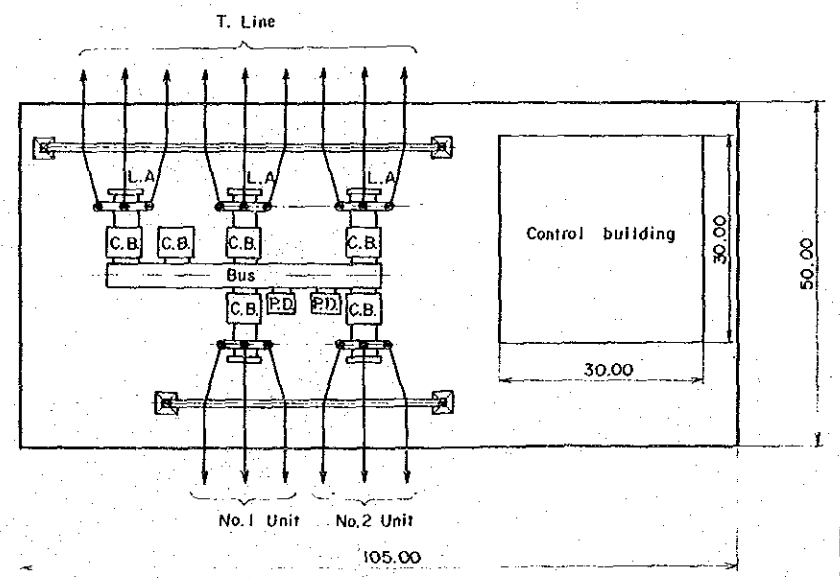
LOCATION OF SWITCHYARD

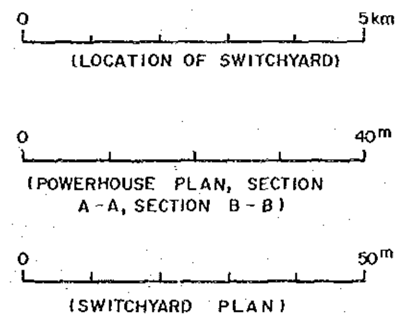


SECTION A - A



SWITCHYARD PLAN





ÇORUH RIVER HYDROELECTRIC POWR DEVELOPMENT PROJECT

ARTVIN PROJECT

POWERHOUSE

DWG. 10–10	DECEMBER 1986

CHAPTER 11 CONSTRUCTION PLANNING AND COST ESTIMATION

CHAPTER 11. CONSTRUCTION PLANNING AND COST ESTIMATION

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CHAPTER 11. CONSTRUCTION PLANNING AND COST ESTIMATION

11.1 Construction Planning and Construction Schedule

11.1.1 Basic Condition

The outlines of matters that affect construction planning and the construction schedule of this Project are as follows:

(1) Meteorology

The meteorological conditions for the Project are as described in Chapter 6. The construction schedule was prepared on the assumption that work could be performed 10 months of the year for core embankment of rockfill dam and concrete placement of concrete dam.

(2) Transportation

With regard to road conditions to the project sites it will be possible to utilize the national highway from Hopa to Erzurum which passes through Artvin and Yusufeli dam sites.

The nearest ports are Hopa (Capacity of existing unloading facility is 10 ton) and Trabzon (25 ton). Temporary cargo unloading facilities are to be prepared for items that exceed these capacities at the time the Project is carried out.

(3) Construction Materials

i) Cement

The main sources of supply of cement would be the two cement mills at Kars (232 km from Yusufeli) and Trabzon (306 km from Yusufeli).

ii) Reinforcement and Steel Materials

The principal items of steel such as structural steel would be supplied mostly from a mill at Karabuk (1,069 km from Yusufeli).