catchment discharge in the downstream part from the San Cancio Power plant intake gate point.

The length of the conduction channel of San Cancio, Intermedia, and Municipal Power plants are approximately 2,400 m, 3,100 m and 2,400 m respectively. At all these facilities, some parts of the open channel are unevenly shaped. However, in general they are well maintained and managed.

Since the passage area of these conduction channel is in the conglomerate area, rains induce the flow of sand and soil into some sections due to flowing surface damage or small scale landslides. Since the conduction channel of the Intermedia Power plant is merely an excavated open channel, so it should be lined with concrete.

The generating equipment has been utilized between 43 to 61 years. In the San Cancio Power plant, a 1929 made horizontal shaft Francis type turbine (rated output 970 kW) and 1947 made horizontal shaft Francis type turbine (rated output 1,350 kW) are installed side by side in the same powerhouse. In the Intermedia Power plant a 1947 made Pelton type turbine (rated output 1,120 kW) is installed, while 2 units of 1945 made Pelton type turbine (rated output 1,056 kW) are installed in Municipal Power plant.
In the Intermedia and Municipal Power plants, there is a great gap between the theoretical output and the installed capacity. In both plants the installed capacity is too small.

(2) Alternative rehabilitation plan

As indicated in the river flow-duration curve form (Figure 6.2) at the intake gate point of the San Cancio Power plant the design discharge Q=5.6 m^3/s, is relatively large for a run-of-river type hydroelectric power plant. Thus, the number of days guaranteed throughout the year is approximately 55%, which is equivalent to 89% of the available discharge, by calculating with the discharge facility utilization factor. Therefore, the rehabilitation plan was focused on two points, since there is no space for a comparative study of the maximum available discharge.

1) Elimination of the gap between the theoretical output and installed capacity.

Fig-6.2 TYPICAL FLØW DURATIØN CURVE AT INTAKE SITE

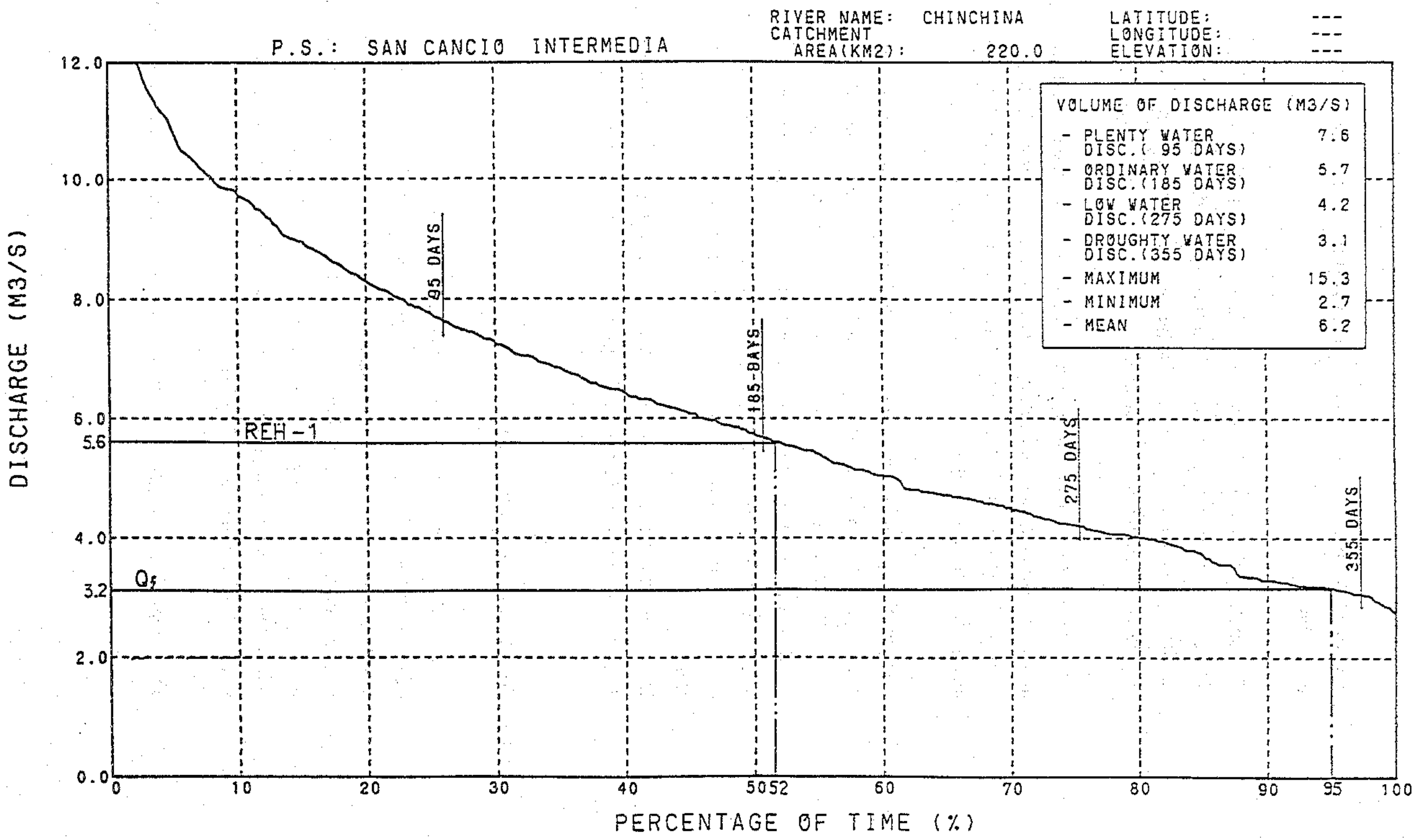
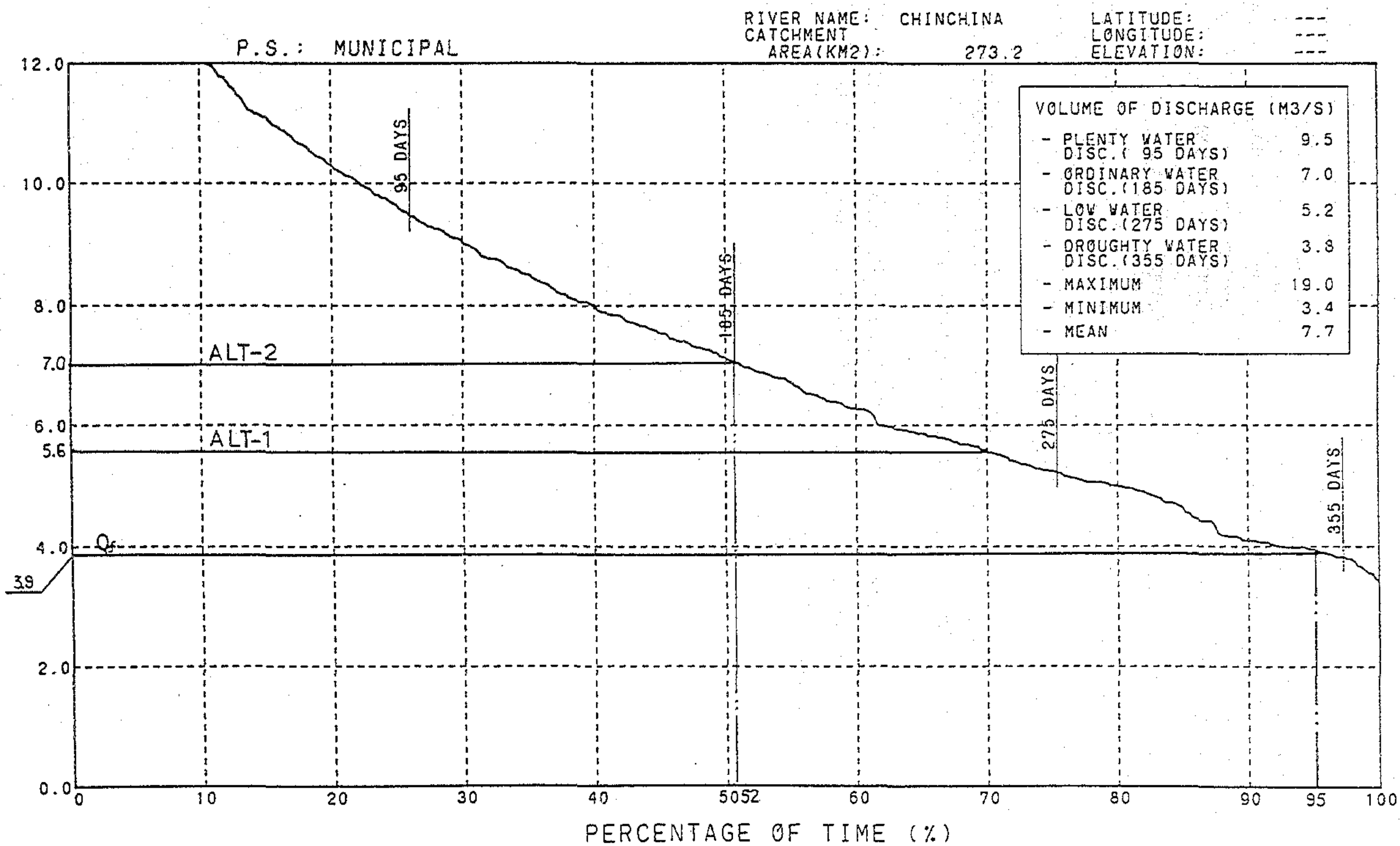


Fig-6.2 TYPICAL FLOW DURATION CURVE AT INTAKE SITE



Name of Plant	Q (m3/s)	H (m)	Generating output P (kW)	Installed capacity Po (kW)	P-Po (kW)
San Cancio	5.6	53.8	2,400	2,320	80
Intermedia	5.6	56.8	2,500	1,120	1,380
Municipal	5.6	79.6	3,600	2,112	1,488
Total			8,500	5,552	2,948

2) Arrangement of turbines of the same model will standardize the operation, inspection, maintenance and management, as well as spare parts.

A comparative analysis of the rehabilitation plan proposals is shown in Table 6.3 to consider the feasibility of utilizing the remaining catchment at the Municipal Power plant located furthest downstream.

Table 6.3 Alternative plans for San Cancio, Intermedia and Municipal Power plants Rehabilitation

Item		San Cancio	Intermedia	Municipal ALT-1	Municipal ALT-2
Available discharge, Q (m^3/s)		5.6	5.6	5.6	7.0 (Discharge at remaining river basin: 1.4)
Maximum output, P (kW)		2,400	2,500	3,600	4,500
Facility utilization factor (%)		88	88	94.5	88
Rehabilitation and improvement plan	Diversion weir	Modify and install sand trap gate or facility	-	Leave as it is	Modify to permanent structure
	Intake	Make change in facility design to secure discharge of 5.6 m/s	Leave as it is	Leave as it is	Partial improvement
	Desilting basin	Partial improvement	Partial improvement (together with head tank)	Partial improvement	Partial improvement
	Conduction channel	Leave as it is except cover placement	Modify to concrete channel entirely	Leave as it is except cover placement	
	Head tank	Increase adjusting capacity by modification	Partial improvement	Modify to suitable scale	Modify to suitable scale
	Penstocks	Leave as it is	Leave as it is	Leave as it is	
	Generating Equipment	Replace with new one	Replace with new one	Replace with new one	
	Powerhouse building	Partially renovate the existing building and improve only foundation section for generating equipment.			

(3) Selection of optimum plan

The results of the study on the rehabilitation plan of the San Cancio, Intermedia, and Municipal Power plants are shown in Table 6.4. The rehabilitation of these three run-of-river type hydroelectric power plants must be considered as a package.

As indicated in Table 6.4, the study team made the basic design during the F/S of the ALT-2 proposal for an additional intake of 1.4 m^3/s from the remaining catchment discharge at Municipal Power plant and recorded the results in the separate report

Table-6.4 Comparison of Rehabilitation Plan for the San Cancio / the Intermedia / the Municipal Power Plant

Alternative Plan	(1) Specifications for Existing Generating Facilities					(2) Rehabilitation Plan							(3) Recovered or Increased Energy	
	(10)	(11)	(12)	(13) Present facility capacity		(20)	(21)	(22)	(23)	(24)	(25)	(26)	(30)	(31)
	Max. available discharge Qo (m³/s)	Net head Ho (m)	Rated output Po (kW)	(14) Output Pe (kW)	(15) Generated energy Ee (GWh)	Max. available discharge Q1 (m³/s)	Standard net head H1 (m)	Theoretical output =9.8x(20)x(21) (kW)	Resultant efficiency η	Output =(22)x(23) P1 (kW)	Annual probable generated energy E1 (GWh)	Facility utilization factor ε (%)	Output =(24)-(14) ΔP (kW)	Annual probable generated energy (25)-(15) ΔE (GWh)
San Cancio	5.6	53.8	2,320	1,750	8.44	5.6	53.8	2,952	0.830	2,400	18.5	88	650	10.1
Intermedia	5.6	56.8	1,120	900	3.33	5.6	56.8	3,117	0.830	2,500	19.7	88	1,600	16.4
Municipal (ALT-1)	5.6	79.6	2,112	1,400	5.94	5.6	79.6	4,368	0.830	3,600	29.9	94	2,200	24.0
Municipal (ALT-2)	---	----	-----	-----	----	7.0	79.6	5,460	0.835	4,500	34.8	88	3,100	28.9
Total	---	----	5,552	4,050	17.71	---	----	10,437 11,529	-----	8,500 9,400	68.1 73.0	--	4,450 5,350	50.4 55.3

Alternative Plan	(4) Rehabilitation Work Cost (US$1000)					(5) Construction Cost per kW (US$/kW)		(6) Total of Annual Cost at Generating Terminal (US$1000)					(7) Average Generating Cost per kWh (mills/kWh)		(8) Cost/Benefit	(9)
	(40) Generating Equipment Cost			(44)	(45)	(50)	(51)	(60)	(61) Principal repayment amount for construction cost (25-year average)			(65)	(70)	(71)		
	(41) Foreign currency portion C1f	(42) Local currency portion C1ℓ	(43) (41)+(42) C1	Civil work cost C2	(43)+(44) C	Cost per ΔP =(45)/(30) C/ΔP	Cost per P1 =(45)/(24) C/P1	Operation and maintenance costs AOM	(62) Foreign currency portion 2.610 x (41) ÷ 25	(63) Local currency portion 2.016 x ((42)+(44)) ÷ 25	(64) (62)+(63)	(60)+(64)	per E1 =(65)/(25) ÷0.95	per ΔE =(65)/(31) ÷0.95	C/B	Priority order
San Cancio	1,900	750	2,650	600	3,250	5,035	1,350	9.6	197	111	308	318	18	33	1.40	4
Intermedia	1,900	750	2,650	1,050	3,700	2,310	1,500	10.0	197	145	342	352	19	23	1.37	3
Municipal (ALT-1)	2,300	900	3,200	500	3,700	1,700	1,050	14.4	240	115	355	369	13	16	0.89	2
Municipal (ALT-2)	2,450	1,000	3,450	750	4,200	1,350	950	18.0	255	140	395	413	13	15	0.86	1
Total ALT-1 ALT-2	6,100 6,250	2,400 2,500	8,500 8,750	2,150 2,400	10,650 11,150	2,406 2,100	1,250 1,200	34.0 37.6	634 649	373 397	1,007 1,046	1,041 1,084	16 16	22 21		

(Notes)

(1) : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

(7) : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

(8) : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

(15) : Ee is computed according to the average annual operation record for 5 years from 1984 to 1988

(23) : η is the resultant efficiency of turbine and generator.

(26) : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s\cdot hr)}{Q_1 \times 365 \times 24} \times 100(\%)$

(60) : The annual AOM is the amount which is equivalent to US$4 per kW.

(61) : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

6.1.4 Silva Hydroelectric Power plant

This power plant is located along the Piendamo River in Cauca Department. It is a run-of-river type hydroelectric power plant with a rated output of 604 kW owned and operated by CEDELCA.

The plant's civil structures, including the diversion weir, intake gate, open channel with a 609 m extension, desilting basin/head tank and penstocks, are well maintained. However, the horizontal shaft Francis type turbine manufactured in 1954 (rated output: 500 kW) broke down in 1972 and has been left without repair for 18 years. At present, only a horizontal shaft Francis type turbine with a rated output of 104 kW is in operation.

(1) Rehabilitation plan

The rehabilitation plan of the Silvia Power plant is limited to the replacement of the No. 1 generating unit with a rated output of 500 kW, which has been left unprepared. There is no other conceivable alternative plan.

The design discharge is set at (Q=1.5 m^3/s), in accordance to the river flow-duration at the intake gate, as shown in Fig. 6.3, is considered appropriate for a run-of-river-type hydroelectric power plant.

Although at present, a transformer of 480V/13.2 kV, 142.5 kVA is installed, the replacement of the generating equipment will necessitate the replacement of the transformer, as well, in accordance to the generator capacity.

A 13.2 kV distribution line connects the power plant with the surrounding consumers and Piendamo substation. There is no need to rehabilitate this distribution line.

Even if the No.1 horizontal shaft Francis type turbine (rated output: 500 kW) is replaced with a new product, the maximum output will only reach 240 kW. From the start, the No.1 unit had an excessive installed capacity of 260 kW.

The power generation plan under the rehabilitation is indicated in Table 6.5. The rehabilitation plan evaluates the necessity of replacing No.1 unit, which is not in operation, with a new 240 kW unit.

This will be decided according to the increase in power demand for the affected area.

Fig-6.3 TYPICAL FLOW DURATION CURVE AT INTAKE SITE

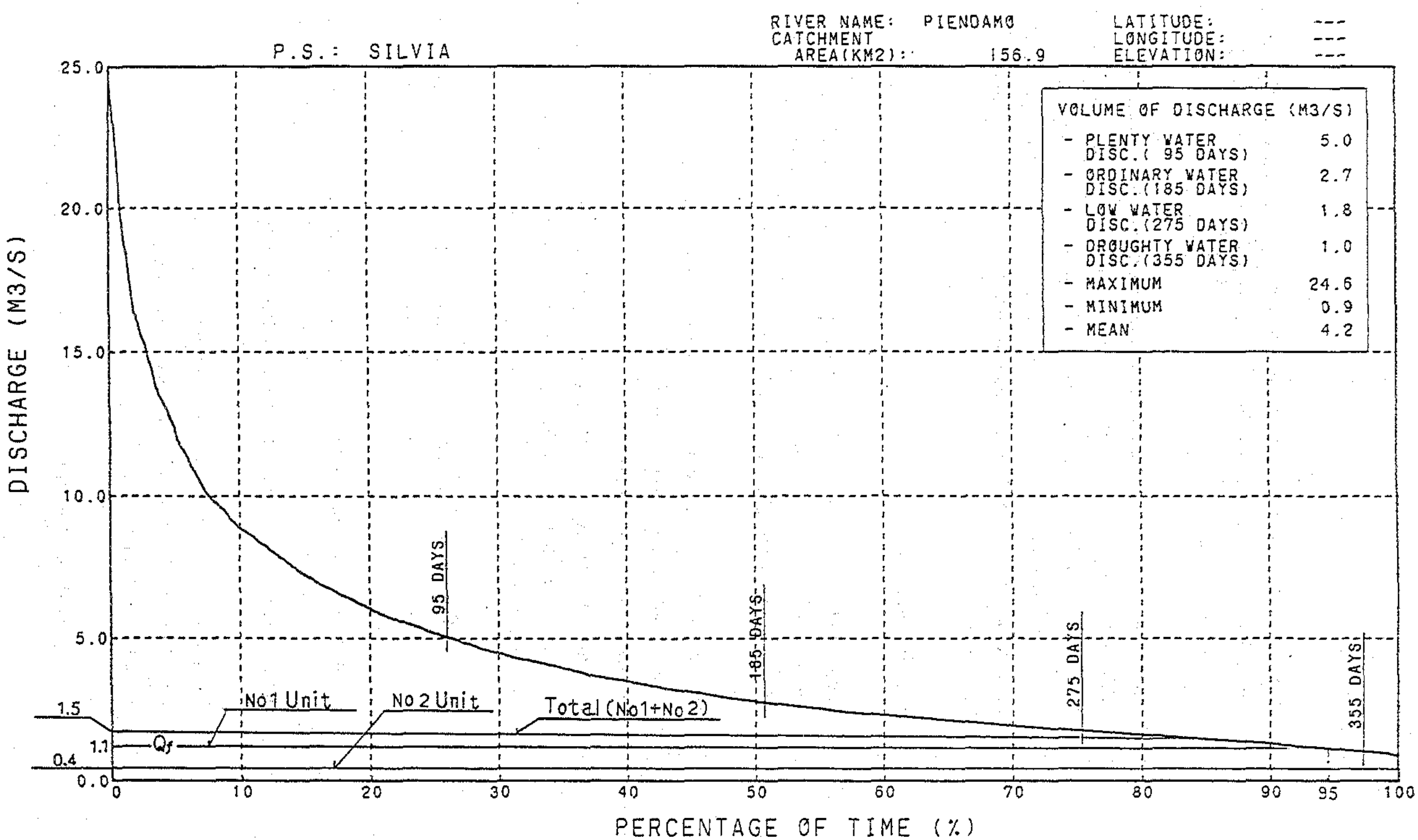


Table-6.5 Comparison of Rehabilitation Plan for the Silvia Power Plant

Alternative Plan	① Specifications for Existing Generating Facilities					② Rehabilitation Plan							③ Recovered or Increased Energy	
	⑩	⑪	⑫	⑬ Present facility capacity		⑳	㉑	㉒	㉓	㉔	㉕	㉖	㉚	㉛
	Max. available discharge Qo (m³/s)	Net head Ho (m)	Rated output Po (kW)	⑭ Output Pe (kW)	⑮ Generated energy Ee (GWh)	Max. available discharge Q1 (m³/s)	Standard net head H1 (m)	Theoretical output =9.8x⑳ x㉑ (kW)	Resultant efficiency η	Output =㉒x㉓ P1 (kW)	Annual probable generated energy E1 (GWh)	Facility utilization factor ε (%)	Output =㉔-⑭ ΔP (kW)	Annual probable generated energy ㉕-⑮ ΔE (GWh)
No1 Unit	1.1	31.0	500	0	0	1.1	31.0	334	0.740	240	2.1	100	240	2.1
No2 Unit	0.4	31.0	104	100	0.82	0.4	31.0	121	0.826	100	0.8	---	0	0
Total	1.5	31.0	604	100	0.82	1.5	31.0	455	------	340	2.9	98	240	2.1

Alternative Plan	④ Rehabilitation Work Cost (US$1000)					⑤ Construction Cost per kW (US$/kW)		⑥ Total of Annual Cost at Generating Terminal (US$1000)					⑦ Average Generating Cost per kWh (mills/kWh)		⑧ Cost/Benefit	⑨
	㊵ Generating Equipment Cost			㊹	㊺	㊿	51	60	61 Principal repayment amount for construction cost (25-year average)			65	70	71		
	㊶ Foreign currency portion C1f	㊷ Local currency portion C1ℓ	㊸ ㊶+㊷ C1	Civil work cost C2	㊸+㊹ C	Cost per ΔP =㊺/㉚ C/ΔP	Cost per P1 =㊺/㉔ C/P1	Operation and maintenance costs AOM	62 Foreign currency portion 2.610 x ㊶ ÷ 25	63 Local currency portion 2.016 x [㊷+㊹] ÷ 25	64 62+63	60+64	per E1 =65/㉕ ÷0.95	per ΔE =65/㉛ ÷0.95	C/B	Priority order
No1 Unit	458	184	642	34	676	2,800	2,800	1.0	48	18	66	67	33	33	2.02	——
No2 Unit	---	---	---	--	---	---	---	---	--	--	--	--	--	--		
Total	---	---	---	--	---	---	---	---	--	--	--	--	--	--		

(Notes)

① : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

⑦ : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

⑧ : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

⑮ : Ee is computed according to the average annual operation record for 5 years from 1984 to 1988

㉓ : η is the resultant efficiency of turbine and generator.

㉖ : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s\cdot hr)}{Q_1 \times 365 \times 24} \times 100(\%)$

60 : The annual AOM is the amount which is equivalent to US$4 per kW.

61 : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

6.1.5 Ovejas Hydroelectric Power plant

This power plant is a run-of-river type hydroelectric power plant with a rated output of 900 kW, located along the Ovejas River in Cauca Department and owned and operated by CEDELCA. It has been in operation for 51 years since 1939. As of July 1989, its maximum output was 650 kW and its generated energy for 1988 was recorded at 3,747 MWh.

(1) The present status of the power plant facilities and problems

A special characteristic of this power plant is the fact that its conduction channel which extends to a total length of 1,490 m, was constructed using iron pipe with a diameter of 1,800 mm. This penstock built in 1939 has horizontal shaft and vertical distortions in many locations causing leakages after over 50 years of service. The original 8 mm thick iron pipe, has been worn down to a 4 mm thickness.

The diversion weir, made of rough stone concrete, is filled with sand to its top edge, thereby making it incapable of intaking the required water quantity.

A horizontal shaft Francis type turbine manufactured in 1939 is still in operation. However, its output has declined to 650 kW, which is approximately 75% of the original rated output. The 500 kW gap between the theoretical output and the installed capacity causes this power plant to have a much smaller installed capacity.

(2) Alternative of the rehabilitation plan proposals

The main focus in the rehabilitation plan of the Ovejas Hydroelectric Power plant is predicting the lifespan of the 1,490 m long conduction channel.

This F/S, giving priority to safety first, proposes a rehabilitation plan in which all the installed conduction channel iron pipes which have been deformed, damaged or worn out are replaced and a new headrace structure is reestablished. Thus, a proposal to only provide replacements of the parts which have extreme distortion and worn out spots in the conduction channel iron pipes with new iron pipes is not adopted for the following reasons:

1) A proposal for partial replacement would make it necessary to undertake a large scale site inspection for determining the degree of distortion and wear of the iron

pipes, as well as safety rate. The present F/S study cannot accommodate such an investigation because of time and personnel constraints.

2) Most of the iron pipes need to be replaced, according to the results of the site reconnaissance and external observation.

The flow-duration curve at the intake gate point, shown in Figure 6.4, indicates that the maximum available discharge of the current plan, Q=7.0 m3/s, is uneconomical according to the water utilization rate. Also, it is necessary to remove the gap between the theoretical output (1,400 kW) and the installed capacity (900 kW). Therefore, the rehabilitation plan assumes the removal of all the iron pipes of the conduction channel , not only is a current status rehabilitation plan considered, but it is also compared with the power generation scale optimization proposals at the same time. Table 6.6 indicates the summary of the contents of the comparative alternative plans adopted for this rehabilitation plan.

Fig-6.4 TYPICAL FLOW DURATION CURVE AT INTAKE SITE

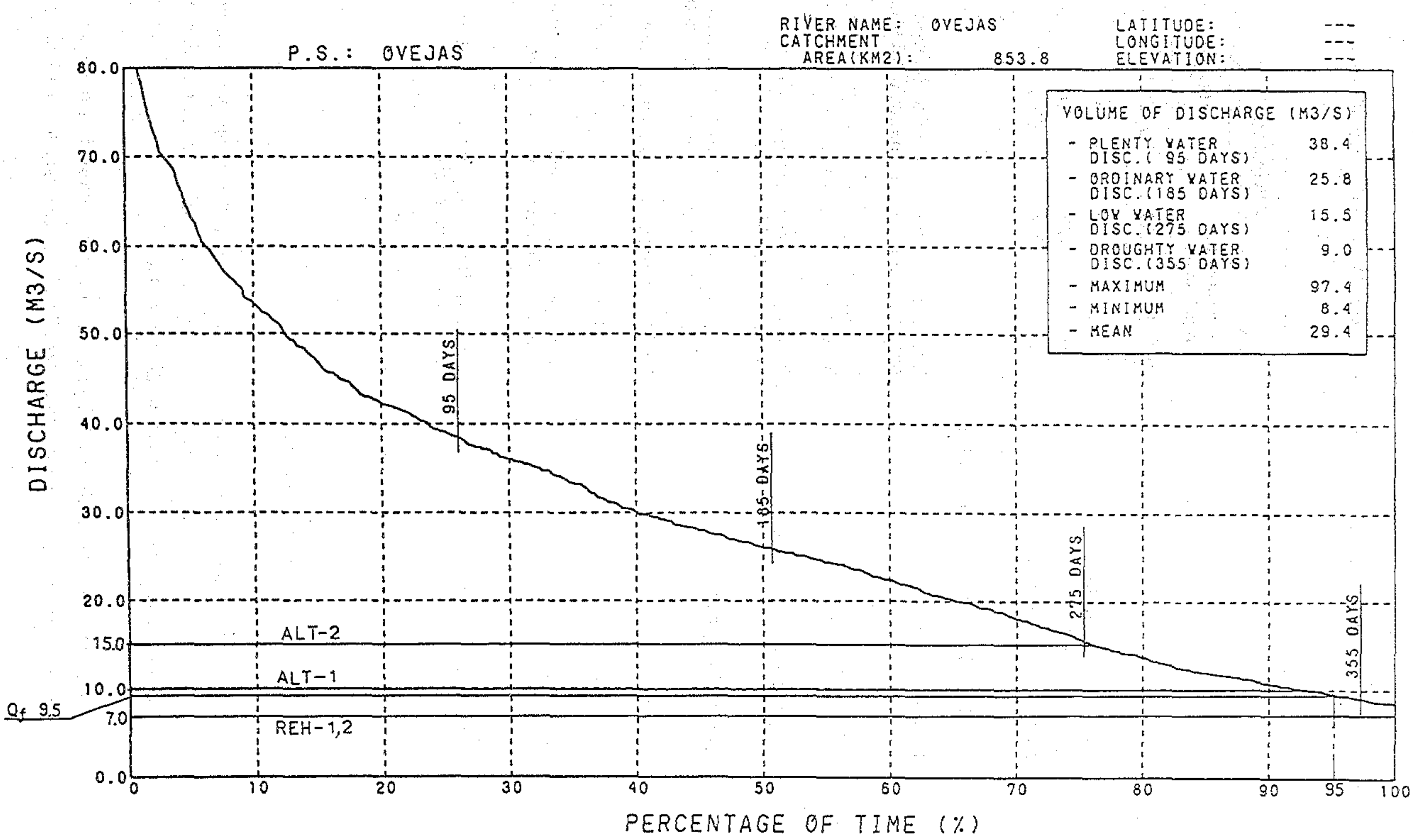


Table 6.6 Alternative Plans for Ovejas Power plant Rehabilitation

Item	Alternative			
	Steel conduit pipeline plan		RC culvert plan	
	REH-1	REH-2	ALT-1	ALT-2
Discharge, Q (m^3/s)	7.0	7.0	10.0	15.0
Max. output, P (kW)	1,000	1,000	2,100	3,100
Facility utilization factor (%)	100	100	99.5	94
Rehabilitation and improvement plan:				
Diversion weir	Improve because of damage to weir. A new sandtrap will be built (common to all plans).			
Intake	Improve diversion weir. Improvement to allow for stable intake of max. available discharge.			
Desilting basin	A new, suitable-sized one will be constructed (there is no desilting basin at present).			
Conduction channel	The cross section at certain sections will be enlarged for new max. available discharge.			
Head tank	It will be enlarged at its present location.			
Penstocks	Leave as it is		New construction	
Generating equipment	A new unit will be added to existing equipment to create a 2-unit system		Will be replaced new one	
Powerhouse building	An additional equipment building will be constructed downstream.			

(3) Selection of the optimum plan

The rehabilitation plan proposed in ALT-2 to change the conduction channel from iron pipes to a reinforced concrete culvert (refer to Table 6.7) is the most beneficial. Unfortunately, ALT-2 is economically unfeasible.

The basic design of the ALT-2 proposal has been reported in the F/S in a separate document. For this proposal to materialize, it is necessary to additionally conduct a topographical gauging and geological survey along the route where the new concrete culvert conduction channel would be built, as well as a study on the compensation items. At the same time, the construction work cost for the headrace structure would need to be recalculated.

Table-6.7 Comparison of Rehabilitation Plan for the Ovejas Power Plant

Alternative Plan		① Specifications for Existing Generating Facilities			⑬ Present facility capacity		② Rehabilitation Plan							③ Recovered or Increased Energy	
		⑩ Max. available discharge Qo (m³/s)	⑪ Net head Ho (m)	⑫ Rated output Po (kW)	⑭ Output Pe (kW)	⑮ Generated energy Ee (GWh)	⑳ Max. available discharge Q1 (m³/s)	㉑ Standard net head H1 (m)	㉒ Theoretical output =9.8x⑳x㉑ (kW)	㉓ Resultant efficiency η	㉔ Output =㉒x㉓ P1 (kW)	㉕ Annual probable generated energy E1 (GWh)	㉖ Facility utilization factor ε (%)	㉚ Output =㉔-⑭ ΔP (kW)	㉛ Annual probable generated energy ㉕-⑮ ΔE (GWh)
REH-1&2	New	0	0	0	0	0	3.5	26.0	891	0.830	700	6.5	100	700	6.5
REH-1&2	Old	7.0	24.5	900	650	2.97	3.5	26.0	892	0.340	300	2.6	100	-350	-0.4
REH-1&2	Total	7.0	24.5	900	650	2.97	7.0	26.0	1,783		1,000	9.1	100	350	6.1
ALT-1							10.0	26.0	2,548	0.830	2,100	18.4	99.5	1,450	15.4
ALT-2							15.0	26.0	3,822	0.830	3,100	26.2	94	2,450	23.2

Alternative Plan	④ Rehabilitation Work Cost (US$1000)					⑤ Construction Cost per kW (US$/kW)		⑥ Total of Annual Cost at Generating Terminal (US$1000)					⑦ Average Generating Cost per kWh (mills/kWh)		⑧ Cost/Benefit	⑨
	㊵ Generating Equipment Cost: ㊶ Foreign currency portion Cif	㊷ Local currency portion Ciℓ	㊸ ㊶+㊷ C1	㊹ Civil work cost C2	㊺ ㊸+㊹ C	(50) Cost per ΔP =㊺/㉚ C/ΔP	(51) Cost per P1 =㊺/㉔ C/P1	(60) Operation and maintenance costs AOM	(61) Principal repayment amount for construction cost (25-year average): (62) Foreign currency portion 2.610 x ㊶ ÷ 25	(63) Local currency portion 2.016 x [㊷+㊹] ÷ 25	(64) (62)+(63)	(65) (60)+(64)	(70) per E1 =(65)/㉕ ÷0.95	(71) per ΔE =(65)/㉛ ÷0.95	C/B	Priority order
REH-1	1,000	400	1,400	5,150	6,550	18,800	6,500	4.0	106	447	553	557	65	96	6.19	4
REH-2	1,000	400	1,400	2,900	4,300	12,400	4,300	4.0	106	266	372	376	44	65	3.98	3
ALT-1	2,200	900	3,100	3,650	2,650	4,700	3,200	8.4	231	366	597	605	35	41	2.84	2
ALT-2	2,650	1,050	3,700	4,300	8,000	3,300	2,600	12.4	277	433	710	722	29	33	2.63	1

(Notes)

① : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

⑦ : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

⑧ : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

⑮ : Ee is computed according to the average annual operation record for 5 years from 1984 to 1988 .

㉓ : η is the resultant efficiency of turbine and generator.

㉖ : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s \cdot hr)}{Q_1 \times 365 \times 24} \times 100(\%)$

(60) : The annual AOM is the amount which is equivalent to US$4 per kW.

(61) : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

6.1.6 La Vuelta Hydroelectric Power plant

This power plant is a run-of-river type hydroelectric power plant with a rated output of 2000 kW. It is located along the Andagueda River in Choco Department and owned and managed by Choco Mining Company. It has been in operation for 76 years since it was built in 1916. Its maximum output, however, has declined to 500 kW and its generated energy in 1986 was recorded to be 2,364 MWh.

(1) The present status of the power plant and problems

This power plant is a hydroelectric power plant which has a small head. It uses the head to provide a short cut for the winding river flow from the abundant water quantity of the Andagueda River.

The diversion weir, built around 1916, has been lost and the facility in the forebay has deteriorated. The river water is scooped up by Trincho, a wooden board made of special lumber with a large specific gravity, which is suspended by wire at a point approximately 130 m downstream from the intake gate point.

The intake from the river is through the perpendicularly excavated, unlined open channel, with a width of 15 - 35 m, length of 78 m, and water depth of 4.00 m. An intake gate screen and water control gate have been installed in the front side of the powerhouse. The maximum water level at the time of a flood is recorded at elev. 75 feet, by the indicator gauge on the front side of the intake gate.

The powerhouse size is relatively larger than needed due to the performance of the generating equipment and obsolete arrangement plan. However, the structure itself is still strong.

On the upstream side of the powerhouse there is a still functioning navigation lock for boats. The water level at this navigation lock indicates the total head of this power plant. The average total head obtained from the water level observation reference material (from January to September 1921) is 14 feet (4.31 m).

The generating equipment consists of two vertical shaft Francis type turbine with a rated output of 1000 kW, which are in operation. These generators were manufactured in 1915 and in 1930 respectively.

(2) Comparative alternative rehabilitation plans

Judging from the flow-duration curve at the intake gate point shown in Figure 6.5, it is possible to raise the current available discharge for the power generation plan of this run-of-river hydroelectric power plant, from Q=54 m^3/s to 100 m^3/s. Therefore, two comparative plans with maximum available discharges of 50 m^3/s and 100 m^3/s, respectively, are adopted.

The existing turbines are the old Francis type. Since this type is no longer manufactured, they must be replaced with a different model, making it impossible to install the new equipment at the current location inside the powerhouse. Therefore, the layout for the rehabilitation plan will be studied within the context of building a new route nearby.

The cost of reconstructing the diversion weir, which has been lost, represents a large portion of the total budget for the rehabilitation plan. However, if this diversion weir is rebuilt in concrete, the increase in head would be considerable.

The alternative rehabilitation plans for this power plant is, as shown in Table 6.8 , are divided into either reinforcing and repairing the existing Trincho at the current site, or changing to a concrete intake dam.

Fig-6.5 TYPICAL FLOW DURATION CURVE AT INTAKE SITE

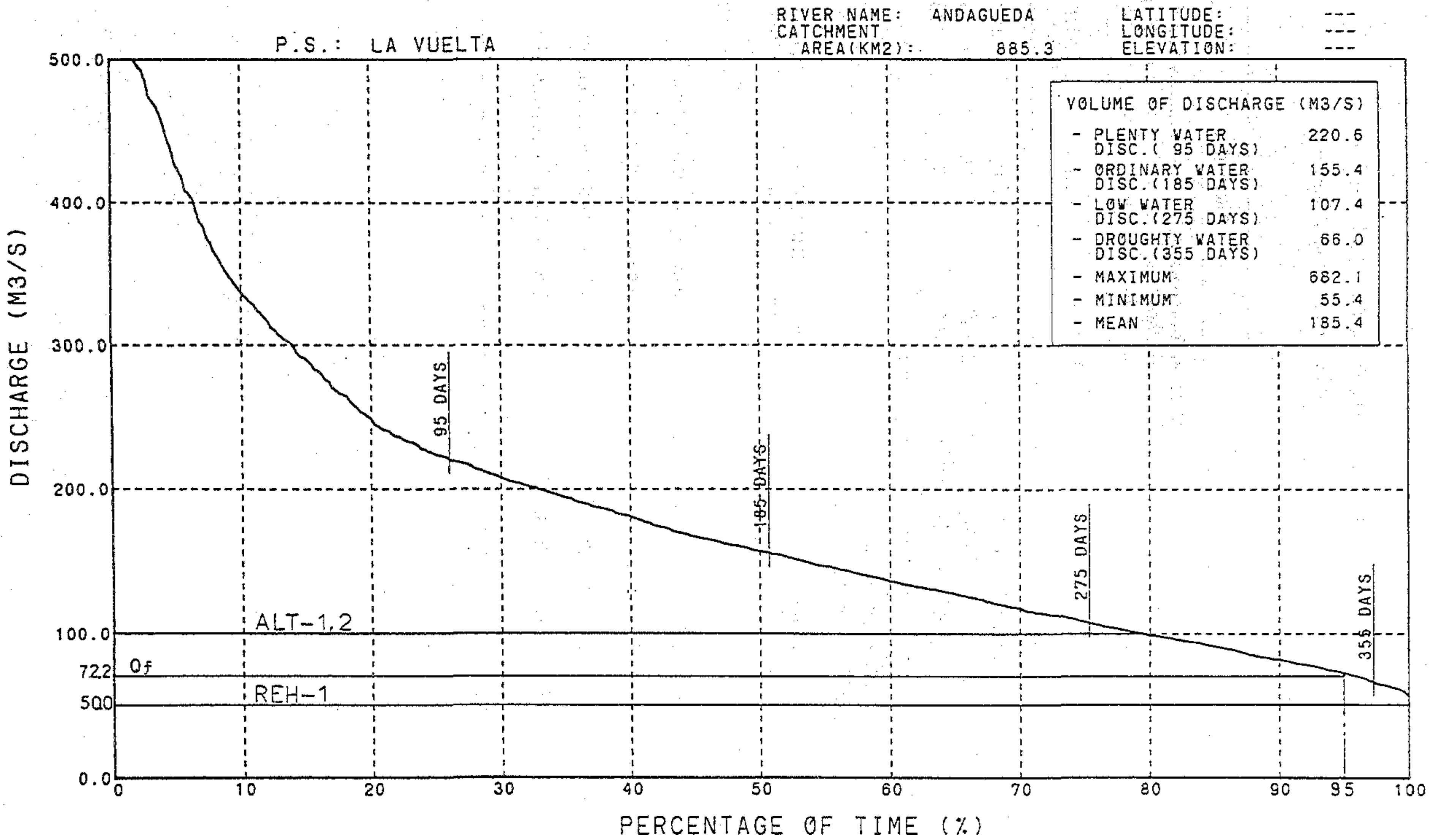


Table 6.8 Alternative Plans for La Vuelta Power plant Rehabilitation

Item	Alternative		
	Proposal for repairing the Trincho at the present site	Proposal for changing the structure to the concrete intake dam	
	REH-1	ALT-1	ALT-2 (Tentative)
Discharge, Q (m^3/s)	50	100	100
Max. output, P (kW)	1,700	3,500	7,700
Facility utilization factor (%)	100	96	96
Rehabilitation and improvement plan:			
Diversion weir		Restore TRINCHO at existing location	Renovate the TRINCHO with reinforced concrete
Forebay	New one at adjacent site		
Intake	New one at adjacent site		
Generating equipment	Replace with new equipment		
Powerhouse building	New building at adjacent site		

(3) Selection of optimum plan

The summary of the result of the study on the comparative alternative plans is shown in Table 6.9..

The relatively advantageous proposal as the rehabilitation plan is the ALT-2 Proposal for increasing the available discharge from 50 m^3/s to 100 m^3/s, by changing the diversion weir structure to a concrete dam thus gaining a greater head. However, in the case of the ALT-2 Proposal, since the following uncertain elements are involved, it is necessary to conduct an additional and more detailed study in order to check if the proposal is actually feasible.

1) The concrete intake dam base, especially the geological conditions on the left bank hilly part have not been studied.
2) The impact and range of the back water due to dam scooping are not known.
3) No study has been conducted with regard to the items to be compensated such as building, agricultural field, and forest etc.

During the F/S the basic design on ALT-1 was conducted and is contained in a separate report.

It is inappropriate to evaluate the rehabilitation plan solely by the expected benefits for La Vuelta Power plant, since the following adverse conditions exist:

1) Since the plant is a run-of-river type hydroelectric power plant with a low head, it has the tubular type with a relatively higher cost.
2) Although the plan is for rehabilitation, almost all the facilities need to be replaced.
3) Since the plant is located in an isolated area, material transportation and construction work costs will be relatively high.

Table-6.9 Comparison of Rehabilitation Plan for the La Vuelta Power Plant

Alternative Plan	① Specifications for Existing Generating Facilities					② Rehabilitation Plan							③ Recovered or Increased Energy	
	⑩	⑪	⑫	⑬ Present facility capacity		⑳	㉑	㉒	㉓	㉔	㉕	㉖	㉚	㉛
	Max. available discharge Qo (m^3/s)	Net head Ho (m)	Rated output Po (kW)	⑭ Output Pe (kW)	⑮ Generated energy Ee (GWh)	Max. available discharge Q1 (m^3/s)	Standard net head H1 (m)	Theoretical output =9.8x⑳x㉑ (kW)	Resultant efficiency η	Output =㉒x㉓ P1 (kW)	Annual probable generated energy E1 (GWh)	Facility utilization factor ε (%)	Output =㉔-⑭ ΔP (kW)	Annual probable generated energy ㉕-⑮ ΔE (GWh)
REH-1	54.0	4.8	2,000	500	6.25	50.0	4.4	2,156	0.815	1,700	15.4	100	1,200	9.1
ALT-1						100.0	4.4	4,312	0.823	3,500	29.9	96	3,000	23.6
ALT-2						100.0	9.65	9,457	0.823	7,700	65.7	96	7,200	59.4

Alternative Plan	④ Rehabilitation Work Cost (US$1000)					⑤ Construction Cost per kW (US$/kW)		⑥ Total of Annual Cost at Generating Terminal (US$1000)					⑦ Average Generating Cost per kWh (mills/kWh)		⑧ Cost/Benefit	⑨
	㊵ Generating Equipment Cost			㊹	㊺	㊿	51	60	61 Principal repayment amount for construction cost (25-year average)			65	70	71		
	㊶ Foreign currency portion Cif	㊷ Local currency portion Cil	㊸ ㊶+㊷ Ci	Civil work cost C2	㊸+㊹ C	Cost per ΔP =㊺/㉚ C/ΔP	Cost per P1 =㊺/㉔ C/P1	Operation and maintenance costs AOM	62 Foreign currency portion 2.610 x ㊶ ÷ 25	63 Local currency portion 2.016 x [㊷+㊹] ÷ 25	64 62+63	60+64	per E1 =65/㉕ ÷0.95	per ΔE =65/㉛ ÷0.95	C/B	Priority order
REH-1	3,950	1,600	5,550	2,410	7,960	6,600	4,700	6.8	414	323	737	744	51	86	4.24	3
ALT-1	5,400	2,150	7,550	3,320	10,870	3,600	3,100	14.0	561	441	1,002	1,016	36	45	2.71	2
ALT-2	7,400	2,950	10,350	9,700	20,120	2,800	2,600	30.8	772	1,026	1,798	1,829	29	32	2.29	1

(Notes)

① : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

⑦ : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

⑧ : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

⑮ : Ee is computed according to the average annual operation record for 5 years from 1984 to 1988 .

㉓ : η is the resultant efficiency of turbine and generator.

㉖ : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s \cdot hr)}{Q_1 \times 365 \times 24} \times 100(\%)$

60 : The annual AOM is the amount which is equivalent to US$4 per kW.

61 : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

6.1.7 Julio Bravo Hydroelectric Power plant

This power plant is a run-of-river type hydroelectric power plant (rated output: 1500 kW), located along the Pasto River in Nariño Department and owned and managed by CEDENAR. It has completely stopped operation since 1984 because of damage to its penstock.

(1) The present status of the power plant facilities and problems

No. 1, No. 2 and No. 3 Pelton type turbines (500 kW each) were originally installed at the power plant in 1942. However No.3 unit has already been removed due to failure.

In 1948, during replacement of a penstock which had exploded, No. 2 unit was moved to No. 4 unit and No. 5 unit was added to replace No. 3 unit. At present the generating equipment consists of No. 1, No. 4, and No. 5.

The second penstock became unusable in 1984 because of wear and tear. Power generation at the plant ceased in the same year. The presently installed No. 1, No. 4 and No. 5 units are also extensively damaged, having been in service for a period of 42 to 48 years. They have been left unattended, without any inspection or maintenance. The step-up transformer has also been removed and installed at another power plant.

The open channel, approximately 2,500 m long, is a structure built from stone piling, and is maintained in relatively good condition. However, the diversion weir and intake damaged gate have been partially damaged.

Although the desilting basin remains in good form, its function must be checked since its design is obsolete.

The water flowing into the intake gate, coming from Pasto City located upstream, has been progressively polluted (refer to Table 6.10).

Table 6.10 The Result of the Pasto River Water Quality Analysis

Year	pH	Specific resistance (Ohm-cm)
1985	6.3 - 4.0	345 - 166
1986	6.8 - 4.4	346 - 162
1987	6.8 - 4.2	302 - 182
1988	5.2 - 4.6	460 - 315

(2) Comparative alternative rehabilitation plans

Since most of the headrace structures of this hydroelectric power plant have been damaged or become structurally defective, rehabilitation or reconstruction is necessary except for the 2,500 m long conduction channel. New replacements for the generating equipment or step-up transformer need to be procured for the reasons described in the preceding section.

According to the results of the hydrological analysis, the current open channel has the capacity for safely conducting a discharge of up to 4.0 m^3/s. Therefore, in this rehabilitation plan, not only was the current status rehabilitation plan considered, but it was also compared to the plan that includes optimizing the power generation scale.

The typical flow-duration curve at the intake site (Figure 6.6) shows the planned available discharges are set at 2.0 m^3/s (the maximum available discharge of the currently installed power plant), 3.0 m^3/s and 4.0 m^3/s, within the range of the discharge facility utilization factor of 50%, and the respective plans will be compared. The outline of the comparative alternative plans is shown in Table 6.11.

Even with rehabilitation to the current status and planned available discharge of 2.0 m^3/s, there is an approximately 23 m correction in the positive direction in the standard net head, and a gap between the theoretical output and installed capacity. Thus, the installed capacity (1,500 kW) of the existing generating equipment will naturally increase.

Fig-6.6 TYPICAL FLOW DURATION CURVE AT INTAKE SITE

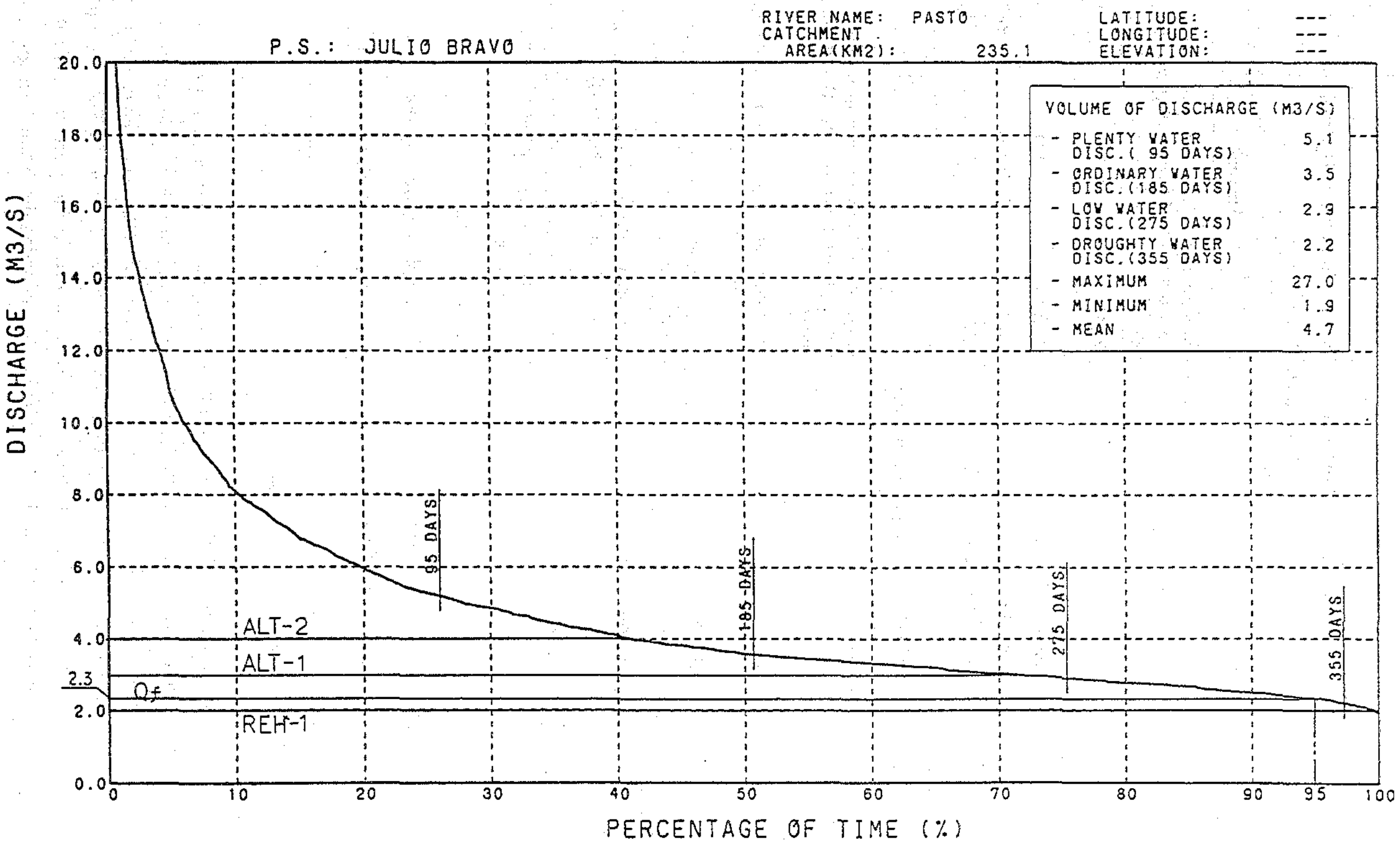


Table 6.11 Alternative Plans for Julio Bravo Hydroelectric Power plant Rehabilitation

Item	Alternative		
	Rehabilitation of the existing facilities	Increase of power output	
	REH	ALT-1	ALT-2
Discharge, Q (m^3/s)	2.0	3.0	4.0
Max. output, P (kW)	2,300	3,500	4,600
Facility utilization factor (%)	100	97	85

Rehabilitation and improvement plan:

Diversion weir	Because of damage to this weir, a new diversion weir will be built (common to all plans)
Intake	Improvement to allow for stable intake of maximum available discharge
Desilting basin	A new, suitable-sized one will be constructed (common to all plans)
Conduction channel	Maintain the current status, except for attaching the cover (common to all plans)
Head tank	Will be expanded at its present location to increase regulating capacity and a new spillway will be installed
Penstocks	New construction
Generating equipment	Will be replaced with new one
Powerhouse building	Will be expanded at its present location

(3) Selection of optimum plan

A summary of the analysis of the comparative alternative plans is shown in Table 6.12. From this study, ALT-1 was selected as the optimum plan. The basic design for ALT-1 was conducted during the F/S. However, the results in Table 6.12 indicate that there is little difference between ALT-1 and ALT-2. Accordingly, the optimum available discharge should be reevaluated at planned available discharge values ranging from Q = 3.0 - 5.0 m^3/s in conducting the detailed design.

Table-6.12 Comparison of Rehabilitation Plan for the Julio Bravo Power Plant

Alternative Plan	(1) Specifications for Existing Generating Facilities					(2) Rehabilitation Plan							(3) Recovered or Increased Energy	
	(10)	(11)	(12)	(13) Present facility capacity		(20)	(21)	(22)	(23)	(24)	(25)	(26)	(30)	(31)
	Max. available discharge Qo (m^3/s)	Net head Ho (m)	Rated output Po (kW)	(14) Output Pe (kW)	(15) Generated energy Ee (GWh)	Max. available discharge Q_1 (m^3/s)	Standard net head H_1 (m)	Theoretical output =9.8x(20) x(21) (kW)	Resultant efficiency η	Output =(22)x(23) P_1 (kW)	Annual probable generated energy E_1 (GWh)	Facility utilization factor ε (%)	Output =(24)-(14) ΔP (kW)	Annual probable generated energy (25)-(15) ΔE (GWh)
REH-1	2.0	120.0	1,500	0	0	2.0	143.0	2,802	0.830	2,300	20.4	100	2,300	20.4
ALT-1						3.0	143.0	4,204	0.835	3,500	29.4	97	3,500	29.4
ALT-2						4.0	143.0	5,605	0.835	4,600	34.6	85	4,600	34.6

Alternative Plan	(4) Rehabilitation Work Cost (US$1000)					(5) Construction Cost per kW (US$/kW)		(6) Total of Annual Cost at Generating Terminal (US$1000)					(7) Average Generating Cost per kWh (mills/kWh)		(8) Cost/Benefit	(9)
	(40) Generating Equipment Cost			(44)	(45)	(50)	(51)	(60)	(61) Principal repayment amount for construction cost (25-year average)			(65)	(70)	(71)		
	(41) Foreign currency portion C_{1f}	(42) Local currency portion $C_{1\ell}$	(43) (41)+(42) C_1	Civil work cost C_2	(43)+(44) C	Cost per ΔP =(45)/(30) C/ΔP	Cost per P_1 =(45)/(24) C/P_1	Operation and maintenance costs AOM	(62) Foreign currency portion 2.610 x (41) ÷ 25	(63) Local currency portion 2.016 x [(42)+(44)] ÷ 25	(64) (62)+(63)	(60)+(64)	per E_1 =(65)/(25) ÷ 0.95	per ΔE =(65)/(31) ÷ 0.95	C/B	Priority order
REH-1	1,900	750	2,650	950	3,600	1,570	1,570	9.2	200	136	336	345	18	18	1.16	3
ALT-1	2,300	950	3,250	1,050	4,300	1,220	1,220	14.0	242	158	400	414	15	15	0.96	1
ALT-2	2,650	1,050	3,700	1,200	4,900	1,070	1,070	18.4	275	183	458	476	15	15	0.94	1

(Notes) (1) : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

(7) : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

(8) : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

(15) : Ee is computed according to the average annual operation record for 5 years from 1984 to 1988 .

(23) : η is the resultant efficiency of turbine and generator.

(26) : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s \cdot hr)}{Q_1 \times 365 \times 24} \times 100(\%)$

(60) : The annual AOM is the amount which is equivalent to US$4 per kW.

(61) : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

6.1.8 Zaragoza Hydroelectric Power Plant

This power plant is run-of-river type hydroelectric power plant with a rated output of 1,560 kW. It is located along the Surata River in Santander department and owned and managed by ESSA.

The power plant has three horizontal shaft Francis type turbines (rated output: 520 kW), which were manufactured in 1932, 1937 and 1950 respectively. The current output as of September 1989 was 1,200 kW, or 77%, of the rated output. The generated energy in 1988 was recorded as 4,870.3 MWh.

(1) The current status of the power plant and problems

A conducting bank crossing the river diagonally is installed for conducting the water into the intake gate, instead of a diversion weir. The intake facility has been repaired every time it was damaged, thus maintaining its function. However, it is not well-designed. The conduction channel (open channel), approximately 1,700 m long, was built along a steep mountain slope, leaving no room for expanding the width. The tank capacity is small.

Operation of the generating equipment has been stopped for repairs but at present all of the machines from are in operation. However, according to the record on the yearly generated energy, the plant utilization factor is low, at 36 - 57%.

Year	Annual generated energy (MWh)	Plant utilization factor (%)
1984	6,882.4	50
1985	7,757.5	57
1986	6,883.7	50
1987	5,067.9	37
1988	4,870.3	36

The water supply diversion weir and water treatment plant for the city of Bucaramanga are located directly downstream from the power plant outlet. The JICA Study Team obtained the observation record on the Surata River discharge for 7 years between 1982 and 1988 at the intake gate point of the water treatment plant. However, the record for the first 5 years has too many unrecorded days. Thus, the record for only the 2 years between 1987 and 1988 could be used.

There is an active fault running N 30° W approximately 300 m downstream from the powerhouse. However, it is not directly related to this rehabilitation plan.

(2) Comparative alternative rehabilitation plans

The flow-duration curve (Figure 6.7) at the intake gate of the Zaragoza Hydroelectric Power plant indicates that the maximum available discharge for the current power plant Q=6.5 m^3/s is an appropriate value as the design discharge for a run-of-river type hydroelectric power plant. For reference purpose, a plan has been studied for raising the maximum available discharge to Q=10.0 m^3/s. Table 6.13 shows the outline of the comparative alternative plans.

Fig-6.7 TYPICAL FLOW DURATION CURVE AT INTAKE SITE

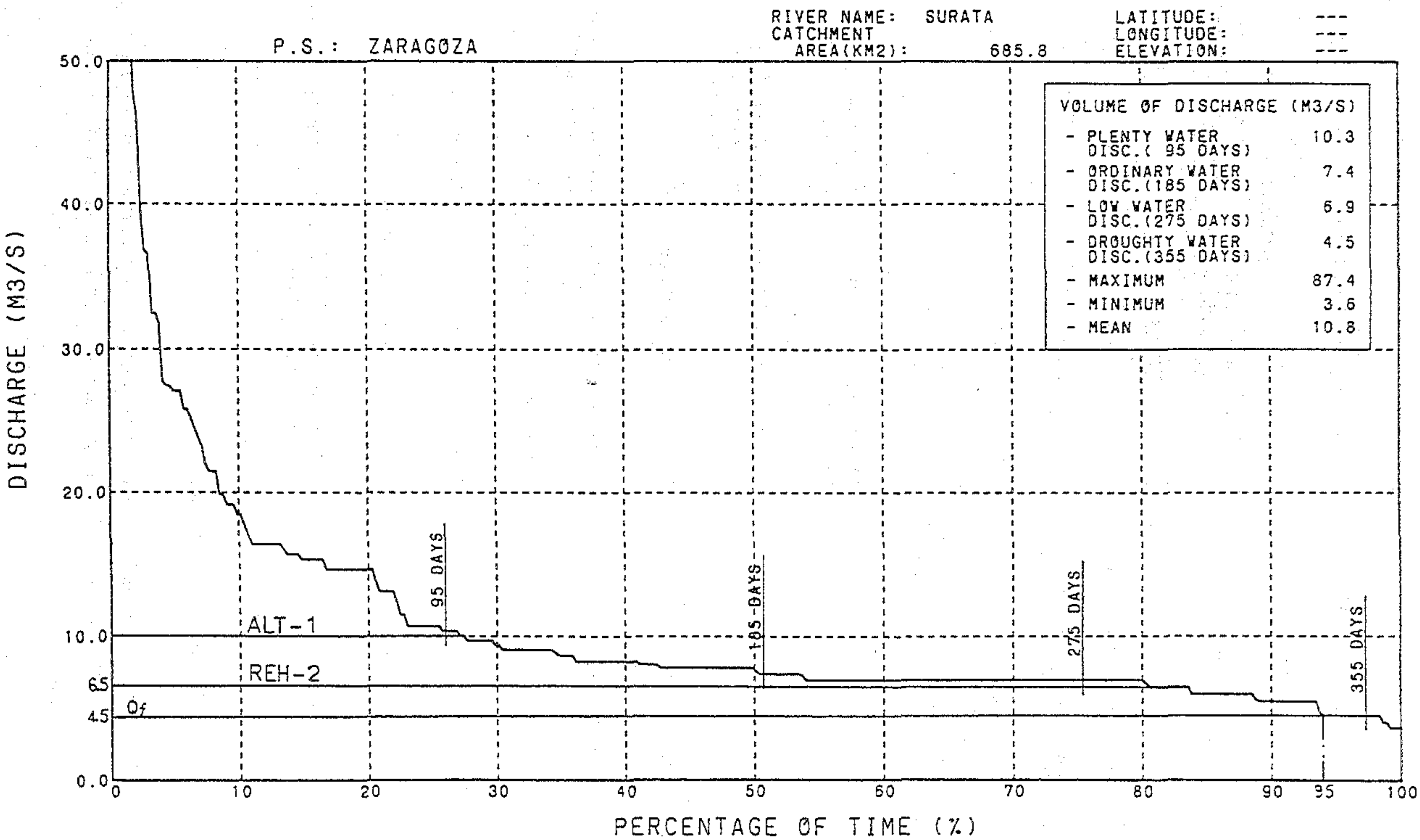


Table 6.13 Alternative Plans for Zaragoza Hydroelectric Power plant Rehabilitation:

Item	Alternative	
	Rehabilitation of the existing facilities	Increase of power output
	REH-1	ALT-1
Available discharge Q(m^3/s)	6.5	10.0
Maximum generated energy, P(kW)	1,700	2,600
Discharge facility utilization factor (%)	96.5	78
Rehabilitation/reform plan:		
Diversion weir	Maintain the conduction bank structure	Reform the diversion weir and install sand for removal gate
Intake gate	Maintain the current status	Modify the design in accordance to the diversion weir structure
Desilting basin	Reform to fit the appropriate scale	
Conduction channel	Maintain the current status	Execute work for expanding the width, and reform
Head tank	Reform in order to increase the capacity	
Penstock	Maintain the current status	Newly install
Generating equipment	Install two units of new equipment	
Powerhouse	Reform the foundation of the generating equipment by using the existing powerhouse.	

(3) Selection of the optimum plan

Table 6.14 indicates the summary of the study on the comparative alternative plans. ALT-1 was selected as the optimum plan because it is both economic advantageous and beneficial.

Table-6.14 Comparison of Rehabilitation Plan for the Zaragoza Power Plant

Alternative Plan	① Specifications for Existing Generating Facilities					② Rehabilitation Plan							③ Recovered or Increased Energy	
	⑩	⑪	⑫	⑬ Present facility capacity		⑳	㉑	㉒	㉓	㉔	㉕	㉖	㉚	㉛
	Max. available discharge Qo (m^3/s)	Net head Ho (m)	Rated output Po (kW)	⑭ Output Pe (kW)	⑮ Generated energy Ee (GWh)	Max. available discharge Q1 (m^3/s)	Standard net head H1 (m)	Theoretical output =9.8x⑳x㉑ (kW)	Resultant efficiency η	Output =㉒x㉓ P1 (kW)	Annual probable generated energy E1 (GWh)	Facility utilization factor ε (%)	Output =㉔-⑭ ΔP (kW)	Annual probable generated energy ㉕-⑮ ΔE (GWh)
REH-1	6.5	30.0	1,560	1,200	6.29	6.5	32.8	2,089	0.830	1,700	14.7	96.5	500	8.4
ALT-1						10.0	32.8	3,214	0.830	2,600	18.4	78	1,400	12.1

Alternative Plan	④ Rehabilitation Work Cost (US$1000)					⑤ Construction Cost per kW (US$/kW)		⑥ Total of Annual Cost at Generating Terminal (US$1000)					⑦ Average Generating Cost per kWh (mills/kWh)		⑧ Cost/Benefit	⑨
	㊵ Generating Equipment Cost			㊹	㊺	㊿	(51)	(60)	(61) Principal repayment amount for construction cost (25-year average)			(65)	(70)	(71)		
	㊶ Foreign currency portion Clf	㊷ Local currency portion Clℓ	㊸ ㊶+㊷ C1	Civil work cost C2	㊸+㊹ C	Cost per ΔP =㊺/㉚ C/ΔP	Cost per P1 =㊺/㉔ C/P1	Operation and maintenance costs AOM	(62) Foreign currency portion 2.610 x ㊶ ÷ 25	(63) Local currency portion 2.016 x [㊷+㊹] ÷ 25	(61) (62)+(63)	(60)+(61)	per E1 =(65)/㉕ ÷0.95	per ΔE =(65)/㉛ ÷0.95	C/B	Priority order
REH-1	2,100	850	2,950	400	3,350	6,650	1,950	6.0	220	98	318	324	23	40	1.91	2
ALT-1	2,250	900	3,150	1,000	4,150	2,900	1,600	10.4	236	154	390	400	23	35	1.74	1

(Notes)

① : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

⑦ : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

⑧ : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

⑮ : Ee is computed according to the average annual operation record for 5 years from 1984 to 1988 .

㉓ : η is the resultant efficiency of turbine and generator.

㉖ : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s\cdot hr)}{Q_1 \times 365 \times 24} \times 100(\%)$

(60) : The annual AOM is the amount which is equivalent to US$4 per kW.

(61) : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

6.1.9 Lagunilla Hydroelectric Power plant

This power plant is a run-of-river type hydroelectric power plant with a rated output of 392 kW. It is located along the Lagunilla river in Tolima Department and owned and operated by ELECTROLIMA. The operation of the power plant started in 1940 but it has not been in operation since 15 years ago due to the failure of the generating equipment. The plant is deserted and its transmission lines have been removed. The intake facility has been lost in the river during the Nevado del Ruiz volcanic eruption in 1985.

(1) The current status of the power plant and problems

Although there is no intake facility remaining, before plant operation stopped, it was using a simple diversion weir installed upstream of a water fall. This is a 56 m-long open channel which leads to the head tank. The total head of the water fall is approximately 300 m. However, due to the topographical restraints, the power plant was using only approximately 1/3 of the total head.

In 1984, a feasibility study was conducted for achieving the planned available discharge of Q=9.0 m^3/s, and the total length of the right bank conducting channel, L = 4,960 m, total head, H = 897 m and, the maximum output, P = 66.5 MW, through establishing a series of 2 hydroelectric power plants and the installation of a diversion weir at an elevation 1,960 m at a point upstream of the water fall. However, the plan has not been realized because of the Nevado del Ruiz volcanic eruption in 1985.
Since there is no hydrological gauging station in the catchment of the Lagunilla River, it is difficult to prepare a rehabilitation plan for this power plant. In this F/S report, the power generation plan was established according to the discharge data from 8 years of observations from 1957 to 1964 at the El Bosque Hydrological gauging station, which was collected by ELECTRAGUAS, the original organization of the present HIMAT. A hydrological gauging station needs to be set up immediately to gather current flow data of the Lagunilla River for the realization of this plan.

(2) Comparative alternative rehabilitation plans

The rehabilitation plan for this power plant is not for a current status rehabilitation plan but is the result of evaluating the comparative alternative proposals for selecting the most optimal plan for a new power generation scale. Therefore, the following preconditions for establishing the comparative alternative plans were considered.

1) The typical flow-duration curve (Figure 6.8) at the intake gate indicates the planned available discharges should be set at 2.0, 3.0, 4.0 m^3/s, within a range not exceeding 50% of the discharge facility utilization factor.
2) The power generation plan must fully utilize the water fall head of approximately 300 m. However, if the conducting channel is installed below the current power house (elev. 1,650 m) on the right bank,where the topography is extremely steep, the structure will have to be built underground. Thus the usable head would be smaller than the 1,650 m mentioned above.
3) According to the study result, sand and stone flow once every 70 years. However, a layout and design which safeguard against sand and stone flow will be adopted for all structures and facilities, except for the intake facility. The summary of the comparative alternative plans and layout is shown in Table 6.15 and Fig. 6.9.

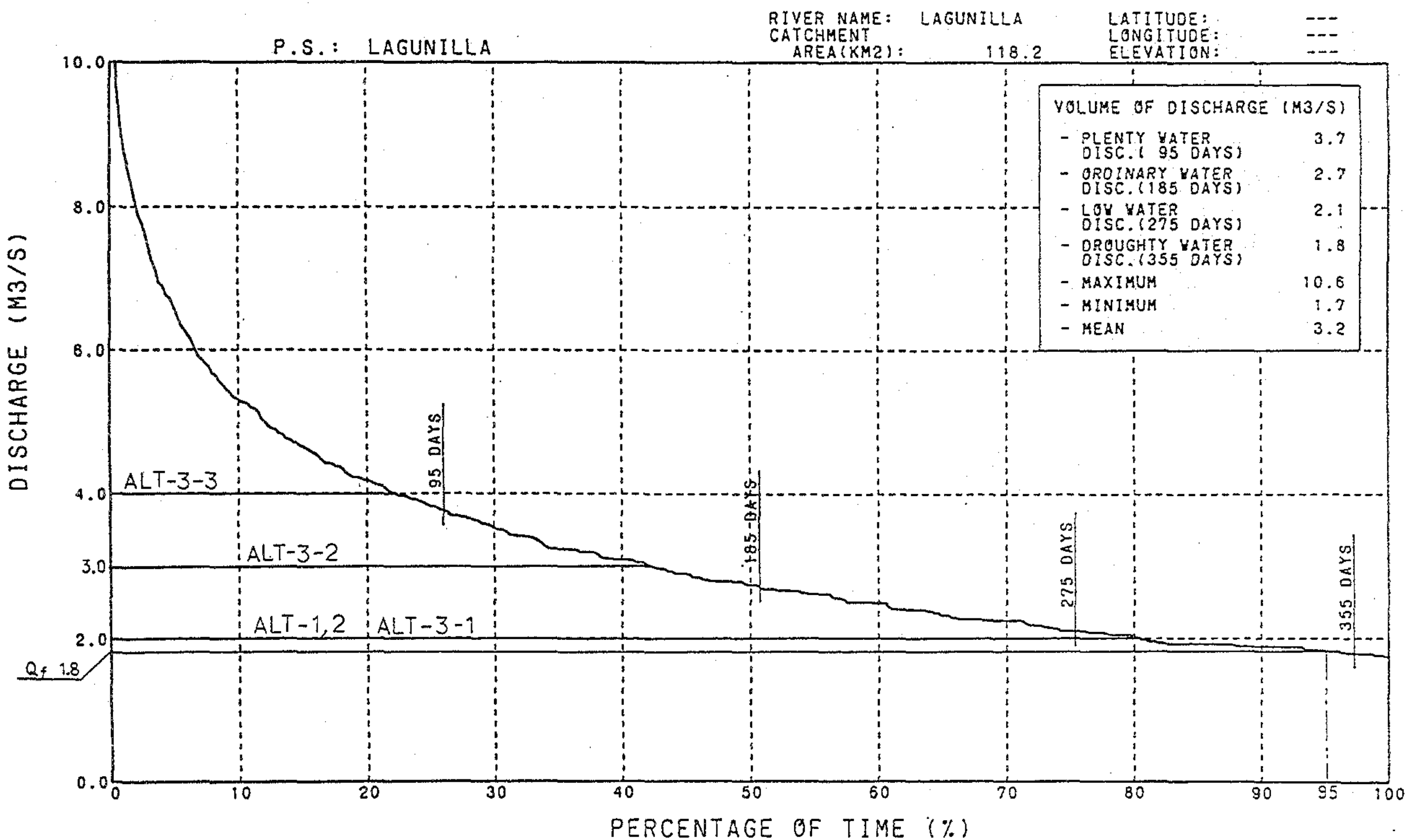
Table 6.15 Alternative Plans for Lagunilla Power plant Rehabilitation

Item	Alternative Plans				
	ALT-1	ALT-2	ALT-3		
Elevation at the intake (m)	1,782.5	1,821			
Conduction channel route	Right-bank route		Left-bank route		
Location of power plant	Existing power plant site (Elev. = 1,650 m)		Left bank (Elev. = 1,500 m)		
Net head, H (m)	125.9	161.5	309.0		
Discharge, Q (m^3/s)	2.0	2.0	2.0	3.0	4.0
Maximum output P (kW)	2,000	2,600	5,000	7,700	10,200
Facility utilization factor(%)	99	99	99	85	71

(3) Selection of the optimum plan

A summary of the analysis of the comparative alternative plans is shown in Table 6.16. The left-bank route Q = 2.0 m^3/s (ALT-3-1) plan was selected as the optimum plan with the greatest economic advantages and benefits. The basic design of ALT-3-1 at the F/S stage is contained in a separate report.

Fig-6.8 TYPICAL FLOW DURATION CURVE AT INTAKE SITE



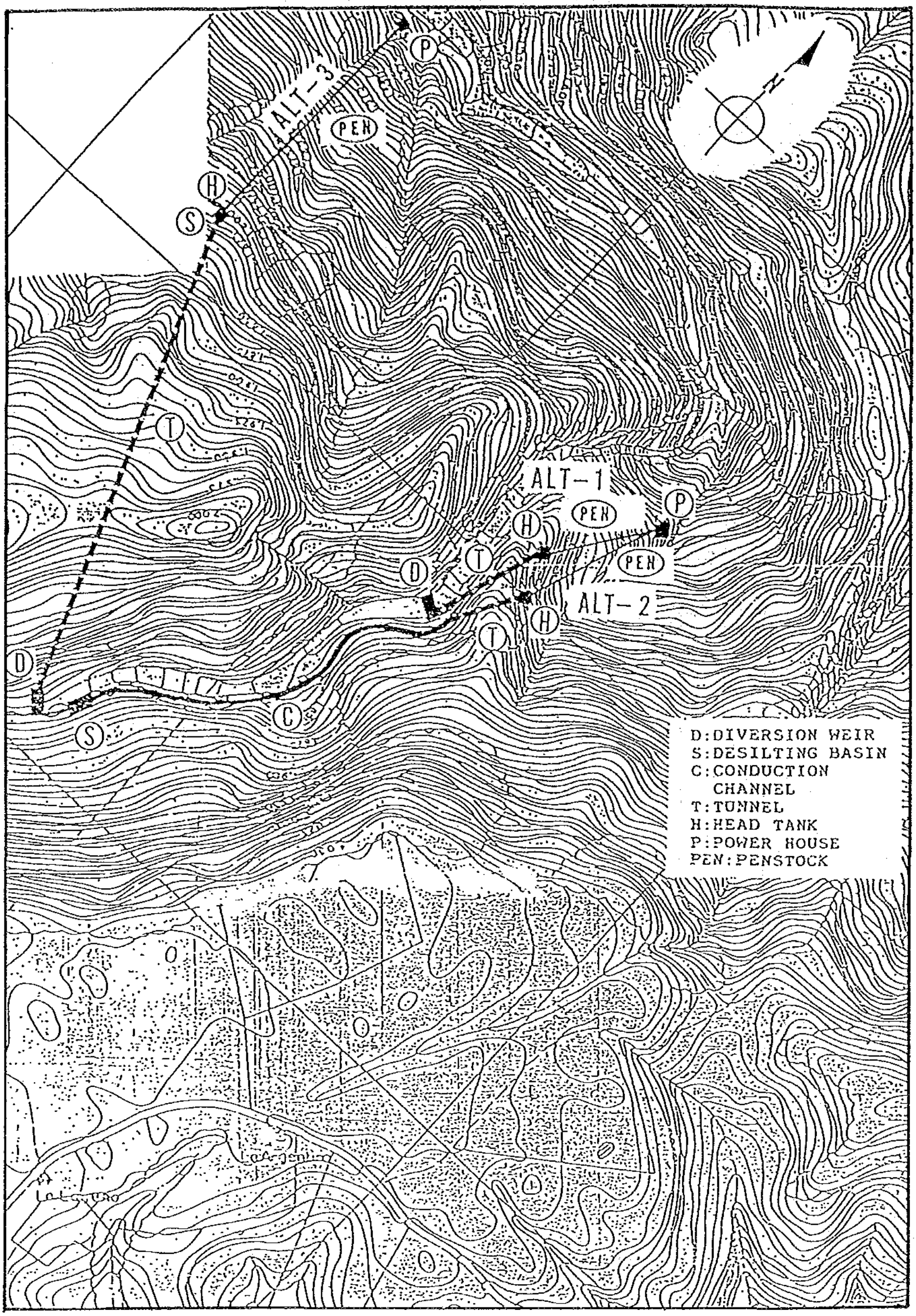


Fig. 6.9 Layout for the Alternative Plans.

Table-6.16 Comparison of Rehabilitation Plan for the Lagunilla Power Plant

Alternative Plan	(1) Specifications for Existing Generating Facilities					(2) Rehabilitation Plan							(3) Recovered or Increased Energy	
	(10)	(11)	(12)	(13) Present facility capacity		(20)	(21)	(22)	(23)	(24)	(25)	(26)	(30)	(31)
	Max. available discharge Qo (m^3/s)	Net head Ho (m)	Rated output Po (kW)	(14) Output Pe (kW)	(15) Generated energy Ee (GWh)	Max. available discharge Q1 (m^3/s)	Standard net head H1 (m)	Theoretical output =9.8x(20) x(21) (kW)	Resultant efficiency η	Output =(22)x(23) P1 (kW)	Annual probable generated energy E1 (GWh)	Facility utilization factor ε (%)	Output =(24) - (14) ΔP (kW)	Annual probable generated energy (25) - (15) ΔE (GWh)
ALT-1	0.5	120.0	392	0	0	2.0	125.9	2,468	0.830	2,000	17.6	99	2.000	17.6
ALT-2						2.0	161.5	3,165	0.830	2,600	22.6	99	2,600	22.6
ALT-3-1						2.0	309.0	6,056	0.830	5,000	43.2	99	5,000	43.2
ALT-3-2						3.0	309.0	9,084	0.850	7,700	56.7	85	7,700	56.7
ALT-3-3						4.0	309.0	12,112	0.850	10,200	62.4	71	10,200	62.4

Alternative Plan	(4) Rehabilitation Work Cost (US$1000)					(5) Construction Cost per kW (US$/kW)		(6) Total of Annual Cost at Generating Terminal (US$1000)					(7) Average Generating Cost per kWh (mills/kWh)		(8) Cost/Benefit	(9)
	(40) Generating Equipment Cost			(44)	(45)	(50)	(51)	(60)	(61) Principal repayment amount for construction cost (25-year average)			(65)	(70)	(71)		
	(41) Foreign currency portion Clf	(42) Local currency portion Clℓ	(43) (41)+(42) C1	Civil work cost C2	(43)+(44) C	Cost per ΔP =(45)/(30) C/ΔP	Cost per P1 =(45)/(24) C/P1	Operation and maintenance costs AOM	(62) Foreign currency portion 2.610 x (41) ÷ 25	(63) Local currency portion 2.016 x [(42)+(44)] ÷ 25	(64) (62)+(63)	(60)+(64)	per E1 =(65)/(25) ÷0.95	per ΔE =(65)/(31) ÷0.95	C/B	Priority order
ALT-1	2,000	800	2,800	700	3,500	1,750	1,750	8.0	207	121	228	336	20	20	1.28	4
ALT-2	2,400	1,000	3,400	900	4,300	1,650	1,650	10.4	251	154	405	415	19	19	1.24	3
ALT-3-1	3,800	1,500	5,300	1,600	6,900	1,400	1,400	20.0	401	252	653	673	16	16	1.06	1
ALT-3-2	5,600	2,300	7,900	1,900	9,800	1,300	1,300	30.8	587	335	922	953	18	18	0.96	1
ALT-3-3	7,300	2,900	10,200	2,200	12,400	1,200	1,200	40.8	764	414	1,178	1,219	21	21	1.29	5

(Notes)

(1) : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

(7) : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

(8) : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

(15) : Ee is computed according to the average annual operation record for 5 years from 1984 to 1988 .

(23) : η is the resultant efficiency of turbine and generator.

(26) : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s \cdot hr)}{Q_1 \times 365 \times 24} \times 100(\%)$

(60) : The annual AOM is the amount which is equivalent to US$4 per kW.

(61) : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

6.2 Optimum Rehabilitation Plan for Each Power plant

For 11 small-scale hydroelectric power plants that were nominated for the FS of rehabilitation plan, the outline of the plans which were evaluated as the optimum ones among the comparative alternatives (for each power plant), is shown in Table 6.17.

In Table 6.17, the case of P. Guillermo hydroelectric power plant in Boyaca Department is excluded from the object of selection, because the rehabilitation plan will be made if the reconstruction works of head tank and penstock are executed.

Construction cost per kW and generating cost per kWh greatly fluctuate in the optimum rehabilitation plans, as shown in Table 6.17. The following three standard values are applied to evaluate the superiority of the rehabilitation plans for these power plants.

Criterion ① : Recovered or increased output is more than 1000 kW

Criterion ② : Construction cost per kW is less than US$2,000 kW

Criterion ③ : Generating cost per kWh is less than 30 mills/kWh

Table 6.18 Evaluation of the Generation Plan for Each Power plant

Power plant	Economic indices of generation plan					
	Output increase ΔP (kW)		Rehabilitation cost per ΔP(US$/kW)		Generating cost per ΔE (mills/kWh)	
Caracoli	4,400	O	1,600	O	18	O
San Cancio	650	X	5,035	X	33	X
Intermedia	1,600	O	2,310	X	23	O
Municipal	3,100	O	1,350	O	15	O
Silvia	240	X	2,800	X	33	X
Ovejas	2,450	O	3,300	X	33	X
La Vuelta	7,200	O	2,800	X	32	X
Julio Bravo	3,500	O	1,220	O	15	O
Zaragoza	1,400	O	2,900	X	35	X
Lagunilla	5,000	O	1,400	O	16	O

Note: O: satisfies the value of selection criteria
X: does not satisfy the value of selection criteria

Table-6.17 General Statement of the Optimum Rehabilitation Plan for Hydroelectric Power Plants

Group	Power Plant	(1) Specifications for Existing Generating Facilities					(2) Rehabilitation Plan							(3) Recovered or Increased Energy	
		(10)	(11)	(12)	(13) Present facility capacity		(20)	(21)	(22)	(23)	(24)	(25)	(29)	(30)	(31)
		Max. available discharge Qo (m³/s)	Net head Ho (m)	Rated output Po (kW)	(14) Output Pc (kW)	(15) Generated energy Ec (GWh)	Max. available discharge Ql (m³/s)	Standard net head Hl (m)	Theoretical output =9.8x(20)x(21) (kW)	Resultant efficiency η	Output =(22)x(23) Pl (kW)	Annual probable generated energy El (GWh)	Facility utilization factor ε (%)	Output =(24)-(14) ΔP (kW)	Annual probable generated energy (25)-(15) ΔE (GWh)
1	Caracoli (ALT-1)	5.0	86.0	3,200	2,300	18.81	10.0	82.9	8,124	0.835	6,700	57.0	96	4,400	38.1
	Municipal (ALT-2)	5.6	79.6	2,112	1,400	5.94	7.0	79.6	5,460	0.835	4,500	34.8	88	3,100	28.9
	Julio Bravo (ALT-1)	2.0	120.0	1,500	0	0	3.0	143.0	4,204	0.835	3,500	29.4	97	3,500	29.4
	Lagunilla (ALT-3-1)	0.5	120.0	392	0	0	2.0	309.0	6,056	0.830	5,000	43.2	99	5,000	43.2
2	Intermedia	5.6	56.8	1,120	900	3.33	5.6	56.8	3,117	0.830	2,500	19.7	88	1,600	16.4
	San Cancio	5.6	53.8	2,320	1,750	8.44	5.6	53.8	2,952	0.830	2,400	18.5	88	650	10.1
	La Vuelta (ALT-2)	54.0	4.8	2,000	500	6.25	100.0	9.65	9,457	0.823	7,700	65.7	96	7,200	59.4
3	Silvia Total	1.5	31.0	604	100	0.82	1.1	31.0	334	0.740	240	2.1	98	240	2.1
	Silvia No.1 Unit	1.1		500	0	0									
	Ovejas (ALT-2)	7.0	24.5	900	650	2.97	15.0	26.0	3,822	0.830	3,100	26.2	94	2,450	23.2
	Zaragoza (ALT-1)	6.5	30.0	1,560	1,200	6.29	10.0	32.8	3,214	0.830	2,600	18.4	78	1,400	12.1

Group	Power Plant	(4) Rehabilitation Work Cost (US$1000)					(5) Construction Cost per kW (US$/kW)		(6) Total of Annual Cost at Generating Terminal (US$1000)					(7) Average Generating Cost per kWh (mills/kWh)	
		(40) Generating Equipment Cost			(44)	(45)	(50)	(51)	(60)	(61) Principal repayment amount for construction cost (25-year average)			(65)	(70)	(71)
		(41) Foreign currency portion Clf	(42) Local currency portion Clℓ	(43) (41)+(42) Cl	Civil work cost C2	(43)+(44) C	Cost per ΔP =(45)/(30) C/ΔP	Cost per Pl =(45)/(24) C/Pl	Operation and maintenance costs AOM	(62) Foreign currency portion 2,610 x (41) ÷ 25	(63) Local currency portion 2,016 x [(42)+(44)] ÷ 25	(64) (62)+(63)	(60)+(64)	per El =(65)/(25) ÷ 0.95	per ΔE =(65)/(31) ÷ 0.95
1	Caracoli (ALT-1)	2,900	1,200	4,100	2,900	7,000	1,600	1,050	26.8	305	329	634	661	12	18
	Municipal (ALT-2)	2,450	1,000	3,450	750	4,200	1,350	950	18.0	255	140	395	413	13	15
	Julio Bravo (ALT-1)	2,300	950	3,250	1.050	4,300	1,220	1,220	14.0	242	158	400	414	15	15
	Lagunilla (ALT-3-1)	3,800	1,500	5,300	1,600	6,900	1,400	1,400	20.0	401	252	653	673	16	16
2	Intermedia	1,900	750	2,650	1,050	3,700	2,310	1,500	10.0	197	145	342	352	19	23
	San Cancio	1,900	750	2,650	600	3,250	5,035	1,350	9.6	197	111	308	318	18	33
	La Vuelta (ALT-2)	7,400	2,950	10,350	9,770	20,120	2,800	2,600	30.8	772	1,026	1,798	1,829	29	32
3	Silvia No.1 Unit	458	184	642	34	676	2,800	2,800	1.0	48	18	66	67	33	33
	Ovejas (ALT-2)	2,650	1,050	3,700	4,300	8,000	3,300	2,600	12.4	277	433	710	722	29	33
	Zaragoza (ALT-1)	2,250	900	3,150	1,000	4,150	2,900	1,600	10.4	236	154	390	400	23	35

6.2.1 Power plants Whose Repairing Plans are Feasible (Group 1)

Among those optimum repairing plans for each power plant shown in Table 6.17, the following four power plants satisfy the standard values described above.

1) Caracoli Run-of-river Type Hydroelectric Power plant
   (Antioquia Dept. Owner: EADE, Rated output 3,200 kW)

   Present output: 2,300 kW → Post-rehabilitation output: 6,700 kW

2) Municipal Run-of-river Type Hydroelectric Power plant
   (Caldas Dept. Owner: CHEC, Rated output: 2,112 kW)

   Present output: 1,400 kW → Post-rehabilitation output: 4,500 kW

3) Julio Bravo Run-of-river Type Hydroelectric Power plant
   (Narinõ Dept. Owner: CEDENAR, Rated output: 1,500 kW)

   Present output: 0 kW → Post-rehabilitation output: 3,500 kW

4) Lagunilla Run-of-river Type Hydroelectric Power plant
   (Tolima Dept. Owner: ELECTROLIMA, Rated output: 392 kW)

   Present output: 0 kW → Post-rehabilitation output: 5,000 kW

There are following problems in power plants whose rehabilitation plans are most feasible. ICEL group, therefore, has to immediately take proper steps to solve these problems so that these plans can be implemented.

1) Caracoli Hydroelectric Power plant

   The optimum rehabilitation plans selected for the study are to optimize power-generation scale.

   To realize the rehabilitation of this power plant, the following data is necessary.

   ① Observation of discharge at the intake site and arrangement of the discharge data.

③ Investigation of conditions of worn steel conduit pipes and verification of remaining life.

2) Municipal Hydroelectric Power plant

River discharge should be observed to investigate hydrological regime at the remaining watershed (47.1 km^2), located furthest downstream from the intake at San Cancio power plant. Since the water of the Chinchina River has been polluted, water quality needs to be inspected. It is necessary to investigate water flow capacity of the existing conduction channel.

3) Julio Bravo Hydroelectric Power plant

The water used for this plant has been polluted by the inflow of sewage from Pasto City. It is necessary to keep complete data of the river water quality analysis in connection with the anti-corrosive measures of materials used for penstocks, turbines, etc.

4) Lagunilla Hydroelectric Power plant

All hydrological gauging stations located along the Lagunilla River were washed away by debris flow caused when Nevado del Ruiz erupted in November, 1985. Thus, facilities for observing river discharge should be immediately constructed near the planned intake site to keep complete observation records. In addition, a geological survey near the proposed route of the conduction channel tunnel and penstock should be conducted for the rehabilitation of these power plants.

6.2.2 Power plants Required to Consider the Located Condition or Regional Characteristic (Group 2)

The following three power plants do not meet all three standard values, but should be considered because of location and/or regional characteristics.

1) Intermedia Run-of-river Type Hydroelectric Power plant
(Caldas Dept. Owner: CHEC, Rated output: 1,120 kW)

Present output: 900 kW → Post-rehabilitation output: 2,500 kW

2) San Cancio Run-of-river Type Hydroelectric Power plant
(Caladas Dept. Owner: CHEC, Rated output: 2,320 kW)

Present output: 1,750 kW → Post-rehabilitation output: 2,400 kW

3) La Vuelta Run-of-river Type Hydroelectric Power plant
(Choco Dept. Owner: CHOCO, Rated output: 2,000 kW)

Present output: 500 kW → Post-rehabilitation output: 3,500 - 7,700 kW

- Intermedia and San Cancio Power plants (Caldas Dept. Owner: CHEC) are nominated as Group 2 for the following reasons:

Three of these power plants are located along the Chinchina River. The tailrace for San Cancio power plant is connected to the intake of Intermedia power plant. Similarly, the tailrace of Intermedia power plant is connected to the intake of Municipal power plant. Thus, the planned available discharge at the respective power plants is limited by the maximum available discharge ($Q = 5.6\ m^3/s$) at San Cancio power plant, which is located furthest upstream. Since there is no difference in the standard net head at each power plant, the standardization of the optimum machine types, administration, operation and maintenance, as well as parts should be considered for the rehabilitation of these power plants.

In case three hydroelectric power plants of San Cancio, Intermedia and Municipal are considered as one package, the construction cost per recovered or increased output (ΔP) is less than US$2000/kW, as shown in Table 6.19.

Table 6.19 San Cancio, Intermedia and Municipal Hydroelectric Power plants Group as One Package - Comparison to Standard Values

Power plant	Selection Criteria		
	Recovered or increased output, ΔP (kW)	Construction cost per ΔP (US$/kW)	Generating cost per kWh (mills/kWh)
			Per annual average power ΔE
Municipal and Intermedia 2 package	4,700 > 1,000	1,680 < 2,000	18
Municipal, Intermedia and San Cancio 3 package	5,350 > 1,000	2,100 ÷ 2,000	21

La Vuelta Hydroelectric Power plant (Choco Dept. Owner: Metales Preciosos del Choco) is nominated for Group 2, since the adoption of a rehabilitation or improvement plan cannot be decided solely by the economic indices of the generation plan.

Social, economic and other considerations, including ripple effects by the development of this area, should be requested.

In the rehabilitation plan of La Vuelta Hydroelectric Power plant, the plan in which the Torincho type diversion weir will be reconstructed into a concrete dam, is selected.

The following basic data is insufficient.

- Geological survey data for dam foundation
- Geographical survey data of submerged extent.
- Investigation data of compensation for submerged items, etc.

6.2.3 Power plants Whose Rehabilitation is Infeasible (Group 3)

Rehabilitation of the following three power plants is infeasible, as shown in Table 6.18.

1) Silvia Run-of-River Type Hydroelectric Power plant
(Cauca Department, Owner: CEDELCA, rated output: 604 kW)

Present output: 100 kW → Post-rehabilitation output: 340 kW

2) Ovejas Run-of-River Type Hydroelectric Power plant
(Cauca Department, Owner: CEDELCA, rated output: 900 kW)

Present output: 650 kW → Post-rehabilitation output: 3,100 kW

3) Zaragoza Run-of-River Type Hydroelectric Power plant
(Santander Department, Owner: ESSA, rated output: 1,560 kW)

Present output: 1,200 kW → Post-rehabilitation output: 2,600 kW

6.3 Economic and Financial Analyses

A cost-benefit analysis is adopted to evaluate the profitability of the rehabilitation plans. The difference between the revenue after the existing facilities are rehabilitated and the revenue when the existing facilities are not rehabilitated is regarded as the profitability of the investment (Refer to Fig. 6.10.)

6.3.1 Preconditions for Financial Analysis

Assumptions for this financial analysis are summarized below.

(1) Residual life of existing power plant

If the existing facilities are not changed, the residual life of the existing power plant is estimated to be five years after the installation of new equipment.

(2) Estimation of construction cost

The construction cost is estimated in both foreign and local currency apportionments, according to the exchange rate as of September, 1989. Currency exchange rate between foreign currency (US$) and local currency (Col.$) is set at US$1.00 = Col.$369.4, as determined by DNP. The construction cost includes the contingency and technical management expense. Land acquisition cost is not included, since this plan is for the rehabilitating the existing power plant. The FOB price of the generating facilities is taken from the Japanese market price. The CIF price is calculated in a ratio of CIF price to FOB price, which ISA usually applies to a hydroelectric power generation project. Thus, the ratio is set at 1.00 : 1.12.

(3) Service life

The service life of the project is set to 25 years after rehabilitation for evaluating the profitability.

The annual depreciation of facilities will be based on the fixed amount method adopted by ICEL. The service life, described below, is determined according to the facility. The residual price will be set at zero.

1) Service life of civil structure : 50 years
2) Service of generating facilities : 25 years

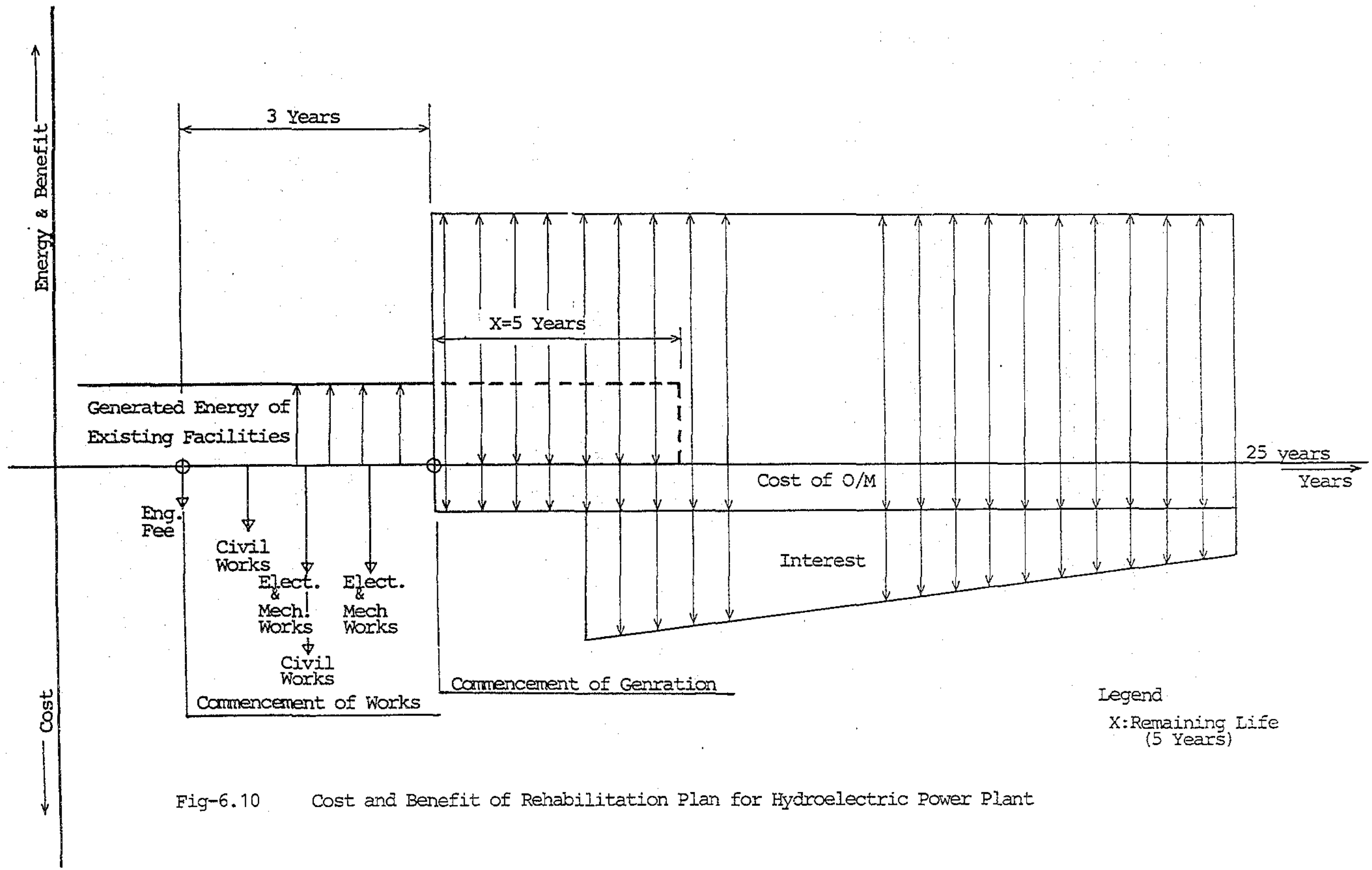


Fig-6.10 Cost and Benefit of Rehabilitation Plan for Hydroelectric Power Plant

(4) Operation and maintenance costs

Generally, the operation and maintenance costs consist of the fixed cost, which depends upon the scale invested in the facilities, and the variable cost, which fluctuates in proportion to generated electric power. This study adopts the average cost of US$4.0 per installed capacity (kW) per year, which ISA usually applies in estimating the operating and maintenance costs of a hydroelectric power plant.

(5) Estimation of revenue

ICEL's electricity selling unit price of US$13.36/MWh (Col.$4,936.18/MWh) and US$2,942.36/MW (Col.$1,086,909.69/MW) in December, 1988 is adopted as the financial unit price. Annual revenue can be estimated by multiplying the rated capacity with the annual supplied power at the generating terminal.

(6) Discount rate

The discount rate, which is used to calculate the net present value (NPV) and the cost-benefit ration (C/B ratio) is set at 7.6% per year. It is determined by the real interest rate in Colombia.

(7) Conditions for borrowing capital on investment

The loan conditions for borrowing capital in foreign and local currency are as follows:

1) Loan conditions of foreign currency

- Annual interest : 10%
- Period for principal repayment : 25 years (including a 4-year grace period)
- Terms of payment : Repayment of the principle in equal, annual amounts

2) Loan conditions of local currency

- Annual interest : 21%
- Period for principal repayment : 8 years (including a 1-year grace period)

- Terms of payment : Repayment of the principal in equal, annual amounts

(8) Constant price

The annual inflation rate in Colombia varied from 24 to 30%, but the prices used in the cost and benefit stream are set at the constant price for 1989.

(9) Evaluation index

For evaluating profitability, the following three indices, which are commonly used, are adopted.

(1) Cost-benefit ratio (C/B ratio)
(2) Net present value (NPV)
(3) Internal rate of return (IRR)

These indices are calculated are calculated for both the implementation and non-implementation of this project.

6.3.2 Cost-Benefit Analysis for Hydroelectric Power Plants in Group-1

The results of the cost-benefit analysis for hydroelectric power plants having a high possibility of implementation were assigned to Group-1, as shown below.

Table 6.20 Evaluation Index of Rehabilitation Plan of Hydroelectric Power Plants in Group-1

Power Plant	Evaluation Index of Generation Plan			Cost-Benefit Analysis		
	Incremental Output ΔP (kW)	Construction Cost per ΔP (US$/kW)	Generating cost per Energy Increment ΔE (mill/kWh)	C/B	NPV (US$1,000)	FIRR (%)
Caracoli	4,400	1,600	18	0.99	53	7.7
Municipal	3,100	1,350	15	0.86	366	9.2
Julio Bravo	3,500	1,220	15	0.96	100	8.1
Lagunilla	5,000	1,400	16	1.06	- 202	7.0

The projected profit-loss statement and the cash flow for rehabilitation plans of each hydroelectric power plant listed in Group-1 are shown in Tables 6.21 - 6.24.

Table - 6.21 : PROJECTED FINANCIAL STATEMENTS FOR CARACOLI HYDROPOWER PLANT

(1) PROJECTED REVENUE AND EXPENDITURE STATEMENT (at 1989 Price)

== Caracoli : ALT-1 ==

Year	Year in Order	(A) Total Operating Revenue	(B) Operating Expenditure (US$:1000) O/M Cost	Depreciation	Interest on Investment	Total	(C) Net Benefit (A)-(B)
1989	-6	258.1	9.2	0.0	0.0	9.2	248.9
1990	-5	258.1	9.2	0.0	0.0	9.2	248.9
1991	-4	258.1	9.2	0.0	0.0	9.2	248.9
1992	-3	258.1	9.2	0.0	20.6	29.8	228.3
1993	-2	258.1	9.2	0.0	41.2	50.4	207.7
1994	-1	258.1	9.2	0.0	51.5	60.7	197.4
1995	0	31.4	9.2	0.0	300.6	309.8	-278.4
1996	1	31.4	9.2	193.9	788.1	991.2	-959.8
1997	2	742.7	26.8	193.9	1011.0	1231.7	-489.0
1998	3	742.7	26.8	193.9	912.3	1133.0	-390.4
1999	4	742.7	26.8	193.9	798.4	1019.1	-276.5
2000	5	742.7	26.8	193.9	684.5	905.2	-162.5
2001	6	742.7	26.8	193.9	570.6	791.3	-48.6
2002	7	742.7	26.8	193.9	259.4	480.1	262.6
2003	8	742.7	26.8	193.9	244.1	464.8	277.8
2004	9	742.7	26.8	193.9	228.9	449.6	293.1
2005	10	742.7	26.8	193.9	213.6	434.3	308.3
2006	11	742.7	26.8	193.9	198.3	419.1	323.6
2007	12	742.7	26.8	193.9	183.1	403.8	338.9
2008	13	742.7	26.8	193.9	167.8	388.6	354.1
2009	14	742.7	26.8	193.9	152.6	373.3	369.4
2010	15	742.7	26.8	193.9	137.3	358.0	384.6
2011	16	742.7	26.8	193.9	122.1	342.8	399.9
2012	17	742.7	26.8	193.9	106.8	327.5	415.1
2013	18	742.7	26.8	193.9	91.5	312.3	430.4
2014	19	742.7	26.8	193.9	76.3	297.0	445.7
2015	20	742.7	26.8	193.9	61.0	281.8	460.9
2016	21	742.7	26.8	193.9	45.8	266.5	476.2
2017	22	742.7	26.8	193.9	30.5	251.2	491.4
2018	23	742.7	26.8	193.9	15.3	236.0	506.7
2019	24	742.7	26.8	193.9	0.0	220.7	521.9
2020	25	742.7	26.8	193.9	0.0	220.7	521.9
TOTAL		18661.2				13050.4	5610.9
						C/B:	0.70

(2) PROJECTED FUNDS FLOW STATEMENT (Constant Price at 1989)

== Caracoli : ALT-1 ==

(US$:1000)

Year	Year in Order	(A) Source: Benefit before Interest	Depreciation	Balance Brought Forward	Long/Short Term Borrowing	Total	(B) Application: Construction Progress	Debt Service: Interest	Debt Service: Principal	Total	Cash Balance (A)-(B)
1989	-6	248.9	0.0		0.0	248.9	0.0	0.0	0.0	0.0	248.9
1990	-5	248.9	0.0		0.0	248.9	0.0	0.0	0.0	0.0	248.9
1991	-4	248.9	0.0		206.0	454.9	206.0	0.0	0.0	206.0	248.9
1992	-3	248.9	0.0		206.0	454.9	206.0	20.6	0.0	226.6	228.3
1993	-2	248.9	0.0		103.0	351.9	103.0	41.2	0.0	144.2	207.7
1994	-1	248.9	0.0		1327.1	1576.0	1327.1	51.5	0.0	1378.6	197.4
1995	0	22.2	0.0		2955.1	2977.3	2955.1	300.6	0.0	3255.7	-278.4
1996	1	-171.7	193.9		1695.3	1717.5	1695.3	788.1	469.8	2953.2	-1235.6
1997	2	521.9	193.9			715.9		1011.0	469.8	1480.7	-764.9
1998	3	521.9	193.9			715.9		912.3	622.3	1534.7	-818.8
1999	4	521.9	193.9			715.9		798.4	622.3	1420.7	-704.9
2000	5	521.9	193.9			715.9		684.5	622.3	1306.8	-591.0
2001	6	521.9	193.9			715.9		570.6	622.3	1192.9	-477.1
2002	7	521.9	193.9			715.9		259.4	622.3	881.7	-165.8
2003	8	521.9	193.9			715.9		244.1	152.6	396.7	319.2
2004	9	521.9	193.9	319.2		1035.1		228.9	152.6	381.4	653.6
2005	10	521.9	193.9	653.6		1369.5		213.6	152.6	366.2	1003.3
2006	11	521.9	193.9	1003.3		1719.2		198.3	152.6	350.9	1368.3
2007	12	521.9	193.9	1368.3		2084.2		183.1	152.6	335.7	1748.5
2008	13	521.9	193.9	1748.5		2464.4		167.8	152.6	320.4	2144.0
2009	14	521.9	193.9	2144.0		2859.9		152.6	152.6	305.1	2554.7
2010	15	521.9	193.9	2554.7		3270.6		137.3	152.6	289.9	2980.7
2011	16	521.9	193.9	2980.7		3696.6		122.1	152.6	274.6	3421.9
2012	17	521.9	193.9	3421.9		4137.8		106.8	152.6	259.4	3878.5
2013	18	521.9	193.9	3878.5		4594.3		91.5	152.6	244.1	4350.2
2014	19	521.9	193.9	4350.2		5066.1		76.3	152.6	228.9	4837.2
2015	20	521.9	193.9	4837.2		5553.1		61.0	152.6	213.6	5339.5
2016	21	521.9	193.9	5339.5		6055.4		45.8	152.6	198.3	5857.0
2017	22	521.9	193.9	5857.0		6572.9		30.5	152.6	183.1	6389.8
2018	23	521.9	193.9	6389.8		7105.7		15.3	152.6	167.8	6937.9
2019	24	521.9	193.9	6937.9		7653.7		0.0	0.0	0.0	7653.7
2020	25	521.9	193.9	7653.7		8369.6		0.0	0.0	0.0	8369.6

Table - 6.22 : PROJECTED FINANCIAL STATEMENTS FOR MUNICIPAL HYDROPOWER PLANT

(1) PROJECTED REVENUE AND EXPENDITURE STATEMENT (at 1989 Price)
== Municipal : ALT-2 ==

Year	Year in Order	(A) Total Operating Revenue	(B) Operating Expenditure (US$:1000) O/M Cost	Depreciation	Interest on Investment	Total	(C) Net Benefit (A)-(B)
1989	-6	83.5	5.6	0.0	0.0	5.6	77.9
1990	-5	83.5	5.6	0.0	0.0	5.6	77.9
1991	-4	83.5	5.6	0.0	0.0	5.6	77.9
1992	-3	83.5	5.6	0.0	11.8	17.4	66.1
1993	-2	83.5	5.6	0.0	23.6	29.2	54.2
1994	-1	83.5	5.6	0.0	29.6	35.2	48.3
1995	0	56.7	5.6	0.0	128.2	133.8	-77.1
1996	1	56.7	5.6	132.5	390.4	528.5	-471.8
1997	2	454.6	18.0	132.5	576.8	727.3	-272.7
1998	3	454.6	18.0	132.5	530.8	681.3	-226.7
1999	4	454.6	18.0	132.5	472.6	623.1	-168.5
2000	5	454.6	18.0	132.5	414.4	564.9	-110.3
2001	6	454.6	18.0	132.5	356.3	506.7	-52.1
2002	7	454.6	18.0	132.5	206.0	356.4	98.1
2003	8	454.6	18.0	132.5	193.9	344.3	110.3
2004	9	454.6	18.0	132.5	181.7	332.2	122.4
2005	10	454.6	18.0	132.5	169.6	320.1	134.5
2006	11	454.6	18.0	132.5	157.5	308.0	146.6
2007	12	454.6	18.0	132.5	145.4	295.9	158.7
2008	13	454.6	18.0	132.5	133.3	283.8	170.8
2009	14	454.6	18.0	132.5	121.2	271.6	183.0
2010	15	454.6	18.0	132.5	109.0	259.5	195.1
2011	16	454.6	18.0	132.5	96.9	247.4	207.2
2012	17	454.6	18.0	132.5	84.8	235.3	219.3
2013	18	454.6	18.0	132.5	72.7	223.2	231.4
2014	19	454.6	18.0	132.5	60.6	211.1	243.5
2015	20	454.6	18.0	132.5	48.5	198.9	255.7
2016	21	454.6	18.0	132.5	36.3	186.8	267.8
2017	22	454.6	18.0	132.5	24.2	174.7	279.9
2018	23	454.6	18.0	132.5	12.1	162.6	292.0
2019	24	454.6	18.0	132.5	0.0	150.5	304.1
2020	25	454.6	18.0	132.5	0.0	150.5	304.1
TOTAL		11274.1				8560.2	2713.9
						C/B:	0.76

(2) PROJECTED FUNDS FLOW STATEMENT (Constant Price at 1989)
== Municipal : ALT-2 ==

Year	Year in Order	(A) Source: Benefit before Interest	Depreciation	Balance Brought Forward	Long/Short Term Borrowing	Total	(B) Application (US$:1000): Construction Progress	Debt Service Interest	Debt Service Principal	Total	Cash Balance (A)-(B)
1989	-6	77.9	0.0		0.0	77.9	0.0	0.0	0.0	0.0	77.9
1990	-5	77.9	0.0		0.0	77.9	0.0	0.0	0.0	0.0	77.9
1991	-4	77.9	0.0		118.2	196.1	118.2	0.0	0.0	118.2	77.9
1992	-3	77.9	0.0		118.2	196.1	118.2	11.8	0.0	130.1	66.1
1993	-2	77.9	0.0		59.1	137.0	59.1	23.6	0.0	82.8	54.2
1994	-1	77.9	0.0		587.3	665.2	587.3	29.6	0.0	616.8	48.3
1995	0	51.1	0.0		1778.7	1829.8	1778.7	128.2	0.0	1906.9	-77.1
1996	1	-81.4	132.5		1418.0	1469.0	1418.0	390.4	219.3	2027.6	-558.6
1997	2	304.1	132.5			436.6		576.8	219.3	796.2	-359.6
1998	3	304.1	132.5			436.6		530.8	340.5	871.3	-434.7
1999	4	304.1	132.5			436.6		472.6	340.5	813.1	-376.5
2000	5	304.1	132.5			436.6		414.4	340.5	754.9	-318.3
2001	6	304.1	132.5			436.6		356.3	340.5	696.7	-260.1
2002	7	304.1	132.5			436.6		206.0	340.5	546.4	-109.9
2003	8	304.1	132.5			436.6		193.9	121.2	315.0	121.6
2004	9	304.1	132.5	121.6		558.2		181.7	121.2	302.9	255.3
2005	10	304.1	132.5	255.3		691.9		169.6	121.2	290.8	401.1
2006	11	304.1	132.5	401.1		837.7		157.5	121.2	278.7	559.0
2007	12	304.1	132.5	559.0		995.6		145.4	121.2	266.6	729.0
2008	13	304.1	132.5	729.0		1165.6		133.3	121.2	254.4	911.2
2009	14	304.1	132.5	911.2		1347.8		121.2	121.2	242.3	1105.5
2010	15	304.1	132.5	1105.5		1542.1		109.0	121.2	230.2	1311.9
2011	16	304.1	132.5	1311.9		1748.5		96.9	121.2	218.1	1530.4
2012	17	304.1	132.5	1530.4		1967.0		84.8	121.2	206.0	1761.0
2013	18	304.1	132.5	1761.0		2197.6		72.7	121.2	193.9	2003.7
2014	19	304.1	132.5	2003.7		2440.3		60.6	121.2	181.7	2258.6
2015	20	304.1	132.5	2258.6		2695.2		48.5	121.2	169.6	2525.6
2016	21	304.1	132.5	2525.6		2962.1		36.3	121.2	157.5	2804.6
2017	22	304.1	132.5	2804.6		3241.2		24.2	121.2	145.4	3095.8
2018	23	304.1	132.5	3095.8		3532.4		12.1	121.2	133.3	3399.2
2019	24	304.1	132.5	3399.2		3835.7		0.0	0.0	0.0	3835.7
2020	25	304.1	132.5	3835.7		4272.3		0.0	0.0	0.0	4272.3

Table - 6.23 : PROJECTED FINANCIAL STATEMENTS FOR J. BRAVO HYDROPOWER PLANT

(1) PROJECTED REVENUE AND EXPENDITURE STATEMENT (at 1989 Price)
== Julio Bravo : ALT-1 ==

Year	Year in Order	(A) Total Operating Revenue	(B) Operating Expenditure (US$:1000) O/M Cost	Depreci- ation	Interest on Investment	Total	(C) Net Benefit (A)-(B)
1989	-6	0.0	0.0	0.0	0.0	0.0	0.0
1990	-5	0.0	0.0	0.0	0.0	0.0	0.0
1991	-4	0.0	0.0	0.0	0.0	0.0	0.0
1992	-3	0.0	0.0	0.0	12.7	12.7	-12.7
1993	-2	0.0	0.0	0.0	25.3	25.3	-25.3
1994	-1	0.0	0.0	0.0	31.6	31.6	-31.6
1995	0	0.0	0.0	0.0	154.4	154.4	-154.4
1996	1	191.8	7.0	133.6	441.8	582.3	-390.5
1997	2	383.6	14.0	133.6	618.5	766.1	-382.5
1998	3	383.6	14.0	133.6	565.2	712.7	-329.1
1999	4	383.6	14.0	133.6	500.1	647.7	-264.1
2000	5	383.6	14.0	133.6	435.1	582.7	-199.1
2001	6	383.6	14.0	133.6	370.1	517.6	-134.0
2002	7	383.6	14.0	133.6	198.3	345.8	37.7
2003	8	383.6	14.0	133.6	186.6	334.2	49.4
2004	9	383.6	14.0	133.6	175.0	322.5	61.1
2005	10	383.6	14.0	133.6	163.3	310.9	72.7
2006	11	383.6	14.0	133.6	151.6	299.2	84.4
2007	12	383.6	14.0	133.6	140.0	287.5	96.1
2008	13	383.6	14.0	133.6	128.3	275.9	107.7
2009	14	383.6	14.0	133.6	116.6	264.2	119.4
2010	15	383.6	14.0	133.6	105.0	252.5	131.1
2011	16	383.6	14.0	133.6	93.3	240.9	142.7
2012	17	383.6	14.0	133.6	81.6	229.2	154.4
2013	18	383.6	14.0	133.6	70.0	217.5	166.1
2014	19	383.6	14.0	133.6	58.3	205.9	177.7
2015	20	383.6	14.0	133.6	46.7	194.2	189.4
2016	21	383.6	14.0	133.6	35.0	182.6	201.0
2017	22	383.6	14.0	133.6	23.3	170.9	212.7
2018	23	383.6	14.0	133.6	11.7	159.2	224.4
2019	24	383.6	14.0	133.6	0.0	147.6	236.0
2020	25	383.6	14.0	133.6	0.0	147.6	236.0
TOTAL		9398.1				8621.3	776.8
						C/B:	0.92

(2) PROJECTED FUNDS FLOW STATEMENT (Constant Price at 1989)
== Julio Bravo : ALT-1 ==

(US$:1000)

Year	Year in Order	(A) Source Benefit before Interest	Depreci- ation	Balance Brought Forward	Long/Short Term Borrowing	Total	(B) Application Construc- tion Progress	Debt Service Interest	Debt Service Principal	Total	Cash Balance (A)-(B)
1989	-6	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	-5	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	-4	0.0	0.0		126.5	126.5	126.5	0.0	0.0	126.5	0.0
1992	-3	0.0	0.0		126.5	126.5	126.5	12.7	0.0	139.2	-12.7
1993	-2	0.0	0.0		63.3	63.3	63.3	25.3	0.0	88.6	-25.3
1994	-1	0.0	0.0		696.2	696.2	696.2	31.6	0.0	727.8	-31.6
1995	0	0.0	0.0		1871.4	1871.4	1871.4	154.4	0.0	2025.7	-154.4
1996	1	51.2	133.6		1344.6	1529.4	1344.6	441.8	254.2	2040.5	-511.1
1997	2	236.0	133.6			369.6		618.5	254.2	872.7	-503.1
1998	3	236.0	133.6			369.6		565.2	370.8	936.0	-566.4
1999	4	236.0	133.6			369.6		500.1	370.8	870.9	-501.3
2000	5	236.0	133.6			369.6		435.1	370.8	805.9	-436.3
2001	6	236.0	133.6			369.6		370.1	370.8	740.9	-371.3
2002	7	236.0	133.6			369.6		198.3	370.8	569.1	-199.5
2003	8	236.0	133.6			369.6		186.6	116.6	303.3	66.3
2004	9	236.0	133.6	66.3		435.9		175.0	116.6	291.6	144.3
2005	10	236.0	133.6	144.3		513.9		163.3	116.6	279.9	234.0
2006	11	236.0	133.6	234.0		603.6		151.6	116.6	268.3	335.3
2007	12	236.0	133.6	335.3		704.9		140.0	116.6	256.6	448.3
2008	13	236.0	133.6	448.3		817.9		128.3	116.6	244.9	573.0
2009	14	236.0	133.6	573.0		942.5		116.6	116.6	233.3	709.3
2010	15	236.0	133.6	709.3		1078.9		105.0	116.6	221.6	857.2
2011	16	236.0	133.6	857.2		1226.8		93.3	116.6	210.0	1016.9
2012	17	236.0	133.6	1016.9		1386.5		81.6	116.6	198.3	1188.2
2013	18	236.0	133.6	1188.2		1557.8		70.0	116.6	186.6	1371.2
2014	19	236.0	133.6	1371.2		1740.8		58.3	116.6	175.0	1565.8
2015	20	236.0	133.6	1565.8		1935.4		46.7	116.6	163.3	1772.1
2016	21	236.0	133.6	1772.1		2141.7		35.0	116.6	151.6	1990.1
2017	22	236.0	133.6	1990.1		2359.7		23.3	116.6	140.0	2219.7
2018	23	236.0	133.6	2219.7		2589.3		11.7	116.6	128.3	2461.0
2019	24	236.0	133.6	2461.0		2830.6		0.0	0.0	0.0	2830.6
2020	25	236.0	133.6	2830.6		3200.2		0.0	0.0	0.0	3200.2

Table - 6.24 : PROJECTED FINANCIAL STATEMENTS FOR LAGUNILLA HYDROPOWER PLANT

(1) PROJECTED REVENUE AND EXPENDITURE STATEMENT (at 1989 Price)
== Lagunilla : ALT-3-1 ==

Year	Year in Order	(A) Total Operating Revenue	(B) Operating Expenditure (US$:1000) O/M Cost	Depreciation	Interest on Investment	Total	(C) Net Benefit (A)-(B)
1989	-6	0.0	0.0	0.0	0.0	0.0	0.0
1990	-5	0.0	0.0	0.0	0.0	0.0	0.0
1991	-4	0.0	0.0	0.0	0.0	0.0	0.0
1992	-3	0.0	0.0	0.0	20.5	20.5	-20.5
1993	-2	0.0	0.0	0.0	41.0	41.0	-41.0
1994	-1	0.0	0.0	0.0	51.3	51.3	-51.3
1995	0	0.0	0.0	0.0	245.4	245.4	-245.4
1996	1	281.7	10.0	218.9	709.5	938.4	-656.7
1997	2	563.4	20.0	218.9	1002.7	1241.6	-678.2
1998	3	563.4	20.0	218.9	917.3	1156.2	-592.8
1999	4	563.4	20.0	218.9	812.6	1051.5	-488.1
2000	5	563.4	20.0	218.9	708.0	946.9	-383.4
2001	6	563.4	20.0	218.9	603.3	842.2	-278.8
2002	7	563.4	20.0	218.9	327.8	566.7	-3.3
2003	8	563.4	20.0	218.9	308.5	547.5	16.0
2004	9	563.4	20.0	218.9	289.3	528.2	35.3
2005	10	563.4	20.0	218.9	270.0	508.9	54.6
2006	11	563.4	20.0	218.9	250.7	489.6	73.8
2007	12	563.4	20.0	218.9	231.4	470.3	93.1
2008	13	563.4	20.0	218.9	212.1	451.0	112.4
2009	14	563.4	20.0	218.9	192.8	431.8	131.7
2010	15	563.4	20.0	218.9	173.6	412.5	151.0
2011	16	563.4	20.0	218.9	154.3	393.2	170.3
2012	17	563.4	20.0	218.9	135.0	373.9	189.5
2013	18	563.4	20.0	218.9	115.7	354.6	208.8
2014	19	563.4	20.0	218.9	96.4	335.3	228.1
2015	20	563.4	20.0	218.9	77.1	316.1	247.4
2016	21	563.4	20.0	218.9	57.9	296.8	266.7
2017	22	563.4	20.0	218.9	38.6	277.5	286.0
2018	23	563.4	20.0	218.9	19.3	258.2	305.2
2019	24	563.4	20.0	218.9	0.0	238.9	324.5
2020	25	563.4	20.0	218.9	0.0	238.9	324.5
TOTAL		13804.5				14025.1	-220.6
					C/B		1.02

(2) PROJECTED FUNDS FLOW STATEMENT (Constant Price at 1989)
== Lagunilla : ALT-3-1 ==

Year	Year in Order	(A) Source: Benefit before Interest	Depreciation	Balance Brought Forward	Long/Short Term Borrowing	Total	(B) Application (US$:1000): Construction Progress	Debt Service Interest	Debt Service Principal	Total	Cash Balance (A)-(B)
1989	-6	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	-5	0.0	0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	-4	0.0	0.0		205.2	205.2	205.2	0.0	0.0	205.2	0.0
1992	-3	0.0	0.0		205.2	205.2	205.2	20.5	0.0	225.7	-20.5
1993	-2	0.0	0.0		102.6	102.6	102.6	41.0	0.0	143.6	-41.0
1994	-1	0.0	0.0		1109.6	1109.6	1109.6	51.3	0.0	1160.9	-51.3
1995	0	0.0	0.0		3043.8	3043.8	3043.8	245.4	0.0	3289.2	-245.4
1996	1	52.8	218.9		2229.7	2501.4	2229.7	709.5	406.6	3345.8	-844.4
1997	2	324.5	218.9			543.4		1002.7	406.6	1409.3	-865.9
1998	3	324.5	218.9			543.4		917.3	599.5	1516.8	-973.3
1999	4	324.5	218.9			543.4		812.6	599.5	1412.1	-868.6
2000	5	324.5	218.9			543.4		708.0	599.5	1307.4	-764.0
2001	6	324.5	218.9			543.4		603.3	599.5	1202.7	-659.3
2002	7	324.5	218.9			543.4		327.8	599.5	927.3	-383.8
2003	8	324.5	218.9			543.4		308.5	192.8	501.4	42.1
2004	9	324.5	218.9	42.1		585.5		289.3	192.8	482.1	103.4
2005	10	324.5	218.9	103.4		646.8		270.0	192.8	462.8	184.0
2006	11	324.5	218.9	184.0		727.5		250.7	192.8	443.5	283.9
2007	12	324.5	218.9	283.9		827.4		231.4	192.8	424.3	403.1
2008	13	324.5	218.9	403.1		946.6		212.1	192.8	405.0	541.6
2009	14	324.5	218.9	541.6		1085.0		192.8	192.8	385.7	699.4
2010	15	324.5	218.9	699.4		1242.8		173.6	192.8	366.4	876.4
2011	16	324.5	218.9	876.4		1419.8		154.3	192.8	347.1	1072.7
2012	17	324.5	218.9	1072.7		1616.2		135.0	192.8	327.8	1288.3
2013	18	324.5	218.9	1288.3		1831.8		115.7	192.8	308.5	1523.2
2014	19	324.5	218.9	1523.2		2066.7		96.4	192.8	289.3	1777.4
2015	20	324.5	218.9	1777.4		2320.9		77.1	192.8	270.0	2050.9
2016	21	324.5	218.9	2050.9		2594.3		57.9	192.8	250.7	2343.6
2017	22	324.5	218.9	2343.6		2887.1		38.6	192.8	231.4	2655.7
2018	23	324.5	218.9	2655.7		3199.1		19.3	192.8	212.1	2987.0
2019	24	324.5	218.9	2987.0		3530.4		0.0	0.0	0.0	3530.4
2020	25	324.5	218.9	3530.4		4073.9		0.0	0.0	0.0	4073.9

6.3.3 Cost-Benefit Analysis for Hydroelectric Power Plants in Group-2.

San Cancio, Intermedia and Municipal power plants in Caldas Department are grouped into one rehabilitation plan because they are all located at the Chinchina River and owned by CHEC. The result of the cost-benefit analysis for this rehabilitation plan is shown below.

Table 6.25 Evaluation Index of Rehabilitation Plan for Hydroelectric Power Plants Located at Chinchina River

Power Plant Package*	Evaluation Index of Generation Plan			Cost-Benefit Analysis		
	Incremental Output ΔP (kW)	Construction cost per ΔP (US$/kW)	Generating cost per Energy Increment ΔE (mills/kWh)	C/B	NPV ($US\$10^3$)	FIRR (%)
Package ①	4,700	1,680	18	1.01	- 177	7.5
Package ②	5,350	2,100	21	1.07	- 384	6.8

*Package ①: Combination of Municipal and Intermedia.
Package ②: Combination of Municipal, Intermedia and San Cancio

The projected financial statements for the consecutive rehabilitation of Municipal, Intermedia and San Cancio hydroelectric power plants are shown in Table 6.26.

Table - 6.26 : PROJECTED FINANCIAL STATEMENTS FOR 3 HYDROPOWER PLANTS
ALONG WITH CHINCHINA RIVER (PACKAGE-2)

(1) PROJECTED REVENUE AND EXPENDITURE STATEMENT (at 1989 Price)
== San Can: Inter & Mun. ALT-2 (Series)==

Year	Year in Order	(A) Total Operating Revenue	(B) Operating Expenditure (US$:1000) O/M Cost	Depreciation	Interest on Investment	Total	(C) Net Benefit (A)-(B)
1989	-6	248.6	16.2	0.0	0.0	16.2	232.4
1990	-5	248.6	16.2	0.0	0.0	16.2	232.4
1991	-4	248.6	16.2	0.0	0.0	16.2	232.4
1992	-3	248.6	16.2	0.0	29.5	45.7	202.9
1993	-2	248.6	16.2	0.0	59.0	75.2	173.4
1994	-1	248.6	16.2	0.0	73.8	90.0	158.6
1995	0	169.5	16.2	0.0	363.8	380.0	-210.4
1996	1	169.5	16.2	345.4	1083.1	1444.7	-1275.2
1997	2	901.9	37.6	345.4	1557.9	1940.9	-1039.0
1998	3	916.2	37.6	345.4	1427.7	1810.7	-894.5
1999	4	954.1	37.6	345.4	1266.7	1649.7	-695.6
2000	5	954.1	37.6	345.4	1105.7	1488.7	-534.6
2001	6	954.1	37.6	345.4	944.8	1327.8	-373.6
2002	7	954.1	37.6	345.4	523.4	906.4	47.7
2003	8	954.1	37.6	345.4	492.6	875.6	78.5
2004	9	954.1	37.6	345.4	461.8	844.8	109.3
2005	10	954.1	37.6	345.4	431.0	814.0	140.1
2006	11	954.1	37.6	345.4	400.2	783.2	170.9
2007	12	954.1	37.6	345.4	369.4	752.5	201.7
2008	13	954.1	37.6	345.4	338.7	721.7	232.5
2009	14	954.1	37.6	345.4	307.9	690.9	263.2
2010	15	954.1	37.6	345.4	277.1	660.1	294.0
2011	16	954.1	37.6	345.4	246.3	629.3	324.8
2012	17	954.1	37.6	345.4	215.5	598.5	355.6
2013	18	954.1	37.6	345.4	184.7	567.7	386.4
2014	19	954.1	37.6	345.4	153.9	536.9	417.2
2015	20	954.1	37.6	345.4	123.1	506.2	448.0
2016	21	954.1	37.6	345.4	92.4	475.4	478.8
2017	22	954.1	37.6	345.4	61.6	444.6	509.5
2018	23	954.1	37.6	345.4	30.8	413.8	540.3
2019	24	954.1	37.6	345.4	0.0	383.0	571.1
2020	25	954.1	37.6	345.4	0.0	383.0	571.1
	TOTAL	23893.5				22241.0	1652.5
						C/B:	0.93

(2) PROJECTED FUNDS FLOW STATEMENT (Constant Price at 1989)
== San Can: Inter & Mun. ALT-2 (Series)==

Year	Year in Order	(A) Source Benefit before Interest	Depreciation	Balance Brought Forward	Long/Short Term Borrowing	Total	(B) Application (US$:1000) Construction Progress	Debt Service Interest	Debt Service Principal	Total	Cash Balance (A)-(B)
1989	-6	232.4	0.0		0.0	232.4	0.0	0.0	0.0	0.0	232.4
1990	-5	232.4	0.0		0.0	232.4	0.0	0.0	0.0	0.0	232.4
1991	-4	232.4	0.0		295.1	527.4	295.1	0.0	0.0	295.1	232.4
1992	-3	232.4	0.0		295.1	527.4	295.1	29.5	0.0	324.6	202.9
1993	-2	232.4	0.0		147.5	379.9	147.5	59.0	0.0	206.5	173.4
1994	-1	232.4	0.0		1681.0	1913.4	1681.0	73.8	0.0	1754.8	158.6
1995	0	153.3	0.0		4775.6	4928.9	4775.6	363.8	0.0	5139.3	-210.4
1996	1	-192.1	345.4		3611.0	3764.3	3611.0	1083.1	620.0	5314.1	-1549.8
1997	2	518.9	345.4			864.3		1557.9	620.0	2177.9	-1313.6
1998	3	533.2	345.4			878.6		1427.7	927.9	2355.6	-1476.9
1999	4	571.1	345.4			916.5		1266.7	927.9	2194.6	-1278.1
2000	5	571.1	345.4			916.5		1105.7	927.9	2033.6	-1117.1
2001	6	571.1	345.4			916.5		944.8	927.9	1872.6	-956.1
2002	7	571.1	345.4			916.5		523.4	927.9	1451.2	-534.7
2003	8	571.1	345.4			916.5		492.6	307.9	800.5	116.1
2004	9	571.1	345.4	116.1		1032.6		461.8	307.9	769.7	262.9
2005	10	571.1	345.4	262.9		1179.4		431.0	307.9	738.9	440.5
2006	11	571.1	345.4	440.5		1357.1		400.2	307.9	708.1	648.9
2007	12	571.1	345.4	648.9		1565.5		369.4	307.9	677.3	888.2
2008	13	571.1	345.4	888.2		1804.7		338.7	307.9	646.5	1158.1
2009	14	571.1	345.4	1158.1		2074.7		307.9	307.9	615.7	1458.9
2010	15	571.1	345.4	1458.9		2375.4		277.1	307.9	585.0	1790.5
2011	16	571.1	345.4	1790.5		2707.0		246.3	307.9	554.2	2152.8
2012	17	571.1	345.4	2152.8		3069.4		215.5	307.9	523.4	2546.0
2013	18	571.1	345.4	2546.0		3462.5		184.7	307.9	492.6	2969.9
2014	19	571.1	345.4	2969.9		3886.4		153.9	307.9	461.8	3424.6
2015	20	571.1	345.4	3424.6		4341.1		123.1	307.9	431.0	3910.1
2016	21	571.1	345.4	3910.1		4826.6		92.4	307.9	400.2	4426.4
2017	22	571.1	345.4	4426.4		5342.9		61.6	307.9	369.4	4973.5
2018	23	571.1	345.4	4973.5		5890.0		30.8	307.9	338.7	5551.3
2019	24	571.1	345.4	5551.3		6467.9		0.0	0.0	0.0	6467.9
2020	25	571.1	345.4	6467.9		7384.4		0.0	0.0	0.0	7384.4

The results of the cost-benefit analysis for La Vuelta Hydroelectric Power Plant, owned by CHOCO Metal Company in CHOCO Department listed in Group-2 are as follows.

Table 6.27 Evaluation Index of Rehabilitation Plan for La Vuelta Hydroelectric Power Plant

Power Plant	Evaluation Index of Generation Plan			Cost-Benefit Analysis		
	Incremental Output ΔP (kW)	Construction Cost per ΔP (US$/kW)	Generating Cost per Energy Increment ΔE (mill/kWh)	C/B	NPV (US$1,000)	FIRR (%)
La Vuelta	7,200	2,800	32	2.29	- 6,398	0.5

6.3.4 Cost-Benefit Analysis for Hydroelectric Power Plants in Group-3

The results of the cost-benefit analysis of rehabilitation plan for Silvia and Ovejas hydroelectric power plants owned by CEDELCA in Cauca Department and Zaragoza Hydroelectric Power Plant owned by ESSA in Sandtander Department show a very low profitability and low possibility of materialization. The evaluation index of generation plan for each hydroelectric power plant, measured by the construction cost per kW and generating cost per KWh, and the results of the cost-benefit analysis are shown in Table 6.28.

Table 6.28 Evaluation of Rehabilitation Plan for Hydroelectric Power Plants

Group	Rehabilitation Plans	Economic Index of Generation Plan			Cost-benefit Analysis			
		Incremental output ΔP (kW)	Construction cost per ΔP (US$/kW)	Generating cost per energy incremental ΔE (mills/kWh)	C/B	NPV (US$1,000)	FIRR (%)	EIRR (%)
Group-1	Caracoli ALT-1	4,400	1,600	18	0.99	53	7.7	11.2
	Municipal ALT-2	3,100	1,350	15	0.86	366	9.2	11.5
	Julio Bravo ALT-1	3,500	1,220	15	0.96	100	8.1	10.5
	Lagunilla ALT-3-1	5,000	1,400	16	1.06	-202	7.0	10.4
Group-2	Intermedia	1,600	2,310	23	1.37	-538	4.6	5.8
	San Cancio	650	5,035	33	1.40	-491	4.6	6.9
	La Vuelta ALT-2	7,200	2,800	32	2.29	-6,398	0.5	2.4
Group-3	Silvia REH	240	2,800	33	2.02	-173	1.1	3.4
	Ovejas ALT-2	2,450	3,300	33	2.63	-3,226	-0.4	1.5
	Zaragoza ALT-1	1,400	2,900	35	1.74	-936	2.7	5.0

6.3.5 Sensitivity Analysis

A sensitivity analysis was conducted for Group-1, showing a high possibility of materialization. Preconditions for the analysis were stated below, and calculation results are shown in Table 6.29.

(1) Case 1 (change in profit): The cost stream remains unchanged and the profit stream fluctuates by 10% from the planned value.

(2) Case 2 (change in investment cost):
The profit stream remains unchanged and only the investment cost of the cost stream fluctuates by 10%.

(3) Case 3 (change in operation and maintenance cost):
The profit stream remains unchanged and only the operation and maintenance cost of the cost stream increases or decreases by 10%.

(4) Case 4 (change in investment cost and operation and maintenance cost):
The profit stream remains unchanged and the cost stream (both investment and operation and maintenance) fluctuate by 10%.

Table 6.29 Sensitivity Analysis

Power Plant	Plan	Case 1		Case 2		Case 3		Case 4	
		+ 10%	- 10%	+ 10%	- 10%	+ 10%	- 10%	+ 10%	- 10%
Caracoli	7.7	8.8	6.6*	6.9*	8.7	7.7	7.8	6.8*	8.7
Municipal	9.2	10.4	8.0*	8.2*	10.4	9.2	9.3	8.2*	10.4
Julio Bravo	8.1	9.2	6.9*	7.0*	9.3	8.0*	8.1	7.0*	9.3
Lagunilla	7.0	8.1	5.9*	6.0*	8.1	7.0	7.0	6.0*	8.2

* Profitability of proposed rehabilitation plan would decrease.

According to the results of a sensitivity analysis, the most influential factor which might change profitability would be fluctuations in income. A secondary factor is the fluctuation of investment cost.

6.3.6 Preconditions for Economic Analysis

Within the scope of the national economy, an economic analysis was conducted to evaluate the investment propriety of the optimum plan for each site selected through the financial analysis. The preconditions for the economic analysis, as explained below, differ from those of the financial analysis.

(1) Economic Cost

The financial costs obtained from market prices will be converted into economic costs under the following considerations:

1) Deduction of taxes, etc.

According to Colombian law, customs duty and value-added tax are imposed upon imported goods. However, these items are deducted from the financial costs as transfer items.

2) Border prices

Costs of equipment to be procured in Colombia are estimated by border prices, in which standard conversion factors (SCF) are converted into financial costs. For SCF, the following factors are adopted, which the World Bank applies for the economic evaluation of Colombia:

- Maintenance: 0.91
- SCF: 0.92

3) Calculated cost for unskilled labor

Economic costs are calculated by assuming latent water rates. Statistics show that the current unemployment rate in Colombia is approximately 10% under the latent wage rates.

Latent wage rate = market wage rate x (1.25 - unemployment rate/0.20)

Accordingly, a latent wage rate of 75% is applied against the market labor cost for calculated costs of unskilled labor.

(2) Economic Benefit

Benefit unit costs estimated by market prices are converted into calculated costs for obtaining economic benefits to be calculated through economic analysis. Accordingly, the electricity conversion factor (ECF) of 0.92, as adopted by the World Bank, will be applied.

The economic values of electric power are established within a measurable range of (1) amounts which users are willing to pay for power service; and (2) costs which can be saved for alternatives to electric power.

Item (1) is electric charges per KWh, which end-users pay to electric companies. Electric charges vary by region and user. However, an established average charge of US$28.1/MWh = Col.$10,380/MWh is used. The balance between this amount the users will pay and ICEL's average selling unit price (US$13.36/MWh = Col.$4,936.18/MWh) is an economic benefit.

Item (2) is the balance of the cost of thermal power generation. The average O/M cost of thermal power generation, as estimated by ISA, is US$18/KWh. Therefore, the balance of US$14/KW, with the average O/M cost of hydroelectric power (US$4/KW) is an economic benefit. The aggregate amount from (1) and (2) is defined as the total economic benefit.

6.3.7 Results of Economic Analysis

The results of the economic analysis obtained under the aforementioned conditions for the optimum plan of each site is shown in Table 6.30. The four power plants in Group-1 surpass the estimated 7 to 10% opportunity cost of capital in Colombia. The economic cash flow of the four rehabilitation plans are shown in Table 6.31 and table 6.32.

Table 6.30 Economic Evaluation Index for the Optimum Plan of Each Site

Power Plant	Alternative	Analyzed Value		Remarks
		NPV (US$1,000)	EIRR (%)	
Caracoli	ALT-1	1,235	11.2	Table 6.29
San Cancio	-	- 109	6.9	
Intermedia	-	- 334	5.8	
Municipal	ALT-2	850	11.5	Table 6.29
Silvia	REH	- 101	3.4	
Ovejas	ALT-2	- 2,207	1.5	
La Vuelta	ALT-2	- 4,348	2.4	
Julio Bravo	ALT-1	588	10.5	Table 6.30
Zaragoza	ALT-1	- 491	5.0	
Lagunilla	ALT-3-1	828	10.4	Table 6.30

Table - 6.31 : ECONOMIC CASH FLOW FOR CARACOLI AND MUNICIPAL HYDROPOWER PLANTS

(1) PROJECTED CASH FLOW STATEMENT (Constant Price at 1989)
== Caracoli : ALT-1 ==

Economic IRR Stream (US$:1000)

Year	Year in Order	Existing Plant O/M Cost	Existing Plant Operating Revenue	Investment Cost	Increment Operating Cost	Increment Operating Revenue	Net Benefit
1989	-6	8.4	255.0		8.4	255.0	0.0
1990	-5	8.4	255.0		8.4	255.0	0.0
1991	-4	8.4	255.0	189.1	8.4	255.0	-189.1
1992	-3	8.4	255.0	189.1	8.4	255.0	-189.1
1993	-2	8.4	255.0	94.5	8.4	255.0	-94.5
1994	-1	8.4	255.0	1153.1	8.4	255.0	-1153.1
1995	0	8.4	255.0	2370.5	8.4	255.0	-2370.5
1996	1	8.4	255.0	1193.5	24.4	782.4	-682.1
1997	2	8.4	255.0		24.4	782.4	511.4
1998	3	8.4	255.0		24.4	782.4	511.4
1999	4	8.4	255.0		24.4	782.4	511.4
2000	5	8.4	255.0		24.4	782.4	511.4
2001	6				24.4	782.4	758.0
2002	7				24.4	782.4	758.0
2003	8				24.4	782.4	758.0
2004	9				24.4	782.4	758.0
2005	10				24.4	782.4	758.0
2006	11				24.4	782.4	758.0
2007	12				24.4	782.4	758.0
2008	13				24.4	782.4	758.0
2009	14				24.4	782.4	758.0
2010	15				24.4	782.4	758.0
2011	16				24.4	782.4	758.0
2012	17				24.4	782.4	758.0
2013	18				24.4	782.4	758.0
2014	19				24.4	782.4	758.0
2015	20				24.4	782.4	758.0
2016	21				24.4	782.4	758.0
2017	22				24.4	782.4	758.0
2018	23				24.4	782.4	758.0
2019	24				24.4	782.4	758.0
2020	25				24.4	782.4	758.0

EIRR: 11.2%
C/B Ratio: 0.73
NPV: 1235.0

(2) PROJECTED CASH FLOW STATEMENT (Constant Price at 1989)
== Municipal : ALT-2 ==

Economic IRR Stream (US$:1000)

Year	Year in Order	Existing Plant O/M Cost	Existing Plant Operating Revenue	Investment Cost	Increment Operating Cost	Increment Operating Revenue	Net Benefit
1989	-6	5.1	98.6		5.1	98.6	0.0
1990	-5	5.1	98.6		5.1	98.6	0.0
1991	-4	5.1	98.6	109.0	5.1	98.6	-109.0
1992	-3	5.1	98.6	109.0	5.1	98.6	-109.0
1993	-2	5.1	98.6	54.5	5.1	98.6	-54.5
1994	-1	5.1	98.6	482.1	5.1	98.6	-482.1
1995	0	5.1	98.6	1362.1	5.1	65.7	-1395.0
1996	1	5.1	98.6	1025.0	5.1	65.7	-1057.9
1997	2	5.1	98.6		16.4	505.7	395.9
1998	3	5.1	98.6		16.4	505.7	395.9
1999	4	5.1	98.6		16.4	505.7	395.9
2000	5	5.1	98.6		16.4	505.7	395.9
2001	6				16.4	505.7	489.3
2002	7				16.4	505.7	489.3
2003	8				16.4	505.7	489.3
2004	9				16.4	505.7	489.3
2005	10				16.4	505.7	489.3
2006	11				16.4	505.7	489.3
2007	12				16.4	505.7	489.3
2008	13				16.4	505.7	489.3
2009	14				16.4	505.7	489.3
2010	15				16.4	505.7	489.3
2011	16				16.4	505.7	489.3
2012	17				16.4	505.7	489.3
2013	18				16.4	505.7	489.3
2014	19				16.4	505.7	489.3
2015	20				16.4	505.7	489.3
2016	21				16.4	505.7	489.3
2017	22				16.4	505.7	489.3
2018	23				16.4	505.7	489.3
2019	24				16.4	505.7	489.3
2020	25				16.4	505.7	489.3

EIRR: 11.5%
C/B Ratio: 0.56
NPV: 850.4

Table - 6.32 : ECONOMIC CASH FLOW FOR J.BRAVO AND LAGUNILLA HYDROPOWER PLANTS

(1) : PROJECTED CASH FLOW STATEMENT (Constant Price at 1989)

== Julio Bravo : ALT-1 ==

Economic IRR Stream (US$:1000)

Year	Year in Order	Existing Plant O/M Cost	Existing Plant Operating Revenue	Investment Cost	Increment Operating Cost	Increment Operating Revenue	Net Benefit
1989	-6	0.0	0.0		0.0	0.0	0.0
1990	-5	0.0	0.0		0.0	0.0	0.0
1991	-4	0.0	0.0	116.5	0.0	0.0	-116.5
1992	-3	0.0	0.0	116.5	0.0	0.0	-116.5
1993	-2	0.0	0.0	58.2	0.0	0.0	-58.2
1994	-1	0.0	0.0	587.3	0.0	0.0	-587.3
1995	0	0.0	0.0	1464.3	0.0	0.0	-1464.3
1996	1			972.1	6.4	211.9	-766.6
1997	2				12.7	423.8	411.0
1998	3				12.7	423.8	411.0
1999	4				12.7	423.8	411.0
2000	5				12.7	423.8	411.0
2001	6				12.7	423.8	411.0
2002	7				12.7	423.8	411.0
2003	8				12.7	423.8	411.0
2004	9				12.7	423.8	411.0
2005	10				12.7	423.8	411.0
2006	11				12.7	423.8	411.0
2007	12				12.7	423.8	411.0
2008	13				12.7	423.8	411.0
2009	14				12.7	423.8	411.0
2010	15				12.7	423.8	411.0
2011	16				12.7	423.8	411.0
2012	17				12.7	423.8	411.0
2013	18				12.7	423.8	411.0
2014	19				12.7	423.8	411.0
2015	20				12.7	423.8	411.0
2016	21				12.7	423.8	411.0
2017	22				12.7	423.8	411.0
2018	23				12.7	423.8	411.0
2019	24				12.7	423.8	411.0
2020	25				12.7	423.8	411.0

EIRR: 10.5%
C/B Ratio: 0.78
NPV: 588.4

(2) PROJECTED CASH FLOW STATEMENT (Constant Price at 1989)

== LAGUNILLA: ALT-3-1 ==

Economic IRR Stream (US$:1000)

Year	Year in Order	Existing Plant O/M Cost	Existing Plant Operating Revenue	Investment Cost	Increment Operating Cost	Increment Operating Revenue	Net Benefit
1989	-6	0.0	0.0		0.0	0.0	0.0
1990	-5	0.0	0.0		0.0	0.0	0.0
1991	-4	0.0	0.0	188.9	0.0	0.0	-188.9
1992	-3	0.0	0.0	188.9	0.0	0.0	-188.9
1993	-2	0.0	0.0	94.5	0.0	0.0	-94.5
1994	-1	0.0	0.0	932.0	0.0	0.0	-932.0
1995	0	0.0	0.0	2372.6	12.7	302.8	-2069.7
1996	1			1612.0	12.7	605.7	-1019.0
1997	2				12.7	605.7	593.0
1998	3				12.7	605.7	593.0
1999	4				12.7	605.7	593.0
2000	5				12.7	605.7	593.0
2001	6				12.7	605.7	593.0
2002	7				12.7	605.7	593.0
2003	8				12.7	605.7	593.0
2004	9				12.7	605.7	593.0
2005	10				12.7	605.7	593.0
2006	11				12.7	605.7	593.0
2007	12				12.7	605.7	593.0
2008	13				12.7	605.7	593.0
2009	14				12.7	605.7	593.0
2010	15				12.7	605.7	593.0
2011	16				12.7	605.7	593.0
2012	17				12.7	605.7	593.0
2013	18				12.7	605.7	593.0
2014	19				12.7	605.7	593.0
2015	20				12.7	605.7	593.0
2016	21				12.7	605.7	593.0
2017	22				12.7	605.7	593.0
2018	23				12.7	605.7	593.0
2019	24				12.7	605.7	593.0
2020	25				12.7	605.7	593.0

EIRR: 10.4%
C/B Ratio: 0.80
NPV: 828.4

6.4 The Operation and Maintenace Manual

The operation and maintenance manual is a set of rules for guaranteeing the stability of the electric power supply, as well as for maintaining the normal status of the equipment. Thus, it should be compiled for each public electric power company, in line with individual management policy. Since all generating equipment, including turbines, generators and main transformers will have new repalcements, the machine manufacturers should provide the companies with manuals for the operation, maintenance and management which are suitable for the respective specifications of the equipment. Included in the appendix-4 of this report is the General Manual for operation and maintenance for generating equipment and civil structures.

CHAPTER 7 CONCLUSION

From the 12 power plants (thermal: 1, hydroelectric: 11) selected for F/S of small-scale generating facilities rehabilitation, the following power plants (thermal: 1, hydroelectric: 4) were proposed as highly feasible sites for rehabilitation.

Power Plant	Type	Department	Jurisdiction
Thermopaipa	thermal power plant	Boyaca	EBSA
Municipal	run-of-river type hydroelectric power plant	Caldas	CHEC
Intermedia	run-of-river type hydroelectric power plant	Caldas	CHEC
San Cancio	run-of-river type hydroelectric power plant	Caldas	CHEC
Julio Bravo	run-of-river type hydroelectric power plant	Nariño	CEDENAR

7.1 Rehabilitation Plan of Termopaipa Thermal Power Plant

The three items to be investigated at Termopaipa Thermal Power Plant are described below. The first two items relate to the investigation for the improvement plan for solving the malfunction at the existing No. 2 unit (available output: 66 MW); and for the improvement of the operation, maintenance and inspection systems.

- Investigation item (1): Plan to increase output by replacing turbine of unit No. 2 (66 MW → 74 MW)

In unit No. 2, manufactureed in 1975, an 8 MW difference exists between the rate output of the turbine (rated output: 66 MW) and the generator (rated output: 74 MW). Existing turbine parts, including turbine rotors, blades, nozzles, diaphragm and the feed water heater will be replaced with new ones to increase the turbine output to 74 MW.

- Investigation item (2): Plan to replace existing pneumatic instrumentation system

This improvement plan will replace the existing pneumatic instrumentation system with an electrical instrumentation system; simplify operation, maintenance and inspection;

and improve monitoring and control systems. A computer-controlled electrical instrumentation system will replace both the central supervisory panel which supervises and controls the boiler and the instrumentation unit of the turbine.

Investigation item No.3 is for the F/S of the improvement of the cooling system cooling water for the power plant.

- Investigation item (3): Plan to change to a closed cooling system

The existing cooling system, which discharges the water used to cool the condenser and auxiliary bearings at the upstream of the intake at Chicamocha River, has the problems described below. The installation of a new cooling tower and the improvement of cooling water circulation in the cooling system should increase the cooling coefficient and solve these problems.

Problems of the existing cooling system

1) A wide area for the cooling reservoir is necessary for natural cooling.

2) The temperature of the cooling water increases during intake, so the cooling coefficient is low.

3) Since a cooling reservoir is used for natural cooling, the cooling coefficient fluctuates with atmospheric temperature

4) Rising cooling reservoir temperature causes marine vegetation to flourish which reduces circulation. Thus, there is some cost involved for removing the marine vegetation.

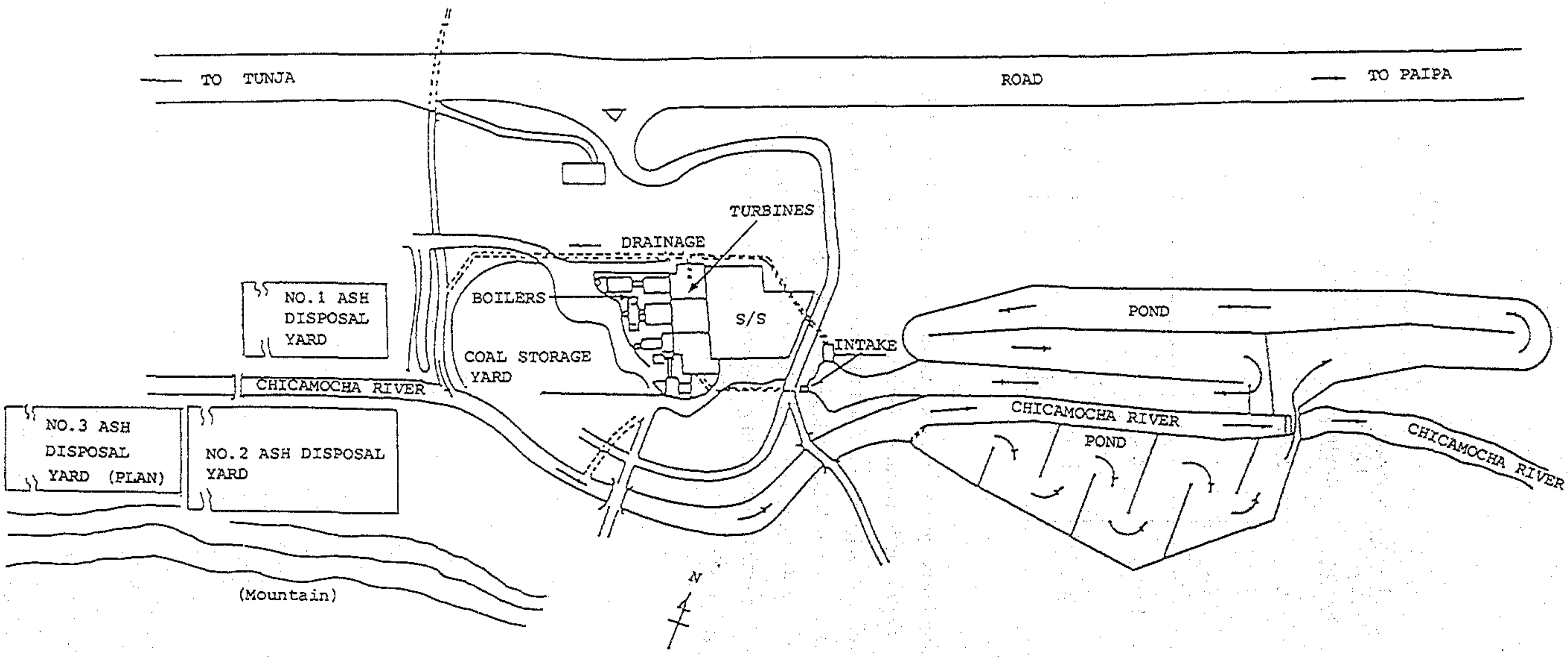
Although there are many types of cooling water towers, the forced ventilation cooling tower has been selected.

For the rehabilitation plan of Termopaipa thermal power plant, the necessary construction costs based on September, 1989 estimates are shown in the following.

(unit: US$$10^6$)

Rehabilitation Item	Equipment cost		Foundation work cost	Total
	Foreign portion	Local portion	Local portion	
1) Plan to increase output of No. 2 unit	4.06	2.28	—	6.34
2) Change measuring system of No. 2 unit	3.68	2.07	—	5.75
3) Change water tower system	8.76	4.94	1.17	14.87
Total	16.5	9.29	1.17	26.96

The change of the cooling tower system will not only improve the cooling coefficient, but by replacing the existing open cycle cooling system, which uses the cooling reservoir to a closed cycle cooling system, which uses a cooling tower, the wide area used for the cooling reservoir site will be available for other uses. Furthermore, No. 1 unit (rated: 33,000 kW), manufactured in 1958 is obsolete and worn out, so for future increase, it is essential to protect the surrounding environment and prevent air pollution by securing a disposal site for ash.



<u>SPACE OF ASH DISPOSAL YARD</u>

NO.1 : 100m x 600m (full)

NO.2 : 300m x 1,500m (about 80% is ocupied)

NO.3 : (250m x 2,000m) (plan)

<u>AREA OF POND</u> = 580,000m^2 (Average depth:3m)

Fig.7.1 GENERAL LAYOUT IN TERMOPAIPA POWER PLANT

7.2 Rehabilitation Plan of Hydroelectric Generating Equipment

The JICA Study Team recommended the following four power plants as possible candidates for rehabilitation, after hearings with the electric power companies and evaluation of the respective hydroelectric power plants, as described in Chapter 6.

1) Municipal run-of-river type hydroelectric power plant
   Owner: CHEC

   Present rated output: 2,112 kW → Post-rehabilitation output: 4,500 kW

2) Intermedia run-of-river type hydroelectric power plant
   Owner: CHEC

   Present rated output: 1,120 kW → Post-rehabilitation output: 2,500 kW

3) San Cancio run-of-river type hydroelectric power plant
   Owner: CHEC

   Present rated output: 2,320 kW → Post-rehabilitation output: 2,400 kW

4) Julio Bravo run-of-river type hydroelectric power plant
   Owner: CEDENAR

   Present rated output: 1,500 kW → Post-rehabilitation output: 3,500 kW

7.2.1 Municipal, Intermedia and San Cancio Hydroelectric Power Plants

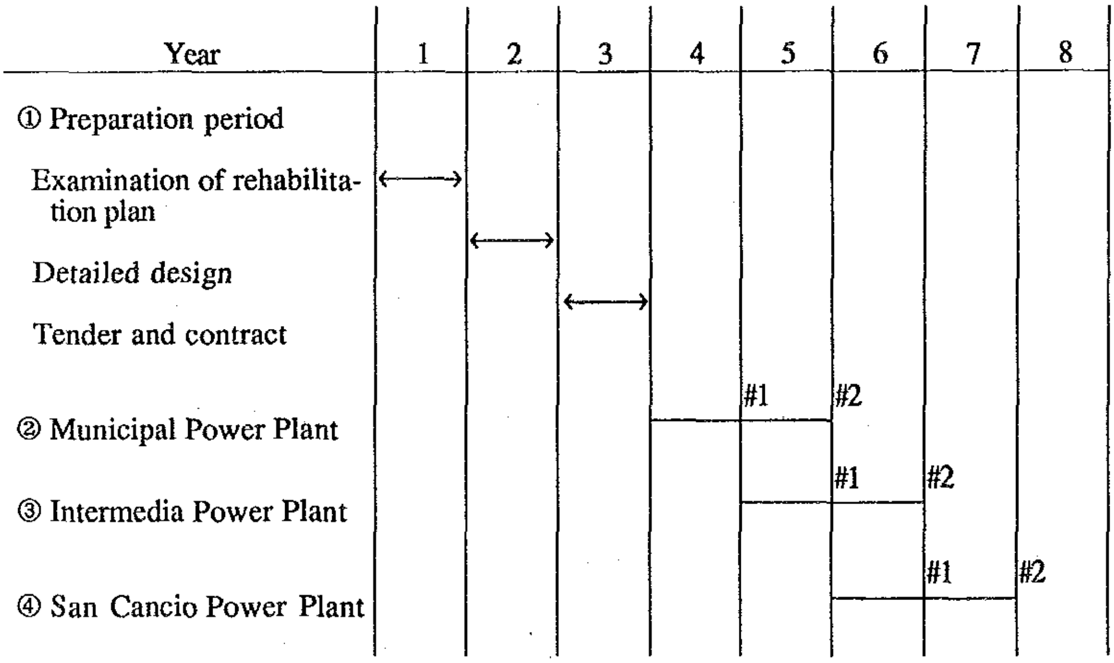
San Cancio, Municipal and Intermedia power plants, owned by CHEC, are located along the Chinchina River in Caldas Department. Compared individually, the rehabilitation plan for Municipal Power Plant is deemed best. However, these three power plants should be grouped into one generation plan with rehabilitation made in the order of Municipal, Intermedia and San Cancio power plants.

- Plan for rehabilitation work
  The cost for rehabilitation work is estimated at US$11,150,000 (foreign currency apportionment: US$6,250,000; local currency apportionment: US$4,900,000) according to September, 1989 market price. The ration of foreign currency to local currency is 0.56 : 0.44.

(unit: US$10³)

Power Plant	Foreign currency apportionment	Local currency apportionment	Total
Municipal	2,450	1,750	4,200
Intermedia	1,900	1,800	3,700
San Cancio	1,900	1,350	3,250
Total	6,250	4,900	11,150

If the rehabilitation work is executed in the order of Municipal, Intermedia and San Cancio power plants, the construction is estimated to take 48 months.



- The economic index of these three power plants grouped into one rehabilitation plan is as follows.

Increased output ΔP (kW):	5,350
Annual potential power generation increment ΔE (MWh):	55,400
Construction cost per ΔP (US$/kW):	2,100
Generating cost per ΔE (mills/kWh):	21
C/B ratio:	1.07

Net present value (NPV) (US$$10^3$): - 384
Internal rate of return (IRR) (%): 6.8

Items to be recorded for implementation

The ICEL group should record data on the following items at an early date for implementing the rehabilitation of the three power plants.

① Discharge capacity of the existing conduction channel
② Discharge at the remaining waterbasin at the intake site of Municipal power plant
③ Water quality of the Chinchina River

7.2.2 Julio Bravo Hydroelectric Power Plant

Data for some items is needed for the implementing the rehabilitation of Julio Bravo power plant, which has a high possibility of implementation.

- Plan for rehabilitation work
  The cost for rehabilitation work is estimated at US$4,300,000 according to September, 1989 market price. The ration of foreign currency to local currency is 0.54 : 0.46.

(unit: US$$10^3$)

Power Plant	Foreign currency apportionment	Local currency apportionment	Total
Julio Bravo	2,300	2,000	4,300

The rehabilitation work period is estimated at 36 months, and preparation period at 48 months.

Year	1	2	3	4	5	6	7	8
Preparation period								
Examination of rehabilitation plan	←→							
Detailed design		←—	—→					
Tender and contract				←→				
Civil construction					←—	—→		
Equipment manufacturing					←—	—→		
Equipment installation						# ←—	#1 —→	#2

- Economic index of this rehabilitation plan is as follows.

Increased output ΔP (kW):	3,500
Annual potential power generation increment ΔE (MWh):	29,400
Construction cost per ΔP (US$/kW):	1,220
Generating cost per ΔE (mills/kWh):	15
C/B ratio:	0.96
Net present value (NPV) (US$$10^3$):	100
Internal rate of return (IRR) (%):	8.1

Items to be recorded for implementation

The ICEL group should record data on the following two items at an early date for implementing the rehabilitation of Julio Bravo power plants.

① Hydrological regime at the existing diversion weir

② Year-to-year transition of water quality at the intake site

7.2.3 Power plants excluded from consideration

Caracoli Power Plant in Antioquia Department (owned by EADE), and Lagunilla Power Plant in Tolima Department (owned by ELECTROLIMA) were excluded from consideration since work cannot commence at an early date.

- Caracoli Power Plant

The reconstruction plan for doubling the available discharge is considered more advantageous than the rehabilitation plan. The inspection for worn pipes and the identification of residual life must precede the execution of either plan. For the reconstruction plan, the existing penstock (diameter: 1,350 mm, length: 1,300 m) needs to be replaced, even though it appears to be well maintained.

- Lagunilla Power Plant

The hydrological gauging station which was located at Lagunilla River was washed away during the volcanic eruption of Nevado del Ruiz in November, 1985. However, debris flow has changed the hydrological regime at the river basin, so a two-year record of discharge data recorded at Lagunilla River is needed.

7.3 Recommendations on Rehabilitation of Small-scale Hydroelectric Power Plants

Sixty-two small-scale hydroelectric power plants were nominated by ICEL for pre-F/S in November, 1987. This F/S concluded that the four power plants described in Section 7.2 have the highest probability of implementation, from the present total output of 8,800 kW to a post-rehabilitation output of 14,900 kW. These results are within the study scope limits of the rehabilitation of the existing generating facilities of this S/W. However, an examination of the other power plants outside of the study scope limits suggests that other measures can be implemented for improvement, as suggested by the following examples.

① Investigate the water utilization coefficient at power plants with low hydroelectric power

Inza Hydroelectric Power Plant (Cauca Department)

Rio Recio Hydroelectric Power Plant (Tolima Department)

② Power plants located along the same river should be developed as a group

Bayona, Campestre and La Union hydroelectric power plants, along the Quindio River in Quindio Department

③ Existing diesel power plants to be substituted with hydroelectric power plants

Rio Napia Hydroelectric Power Plant (Cauca Department)

APPENDIXES

APPENDIX-1 The List of Feasibility/Study Reports

The Feasibility Study (F/S) Reports are contained in separte study reports for each power plant, as shown in the following list.

Vol. - 1	Termopaipa
Vol. - 2	Puente Guillermo
Vol. - 3	Caracoli
Vol. - 4	San Cancio, Intermedia and Municipal
Vol. - 5	Julio Bravo
Vol. - 6	Lagunilla
Vol. - 7	La Vuelta
Vol. - 8	Silvia
Vol. - 9	Ovejas
Vol. - 10	Zaragoza

Appendix-2 The List of Candidate Small-Scale Power Plants as the Rehabilitation

(1) Thermal Power Plants

No.	Department	Electric Company	Power Plant	Installed Capacity Ⓟ (kW)	Generating Facility				Available Capacity (kW)		Ⓟe / Ⓟ (%)	Generator Voltage (kV)	Distribution (kV)	Remarks
					Installed Year	Type	No. of Unit	Unit Capacity (kW)	Unit	Total Ⓟe				
101	Boyaca	EBSA	Termo-paipa #I	173,000	1958	Steam Turbine	1	33,000	30,000	170,000	98	13.8	13.2 66 115 230	
			Termo-paipa #II		1974	Steam Turbine	1	66,000	66,000					
			Termo-paipa #III		1982	Steam Turbine	1	74,000	74,000					
102	Santander	ESSA	Termo-barranca #III	66,000	1978	Steam Turbine	1	66,000	40,000	40,000	61	13.8	34.5 115 220	
103	Santander	ESSA	Termo-palenque #IV	15,000	1972	Gas Turbine	1	15,000	0	0	0	13.8	13.2 34.5 115	
		Total		254,000			5			210,000	83			

(2) Hydroelectric Power Plants (1/4)

No.	Depart-ment	Electric Company	Power Plant	River	Design Data Q (m^3/sec)	Design Data H (m)	Design Data (P) (kW)	Generating Facility Installed Year	Generating Facility Type *1	Generating Facility No. of Unit	Generating Facility Unit Capa-city (kW)	Available Capacity (kW) Unit	Available Capacity (kW) Total (Pe)	(Pe)/(P) x100 (%)	Genera-tor Voltage (kV)	Distribu-tion Voltage (kV)	Remarks
201	Antioquia	EADE	Caracolí	Nus	5.0	86	3,200	1935 1963	P F	1 1	1,600 1,600	1,150 1,150	2,300	72	2.3 2.3	13.2 44	
202			La Rebusca	San Roque	1.0	90	700	1932 1934	P P	1 1	350 350	250 220	470	67	2.3 2.3	13.2 44	
203			Calera	Q. Malena	1.0	20	160	1938 1938	P P	1 1	80 80	0 64	64	40	2.4 2.4	7.62	
204			Rio Abajo	Negro	2.5	51	1,000	1947 1947	P P	1 1	500 500	300 300	600	60	2.4 2.4	13.2	
205			Piedras	Piedras	1.5	49	458	1935 1958	F F	1 1	250 208	250 0	250	53	0.4 0.4	13.8	
206			Sonson	Sonson	1.0	536	3,600	1967	P	1	3,600	3,600	3,600	100	6.6	44	
207			Tamesis	Frio	1.2	167	1,508	1940 1951 1961	P P P	1 1 1	500 504 504	420 420 320	1,160	77	6.6 0.5 0.5	13.8 44	
208		E.P. de Urrao	Urrao	Urrao	1.5	70	824	1964 1964	F P	1 1	624 200	325 105	430	52	0.5 2.4	13.2	
209		E.P. de Abejorral	Abejorral	Q. Yeguas	1.0	135	724	1960 1960	P P	1 1	528 196	355 135	490	68	0.4 0.4	13.2	
210	Boyaca	EBSA	P. Guillermo	Suarez	2.6	58	1,280	1963 1963	F F	1 1	640 640	0 0	0	-0	0.24 0.24	22	
211	Caldas	CHEC	San Cancio	Chinchiná	5.6	59.75	2,320	1929 1947	P F	1 1	1,350 970	1,000 750	1,750	75	4.16 4	4.16	
212			Intermedia	Chinchiná	5.6	59.01	1,120	1947	P	1	1,120	900	900	80	4	4.16	
213			Municipal	Chinchiná	5.6	80.57	2,112	1945 1945	P P	1 1	1,056 1,056	700 700	1,400	66	4.3 4.3	4.3 13.2	
214			Guacaica	Guacaica	4.0	67.8	1,120	1929	P	1	1,120	0	0	0	4.16	33	
215		E.P. de Salamina	Salamina	Q. Frisolera Q. Palo	0.4	85	280 (Assumed)	1943	P	1	280	140 (Assumed)	140	50	4	4	
216		E.P. de Anserma	Anserma					(Deleted)									*2

(2) Hydroelectric Power Plants (2/4)

No.	Depart-ment	Electric Company	Power Plant	River	Design Data Q (m^3/sec)	Design Data H (m)	Design Data Ⓟ (kW)	Generating Facility Installed Year	Generating Facility Type *1	Generating Facility No. of Unit	Generating Facility Unit Capa-city (kW)	Available Capacity (kW) Unit	Available Capacity (kW) Total Ⓟe	Ⓟe/Ⓟ x100 (%)	Genera-tor Voltage (kV)	Distribu-tion Voltage (kV)	Remarks
217	Risaralda	EPP	Belmonte	Otun	6.0	115	3,760	1941 1941	P P	1 1	1,880 1,880	1,650 1,650	3,300	88	2.4 2.4	2.4 13.1 17.3	
218			Dos Quebradas	Otun	10.0	113	8,500	1955 1955	F F	1 1	4,250 4,250	4,100 4,100	8,200	96	4.16 4.16	13.2 33	
219		E.P. de Santa Rosa	Santa Rosa	San Eugenio	1.2	55	450	1927 1927	P F	1 1	350 100	139 0	139	31	2.4 2.4	4.16	
220	Quindo	E.P. de Armenia	El Bosque	Quindio	4.0	90	2,280	1929	P	1	2,280	0	0	0	3.3	20	
221		E.P. de Calarca	Bayona	Quindio	2.5	30	1,008	1952	F	1	1,008	159	159	16	6.6	6.6	
222			Campestre	Quindio	2.5	54	1,120	1956	F	1	1,120	62	62	6	0.5	13.2	
223			La Union	Quindio	2.5	43	1,000	1938	F	1	1,000	0	0	0	6.6	6.6	
224	Cauca	CEDELCA	Sajandi	Sajandi	3.0	104	2,480	1960 1960 1960	P F F	1 1 1	800 840 840		1,640	66	4.4 4.4 4.4	41.5	
225			El Palo	El Palo	6.0	24.5	1,440	1964 1964	F F	1 1	720 720	640 640	1,280	89	0.44 0.44	33	
226			Mondomo	Mondomo	2.0	29	600	1958 1958	F F	1 1	300 300	230 240	470	78	2.4 2.4	14.4	
227			Silvia	Piendamo	1.5	31	604	1960 1960	F F	1 1	500 104	0 100	100	17	6.9 0.48	13	
228			Ovejas	Ovjas	7.0	24.5	900	1939	F	1	900	650	650	72	12.5		
229			Asnazu	Asnazu	1.0	134	450	1932	P	1	450	300	300	67	4.2	12.5	
230			Inza	Ullucos	0.6	72	360	1971	F	1	360	0	0	0	0.23	13.2	
231			Toribio	Isabelilla	0.5	13	63	1968		1	63	35	35	55	0.23	13.2	
232			Florida-I	Cauca	6.5	48	2,300	1956 1956	P F	1 1	1,150 1,150	0 0	0	0	0.5 0.5	11.4	
233	CHoco	E. Choco (Mineros del Chuco S.A.)	La Vuelta	Andagueda	54.0	4.8	2,000	1916 1916	F F	1 1	1,000 1,000	300 200	500	25	4.4 4.4	4.4 34.5	

(2) Hydroelectric Power Plants (3/4)

No.	Department	Electric Company	Power Plant	River	Design Data Q (m³/sec)	Design Data H (m)	Design Data (P) (kW)	Generating Facility Installed Year	Type *1	No. of Unit	Unit Capacity (kW)	Available Capacity (kW) Unit	Available Capacity (kW) Total (Pe)	(Pe)/(P) x100 (%)	Generator Voltage (kV)	Distribution Voltage (kV)	Remarks
234	Cundinamarca	CELGAC	La Salada	Bogotá	2.3	15	280	1935	F	1	280	0	0	0	4.16		
235			Rio Negro	Negro	13.0	78.2	9,600	1974 1974	F F	1 1	4,800 4,800	3,000 1,500	4,500	47			*2
236		E.P. de Choachi	Choachi	Palmar	1.0	45	300	1954	F	1	300	19	6	0	0.38	6.6	
237		ECSA (Cementos Diamantes S.A.)	Apulo	Bogotá	23.0	15	3,000	1928 1928 1928 1947 1947	T T T T T	1 1 1 1 1	600 600 600 600 600	0 0 0 0 0	0	0	6.6	34.5	
238	Huila	E. Huila	La Viciosa	Q. Viciosa	0.5	45.5	225	1950 1950	F F	1 1	100 125	0 0	0	0			
239			La Pita	Q. Mayo	0.75	120.5	1,420	1973 1964	F F	1 1	700 720	460 600	1,060	75			
240			Fortalecillas	Fortalecillas	2.0	28	408	1968	F	1	408	0	0	0			
241			Rio Iquira-I	Iquira	2.5	192.4	4,320	1951 1951 1961	P P P	1 1 1	1,440 1,440 1,440	1,130 1,100 0	2,230	52			
242			Rio Iquira-II	Iquira	2.5	98.4	2,400	1954	F	1	2,400	700	700	29			
243	Meta	EMSA	El Calvario	Q. Panela	0.04	60	20	1984	P	1	20	16	16	80	0.208		
244			San Juanito	Guajaro	0.1	53	20	1986	F	1	20	20	20	100	0.22	13.2	
245	Nariño	CEDENAR	Rio Mayo-II	Mayo	12.5	218	21,000	1969 1969 1969	F F F	1 1 1	7,000 7,000 7,000	7,000 7,000 6,000	20,000	95	6.6		
246			Rio Bobo	Bobo	1.8	306	4,368	1956 1956 1956	P P P	1 1 1	1,440 1,440 1,488	0 0 0	0	0	3.3		
247			Rio Sapuyes	Sapuyes	2.0	107	1,856	1956 1956 1956	F F F	1 1 1	328 328 1,200	110 170 500	780	42	0.5		
248			Julio Bravo	Pasto	2.0	120	1,500	1942 1942 1942	P P P	1 1 1	500 500 500	0 0 0	0	0	6.9	13.2	
249	Putumayo	E.P. de Mocoa	Mulato	Mulato	0.5	50	168	1964	F	1	168	0	0	0			*2

(2) Hydroelectric Power Plants (4/4)

No.	Depart-ment	Electric Company	Power Plant	River	Design Data Q (m^3/sec)	Design Data H (m)	Design Data (P) (kW)	Generating Facility Installed Year	Type *1	No. of Unit	Unit Capacity (kW)	Available Capacity (kW) Unit	Available Capacity (kW) Total (Pe)	(Pe)/(P) x100 (%)	Generator Voltage (kV)	Distribution Voltage (kV)	Remarks
250	Santander	ESSA	Palmas	Lebrija	17.0	150	18,000	1950 1950 1960 1960	F F F F	1 1 1 1	4,500 4,500 4,500 4,500		13,000	72			
251			Zaragoza	Surata	6.5	30	1,560	1931 1935 1948	F F F	1 1 1	520 520 520	0	800	51			
252			Cascada	Fonce	18.8	24.5	3,350	1952 1952 1939 1956 1963	F F F F F	1 1 1 1 1	490 240 220 1,200 1,200	0 0 0	1,300	39			
253			Comoda	Lenguaruco	1.3	89	880	1912 1912 1954 1954	P P F F	1 1 1 1	160 160 280 280	0 0 0 0	0	0			
254			Servitá	Servitá	0.6	169.5	800	1962 1962	F F	1 1	400 400	360 360	720	90	0.44 0.44	13.2	*2
255			Calichal	Servitá	1.2	26	280	1950 1950	F F	1 1	125 155	100 120	220	79	2.4 0.5	7.2 13.8	*2
256	Tolima	ELECTROLIMA	Guali (Honda)	Guali	12.0	13.9	1,048	1926 1955 1955	F F F	1 1 1	748 150 150	0 0 0	0	0	4.16 2.3 2.3		
257			Rio Recio	Recio	5.0	100	4,000	1960 1960	F F	1 1	2,000 2,000	0 1,200	1,200	30	4.16	33	
258			Mirolindo	Combeima	4.7	97	3,600	1946 1946 1946	F F F	1 1 1	1,200 1,200 1,200	1,000 0 0	1,000	28	2.4	13.8	
259			Pastales	Combeima Q. La Plata	3.87	30	840	1947	F	1	840	0	0	0	0.5	13.8	
260			Prado	Prado	112.0	56	51,000	1974	F F F F	1 1 1 1	15,300 15,300 15,300 5,100	15,300 15,300 15,300 5,100	51,000	100	6.6 6.6 6.6 4.16	33 115	
261			Lagunilla	Lagunilla	0.5	120	(Assumed) 452	1940	P P	1 1	300 152	0 0	0	0	4.4		
262			Ventanas	Coello	25.3	28.6	6,000	1958	F F	1 1	3,000 3,000	0 2,500	2,500	42	4.16	14.4 33	
			Total				192,416	-		124	-		131,454	68	-		

Notes *1 P: Pelton
F: Francis
T: Tubular

*2 The site marked with (*) was not investigated.
This data is based on the information supplied by ICEL.

(3) Diesel Power Plants (1/2)

No.	Department	Electric Company	Power Plant	Installed Capacity (P) (kW)	Generating Facility: Installed Year	Type	No. of Unit	Unit Capacity (kW)	Available Capacity (kW): Unit	Total (Pa)	Pa/P (%)	Generator Voltage (kV)	Distribution (kV)	Remarks
301	CHOCO	E.CHOCO	Acandi	275	1981	Indoor	1	275	0	0	0	0.24	13.2	
302			Pizarro	120	No Data	Indoor	1	120	120	120	100	0.22	No Data	(*)
303			Unguia	150	1980	Indoor	1	150	150	150	100	0.22	13.2	
304			Capurgana	150	1985	Indoor	1	150	150	150	100	0.22	13.2	
312			Villa Claret	25	1983	Indoor	1	25	0	0	0	0.24	No Data	(*)
314			Sipi	80	No Data	Indoor	1	80	80	80	100	No Data	No Data	(*)
315			Bahia Solano	100	1978	Indoor	1	100	0			0.24	2.4	
				140	1972	Indoor	1	140	0	0	0	0.24		
321			Nuqui	150	1980	Indoor	1	150	0	0	0	0.22	13.2	
-			Zapzurro	17.5	1958	Indoor	1	17.5	0	0	0	0.127/0.22	0.127	
337	Meta	EMSA	Puerto Lopez		1983	Indoor	1	275	275			0.22	13.2	
					1971	Indoor	1	245	245			0.23		
					1987	Indoor	1	930	930			0.48		
					1983	Indoor	1	240	0			0.22		
					1985	Indoor	1	240	240			0.22		
				2,220	1971	Indoor	1	145	145			0.22		
					1971	Indoor	1	145	145	1,880	89	0.22		
339			San Juan de Arama		No Data	Indoor	1	150	0			0.24	13.2	
					1971	Indoor	1	145	0			0.23		
				525	1986	Indoor	1	230	230	230	44	0.208		
340			Vista Hermosa		1984	Indoor	1	230	230			0.22	13.2	
				455	1955	Indoor	1	225	225	455	100	0.23		(*)
341	Nariño	CEDENAR	Termo Tumaco		1977	Indoor	1	3,000	3,000			4.16	13.2	
					1978	Indoor	1	3,000	3,000			4.16		
					1965	Outdoor	1	2,000	0			4.16		
				10,000	1965	Outdoor	1	2,000	2,000	7,800	78	4.16		

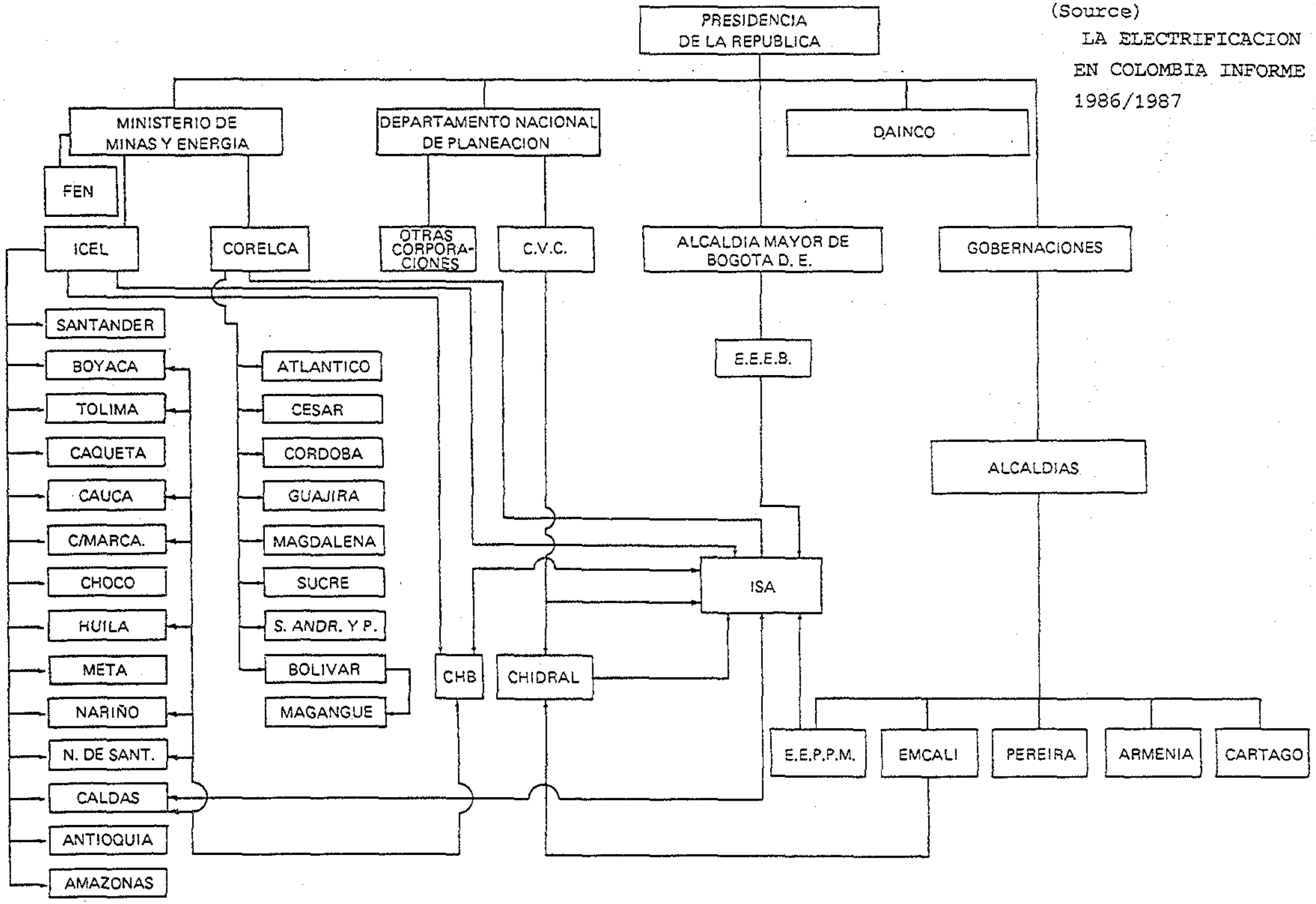
(3) Diesel Power Plants (2/2)

No.	Department	Electric Company	Power Plant	Installed Capacity (P) (kW)	Generating Facility				Available Capacity (kW)		(Pe)/(P) (%)	Generator Voltage (kV)	Distribution (kV)	Remarks
					Installed Year	Type	No. of Unit	Unit Capacity (kW)	Unit	Total (Pe)				
344	Nariño	CEDENAR	LLorente	120	1971	Indoor	1	120	0	0	0	0.22	5.715	
345			Sala Honda	210	No Data	Indoor	1	60	0			0.24	5.715	
					1985	Indoor	1	150	150	150	71	0.24		
350			La Playa	75	1955	Indoor	1	75	0	0	0	0.22	12.47	
357			Baquerias	35	1981	Indoor	1	35	0	0	0	0.22	13.2	
	Total			14,847.5	-	-	31	-	-	11,015	74	-	-	

Note: The site marked with (*) was not investigated. This data is based on the information supplied by ICEL.

Appendix-3 Operational Organization Table of Electric Power Sector in Colombia

ESQUEMA OPERACIONAL DEL SECTOR ELECTRICO COLOMBIANO



(Source)
LA ELECTRIFICACION
EN COLOMBIA INFORME
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Appendix-4 General Manual for Operation and Maintenance for the Run-of-River Type Hydroelectric Power Plants

1. Maintenance of Water Turbine and Ancillary Equipment

2. Maintenance of Electric Facilities

3. Maintenance of Civil Structure

1. Maintenance of Water Turbine and Ancillary Equipment

(1) Maintenance of water turbine

1) Daily inspections: Generally precautions should be taken for abnormal sound, offensive odors and vibration, and the following items should be inspected.

(a) State of guide vane operation
(b) Leakage around guide vane stems, of weak point pins
(c) Leakage through joints
(d) Oil level and amount of oil supply at main bearings
(e) Temperature and amount of cooling water at main bearings
(f) Abnormal sound or vibration

2) External inspection: In addition to the above, the following items should be inspected:

(a) Abnormal condition of thermometer elements, relays, wiring, etc.
(b) Relation between opening and output of the guide vane
(c) Measurement of vibration

3) Internal inspection (overhaul): Detailed inspection is necessary every 5 to 10 years in addition to the daily and external inspection. If any abnormal state is detected, a special internal inspection should be made to check the following points or replace parts:

(a) Francis turbine: (1) Wear on main shaft metal, (2) wear on main shaft sleeve and seals, (3) wear on runner and measurement of gap between labyrinth seals, (4) measurement of gap between guide vane shutter surface and that between the guide vane and covers, and (5) wear on bearing bushings.
(b) Pelton turbine: (1) Cracks, wear and erosion at the bucket, and (2) erosion on the needle and the nozzle, gap between needle and nozzle at fully closed position, and wear on the needle rod.
(c) Tubular turbine: Inspection items are almost the same as for the Francis turbine but the following items are to be added: (1) oil leak at oil header and abnormal state in return mechanism, (2) presence of oil leak from

the runner boss or from runner servo motor, and (3) relation between guide vane opening and runner blade angle.

(2) Maintenance of inlet valves

1) Butterfly valve

(a) Lubrication to bearings
(b) Servo motor mechanism
(c) Water leak from gland packing
(d) Wear and water leak at valve seat
(e) Opening/closing operation and time
(f) Operation of limit switch
(g) Coupling of motor with driving shaft, and wear on gears

2) Sluice valves

(a) Wear on valve and valve seat
(b) Wear on cylinder and damage to cylinder gland packing and piston packing
(c) Wear on coupling portion of spindle and valve
(d) Operating conditions of limit switch
(e) Situation of the operation mechanism and coupling portion for motor-operated type

(3) Maintenance of governor

(a) Abnormal condition of potentiometer and dust sticking to the converter
(b) Overheat, discoloration and checking of resistor connections
(c) Link pins of return mechanism, and clearance and elongation of wires
(d) Clogging of strainers
(e) Lubricating condition of movable parts

(4) Maintenance of oil pressure supply system

1) Daily inspection, external inspection

(a) Operating condition of pumps, abnormal sound, offensive odors
(b) Oil level, oil presusre
(c) Oil leak from pipes and gauges, etc.
(d) Cooling water volume and oil temprature at sump tank

2) Internal inspection

(a) Wear on gear pump and its side gap
(b) Wear on pumps and motor bearings
(c) Wear and lap on pilot valve
(d) Presence of sludge and foreign substances in oil

(5) Maintenance for other equipment

1) Lubricating system: Daily and external inspections are the same as for oil pressure supply system but the following items are to be added:

(a) Conditions of oil leak from piping and fittings
(b) Operating condition of the oil level relay and limit switch in sump tank
(c) Amount of oil supply and oil level
Internal inspection is the same as for oil pressure supply sytem

2) Water supply system: Daily and external inspections are as shown below.

(a) Condition of strainers
(b) Clogging and water leak from pipes
(c) Quantity of water supply and operating conditions of flow relays

3) Drainage system

(a) Conditions of water level indicator
(b) Overheating, vibration and drainage capacity of pumps and lubricating condition on each part of pumps.

(6) Inspection frequency is roughly estimated as shown below.

Item	Frequency
Daily inspection	daily
External inspection	6 months
Internal inspection (overhaul)	5 years

(7) Number of technical personnel required for the maintenance of turbine and ancillary equipment

If regular supervisory control method is adopted for supervisory control and machine-side manual control method or one man control method as operation method, then about 2 to 3 persons are necessary for maintenance personnel.

2. Maintenance of Electric Facilities

As a result of the recent progress in insulating materials for electric equipment and shifting to stationary equipment using semiconductors, the reliability of facilities has been greatly improved. However, proper maintenance and full understanding of the properties of each item of equipment should ensure stable power generation for many years and long life of equipment. Maintenance standards are shown in Table 1.

Table 1 Maintenance Standards for Electric Facilities

Patrol			Inspection		Measurement	
Equipment	Period	Equipment	Inspection item	Period every	Measurement item	Period every
Daily visual inspection for generator, transformer switchboard etc.	Daily	Generator & exciter	External inspection	1 year	Insulation resistance	6 months
			Internal inspection	5 years	Other various measuring tests	1 to 2 years
		Main transformer	External inspection	6 years	Insulation resistance	6 months
					Insulating oil property tests	1 year
			Internal inspection	3 years	Other various measuring tests	1 year
		Main circuit breaker	External inspection	1 year	Insulation resistance	1 year
			Internal inspection	4 to 5 years	Other various measuring tests	1 to 2 years
		Switchboard	External inspection	6 months	Insulation resistance	1 year
			Internal inspection	4 to 5 years		
		Other switchboard housing device	External inspection	6 months	Various measuring tests such as insulation resistance	1 to 2 years
			Internal inspection	4 to 5 years		

External inspection: Inspections and tests mainly performed from outside to confirm and maintain equipment functions.

Internal inspection: For the purpose of function recovery, equipment is disassembled and the inside is inspected precisely. Damaged or worn parts or other abnormal parts are replaced or repaired and additional detailed inspection and performance tests are conducted.

(1) Generator

1) Purpose of daily patrol and inspection is to determine overall conditions of the equipment at ordinary times.

(a) Any deviation of voltage, frequency, power or power factor of generator from rated values by visual inspection
(b) Vibration, change in sound, temperature rise at windings and core, abnormal smell, and clogging at vent hole and filter for main body of generator
(c) Change in vibration, oil level, adequacy of the amount of oil supplied, temperature rise and presence of oil leak for bearings
(d) Damage, oil leak or air leak for dampers

2) The following items are added to the above for external inspection:

(a) Inspection of each tightened portion
(b) Detailed visual inspection
(c) Operation tests for dampers
(d) Cleaning of each part

3) Internal isnpection

(a) Condition of rotors and stators (insulating conditions, loose wedges, conditions of coil outlet)
(b) Gap and wear at bearings
(c) Condition of main shaft
(d) Wear and operating conditions of controllers

4) Measuring test

(a) Measuring shaft runout
(b) Measuring shaft voltage
(c) Characteristic test (measuring resistance and insulation resistance of windings, no-load test and short-circuit test)
(d) Load tests
The results of the above tests should be recorded.

(2) Exciter (synchronous generator)

1) Daily patrol and inspection

(a) Vibration, abnormal sound and temperature rise at the main body of exciters
(b) Presence of abnormal state in controllers
(c) Abnormal sound, abnormal smell and temperature at power transformer

2) External inspection

(a) Detailed visual inspection of power transformer, controllers (exciter, rectifier) and field switch
(b) Lubricating conditions of driving assembly
(c) Conditions of contact portions
(d) Insulation resistance measurement

3) Internal isnpection

(a) Insulation resistance measurement and dielectric strength test for power transformer
(b) Rectifier performance check
(c) Insulation resistance measurement for windings and wiring
(d) Load test for single unit of equipment
The above should be performed and the characteristics of exciter should recorded.

(3) Transformer

1) Daily isnpection

(a) Abnormal sound, abnormal smell, abnormal temperature rise
(b) Adequacy of oil volume (check for oil leaks)
(c) Damage or dirt on windings, insulators, terminals
(d) Condition of lead wires

(e) Pressure of N_2-sealing device (if N_2-sealing adopted)
(f) Condition of ground wire
Note: (b) and (e) are not applicable for dry transformers.

2) External inspection: Above inspection should be carefully conducted and the following insulation resistance measured, recorded and pigeonholed.

(a) Between winding and ground
(b) Between primary and secondary windings

3) Internal inspection

Pressure test and dielectric strength test of insulating oil should be performed, and conditions of tightened portions should be carefully inspected.

(4) Switchboard and switchgear

1) Circuit breaker

(a) Daily patrol and inspection
a) Visual inspection of appearance (dirt, damages)
b) Abnormal sound, abnormal smell
c) Conditions of switch indicating devices

(b) External inspection
a) Operation test
b) Mounting condition
c) Measurement of insulation resistance

(c) Internal inspection
a) Contact conditions (unbalanced 3-phase contacts)
b) Wiring conditions
c) Operation of switch indicators
d) Test of closing/trip coils or operating motors

2) Switchboard

(a) Daily patrol and inspection
a) Inspect appearance for dirt and damage
b) Abnormal sound, abnormal smell
c) Inspection of indicating lamps

(b) External inspection
a) Operation of operating switch
b) Dirt or stagnant pool in cable pit, dirt on terminals
c) Tightened conditions at connecting terminals
d) Measurement of insulation resistance

(c) Internal inspection
a) Contacts of operating switches and auxiliary relays, etc.

3) Instrument transformer and protective relay

(a) Daily patrol and inspection
a) Inspection of appearance for dirt and damage
b) Abnormal smell, abnormal sound
c) Whether operation indication is displayed at the relay

(b) External inspection
a) Operation test and sequence test for protective relays
b) Measurement of insulation resistance
c) Additional tightening and surface cleaning for wiring terminals

(c) Internal inspection
a) Characteristic test for protective relays
b) Characteristic test for instrument transformer

4) Other equipment, lightning arresters, capacitors

(a) Daily patrol and inspection
a) Appearance inspection for dirt, damage, cracks, etc.
b) Abnormal sound, abnormal smell

(b) External inspection

a) Mounting conditions

b) Measurement of insulation resistance

5) DC power source board

(a) Daily patrol and inspection

For storage batteries:

a) Deformation and damage at cells and conductors

b) Damage or corrosion at supports

c) Conditions inside battery cells

d) Temperature, specific gravity and volume of electrolyte

e) Voltage per cell and overall voltage

For battery charger:

a) Adequacy of charging voltage

b) Conditions of signal lamps and switches

c) Abnormal sound and abnormal smell

(b) External inspection: The following items should be inspected in addition to the above:

a) Tightened conditions at connecting terminals

b) Visual inspection inside of battery charger

c) Clean each part

If the storage batteries are always used in floated charging state, the charging conditions of cells may be dispersed and thus uniform charging should be adopted. Alkaline storage batteries should be activated and regenerated by replacing their electrolyte and cleaning plates approximately once every 5 years. The life of storage batteries is about 8 to 10 years for lead storage batteries and 15 to 20 years for alkaline storage batteries activated and regenerated.

3. Maintenance of Civil Structure

Civil Structure	Contents
Reserovir, regulating pondage, river	Water levels, water diversion, freezing of water surface, sediment accumulation, structural failure, slope stability, snow, deadwood and flood conditions
Dam	Water levels, overflow, water diversion, obstacles, structural failure, flood, gate and equipment conditions
Intake	Water levels, water diversions, in-flow, flow, sediment amounts, rubbish, structural failure, flood, stabilizer, gate, screen and boom, machine conditions
Desilting basin	Water levels, water diversion, overflow, sediment settling rate, rubbish, ice flow, dripping water, structural failure, stabilizer, gate and screen conditions
Headrace	Ground conditions, water diversion, slope stability, snow, deadwood, cave-ins, structural failure, flood
Penstock	Noise, vibration, water diversion, slope stability, falling stone, snow, dead wood, structural failure, air pipes, air valves, expansion joints, springs, dripping water, drainage, control valves conditions
Tailrace	Downflow, water diversion, outlet condition existence of snow, deadwood, cave-ins, structural failure
Civil equipment	Environment, noise vibration, oil stocks, existence of oil, fuse condition

JICA

FEASIBILITY STUDY ON SMALL-SCALE
POWER PLANTS REHABILITATION PROJECT
IN THE REPUBLIC OF COLOMBIA

MAIN REPORT

MARCH [illegible]