CHAPTER 9 REHABILITATION PLAN

Since the present facilities-rehabilitating and output increase plans are not based on scrap and build methods, the power-generating capacity will be recovered or improved by making maximum use of existing facilities. The rehabilitation plan will be formulated according to standards established by ISA (Interconexion Electrica SA) in June, 1987.

9.1 Formulation of Rehabilitation Plans

As previously stated in 4.3, headrace structure, with the exception of about 1,300-meter-long headrace and powerhouse building, needs to be improved or newly constructed. The generating equipment and transformer requires new procurement or replacement with new equipment. In comparing maximum available discharge, three rehabilitation plans with cases of $Q = 5.00\ m^3/s$, $Q = 10.00\ m^3/s$ and $Q = 15.00\ m^3/s$ are shown in Table 9.1.

For each rehabilitation plan the total costs, including construction costs per kW output and generating costs are calculated and compared. The optimum rehabilitation plan is then chosen.

Table 9.1 Comparison of Alternative Rehabilitation Plans

Item	Alternative				
	Rehabilitation of the existing facilities			Increase of power output	
	REH-1			ALT-1	ALT-2
	Unit No.1	Unit No.2	Total		
Discharge, Q (m^3/s)	2.5	2.5	5.0	10.0	15.0
Max. output, P (kW)	1,700	1,100 (present output)	2,800	6,700	10,200
Facility utilization factor (%)			100	96	80

Rehabilitation and improvement plan:

Item	Rehabilitation of the existing facilities (REH-1)	Increase of power output (ALT-1, ALT-2)
Diversion weir	Because of damage to this weir, a new sandtrap will be built. (common to all plans)	
Intake	Will be reconstructed into the horizontal intake type in accordance with the intake modification. Screen and gate will be replaced.	
Desilting basin (head tank)	Will be reconstructed in accordance with the intake layout to prevent vortexes from occuring. (common to all plans)	
Penstocks	The existing penstocks will be used.	Will be replaced with new one.
Generating equipment	#1 Pelton turbine with be replaced with new one.	Will be replaced with new one.
Powerhouse building	The existing buildings and the overhead crane will be used after partial repair. The base of the generating equipment will be remodeled.	

9.2 Estimated Rehabilitation Construction Costs

The construction costs can be divided into the estimate for generating equipment and the cost of civil works and calculated. This can then be divided into foreign currency portion and local currency portion and calculated at the present exchange rates (September 1989) based on the U.S. dollar.

9.2.1 Estimated Generating Equipment Costs

According to the ISA valuation standard, CIF costs of generating equipment are calculated based on the FOB from Japan. The generating equipment specifications and FOB costs are shown in Table 9.2.

As shown in Table 9.3 for the CIF costs, the CIF/FOB ratio is 1.12.

Table 9.2 Generating Equipment Specifications and FOB Costs

Item	Alternative		
	Rehabilitation of the existing facilities	Increase of power output	
	REH-1	ALT-1	ALT-2
1. Specifications			
Design discharge (m^3/s)	2.5	5.0	7.5
Net head (m)	82.9	82.9	82.9
Theoretical output (kW)	2,031	4,062	6,093
Turbine type	H.F.	H.F.	H.F.
Turbine output (kW)	1,800	3,600	5,400
Generator power factor	0.9	0.9	0.9
Generator output (kVA)	1,900	3,800	5,700
Main transformer capacity (kVA)	Existing transformer is used	3,800	5,700
2. FOB costs (US$ 1,000)			
Generating equipment			
(1) Turbine, etc.	432.1	577.15	631.45
(2) Generator, etc.	228.6	340	497.85
(3)=(1)+(2) Sub-total:	660.7	917.15	1,129.3
(4) Number of units	1	2	2
(5)=(3)x(4) Subtotal:	660.7	1,834.3	2,258.6
(6) switchgear, etc.	52.1	88.6	88.6
(7) transformer	0	108.6	162.9
(8)=(5)+(6)+(7) Total:	712.8	2,031.5	2,510.1

Note: H.F. = horizontal Francis

Table 9.3 Implementation Cost of Generating Equipment

(Units: US$1,000)

		Alternative					
		Rehabilitation of the existing facilities		Increase of power output			
		REH-1		ALT-1		ALT-2	
		A	B	A	B	A	B
1) FOB cost		712.8	-	2,031.5	-	2,510.1	-
2) Transportation costs, insurance	1) x 0.12	85.5	-	243.8	-	301.2	-
3) Tax	1) x 0.223	-	159	-	453	-	559.8
4) Value-added tax	1) x 0.134	-	95.9	-	272.2	-	336.4
5) Others	1) x 0.22	-	156.8	-	446.9	-	552.2
6) Subtotal		798.3	411.3	2,275.3	1,172.1	2,811.3	1,448.4
7) Contingency	1) x 0.17	121.2	-	345.4	-	426.7	-
8) Eng. fees	1) x 0.149	106.2	-	302.7	-	374	-
9) Subtotal	6) + 7) + 8)	1,025.7	411.3	2,923.4	1,172.1	3,612	1,448.4
10) Total		1,437		4,095.5		5,060.4	

Note: A = foreign currency portion
B = local currency portion

9.2.2 Estimation of Civil Work Cost

The work volume for the rehabilitation or improvement of the main structures is multiplied by the unit costs (as shown in Table 5.2) as decided by EADE and the civil work costs are estimated in the local currency base.

The total civil work costs for each rehabilitation plan are calculated and compared as shown in Table 9.4.

Table 9.4 Estimation of Civil Construction Cost

(unit: 10^6 pesos)

Item	Alternative		
	Rehabilitation of the existing facilities	Increase of power output	
	REH-1	ALT-1	ALT-2
Diversion weir and intake construction	53.2	53.2	53.2
Head tank construction	22.0	22.0	22.0
Penstock construction	33.0	603.0	844.9
Foundation of equipment construction	5.8	17.4	21.0
Powerhouse building construction	0	2.5	2.5
Temporary facilities construction	19.0	19.0	19.0
Other construction	0	0	0
① Subtotal	133.0	717.1	812.6
② Contingency (① x 0.15)	20.0	107.6	144.4
③ Engineering fees ((① + ②) x 0.10)	15.3	82.5	110.7
④ Total (① + ② + ③)	168.3	907.2	1,217.7
⑤ Output loss	167.5	167.5	167.5
⑥ Grand total ④ + ⑤	335.8	1,074.7	1,385.2

9.3 Comparison of Economic Indices

To compare the economic indices of the construction cost per kW and the generating cost per kW, the basic conditions for all the alternative plans are as follows.

(1) Exchange rate based on September 1989, is as follows.

US$ 1 = ¥140
US$ 1 = 369.4 pesos
1 peso = ¥0.379

(2) The life of new generating equipment and the repaired and reconstructed structures is 25 years.

(3) The interest rate is divided into the foreign currency portion and the local currency portion under the following conditions.

- The foreign currency portion is based on an annual interest rate of 10% (unredeemable for 4 years), with repayment of the principal in equal annual amounts over 25 years.

- The local currency portion is based on an annual interest rate of 21% (unredeemable for 1 year), with repayment of the principal in equal annual amounts over 8 years.

(4) The operation, maintenance and management costs of hydroelectric power plants per year is US$4 per installed-capacity (kW).

9.3.1 Comparison of Construction Cost per kW

A comparison of the construction cost per kW is shown in Table 9.5. The plan ALT-2 indicates US$ 1,100/kW per increase in power output and this is the lowest costs.

Table 9.5 Comparison of Construction Costs per kW

Item		Alternative		
		Rehabilitation of the existing facilities	Increase of power output	
		REH-1	ALT-1	ALT-2
Existing equipment output (kW)				
Rated output	Po	1,600	3,200	3,200
Available output	Pe	1,200	2,300	2,300
Post-rehabilitation output	P_1 (kW)	1,700	6,700	10,200
Recovered/increased output $\Delta P = P_1 - Pe$ (kW)		500	4,400	7,900
Rehabilitation work cost	(US$1,000)			
Foreign currency portion Cf		1,000	2,900	3,600
Local currency portion Cl		1,300	4,100	5,200
Total C = Cf + Cl		2,300	7,000	8,800
Construction cost per kW	(US$/kW)			
C/P_1		1,400	1,050	860
$C/\Delta P$		4,700	1,600	1,100

9.3.2 Comparison of Generating Cost per kWh

The generating cost per kWh is calculated from the following equation:

$$\text{Generating cost} = \frac{\text{Total cost at generating terminal}}{\text{Supplied output per year}}$$

where

the supplied output per year = annual potential generated energy (E) x utilization factor
= 0.95 E

The annual total cost at generating terminal is shown in Figure 9.1. Since the estimated service life of the hydroelectric power plant is 25 years, the operation, maintenance and management costs (AOM per year = US$4 per kW) plus interest payments for the construction are totaled and divided by 25 years.

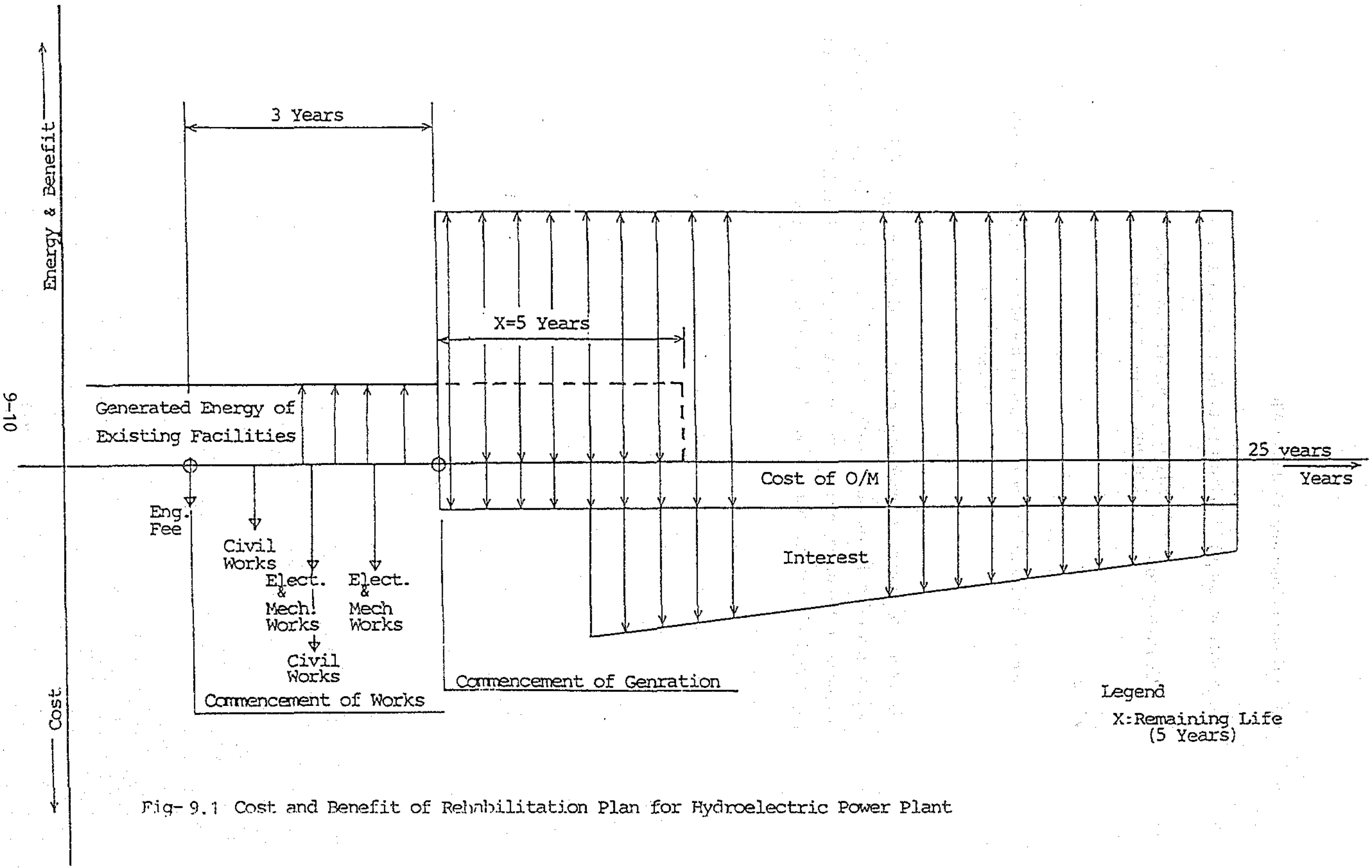


Fig- 9.1 Cost and Benefit of Rehabilitation Plan for Hydroelectric Power Plant

The results of calculation of generating costs per kWh are shown in Table 9.6. The generating cost per annually supplied energy (E1) is 12 mills/kWh according to ALT-1 and ALT-2. The generating cost per increased energy (ΔE) is 16 mills/kWh according to ALT-2 and the respective lowest costs are shown.

Table 9.6 Comparison of Generating Cost per kWh

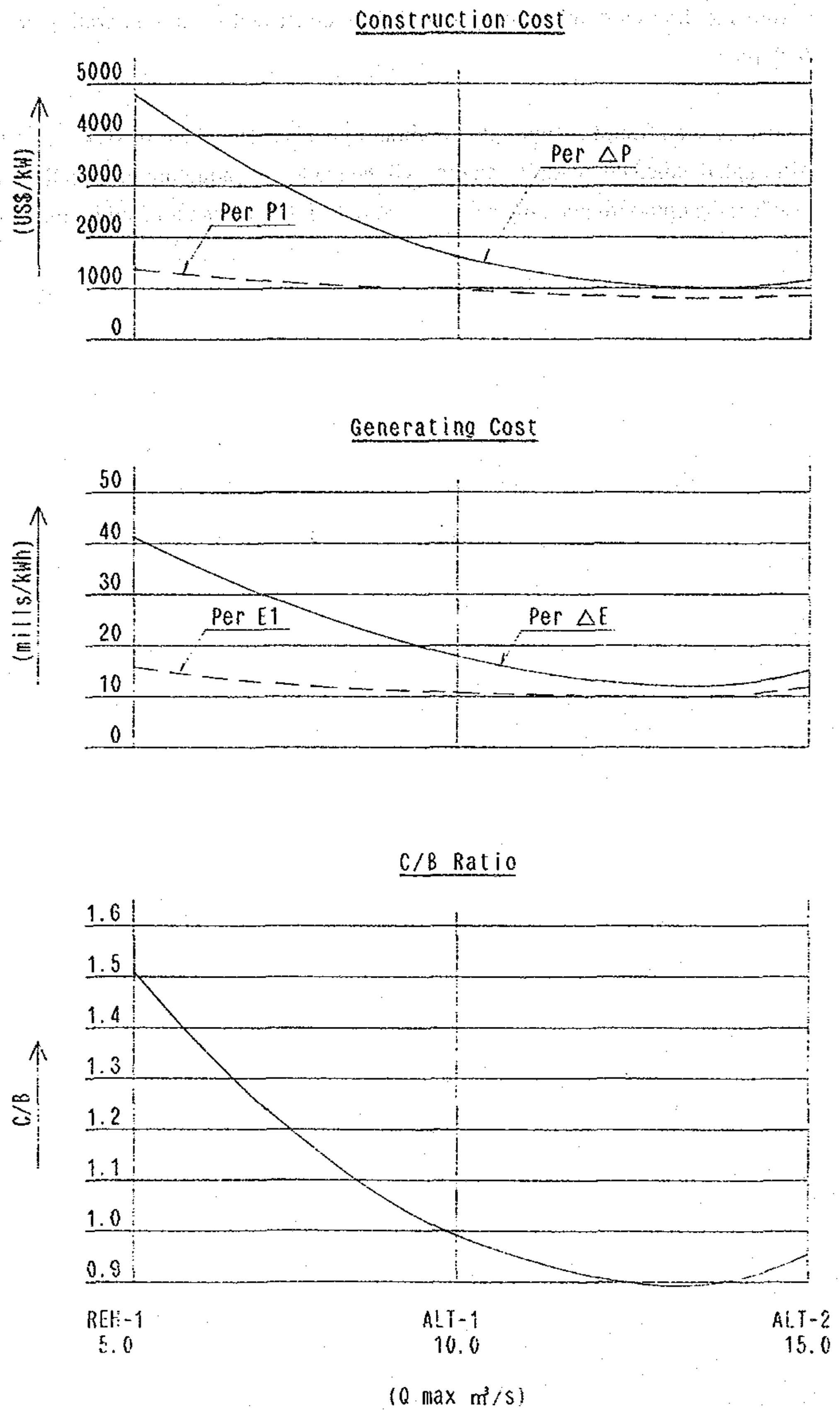
Item		Alternative		
		Rehabilitation of the existing facilities	Increase of power output	
		REH-1	ALT-1	ALT-2
Existing equipment capacity:				
Power output	Po (kW)	1,600	3,200	3,200
Energy	Ee (GWh)	9.17	18.81	18.81
Rehabilitation plan:				
Power output	P_1(kW)	1,700	6,700	10,200
Generated energy	E_1 (GWh)	14.9	57	72.3
Recovered/increased power				
Output	$\Delta P = P_1 - Pe$(kW)	500	4,400	7,900
Energy	$\Delta E = E_1 - Ee$(GWh)	5.7	38.1	53.5
Total expenses at generating terminal: (US$1,000)				
Construction work cost				
Foreign currency portion Cf_1		1,000	2,900	3,600
Local currency portion Cl_1		1,300	4,100	5,200
Construction cost total $C_1 = Cf_1 + Cl_1$		2,300	7,000	8,800
Interest payment C_2				
Foreign currency portion Cf_2		1,610	4,669	5,796
Local currency portion Cl_2		1,320.8	4,165.6	5,283.2
Total $C_2 = Cf_2 + Cl_2$		29 30.8	8,834.6	11,079.2
Cost for operation and maintenance (AOM)				
C_3 = US$4 x Pl x 25 years		170	670	1,020
Total $\Sigma Ci = C_1 + C_2 + C_3$		5,400.8	16,504.6	20,899.2
Average annual cost $C = \Sigma Ci/25$		216	661	837
Generating cost per annually supplied energy (mills/kWh)				
Per E_1 $C/(E_1 \times 0.95)$		16	12	12
Per ΔE $C/(\Delta E \times 0.95)$		41	18	16

9.3.3 Overall Evaluation

Figure 9.2 shows a graphic comparison of the construction and generating costs for each plan.

As can be seen from the figure, the optimum plan is selected from ALT-1 or ALT-2. Although detailed comparative studies will be made in conducting the detailed design to select the optimum plan, the basic design for ALT-1 was conducted in this report.

Fig - 9.2 Optimum Plan



CHAPTER 10 FINANCIAL ANALYSIS

To evaluate the profitability of rehabilitation plans, a cost-benefit analysis is adopted. The difference between 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. Then the financial analysis of the selected rehabilitation plan is made for the planning of the balance of revenue and expenditure in accordance with the cash balance. For the evaluation of the investment propriety within the national economy, refer to the economic analysis described in the main report.

10.1 Preconditions for the Financial Analysis

Preconditions set up for the financial analysis are summarized below:

(1) Residual life of existing power plant

In case of unchanging the existing facilities with new ones, residual life of the existing power plant is tentatively set at five years after the installation of new equipment.

(2) Estimation of construction cost

The construction cost is estimated in both foreign and local currency portion according to the market price 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. The land acquisition cost is not accounted because the plan is for rehabilitating the existing power plant. The FOB price of the generating facilities is taken from Japanese market price. The CIF price is calculated in the ratio of CIF price to FOB price which ISA usually applies to a hydroelectric power generation project. The ratio of CIF price to FOB price is 1.00 : 1.12.

(3) Service life

The service life of the project is set at 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, as 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 life of generating facilities : 25 years

(4) Operation and maintenance costs

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, i.e., US$4.0 per installed capacity (kW) per year, which ISA usually applies to make an estimate of operation 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. The estimation of annual revenue can be made by multiplying the rated capacity and the annual supplied power at generating terminal.

(6) Discount rate

The discount rate which is used to calculate the net present value (NPV) and the cost-benefit ratio (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 in 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 by using "with" and "without" the project.

10.2 Comparison of Profitability

The profitability of the generating plans is calculated using the cash flow for each alternative plan, as shown in Table 10.1.

Table 10.1 Profitability Index of Alternative Plans

Alternative	C/B	NPV (US$1,000)	IRR (%)
REH-1	1.51	- 346	4.8
ALT-1	0.99	53	7.7
ALT-2	0.96	251	8.0

From the results of the financial analysis according to cash generation of the project, ALT-2 is determined to be the most profitable plan.

The rehabilitation plan, ALT-1 is selected as the optimum plan, which is described in Section 9.3.3, since it has a high profitability amongst the alternatives.

10.3 Financial Planning

The cash balance of the selected rehabilitation plan is prepared as a projected financial statement. The projected Profit-Loss Statement and Fund Flows Statement are shown in Table 10.2. According to the financial plan, the selected rehabilitation plan will show a profit from the year 2002, with a projected aggregate profit of US$5,611,000 at the end of service life.

Table - 10.2 PROJECTED FINANCIAL STATEMENTS

(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 ==

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	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	-165.3
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	6389.3		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

CHAPTER 11 BASIC DESIGN

11.1 Facilities Design

ALT-1 is selected as the rehabilitation plan. The basic design for ALT-1 is described below.

11.1.1 Design Standards of Civil Structures

The following standards were applied to the design of facilities.

(1) The diversion weir, less than 15 m wide, is at the concrete gravity dam. The design flood discharge, with no gate, can safely flow over the overflow crest.

(2) A sandtrap will be constructed between the intake and the diversion weir. The width of the sandtrap water channels is in line with the need to remove all sediment. As such, a CAT D4C bulldozer (width 1.83 m and weight 6.85 tons) can enter and leave the channel.

(3) The intake will be designed to take water at a right angle from the river and a screen will be installed at the entrance. The flow rate at the screen is 0.6 - 1.0 m/s.

(4) The desilting basin has a capacity to enable removal of all particles greater than 0.5 mm in size. The size of the head tank is designed to be equivalent to 2 minutes capacity at design flow. The free board of the water channels is 0.3 m.

(5) The practicality of the penstock is most important and reference is made to the best practical examples for dimensions.

11.1.2 Design of Improvement for the Main Structure

(1) Intake facilities

The new diversion weir has an overflow crest at elevation 998m, a length of 32.5m and a design flood discharge of 380 m^3/s at the HWL (1001.7 m). The depth at the overflow is 3.7m. The intake sill, at elevation 996m, is 1.0m higher than the sand trap sill (995m) and is 5.0m wide and 2.8m high. The flow at the entrance is 1.0m/s. In front of the intake, a screen will be provided. The sand trap width is 2.0m with the sill gradient, 1:25, producing a good flow of both silt and water.

A gate will be provided at the water channel entrance of the intake. An estimated 2 m^3/day silt accumulates in front of the diversion weir, and is regularly removed by mechanical methods. The silt is deposited in a dump.

(2) *Head tank (Desilting basin)*

To secure the head tank capacity and to attain the safety of the head tank at the time of a flood, the existing wall on the river side will be reconstructed. The width, length, average depth of the head tank are 18m, 25m and 3m, respectively. The spillway (free overflow crest of length 9.5m at elevation 998m with a depth of 0.7m) will be provided with the wall reconstruction on the river side. The existing sand flush channel will be used as before. Five sand trap gates will be replaced.

(3) Penstock

From the relation shown in Fig. 11.1, one penstock, with a diameter of 1.65m and at a flow velocity of 4.68m/s, will be used, supported by a ring guard. The screen (5.0m x 3.0m) will be provided at the penstock entrance. The penstock is provided inside the tunnel for 135m on the upstream, partially plugged with concrete around the penstock for 30m.

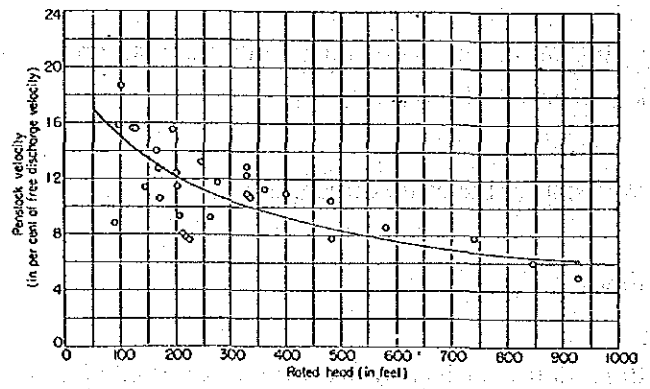


Fig.11.1 Penstock Velocities
at Full Turbine Discharge
Existing Plants

(4) Powerhouse

The powerhouse will be increased in the west of the existing power house. The base-rock can be used as the foundation of the generating equipment.

(5) Tailrace

Only the fitting portion in the powerhouse will be modified because the existing tailrace can fully handle the design discharge.

11.1.3 Gate and Valve Specifications and Types

A summary of these equipments (gates and valves) is shown in Table 11.1.

Table 11.1 Summary of Gate and Valve Types

	Regulating gate	Sand-flush gate	Screen	Sand-flush gate	Screen
Use	Water intake	Sand trap sand removal	Silt removal	Head tank sand removal	Silt removal
Type	Steel, sluice gate	Wooden, sluice gate	Fixed type	Steel, sluice gate	Fixed type
Width x height	2.6 x 2.3 m	2.6 x 2.3 m	5.0 x 2.8 m	0.4 x 0.4 m 4 gates	3.0 x 5.0 m
Design depth	10 m	10 m	10 m	6 m	
Stopwater method	Reverse 4 direct.	Reverse 4 direct.	Rack spacing 100 mm	Reverse 4 direct.	Rack spacing 100 mm
Starting method	Spindle	Spindle		Spindle	
Hoisting device	Engine or manual	Engine or manual		Manual	
Lifting speed	0.1 m/min.		Gradient 1:0.3		Gradient 1:0.3
Lifting torque	10 kg				
Lift	3 m	3 m	-	0.5 m	
Material weight	Gate: 3 t Hoisting device: 3 t	1 t	2.5 t	Gate 2.7 t Pully 2.5 t	2.7 t
	Hoisting device shall also be used as sand-flush gate.				

11.1.4 Standard Specifications for Generating Equipment

For the generating equipment the specifications for the generators and water turbines are shown below.

(1) Number of water turbines and generators

There are two water turbines and generators since water turbines and generators can be inspected and repaired alternately and when the generating equipment is stopped revenue is reduced.

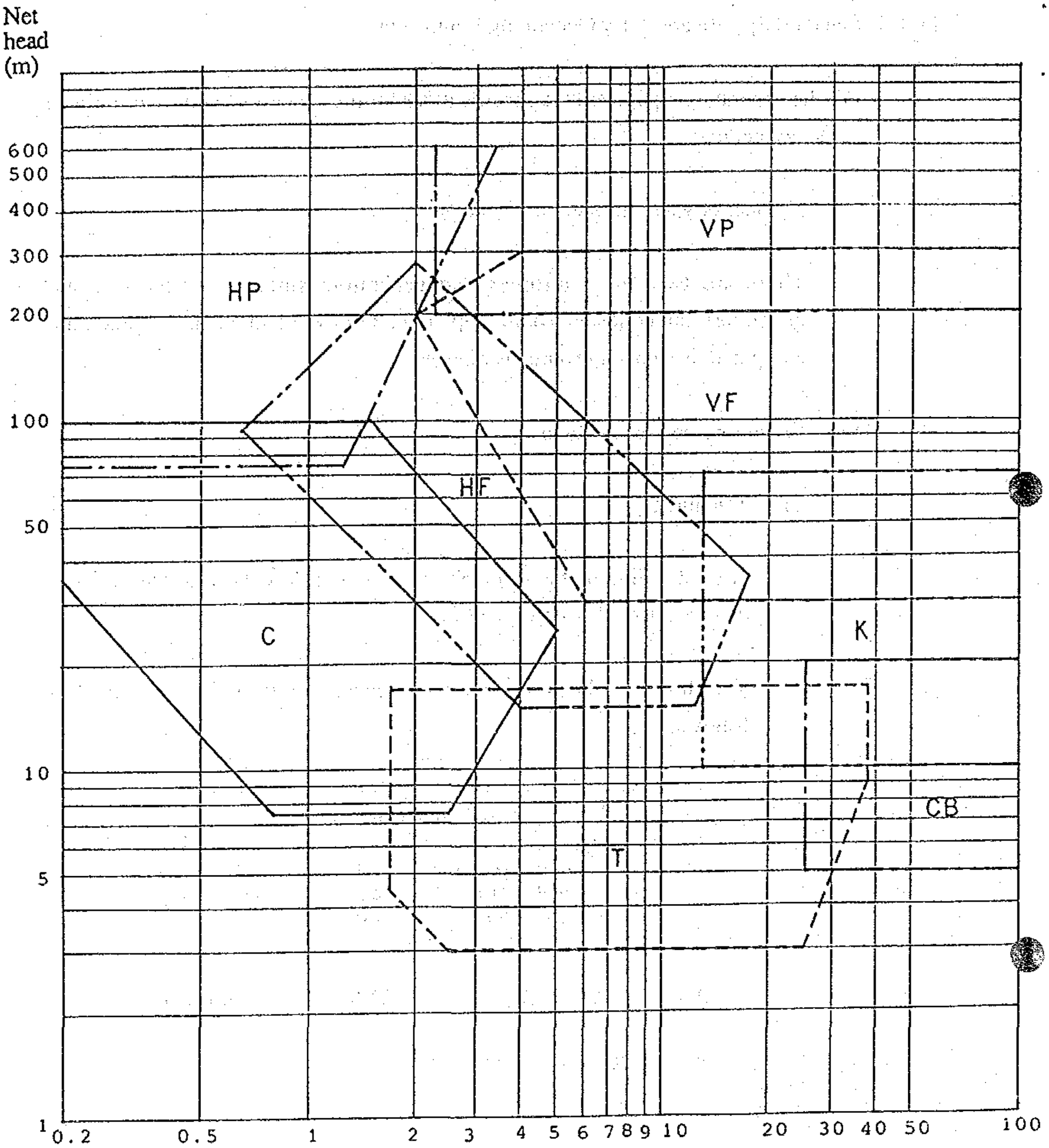
(2) Water turbine specifications

1) Machine type

After deciding on the turbine's net head and flow the water turbine type can be selected from Fig. 11.2.

The choice for the optimum plan for generation rehabilitation is made as follows:

Plan	Rehabilitation plan		Chosen machine type
	Discharge per water turb. (m^3/s)	Net head (m)	
ALT-1	5.0	82.9	horiz. Francis



KEY

Fig. 11.2 Turbine Type Selection Table

H = horizontal shaft type
V = vertical shaft type
P = Pelton turbine
F = Francis turbine
K = Kaplan turbine
C = cross flow turbine
T = tubular turbine
CB = conduit type bulb turbine

(Source: Enterprise Bureau, Gunma Prefectural Government)

2) Output

The output per turbine in the optimum plan is as follows:

Plan	Rehabilitation plan		Water turb. estimated efficiency η_T	Water turb. output P_T (kW)
	Flow per water turb. Q (m^3/s)	Net head H_e(m)		
ALT - 1	5.0	82.9	0.879	3,600

The water turbine (kW) may be calculated from the following equation.

$P_T = 9.8 \times Q \times H_e \times \eta_T$ (kW)

3) Number of revolutions

The number of revolutions of the turbine can be calculated from the following.

For the case of a Francis turbine the limit of specific speed is shown in the following equation.

$$Ns \leqq \frac{20{,}000}{H_e+20} + 30 \text{ (m-kW)} \quad \text{.............................. (1)}$$

where H_e is the net head (m).

The number of revolutions is shown in the following equation.

$$N = Ns \times \frac{H_e^{5/4}}{P^{1/2}} \text{ (rpm)} \quad \text{.................................. (2)}$$

where N_s is the specific speed taken from eq. (1)
H_e is the net head (m)
P is the water turbine output (kW)

The generator's synchronous speed (N) is shown in the following equation:

$$N = \frac{120f}{pole} = \frac{120 \times 60}{pole} = \frac{7200}{pole} \text{ (rpm)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where f is the frequency
and pole is the number of pole.

A value for the pole is chosen such that the value of N in eq. (3) is less than but close to the value of N in eq. (2).

The value of N from eq. (3) is then substituted into eq. (2) to obtain a value for Ns.

The results for the optimum plan are shown in the following table.

Plan	Net head, He (m)	Turbine output, P (kW)	Number of poles	Specific speed, Ns (m-kW)	Number of revolution N (rpm)
ALT-1	82.9	3,600	6	288	1,200

(3) Generator specifications

1) Cooling system

The generator cooling system will be designed to evacuate air from the powerhouse and blow it into the powerhouse.

2) Rated voltage

In REH-1, the rated voltage of the generator will be set to 2.3 kV in accordance with the voltage of the existing main transformer.

In ALT-1 and ALT-2, the main transformer will be replaced. The rated voltage of the generator will be set to 4.16 kV to standardize the rated voltage.

3) Power factor

Large-capacity generators, aiming to supply reactive power to the power system network, have a power factor of 0.8-0.85. However, since this factor is not as important in small-capacity generators, an economical power factor of 0.9 is available.

4) Number of poles

In deciding the turbine speed, the number of poles for the generator pole is decided and reference is made to the previous water turbine specifications.

5) Generator capacity

The capacity per generator in the optimum plan is as follows:

Plan	Rehabilitation plan: Discharge per turbine Q (m^3/s)	Rehabilitation plan: Net head H e(m)	Estimated turbine effic. η_T	Estimated generator effic. η_G	Generator capacity P_G (kW)	Power factor	Generator capacity (kVA)
ALT-1	5.0	82.9	0.879	0.95	3,350	0.9	3,800

The generator capacity (kW) may be calculated from the following equation:

$$P_G = 9.8 \times Q \times H \times \eta_T \times \eta_G \text{ (kW)}$$

11.1.5 Standard Specifications for Electrical Equipment

The machine specifications for the electrical equipment attached to the generator and the substation electrical equipment are explained in the following.

(1) Excitation equipment

A brushless excitation method is used for the generator excitation method so that maintenance inspection is quick and easy.

(2) Grounding method

In order to protect the generator when the value of the generator's current flow to the ground is small, the transformer uses a high resistance grounding method.

(3) Switchgear

With the generator circuit the switchgear contains the following electrical items.

- circuit breaker
- lightning arrester
- current transformer and voltage transformer
- excitation transformer
- auxiliary transformer
- low-voltage distribution board

(4) Direct current equipment

The direct current supply for the initial excitation for the generator's excitation circuit and the control panel is supplied by a charger and lead batteries.

(5) Control and protective relay panels

The simultaneous start, stop and generator circuit breakers, for the water turbine and generators, emergency and all essential controls are contained in a water turbine/generator control board. Thus, one operator can control the system.

Furthermore, the protective relay for the generator circuit is contained in the protective relay board. If an accident occurs the relay is put into action and the water turbine and generator stop simultaneously as a buzzer and flickering light warn the operator.

(6) Substation equipment

In the existing substation, the 44 kV outside substation and the 13.2 kV switchgear are installed. The substation equipment will be replaced to increase the capacity for the generating equipment rehabilitation. Table 11.2 shows the specifications of substation equipment.

Table 11.2 Substation equipment specifications

Item	Alternative Plans		
	REH-1	ALT-1	ALT-2
1. 13.2 kV switchgear	The existing switchgear will be used.	Same as left	Same as left
2. 44 kV substation			
(1) Main transformer	The existing transformer will be used.	Will be replaced.	Same as left
1) Number	Single phase x 3	Three phase x 2	Three phase x 2
2) type	ONAN	ONAN	ONAN
3) Voltage (kV)	2.3/44	4.16/44	4.16/44
4) Capacity (kVA)	667 x 3	3,800	5,700
5) Connection	Δ/人	Δ/人	Δ/人
(2) Circuit breaker	The existing breaker will be used.	Same as left	Same as left
(3) Disconnecting switch	The existing disconnector will be used.	150/5A	200/5A
(4) Current transformer	The existing transformer will be used.	Will be replaced.	Same as left
1) Ratio of current transformation	100-50/5A	150/5A	200/5A
(5) Transformer	The existing transformer will be used.	Same as left	Same as left
(6) Lightning arrester	The existing arrester will be used.	"	"

(7) Transmission and distribution lines

Presently the power plant has the 44 kV transmission line and the 13.2 kV power distribution line. The cost of rehabilitation or replacement of existing lines is not considered at the stage of this study.

11.2 Construction Execution Plan

11.2.1 Investigation into Construction Conditions

In the existing power plant, two generators (3,200 kW in total) are now in operation. Their operation will be suspended during the construction but the power supply to the Caracoli village and its neighboring areas will be continued.

There are no other water uses. The site for the penstock construction shall be secured.

11.2.2 Preparatory Work

(1) Shutoff and water diversion

Before installing the intake equipment a river diversion work will be undertaken in the river, the main channel will be diverted to the left bank and the right bank will be closed off. Sediment will be heaped up to close off the area, and gabions and sand bags will be used to prevent erosion of the surface. Within the closed off area of the right bank the intake, a sand trap and one part of the diversion weir will be constructed. After the right bank work is completed, the completed sand trap will be used and river flow will be diverted to the right bank. The left bank area will then be closed off and the remainder of the diversion weir will be finished.

Further management of the river flow includes a one year construction period for a low concrete dam and using the probability discharge 1-3 times per year of 80 m^3/s.

11.2.3 Construction Access Road Work

The access roads will be necessary for the construction, one is from Caracoli to the dam site, and the other is from the power plant to the penstock (the exposed area). The former is assigned the previously-used track, and the latter will be constructed almost in parallel with the penstock.

11.2.4 Temporary Works Equipment

The main temporary works equipment are as follows:

1. Excavation equipment
2. Concrete
3 Cable equipment

(1) Excavation equipment

The main excavation work is at the intake facilities site and penstock area, and rock excavation represents a major part of the intake facilities construction. In the rock excavation, 2 shinka (air-driven 2.0 m^3/min., weight 14 kg) and a compressor (portable type, capacity 5 m^3/min., delivery pressure 7 kg/cm^2, weight 1 ton) will be used.

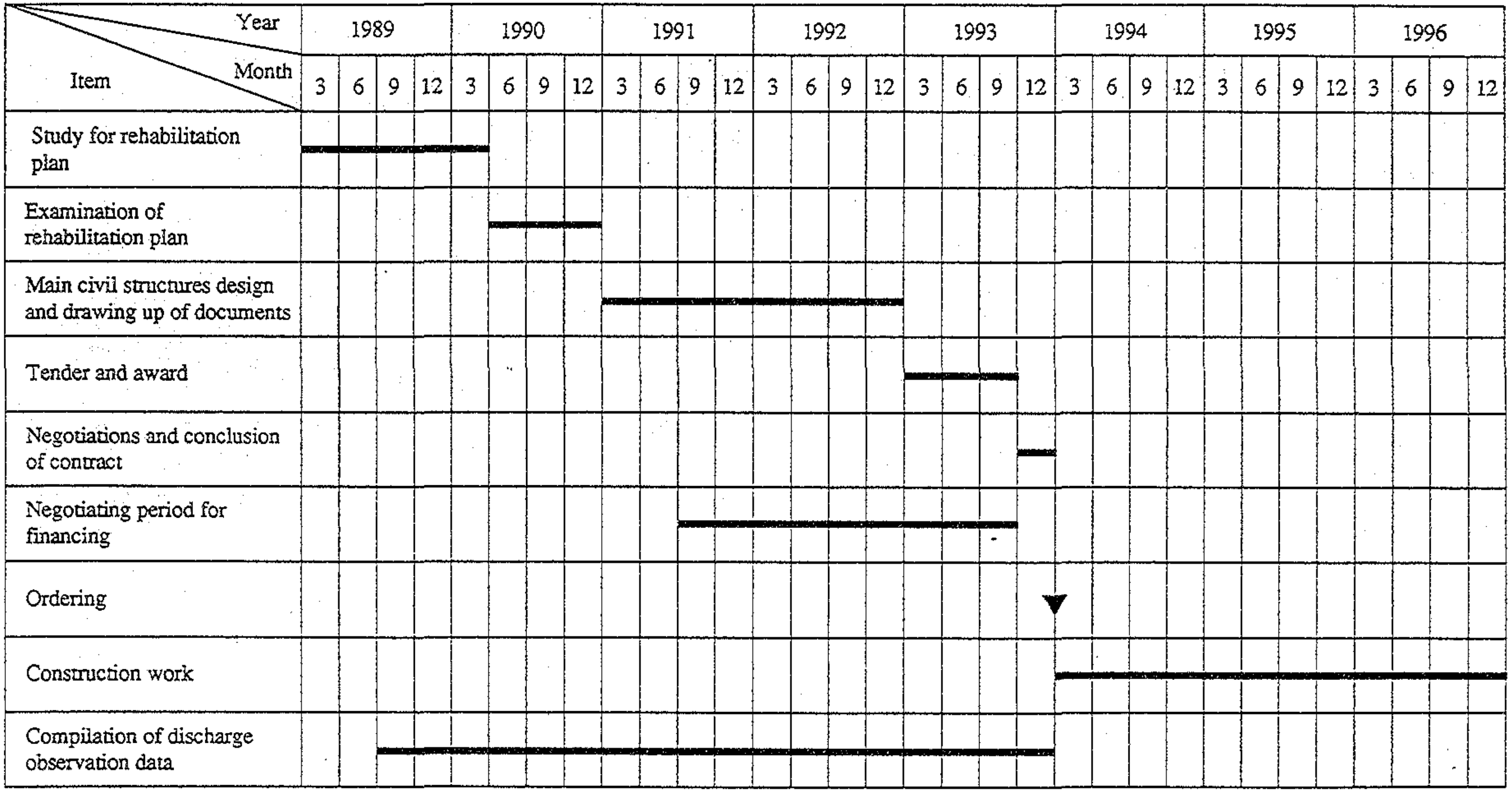
(3) Concrete equipment

Concrete will be placed using 0.5 m^3 x mixers. The aggregate (sand and gravel) and cement storage sheds will be close to the powerhouse and intake. It will be possible to take the cobble stone for the concrete and rough concrete from the terrace deposit close to the intake and the powerhouse. Cement and reinforcing bars will be obtainable from Medellin.

11.2.5 Work Schedule

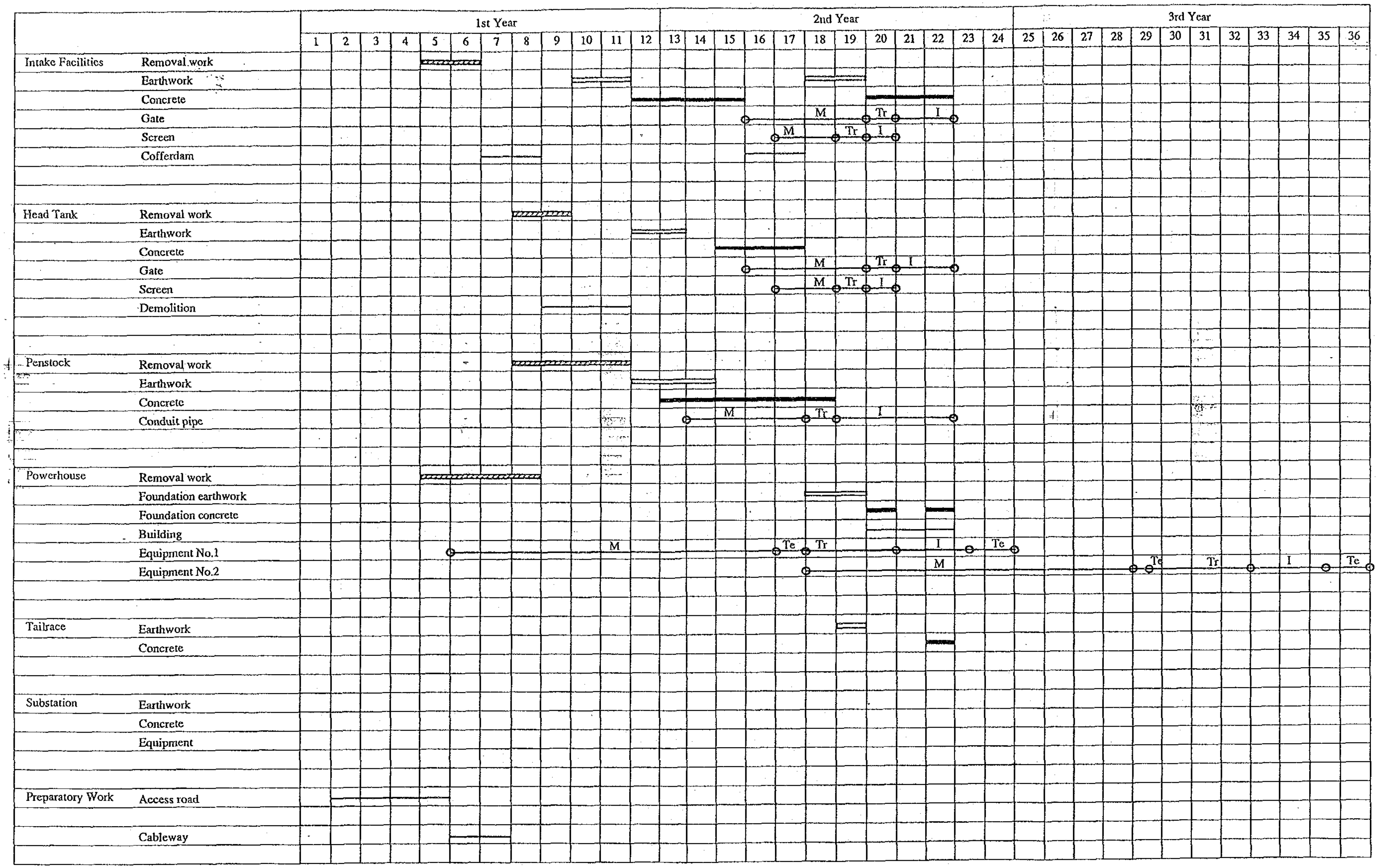
The work schedule is shown in Table 11.3.

Table 11.3 Caracoli Hydroelectric Power Plant Rehabilitation Plan Work Schedule



Note) The details of the construction period are in Table 11.4.

Table 11.4 Construction Period



Note: M = Manufacturing, Te = Testing, Tr = Transportation, I = Installation

11.3 Construction Costs

11.3.1 Basic Conditions of Estimates

(1) Estimate method

(a) Estimate of work content

Project-related approximate construction costs include the following items:

Civil works costs
Direct work costs + contingency + engineering costs

Equipment costs
FOB + sea transport costs (inc. insurance) + land transport costs (inc. insurance) + various taxes + installation costs + testing costs + contingency + engineering costs

(b) Civil work cost calculation

- Direct costs are calculated as the work quantity x unit price.

- The work quantity is estimated based on attached Dwg. No.CA-C-01 ~ No. CA-C-05.

- Within the unit direct temporary work costs (AIU) are taken as 30% in Colombia.

- The contingency and engineering costs are based on the ISA hydro-electric power project's construction costs as follows:

Contingency	direct construction costs x 15%
Engineering costs	(direct cost construction + contingency) x 10%

(c) Estimate of equipment and construction costs

Using the FOB and the ISA hydroelectric power plant project direct construction costs, equipment and construction costs may be calculated as follows:

- FOB	100%	
- sea transport costs	FOB x 10%	
- sea transport insurance	FOB x 2%	
- taxes		3.15 x 1.105
- law 68	FOB x 22.3%	2.0 x 1.105
- law 50		8.0 x 1.105
- proexpo		5.0 x 1.105
- value-added tax	FOB x 13.4%	10% of above
- land transport/insurance	FOB x 6%	
- installation	FOB x 10%	
- test, connection	FOB x 6%	
- direct construction costs	FOB x 169.7%	
- contingency	FOB x 17%	10% of direct costs
- engineering costs	FOB x 14.9%	8% of (direct construction costs + contingency)

(d) Division of work type

The cost estimate for the Caracoli hydroelectric power plant is divided as follows:

Intake dam/intake : earthwork, removal of existing concrete, concrete, cobble concrete, reinf. steel, gate, screen, gabions

Head tank : earthwork, removal of existing concrete, concrete, reinforcing bars, gate, screen, slope protection

Penstock : earthwork, concrete, reinforcing bars, pipework

Powerhouse : earthwork, concrete, reinforcing bars, removal of existing concrete, building (new/repair)

Substation : earthwork, concrete, reinforcing bars

Furthermore, the generating facilities are divided as follows:

- turbine and ancillary equipment
- generator and ancillary equipment
- turbine/generator control board
- generator switchgear
- auxiliary transformer, distribution board, battery, charger
- main transformer and so on

(e) Annual estimate

Estimation rate was used as of September 1989 according to the meeting with ICEL.

(2) Civil construction figures

As shown in 5.4 the figures prepared by EADE in September 1989 were used. The cost of temporary work camps, electricity sources, communication facilities etc., are included within the present figures.

(3) Equipment FOB costs

Quotes were taken from two Japanese companies, and 90% of the lowest cost is determined as FOB cost.

11.3.2 Breakdown of Civil Work Costs

The breakdown of the costs of civil works for ALT-1 is shown on the following pages.

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
	Caracoli Q = 10 m^3/s (ALT-1)					
1.	Diversion Weir & Intake					
1.1	Earthwork	m^3	500	2,400	1,200,000	
1.2	Concrete Work	"	1,100	26,300	28,930,000	
1.3	Reinforcing Bar	ton	20	354,000	7,080,000	
1.4	Gate	"	4	1,682,000	6,728,000	
1.5	Screen	"	25	1,682,000	4,205,000	
1.6	Hoist	"	3	1,682,000	5,046,000	
1.7	Concrete Removal	m^3	-	13,000	-	
	Sub Total	-	-	-	53,189,000	
2.	Head Tank					
2.1	Earthwork	m^3	50	2,400	120,000	
2.2	Concrete Work	"	200	26,300	5,260,000	
2.3	Reinforcing Bar	ton	16	254,000	5,664,000	
2.4	Gate	ton	2.5	1,682,000	4,205,000	
2.5	Screen	ton	2.7	1,682,000	4,541,400	
2.6	Concrete Removal	m^3	170	13,000	2,210,000	
	Sub Total				22,000,400	
3.	Penstock					
3.1	Earthwork	m^3	900	2,400	2,160,000	
3.2	Concrete Work	"	2,200	26,300	57,860,000	
3.3	Reinforcing Bar	ton	65	254,000	23,010,000	
3.4	Penstock	ton	520	1,000,000	520,000,000	
	Sub Total				603,030,000	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
4.	Foundation of Equip.					
4.1	Excavation	m3	200	2,400	480,000	
4.2	Concrete	"	300	26,300	7,890,000	
4.3	Reinforcing Bar	ton	24	354,000	8,496,000	
4.4	Concrete Removal	m3	40	13,000	520,000	
	Sub Total	-	-	-	17,386,000	
5.	Powerhouse					
5.1	Building	m^3	50	50,000	2,500,000	
5.2	Excavation	m3	-	-	-	
5.3	Concrete	m3	-	-	-	
5.4	Reinforcing Bar	ton	-	-	-	
5.5	Concrte Removal	m3	-	-	-	
	Sub Total	-	-	-	2,500,000	
6.	Temporary Facilities					
6.1	Construction Access Road	L.S			15,000,000	
6.2	Cableway	L.S			4,000,000	
6.3	Sub Total				19,000,000	
7.	Grand Total				717,105,400	

11.3.3 Breakdown of Generating Equipment Costs

The breakdown of generating equipment costs for ALT-1 is shown below.

No.	Description	FOB Cost (US$1,000)
1	Water Turbine and Auxiliary Equipment	1,154.3
2	Generator and Auxiliary Equipment	582.9
3	Turbine and Generator Control Panel	97.1
4	Switchgear for Generator	72.9
5	Battery and Charger	15.7
6	Main Transformer	108.6
	Total	2,031.5

11.3.4 Annual Construction Costs

The annual construction costs calculated according to the total cost and the construction schedule are shown in the following table.

Table Annual Estimation of Civil Construction Cost

(Units: 10^6 pesos)

	Alternative Plans					
	REH-1		ALT-1		ALT-2	
	1st year	2nd year	1st year	2nd year	1st year	2nd year
Diversion weir and intake construction	6.6	46.6	6.6	46.6	6.6	46.6
Head tank construction	2.3	19.7	2.3	19.7	2.3	19.7
Penstock construction	-	33.0	0.7	602.3	1.0	843.9
Equipment foundation construction	-	5.8	-	17.4	-	21.0
Powerhouse building construction	-	-	-	2.5	-	2.5
Temporary facilities construction	19.0	-	19.0	-	19.0	-
Other work	-	-	-	-	-	-
① Total	27.9	105.1	28.6	688.5	28.9	933.7
② Contingency (① x 0.15)	4.2	15.8	4.3	103.3	4.3	140.1
③ Engineering fees (① + ②) x 0.10	3.2	12.1	3.3	79.2	3.3	107.4
④ Total ① + ② +③	35.3	133.0	36.2	871.0	36.5	1,181.2
⑤ Output loss	68.0	99.5	68.0	99.5	68.0	99.5
Total (④ + ⑤)	103.3	232.5	104.2	970.5	104.5	1,280.7

CHAPTER 12 CONCLUSION AND RECOMMENDATIONS

This chapter describes the conclusion of JICA study team's feasibility study for the rehabilitation of the Caracoli hydroelectric P/P (from November 1988 to March 1990), which was conducted following the pre-feasibility study (from November 1987 to June 1988).

12.1 Most Feasible Rehabilitation Plan

At this facility, the existing headrace is damaged and the efficiency of generating facilities are low, operating at a maximum output of 2,300 kW. The most economical and feasible rehabilitation plan is summarized below.

Table 12.1 Summary of Post-rehabilitation Optimum Generating Facilities (ALT - 1)

Item				Unit	Content
(1) Generation plan requirements	Max. available discharge		Q	m^3/s	10.0
	Standard net head		H	m	82.9
	Theoretical output			kW	8,124
	Max. output		P	kW	6,700
	No. of generating equipment				2
	Annual potential generated energy		E_1	GWh	57.0
	Plant utilization factor			%	96
(2) Civil structure length) specification	Diversion weir	Type			Gravity type concrete dam
		Dimensions		m	3.50 (height), 32.50 (crest
	Sand flush gate	Type			Wooden sluice gate
		No. of gates			One gate
		Dimensions		m	2.60 (width), 2.30 (height)
	Intake	Type			Non-pressure type, rectangular
		Dimensions		m	5.00 (width), 2.80 (height)
	Intake gate	Type			Steel sluice gate,
		No. of gates			1
		Dimensions		m	2.60 (width), 2.30 (height)
	Desilting basin	Type			N/A
		Dimensions		m	
	Sand trap gate	Type			N/A
		No. of gates			
		Dimensions		m	
	Conduction channel	Type			N/A
		Length		m	
		Dimensions		m	
	Head tank	Type			Rectangular open channel
		Dimensions		m	18.00 (width), 3.00 (depth), 25.00 (length)
	Head tank gate	Type			
		Dimensions		m	N/A
	Penstock	Shape			Steel pipe
		No. of penstocks			1
		Diameter		m	ø1.65
		Pipe thickness		mm	9

Table 12.1 Summary of Post-rehabilitation Optimum Generating Facilities (cont'd)

Item			Unit	Content
	Powerhouse	Shape Dimensions	 m	Exposed type, RC structure 23.75 (width), 13.30 (depth) 7.0 (height)
	Tailrace	Shape Dimensions	 m	Rectangular 2.00 (width), 2.50 (height)
(3) Generating equipment specifications	Turbine Revolution	Type No. of turbines Output rpm	 kW	H.F 2 3,600 1,200
	Generator	Type No. of generators Output No. of poles Revolution	 kVA rpm	Synchronous 2 3,800 6 1,200
	Main transformer	Type No.of transformer Voltage Capacity	 kV kVA	ONAN 3 phase x 2 sets 4.16/44 3,800
(4) Rehabilitation work cost	Generating equipment	Foreign currency portion Local currency portion	US$ US$	2,900 1,200
	Civil and building work cost	Foreign currency portion Local currency portion	US$ US$	0 2,900
	Project cost		US$	7,000
	Construction cost	per kW per kWh	US$/kW mills/kWh	1,050 123

12.2 Economic Indices

As general indices to evaluate the feasibility, the construction cost per kW and the average generating cost per kWh are explained in the General Criteria Vol.1 issued by ISA in June, 1987. The study result of these economic indices is described in Section 9. Economic indices in the case of the optimum rehabilitation plan shown in Table 12.1 are as follows:

Construction cost per kw: US$ 1,050/kW
Average generating cost for annual supplied electric energy: 12 mills/kWh

12.3 Operation and Maintenance Manual

The maintenance manual contains regulations to secure a stable power supply and to maintain the installed facilities at normal condition. Each electric power company shall establish such regulations based on its managerial policy.

In the rehabilitation of the hydroelectric P/P, generating equipment including turbines, generators and main transformers will be replaced with new equipment. Therefore, equipment manufacturers will provide operation and maintenance manuals conforming to specification.

Accordingly, the attached data in the main report contains the general management manual for the maintenance and inspection of the primary civil structures and generating equipment.

12.4 Technical Recommendations on the Rehabilitation Plan

When the rehabilitation plan of Caracoli hydroelectric P/P is realized, the following points should be carefully considered when implementing the recommendations of the feasibility study.

(1) Topographic, geologic and biological incrustation survey of the watershed

A topographic map on a scale of 1:5,000 - 10,000 will be drawn from aerial photographs. A survey of the present condition of the topography, geology and biological growth on the watershed is advisable. Catchment area at the intake and the Caramanta hydrological gauging station shall be checked.

(2) River flow survey

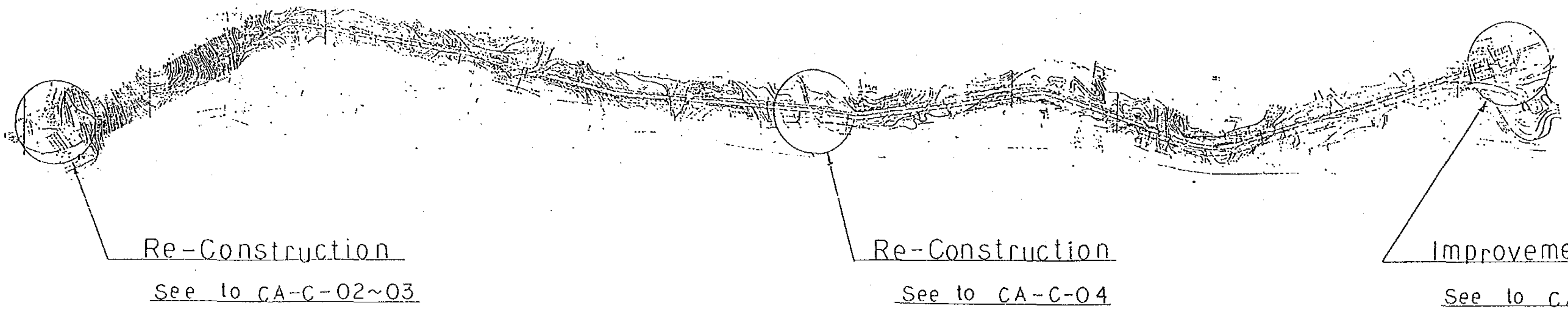
Measurement of rating curves used by HIMAT's Caramanta gauging station which offers discharge observation data should be made. Furthermore, water quality tests should be continuously conducted for an accurate measurement of river deposits and water quality characteristics.

(3) Protection of the headrace

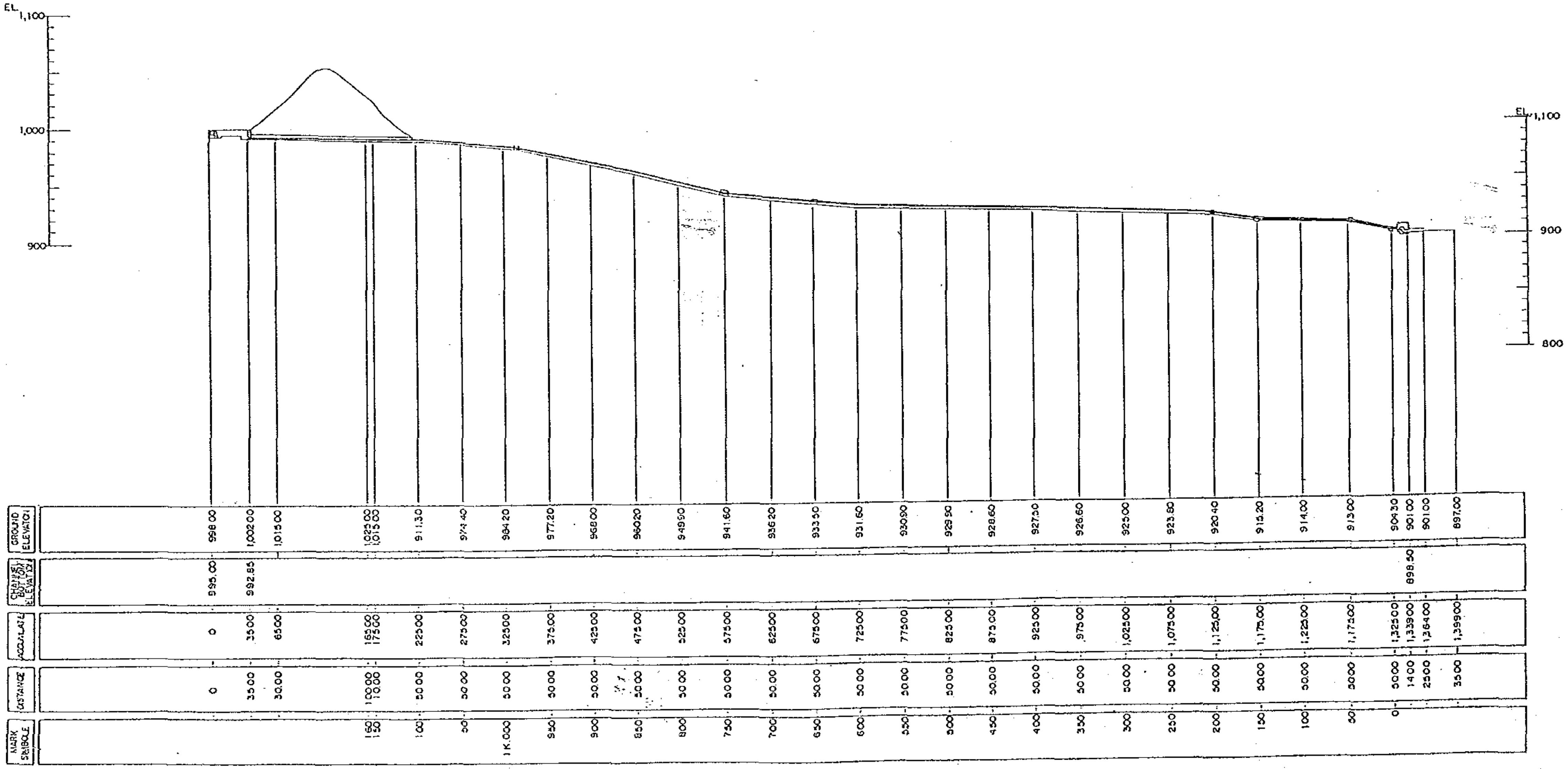
The characteristics of river flow debris should be studied to prevent the flow of debris and sediment into the headrace from the diversion weir. A counterplan for removing the sediment shall be worked out.

Drawings

Title	Drawing No.
General Plan and Section	CA-C-01
Plan of Diversion Weir, Intake and Head Tank	CA-C-02
Diversion Weir Profile and Sections	CA-C-03
Penstock, Sections	CA-C-04
Powerhouse, Plan and Sections	CA-C-05
Duration curves	CA-H-01
Geological Plan and Profile	CA-G-01
One Line Diagram	CA-E-01

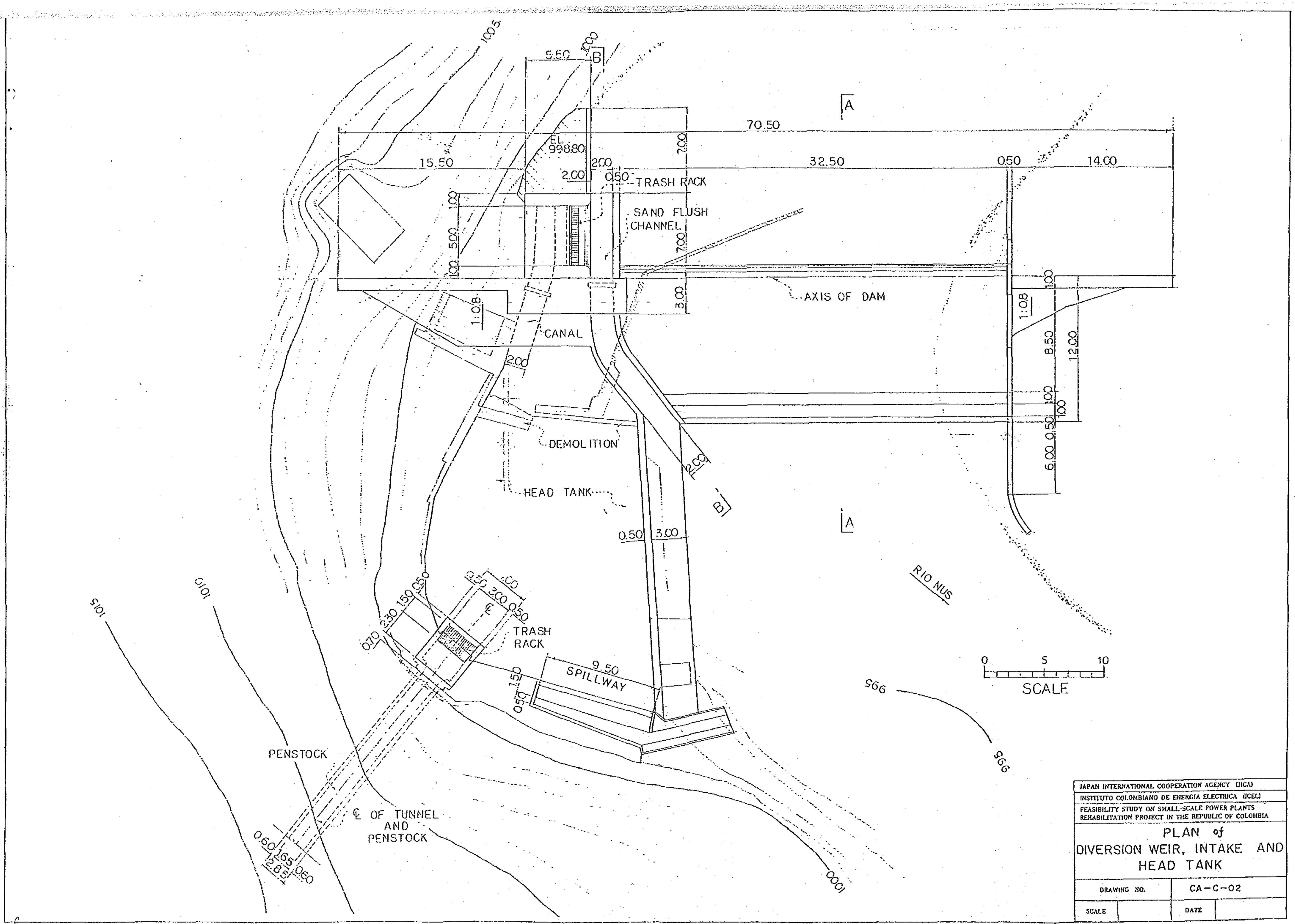


PLAN

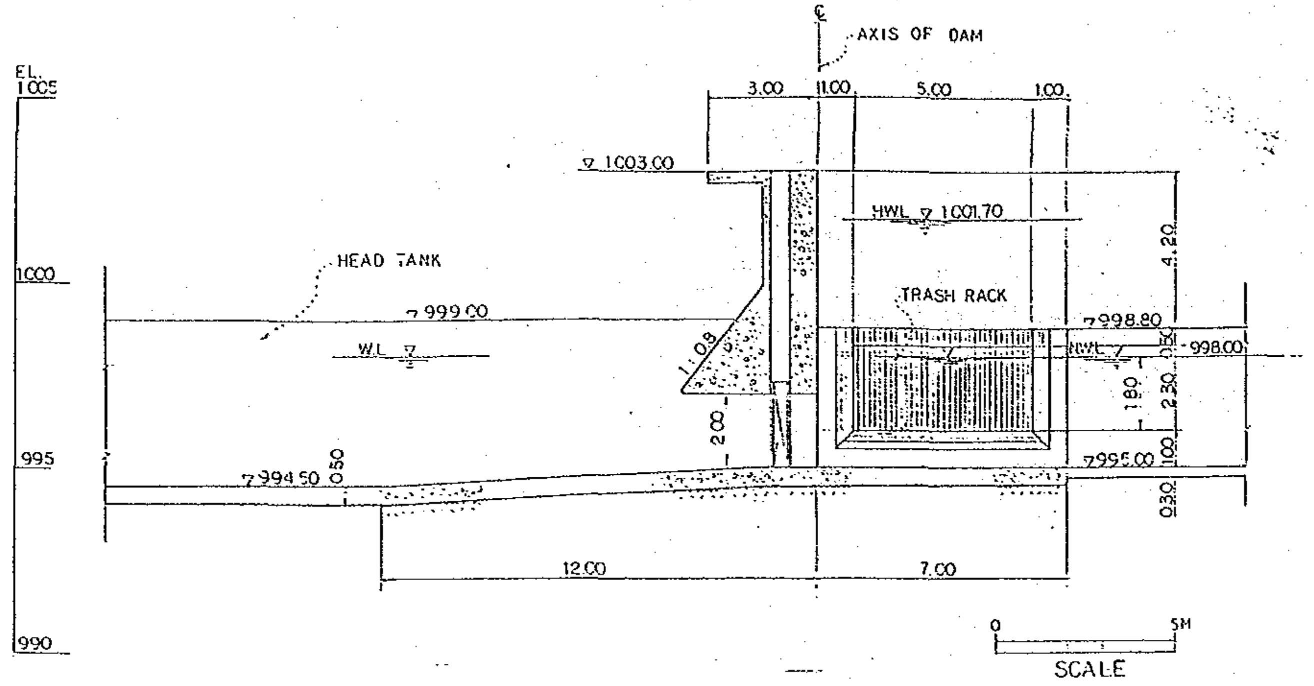


PROFILE

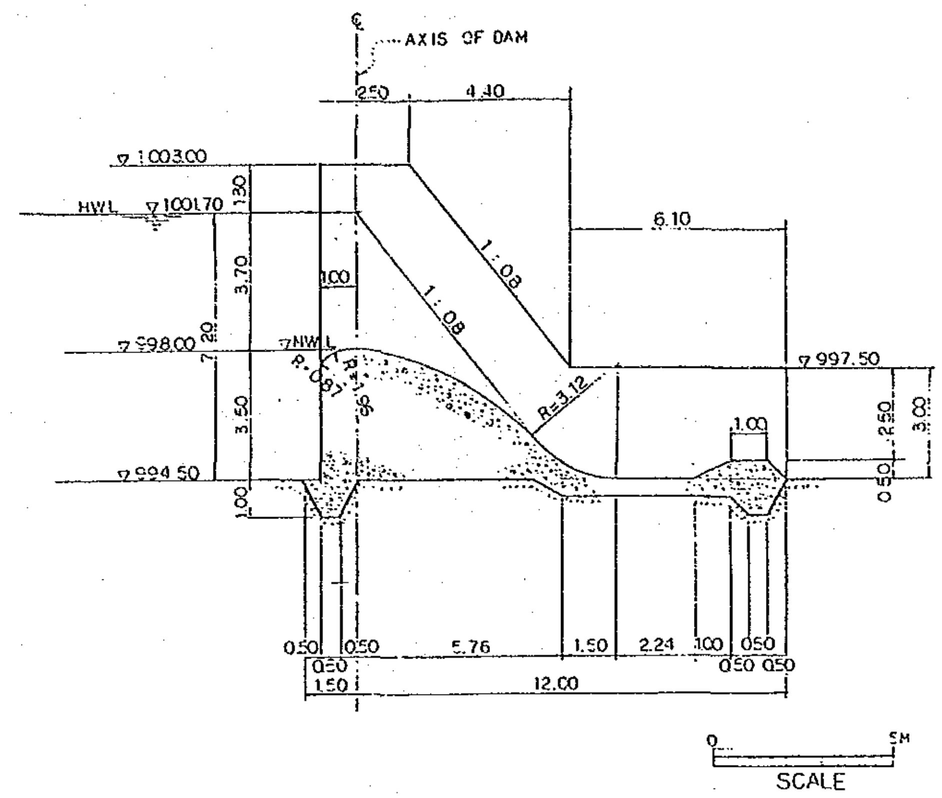
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
GENERAL PLAN AND SECTION	
DRAWING NO.	CA-C-01
SCALE	DATE



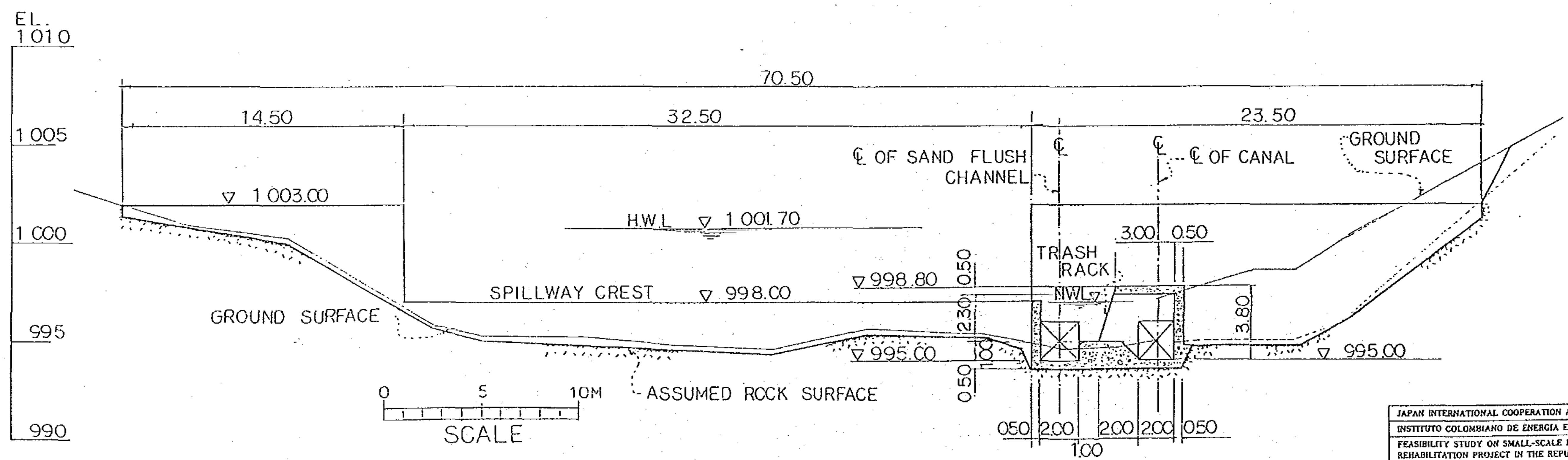
5.50
B
70.50
A
EL 998.80
15.50
2.00
2.00
0.50
TRASH RACK
32.50
0.50
14.00
7.00
SAND FLUSH CHANNEL
1.00
5.00
1.00
7.00
3.00
AXIS OF DAM
1:0.8
CANAL
2.00
1.00
8.50
12.00
1.00
1.00
0.50
6.00
DEMOLITION
HEAD TANK
2.00
B
A
0.50
3.00
RIO NUS
TRASH RACK
0.70
3.30
1.50
0.50
0.50
3.00
0.50
1.00
9.50
SPILLWAY
1.50
0.50
0
5
10
SCALE
995
995
1015
1010
1005
1000
1000
PENSTOCK
℄ OF TUNNEL AND PENSTOCK
0.60
1.65
2.85
0.60
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA
PLAN of DIVERSION WEIR, INTAKE AND HEAD TANK
DRAWING NO.
CA-C-02
SCALE
DATE



SECTION B — B



SECTION A — A

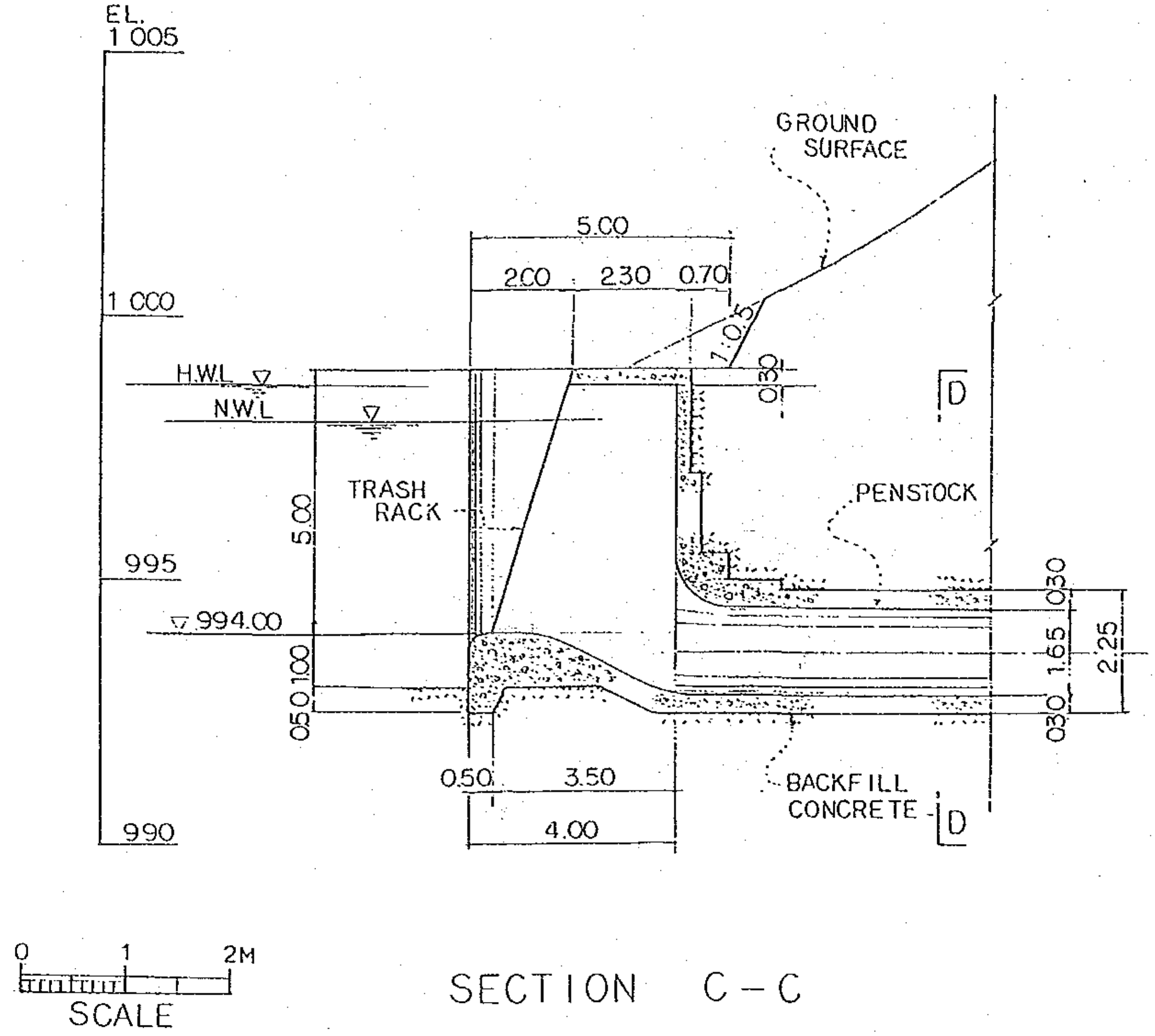


PROFILE

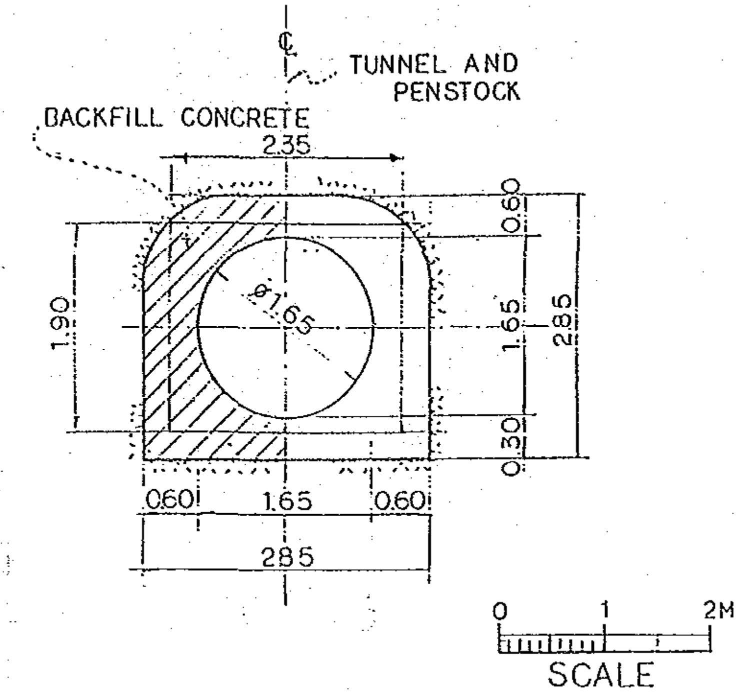
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

DIVERSION WEIR
PROFILE AND SECTIONS

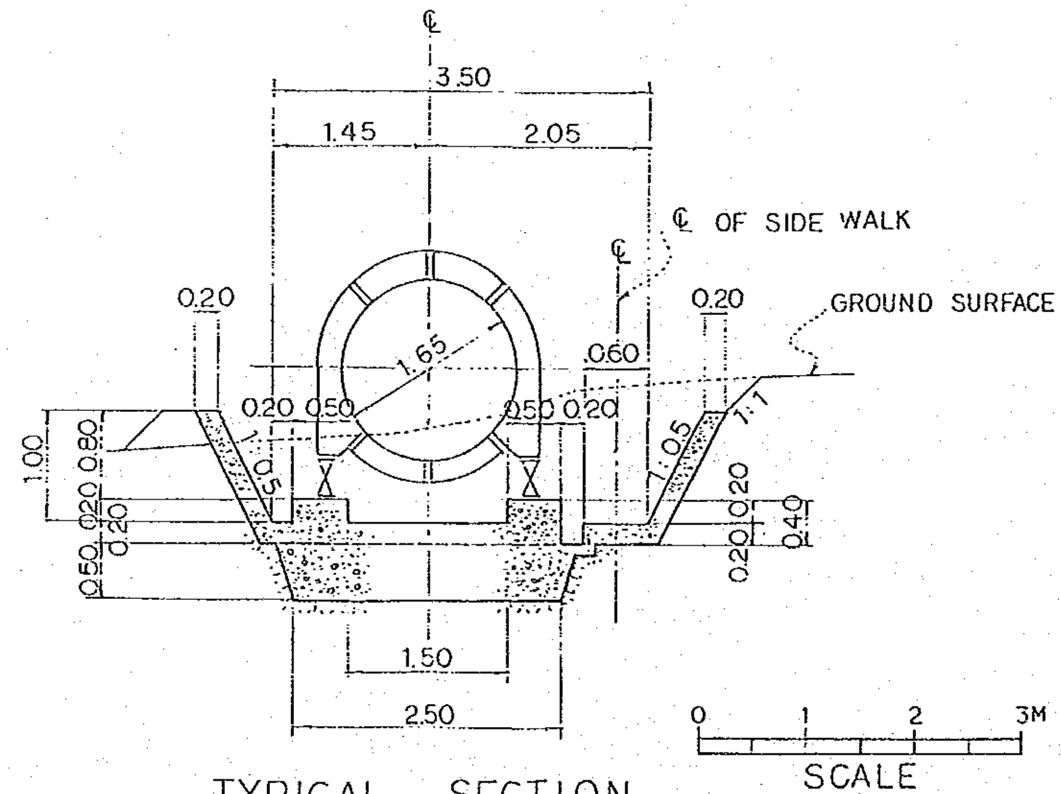
DRAWING NO.	CA – C – 03
SCALE	DATE



SECTION C-C

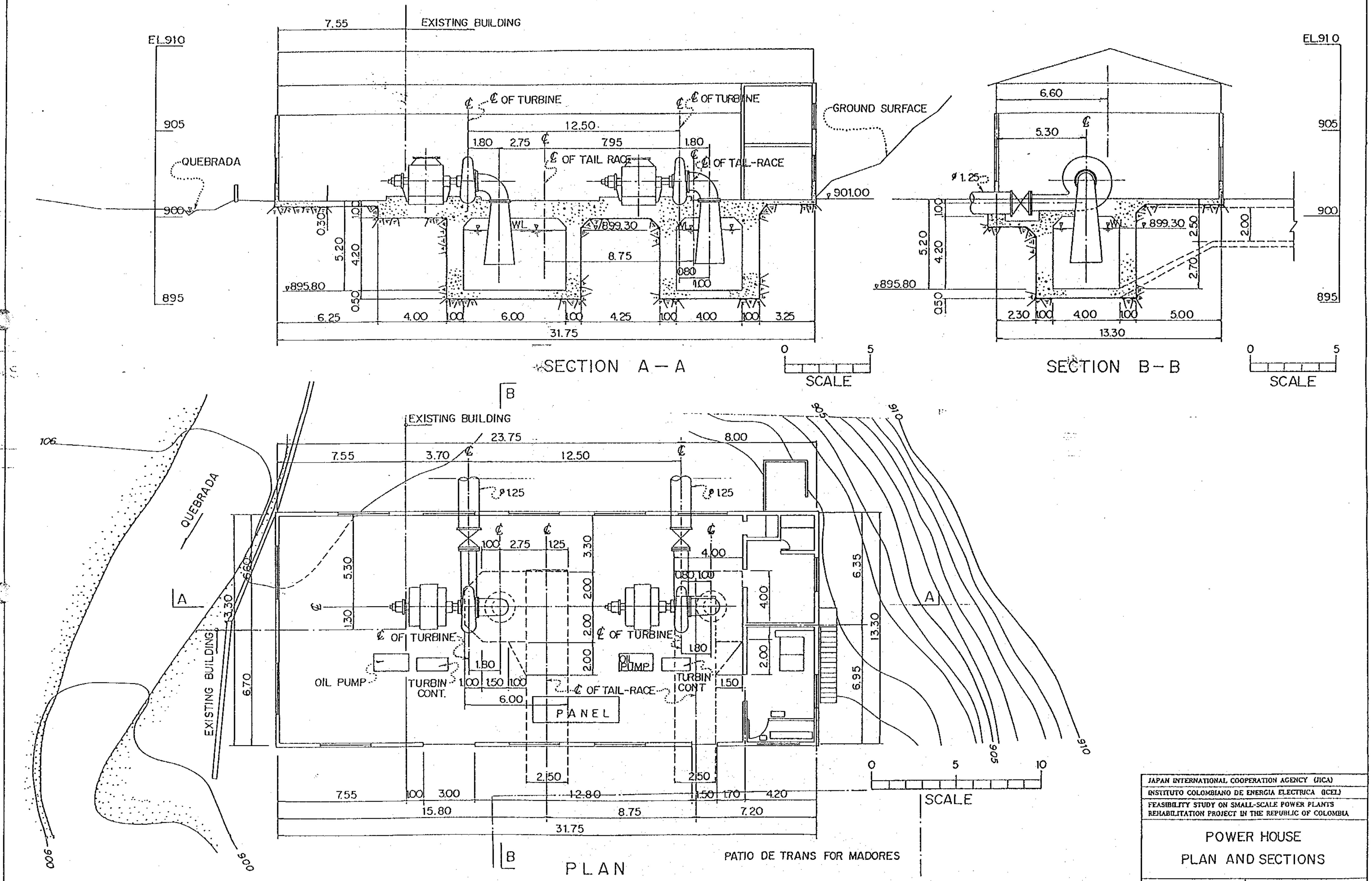


SECTION D-D



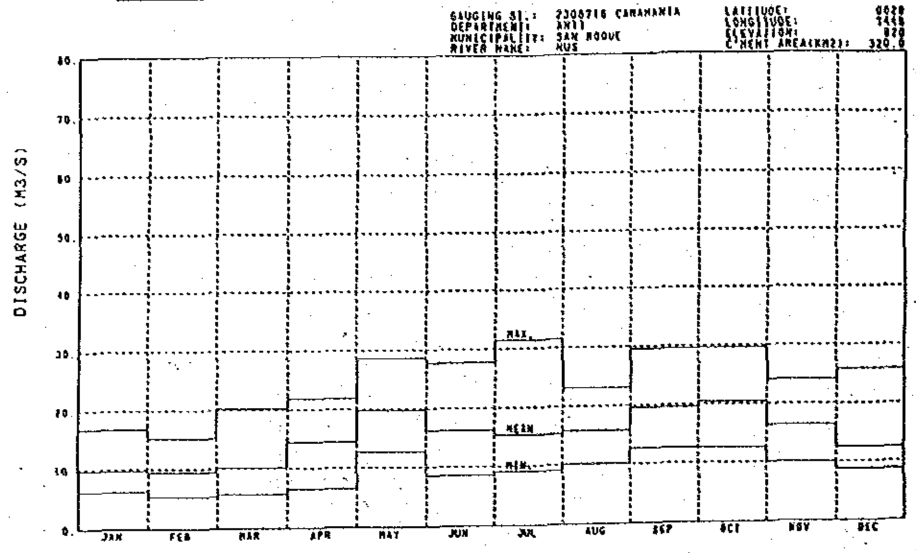
TYPICAL SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
PENSTOCK SECTIONS	
DRAWING NO.	CA-C-04
SCALE	DATE

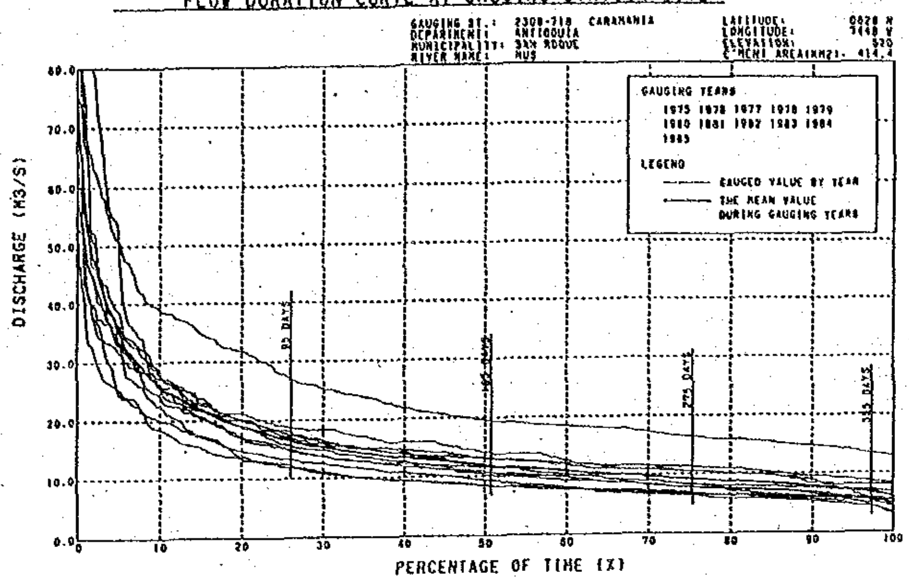


JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
POWER HOUSE PLAN AND SECTIONS	
DRAWING NO.	CA – C – 05
SCALE	DATE

(1) MONTHLY MEAN VALUE OF DAILY AVERAGE FLOW AT G.S. SITE



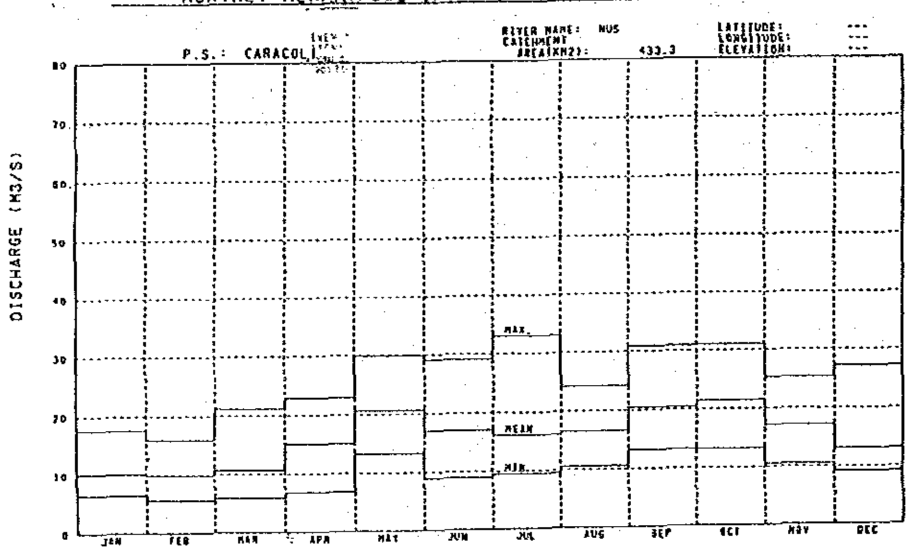
(3) FLOW DURATION CURVE AT GAUGING STATION SITE



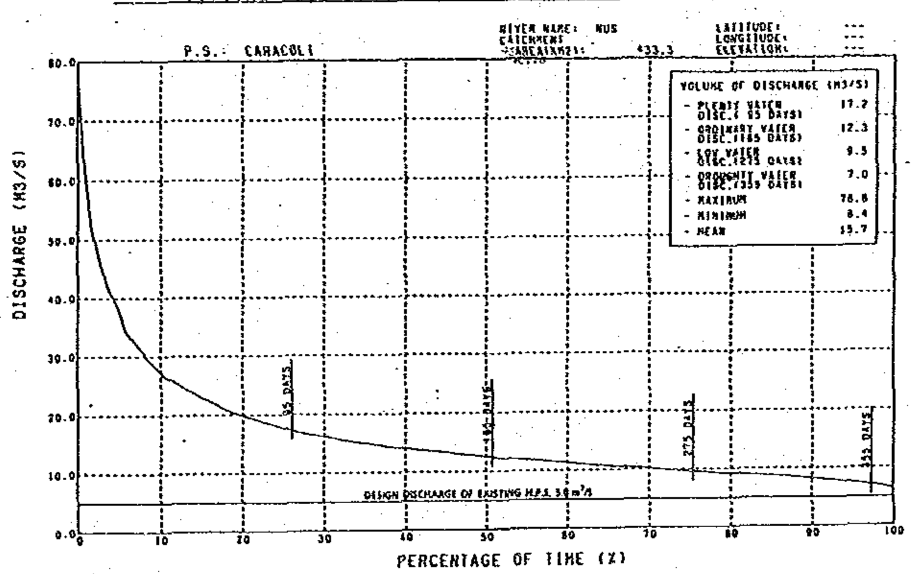
Data of Hydrological Gauging Station

No. of Station	2308-716
Name of Station	Caramanta
River	Nús
Management	HIMAT
Installation Year -- Month	1973 07
Coordinates (Deg. - Min.)	
Latitude	0628
Longitude	7443
Above Sea Level s. n. m. (m)	820
Long River (km)	43
Catchment Area (km²)	320.0
Water Shed (m)	1370
Observation Period	1975 - 1985

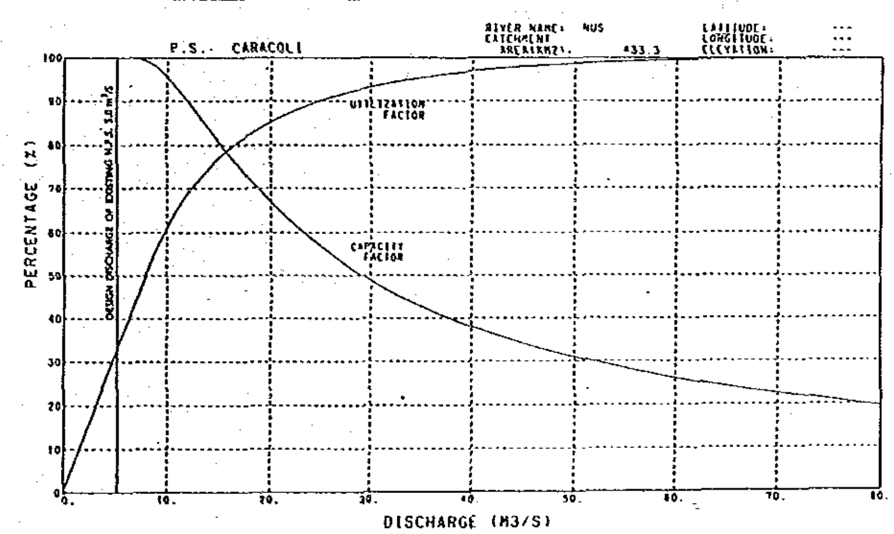
(2) MONTHLY MEAN VALUE OF DAILY AVERAGE FLOW AT INTAKE SITE



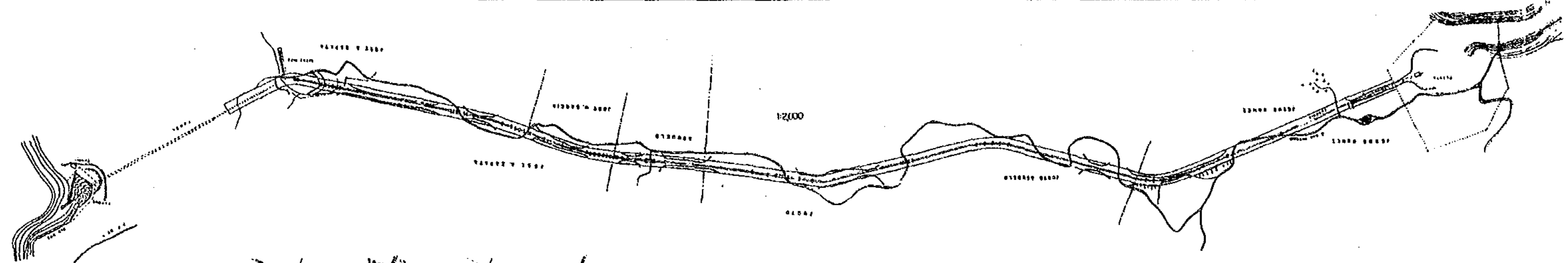
(4) TYPICAL FLOW DURATION CURVE AT INTAKE SITE

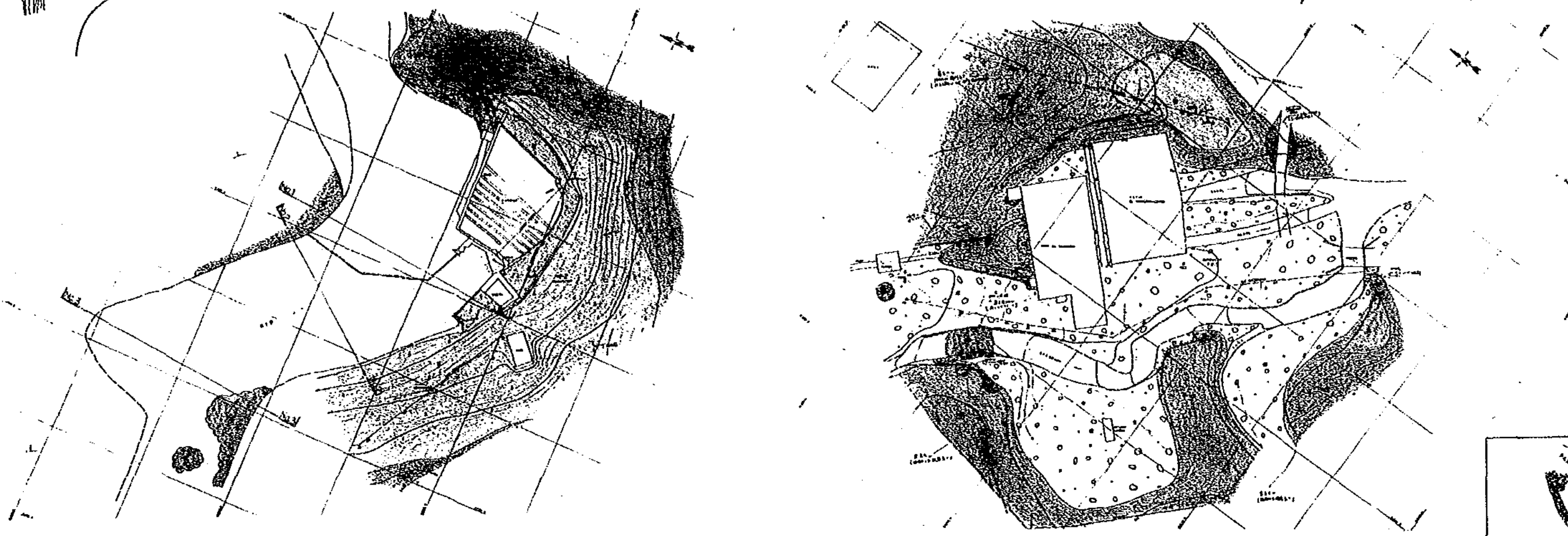


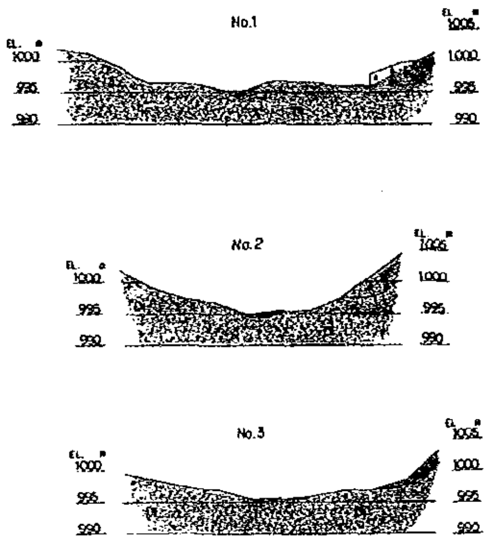
(5) UTILIZATION & CAPACITY FACTOR

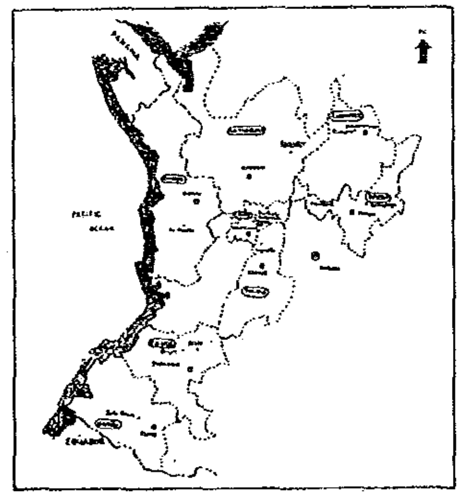


JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
DURATION CURVES	
DRAWING NO.	CA-H-01
SCALE ----	DATE





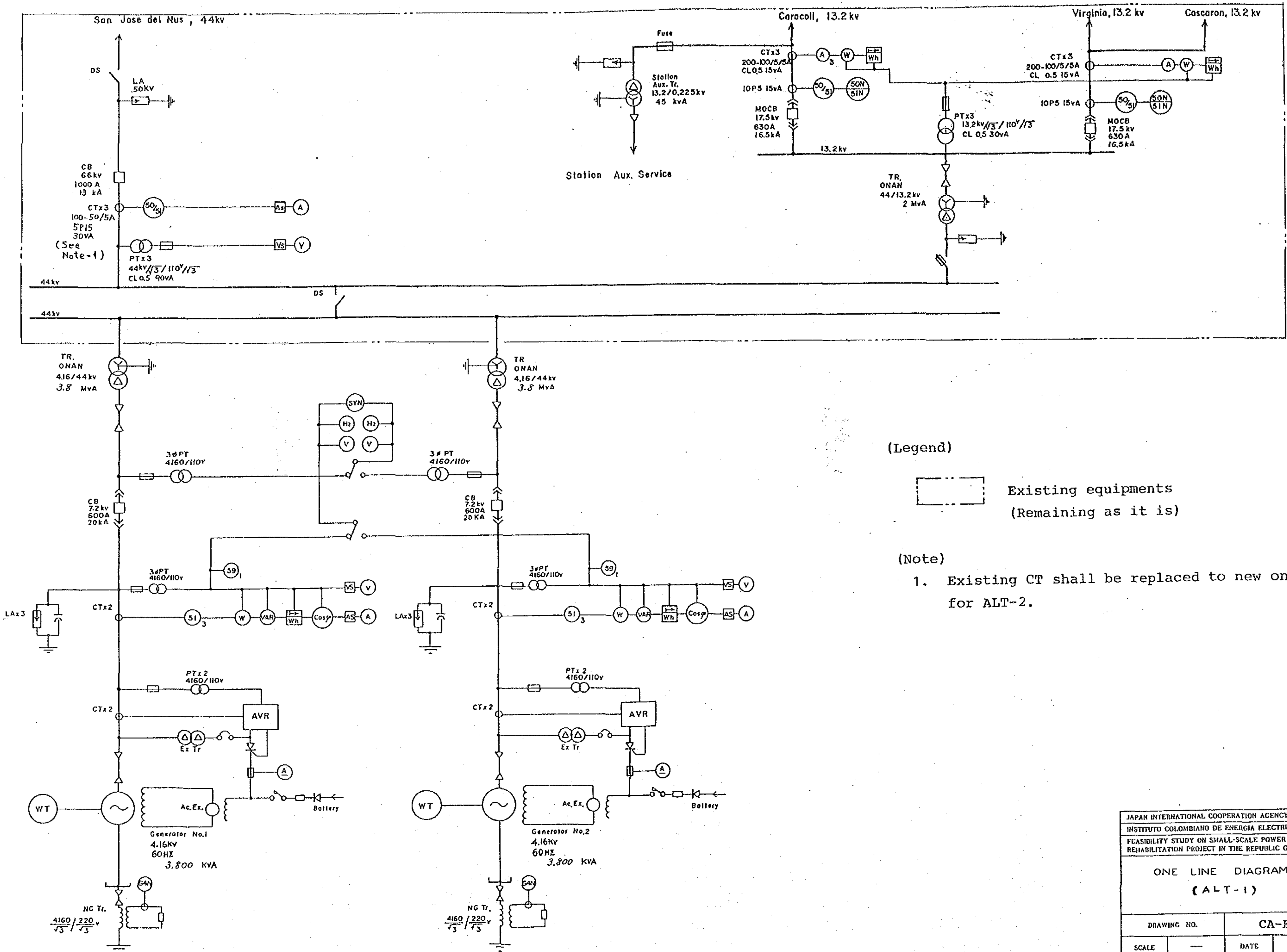




LEGEND

	River bed deposits
	Talus deposits
	Terrace deposits
	Granodiorite (fresh)
	Weathered Granodiorite
	Geological boundary
○	Borehole

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)			
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)			
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA			
Geological Plan and Profile Caracoli			
DRAWING NO.		CA-G-01	
SCALE	1/1,160	DATE	



(Legend)

Existing equipments
(Remaining as it is)

(Note)

1. Existing CT shall be replaced to new one for ALT-2.

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
ONE LINE DIAGRAM (ALT-1)	
DRAWING NO.	CA-E-01
SCALE ----	DATE

Attached Data

1. Facility Register for the Existing Power Plant

2. Survey Record

Facility Register for the Existing Power Plant

Power Plant	Caracoli
Electric Power Company	EADE
Location	Caracoli, Antioquia
River	Nus
Generating Method	Run-of-River
Year Installed	1935/1963
Years in Service	1935/1963
Installed Capacity	3,200 kW
Available Capacity	3,200 kW

Civil	
Item	**Data**
1. Dam	
1) Type	Concrete, overflow
2) Height (m)	2.0
3) Crest length (m)	45.0
4) Height of overflowing crest (m)	no data available
5) Width of overflowing crest (m)	45.0
6) Depth of overflowing crest (m)	0.08
2. Intake Gate	
1) Type	Sluice
2) Number of gates	2
3) Dimensions (W x H)(m)	2.0 x 6.0
3. Intake	
1) Intake sill height (m)	no data available
2) Number of intake	1
3) Dimensions (W x H)(m)	4.0 x 6.0
4. Desilting Basin	
1) Dimensions (W x L x H)(m)	25.0 x 30.0 x 9.0
5. Sand Trap Gate	
1) Type	sluice
2) Number of gates	2
3) Dimensions (W x H)(m)	1.0 x 3.0
6. Headrace	
1) Type	no data available
2) Dimensions (W x H)(m)	〃
3) Length (m)	〃

Civil	
Item	**Data**
7. Reservoir Tank	
1) Dimensions (W x L x H)(m)	N/A
8. Forebay	
1) Dimensions (W x H)(m)	〃
9. Penstock	
1) Number of lines	1
2) Penstock diameter (d)(m)	1.4
3) Penstock length (L)(m)	1,200
10. Tailrace	
1) Dimensions (W x H)(m)	2.3 x 0.8 2.4 x 1.1

Equipment		
Item	**Data**	
	#1	#2
1. Water Turbine		
1) Manufacturer's name	S. Morgan Smith Co.	Escher Wyss
2) Year manufactured	1935	1963
3) Type	Pelton	Francis
4) Output (kW)	2,500 HP	2,500 HP
5) Revolution (rpm)	327	1,200
6) Ancillary equipment		
a) Type of governor	Oil	Oil
b) Inlet valve		
- Type	Gate	Gate
- Diameter (mm)	1,100	750
2. Generator and Exciter		
1) Manufacturer's name	Westinghouse	Schorch
2) Year manufactured		
3) Type	Synchro.	Synchro.
4) Capacity (kVA)	2,000	2,000
5) Power factor (%)	80	80
6) Voltage (V)	2,300	2,300
7) Frequency (Hz)	60	60
8) Revolution (rpm)	327	1,200
9) Method of neutral earthing	Direct	Direct
10) Type of exciter	no data available	

Equipment			
Item	Data		
3. Transformer			
1) Manufacturer's name	Westinghouse	Schorch	
2) Year manufactured		1961	
3) Type	Outdoor ONAN	Outdoor ONAN	Outdoor ONAN
4) Capacity (kVA)	667x3	2,000	2,000
5) Primary voltage (kV)	2.3	2.3	13.2
6) Secondary voltage (kV)	23	44	44
7) Number of unit	3	1	1
8) Vector-group symbol	D/Y	D/Y	D/Y
9) Impedance (%)		no data available	
10) Purpose for use	Step-up	Step-up	Step-up
4. Circuit Breaker	44 Kv	13.2 Kv	2.3 Kv
1) Manufacturer's name		no data available	
2) Year manufactured		〃	
3) Type	M. Oil	M. Oil	
4) Voltage (kV)	66	17.5	13.8 17.5
5) Rated current (A)	1,000	630	630 800
6) Rupturing capacity (kA)	13	16.5	14.6 16 (Gen. income)
7) Purpose for use	transmission line	transmission line	Gen. income

Equipment			
Item		Data	
5.	Transmission Line	44 KV	13.2 KV
	1) Destination	San Jose del Nus	Caracoli, etc
	2) Length (m)	no data available	
	3) Voltage (kV)	44	13.2
	4) Number of circuit	1	3
	5) Number of pylons	no data available	
	6) Size of conductors	3/0	2/0
	7) Materials of conductors	ACSR	ACSR
6.	Battery		
	1) Manufacturer's name	Exide	
	2) Year manufactured	no data available	
	3) Capacity (AH/HR)		
	4) DC voltage (V)	10 x 12V	
	5) Type	Lead acid	
7.	Battery Charger		
	1) Manufacturer's name	Nite Jungneh	
	2) Year manufactured	1979	
	3) Capacity	5.4 kVA (input)	3.12 kW (output)
	4) Incoming voltage (V)	AC 3 x 208 V	DC 125 V
8.	Overhead Crane		
	1) Weight (ton)	7.5	
	2) Method of operation	Motor	
	3) Span (m)	no data available	

Survey Records

Caracoli Hydroelectric Power Plant

Date of Survey : 6 ~ 10 Feb. 1988

I. RECORDS BY VISUAL INSPECTION AND HEARING SURVEY

Unit No.: 1

Type of Turbine: Pelton

	Generating Facilities	Check item by visual inspection and hearing	Results
Pelton Turbine	Cover	1) Presence of vibration	1) no objection up to max. 1.5MW
	Bucket	1) Existence of corrosion	1) Abrasion is existing same as spare one (See Photo - 1)
	Shaft	1) Shaking of shaft axis	1) moved ← shaft → (0.5cm)
	Bearing	1) Oil shortage on bearing surface	1) No objection, but temperature alarm is not provided.
		2) Lack of oil viscosity	2) no objection (using Turbine Oil 68)
	Governor control	1) Control by belt-driven type 2) Speed detection device 3) Speed regulation system	1) Belt 2) Speeder 3) manual operation
		4) Installation of load limiter	4) not provided
		5) Accuracy of governor speed regulation	5) The variation of frequency does not occur while this generator is interconnected with 44kv line (EPM's system). But, this generator cannot regulate the variation of frequency which is caused by the load variation of 13.2kv line, while it is supplying the energy to the 13.2kv line and not interconnected with 44kv line.

Therefore, this generator is stopped while 44kv line is not energized due to the accidents and so on, because it is impossible to supply the stable power to 13.2kv lines.

Generating Facilities		Check item by visual inspection and hearing	Results
Pelton Turbine	Oil pressure equipment	1) Existence of oil leakage 2) Application of oil pressure pumping system	1) no objection 2) turbine shaft driven (by belt)
	Inlet valve	1) Operation method 2) Locking condition 3) Smoothness of pressurized oil operation	1) manual (4 men are necessary) 2) water is flown a little 3) N/A
	Nozzle and Needle	1) Existence of corrosion 2) Presence of water leakage from nozzle pipe when needle is closed	1) cann't inspected 2) no objection
	Deflector	1) Smoothness of control	1) no objection (manual operation)
	Jet Brake	1) Smoothness of control	1) not provided

Unit No. /

Generating Facilities		Check item by visual inspection and hearing	Results
Generator *for Pelton*	Rotor	1) Discoloration of winding surface due to heat 2) Existence of erosion for core 3) Fitness of between rotor and shaft	1) 2) 3) No objection, because rotor was repaired at the same time when stator was burnt 5 years ago.
	Stator winding	1) Frequency of burning trouble or repair 2) Reduction of insulation resistance 3) Rust and erosion of core	1) Winding was changed new one 5 years ago due to short circuit. 2) Winding was changed to high grade insulation 5 years ago 3) No objection
	Bearing	1) Occurrence of deformation on metal surface 2) Lack of oil lubrication 3) Occurrence of temperature rise	1) No objection 2) ditto 3) ditto (It has not been over 45°c max.)
	Exciter	1) Exchange frequency of brushes worn out 2) Sufficient stock of spare brush	1) Per 4 months due to deformation of rotor surface 2) Sufficient
	Voltage regulator	1) Operation method of voltage regulator 2) Response of voltage detection for load variation	1) Manual (at synchronizing), Auto. (at normal 2) The voltage of 44KV line is not able to regulate by this generator because this unit capacity is very small.

Unit No.: 2

Type of Turbine: Francis

	Generating Facilities	Check item by visual inspection and hearing	Results
Francis Turbine	Casing	1) Existence of corrosion	1) abrasion is existing by sand
		2) Wear in thickness	2) ditto
		3) Presence of vibration	3) no objection
	Runner	1) Existence of corrosion 2) Occurrence of porosity by sand pitting	1) 2) } Abrasion is existing by sand, therefore vanes are changed per 5 years
	Shaft	1) Shaking of shaft axis	1) no objection
	Bearing	1) Oil shortage on bearing surface	1) ditto
		2) Lack of oil viscosity	2) ditto
	Governor control	1) Control by belt-driven type	1) belt
		2) Speed detection device	2) speeder
		3) Speed regulation system	3) control panel
		4) Installation of load limiter	4) not provided
		5) Aoouracy of governor speed regulation	5) no objection

Generating Facilities		Check item by visual inspection and hearing	Results
Francis Turbine	Oil pressure equipment	1) Existence of oil leakage 2) Application of oil pressure pumping system	1) no objection 2) shaft driven
	Inlet valve	1) Operation method 2) Locking condition 3) Smoothness of pressurized oil operation	1) manual 2) no objection 3) N/A
	Guide vanes	1) Smoothness of control 2) Presence of water leakage from casing when guide vanes are closed 3) Break frequency of shear pins	1) no objection 2) Runner is rotating even if guide vanes are closed due to abrasion. 3) not provided
	Sealing device	1) Sufficiency of water sealing for shaft 2) Sufficiency of packing for shaft seal	1) N/A 2) packing (Cordón Grafitado) is changed new one per 4 months.

Unit No. 2

Generating Facilities		Check item by visual inspection and hearing	Results
Generator for Francis	Rotor	1) Discoloration of winding surface due to heat	1) no objection
		2) Existence of erosion for core	2) ditto
		3) Fitness of between rotor and shaft	3) ditto
	Stator winding	1) Frequency of burning trouble or repair	1) ditto
		2) Reduction of insulation resistance	2) no objection (heat resistant paint is used)
		3) Rust and erosion of core	3) No objection
	Bearing	1) Occurrence of deformation on metal surface	1) No objection
		2) Lack of oil lubrication	2) ditto
		3) Occurrence of temperature rise	3) ditto (it has not been over 58°c max.)
	Exciter	1) Exchange frequency of brushes worn out	1) per 1 year
		2) Sufficient stock of spare brush	2) Sufficient
	Voltage regulator	1) Operation method of voltage regulator	1) Manual (at synchronizing), Auto (at normal)
		2) Response of voltage detection for load variation	2) The voltage of 44KV line is not able to regulate by this generator because this unit capacity is very small.

Generating Facilities		Check item by visual inspection and hearing	Results
13.2 KV Indoor Switchgear	Insulation level	1) Sufficiency of insulation level 2) Unification of insulation level 3) Reduction of insulation resistance	1) sufficient (15 KV) 2) unified by 15 KV 3) no objection
	Accessi-bility and Safety	1) Accessibility to high voltage devices 2) Sufficiency of protection for high voltage cable terminals 3) Method and reliability of operation for synchronizing circuit breaker	1) no objection 2) ditto 3) not necessary for synchronizing devices in 13.2 KV Circuit breakers.

	Generating Facilities	Check item by visual inspection and hearing	Results
Outdoor Equipment	Transformer	1) Presence of over load operation	1) none
	Circuit breaker	1) Situation of trip for outgoing feeder breaker in case of accident on transmission line 2) Fitness of maintenance in case of oil circuit breaker	1) Good 2) Maintenance is easy due to min. oil circuit breaker. Maintenance is done per 6 months.
	Line switch	1) Operation method 2) Reliability of operation	1) manual 2) no objection
	Insulator	1) Presence of damage and dusts	1) ditto
	Structural steel	1) Occurence of erosion due to rust 2) Presence of injury	1) ditto 2) ditto
	Line protection	1) Existence of adequate protection relays to connect to RED	1) Only 50/51 relay is provided for 44KV line therefore another protection relay is not needed in this present.

II. ACTUAL GENERATED ENERGY AND OPERATION TIME

Unit No.: 1

Installed Capacity of Generator: 1600 KVA

Type of Turbine: PELTON

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL	NOTES
1983	MWH	803	646	495	---	---	---	---	---	156	817	932	859	4708	(1), (2)
	OPE. TIME	730	658	524	---	---	---	---	---	128	641	690	661	4032	
1984	MWH	899	915	825	941	807	800	904	819	848	812	890	890	10350	(1)
	OPE. TIME	708	667	671	683	634	660	704	663	674	668	703	699	8134	
1985	MWH	951	850	873	828	832	814	867	803	803	909	891	955	10376	
	OPE. TIME	735	649	704	678	692	690	713	708	658	709	686	704	8326	
1986	MWH	1021	867	783	866	902	883	924	858	831	744	848	881	10408	
	OPE. TIME	716	650	623	702	719	695	724	672	663	630	694	709	8197	
1987	MWH	896	796	635	786	687	809	838	840	817	852	1742	900	10598	
	OPE. TIME	723	643	494	689	598	681	696	699	679	662	696	717	7977	
1988	MWH	679	802	1019	873	890	1154	922	861	812	874	839	906	10631	
	OPE. TIME	529	585	709	696	725	701	701	711	661	702	692	733	8145	

Unit No.: 2

Installed Capacity of Generator: 1600 KVA

Type of Turbine: FRANCIS

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL	NOTES
1983	MWH	---	---	---	---	---	---	---	---	---	---	---	---	---	(1), (2), (3)
	OPE. TIME	730	658	524	---	---	---	---	---	---	641	690	661	3904	
1984	MWH	---	153,3	847,3	227,7	514,5	688,8	724,6	698,8	697,1	785,1	830	707,5	6874,7	(1)
	OPE. TIME	708	125	684	219	438	652	690	537	659	673	706	568	6659	
1985	MWH	849,1	768	845,6	630,9	770,2	834,7	907,2	892,7	698,5	813,7	743,8	738,1	9492,5	
	OPE. TIME	679	646	736	609	634	702	690	706	651	709	692	702	8156	
1986	MWH	501,8	827,2	889,6	856,4	880,6	764,9	865,2	690,7	508,7	787,9	871,7	724,8	9169,5	
	OPE. TIME	448	657	692	702	714	621	721	620	449	682	694	609	7609	
1987	MWH	772,4	746,4	546,2	871,4	829,4	822	725,7	799,5	753,3	723,2	240,7	685,5	8515,7	
	OPE. TIME	643	648	460	691	697	687	620	712	675	709	215	617	7374	
1988	MWH	852,1	325,9	---	482,3	776,7	764,2	417,1	846,7	752,2	781,5	800,1	856,1	7654,9	(3)
	OPE. TIME	712	263	---	540	717	698	458	721	649	681	693	734	6866	

Notes.

(1) Until January 1984, the measuring equipment didn't exist for each unit, only common.
The informations which appear for the unit 1 belong to both units.

(2) During period between April and August of 1983 the power plant didn't operate.

(3) On September 1983 and on March 1988 the unit 2 didn't work.

III. REPAIR RECORDS

No.	Study Item	Results
	The past records concerning the following items shall be obtained to evaluate reliability of generating facilities.	
1)	Repaired locations and method for repairing	1) Minor repairements are done in this power plant, but majour repairements are done in the factory or EADE's repair shop in Medellin.
2)	Causes for damage/defect	
3)	Duration of repairing and power supply stoppage	
4)	Repaired by;	
	a) staff in Power Plant	
	b) manufacturer	
	c) other	
5)	Repair cost	5) <u>Pelton</u>: 9 years ago, it was $25 millions, including : - Rewinding - Reconstruction of the turbine <u>Francis</u> : 5 years ago, it was $12 millions including : - Reconstruction of seal and change of the turbine
6)	Operation life after the completion of repairing work	It is necessary to do works of repair: Pelton : Each 2 years Francis: Each 5 years

IV. SITUATION OF STOCK SPARE PARTS

No.	Study Item	Results
	Data on the situation of stock spare parts shall be obtained to evaluate maintainability of generating facilities.	The following majour spare parts are stocked.

No	Description	Q'ty	Location
1	Runner for Pelton (See photo – 1)	1 piece	Caracoli
2	Deflector for Palton	1 piece	Caracoli
3	Runner for Francis (See photo – 2)	1 piece	EADE's repair shop (Medellin)
4	Brush for generator	1 lot	Caracoli

Photographic Records

Photo - 1 (Spare rotor)

Actual using buckets are reconstructed with welding
same as spare one.

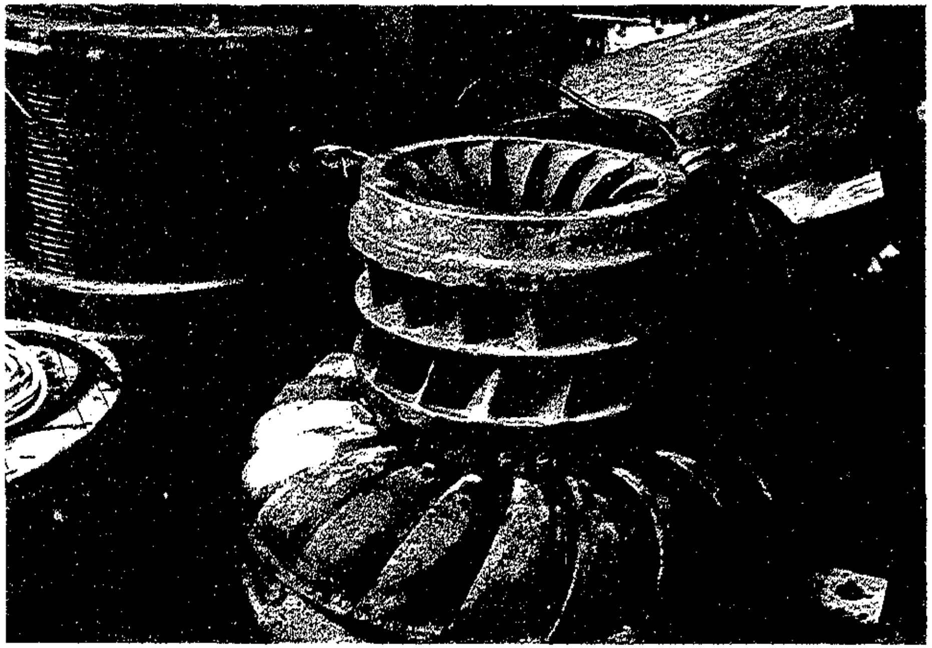


Photo - 2 (Spare Runner for Francis)

Abrasion is existing.

V. EADE's INTENTION FOR REHABILITATION

No.	Study Item	Results			
	Mark with √ in pertinent columns.	Leaving as it is	Repair work	Replacement	Notes
	- Inlet valve		√		1
	- Turbine, governor, auxiliary equipment	√	√		2
	- Generator, exciter		√		3
	- Control panel		√		4
	- Switchgear			√	5
	- Transformer	√			6
	- Substation equipment (Circuit breaker, Isolator, etc.)	√			7
	- Transmission tower, conductor and insulator	√			8
	- Power House	√			
	- Penstock	Doesn't change the flow which enters to the machine. Use deflectors or lead away jet.			

Notes

1. The valve didn't seal completely ; the water leak existed.

2. The turbine Pelton has been reconstructed with welding, by wear and tear.
   The turbine Francis has been replaced completely.
   The governor of both units has been ajusted but repair didn't realize properly for the request.
   The auxiliary equipment has not been changed. (leaving as it is.)

3. The generator of Pelton Unit has been rewinded with F Clase insulation.
   The generator of Francis Unit had only preventive maintenance.
   The exciter has been rectified to the collector.

4. On the controll panel, some measuring apparatus are repleced.
5. It was burned.
6. Only to level of preventive maintenance
7. It has been completed.
8. Preventive maintenance