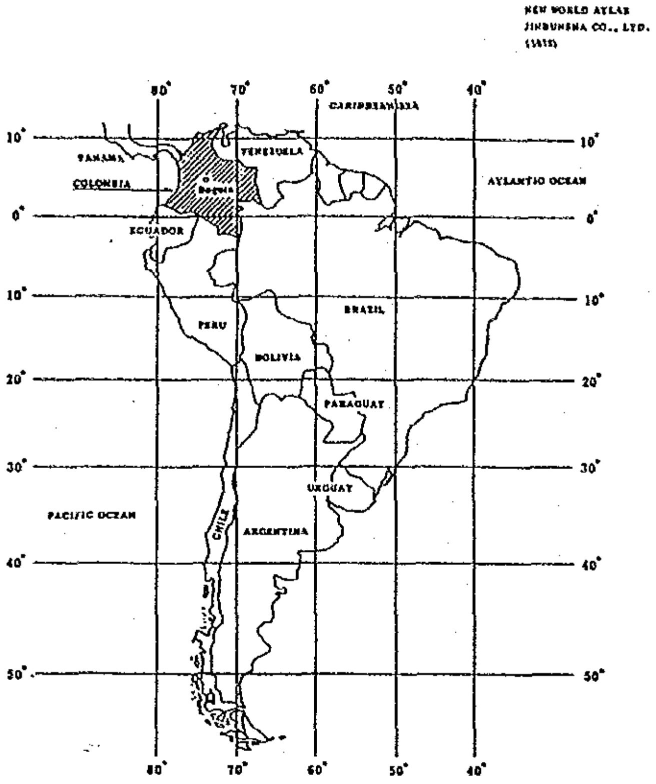
FEASIBILITY STUDY
ON
SMALL-SCALE POWER PLANTS
REHABILITATION PROJECT
IN
THE REPUBLIC OF COLOMBIA

OVEJAS HYDROELECTRIC POWER PLANT

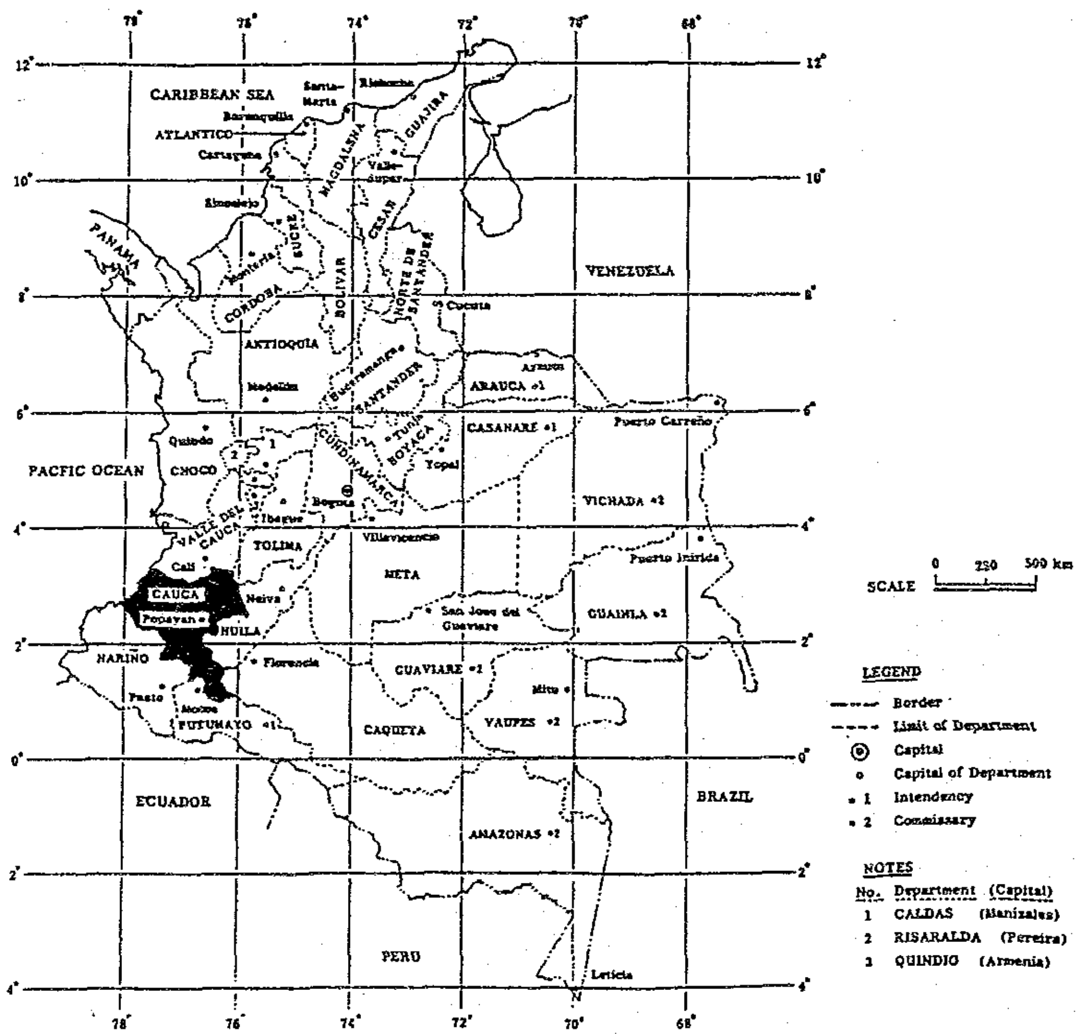
MARCH 1990

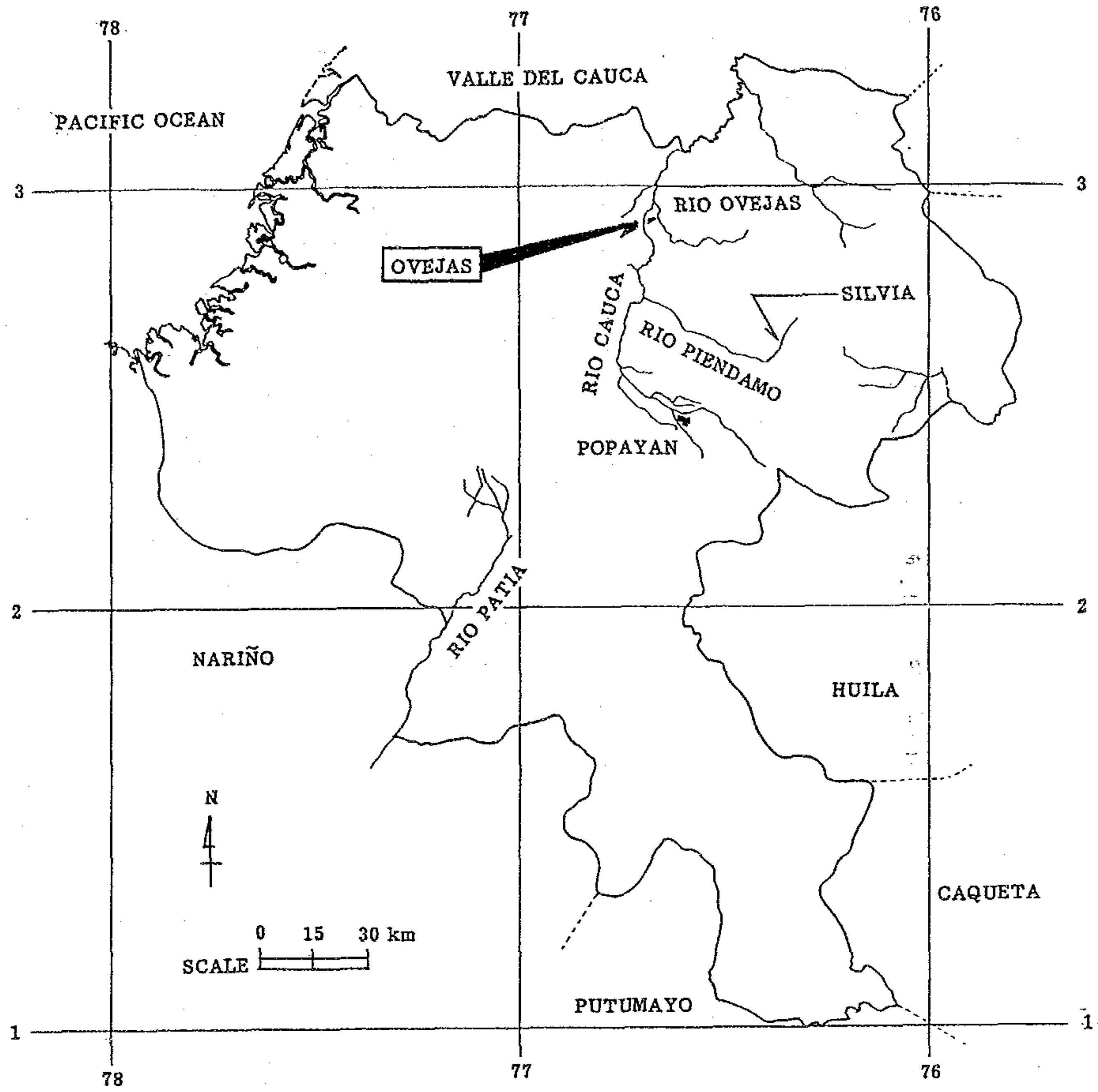
Japan International Cooperation Agency

MAP OF SOUTH AMERICA

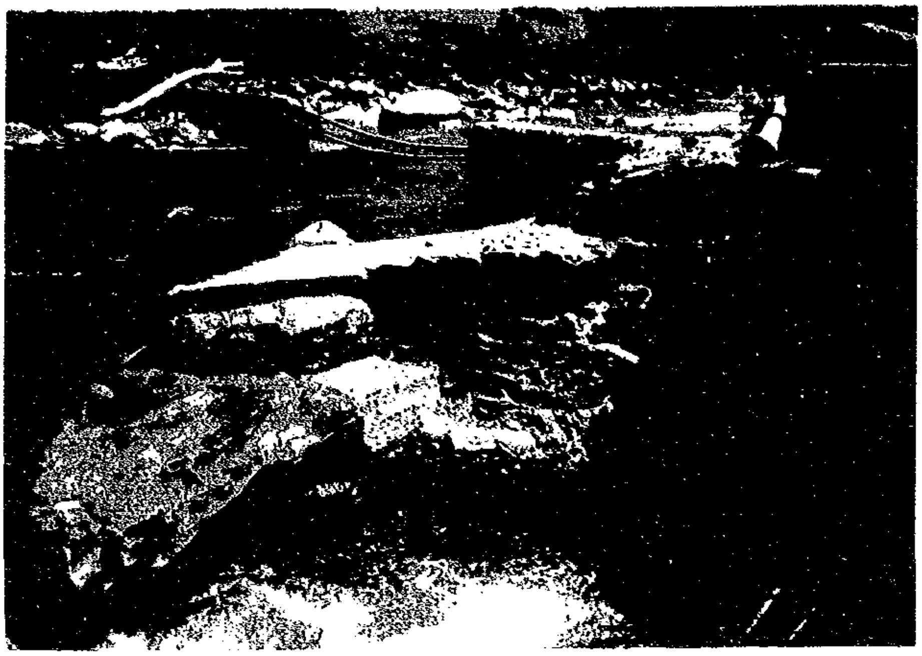


POLITICAL DIVISION IN THE REPUBLIC OF COLOMBIA

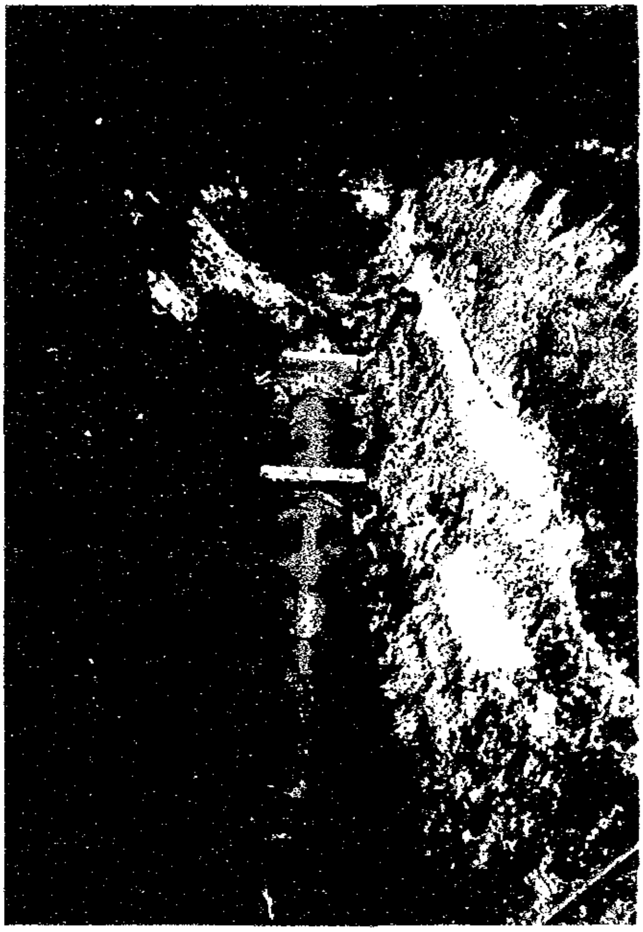




Location Map of Study Area

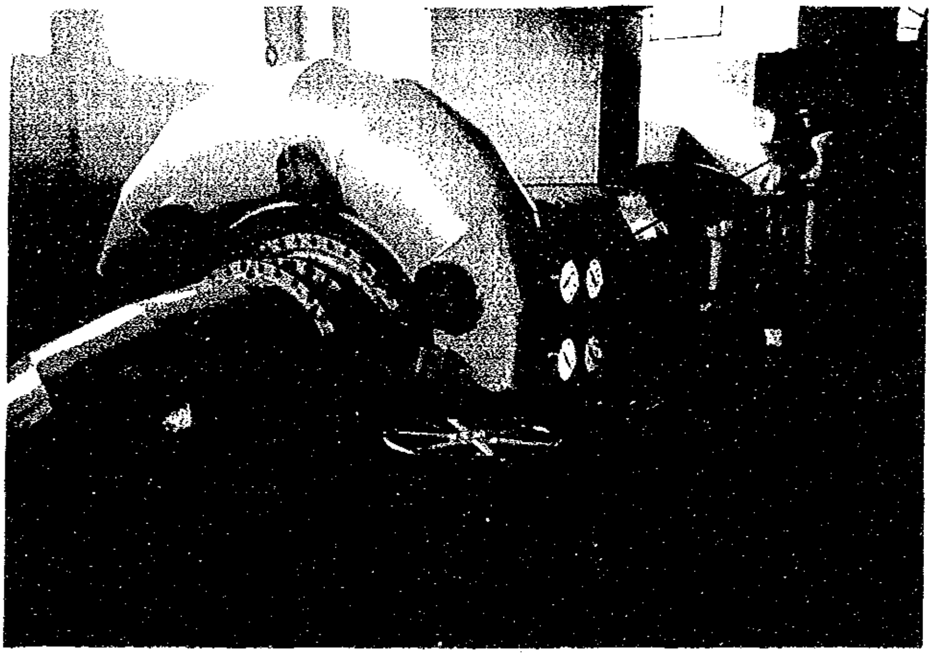


Rio Ovejas and Intake



Conduction channel

Powerhouse



Francis turbine

CONTENTS

CHAPTER 1 INTRODUCTION

The feasibility study (hereinafter referred to as the FS) for the rehabilitation plan of Ovejas run-of-river type hydroelectric power plant (the rated output: 0.65 MW) was conducted following the pre-FS that was carried out for eight months from November, 1987 to June, 1988. This report is prepared to summarize the results of the above FS.

This FS was performed in accordance with the Scope of Work (S/W) agreed and signed in July 1988 between Japan International Cooperation Agency (JICA) and Instituto Colombiano de Energia-Electrica (ICEL). The study was conducted for 17 months from November, 1988 to March 1990.

From among 62 small-scale hydroelectric power plants operated by ICEL that were nominated for the study of the rehabilitation plan, Ovejas hydroelectric power plant (hereinafter referred to as Ovejas P/P) was selected as a candidate for the FS for the following reasons:

1) Basic data relating to river discharge etc., are comparatively well organized.
2) There is no possibility of environmental destruction, and water rights for power generation have already been acquired.
3) The 1,230-meter-long steel conduit pipes (ϕ = 1,800 mm) were laid 50 years ago, and have corroded or deformed, frequently leaking.

From this FS, post-rehabilitation generating scale for Ovejas P/P, for which JICA Study Team proposes as an optimum rehabilitation plan, is as follows:

- Maximum output : 3.1 MW
- Annual potential generated power : 26.2 GWh
- Facility utilization factor : 94%

CHAPTER 2 SUMMARY OF STUDY RESULTS

The power plant, owned by CEDELCA, is the run-of-river type (the rated output: 900 kW), and is located along the Ovejas River in Cauca Department. It began operation 51 years ago in 1939. In July 1989 the maximum output was 650 kW and the annual generation output in 1988 was recorded as 3,747 MWh.

(1) Present condition of generating facilities and their problems

This power plant was built with a headrace 1,490 m long, with 1,800 mm diameter steel conduit pipes. The steel pipes were laid 50 years ago in 1939. Horizontal and vertical displacement, which has been discovered in many locations, has caused deformation and leaks frequently occur. The steel pipe which was originally 8 mm thick is now half as thick, 4 mm, and has reached the tolerance thickness.

The existing diversion weir, constructed of coarse aggregate concrete, is filled with sediment up to crest level and it is difficult to secure the required water intake quantity.

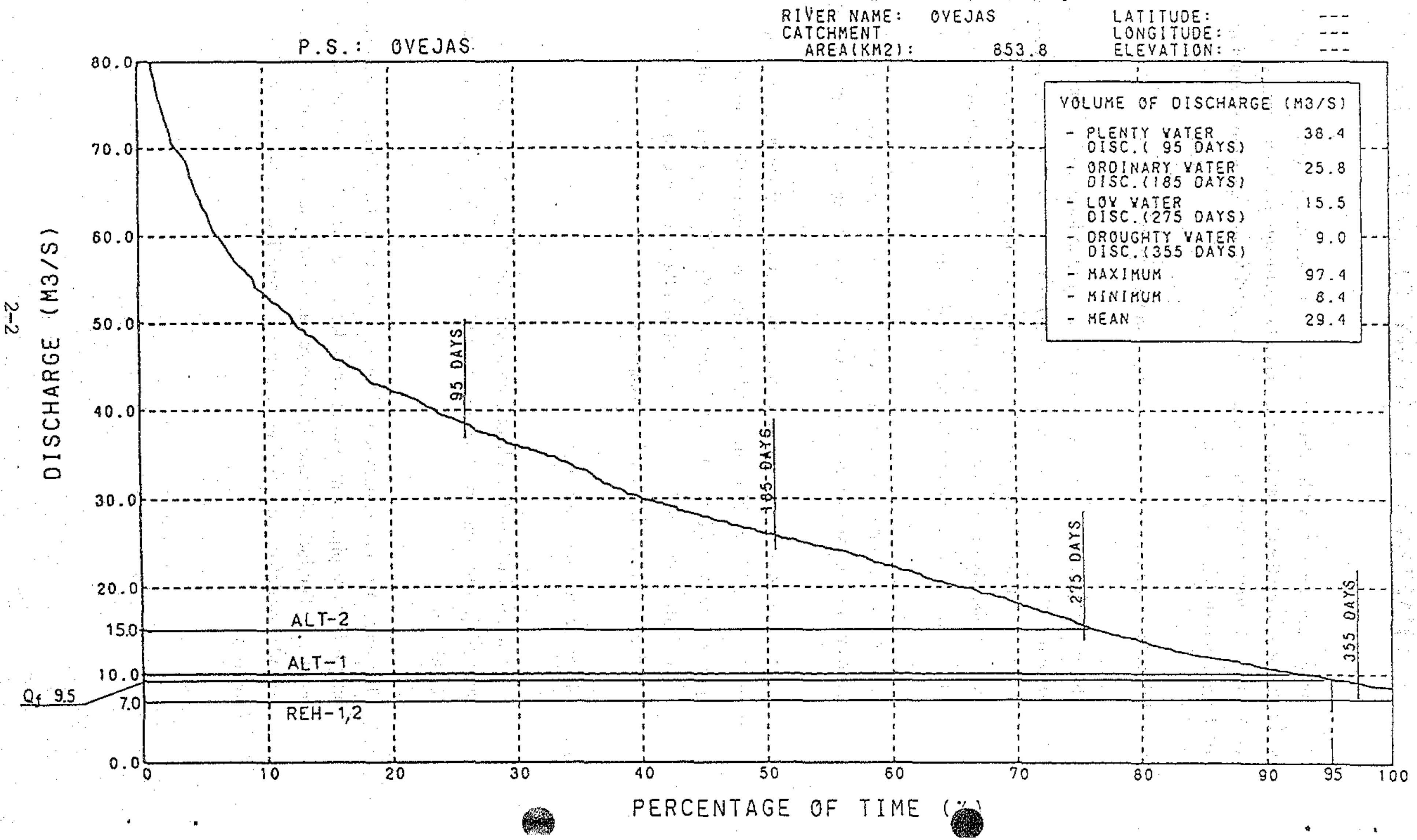
As for the power generating equipment, the horizontal Francis turbine, manufactured in 1939, was still working up until recently, but generating output has reduced to approximately 72% of the rated output, 650 kW. A 500 kW difference between theoretically calculated generated output and the existing equipment capacity has been found and it has reached minimum capacity.

(2) Alternative rehabilitation plans

The main problem in the rehabilitation plans for Ovejas hydroelectric P/P is judging the remaining life span of the 50-year-old 1,200-meter-long steel pipes (diameter: 1,800 mm).

This study, from consideration of safety priorities, is based on the premise that the full length of steel pipes which have corroded or deformed will be initially removed and replaced. The idea of removing and replacing only sections which have considerably corroded or deformed from the existing steel pipeline will not be used for the following reasons.

Fig-2.1 TYPICAL FLOW DURATION CURVE AT INTAKE SITE



① Enormous site investigations are necessary to investigate the degree of corrosion, deformation and safety factors in the steel pipes, and could not be completed in the duration or with the study team members.

② The results of the reconnaissance survey showed that a major portion of the steel pipeline required replacement.

From the river flow-duration curve at the intake site, as shown in Fig. 2.1, it is understood that the present plan's maximum available discharge, $Q = 7\ m^3/sec$, is uneconomical in view of the water utilization ratio. It is necessary to close the gap between the theoretically calculated generating output (1,300 kW) and the existing equipment installed capacity (900 kW).

Therefore, in the rehabilitation plan which assumes removal of existing steel conduit pipes, comparative studies shall be made for the generation-optimizing plan, as well as the rehabilitation plan of the existing generating facilities.

Table 2.1 shows contents of alternative rehabilitation plans.

Table 2.1 Comparison of Alternative Rehabilitation Plans for Ovejas Power Plant

Item	Alternative			
	Steel conduit pipeline plan		Concrete culvert	
	REH-1	REH-2	ALT-1	ALT-2
Discharge, Q (m^3/s)	7.0	7.0	10.0	15.0
Maximum 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	To be altered because the damage is severe, and sandstrap will be constructed (common to all alternatives			
Intake	To be reconstructed corresponding to the alteration of the diversion weir and the design discharge			
Desilting basin	To be newly constructed corresponding to the design discharge (currently not existing)			
Conduction channel	Its adequate cross section will be determined and the channels will be newly constructed			
Head tank	To be expanded at its present position			
Penstocks	Existing penstock and additional new one		New penstock will be installed	
Generating equipment	The existing equipment and additional new one		New, two-unit system	
Powerhouse building	A new building will be constructed on the downstream side to accomodate new generating equipment			

(3) Selection of optimum plan

ALT-2, where the available discharge will be increased from 7.0 m^3/s to 15 m^3/s, and the steel conduit pipes will be reconstructed with reinforced conrete culvert, is considereed to be the more advantageous rehabilitation plan. (Refer to Table 2.2 for details) However, for the implementation of the rehabilitation, topographic surveying, land price and compensation cost investigations will be carried out along a new culvert type headrace route, and recalculation of the headrace construction costs will be required.

Table 2.2 Comparison of Rehabilitation Plan for the Ovejas 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)
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			(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
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.

(25) : E1(Energia Media)

(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

CHAPTER 3 STUDY PLAN

3.1 Organization of Study Team

3.1.1 JICA FS Study Team

JICA FS Study Team, listed below, includes the team leader and two members who participated in the pre-FS, engineers, geologists, a hydrologist and an economist.

Name	Position	Assignment
Masami Ono	Team leader	Total coordinator (civil engineer)
Murao Toyama	Team member	Power generation planner (civil engineer)
Susumu Nonaka	"	Hydrologist
Yoshio Kawasaki	"	Generating equipment planner (civil engineer)
Akira Takahashi	"	Generating equipment planner (mechanical engineer)
Masayuki Tamai	"	Generating equipment planner (electrical engineer)
Nobuhiko Uchiseto	"	Geologist
Takashi Inoue	"	Geologist
Masaaki Ueda	"	Economist

3.1.2 Counterpart Engineers from ICEL

Engineers who were engaged in this study as counterparts to the JICA FS Study Team are as follows:

Name	Field	Position
Juvenal Peñaloza Rosas	Civil Engineering	Head of Central Eng. Div.
Jairo E. Gonzalez Morales	Civil Engineering	Central Eng. Div.
Mario Gutierrez Ospina	Civil Engineering	Central Eng. Div.
Rafael Torres Mariño	Civil Engineering	Central Eng. Div.
Rafael Gomez Florez	Civil Engineering	Central Eng. Div.
Jorge E. Hurtado Muños	Civil Engineering	Central Eng. Div.

3.1.3 Supporting Technical Staff from CEDELCA

JICA FS Study Team obtained cooperation and support from the technical staff as listed below:

Staff	Position
Fernando Iragorri Cajiao	President
Jose Morales M.	Vice President
Larry Guzman M.	Civil Engineer

3.2 Study Items and Study Schedule

The FS was conducted for 17 months from November, 1988 to March, 1990 in accordance with S/W agreed and signed in July, 1988 between JICA and ICEL.

3.2.1 Study Items

Study items for the FS as described in the S/W are as follows:

(1) Review of the existing data
(2) Site reconnaissance
(3) Field work

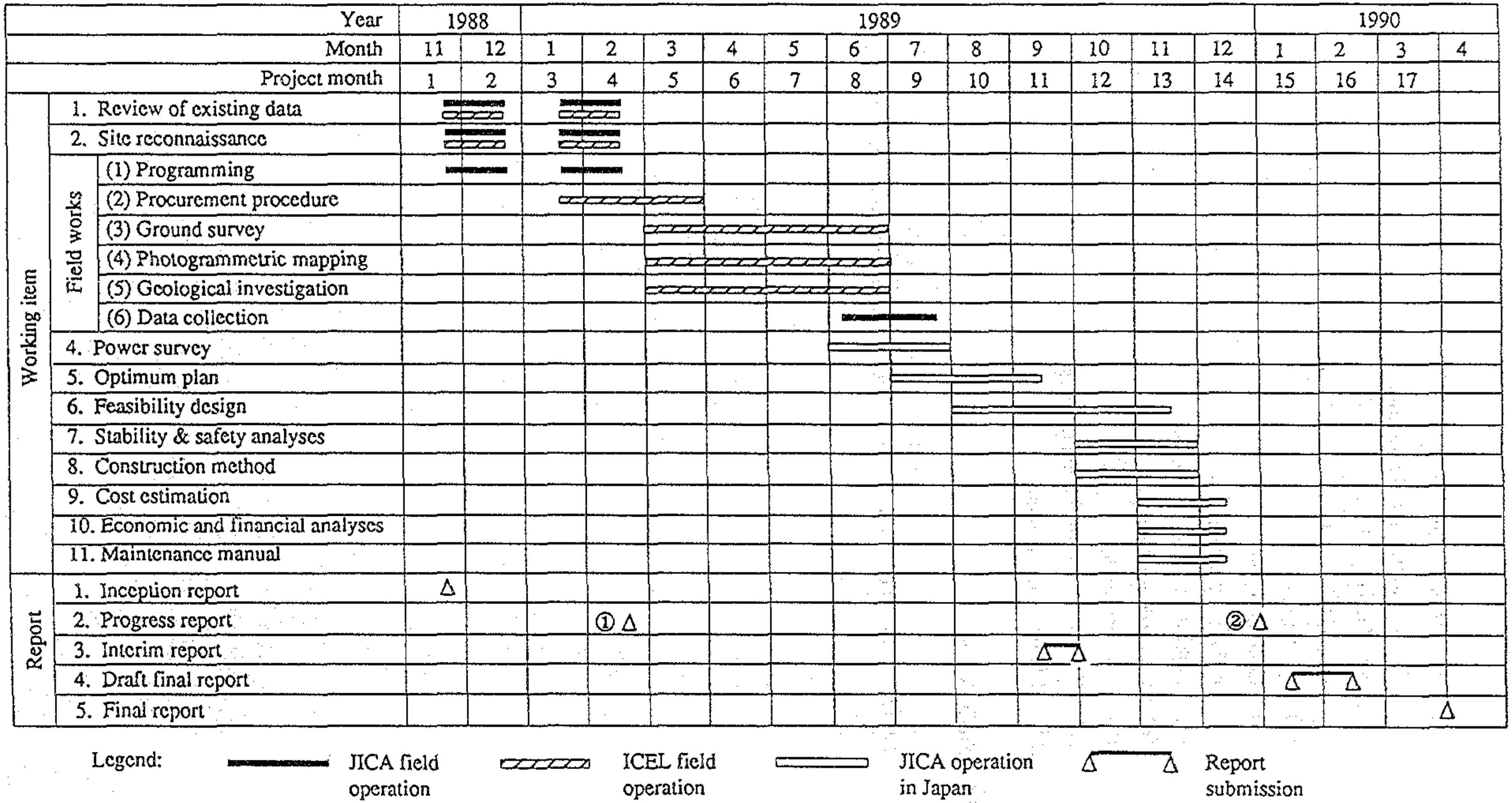
1) Topographic survey
2) Photogrammetric mapping
3) Geological investigation
4) Data collection

(4) Power survey
(5) Optimum plan
(6) Feasibility design
(7) Stability and safety analyses
(8) Construction method
(9) Cost estimation
(10) Economic and financial analyses
(11) Maintenance manual

3.2.2 Study Schedule

Table 3.1 shows the overall study schedule as indicated in the S/W.

Table 3.1 Time Schedule of FS



Two field surveys were conducted at Ovejas P/P, as shown in Table 3.2.

In the first site reconnaissance, two civil engineers responsible for hydroelectric power generating planning conducted the present-condition survey of the existing facilities (mainly civil structures) and collected necessary data.

In the second field survey, three members including team leader, a geologist and hydroelectric power generation planner gathered data relating to the geological survey.

Table 3.2 Field Survey Schedule

The first site reconnaissance

Date	Schedule	Detail of Study Item	Member	
			ICEL	JICA
Jan. 31	Pasto → Popayan	Discussion at CEDELCA, and data collection	J. Gonzalez	Murao Toyama Yoshio Kawasaki
Feb. 1		Field survey at Silvia P/P		
Feb. 2		Field survey at Ovejas P/P		
Feb. 3		Discussion at CEDELCA		
Feb. 4	Popayan → Bogota	Traveling		

The second field survey

Date	Schedule	Detail of Study Item	Member	
			ICEL	JICA
July 12	Bogota → Popoyan	Discussion at CEDELCA, field survey at Silvia P/P	-	Masami Ono Yoshio Kawasaki Takashi Inoue
July 13		Field survey at Ovejas P/P		
July 14		Same as above		
July 15	Popoyan → Bogota	Travel		

3.3 Detail of Field Survey Work

The field survey work planned in consultations between the JICA Study Team and ICEL counterpart staff and according to the results of the site reconnaissance, included topographic surveying and boring survey as described below, but did not include photogrammetric mapping.

3.3.1 Scope of Topographic Surveying

The scope of the topographic surveying is shown in Fig. 3.1. The scales for the topographic maps are as follows:

(1) The existing diversion weir, intake, desilting basin, head tank and powerhouse building were drawn on a scale of 1/200 with contour lines of 2 m. Main structures for the existing facilities and position of bench marks and boring were indicated in the above drawings.

(2) Penstock

The longitudinal section of the existing penstock was drawn on a scale of 1/1000 (plan) and 1/100 (section). This section was also drawn on a scale of 1/100, and with 20 m width and 50 m pitch.

(3) Bench mark

The bench marks shall be set up at the three locations.

3.3.2 Boring Survey Work Plan

The boring survey shall be conducted as follows:

No.	Location	Depth	Note
BH-1	The right side of the diversion weir	10 m	The location of boring holes is shown in Fig. 3.1.
BH-2	Starting point of conduction channels	10 m	
BH-3	Head tank	10 m	
BH-4	Powerhouse building	10 m	

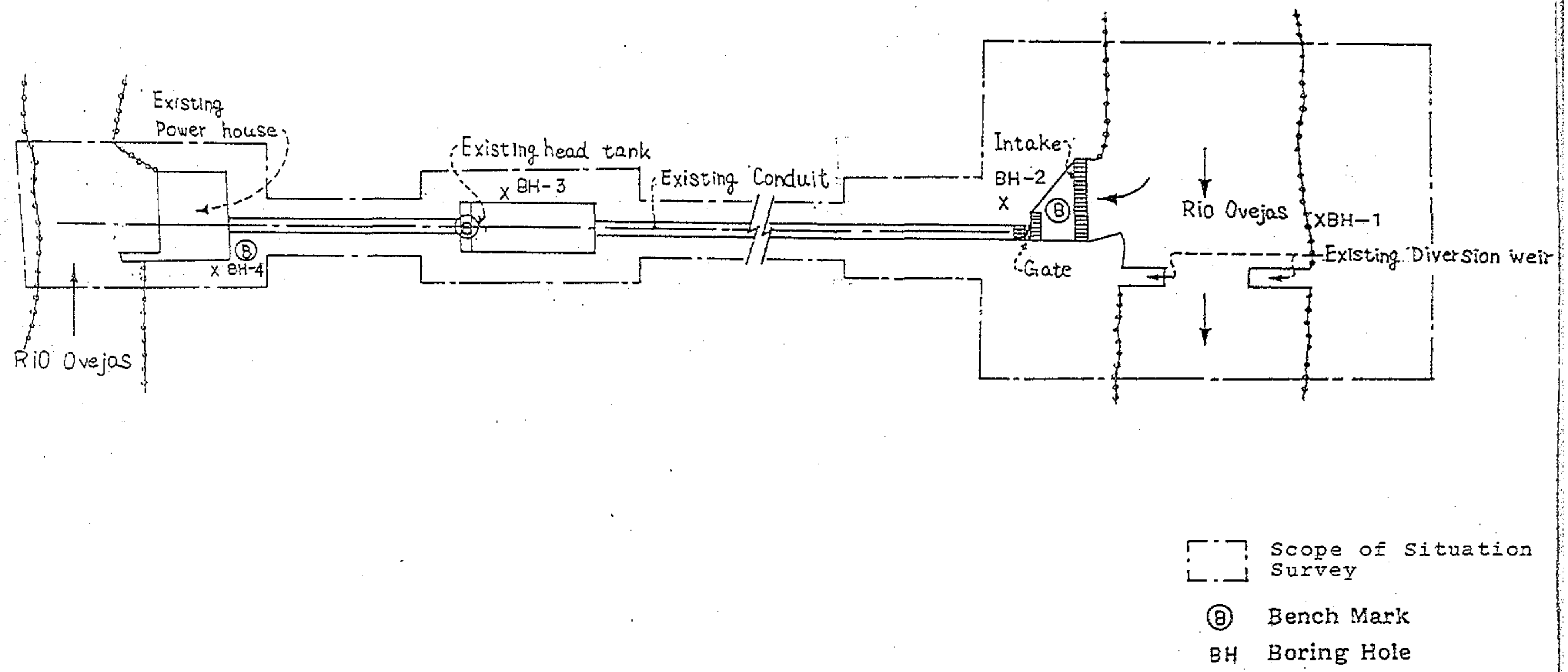


Fig. 3.1 Scope of Topographic Survey and Location of Boring Holes

CHAPTER 4 PRESENT CONDITION OF THE STUDY AREA

4.1 Power Conditions in the Power Sector

Power conditions in the public electric power company operated power plant under study for rehabilitation (hereinafter called public electric power company), are described below.

4.1.1 Balance of Power Supply and Demand

Table 4.1 shows the figures for power supply and demand in the past five years from 1983 to 1987. In 1987, peak demand was 76 MW, while installed capacity was 33 MW (43%). In 1987, electric power was 204 GWh, while supplied power was 114 GWh, which was about 56% of total electric power. The public electric power company bought electricity equivalent to 211 GWh from an other electric power company.

The breakdown of power demand in 1987 indicates that power demand for residential, commercial, industrial and other uses was 73%, 6%, 9% and 12% respectively. The power demand for residential use was high, while that for commercial use was low.

The annual average rate of increase in power demand from 1983 to 1987 was 5.1%. The annual average rate of increase in generated energy has decreased to -3.4%, the rate of buying electricity has increased.

Table 4.1 Power Supply and Demand
(1983-1987)

Item	1983	1984	1985	1986	1987	Annual Average Increase Rate(%)
DEMAND						
1. Peak Demand (MW)	50	56	69	68	76	11.0
2. Electric Power (GWh)						
1) Residential	125	144	142	144	148	4.3
2) Commercial	11	12	12	12	12	2.2
3) Industrial	9	15	13	17	18	18.9
4) Miscellaneous	22	21	18	17	26	4.3
Total	167	192	185	190	204	5.1
SUPPLY						
1. Installed Capacity (MW)	33	33	33	33	33	0
2. Generated Energy (GWh)	131	121	120	127	114	-3.4
3. Power Loss (GWh)	60	66	94	114	121	19.2

(Source: INFORME ESTADISTICO: RESUMEN 1983-1987)

4.1.2 Present Conditions of Generating Facilities

(1) Generating facilities

Table 4.2 shows the installed capacity of the public electric power company. The generating system of facilities owned by the public electric power company is hydroelectric power generation and diesel power generation.

Table 4.2 Total Installed Capacity of the Public Electric Power Company

Item	1983	1984	1985	1986	1987	Annual Average Increase Rate (%)
Total Installed Capacity (MW)						
1. Diesel	0.6	0.6	0.6	0.6	0.6	0
2. Hydroelectric	32.8	328	32.8	32.8	32.8	0
3. Others	0	0	0	0	0	0
Total	33.4	33.4	33.4	33.4	33.4	0

(Source: INFORME ESTADISTICO: RESUMEN 1983-87)

Table 4.3 shows condition of power plants for which the FS was conducted.

Table 4.3 Conditions of Ovejas Power Plant (1984-1988)

Item	1984	1985	1986	1987	1988
1) Installed capacity (kW)	900	900	900	900	900
2) Generated energy (MWh)	4,126	4,065	2,288	622.5	3,747
3) Facility utilization factor (%)	52	52	29	8	48
4) Operating time (%)	97	99	58	22	98

(Source: Data compiled from CEDELCA)

(2) Transmission facilities

The public electric power company provides 115 kV transmission lines to its transmission and substation facilities at Ovejas P/P. Voltage to be transmitted to Ovejas P/P is 13.2 kV.

4.1.3 Generating Cost and Electric Charges

Table 4.4 indicates the changes in generating cost and electric charges in the past five years from 1983 to 1987.

Table 4.4 Generating Cost and Electric Charges

Item	1983	1984	1985	1986	1987	Annual Average Increase Rate(%)
Generating Cost (COL$/kWh)	3.30	4.36	6.41	8.18	10.40	33.2
Electric Charge (Average): (COL$/kWh)						
1. Residential	2.63	3.33	4.44	5.68	7.05	28.0
2. Commercial	4.09	5.29	6.64	8.77	11.85	30.5
3. Industrial	5.21	5.71	7.21	9.27	13.46	26.8
4. Public use	2.98	3.80	5.45	7.39	9.85	34.8
5. Average	2.89	3.65	4,53	6.26	7.96	28.8
Breakdown of Power Demand by customer						
1. Residential	47,936	54,389	59,719	64,565	70,953	10.3
2. Commercial	1,573	1,542	1,690	1,695	1,776	3.1
3. Industrial	246	251	268	287	310	6.0
4. Others	941	993	974	987	1,013	1.9
5. Total	50,696	57,175	62,651	67,534	74,052	9.9
Diffusion of Electricity						
1. Overall (1000 households)	759	777	796	814	833	2.4
2. Power demand (1000 households)	213	241	265	287	315	10.3
3. Electrification rate (%)	28	31	33	35	38	7.9

(Source: INFORME ESTADISTICO: RESUMEN 1983-87)

4.1.4 Forecast of Power Supply and Demand

CEDELCA forecast of the power supply and demand until the year 2000 is shown in the following table

Year	Electric Power (GWh)			Peak Demand (MW)		
	Generated Energy	Electricity-buying	Total	Generated Energy	Electricity-buying	Total
1988	118.51	232.62	351.13	28.7	55.00	83.70
1989	118.51	255.01	423.48	28.7	70.48	99.18
1990	118.51	415.64	534.15	28.7	92.14	120.84
1991	118.51	466.47	584.98	28.7	105.18	133.88
1992	118.51	522.81	641.32	28.7	119.74	148.44
1993	118.51	520.45	703.76	28.7	136.02	164.72
1994	118.51	654.45	772.96	28.7	154.22	182.92
1995	118.51	731.15	849.66	28.7	174.55	203.25
1996	118.51	816.15	934.66	28.7	197.27	225.97
1997	118.51	910.36	1,028.87	28.7	222.67	251.37
1998	448.51	684.77	1,133.28	113.7	166.05	279.75
1999	448.51	800.49	1,249.00	113.7	197.77	311.47
2000	448.51	863.95	1,312.46	113.7	233.21	346.91

4.2 Operation Record of the Existing Power Plant

4.2.1 Generated Energy

The records of generated energy and operating time at the Ovejas P/P during the five years from 1984 to 1988 are shown in Table 4.5. The operating ratio in 1988 was 98% with continuous, no-break operation but the facility utilization factor, at 48%, was low.

Table 4.5 Records of Generated Energy and Operating Time

Year	Output inscribed on the name plate (MW)	Generated energy (MWh)	Operating time (hr)	Equipment util. ratio (%)	Opeating ratio (%)
1984	0.9	4,126	8,494	52	97
1985	0.9	4,065	8,647	52	99
1886	0.9	2,288	5,111	29	58
1987	0.9	622.5	1,912	8	22
1888	0.9	3,747	8,614	48	98

Remarks:

1. The generated energy (MWh) is gross unit

2. The equipment utilization ratio (%) = $\frac{\text{Generated energy (MWh)}}{\text{8760 (hr) x output on the name plate}}$ x 100

3. The operating ratio (%) = $\frac{\text{Operating time (hr)}}{\text{8760 (hr)}}$ x 200

4.2.2 Operation and Maintenance Costs

The records of this power plants operation and maintenance costs for five years from 1984 to 1988 are shown in Table 4.6. Operation and maintenance costs fluctuate but the average is 2,546 pesos/MWh.

Table 4.6 Record of Operation and Maintenance Costs

Year	Generated Energy (MWh)	Operation and Maintenance Costs (Pesos)	Peso / MWh
1984	4,126	4,559,239	1,105
1985	4,065	6,906,408	1,699
1986	2,288	7,523,205	3,288
1987	622.5	6,967,500	11,193
1988	3,747	11,850,013	3,162
Total	14,848.5	37,806,365	2,546

4.3 General Condition of Generating Equipment and Civil Structures

4.3.1 General Condition of Generating Equipment

The present condition of the generating equipment is summarized below:

(1) Generating equipment

The manufacturing years of the turbine and the generator which are inscribed on the name plates are 1938 and 1940 respectively. The existing equipment is already 51-year-old and maximum output is now 650 kW (the output inscribed on the name plate is 900 kW).

As shown in Table 4.5, the operating ratio is close to 100% but equipment utilization ratio is about 50%, a low value. The reason for this is that the generating equipment function has dropped.

Tables 4.7 and 4.8 show the defects in water turbines and generators according to a CEDELCA survey.

Table 4.7 Major Defects in Water Turbines and Auxiliary Equipment

Equipment	Major Defect
Casing	Inside of casing has been worn out by sand
Runner	Runner has been worn out by sand
Guide vane	1) Operation of this vane is difficult 2) Vane cannot be thoroughly closed off; in closed condition water enters runner from casing
Bearing	Bearing surface is not sufficiently lubricated
Inlet valve	Operation of this valve is difficult
Governor	Accuracy is not high since it is belt-driven
Hydraulic equipment	Oil leaks occur

Table 4.8 Major Defects in Generators and Auxiliary Equipment

Equipment	Major Defect
Rotor	The coil surface overheats and discolors
Stator	The insulation resistance is low
Bearings	1) The bearing surface is deformed 2) The bearing is not sufficiently lubricated 3) The bearing overheats
Turbine, Generator Control Panel	1) Inaccurate measuring equipment and protection relays 2) Skill is required because of manual operation for synchronizing

(2) Transformer

There is no voltage transformer since the existing generator voltage is 12.5 kV and this power plant is directly connected to the 12.5 kV distribution lines.

(3) Switchgear

The switchgear for connecting to 12.5 kV power transmission lines is installed in the powerhouse. According to a CEDELCA survey this switchgear is 49 years old and insulation resistance is low. Furthermore it is reported that it is of an old type with exposed charging parts and it is therefore dangerous.

(4) Distribution line

There are existing 12.5 kV power transmission lines connected to the power plant. These distribution lines are also connected to the Asnazu hydroelectric power plant (440 kW) and these plants supply to consumers in the surrounding area. In addition to 12.5 kV distribution lines there are also 13.2 kV distribution lines. The 12.5 kV and 13.2 kV distribution lines separate at El Hato. In future CEDELCA intends to use only the 13.2 kV voltage.

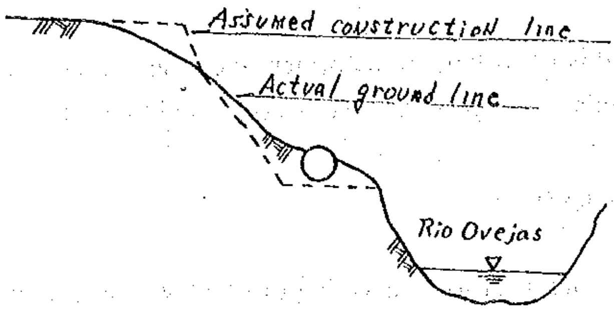
4.3.2 General Conditions of Civil Structures

(1) Intake facilities

The diversion weir, of which crest is 24.0 meter long and 2.5 meter high, was equipped with a wooden stop log in the center of the weir to regulate a water level. At present, the central portion of it is damaged, and the level of the intake dam is lowered because of the damage. The intake is located on the right bank of the river, arranged about 45° in the direction of the flow, and equipped with a manually regulating gate, which is 2.0 m wide and 2.0 m high.

(2) Headrace channel

The 1.2 km-long steel conduit pipes (diameter 1.80 m) are laid on the narrow flat area along the Ovejas River. Presently, the majority part of the channel is filled up with the soil to top of the pipes. They are severely worn out to cause water leakage from aging and deformation by earth pressure.



Pressure pipes are used for the channel to suit the topographic conditions. Some 30 m portion of it in access to the reservoir was ruptured by negative pressure and earth pressure, and was repaired.

(3) Desilting basin

A Desilting basin is not installed.

(4) Head tank

The head tank, 5.2 m wide, 22.5 m long and 3.2 m deep, is in a good condition but the size is not large enough.

(5) Steel pressure pipes

There is no problem in the 65-meter-long steel pressure pipes (diameter: 1.6 m) except painting. However, the inner wall may be worn out by aging.

(6) Powerhouse

The reinforced concrete powerhouse (8.0 mW x 14.0 mL x 5.0 mH) which accommodates one generator, has solidity and enough space.

(7) Gates and valves

Steel gates installed at the intake and the head tank are still functioning, though they have deteriorated.

CHAPTER 5 BASIC DATA COLLECTION

The pre-FS was conducted from November, 1987 to July, 1988. In succession, the FS was carried out in November, 1988 to collect topographical, geological, hydrometeorological and other related data as detailed below:

5.1 Topographic Maps

Ovejas P/P, built along the Ovejas River of the Cauca River system, is located about 10 km upstream of the confluence of the Ovejas River and the Cauca River, which join the Cauca River.

JICA Study Team collected the following topographic data.

- Topographic maps (scale: 1/25,000 - 1/400,000) published by IGAC

- Topographic survey maps that were actually measured by CEDELCA for the study of this power plant

(1) Topographic maps published by IGAC

Scale	Drawing No.	Description
1/400,000	-	the whole area of Cauca Department
1/ 25,000	320-II-C,D 320-IV-A,B,D 321-III-C 342-II-B	Power plant and upstream area are covered.

(2) Topographic maps actually measured by CEDELCA

Topographic survey maps actually measured by CEDELCA from March to June, 1989 for the study of this power plant are as follows:

Topographic Survey Map	Scale
Plan of the whole area and profile	1/500
Plan of diversion weir and vicinity	1/200
Plan of head tank, power plant and vicinity	1/200

5.2 Geological Survey Data

The geological survey data that was collected for this project is as follows:

- Mapa Geologico de Colombia: 1988, INGEOMINAS
- Aerial photographs of the power plant and vicinity
- Informe de Resultados de Perforaciones y Ensayos de Suelos para las Pequenas Centrales, Hidroelectrica de Silvia y Ovejas, 1989, Estudio de Suelos Ltda

5.3 Hydrometeorological Data

Since Ovejas P/P does not have the facilities for monitoring precipitation levels and discharge, the JICA Study Team gathered HIMAT and CVC hydrometeorological data in conducting this survey.

The precipitation observations for the Ovejas River were recorded at the HIMAT gauging station. The discharge observations were recorded at three CVC stations; Los Combulos, Abajo Tarabita and Pte Carretera, the last of which is on the Mondomo River. The collated data is as follows:

Table 5.2 List of Collected Hydrometeorology Data

(1) Precipitation observation record

Meteorological station No.	Meteorological station Name	Controller	Location Latitude	Location Longitude	Altitude (EL. m)	Observation period
2602-002	Silvia Pta Electri	HIMAT	0237	7622	2650	1970-87
260-2-003	Piendamo	HIMAT	0241	7632	1840	1970-87
2602-010	Buenos Aires	HIMAT	0301	7634	1050	1977-87
2602-016	Catalina La	HIMAT	0257	7639	1373	1972-87
2602-020	Amparo El	HIMAT	0253	7629	1850	1971-87
2602-022	Morales	HIMAT	0245	7638	1360	1971-87
2602-039	Ovezes Abayo Alert	HIMAT	0252	7636	1263	1979-87
2603-504	Salvajina La	HIMAT	0258	7642	1100	1972-85

(2) Discharge observation record

Hydrological gauging station No.	Hydrological gauging station Name	River	Controller	Establish-ment	Location Latitude	Location Longitude	Altitude (El, m)	Catchment area (km^2)	Observa-tion period
2602-703	Pte Carretera	Mondomse	CVC	1974-07	0252	7632	1305	--	1954-70
2602-711	Ahajo Tarabita	Ovejas	CVC	1964-09	0252	7636	1263	607	1964-87
2602-728	Los Cambulos	Ovejas	CVC	1980-07	0251	7639	1143	--	1982-86

(3) Water quality data

The observation of water quality was recorded at the Ovejas P/P as shown below.

Observation period: June 1962 - June 1975
Observation items: CO_3, HCO_3, Ca, Cl, Ca, Mg, conductivity, turbidity (ppm)
Observation period: May 1989 - June 1989
Observation items: pH, SO_4, Cl, $CaCO_3$, conductivity

(4) Sediment data

The sediment data recorded at the Los Cambulos gauging station is shown below:

Observation period:	Mach 1982 - April 1982
Observation items:	Sediment grain-size distribution
Observation period:	July 1981 - February 1983
Observation items:	Turbidity (ppm)

5.4 Other Related Data

5.4.1 Construction Prices Data

Construction prices for civil works in Colombia are based on "Catalogo de Precios de Materiales de Construccion (Catalog of Construction Material Prices)" monthly published by CAMACOL (Camera Colombiana de la Construccion) in Cauca Department. However, the above publication is not published in all departments of Colombia. To coordinate the data of the power plant sites where the FS was conducted, construction prices used for this study are based on price data used within CEDELCA (refer to Table 5.2).

5.4.2 Power Condition Data

(1) The following data was collected for the purpose of examining CEDELCA's power condition.

1) CEDELCA's demand forecast from 1970 to 2000

2) CEDELCA's power schematic diagram

(2) The following data was gathered relating to Ovejas P/P.

1) One line diagram

2) Residual value

3) Operation and maintenance personnel

Table 5.2 UNIT PRICE LIST
表-5.2 建設工事単価表

	UNIT	EADE	CHEC	CEDELCA		E.CHOCO	CEDENAR	ESSA	ELECTROLIMA
				SILVIA	OVEJAS				
		NOV./88	FEB./89	JUN./89	JUN./89	MAR./89	JUN./89	APR./89	MAY/89
1. EARTH WORK (EARTH)	p/m^3	2,400	2,925	700	800	2,950	990	2,500	1,100
2. EARTH WORK (ROCK)	p/m^3		3,965				1,900		2,800
3. CONCRETE WORK (MASS CON.)	p/m^3	-	-	-	-	24,000	-	-	-
4. CONCRETE WORK (STRUCTURAL)	p/m^3	26,300	27,625	34,000	40,000	26,800	20,500	15,600	17,900
5. REINFORCING BAR	p/t	354,000	454,000	350,000	360,000	447,500	300,000	320,000	215,000
6. GATE	p/t	1,682,000	500,000	1,310,000	1,420,000	1,100,000	1,100,000	1,100,000	480,000
7. SCREEN	p/t	1,682,000	5,00,000	804,195	874,125	1,000,000	1,000,000	1,000,000	650,000
8. PENSTOCK	p/t	1,000,000	1,000,000	1,250,000	1,250,000	-	815,000	1,260,000	420,000
9. POWER HOUSE (REPAIR)	p/m^2	-	10,000	-	-	-	-	-	-
10. POWER HOUSE (NEW CONST.)	p/m^2	-	40,000	47,000	55,000	50,000	50,000	50,000	50,000
11. CYCLOPEAN CONCRETE	p/m^3	-	14,000	17,000	20,000	-	-	8,000	9,000
12. DEMOLITION CONCRETE	p/m^3	13,000	14,000	17,000	20,000	-	-	8,000	9,000
13. STEEL PIPE	p/t	-	-	-	1,250,000	-	-	-	-
14. GABION	p/m^3	-	-	8,800	-	-	-	-	-
15. TUNNEL EXCAVATION	p/m^3	-	-	-	-	-	-	-	19,600
16. TUNNEL CONCRETE	p/m^3	-	-	-	-	-	-	-	25,000

CHAPTER 6 PRESENT CONDITION OF TOPOGRAPHY AND GEOLOGY

6.1 Topography and Geology in the Area

6.1.1 Topography

The source of the Ovejas River is at the western slope of the Central Cordillera, about 40 km north-northwest of Popayan, from which the Ovejas River flows northwest to join the Rio Cauca near Suarez.

The project site is situated on the downstream side of the Ovejas River and the topography around the project site is formed by gentle hills.

6.1.2 Geology

The bedrock consists of shale formed in the Mesozoic era (or the Palaeozoic era). The shale in a natural condition is black and hard, on which thick gravel covers. The surface layer of gravel is laterized. The quarternary riverbed, tabus, terrace deposits cover the gravel. The stratigraphy in the vicinity of the project site is shown in Table 6.1.

Table 6.1 Stratigraphy in the Vicinity of Project Site

Era	Schematic column	Strata	Remarks
Quartenary		Riverbed deposit	
		Talus deposit	
		Terrace deposit	
Tertiary		Gravel	
Mesozoic		Shale	

6.1.3 Geological Structure

The bedding plane constituting the bedrock strikes N2°W~20°E 75~90. The structure of the boundary surface between the bedrock and the upper thick gravel is not clear.

6.2 Geology in the Project Site

The general conditions for the various structural foundations of the power plant are outlined below. (Refer to Drawing No. OV-G-01)

(Power plant)

Terrace deposits cover the mesozoic shale in the vicinity of the powerhouse. Most of the powerhouse buildings have foundations on the mesozoic shale. The boring survey carried out on the upstream end of the power plant revealed that the plant site lies on the bedrock at a depth of 2.2 m and the rock surface level is the same level as the existing riverbed.

(Head tank, water channels and intake)

The head tank, water channels and diversion weir are located on the thick gravel and do not lie on the bedrock. The boring survey carried out on the left and right banks of the diversion weir revealed that the gravels overlay up to a depth of 10 meters with no presence of shale.

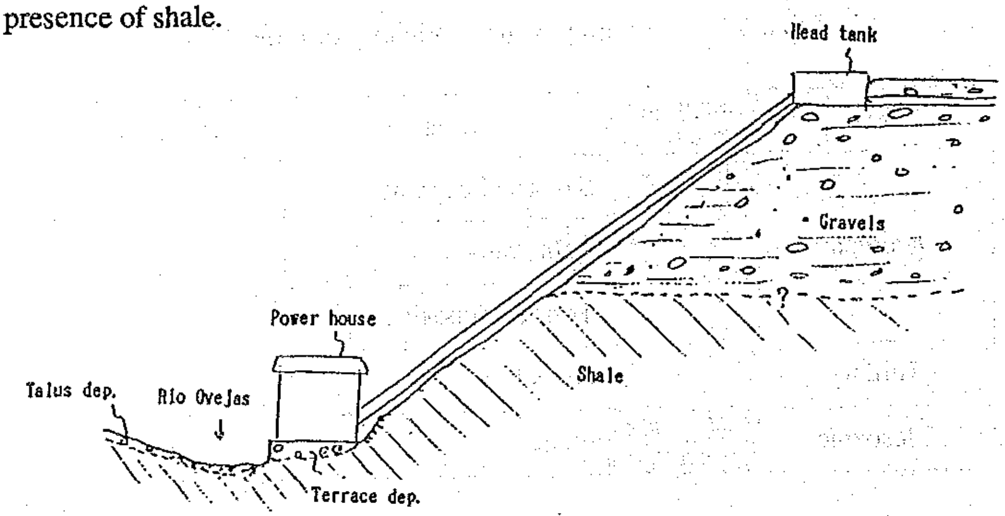


Fig. 6.1 Schematic Geological Profile

6.3 Distribution of Concrete Aggregates

The aggregate for concrete etc., can be produced from riverbed deposits.

6.4 Geological Evaluation

1) Mesozoic shale, constituting the bedrock in the project site, is very hard and dense in the natural condition, and has sufficient bearing capacity and impermeability for the foundations of the various structures.

2) The thick gravel overlying mesozoic shale has sufficient bearing capacity as a structural foundation. However, collapse or landslide have occurred in several areas of the slopes and so there is a problem with slope stability.

3) The steel conduit pipe route runs under the nick point along a gentle slope. The steel conduit pipes have deformed, leaking due to landslide and collapse.

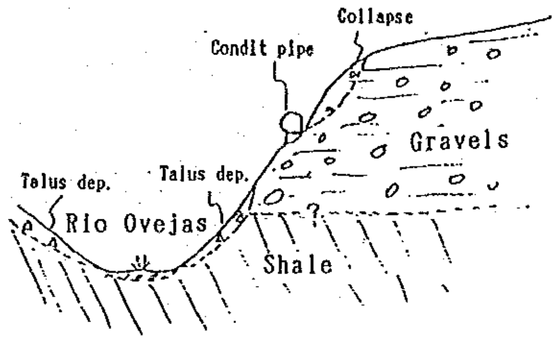


Fig. 6.2 Schematic Geological Profile Near the Conduit Pipe

6.5 Topograhical and Geological Problems

There are no geological problems in the intake, the head tank and the power plant. However, the rock surface is deep below the water channel, and there is evidence of landslides in several places along the pipe route. Therefore, proper measures to prevent landsliding must be taken.

CHAPTER 7 HYDROLOGICAL ANALYSIS

Fig. 7.1 shows the location of the existing gauging stations for monitoring precipitation and discharge in the watershed of the project site.

7.1 General Meteorology in the Planned Area

Cauca Department, in the southwest part of Columbia, lies at 1°00' to 3°20' north latitude, near the equator.

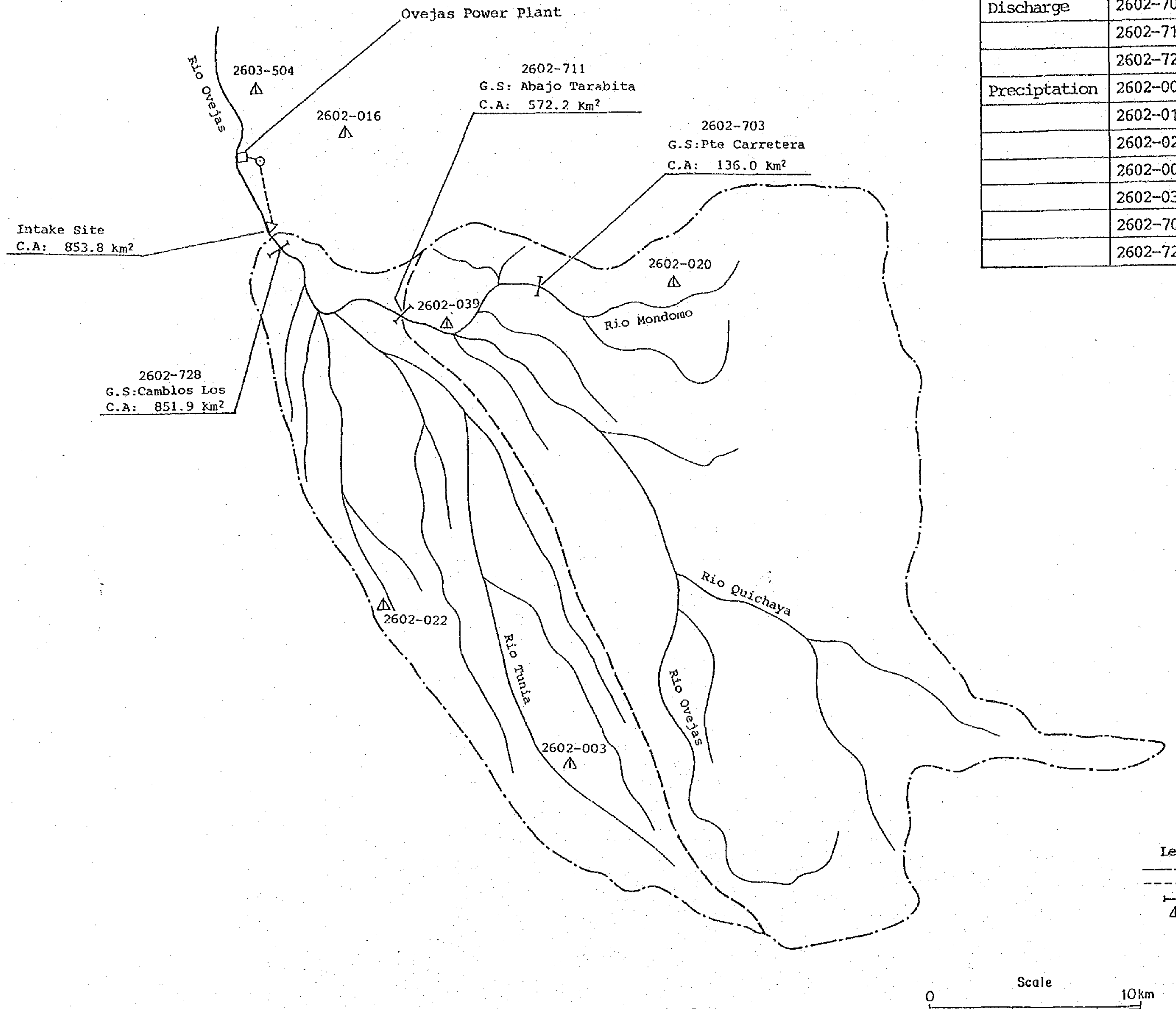
Generally the lowland areas enjoy a tropical climate and have a hot and very humid rainy season. The lowland areas have an average temperature of 24°C, while the highland areas (at an elevation of 1,800 to 2,800 m) range from 12 to 18°C.

Popayan, the capital, lying at an elevation of about 1,500 m, has an average temperature of 15°C. This temperature level remains constant from year to year.

The annual maximum precipitation in the highlands is 1,000 - 2,000 mm, while precipitation is low for the lowland areas. On the west slope of the West Andes Mountain Range the annual maximum precipitation exceeds 6,000 mm.

The project site, at an elevation of about 1,200 m above sea level, is situated to the north of Popayan and lies in the Central Andes Range. The annual precipitation in the project site is typically relatively large, though it fluctuates from year to year. The rainy and dry seasons are clear (refer to Fig. 7.2).

Observation Item	Gauging Station No	Gauging Station Name	Latitude	Longitude
Discharge	2602-703	Pte Carretera	0252	7632
	2602-711	Abajo Tarabita	0252	7636
	2602-728	Camblos Los	0252	7639
Preciptation	2602-003	Piendamo	0241	7632
	2602-016	Catlina La	0257	7639
	2602-020	Amparo El	0253	7629
	2602-002	Morales	0245	7638
	2602-039	Ovejas Abajo Alert	0252	7636
	2602-703	Pte Carretera	0252	7632
	2602-728	Camblos Los	0252	7639



Legend
- — · — · :Boundary of Watershed (Intake)
- - - - - :Boundary of Watershed (Gauging Station)
- ⊢⊣ :Gauging Station (Discharge)
- ⚠ :Gauging Station (Preciptation)

Fig-7.1 Location Map of Gauging Stations in The Watershed of The Study Area.

Meteorological station No.2602-039 Ovejas Abajo Alert
North latitude: 2°52'
West longitude: 76°36'
Elevation: 1,263 m
Annual average precipitation: 1,957.1 mm

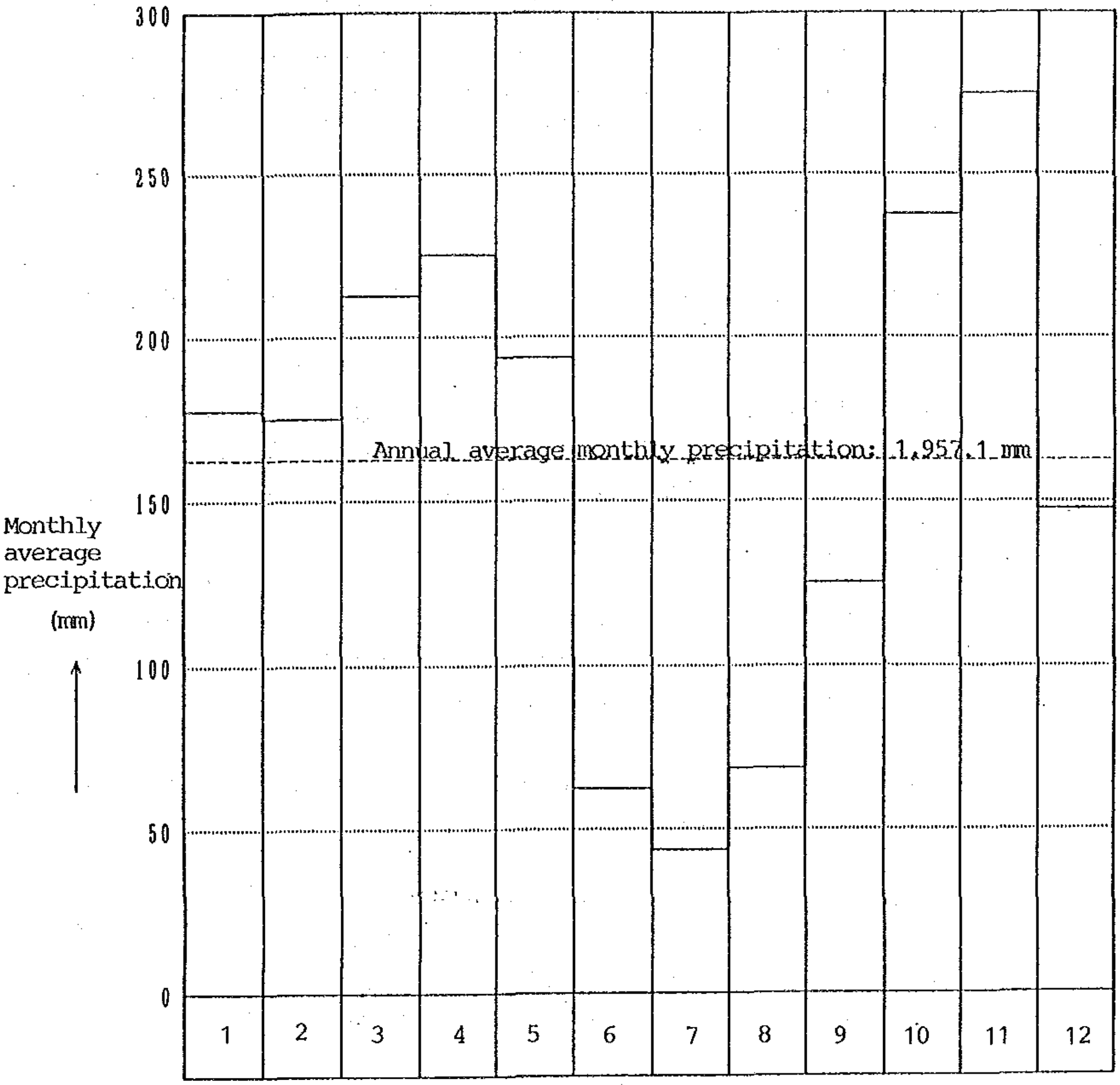


Fig.7.2 Monthly Average Precipitation in the Project Site (1987-87)

7.2 Discharge Analysis

The discharge and flow duration curves in the project site were compiled by comparing the records of Los Cambulos, Abajo Tarabita and Pte Carretera. Five-year observations recorded at Los Cambulos gauging station, where is closest to the planned power plant's intake site, were used as the basic data, after adjustment of the river basin. (Refer to Drawing OV-H-01(04))

7.2.1 Collation of Discharge Data

The observation periods for the discharge data collected by the JICA Study Team is as follows:

Los Cambulos	1982 - 1986	5 years	(Established in Jul. 1980)
Abajo Tarabita	1964 - 1987	24 years	(Established in Sept. 1964)
Pte Carretera	1954 - 1970	17 years	(Established in Jul. 1954)

The gauging station which was closest to the location of the intake of the project site is Los Cambulos, 1 km upstream, but it has only 5-year observation records. Furthermore, observations were recorded continuously for 24 years at Abajo Tarabita gauging station, 9 km upstream from the water intake.

The collected discharge records included non-observed dates. Years that observations were completely recorded are as follows:

Los Cambulos	1982 - 1986	5 years	
Abajo Tarabita	1965 - 1987	23 years	
Pte Carretera	1954 - 1963	10 years	} 13 years
	1966 - 1968	3 years	

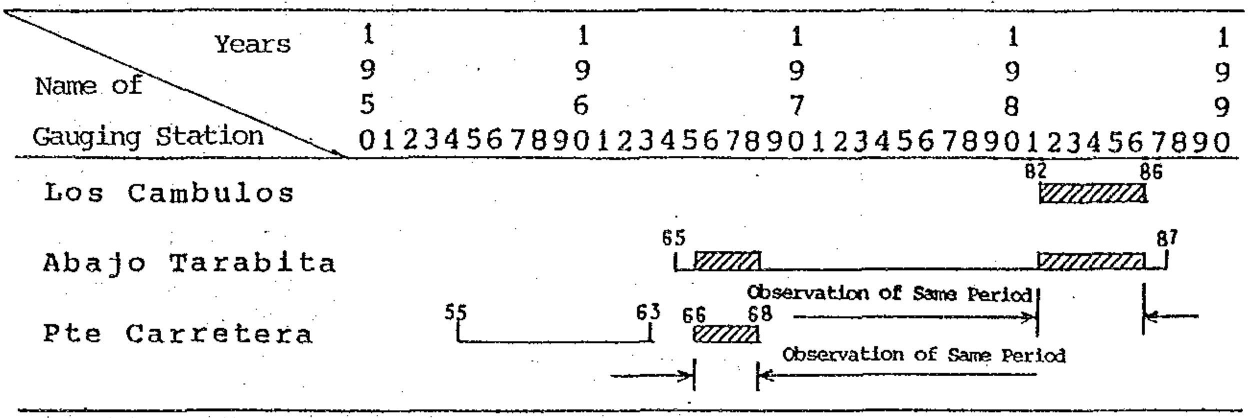
(1) Collation of Catchment Area

Since there are no records of catchment area for Los Cambulos and Pte Carretera, the JICA Study Team measured this from the map on a scale of 1/400,000 issued by IGAC. Since there was a big difference between the recorded values for Abajo Tarabita catchment area according to HIMAT (913 km^2) and CVC (607 km^2) it was decided to use the similarly collated CVC value. Thus, the catchment area for each station, as used in the flow analysis, is as follows:

Gauging Station	Catchment Area
Los Cambulos	851.9 km^2
Abajo Tarabita	607 km^2
Pte Carretera	136 km^2

(2) Collation of Unit Flow Duration Curve per 100 km^2

The observation records for each of the Los Cambulos, Abajo Tarabita and Pte Carretera are as shown on the same time scale diagram below:



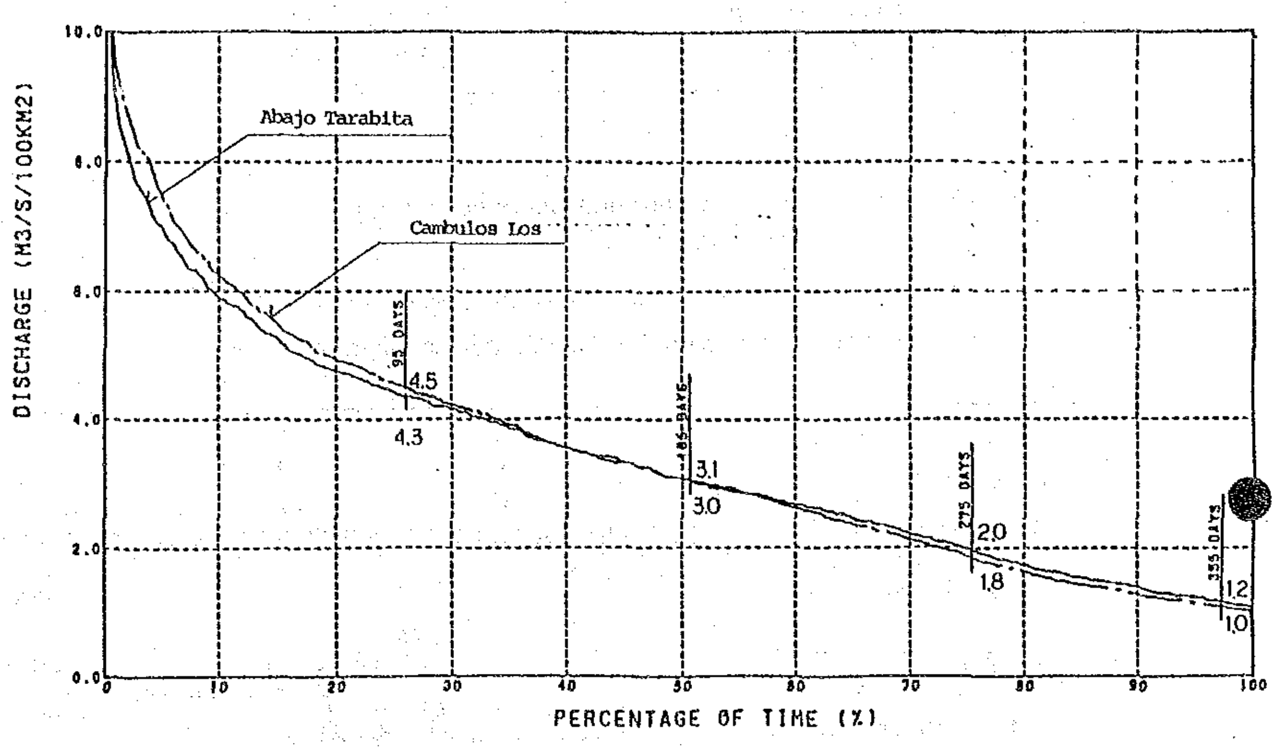
① Los Cambulos and Abajo Tarabita have records for the same five year period 1982-86.

② Abajo Tarabita and Pte Carretera have records for the same three year period 1966-68.

A comparison of observed discharge records for respective gauging stations recorded at the same time, and converted to average unit flow-duration curves, is shown in Fig. 7.3. The discharge pattern for Los Cambulos and Abajo Tarabita is very similar.

(1) Los Cambulos vs. Abajo Tarabita

(Simultaneous observation records during five years from 1982 to 1986)



(2) Abajo Tarabita vs. Pte Carretera

(Simultaneous ovservation records during three years from 1966 to 1968)

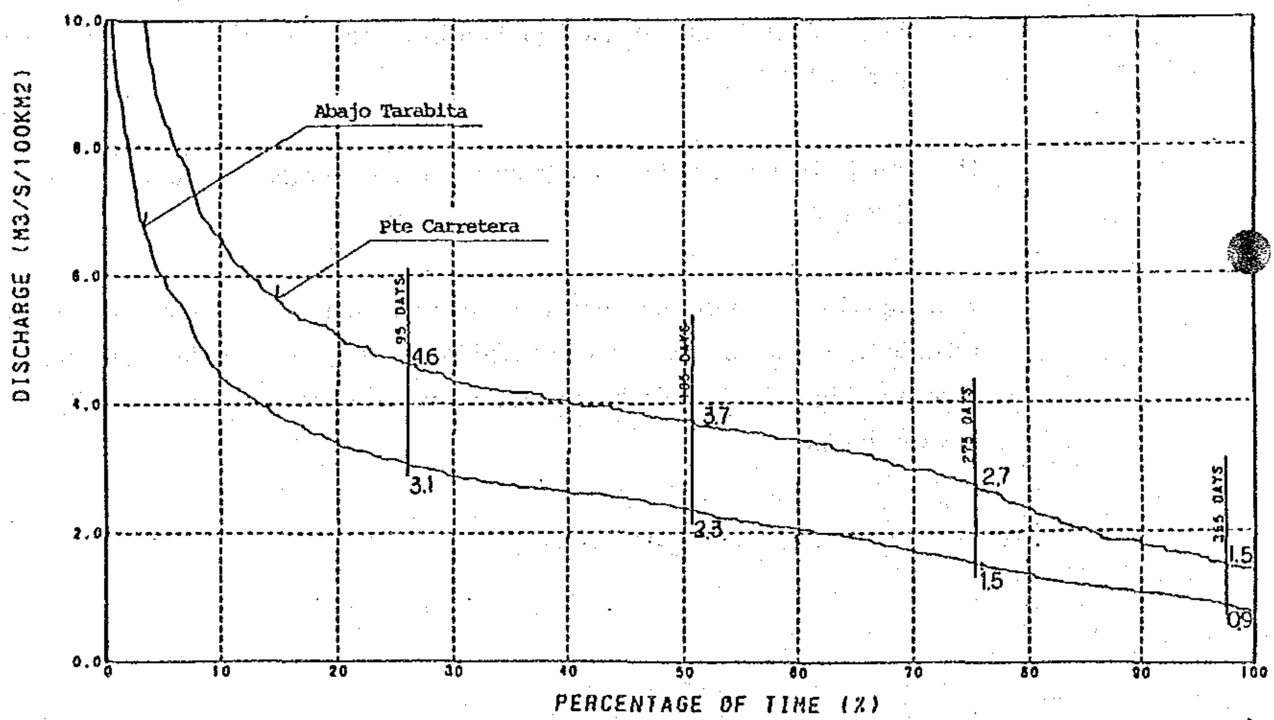


Fig. 7.3 Comparison of Average Unit Flow Duration Curves per 100 km^2

However, although there was only five years of records for Los Cambulos gauging station, which is closest to the intake, it was judged that the records were reliable. It may additionally be noted that if the average unit flow duration curve per 100 km^2 for Abajo Tarabita for 23 years from 1965 to 1987 is compared to Los Cambulos, excluding flood seasons, they are almost similar.

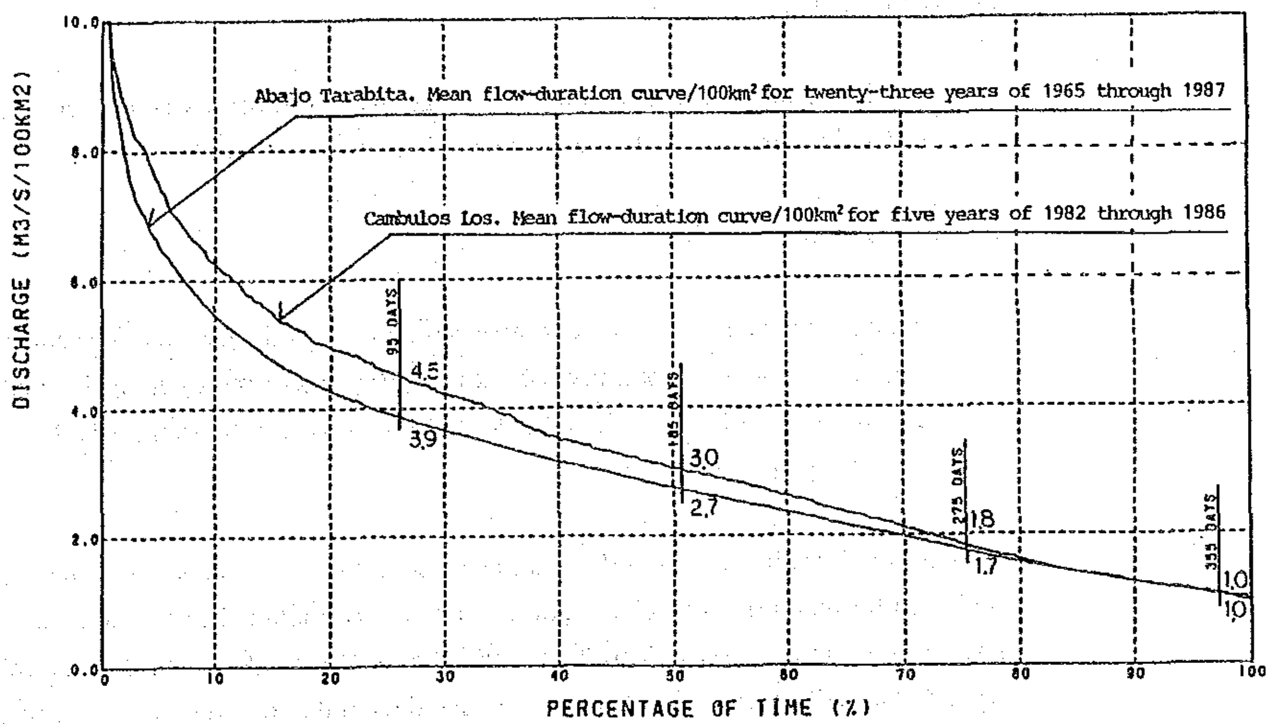


Fig. 7.4 Comparison of Average Unit Flow-duration Curve per 100 km^2

7.2.2 Typical Flow-Duration Curve Form

Year-to-year fluctuations of the river flow-duration curve occur at the same site. In drawing a typical flow-duration curve at a certain site, the following methods are considered:

(a) Parallel Method

Daily average discharge for 365 days is arranged in descending order, the flow-duration curves in each year are drawn and averaged.

(b) Standard year method

Flow-duration curves in each year are drawn. Out of these curves, the flow-duration curve that is deemed to be average is selected, and this curve is used as the flow-duration curve in the standard year.

(c) Series method

This is the method in which daily average discharge for 5 years is arranged in descending order and only the Y axis is corrected as the one-year curve.

(d) Curve insertion method

Average values of 355-day flow, nine-month flow, ordinary water discharge and three-month flow for long periods (at least 10 years or more) are calculated and plotted from a discharge handbook, and the flow-duration curve is drawn by connecting a proper curve.

Typical flow-duration curves at the gauging stations have been drawn using the widely used parallel method. Non-observation years are not included in the preparation of these flow-duration curves. The X axis and Y axis of these flow-duration curves are expressed as daily average discharge (m^3/s) and the number of days (%) respectively.

7.2.3 Typical Flow-duration Curve at Los Cambulos Gauging Station

Discharge data at the Los Cambulos gauging station, located about 1 km upstream from the Ovejas Hydroelectric Power Plant intake site are arranged using 5-year data, as shown in Table 7.1.

In calculating monthly average discharge in Fig. 7.1, the months in which observed data was recorded for less than 10 days are excluded from the calculation. The three-month flow period cannot be distinguished from drought periods in the graphic representation of the monthly average discharge shown in (1) of Drawing OV-H-01.

However, the five months from June to October, and seven months from November to May are designated as the drought periods.

The parallel method typcial flow-duration curves calculated from 1983 to 1986 are shown in (3) of Drawing OV-H-01. Periods of three-month flow, ordinary flow, nine-month flow and 355-day flow in the flow-duration curves are indicated by numerical values, as shown in Table 7.2.

The maximum discharge recorded at Los Cambulos gauging station for six years from 1981 to 1986 is shown in Table 7.3.

Table-7.1 MØNTHLY FLØW TABLE ØF DAILY AVERAGE FLØW AT G.S. SITE

GAUGING ST.: 2602-728 CAMBLØS LØS
RIVER NAME: ØVEJAS

(UNIT: M3/S)

GAUGING YEAR	TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ØCT	NØV	DEC	ANNUAL TØTAL
1982	MAX.	100.9	75.0	78.8	88.9	77.7	46.3	20.1	11.8	14.2	41.4	33.2	37.0	100.9
	MEAN	51.9	42.7	55.2	52.4	50.3	30.2	15.7	9.7	9.6	17.5	23.0	30.4	32.4
	MIN.	29.8	27.4	44.2	44.2	41.6	20.1	11.8	8.2	7.8	8.9	15.9	20.1	7.8
1983	MAX.	35.2	100.9	86.0	82.6	57.0	42.2	17.3	10.6	8.7	17.7	21.3	53.6	100.9
	MEAN	24.1	35.4	32.5	59.2	39.3	25.7	13.2	9.2	7.8	9.3	11.5	22.9	24.2
	MIN.	16.5	17.7	18.6	32.5	29.2	16.9	10.6	8.2	6.9	6.5	8.5	11.2	6.5
1984	MAX.	59.6	51.3	60.4	78.4	81.6	70.7	38.1	23.9	31.1	75.7	93.0	58.0	93.0
	MEAN	39.1	38.6	35.4	43.2	63.6	40.4	21.6	14.9	17.6	31.5	52.1	41.2	38.6
	MIN.	27.4	27.9	26.2	30.4	47.7	25.0	15.6	12.1	11.5	16.5	30.1	31.1	11.5
1985	MAX.	100.0	57.0	51.1	67.3	57.9	46.3	16.9	16.1	16.1	52.0	70.7	54.4	100.0
	MEAN	57.4	33.5	23.0	29.1	36.4	23.4	13.4	11.6	10.2	18.0	35.6	26.9	26.6
	MIN.	29.8	21.9	18.2	19.4	26.2	16.1	12.1	8.9	8.9	10.1	17.3	19.4	8.9
1986	MAX.	72.4	91.2	69.4	46.5	38.9	23.5	17.9	11.2	19.4	44.6	51.1	40.6	91.2
	MEAN	38.7	46.5	53.6	33.0	27.4	18.9	13.0	9.2	9.3	22.9	30.4	23.2	27.2
	MIN.	21.4	28.0	33.9	16.4	19.9	16.1	10.3	7.9	7.1	9.8	21.4	16.9	7.1
TØTAL	MAX.	100.9	100.9	86.0	86.9	81.6	70.7	38.1	23.9	31.1	75.7	93.0	58.0	100.9
	MEAN	42.2	39.3	39.9	43.4	43.4	27.7	15.4	11.0	10.9	19.8	30.5	28.9	29.4
	MIN.	16.5	17.7	18.2	16.4	19.9	16.1	10.3	7.9	6.9	6.5	8.5	11.2	6.5

Table-7.2 FLOW DURATION TABLE AT GAUGING STATION SITE

GAUGING ST.: 2602-728 CAMBLOS LOS
RIVER NAME: OVEJAS

(UNIT: M3/S)

GAUGING YEAR	MAX. (1ST DAY)	PLENTY (95 DAY)	ORDINARY (185 DAY)	LOW (275 DAY)	DROUGHTY (355 DAY)	MIN. (LAST DAY)	MEAN
1982	100.9	46.6	29.8	14.4	8.2	7.8	32.3
1983	100.9	31.8	19.0	10.1	6.9	6.5	24.1
1984	93.0	46.0	34.5	23.9	12.8	11.5	36.6
1985	100.0	33.2	21.9	13.5	9.2	8.9	26.5
1986	91.2	33.9	23.4	15.2	7.6	7.1	27.1
MEAN	97.2	38.3	25.7	15.4	8.9	8.4	29.3

Table-7.3 MONTHLY ABSOLUTE MAXIMUM FLOW TABLE AT G.S. SITE

GAUGING ST.: 2602728 CAMBULOS
RIVER NAME: OVEJAS

(UNIT: M3/S)

GAUGING YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL
1982	244.8	216.1	133.2	144.2	155.3	75.0	26.5	11.8	31.8	41.4	68.6	77.1	244.8
1983	86.0	186.9	154.8	146.1	99.0	68.2	19.9	11.8	10.4	31.8	21.9	121.7	186.9
1984	134.5	120.0	90.5	142.3	132.5	84.3	63.0	54.4	64.7	233.3	226.8	76.7	233.3
1985	138.4	60.4	101.8	86.9	119.6	81.8	30.4	28.6	41.4	80.1	111.6	94.3	138.4
1986	111.6	187.2	100.6	84.1	80.1	40.0	19.3	24.9	44.6	69.9	81.8	71.6	187.2
TOTAL	244.8	216.1	154.8	146.1	155.3	84.3	63.0	54.4	64.7	233.3	226.8	121.7	244.8

7.2.4 Discharge and Flow-Duration Curves at the Intake Site

Since numerical values for the catchment area size are not officially approved the value 853.8 km^2, recorded by the project team, is adopted. Thus the ratio of catchment areas between Ovejas P/P's intake site and Los Cambulos gauging station is set to 853.8/851.9 = 1.002.

Discharge and flow-duration curves at the intake site, adjusted according to catchment area ratio, are shown in Drawing OV-H-01, and representative values of monthly and daily average discharge and of three-month flow, ordinary flow, nine-month flow, ordinary flow, nine-month flow and 355-day flow are indicated in Table 7.4.

1) Monthly average discharge

Item	Month												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Max. average discharge (m^3/s)	57.5	46.6	55.3	59.3	63.7	40.5	21.6	14.9	17.6	31.6	52.2	41.3	36.7
Daily average discharge (m^3/s)	42.2	39.4	40.0	43.5	43.5	27.8	15.4	11.0	11.0	19.8	30.6	29.0	29.5
Min. average discharge (m^3/s)	24.1	33.6	23.0	29.2	27.5	18.9	13.0	9.2	7.8	9.3	11.5	22.9	24.2

2) Typical discharge of flow-duration curve

Three-month flow (95-day flow)	Ordinary water discharge (185-day flow)	Nine-month flow (275-day flow)	355-day flow
38.4 m^3/s	25.8 m^3/s	15.5 m^3/s	9.0 m^3/s

River utilization factor of a certain available discharge to typical flow-duration curves at the intake site (a ratio of total available discharge and total river discharge flowing into the intake site) and facility utilization factor (a ratio of total discharge for which water can be taken in to the available discharge throughout the year and total water amount in the event that available discharge is secured throughout the year are represented graphically in (5) of Drawing OV-H-01.

7.3 Flood Runoff Analysis

The flood discharge is an important factor in the maintenance of existing facilities and repaired sections. The design flood discharge is obtained from the observation records of the discharge at Los Cambulos and Abajo Tarabita gauging stations. The former, which is close to the planned area, has only six years of records, while the latter, which is further upstream, has records for 22 years. In this analysis the data from Abajo Tarabita is statistically processed and is then adjusted using the catchment area ratio.

Table 7.5 Annual Flood Discharge (Ovejas)

Year of Observation	Maximum Yearly Discharge (m^3/sec)	Year of Observation	Maximum Yearly Discharge (m^3/sec)
1964	115.4	1976	135.9
1965	99.3	1977	64.6
1966	122.2	1978	90.5
1967	108.1	1979	99.1
1968	83.5	1980	101.4
1969	145.2	1981	67.8
1970	100.1	1982	103.7
1971	144.5	1983	-
1972	134.0	1984	129.7
1973	87.8	1985	86.8
1974	148.9	1986	125.5
1975	135.9		

22 years of observation data, a relatively short period for such comparative studies, was available. Several methods are available to obtain flood distribution probability, and in this case three methods are examined:

1. Logarithm normal distribution method (slade method)
2. Order probability method
3. Gumbel method

For the order probability method and Gumbel method, both the Thomas plot and Hazen plot are studied.

Figs. 7.5 and 7.6 show that maximum yearly discharge is plotted on the X-axis and that percentage of excess probability calculated is plotted on the Y-axis by using the extreme probability paper. Table 7.6 shows the probable flood discharge for major years of return period obtained from the probability curve shown in the figure.

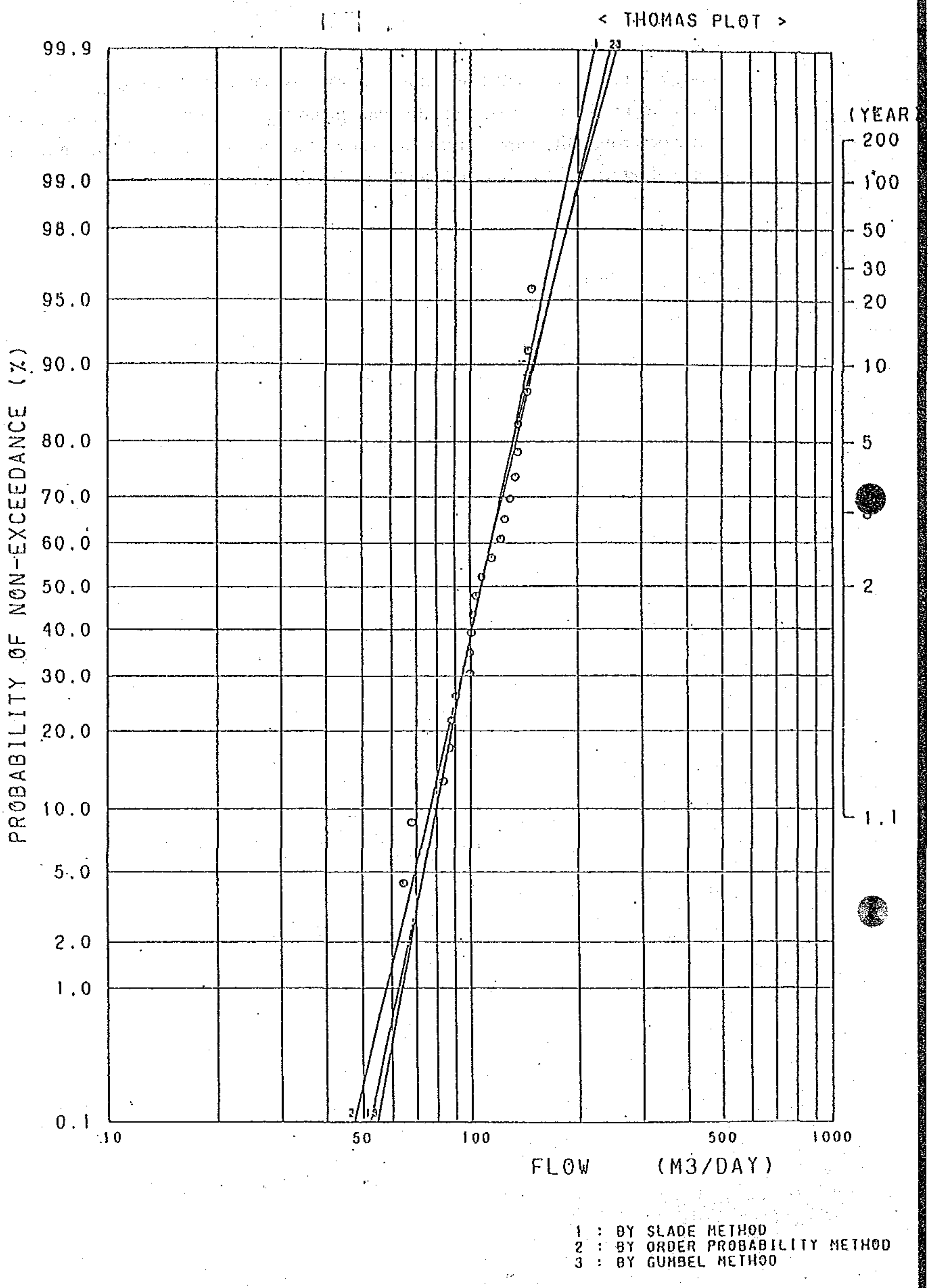


Fig. 7.5 Probability Curve for Rio Ovejas (Thomas Plot)

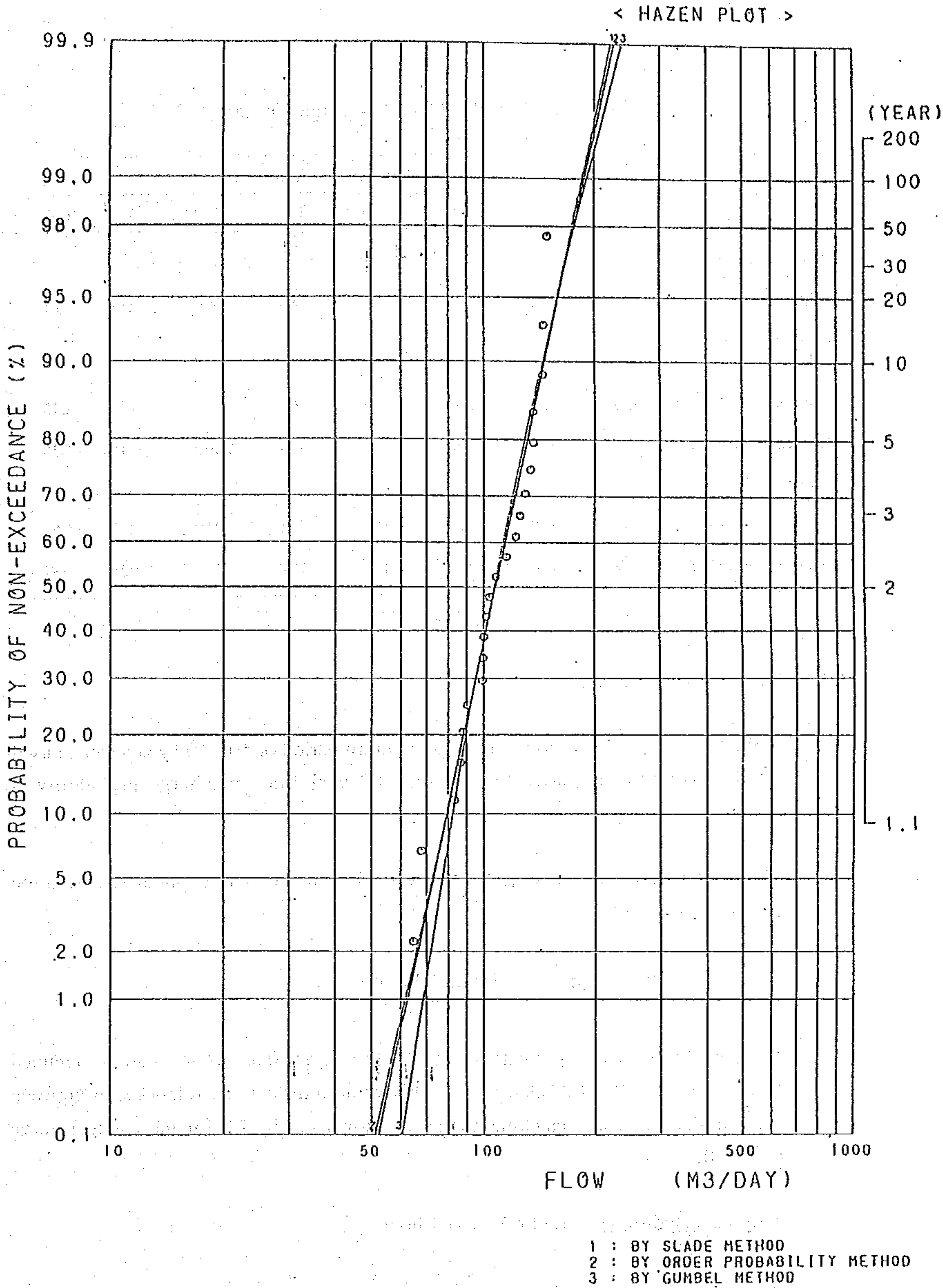


Fig. 7.6 Probability Curve for Rio Ovejas (Hazen Plot)

Table 7.6 Probable Flood Discharge (Ovejas)

Method	Return Period in Years							
	5	10	20	50	100	200	500	1000
Logarithm normal distribution method (m^3/s)	131	145	185	174	185	196	211	221
Order probability method:								
Thomas plot (m^3/s)	135	151	167	186	3200	214	231	245
Hazen plot (m^3/s)	132	146	160	176	188	2300	215	226
Gumbel method:								
Thomas plot (m^3/s)	133	150	166	187	203	219	239	255
Hazen plot (m^3/s)	129	144	159	177	191	205	224	237

7.3.2 Design Flood Discharge

In the case where danger to life is small, a return period of 50 - 100 years can be used for design flood discharge*, where the 100 year flood discharge probability is preferred.

The design flood discharge, Q for the water intake site can be calculated from the catchment area ratio.

$$Q = 165 \times \frac{853.8}{607} = 286 \ldots\ldots 300 \ m^3/s$$

The specific discharge per catchment area (km^2), $q = 0.35 \ m^3/sec$, can be obtained from the design flood discharge, Q. This value indicates the relationship between specific discharge and catchment area, as shown in Fig. 7.7 for the Creager curve $C = 5.0$.

* Applied Hydrology Editor Ven Te Chow

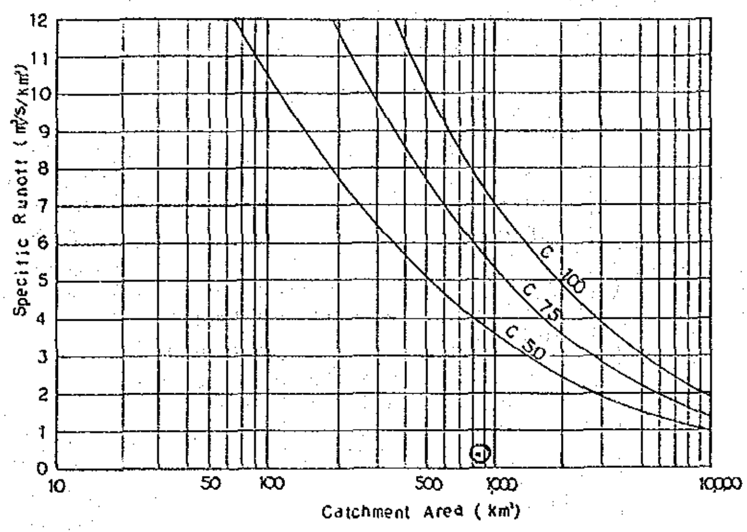


Fig. 7.7 Design Flood Discharge and Creager Curve

7.4 Sediment Analysis

Debris produced from mountainous catchment areas reaches the water intake site, flowing downstream via channel and river. The steps involved in this debris flow are shown in the flow diagram (Fig. 7.8), and from this run-off debris volume can be examined.

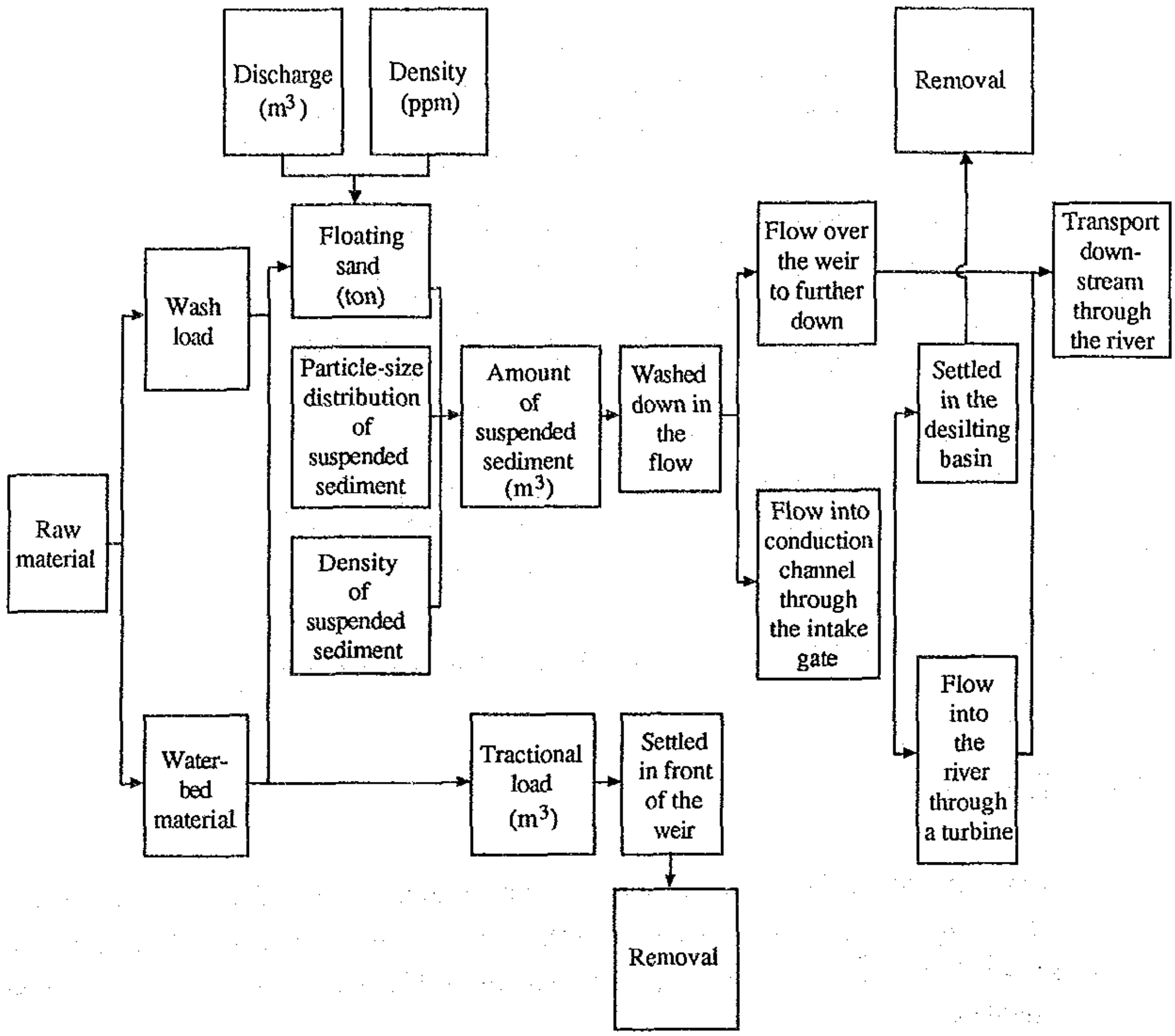


Fig. 7.8 Mechanism of Debris Flow and Calculation Flow of Debris Volume

7.4.1 The Stage of the Run-off Debris

The Rio Ovejas catchment area is formed by relatively steep ravines. Vegetation in the catchment area is abundant. The run-off debris from the upper catchment areas is mainly debris generated by riverbed erosion, riverbank erosion, slope failure and galley erosion etc.

The basic form of the sediment rating curves for Los Cambulos gauging station were used to produce the suspended sediment curves as shown in Fig. 7.9. The sediment volume (ton/year) at the observation station is shown below:

River	Catchment Area (km^2)	River Discharge Rate			Concentration		Suspended Sediment Rate 10^3 tons/year
		Total 10^3 m^3/year	Max. (m^3/s)	Min. (m^3/s)	Max. (ppm)	Min. (ppm)	
Ovejas	851.9	918,200	148.9	3.5	616	9	92

Suspended sediments, which have been transported to the water intake site, amounts to 108 ton/km^2 (classified in relation to catchment area) with the average suspended load concentration in the Rio Ovejas being 100 ppm.

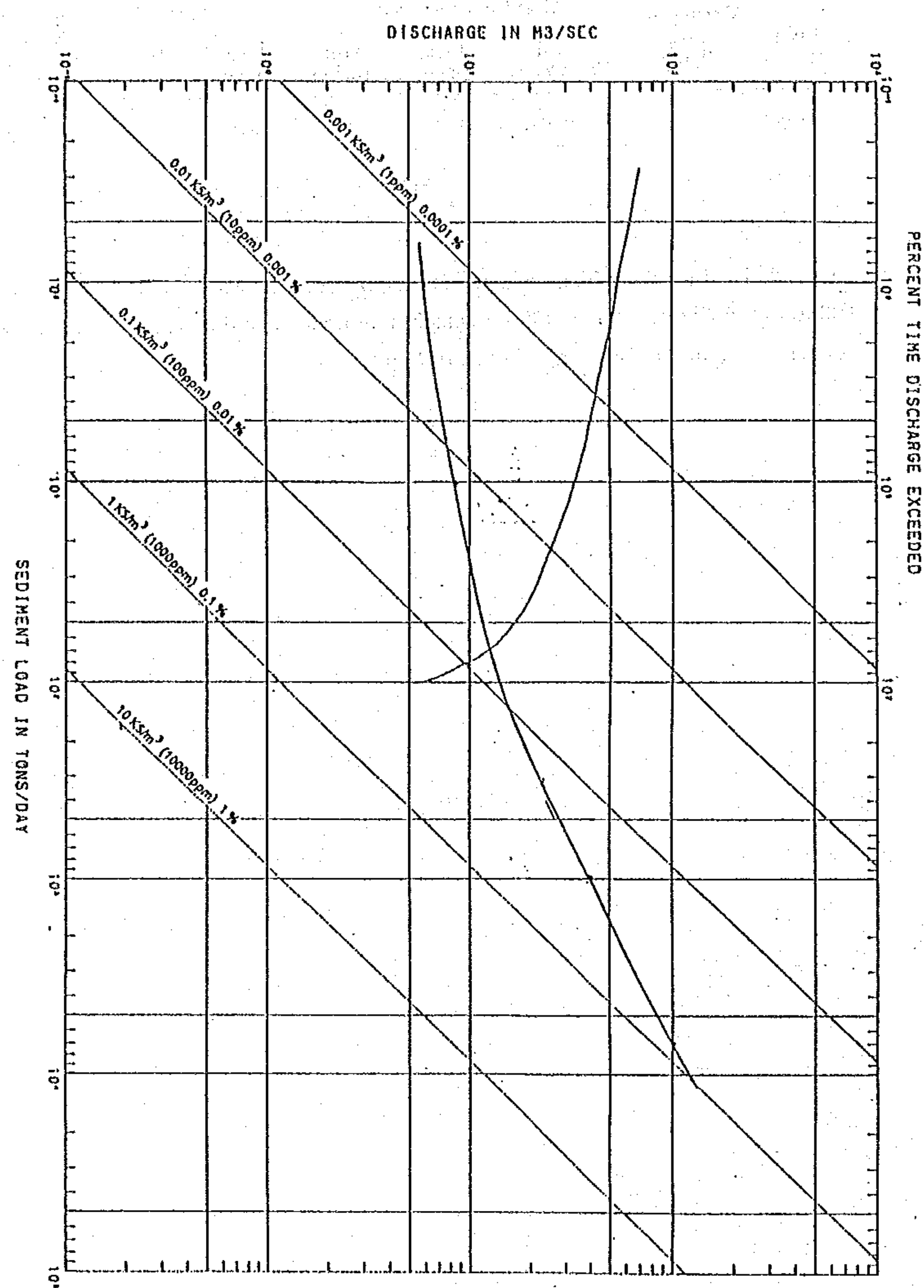


Fig. 7. 9 Sediment Rating Curve

7.4.2 Assumption of Sediment Rate

(1) Major physical properties

(a) Grain size distribution

The grain size distribution of bed load was observed, and its average grain distribution is shown in Fig. 7.10. The grain size constitution is as follows:

Gravel = 70% Sand = 25% Silt = 5%

The JICA Study Team studied the distribution of the suspended sediment and settling sediment but no data was collected. Reference was made to data on reservoir sediment and this grading distribution was assumed, as shown in Fig. 7.11. The composition of the grading was as follows:

Sand = 10% Silt = 60% Clay = 30%

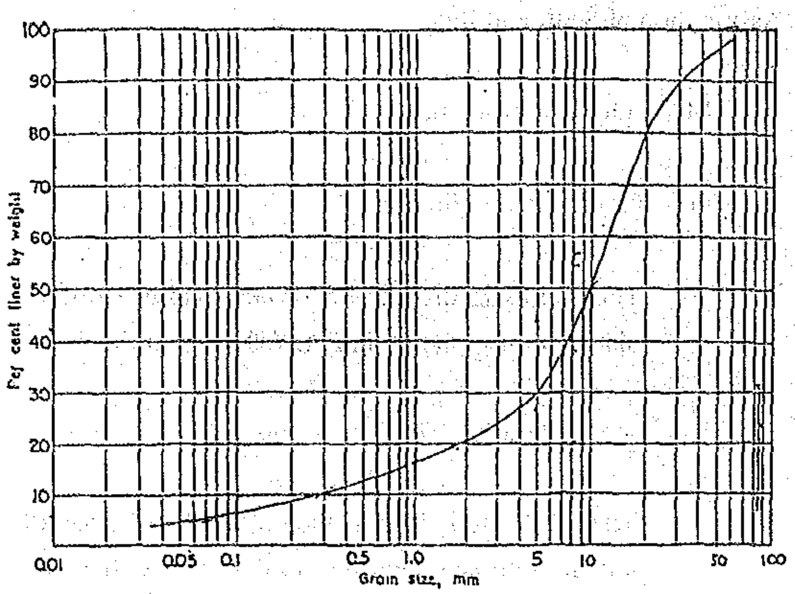


Fig. 7.10 Grain Size of Bed-load

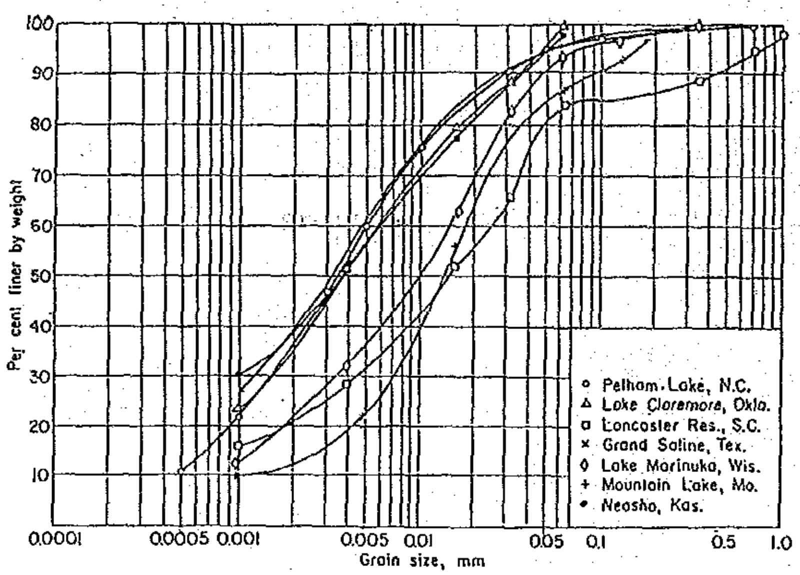


Fig. 7.11 Grain Size Constitution of Suspended Sediment *

* Handbook of Applied Hydrology (17-16)

(b) Unit volume weight

Since data on the sediment unit weight could not be collected, values were decided by referring to the relevant literature. The unit weight of sand and gravel is affected by consolidation loads although consolidation is complete after a relatively short period. However, clay, colloids and other fine grained material require a long period for full consolidation. from previous examples such as grading compositions derived from reservoir sediment under loaded conditions (below and above water surface) a range of unit weights is as shown in Table 7.7.

Table 7.7 Range of Unit Volume Weight*

(units: ton/m^3)

Grain	Almost submerged	Above water
Clay	0.64 - 0.96	0.96 - 1.28
Silt	0.88 - 1.20	1.20 - 1.36
Mix of clay and silt (equal volume)	0.64 - 1.04	1.04 - 1.36
Mix of sand and silt (equal volume)	1.20 - 1.52	1.52 - 1.76
Mix of clay, silt and sand (equal volume)	0.80 - 1.28	1.28 - 1.60
Sand	1.36 - 1.60	1.36 - 1.60
Gravel	1.36 - 2.00	1.36 - 2.00
Sand and gravel	1.52 - 2.08	1.52 - 2.08

* Handbook of Applied Hydrology

(2) Discharge rate of sediment

In studying the volume of run-off sediment at the water intake site, both suspended load and traction load (bed-load) need to be considered. The suspended load can be estimated from the sediment record (concentration measurement) and discharge records.

The traction loads generally account for 10% - 50% of the total sediment rate. In the case of the Colorado River, USA, the traction load accounted for 12% - 50% of the total rate. A study team from the World Bank estimated that at the Tarubera

Dam (Pakistan) on the River Indus the traction load was 5% of the suspended load.

(3) Yearly flowing sediment rate

The sediment flow at the intake per year at the water intake site can be obtained by adjusting the values at the gauging station by the catchment area ratio.

Catchment Area (km^2)	River Discharge Rate (10^6 m^3)	Suspended Sediment Rate (10^3 ton)	Flown Sand Rate (10^3 ton)	Sediment Rate (10^3 ton)
853.8	920	92	8	100

Average grain size of the flowing sediment is calculated from the unit weight by average grain size constitution and each grain diameter as follows.

	Flown Sand			
	Gravel	Sand	Silt	Total
Grain size constitution(%)	70	25	5	100
Unit volume weight (ton/m^3)	1.68	1.48	1.04	
Unit weight per grain size (ton/m^3)	1.176	0.37	0.052	1.598... 1.60

	Suspended Sediment			
	Sand	Silt	Clay	Total
Grain size constitution(%)	10	60	30	100
Unit volume weight (ton/m^3)	1.48	1.04	0.80	
Unit weight per grain size (ton/m^3)	0.148	0.624	0.240	1.01

All of the traction load is deposited at the diversion weir and in front of the water intake point, and does not enter the power station's water channel system.

At or below design discharge ranges suspended load will flow through the water wheel and flowing into the water channels. Coarse grained particles in the suspended load entering the water channels will settle in the settling basins while the remainder of the suspended material, together with discharging water, flows through the water wheel and is flushed back into the river. For river discharge which is above the design discharge suspended load and gravel within the discharge flows over the weir and down the river.

Catchment area (km^2)	River discharge (10^6 (m^3)	Bed-load 10^3 (ton)	Suspended sediment 10^3 (ton)
853.8	920	8	92
		x 10^3 m^3	x 10^3 m^3
		5	91

Design discharge Q m^3/s	Sediment in water channel x 10^3 m^3	Flow down the river x 10^3 m^3
7	23	68
10	32	59
15	45	46

Design discharge Q m^3/s	Settled in the desilting basin (m^3)	Flow down the channel (m^3)
7	2	21
10	3	29
15	4	41

It is assumed from results of the above analysis that annual average sediment in front of the diversion weir will be about 14 m^3/day and sediment settled in the desilting basin will be 8 m^3/day (if available discharge is 10 m^3/s). A counterplan for removal of this sediment will be carefully considered.

7.5 Water Quality Analysis

The acidity, specific resistance etc., which can affect water quality are studied.

7.5.1 Criteria of Judgement

(1) Acidity, etc.

To judge the effects of acidity, reference is made to the standards shown in Table 7.8 and the summarized examples of Table 7.9 .

Table 7.8 Judgement Criteria of Erosion of Water (DIN 4030)

Item	Grade of Erosion		
	Weak Erosion	Strong Erosion	Very Strong Erosion
pH	6.5 - 5.5	5.5 - 4.5	Less than 4.5
CO_2 mg/1	15 - 30	30 - 60	More than 60
NH_4^+ mg/1	15 - 30	30 - 60	More than 60
Mg^{2+} mg/l	100 - 300	300 - 1500	More than 1500
SO_4^{2-} mg/l	200 - 600	600 - 3000	More than 3000

Table 7.9 Damage Example of Concrete in Erosive Environment of Water

Item	Water Characteristics	Damage Status
Groundwater	pH : 2.3 - 6.7	Tunnel concrete Indication of leakage is observed 4 years after construction. Peeling of mortar and cracks in concrete are noted after 7 years.
River water (Azuma River)	pH : 3.1 - 2.7 Mg^{2+}: 13.5 ppm SO^{2-}: 316.8 ppm $C\ell^{-}$: 101.8 ppm	Dipping test concrete specimen (ϕ15cm) When unit cement volume 320 kg/m^3, W/C=35.1% and 3-month old material was placed into the river, the diameter reduced to 14.6 cm after 15 months. About 2 mm of the surface was dissolved, and another 2-3 mm was weakened.

(2) Specific resistance

In water, with a small value of resistivity, much corrosion occurs because there are many types of salt solution included in the water which promote the corrosion of steel. The investigation results from an American standards institute (NBS), as shown in Table 7.10, have clarified understanding of the effects of specific resistivity corrosion damage. However, exceptions are known to exist and judging corrosion effects on the basis of specific resistivity methods alone is not recommended.

Table 7.10 Specific Resistance and Corrosive Nature

Corrosive nature	Degree of acidity		Specific resistance Ω • cm	Maximum hole corrosion depth for 12 years (mm)
	pH	Total acidity		
Weak	7.8	3.0	1770	0.74
	4.5	4.6	11200	1.19
	7.3	2.6	2980	0.99
	5.9	12.8	45000	1.02
Strong	7.6	alkaline	350	3.02
	7.4	"	263	3.48
	9.4	"	278	4.39
	6.8	36.0	800	2.62

7.5.2 Water Quality Evaluation

The results of water quality testing are as follows:

Observation Year	pH	Specific resistance (microohms)	SO4 mg/1	Cl mg/l	CaCO3 (total)	Na	Fe mg/l
1964	-	104 - 56	-	0.3 - 0.05	-	-	-
1965	-	154 - 56	-	0 - 0.05	-	0/3 - 0.08	-
1966	-	80 - 67	-	0.02 - 0.05	-	0.3	-
1969	-	53	0.22	0.30	-	-	-
1970 - 75	-	56	0.31	0.3 - 0.4	-	0 - 0.05	-
1989	7.28 - 6.54	135 - 114	5 - 18	1.5 - 3.5	20		0.65 - 0.15

From the pH value, corrosive nature by acidity is not considered. The nature of specific resistance is low, but the content of chloride is also low. The degree of corrosion is not clear.

CHAPTER 8 GENERATION PLAN

The generation plan is made based on the maximum discharge of 7.0 m^3/s at the existing plant.

For realizing an adequate power plan in respect of technological and economical aspects, the power outputs together with annual output are to be calculated from various maximum discharges using the typical discharge-duration curves at the intake site provided that the facility utilization factor for any of the maximum discharges is not less than 50%.

8.1 Study of the Alternative Plans

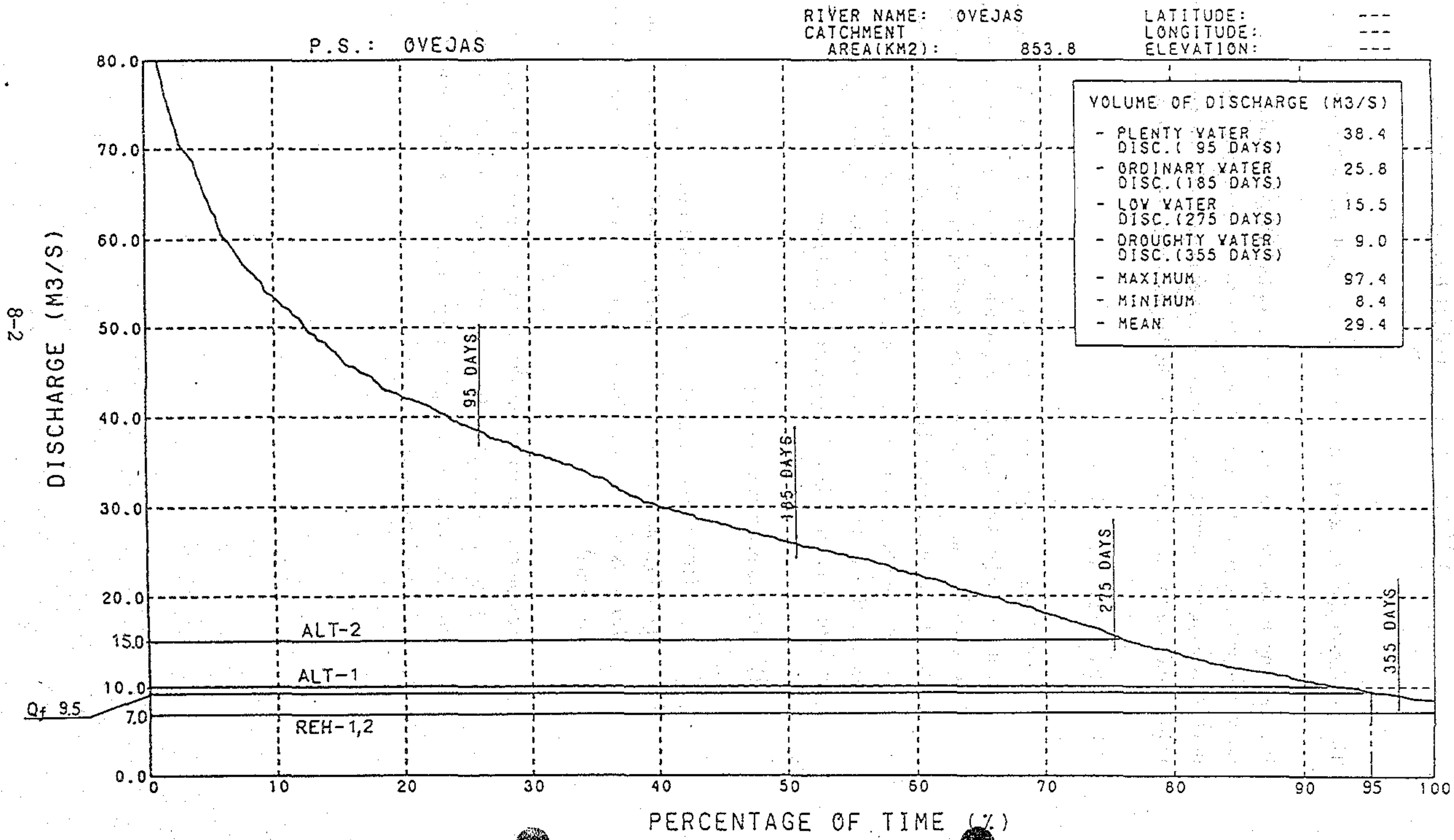
In rehabilitating the power generating facilities at this site, all facilities located from the intake to the head tank must be reconstructed or newly constructed. In addition, a gap between the theoretical power output and the rated output of the existing power generating equipment must be solved. The present water utilization is low in respect of the river discharge, and there is possibility of power output increase. Therefore, comparative studies will be made for the generation-optimizing plan, as well as the rehabilitation plan of the existing generating facilities.

(1) Maximum available discharge

The existing water channels for the planned area are steel pipes. The results of hydrological analyses indicate that the existing steel pipes can discharge up to 7.0 m^3/s and so plans for steel pipes and for concrete culverts have been compared.

To compare the maximum discharge, four rehabilitation plans of $Q = 7.0$ m^3/s (REH-1, REH-2), $Q = 10.0$ m^3/s (ALT-1) and $Q = 15$ m^3/s (ALT-2) were set up. The representative generating output and annual generated power were calculated, as shown in Fig. 8.1.

Fig-8.1 TYPICAL FLOW DURATION CURVE AT INTAKE SITE



(2) Standard net head

Assuming that the net head for determining the turbine output and calculatng annual generated energy is constant, the standard net head calculated under the following standard is used.

The net head (He) is calculated by subtracting the loss of head, obtained from the following formula, using gross head measurements of the water level at the intake and tailrace.

$$He = Hg - \Sigma\Delta H$$
$$\Sigma\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3$$

where:

Hg = total loss of head

1,140.0 m (intake water level) - 1,111.0 m (discharge level)

= 29.0 m

$\Sigma\Delta H$ = total loss of head (m)

ΔH_1 = head loss at the intake (m)

ΔH_2 = head loss at the headrace (m)

ΔH_3 = head loss at the penstock (m)

$$\Delta H_1 = \frac{V^2}{2g} \times (1 + f_1) + \Delta h_1$$

$\frac{V^2}{2g}$ = velocity head (m)

f_1 = coefficient of inflow loss, 0.1

Δh = margin (m)

Table 8.1 Head Loss at the Intake

Plan	Q (m^3/s)	V (m/s)	V/2g (m)	$V^2/2g(1+0.1)$ (m)	Δh_1 (m)	ΔH_1 (m)
REH-1,2	7.0	1.30	0.086	0.095	0.025	0.120
ALT-1	10.0					
ALT-2	15.0					

$\Delta H_2 = i \times L + \Delta h_2$

where i = gradient of the headrace

= 1/1400

L = length of the headrace

= 1230 m

Δh_2 = margin (m)

Head loss is independent of discharge, Q (m^3/s)

ΔH_2 = 1/1400 x 1,230 + 0.02

= 0.90 m

$\Delta H_3 = V^2/2g\ (1 + f_2 + f_3\ L/D + fm) + \Delta h = V^2/2g\ (1.85 + f_3\ L/D) + \Delta h$

where $V^2/2g$ = velocity head (m)

f_2 = coefficient of inflow loss; 0.1

f_3 = coefficient of frictional loss; $124.6\ n^2/D^{1/3}$

L = penstock length (m)

D = penstock diameter (m)

fm = loss coefficient at the branched part; 0.75

Δh = margin (m)

n = coefficient of roughness; 0.012

Table 8.2 Head Loss at the Penstock

Plan	D (m)	L (m)	V (m/s)	$\frac{V^2}{2g}$ (m)	$f_3=\frac{124.6 x n^2 x L}{D^{4/3}}$ n = 0.012	$\frac{V^2}{2g}(f_3+1.85)$ (m)	Δh_3 (m)	ΔH_3 (m)
REH-1	1.6	65.0	3.48	0.618	0.623	1.528	0.5	2.03
ALT-1	2.0	"	3.35	0.573	0.463	1.325	0.5	1.83
ALT-2	2.4	"	3.32	0.561	0.363	1.241	0.5	1.74

Table 8.3 Calculation Result of Effective Head

	Q (m^3/s)	Hg (m)	ΔH_1 (m)	ΔH_2 (m)	ΔH_3 (m)	$\Sigma\Delta H$ (m)	He (m)
REH-1,2	7.0	29.0	0.12	0.90	2.03	3.05	25.95
ALT-1	10.0	29.0			1.83	2.85	26.15
ALT-2	15.0	29.0			1.74	2.76	26.24

He = 26.0 m

8.2 Generated Output

Theoretical output obtained from available discharge (Q) and the standard net head (He) is multiplied by the resultant efficiency coefficient of the equipment, and the generated output is calculated by the following formula.

$$P = 9.8 \times Q \times He \times \eta$$

where:

P = generated output (kW)
Q = arbitrary available discharge (m^3/s)
He = standard net head (m)
η = resultant efficiency of turbine and generator (resultant efficiency of the single unit capacity)
9.8 = constant (acceleration of gravity, m/s^2)

Resultant efficiency (η) is the value representing total efficiency, and this value is obtained by the following formula.

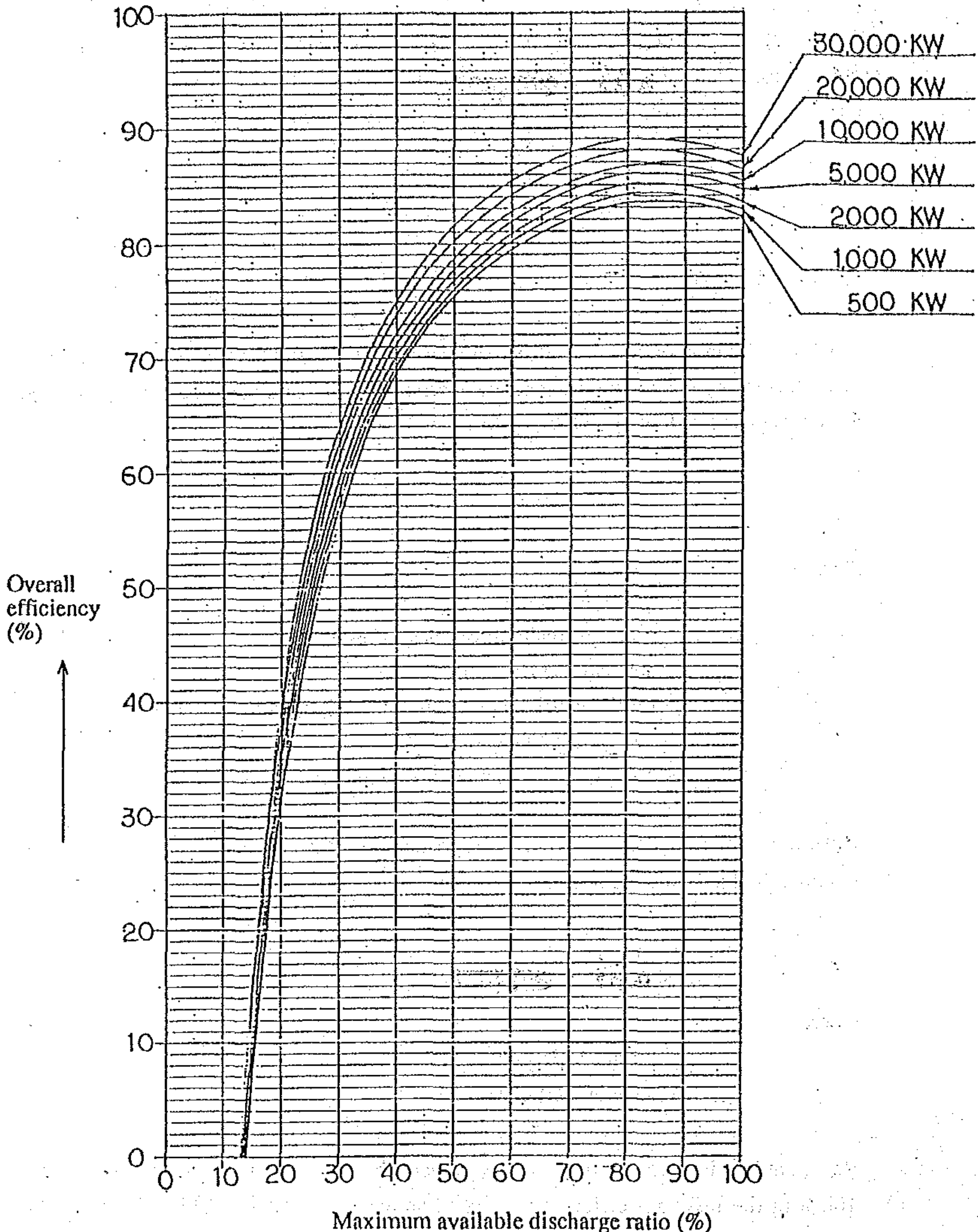
$$\eta = \eta t \times \eta g$$

where:

ηt = turbine efficiency
ηg = generator efficiency

Resultant efficiency corresponds to the value of the maximum available discharge ratio 100% in the resultant efficiency curve as shown in Fig. 8.2. Table 8.3 shows the calculation result of the generated output for the alternative plans.

Fig. 8.2 Resultant Efficiency Curve of Francis Turbine and Generator



(Source: The above curve is drawn according to the study standard for formulation of hydroelectric development plan (March, 1981).

Table 8.3 Calculation of Generated Output

Item / Alternative plan	① Available discharge Q (m^3/s)	② Standard net head H_e(m)	③ 9.8x①x② Theoretical output (kW)	④ Resultant efficiency η	⑤ ③x④ Generated output ρ (kW)
REH-1 Headrace pipeline route plan REH-2 RC culvert plan	7.0	26.0	1,783	-	1,000
ALT-1 RC culvert plan	10.0	26.0	2,548	0.830	2,100
ALT-2 RC culvert plan	15.0	26.0	3,822	0.830	3,100

8.3 Annual Potential Generated Energy

Generated energy is calculated by the following formula.

$$E = P \times t \text{ (kWh)}$$
$$= 9.8 \times Q \times He \times \eta \times t$$

where:

P = generated output (kW)

t = operation time (hour)

Assuming that the power plant operation is not interrupted by accident during the nor suspended for maintenance, inspection and repair purposes during the year, the annual potential generated energy is calculated by the following methods.

(1) Using daily discharge in discharge data plus net head and resultant efficiency at that daily discharge

(2) Combining hydrological regime and resultant efficiency from the flow-duration curve

(3) Using the generating output-to-available discharge ratio

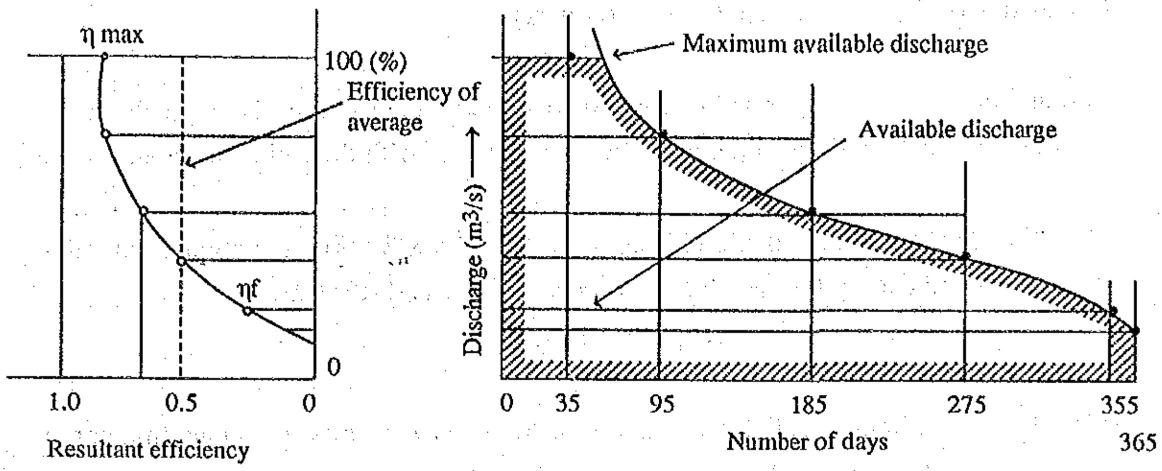
For the calculation of the annual potential generated energy at Ovejas P/P, item (2) as mentioned above is used for the following reasons.

① Instead of recorded observations at the intake site of this power plant, converted data from the Los Cambulos gauging station owned by CVC is used as discharge data.

② Since there are no recorded observations at the Los Cambulos gauging station and the intake site, discharge data is converted according to the catchment area ratio at the above gauging station and intake site.

③ The average generating output-to-available discharge ratio of (3) and flow-duration curve are used for the calculation. However, this method is not as accurate as method (2).

By combining the resultant efficiency and flow duration, taken from the flow duration curve, a rough estimate of annual potential generated energy can be made. The flow duration-efficiency method of calculation is shown below.



Max. available discharge = m³/s Net head = m

① Day	② Number of days	③ Available discharge (m^3/s)	④ Burden ratio Available discharge / Max. available discharge	⑤ Resultant efficiency η	⑥ Generating power (kW)	⑦ Average power (kW)	⑧ Generated energy (kWh)
Max.							
95	95-						
185	185-95 = 90						
275	275-185 = 90						
355	355-275 =80						
365	365-355 = 10						
Total	365					( )	

① Possible intake-water days of maximum available discharge are inserted for the day order ①.
② Represents the difference of the day order of calculation stage and right above stage. This example employed hydrological regime representative days as a matter of convenience.
③ The discharge of the day order topped out by maximum available discharge shall be an available discharge.
④ Available discharge divided by maximum available discharge shall be input load factor, and the resultant efficiency ⑤ shall be read and entered.
⑥ 9.8 x Q x He x η
⑦ Mean value of generated output of calculation stage and right above stage.
⑧ ⑦ x ② x 24 is the generated energy for calculated days, and the total value becomes yearly possible generated energy.

Fig. 8.3 Calculation of Annual Potential Generated Energy According to the Hydrological Regime-Efficiency Method

8.3.1 Calculation of Annual Potential Generated Energy

The annual potential generated energy for respective alternative plans is calculated according to the hydrological regime-efficiency method, with the following results.

(1) For a maximum available discharge of 3.5 m^3/s x 2 units, the annual potential generated energy for the rehbilitation plan REH-1 and REH-2 are

9.1 GWh (100%)

(2) For a maximum available discharge of 5.0 m^3/s x 2 units, the annual potential generated energy for the alternative plan ALT-1 is

18.4 GWh (99.5%)

(3) For a maximum available discharge of 7.5 m^3/s x 2 units, the annual potential generated energy for the alternative plan ALT-2 is

26.2 GWh (94.0%)

Table 8.4 Calculation of Annual Potential Generated Energy

(1) Rehabilitation plan of existing facilities (REH-1 and REH-2)

Max. available discharge Q = 3.5 m^3/s x 2 units
Standard net head He = 26.0m
Turbine type: Francis turbine

Unit No.	① Day	② Number of days	③ Available discharge (m3/s)	④ Burden ratio Available discharge / Max. available-discharge	⑤ Resultant efficiency η	6 Generating power (kW)	⑦ Average power (kW)	⑧ Generated energy (MWh)	Remarks
No. 1	365	365	3.5	1.0	0.830	739	739	6,474	New
No. 2	365	365	3.5	1.0	0.840	300	300	2,628	Existing
Total	-	-	7.0	1.0	-	1,039	1,039	9,102	-

(2) Alternative plan 1 (ALT-1)

Max. available discharge: Q = 5.0 m^3/s x 2 units
Standard net head He: 26.0 m
Turbine type: Francis turbine

Day	Number of days	Available discharge (m^3/s)	Burden ratio $\frac{\text{Available discharge}}{\text{Max. available discharge}}$	Resultant efficiency η	Generating power (kW)	Average power (kW)	Generated energy (MWh)
Max.	338	10.0	1.0	0.83	2114	2114	17,148
340	2	9.9	0.99	0.832	2098	2106	101
345	5	9.6	0.96	0.836	2044	2071	248
350	5	9.3	0.93	0.839	1988	2016	241
355	5	9.0	0.90	0.84	1926	1957	234
360	5	8.6	0.86	0.843	1847	1886	226
365	5	8.4	0.84	0.843	1804	1925	219
Total	365	-	-	-	-	(1996)	18,417

(3) Alternative plan 2 (ALT-2)

Max. available discharge: Q = 7.5 m^3/s x 2 units
Standard net head He: 26.0 m
Turbine type: Francis turbine

Day	Number of days	Available discharge (m^3/s)	Burden ratio $\frac{\text{Available discharge}}{\text{Max. available discharge}}$	Resultant efficiency η	Generating power (kW)	Average power (kW)	Generated energy (MWh)
Max.	278	15.0	1.0	0.83	3172	3162	21,163
280	2	14.9	0.993	0.832	3158	3165	151
295	5	14.4	0.960	0.836	3067	3112	373
290	5	14.1	0.940	0.838	3010	3038	364
295	5	13.2	0.880	0.842	2831	2920	350
300	5	12.9	0.860	0.843	2770	2800	336
305	5	12.4	0.826	0.842	2660	2715	325
310	5	12.0	0.800	0.841	2571	2615	313
315	5	11.6	0.773	0.839	2479	2525	303
320	5	11.4	0.76	0.837	2431	2455	294
325	5	10.9	0.726	0.832	2310	.2370	284
330	5	10.6	0.706	0.830	2241	2275	273
335	5	10.2	0.68	0.824	2141	2191	262
340	5	9.9	0.66	0.819	2065	2103	252
345	5	9.6	0.64	0.814	2028	2028	243
350	5	9.3	0.62	0.808	1919	1852	234
355	5	9.0	0.600	0.802	1839	1876	225
360	5	8.6	0.573	0.792	1735	1786	214
365	5	8.4	0.560	0.788	1686	1710	205
Total	5	-	-	-	-	(2463)	26,164

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 published by ISA (Interconexion Electrica SA) in June, 1987.

9.1 Formulation of Rehabilitation Plans

As stated in 4.3, it is necessary to newly construct the intake facilities, the desilting basin and the waterways, and to alter the head tank. The existing penstocks and generating equipment will be utilized, but a new transformer should be procured and replaced with the existing one.

The rehabilitation plan for this plant focusses on the following:

- a gap between the theoretical output and the rated output will be resolved,

- the current low water utilization will be improved to an adequate level. Following three cases of different maximum discharges, shown on Table 9.1, will be examined as comparative alternatives in this rehabilitation plan.

$Q = 7.00\ m^3/s$
$Q = 10.00\ m^3/s$
$Q = 15.00\ m^3/s$

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 for Ovejas Power Plant

Item	Alternative			
	Steel Pipes	Concrete culvert		
	REH-1	REH-2	ALT-1	ALT-2
Discharge, Q (m^3/s)	7.0	7.0	10.0	15.0
Maximum output, P (kW)	1,000	1,000	2,100	3,100
Facility utilization factor (%)	100	100	99.5	94.0
Rehabilitation and improvement plan:				
Diversion weir	To be altered because the damage is severe, and sandstrap will be constructed (common to all alternatives			
Intake	To be reconstructed corresponding to the alteration of the diversion weir and the design discharge			
Desilting basin	To be newly constructed corresponding to the design discharge (currently not existing)			
Conduction channel	Its adequate cross section will be determined and the channels will be newly constructed			
Head tank	To be expanded at its present position			
Penstocks	Existing penstock and additional new one		New penstock will be installed	
Generating equipment	The existing equipment and additional new one		New, two-unit system	
Powerhouse building	A new building will be constructed on the downstream side to accomodate new generating equipment			

9.2 Estimated Rehabilitation Construction Costs

The construction costs can be divided into the estimate for generating equipment and the civil construction cost and calculated. This can then be divided into foreign currency and local currency apportionments 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 cost of generating equipment are calculated based on the FOB from Japan. The generating equipment specifications and FOB costs are as shown in Table 9.2.

The CIF/FOB ratio for CIF costs is 1.12, as shown in Table 9.3.

Table 9.2 Generating Equipment Specifications and FOB Costs

Item	Alternative			
	REH-1	REH-2	ALT-1	ALT-2
1. Specifications				
Design discharge (m^3/s)	3.5	3.5	5.0	7.5
Net head (m)	26.0	26.0	26.0	26.0
Theoretical output (kW)	891	981	1,274	1,911
Turbine type	H.F.*	H.F.*	H.F.*	H.F.*
Turbine output (kW)	780	780	1,120	1,670
Generator power factor	0.9	0.9	0.9	0.9
Generator output (kVA)	830	830	1,200	1,800
Main transformer capacity (kVA)	830	830	2,400	3,600
2. FOB costs (US$1,000)				
Generating equipment				
(1) Turbine etc.	376.4	376.4	443.55	546.45
(2) Generator etc.	212.9	212.9	242.85	285.7
(3) = (1)+(2) Sub-total:	589.3	589.3	686.4	832.15
(4) Number of units	1	1	2	2
(5) = (3)x(4) Subtotal:	589.3	589.3	1,372.8	1,664.3
(6) 4.16 kV switchgear etc.	61.4	61.4	97.9	97.9
(7) Transformer and switchgear	59.3	59.3	69.3	85.7
(8) = (5)+(6)+(7) Total:	710	710	1,540	1,847.9

*H.F.: Horizontal Francis

Table 9.3 Implementation Cost of Generating Equipment

(units: US$1,000)

Item		Alternative							
		REH-1		REH-2		ALT-1		ALT-2	
		A	B	A	B	A	B	A	B
1) FOB cost		710	-	710	-	1,540	-	1,847.9	-
2) Transportation costs, insurance									
	1) x 0.12	85.2	-	85.2	-	184.8	-	221.7	-
3) Tax	1) x 0.223	-	158.3	-	158.3	-	343.4	-	412.1
4) Value-added tax	1) x 0.134	-	95.1	-	95.1	-	206.4	-	247.6
5) Others	1) x 0.22	-	156.2	-	156.2	-	338.8	-	406.5
6) Subtotal		795.2	409.6	795.2	409.6	1,724.8	888.6	2,069.6	1,066.2
7) Contingency	1) x 0.17	120.7	-	120.7	-	261.8	-	314.1	-
8) Eng. Fee	1) x 0.149	105.8	-	105.8	-	229.5	-	275.3	-
9) Total	6) + 7) + 8)	1,021.7	409.6	1,021.7	409.6	2,216.1	888.6	2,659	1,066.2
10) Grand Total		1,431.3		1,431.3		3,104.7		3,725.2	

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

9.2.2 Estimation of Civil Construction Cost

The work volume for the main structures rehabilitation or improvement were multiplied by the unit costs (refer to Table 5.2) as decided by CEDELCA and the civil construction costs are calculated in the local currency base.

The totals for each rehabilitation plan are calculated and the civil construction costs are compared as shown in Table 9.4.

Table 9.4 Estimation of Civil and Building Construction Costs

(unit: 10^6 pesos)

Item	Alternative			
	Steel pipes	Concrete culvert		
	REH-1	REH-2	ALT-1	ALT-2
Diversion weir and intake construction	101.8	101.8	118.6	157.2
Desilting basin construction	76.7	76.7	96.8	134.9
Conduction channel construction	896.5	242.8	271.7	319.8
Head tank construction	104.9	104.9	136.8	169.6
Penstock construction	6.0	6.0	63.2	84.8
Foundation of equipment construction	26.5	26.5	66.6	78.4
Powerhouse building construction	15.7	15.7	30.2	30.2
Temporary facilities construction	271.7	271.7	271.7	271.7
Other construction	0	0	3.4	3.4
① Subtotal	1,499.8	846.1	1,059.0	1,250.0
② Contingency (① x 0.15)	225.0	126.9	158.8	187.5
③ Engineering fees ((① + ②) x 0.10)	172.5	97.3	121.8	143.8
④ Total (① + ② + ③)	1,897.3	1,070.3	1,339.6	1,581.3
⑤ Output Loss	0	0	10.5	10.5
⑥ Grand Total ④ + ⑤	1,897.3	1,070.3	1,350.1	1,591.8

9.3 Comparison of Economic Indices

From a comparison of the two economic indices, of the construction cost per kW and the generating cost per kW, the basic conditions common to all alternative plans are as follows:

(1) Exchange rate for September, 1989, is adopted as follows.

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

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

(3) The interest rate is divided between 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 four years) with a 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 one year) with a repayment of the principal in equal annual amounts over 8 years.

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

9.3.1 Comparison of Construction Cost per kW

A comparison of the construction cost per kW is shown in Table 9.5. ALT-2 plan is US$ 3,300/kW per increase in power output and this is lowest costs.

Table 9.5 Comparison of Construction Costs per kW

Item		Alternative			
		REH-1	REH-2	ALT-1	ALT-2
Existing equipment output (kW)					
Rated output	Po	900	900	900	900
Available output	Pe	650	650	650	650
Post-rehabilitation output	P_1 (kW)	1,000	1,000	2,100	3,100
Recovered/increased output $\Delta P = p_1 - Pe$ (kW)		350	350	1,450	2,450
Rehabilitation work cost (US$1,000)					
Foreign currency portion Cf		1,000	1,000	2,200	2,650
Local currency portion Cl		5,550	3,300	4,550	5,350
Total C = Cf + Cl		6,550	4,300	6,750	8,000
Construction cost per kW (US$/kW)					
C/P_1		6,500	4,300	3,200	2,600
$C/\Delta P$		18,800	12,400	4,700	3,300

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 Fig. 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.

The results of calculation of generating costs per kWh are as shown in Table 9.6. The generating cost of power supplied per year is 29 mills/kWh according to ALT-2 and the respective lowest costs are as shown.

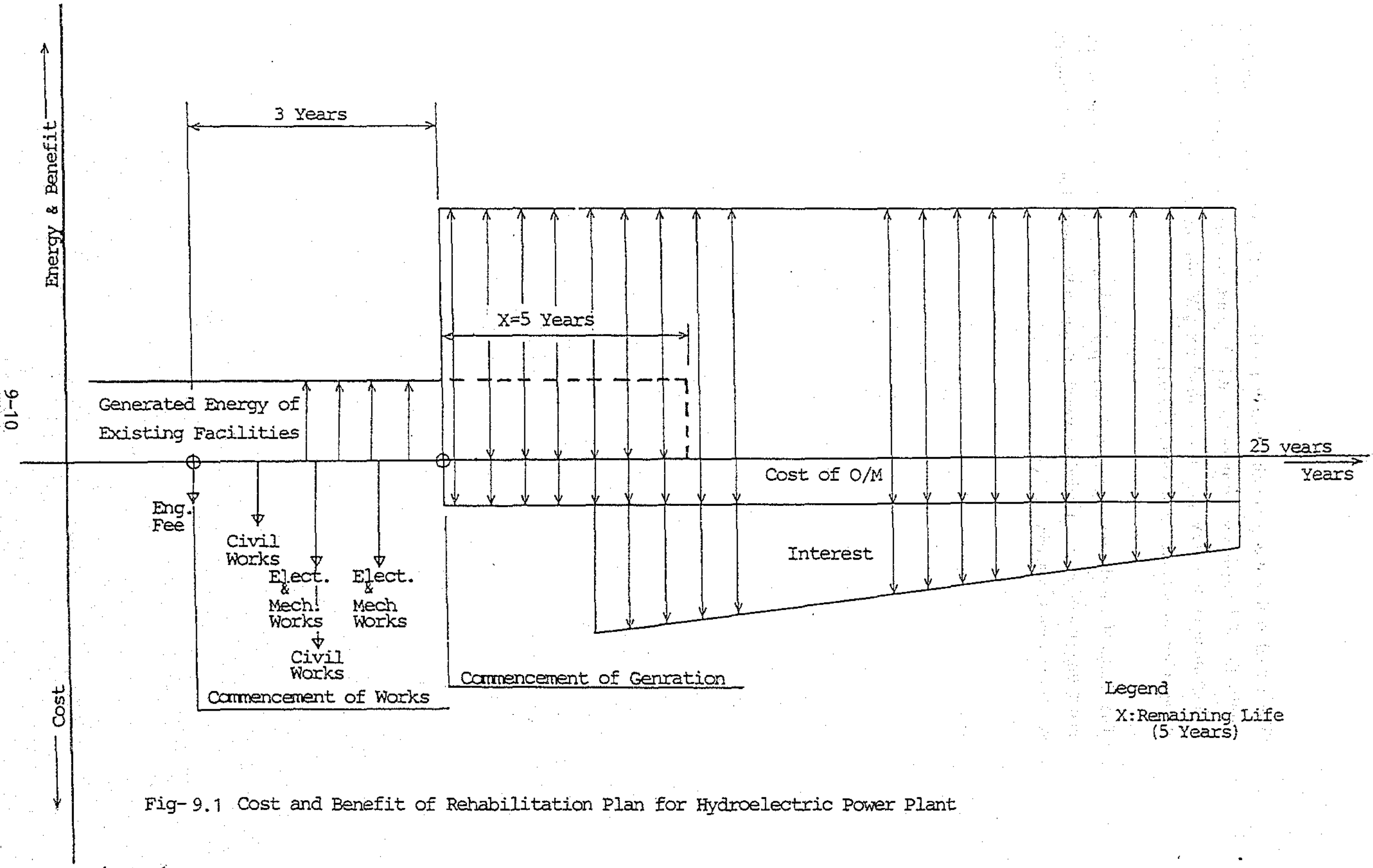


Fig- 9.1 Cost and Benefit of Rehabilitation Plan for Hydroelectric Power Plant

Table 9.6 Comparison of Generating Cost per kWh

Item		Alternative			
		REH-1	REH-2	ALT-1	ALT-2
Existing equipment capacity:					
Power output	Pe (kW)	650	650	650	650
Energy	Ee (GWh)	2.97	2.97	2.97	2.97
Rehabilitation plan:					
Power output	P_1 (kW)	1,000	1,000	2,100	3,100
Total (Ef + Es)	E_1 (GWh)	9.1	9.1	18.4	26.2
Recovered/increased power					
Output	$\Delta P = P_1 - Pe$ (kW)	350	350	1,450	2,450
Energy	$\Delta E = E_1 - Ee$ (GWh)	6.1	6.1	15.4	23.2
Total of expenses at generating terminal: (US$1,000)					
Construction work cost					
Foreign currency portion Cf_1		1,000	1,000	2,200	2,650
Local currency portion $C\ell_1$		5,550	3,300	4,550	5,350
Construction cost total $C_1 = Cf_1 + C\ell_1$		6,550	4,300	6,750	8,000
Interest payment C_2					
Foreign currency portion Cf_2		1,610	1,610	3,542	4,266.5
Local currency portion $C\ell_2$		5,588	3,352.8	4,622.8	5,435.6
Total $C_2 = Cf_2 + C\ell_2$		7,198	4,962.8	8,164.8	9,702.1
AOM C_3 = US$4 x Pl x 25 years		100	100	210	310
Total $\Sigma Ci = C_1 + C_2 + C_3$		13,848	9,362.8	15,124.8	18,012.1
Average annual cost $C = \Sigma Ci/25$		554	375	605	720
Generating cost per annually supplied energy (mills/kWh)					
Per E_1	$C/(E_1 \times 0.95)$	65	44	35	29
Per ΔE	$C/(\Delta E \times 0.95)$	96	65	41	33

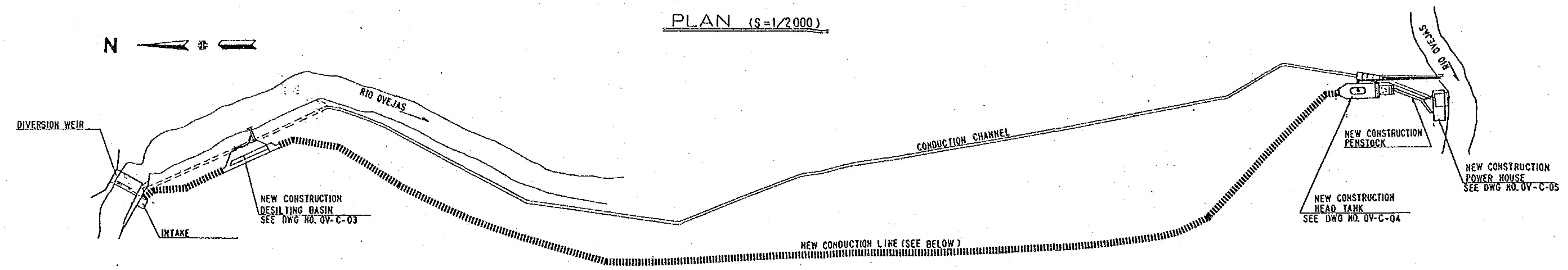
9.3.3 Overall Evaluation

ALT-2 is selected as the optimum plan since it has the lowest construction cost per kW and generating costs per kWh amongst the alternatives.

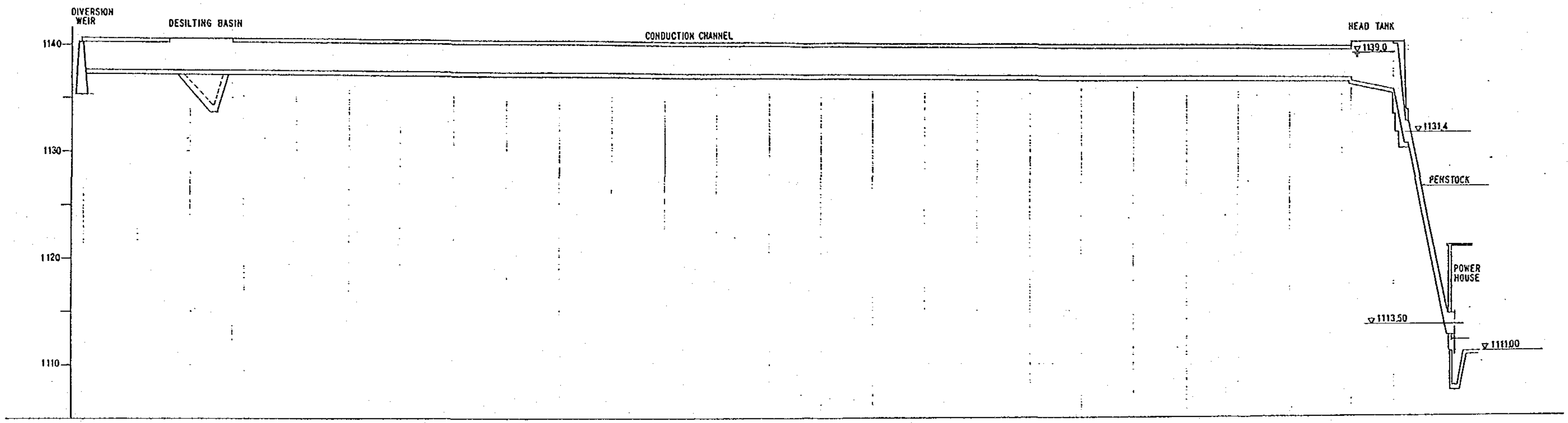
Drawings

Title	Drawing No.
General Plan and Profile (ALT-1)	OV-C-01
Diversion Weir & Intake,Desilting Basin (ALT-1)	OV-C-03
Head Tank (ALT-1)	OV-C-04
Powerhouse and Tailrace (ALT-1)	OV-C-05
Duration Curves	OV-H-01
Geological Plan	OV-G-01

PLAN (S=1/2000)



PROFILE (V=1/200, H=1/2000)



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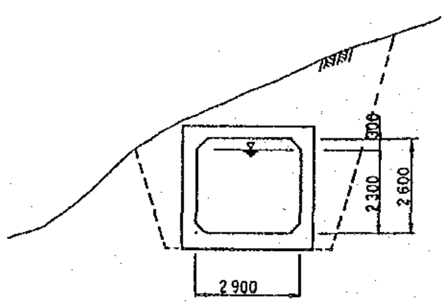
NO. 1	7.66	50.0	50.0
NO.1 +30.0	1137.63	80.0	30.0
NO. 2	7.62	100.0	20.0
NO.2 +39.0	1137.59	139.0	39.0
NO. 3	7.58	150.0	11.0
NO. 4	7.53	200.0	50.0
NO. 5	7.49	250.0	50.0
NO. 6	7.45	300.0	50.0
NO. 7	7.41	350.0	50.0
NO. 8	7.37	400.0	50.0
NO. 9	7.33	450.0	50.0
NO. 10	7.29	500.0	50.0
NO. 11	7.25	550.0	50.0
NO. 12	7.20	600.0	50.0
NO. 13	7.16	650.0	50.0
NO. 14	7.12	700.0	50.0
NO. 15	7.08	750.0	50.0
NO. 16	7.04	800.0	50.0
NO. 17	1137.00	650.0	50.0
NO. 18	1136.96	900.0	50.0
NO. 19	6.91	950.0	50.0
NO. 20	6.87	1 000.0	50.0
NO. 21	6.83	1 050.0	60.0
NO. 22	6.79	1 100.0	50.0
NO. 23	6.75	1 150.0	50.0
NO. 24	6.71 / 1136.7	1 200.0	50.0
NO.24 +10.0	1136.4	1 210.0	10.0
NO. 25	1135.6	1 250.0	40.0

TYPICAL SECTION OF CONDUCTION CHANNEL (S=1/100)

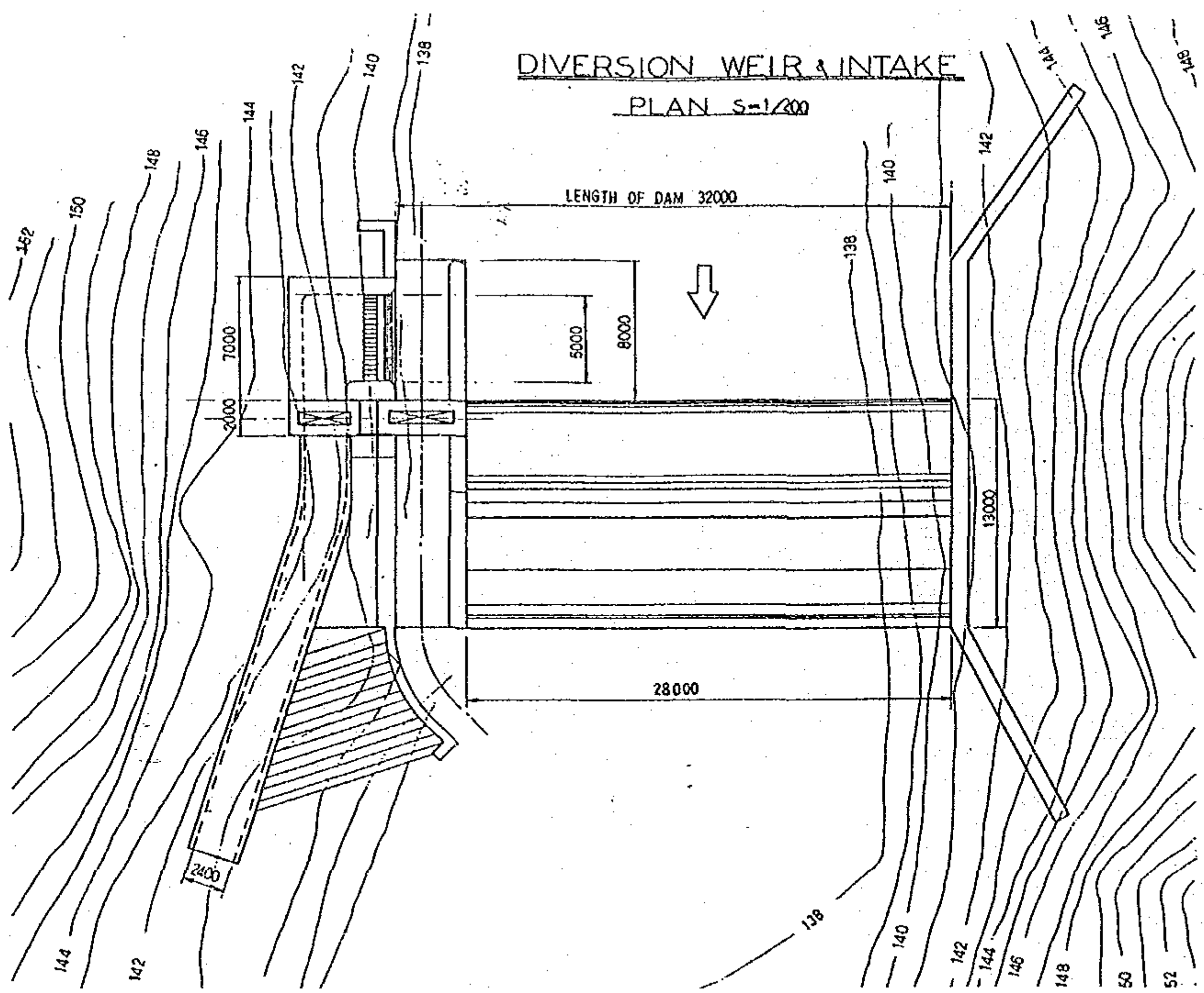


JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
GENERAL PLAN AND PROFILE (ALT-1)	
DRAWING NO.	OV-C-01
SCALE	1/2000
DATE	

9'(7)

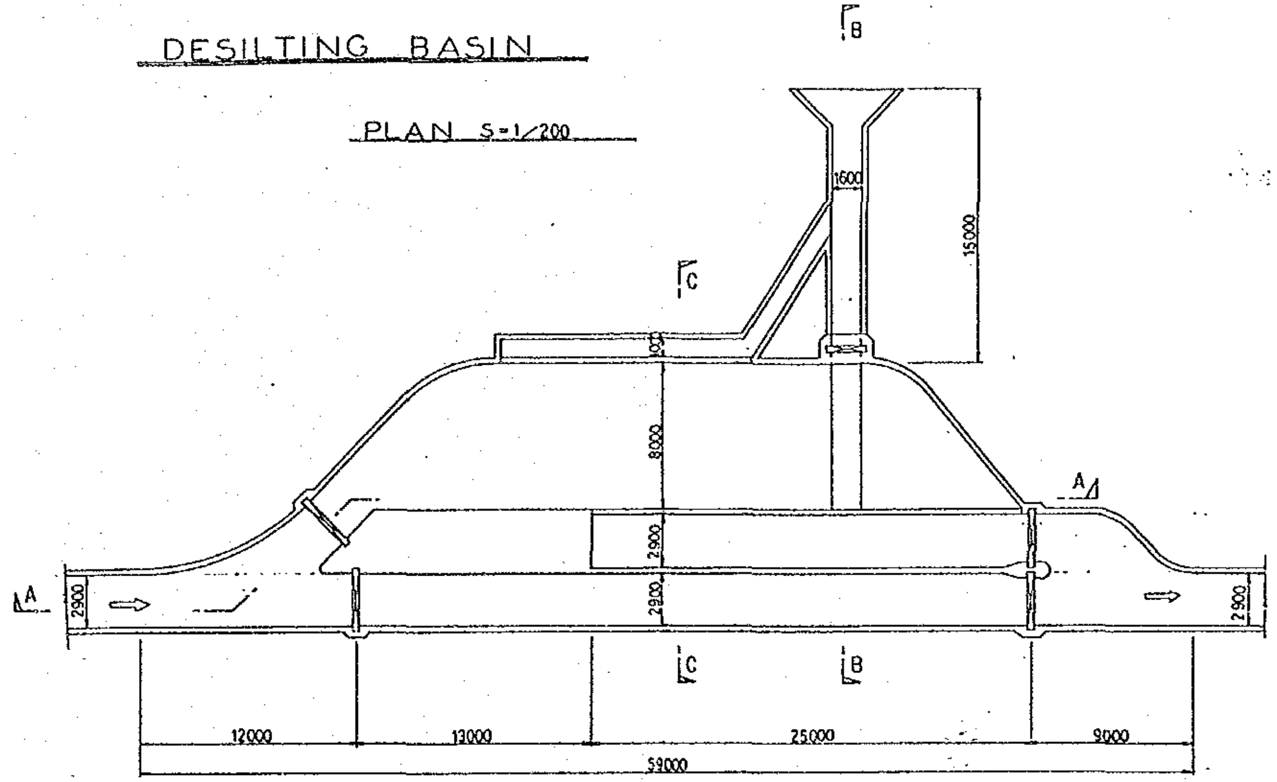
DIVERSION WEIR & INTAKE

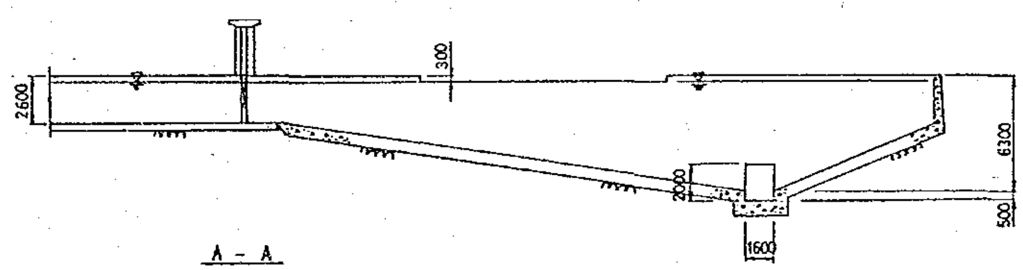
PLAN S=1/200



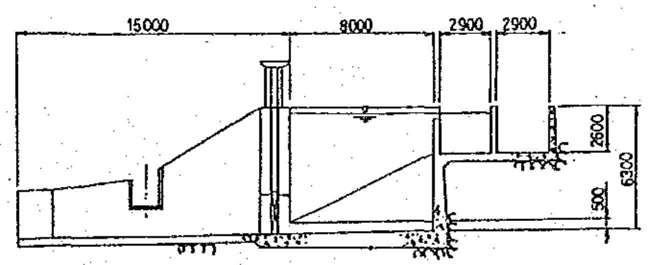
DESILTING BASIN

PLAN S=1/200

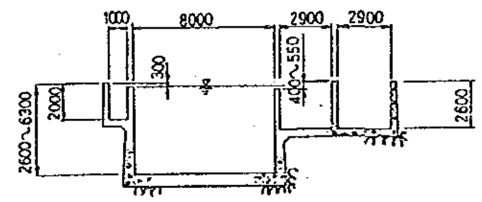




A - A



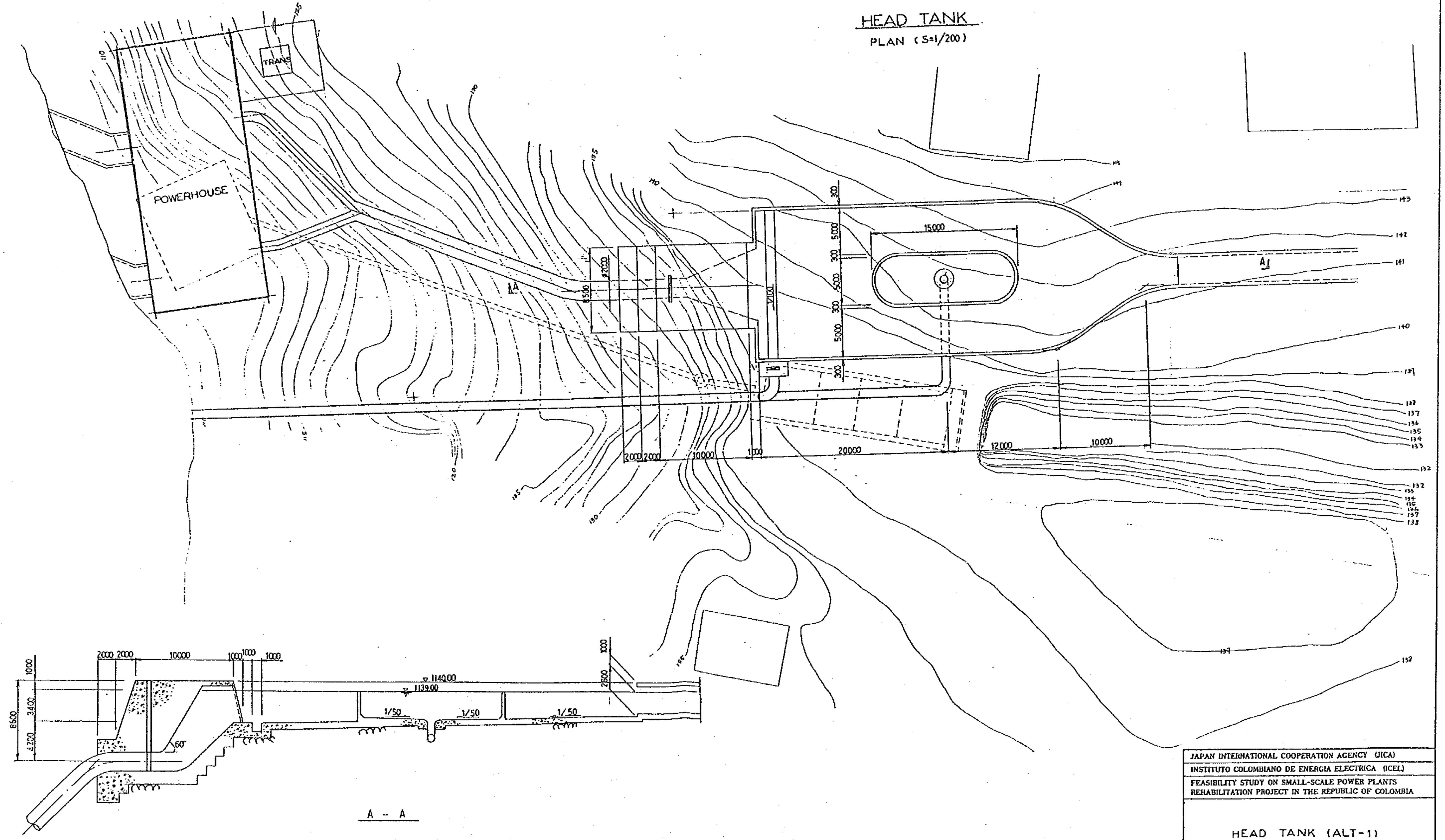
B - B



C - C

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 & INTAKE DESILTING BASIN (ALT-1)	
DRAWING NO.	OV-C-03
SCALE 1/200	DATE

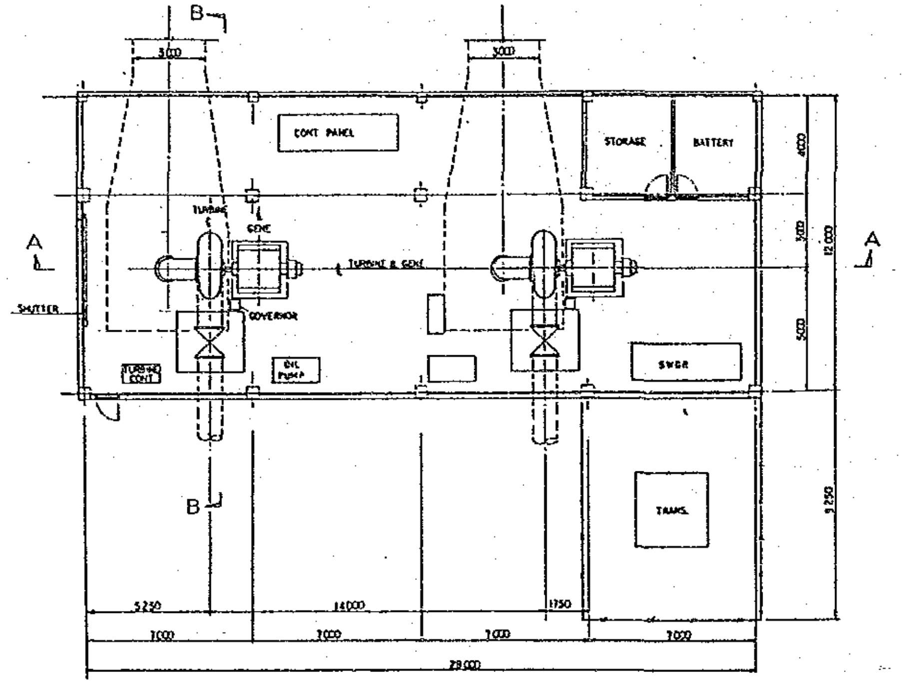
91-3

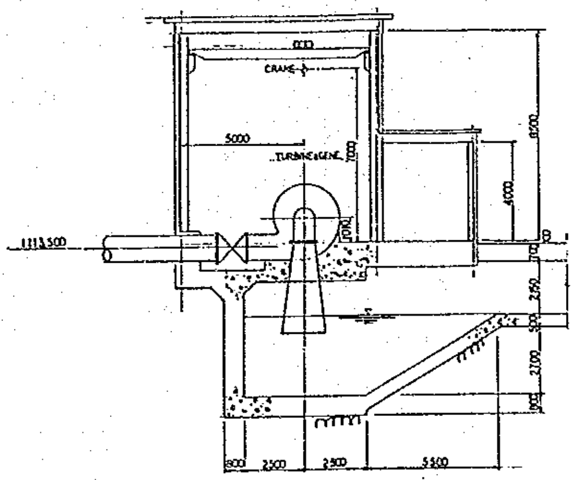


JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
HEAD TANK (ALT-1)	
DRAWING NO.	OV-C-04
SCALE 1/200	DATE

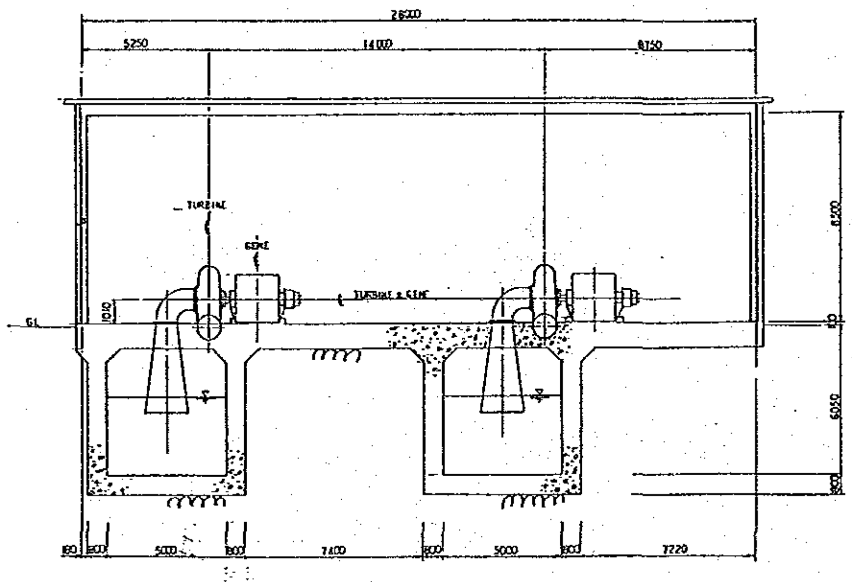
POWERHOUSE & TAILRACE

PLAN (S=1/150)





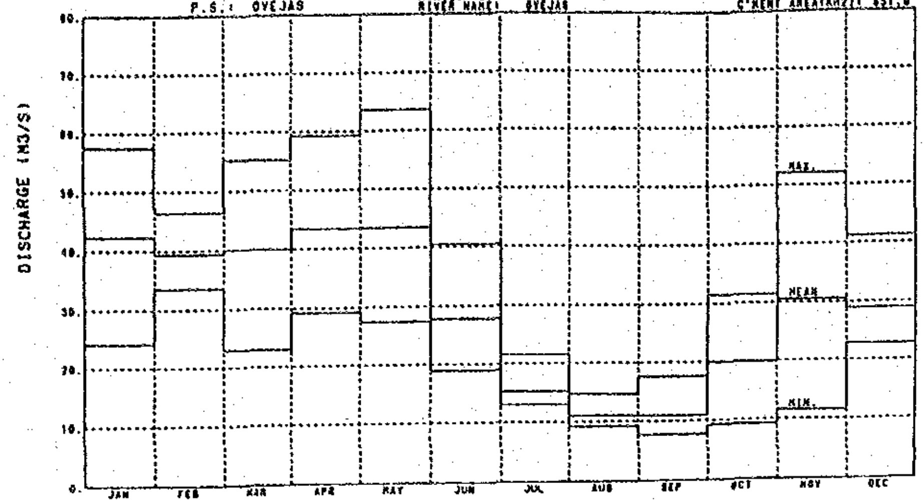
B - B



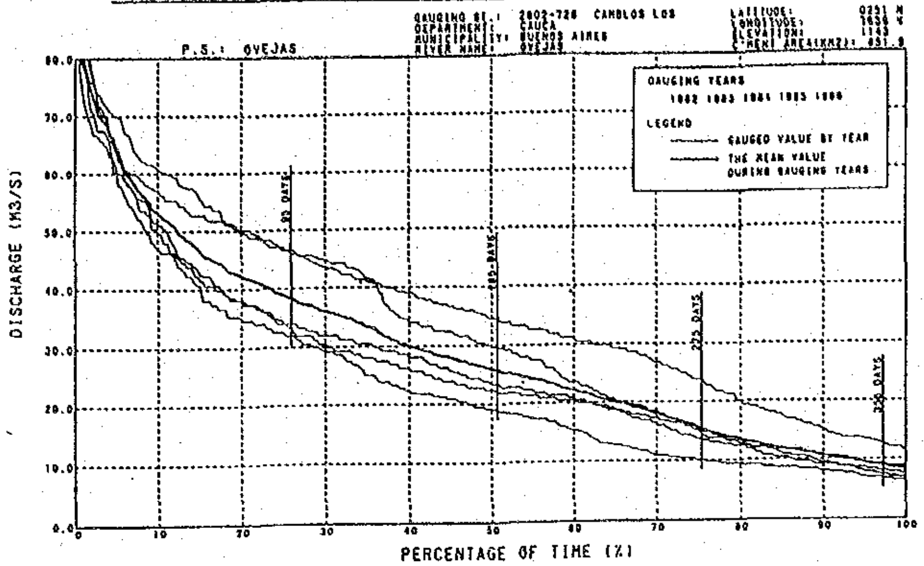
A - A

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	
POWERHOUSE AND TAILRACE (ALT-1)	
DRAWING NO.	OV-C-05
SCALE 1/150	DATE

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



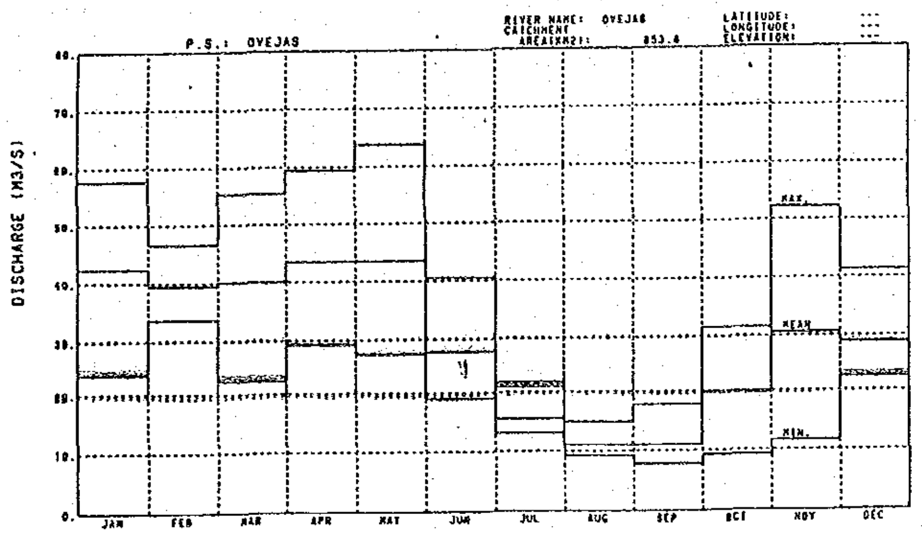
(3)
FLOW DURATION CURVE AT GAUGING STATION SITE



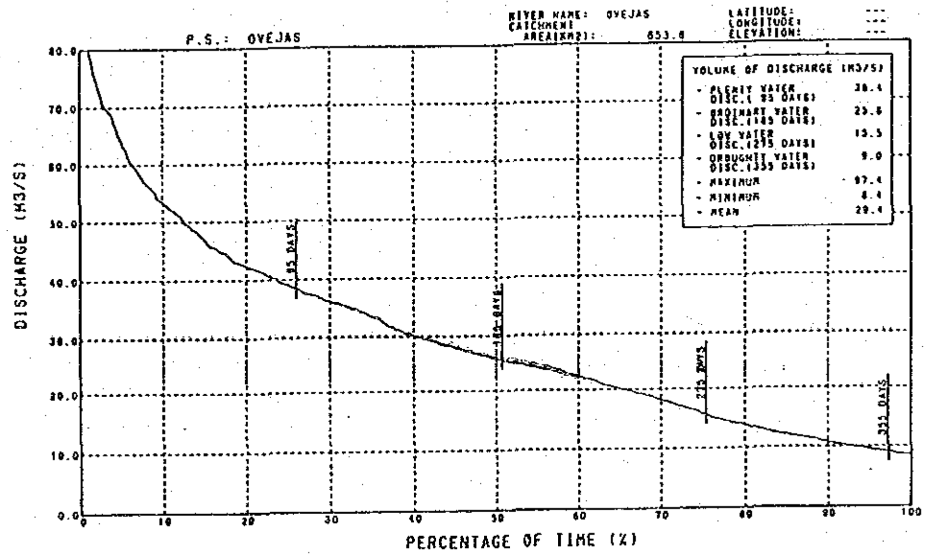
Data of Hydrological Gauging Station

No. of Station	2602 – 728
Name of Station	Cambulos Los
River	Ovejas
Management	CVC
Installation Year – Month	1981 07
Coordinates (Deg. – Min.)	
Latitude	0251
Longitude	7639
Above Sea Level s.n.m. (m)	1143
Long River (km)	— —
Catchment Area (km²)	— —
Water Shed (m)	- - —
Observation Period	1982 – 1986

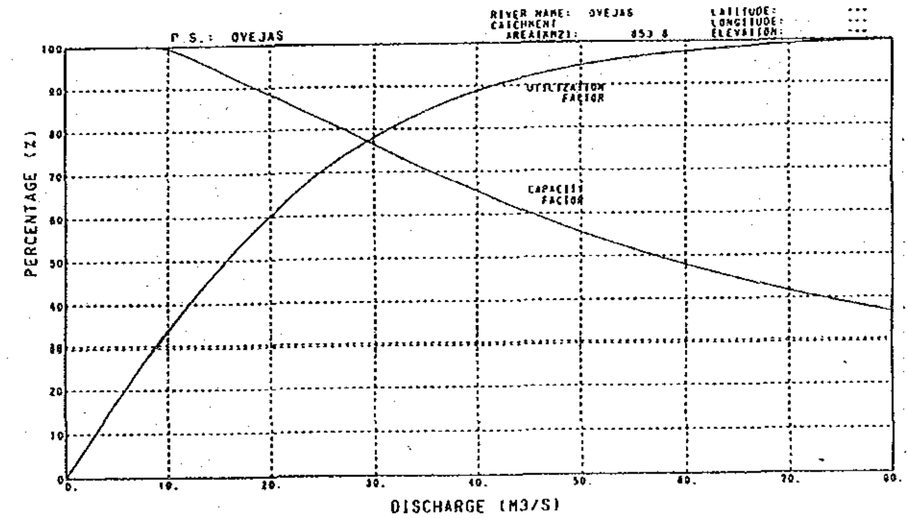
(2)
MONTHLY MEAN VALUE OF DAILY AVERAGE FLOW AT INTAKE SITE



(4)
TYPICAL FLOW DURATION CURVE AT INTAKE SITE

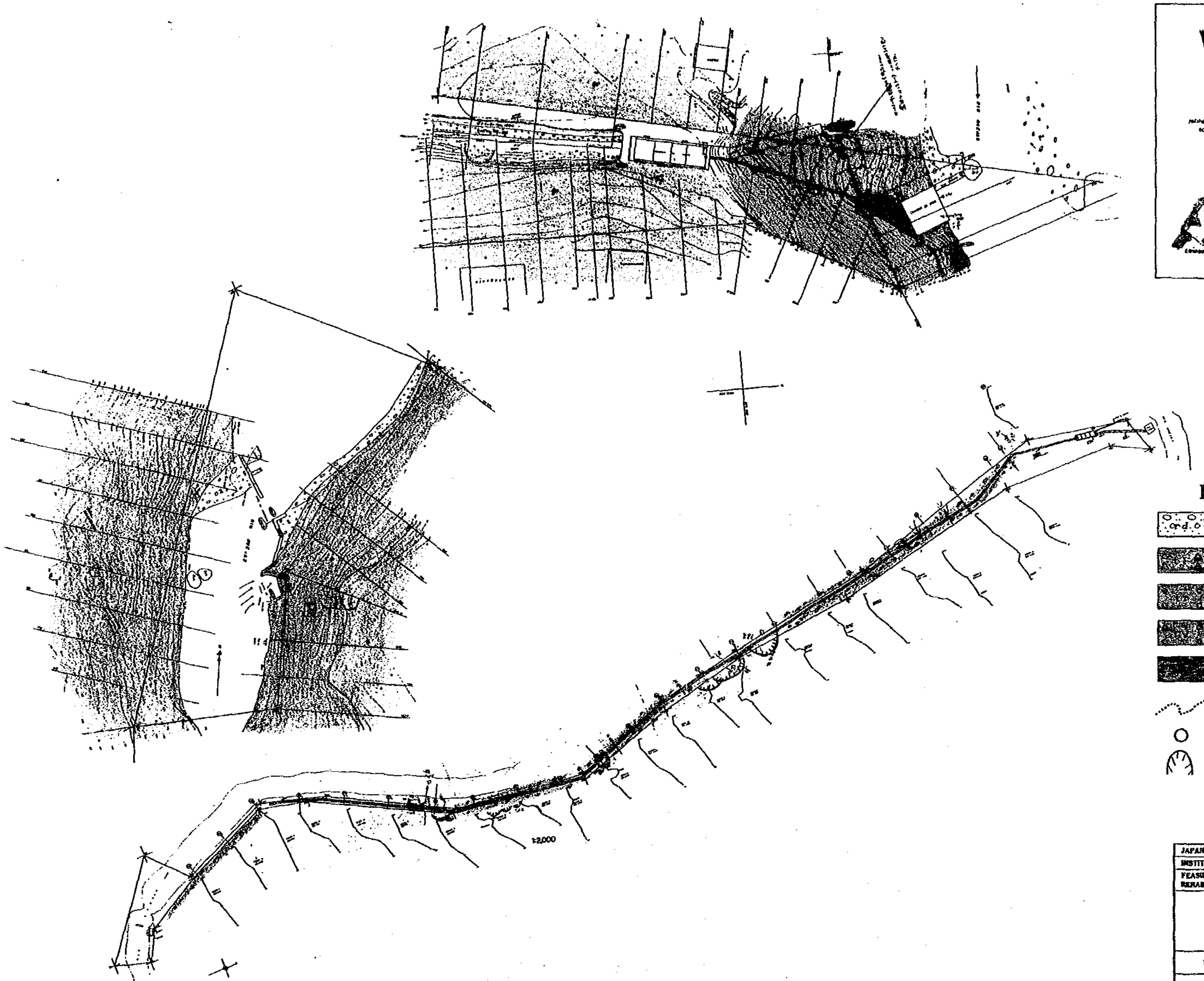


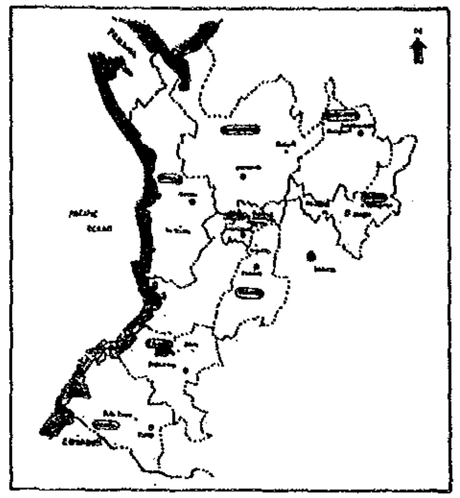
(5)
UTILIZATION & CAPACITY FACTOR



91-b

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.	OV – H – 01
SCALE	——
DATE	





LEGEND

- River bed deposits
- Talus deposits
- Terrace deposits
- Gravels
- Shale
- Geological boundary
- Borehole
- Collapse

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 Orejas	
DRAWING NO.	OV-G-01
SCALE 1/1,160	DATE

Attached Data

1. Facility Register for the Existing Power Plant

2. Survey Record

Facility Register for the Existing Power Plant

Power Plant	Ovejas
Electric Power Company	CEDELCA
Location	Monte Redondo/Cauca
River	Ovejas
Generating Method	Run-of-River
Year Installed	1939
Years in Service	1939
Installed Capacity	900 kW
Available Capacity	650 kW

Civil	
Item	Data
1. Dam	
1) Type	Concrete Gravity
2) Height (m)	2.5
3) Crest length (m)	24.0
4) Height of overflowing crest (m)	1,138.0
5) Width of overflowing crest (m)	24.0
6) Depth of overflowing crest (m)	no data available
2. Intake Gate	
1) Type	Steel Slide
2) Number of gates	1
3) Dimensions (W x H)(m)	2.0 x 2.0
3. Intake	
1) Intake sill height (m)	1,136.8
2) Number of intake	1
3) Dimensions (W x H)(m)	2.0 x 1.3
4. Desilting Basin	
1) Dimensions (W x L x H)(m)	N/A
5. Sand Trap Gate	
1) Type	N/A
2) Number of gates	N/A
3) Dimensions (W x H)(m)	N/A
6. Headrace	
1) Type	Steel pipe
2) Dimensions (W x H)(m)	φ 1.8 m
3) Length (m)	1,230

Civil	
Item	**Data**
7. Reservoir Tank	
1) Dimensions (W x L x H)(m)	5.2 x 22.5 x 3.2
8. Forebay	
1) Dimensions (W x H)(m)	5.5 x 4.0
9. Penstock	
1) Number of lines	1
2) Penstock diameter (d)(m)	1.60
3) Penstock length (L)(m)	65.0
10. Tailrace	
1) Dimensions (W x H)(m)	no data available

Equipment	
Item	**Data**
1. Water Turbine	
1) Manufacturer's name	Dominion Engineering
2) Year manufactured	1940
3) Type	Francis
4) Output (kW)	1,250 HP
5) Revolution (rpm)	400
6) Ancillary equipment	
a) Type of governor	Woadward tipo LRRST - 6700 LB.
b) Inlet valve	
- Type	
- Diameter (mm)	
2. Generator and Exciter	
1) Manufacturer's name	Westinghouse
2) Year manufactured	1938
3) Type	Synchro.
4) Capacity (kVA)	1,125
5) Power factor (%)	80
6) Voltage (V)	12,500
7) Frequency (Hz)	60
8) Revolution (rpm)	400
9) Method of neutral earthing	no data available
10) Type of exciter	"

Equipment	
Item	**Data**
3. Transformer	N/A
1) Manufacturer's name	
2) Year manufactured	
3) Type	
4) Capacity (kVA)	
5) Primary voltage (kV)	
6) Secondary voltage (kV)	
7) Number of unit	
8) Vector-group symbol	
9) Impedance (%)	
10) Purpose for use	
4. Circuit Breaker	N/A
1) Manufacturer's name	
2) Year manufactured	
3) Type	
4) Voltage (kV)	
5) Rated current (A)	
6) Rupturing capacity (kA)	
7) Purpose for use	
5. Transmission Line	no data available
1) Destination	
2) Length (m)	
3) Voltage (kV)	
4) Number of circuit	
5) Number of pylons	
6) Size of conductors	
7) Materials of conductors	

Equipment	
Item	Data
6. Battery 1) Manufacturer's name	no data available
2) Year manufactured	
3) Capacity (AH/HR)	
4) DC voltage (V)	
5) Type	
7. Battery Charger 1) Manufacturer's name	〃
2) Year manufactured	
3) Capacity	
4) Incoming voltage (V)	
8. Overhead Crane 1) Weight (ton)	〃
2) Method of operation	
3) Span (m)	

Survey Records

Ovejas Hydroelectric Power Plant

I. RECORDS BY VISUAL INSPECTION AND HEARING SURVEY

Unit No.: /

Type of Turbine: Francis

Generating Facilities		Check item by visual inspection and hearing	Results
Francis Turbine	Casing	1) Existence of corrosion 2) Wear in thickness	1) 2) X
		3) Presence of vibration	3)
	Runner	1) Existence of corrosion 2) Occurrence of porosity by sand pitting	1) 2) X
	Shaft	1) Shaking of shaft axis	1)
	Bearing	1) Oil shortage on bearing surface	1) X
		2) Lack of oil viscosity	2)
	Governor control	1) Control by belt-driven type 2) Speed detection device 3) Speed regulation system	1) X 2) 3)
		4) Installation of load limiter	4)
		5) Accuracy of governor speed regulation	5)

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) X 2)
	Inlet valve	1) Operation method 2) Locking condition 3) Smoothness of pressurized oil operation	1) Manual 2) 3)
	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) X 2) X 3)
	Sealing device	1) Sufficiency of water sealing for shaft 2) Sufficiency of packing for shaft seal	1) 2) X

Unit No. /

Generating Facilities		Check item by visual inspection and hearing	Results
Generator	Rotor	1) Discoloration of winding surface due to heat	1) X
		2) Existence of erosion for core	2)
		3) Fitness of between rotor and shaft	3)
	Stator winding	1) Frequency of burning trouble or repair	1)
		2) Reduction of insulation resistance	2) X
		3) Rust and erosion of core	3)
	Bearing	1) Occurrence of deformation on metal surface	1) X
		2) Lack of oil lubrication	2) X
		3) Occurrence of temperature rise	3) X
	Exciter	1) Exchange frequency of brushes worn out	1) 1 year
		2) Sufficient stock of spare brush	2) X
	Voltage regulator	1) Operation method of voltage regulator	1)
		2) Response of voltage detection for load variation	2) 0.3 sec.

Generating Facilities		Check item by visual inspection and hearing	Results
Control Board	Metering equipment	1) Sufficiency of accuracy for instruments 2) Lack of necessary instruments 3) Items constantly recorded	1) X 2) 3)
	Protection equipment	1) Lack of relays to be installed 2) Operation method in case of accident in transmission lines	1) 2) Automatic - over current
	Remote control equipment	1) Control method for turbine and generator operation 2) Control method for voltage and speed control 3) Operation method of synchronized switching	1) — 2) — 3) Manual
	Power system	1) Power supply voltage (kV) after rehabilitation work	1)

Generating Facilities		Check item by visual inspection and hearing	Results
Indoor Switchgear	Insulation level	1) Sufficiency of insulation level 2) Unification of insulation level 3) Reduction of insulation registance	1) 2) 3) X
	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) X 2) Regular 3) Manual

Generating Facilities		Check item by visual inspection and hearing	Results
Outdoor Equipment	Transformer	1) Presence of over load operation	1)
	Circuit breaker	1) Situation of tripfor outgoing feeder breaker in case of accident on transmission line 2) Fitness of maintenance in case of oil circuit breaker	1) 2)
	Line switch	1) Operation method 2) Reliability of operation	1) *Automatic and manual* 2) *Acceptable*
	Insulator	1) Presence of damage and dusts	1)
	Structural steel	1) Occurence of erosion due to rust 2) Presence of injury	1) 2)
	Line protection	1) Existence of adequate protection relays to connect to RED	1) *Insufficient*

II. ACTUAL GENERATED ENERGY AND OPERATION TIME

Unit No.: 1

Installed Capacity of Generator: ________ KVA

Type of Turbine: ________

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL	REMARKS
1983	MWH														
	OPE. TIME														
1984	MWH	336	358	400	364	409	322	263	313	309	344	351	357	4,126	
	OPE. TIME	737	690	726	716	740	703	743	534	713	737	715	740	8,494	
1985	MWH	365	331	355	338	354	336	342	372	337	330	282	323	4,065	
	OPE. TIME	742	670	730	717	742	718	736	742	717	740	654	739	8,647	
1986	MWH	334	279	337	320	337	321	322	38	0	0	0	0	2,288	
	OPE. TIME	742	628	741	717	739	716	742	86	0	0	0	0	5,111	
1987	MWH	0	0	0	0	0	0	0	0	0	197.5	99	326	622.5	
	OPE. TIME	0	0	0	0	0	0	0	0	0	744	436	732	1,912	
1988	MWH	283	315	352	322	297	296	317	326	311	309	297	322	3,747	
	OPE. TIME	643	683	743	716	742	707	743	733	716	737	710	741	8,614	

(Note) 1. MWH : Gross

2. OPE. TIME : Hour

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) Problems in penstock. Repairs with welder for turbine, scroll casing.
	2) Causes for damage/defect	
	3) Duration of repairing and power supply stoppage	
	4) Repaired by;	4) Repaired by staff in power plant.
	a) staff in Power Plant	
	b) manufacturer	
	c) other	
	5) Repair cost	
	6) Operation life after the completion of repairing work	

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.	Without available informations