PRE-FEASIBILITY STUDY

ON

SMALL-SCALE POWER PLANTS REHABILITATION PROJECT

IN

THE REPUBLIC OF COLOMBIA

MAIN REPORT

JULY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of Colombia, the Japanese Government decided to conduct a pre-feasibility study on Small-scale Power Plants Rehabilitation Project and entrusted the study to the Japan International Cooperation Agency (J.I.C.A.). J.I.C.A. sent to Colombia a study team headed by Mr. Masami Ono, Vice President, Yachiyo Engineering Co., Ltd. from November, 1987 to June, 1988.

The team had discussion on the Project with the officials concerned of the Government of Colombia and conducted a field survey in the relevant areas in Colombia. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of Colombia for their close cooperation extended to the team.

July, 1988

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

July, 1988

Mr. Kensuke Yanagiya
President
Japan International Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

We have the pleasure of submitting to you a Final Report of the Pre-feasibility study (Pre-F/S) on the Small-scale Power Plants Rehabilitation Project in the Republic of Colombia. These Small-scale Power Plants are possessed by Instituto Colombiano de Energia Electrica (ICEL).

This Pre-F/S was conducted for about seven months from the start of field investigations and studies in November, 1987 to the preparation of the Draft Final Report in June, 1988. That Draft Final Report was submitted to your Agency, and from June 12, to June 21, 1988 the study team visited the Republic of Colombia and discussed with the staff of ICEL on the Draft Final Report. All the findings and comments obtained in the discussions have been fully incorporated in the Final Pre-F/S Report.

The main objective of this Pre-F/S was to select candidate small-scale power plants for the subsequent feasibility study (F/S) on the rehabilitation project among the proposed 82 power plants having installed capacities of 461 MW (three thermal power plants with installed capacity of 254 MW, 62 hydraulic power plants with installed capacity of 192 MW and 17 diesel power plants with installed capacity of 15 MW) which are distributed in 13 departments and one intendancy in the Republic of Colombia.

In the Final Report, candidate 12 power plants (output increase of 29 MW) for the F/S consisting of one thermal power plants (output increase of 8 MW) and 11 hydraulic power plants (output increase of 21 MW) are selected on consideration of the necessity of rehabilitation, rehabilitation effect, balance of power demand and supply, as well as the present condition of the existing facilities surveyed in the field.

The preliminary rehabilitation cost was estimated at about 64 million US$ (about 14.4 million US$ for thermal generating facilities, about 49.6 million US$ for hydraulic generating facilities) at the price level of June 1988. Since the study for rehabilitation plan of diesel generating facilities was completed at the stage of the Pre-F/S, there is no candidate diesel power plants for the F/S.

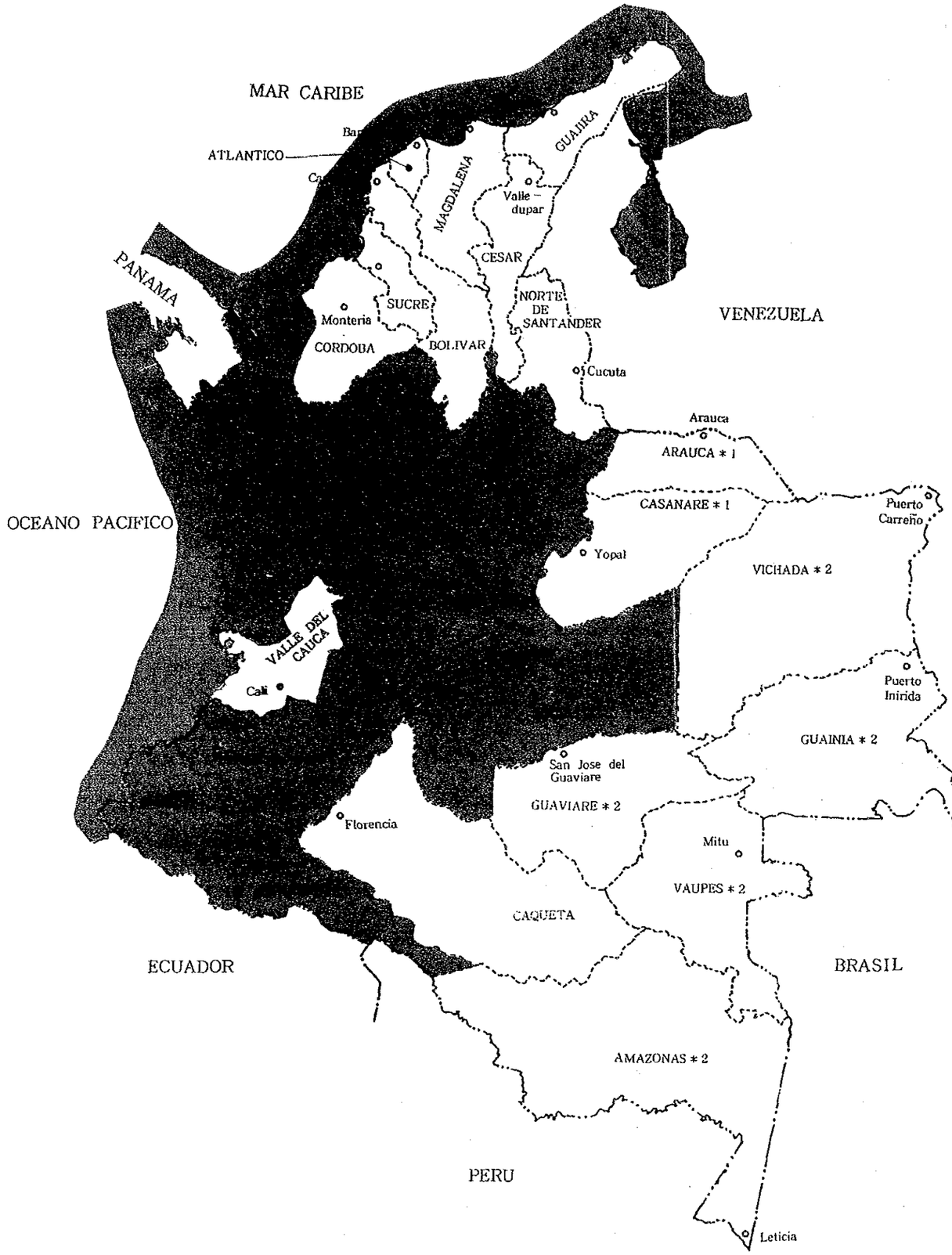
It is our sincere hope that the candidate power plants for rehabilitation selected in this Pre-F/S will proceed toward realization of the Project according to the results of F/S that will subsequently be conducted, and that the outcome of related technologies transferred to ICEL group's counterpart would be fruitful.

In submitting this Pre-F/S Report, we are sincerely grateful to the numerous persons of your Agency, the Embassy of Japan in Colombia and ICEL group for their hospitalities and cooperation extended to us during our field survey as well as home office work.

Yours sincerely,

Masami Ono

Masami Ono
Team Leader
Pre-feasibility Study Team
on Small-scale Power Plants
Rehabilitation Project



(KEY LOCATION MAP)

LEGEND

—··—	BORDER
------	LIMIT OF DEPARTMENT
◉	CAPITAL
○	CAPITAL OF DEPARTMENT
* 1	INTENDANCY
* 2	COMMISSARY

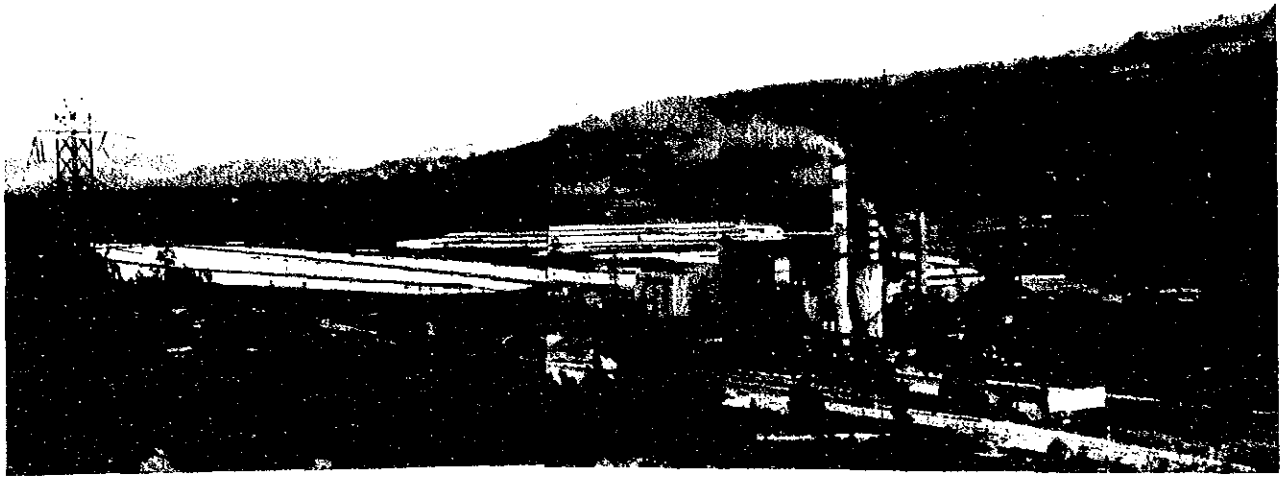
NOTES

	DEPARTMENT	(CAPITAL)
1.	CALDAS	(Manizales)
2.	RISARALDA	(Pereira)
3.	QUINDIO	(Armenia)

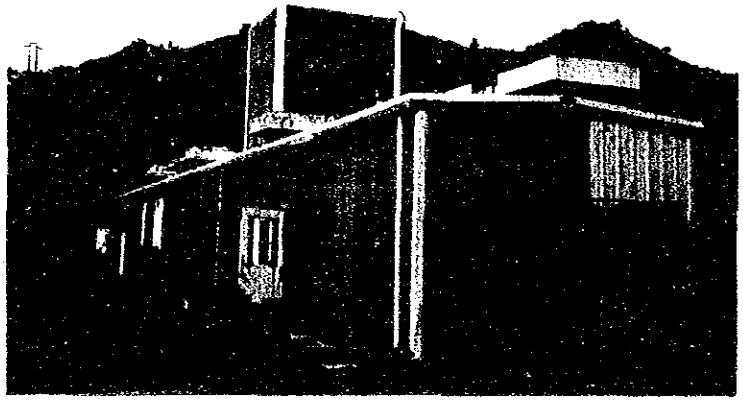
■ PRE- F/S STUDY AREA

POLITICAL DIVISION IN THE REPUBLIC OF COLOMBIA

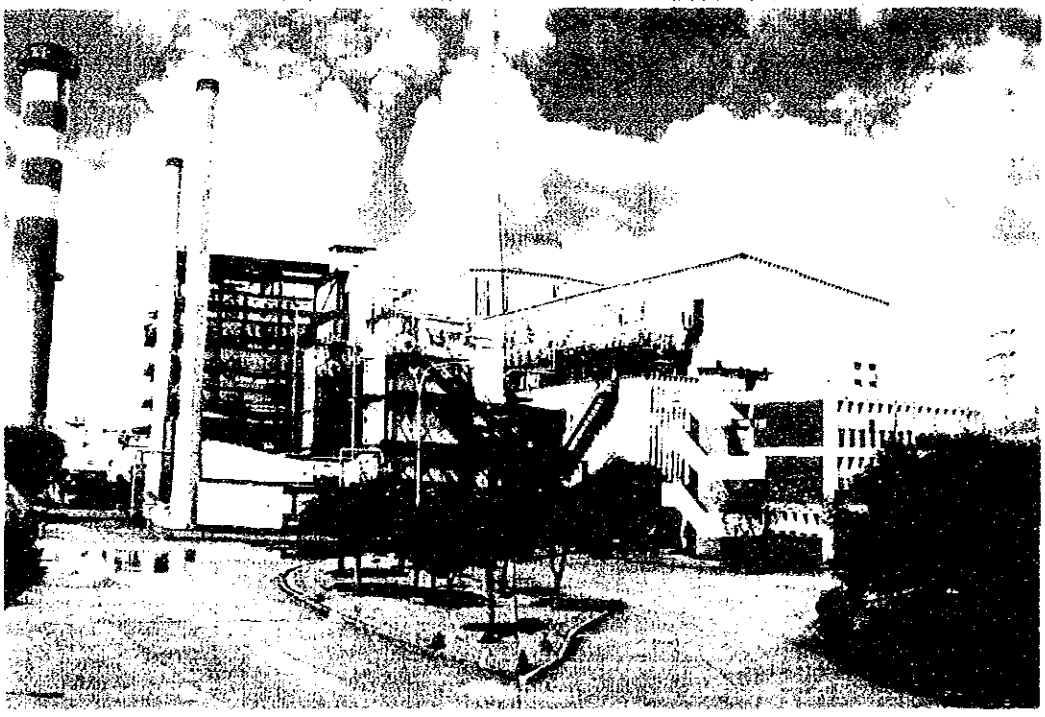
(THERMAL POWER PLANT)



Bird's-eye view
of the TERMOPAIPA
POWER PLANT

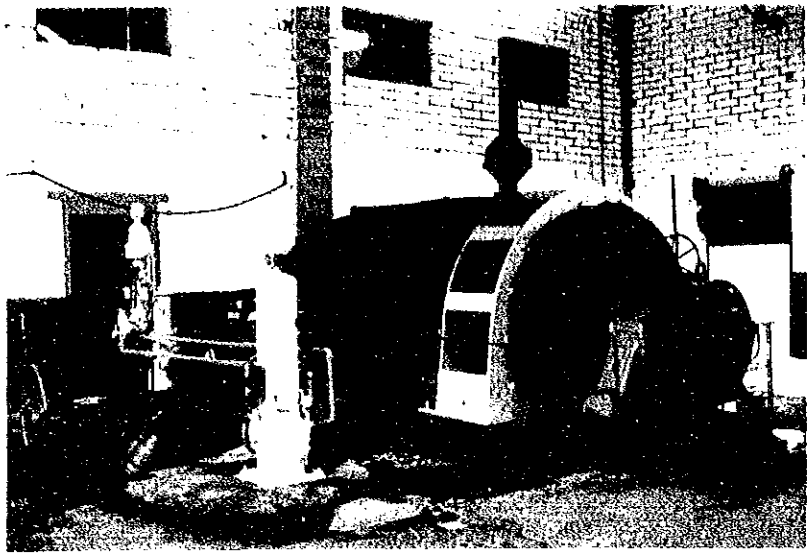


Exterior of No. 4
Unit Gas Turbine
in *TERMOPALENQUE*
POWER PLANT

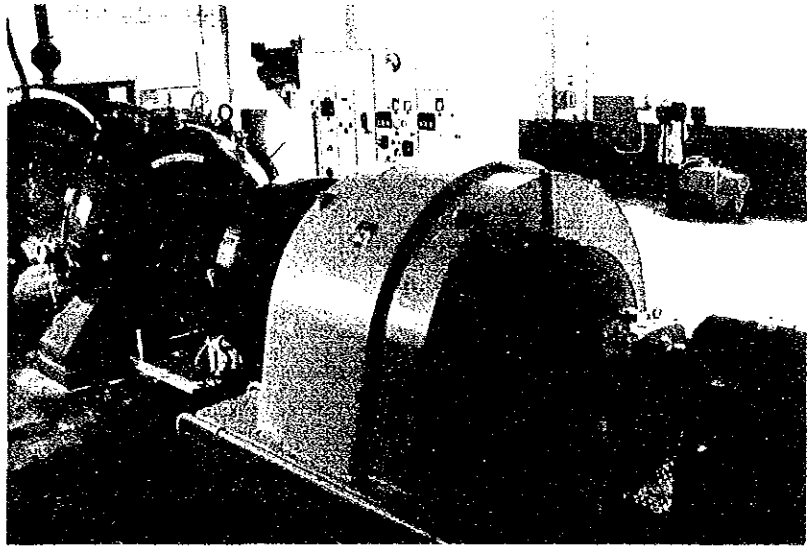


Exterior of
TERMOBARRANCA
POWER PLANT

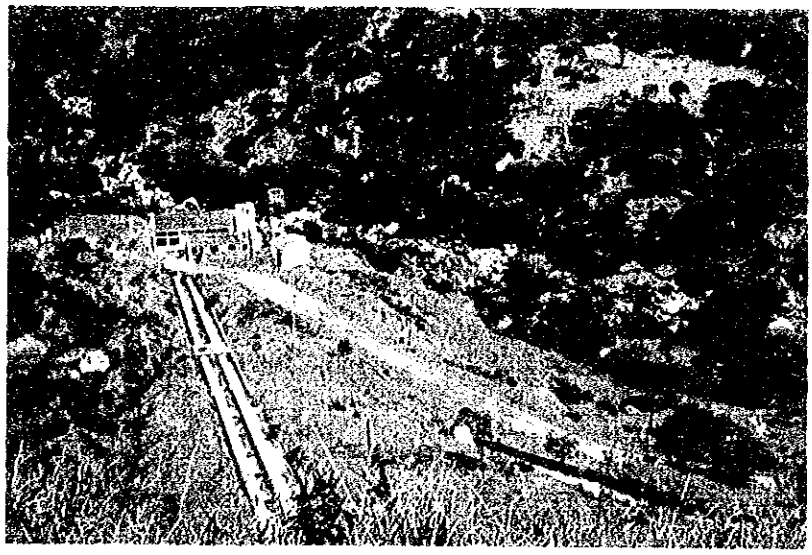
(HYDRAULIC POWER PLANT)



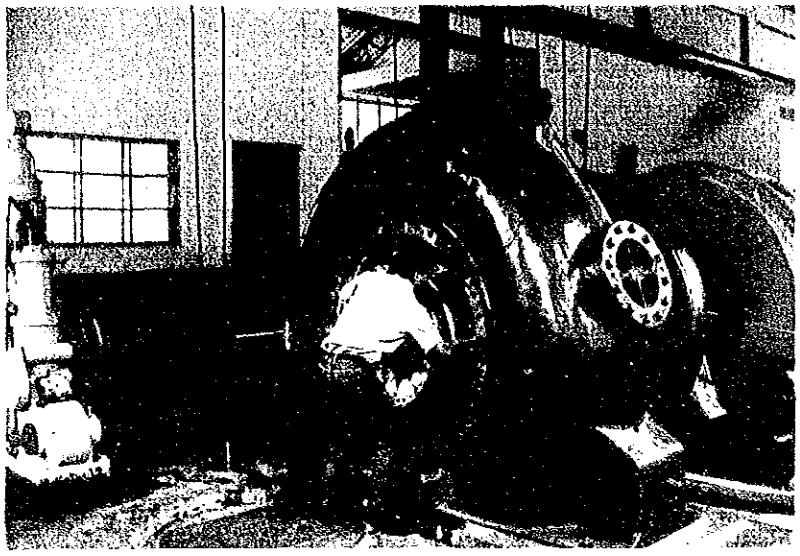
CARACOLI POWER PLANT
No. 1 UNIT (PELTON TYPE)



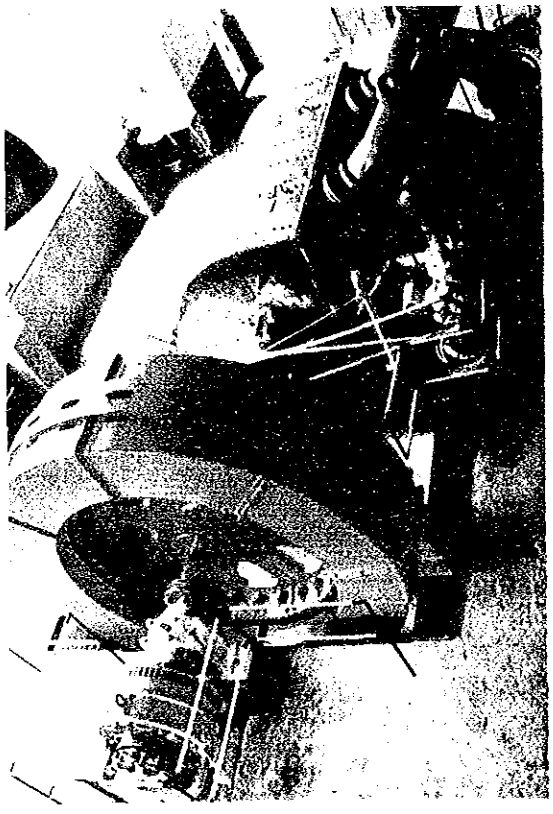
CARACOLI POWER PLANT
No. 2 UNIT (FRANCIS TYPE



P. GUILLERMO
POWER PLANT

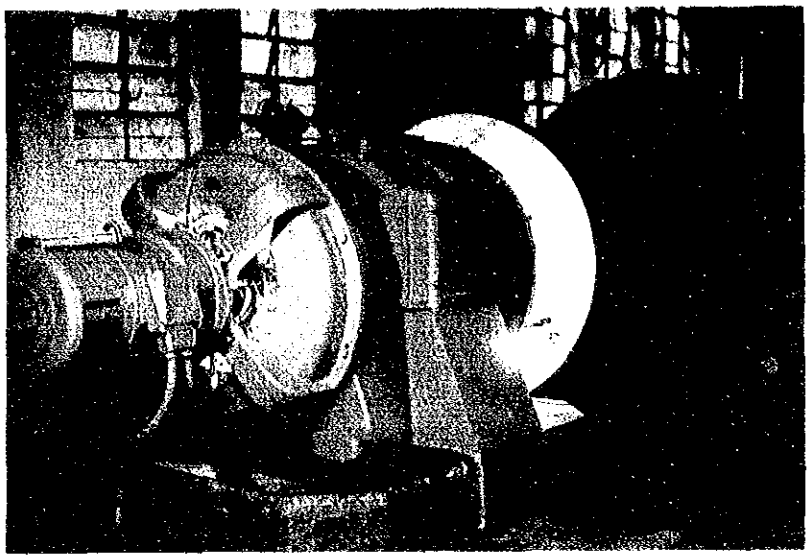


SANCANCIO
POWER PLANT

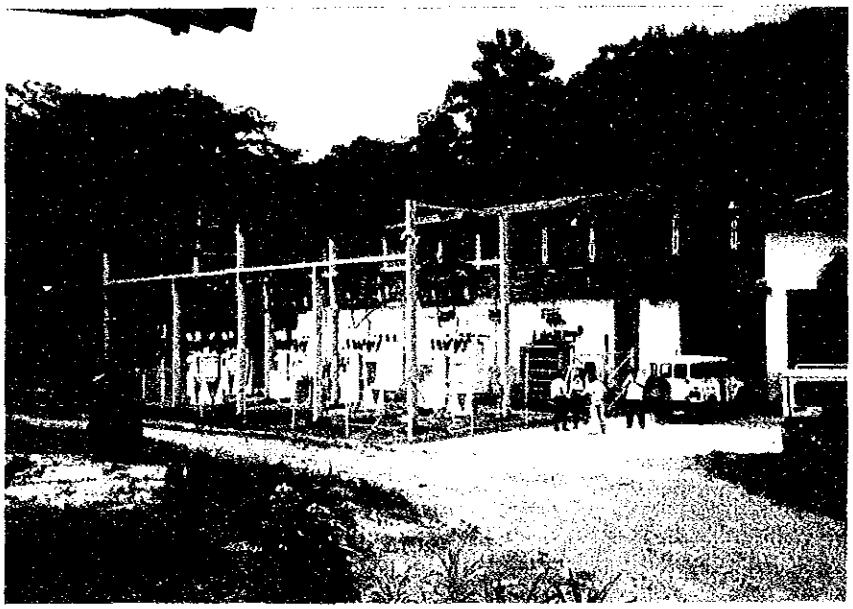


INTERMEDIA
POWER PLANT

MUNICIPAL
POWER PLANT

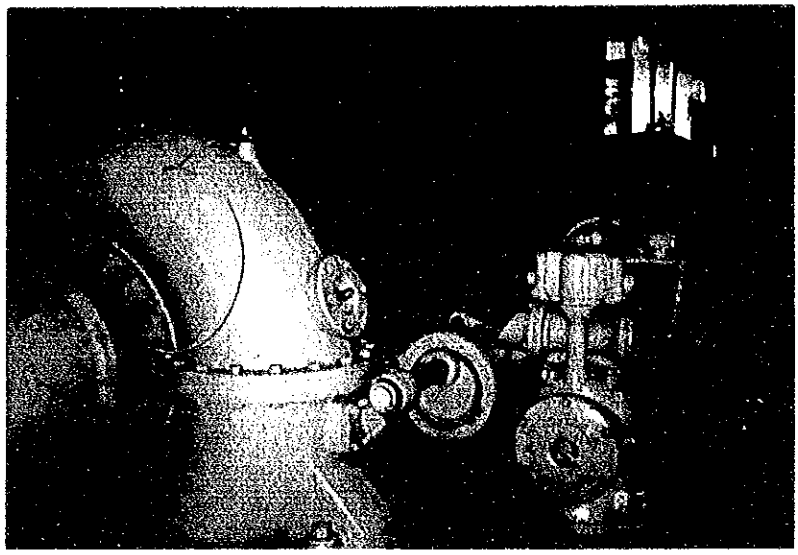


FLORIDA-I
POWER PLANT



IQUIRA-I
POWER PLANT

IQUIRA-II
POWER PLANT

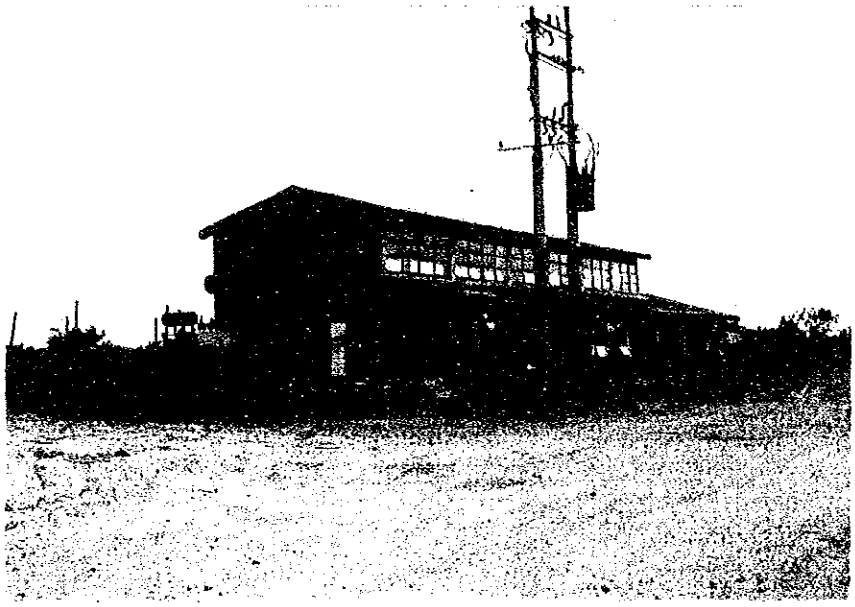


ZARAGOZA
POWER PLANT

LAGUNILLA
POWER PLANT

(DIESEL POWER PLANT)

CAPURGANA POWER PLANT IN CHOCO Department



PUERTO LOPEZ POWER PLANT IN META Department

TERMOTUMACO POWER PLANT IN NARIÑO Department
(No. 1 and 2 unit are installed in Building.
No. 3 and 4 unit are outdoor packages.)

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ABBREVIATIONS

AIR	Annual Average Increase Rate
CEDELCA	Centrales Electricas del Cauca S.A.
CEDENAR	Centrales Electricas de Narino S.A.
CENS	Centrales Electricas del Norte de Santander S.A.
CHEC	Central Hidroelectrica de Caldas S.A.
CRQ	Corporation Autonoma Regional del Quindio
CRAMSA	Corporacion Regional Autonoma Manizales Salamina Aranzazu
DANE	Departmento Administrative National de Estadistica
E.	Electrificadora de
E.P.	Empresas Publicas
E/P	Electric Precipitator
EADE	Empresa Antioquena de Energia S.A.
ECSA	Electrificadora de Cundinamarca S.A.
EEEB	Empresa de Energia Electrica de Bogota
EMSA	Electrificadora del Meta S.A.
EPM	Empresas Publicas de Medellin
EPP	Empresas Publicas de Pereira
ESSA	Electrificadora de Santander S.A.
F/S	Feasibility Study
FOB	Free on Board
HIMAT	Instituto Colombiano de Hidrologia, Meteorologia y Adecuacion de Tierras
HP	High Pressure
ICEL	Instituto Colombiano de Energia Electrica
IGAC	Instituto Geografico "Agustin Codazzi"
ISA	Interconexion Electrica S.A.
JICA	Japan International Cooperation Agency
LP	Low Pressure
P/P	Power Plant
S.A.	Socieda Anonima
WHO	World Health Organization

SUMMARY

CONTENTS

1. Power Plants Proposed by ICEL for Pre-F/S

ICEL has proposed that 82 power plants as described in Appendix I and II in connection with the rehabilitation of small-scale power plants are investigated. Their details are as follows:

- Thermal power plants (including gas turbine)
  - Number of power plants 3
  - Total installed capacity ..... 254,000 kW

- Hydraulic power plants
  - Number of power plants 62
  - Total installed capacity ..... 192,416 kW

- Diesel power plants
  - Number of power plants 17
  - Total installed capacity ..... 14,848 kW

These proposed power plants are widely distributed over the 13 departments of Antioquia, Boyaca, Caldas, Risaralda, Quindio, Cauca, Choco, Cundinamarca, Huila, Meta, Nariño, Santander and Tolima, and one intendancy of Putumayo, as shown below:

No. of Proposed Small-Scale Power Plants

Department	Power Plant			Total
	Thermal	Hydraulic	Diesel	
Antioquia	0	9	0	9
Boyaca	1	1	0	2
Caldas	0	6	0	6
Risaralda	0	3	0	3
Quindio	0	4	0	4
Cauca	0	9	0	9
Choco	0	1	9	10
Cundinamarca	0	4	0	4
Huila	0	5	0	5
Meta	0	2	3	5
Narino	0	4	5	9
Putumayo	0	1	0	1
Santander	2	6	0	8
Tolima	0	7	0	7
Total	3	62	17	82

1.1 Stand-alone Power Plants

Among these 82 power plants, all of the 17 diesel and 11 hydraulic power plants are of stand-alone type isolated from the national transmission line network system.

The 11 stand-alone type hydraulic power plants are as follows:

Code No.	Power Plant	Installed Capacity (kW)	Owner
215	Salamina	280	E.P. de Salamina
216	Anserma	-	E.P. de Anserma
231	Toribio	63	CEDELCA
233	La Vuelta	2,000	Mineros del Choco S.A.
234	La Salada	280	ECSA
236	Choachi	300	E.P. de Choachi
237	Apulo	3,000	Cementos Diamantes S.A.
243	El Calvario	20	EMSA
244	San Juanito	20	EMSA
249	Mulato	168	E.P. de Mocoa
261	Lagunilla	452	E. Tolima
	Total	6,583	-

1.2 Inoperative Generation Units

At present, the generating units which are not in operation are as follows:

Power Plant	Stopped Generating Unit	
	No. of Unit	Installed Capacity (kW)
Thermal	1 (20)	15,000 (6)
Hydraulic	47 (38)	32,707 (17)
Diesel	14 (45)	3,533 (24)

Note: Numerical values in ( ) show percentage to total value in each power plant.

1.3 Service Duration of Hydraulic Power Plants

The duration of service of the 62 hydraulic power plants widely ranges from 1 to 72 years after installation.

Proportion of inoperative generating units tends to increase according to the duration of service after installation, and such duration of service is classified into the following five groups at 10 year's interval.

Duration Years after Installation	Installed Generating Unit		Stopped Generating Unit	
	No. of Unit	Installed Capacity (kW)	No. of Unit	Installed Capacity (kW)
below 15 years	9	61,340	0	0
16 - 25 years	16	31,943	5 (31)	2,216 (7)
26 - 35 years	39	49,984	14 (36)	14,676 (29)
36 - 45 years	26	26,269	9 (35)	5,395 (21)
above 46 years	34	22,880	19 (56)	10,420 (46)
Total	124	192,416	47 (38)	32,707 (17)

Note: Numerical values in ( ) show percentage to the installed generating units in each group.

2. Basic Procedures for the Rehabilitation Study

The main objective of the Pre-F/S is to select candidate small-scale power plants for the subsequent feasibility study (hereinafter referred to as F/S) on the rehabilitation project among the proposed 82 power plants.

The contents of study carried out during this Pre-F/S are as follows:

(1) Review of previous study results and existing data
(2) Site reconnaissance of proposed power plants
(3) Formulation of preliminary rehabilitation plan
(4) Conceptional design
(5) Preliminary estimation of rehabilitation cost
(6) Preliminary economic analysis and evaluation
(7) Evaluation on priority order
(8) Study planning during the stage of the F/S

The candidate power plants for the F/S were selected on consideration of the necessity of rehabilitation, rehabilitation effect, balance of power demand and supply, and actual local condition.

2.1 Procedures for Selection of Proper Power Plants for Preliminary Rehabilitation Plan

In order to select suitable power plants for preliminary rehabilitation plan, the basic procedures as shown in Fig. 2.1 are taken into consideration.

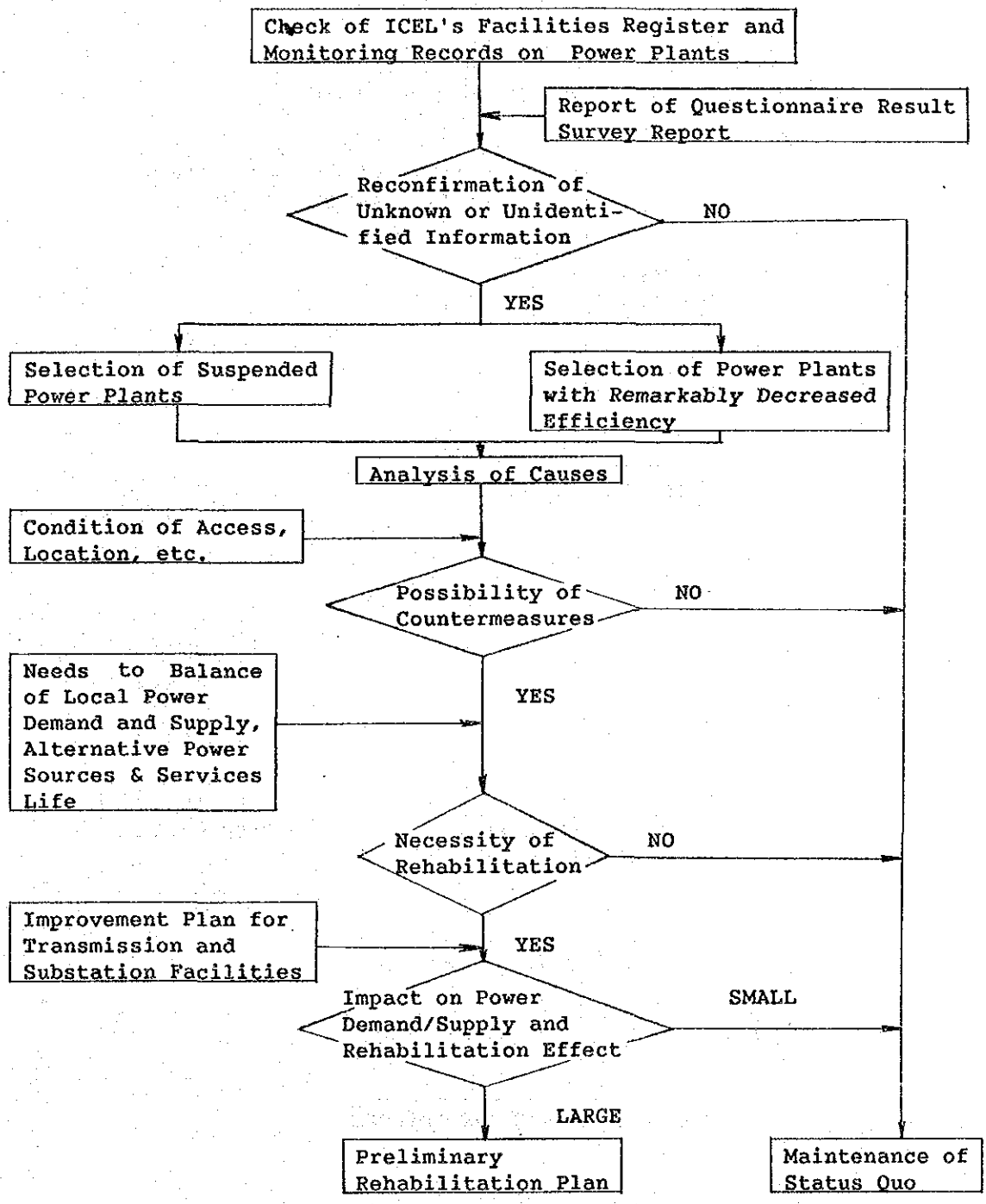

Fig. 2.1 Basic Procedure for Preliminary Rehabilitation Plan

2.2 Study Flow for Thermal Power Plants

Three Termopaipa, Termopalenque and Termobarranca Thermal Power Plants are candidate for the Pre F/S. The study flow for the Pre F/S can be simplified as shown below, because these power plants are interconnected to the national transmission line network system and their output is large.

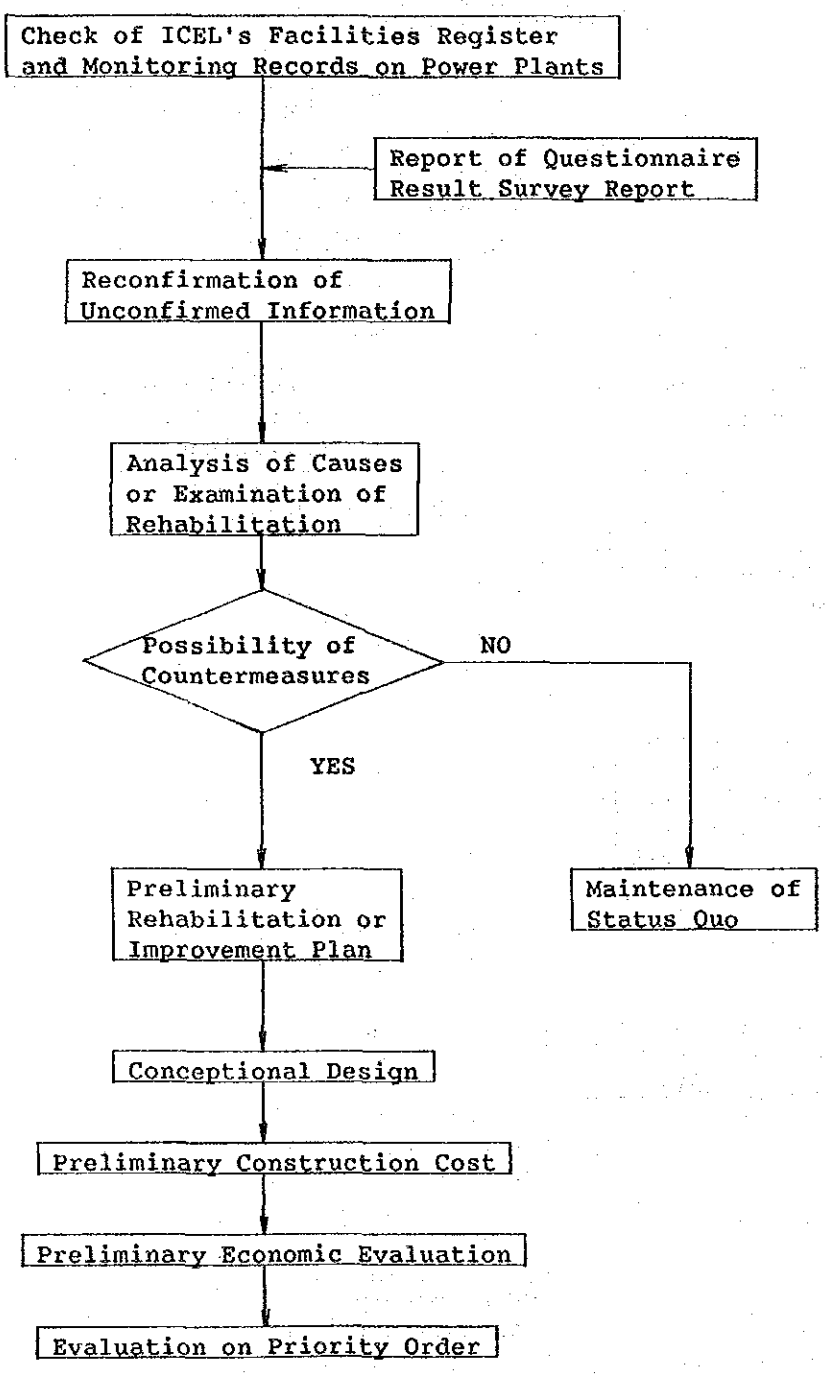

Fig. 2.2 Study Flow for Thermal Power Plants

2.3 Study Flow for Hydraulic Power Plants

In the course of the Pre-F/S for the rehabilitation of hydrualic power plants, an examination and classification as shown in Fig. 2.3 are necessary in order to determine which proposed power plants would fall under the rehabilitation plan and which ones fall under the improvement plan to increase power capacity.

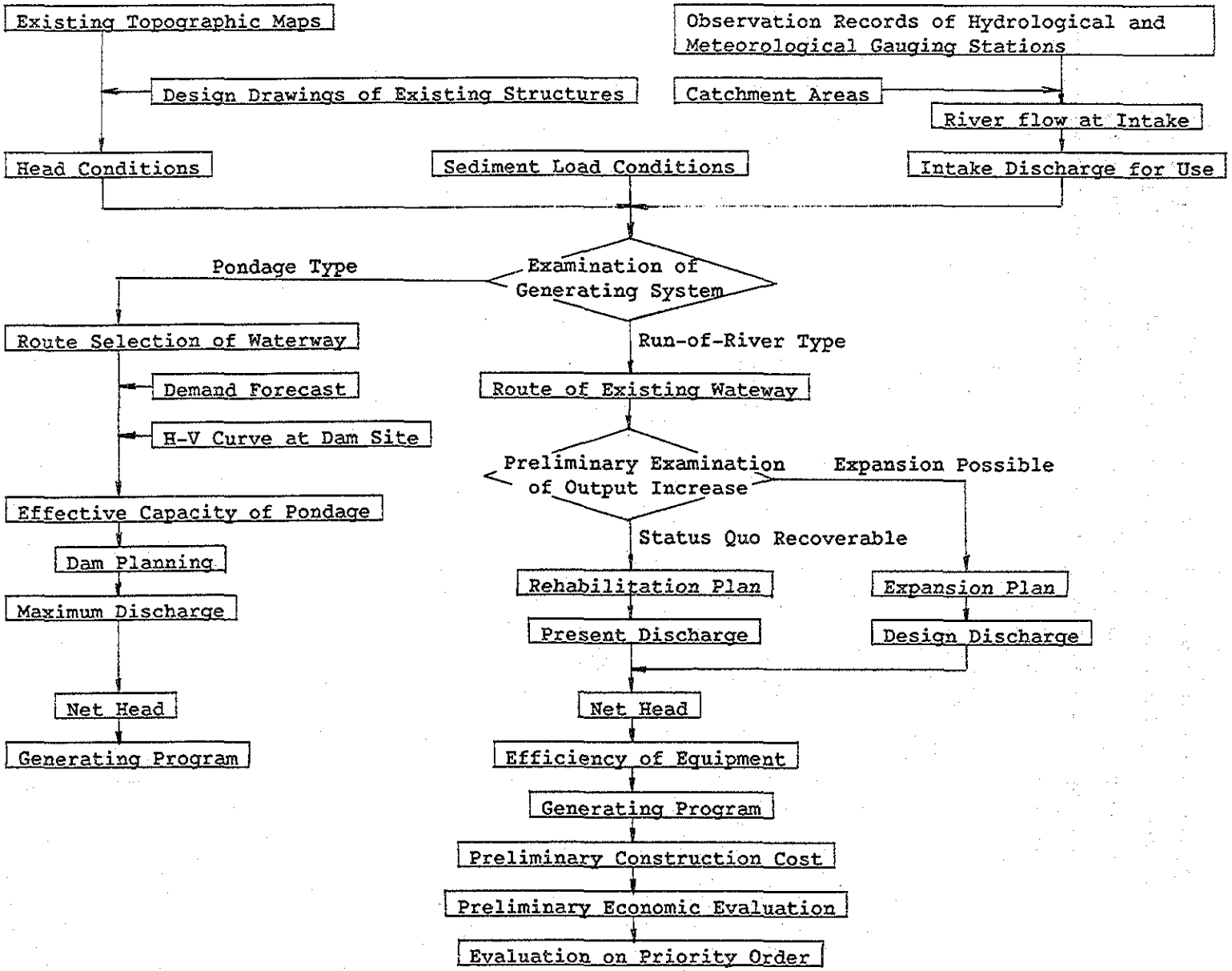

Fig. 2.3 Study Flow for Run-of-River Type Hydraulic Power Plant

2.4 Study Flow for Diesel Power Plants

For all isolated power plants that are located in three Departments of Nariño, Choco and Meta, a special flow chart as shown in Fig. 2.4 was made to study the rehabilitation, taking the characteristics of localities into account.

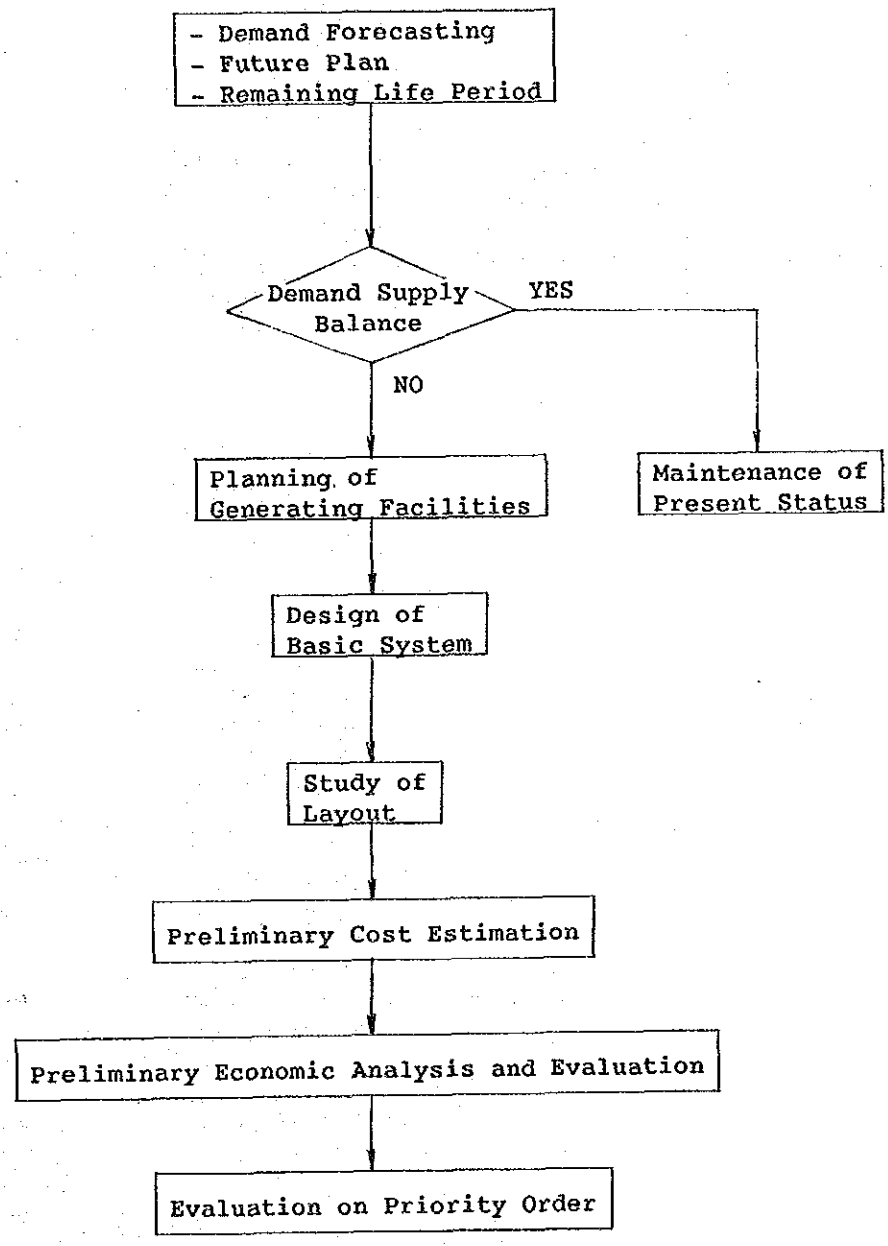

Fig. 2.4 Basic Procedure for Diesel Power Plant

3. Summary of Field Investigation

3.1 Thermal Power Plants

Table 3.1 shows the items to be rehabilitated in three Termopaipa, Termopalenque and Termobarranca Thermal Power Plants which are summarized in accordance with the results of field investigation.

Table 3.1 (1) Items to be Rehabilitated or Improved in Termopaipa

No.	Unit Installed Year	Unit Installed Output (kW)	Unit Available Output (kW)	Items to be Rehabilitated or Improved	Reason
I	1958	33,000	30,000	1) Replacement of air-preheater for boiler	Its efficiency is decreased due to deterioration, so that the frequency of its failure is increased.
				2) Installation of electrostatic precipitator	a. No provision of this device adversely affects the environment. b. Air Pollution Control Law has been established.
II	1974	66,000	66,000	3) Change from pneumatic instrumentation system to electric one	a. Monitoring instrument and automatic control device are either in short supply or do not work properly. b. Procurement of spare parts is difficult.
				4) Increase of turbine output from 66 MW to 74 MW	Output of generator is 74 MW, while that of turbine is 66 MW.
III	1982	74,000	74,000	5) Change of ash handling system	Pressurized conveying system of ash leads to high cost of its maintenance.
Common Problems				6) Ash disposal	Ash from their storage yards flow into the adjacent river, because of insufficient capacity of such storage yard.
				7) Water plant in the cooling ponds	The quantity of cooling water is insufficientand the cost for removing such water plant is high.

Table 3.1 (2) Items to be Rehabilitated or Improved in Termopalenque

Unit No.	Installed Year	Installed Output (kW)	Available Output (kW)	Items to be Rehabilitated or Improved	Reason
IV	1972	15,000	0	Functional recovery through replacement of gas turbine parts (bearings, blades, etc.)	This unit has not been operated since 1980 because of its failure.

Table 3.1 (3) Items to be Rehabilitated or Improved in Termobarranca

Unit No.	Installed Year	Installed Output (kW)	Available Output (kW)	Items to be Rehabilitated or Improved	Reason
III	1978	66,000	40,000	1) Improvement of cooling water system for turbines and generators (from the existing open type to closed cycle type)	The setting basin is not provided for the intake facilities, so that impurities in the water of the river adversely affect the related facilities.
				2) Installation of an automatic cleaning system for condenser	Turbidity in the water of the river is high and the cooling water system is considerably worn out.
				3) Improvement of direct current supply system	Generator circuit-breaker did not operate, and a high reliability can not be secured because of deteriorated uninterruptive power supply system.
				4) Change from pneumatic instrumentation system to electric one	Difficulty in procurement of these spare parts does not enable the control of combustion and turbine with a high reliability.
				5) Installation of event recorder	It takes a lot of time to investigate the cause of failure occurrence.
Common Problem				6) River revetment works	Erosion by river is encountered, because a long-term counterplan is not considered.

3.2 Hydraulic Power Plants

The respective facilities register of hydraulic power plants which is prepared in accordance with the previous study reports and the results of the site reconnaissance is attached in Appendix IV.

3.2.1 Topographic Maps

Aerial photographs of scale 1:25,000 published by IGAC are available, and detailed topographic maps of more larger scale are not kept.

It is possible to prepare aerial photographs of scale 1:5,000 for three power plants of San Cancio, Intermedia and Municipal, because aerial photographs of scale 1:10,000 covering the Chinchina River basin in Caldas Department are possessed by CRAMSA.

3.2.2 Hydrological Gauging Stations

No hydrological gauging stations are located around the following 18 power plants:

Code No.	Power Plant	Department	River
202	La Rebusca	Antioquia	San Roque
203	Calera	Antioquia	Qd. Malena
208	Urrao	Antioquia	Urrao
209	Abejorral	Antioquia	Qd. Las Yeguas
215	Salamina	Caldas	Qd. Frisolera & Qd. Palo
216	Anserma	Caldas	Qd. Cauya
229	Asnazu	Cauca	Asnazu
231	Toribio	Cauca	Isabelilla
234	La Salada	Cundinamarca	Bogota
236	Choachi	Cundinamarca	Palmar
239	La Pita	Huila	Mayo
243	El Calvario	Meta	Qd. Panelo
244	San Juanito	Meta	Guajaro
246	Rio Bobo	Narino	Bobo
247	Rio Sapuyes	Narino	Sapuyes
253	Comoda	Santander	Lenguaruco
254	Servita	Santander	Servita
255	Calichal	Santander	Servita

3.2.3 As-built Drawings

The as-built drawings were lost or missing, and most of design drawings for the existing facilities were not stored in most of hydraulic power plants. For that reason, accurate data and information in regard to catchment area at intake, elevation and head, length of waterway, and so on were not able to obtain.

3.2.4 Generating Equipment

Installed capacities of 27 out of the 62 proposed power plants are less than 1,000 kW.

Generating equipment with large unit output installed in the pondage type Sonson, Rio Negro, Mayo-II, and Palmas power plants or reservoir type Rio Prado power plant are comparatively kept in a good operation and maintenance.

On the other hand, service duration of generating equipment provided on run-of-river type power plants are mostly more than 35 years; such equipment are deteriorated and are in bad operating conditions which cannot be recovered by ordinary repair works.

3.2.5 Priority Order Desired by Public Electric Power Companies

During the field reconnaissance, the priority order of rehabilitation desired by respective electric power companies is as follows:

department	Electric Power Company	Priority Order desired by Electric Power Company						
		1	2	3	4	5	6 or less	No Intention
Antioquia	EADE	Sonson	Tamesis	Caracoli	Rio Abajo	Piedras	Rebusca Calera Urrao Abejorral	—
Caldas Risaralda Quindio	CHEC	Electric Power Company has no intention of determining the priority order and comply with such order as determined by JICA.						Anserma
Cauca	CEDELCA	Inza	Silvia	El Palo	Ovejas	Florida — I	Asnazu Toribio Sajandi Mondomo	—
Cundina-marca	ECSA	Electric Power Company has no intention of determining the priority order.						—
Huila	E. Huila	Rio Iquira — I	Rio Iquira — II	La Pita	La Viciosa	—	—	Fortale-cillas
Meta	EMSA	El Calvario	San Juanito	—	—	—	—	—
Narino	CEDENAR	Julio Bravo	Rio Bobo	Mayo-II	Rio Sapuyes	—	—	—
Santander	ESSA	Palmas	Zaragoza	Cascada	Comoda	—	Calichal Servita	—
Tolima	E.Tolima	Pastales	Mirolindo	Lagunilla	Guali	Rio Recio	Ventanas Prado	—

3.3 Diesel Power Plants

Data and information on facilities and operation of the 17 diesel power plants existing in three departments of Choco, Nariño and Meta are summarized in Table 3.2.

Puerto Lopez diesel power plant in Meta Department and Termotumaco diesel power plant in Narino Department are operated continuously for 24 hours.

The majority of generating equipment are inoperative and are under repair. 64% of these equipment have been operated for more than 10 years.

The following future plans which are substituted for power supply by diesel power plants, are being made:

1) New construction of transmission line (34.5 kV) between Puerto Lopez and Villa Vicencio in Meta Department (1989)

2) New construction of transmission line (230 kV x 1 cct) between Tumaco and Pasto in Nariño Department (1991)

3) New construction of Bahia Solano Hydraulic Power Plant (2.4 MW) in Choco Department (1990)

Table 3.2 Investigation Result of Diesel Power Plant

No.	Department	Power Plant	Property	Unit No.	Capacity (kW)	Condition	Year of Service in	Year of Stop	Fired Hour
1	Choco	Capurgana	ICEL	1	150	OPE.	1985		170
2	Choco	Zapzurro	Municipal	1	17.5	STOP	1958	1988	ND
3	Choco	Acandi	ICEL	1	275	STOP	1981	1986	5,238
4	Choco	Unguia	ICEL	1	150	OPE.	1980		4,010
5	Choco	Bahia Solano	E.Choco	1	100	STOP	1978	1988	ND
	Choco	〃	ICEL	2	140	STOP	1972	1988	10,223
6	Choco	Nuqui	ICEL	1	150	STOP	1980	1988	1,900
7	Choco	Pizarro (*)		1	120	OPE.	ND		ND
8	Choco	Villa Claret (*)		1	25	STOP	1983	ND	ND
9	Choco	Sipi (*)		1	80	OPE.	ND		ND
10	Narino	Termotumaco	ICEL	1	3,000	OPE.	1977		52,178
	Narino	〃	ICEL	2	3,000	OPE.	1978		62,605
	Narino	〃	ICEL	3	2,000	STOP	1965	1988	8,109
	Narino	〃	ICEL	4	2,000	OPE.	1965		3,256
11	Narino	La Playa	Municipal	1	75	STOP	1955	ND	ND
12	Narino	Sala Honda	Municipal	1	60	STOP	1973	ND	ND
	Narino	〃	Municipal	2	150	OPE.	1985	ND	2,729
13	Narino	Baquerias	CEDENAR	1	35	STOP	1981	ND	1,404
14	Narino	Llorente	ICEL	1	120	STOP	1971	1986	15,308
15	Meta	Puerto Lopez	EMSA	1	275	OPE.	1983		8,754
	Meta	〃	ICEL	2	245	OPE.	1971		65,415
	Meta	〃	EMSA	3	930	OPE.	1987		3,532
	Meta	〃	EMSA	4	240	STOP	1983	1987	5,988
	Meta	〃	EMSA	5	240	OPE.	1985		6,899
	Meta	〃	ICEL	6	145	OPE.	1971		73,459
	Meta	〃	ICEL	7	145	OPE.	1971		79,536
16	Meta	San Juan de Arama	Municipal	1	150	STOP	ND	1980	ND
	Meta	〃	ICEL	2	145	STOP	1971	1987	13,040
	Meta	〃	Municipal	3	230	OPE.	1986		130
17	Meta	Vista Hermosa (*)	Municipal	1	230	OPE.	1984		4,799
	Meta	〃	Municipal	2	225	OPE.	1955		

Note : Data Marked with (*) is based on the information from ICEL

ND : No Data

OPE : In Operation

STOP : Stopped

4. Rehabilitation Plan of Thermal Power Plants

4.1 Rehabilitation of Termopaipa Power Plant

The major countermeasures on this power plant are to rehabilitate or improve #2 unit, to increase the output of turbine for #2 unit from 66 MW to 74 MW, and to change from pneumatic instrumentation system to electronic one.

It is also a main subject to solve the insufficient capacity at the ash-storage yard, which will become essential in the near future.

These countermeasures to be taken are as follows.

(1) Output increase of turbine unit #2 (from 66 MW to 74 MW)

Based on consultation between ICEL group and supplier of the existing turbines, the plan for modification of the turbine itself shall be drafted up and then the turbine and feed water heaters for boiler shall be replaced by new ones.

Preliminary modification cost is estimated at US$4.32 million, and the modification cost per output is estimated at US$540/kW.

(2) Change from pneumatic instrumentation system to electric one

The automatic combustion control system for boiler is replaced with a new one because it malfunctioned since start of commercial operation.

The change of instrumentation system would entail the following repair works:

- Replacement of signal oscillators
- Modification of pneumatic piping
- Addition of control power
- Cabling
- Additional installation of relays, power source and control panels

The cost for changing the instrumentation system is approximately estimated at US$1.3 million, and the cost per installed capacity is around US$18.4/kW.

(3) Solution of insufficient capacity of ash-storage yard

If a cooling tower is installed and open type cooling water system is modified to closed cycle type one, the existing cooling ponds on both banks of Chicamocha river are considered to be changed to a new coal ash-storage yard. (Refer to Fig. 4.1)

The closed-cycle type cooling towers are designed under the following conditions.

- Capacity of cooling tower : 19,000 ton/hour
- Temperature of cooling water: 28°C
- Outline specification of circulating water pumps

	Capacity	Head
for Unit #1	6,500 m^3/h	x 32 m
for Unit #2	12,200 m^3/h	x 30 m
for Unit #3	12,200 m^3/h	x 30 m

Preliminary modification cost which stems from the changed cooling system is estimated as follows: Total modification is US$7.84 million and cost per installed capacity is US$46.4/kW.

Preliminary Installation Cost of Cooling Tower System (10^6 US$)

Equipment	Installation	Civil Works	Total
6.4	0.64	0.8	7.84

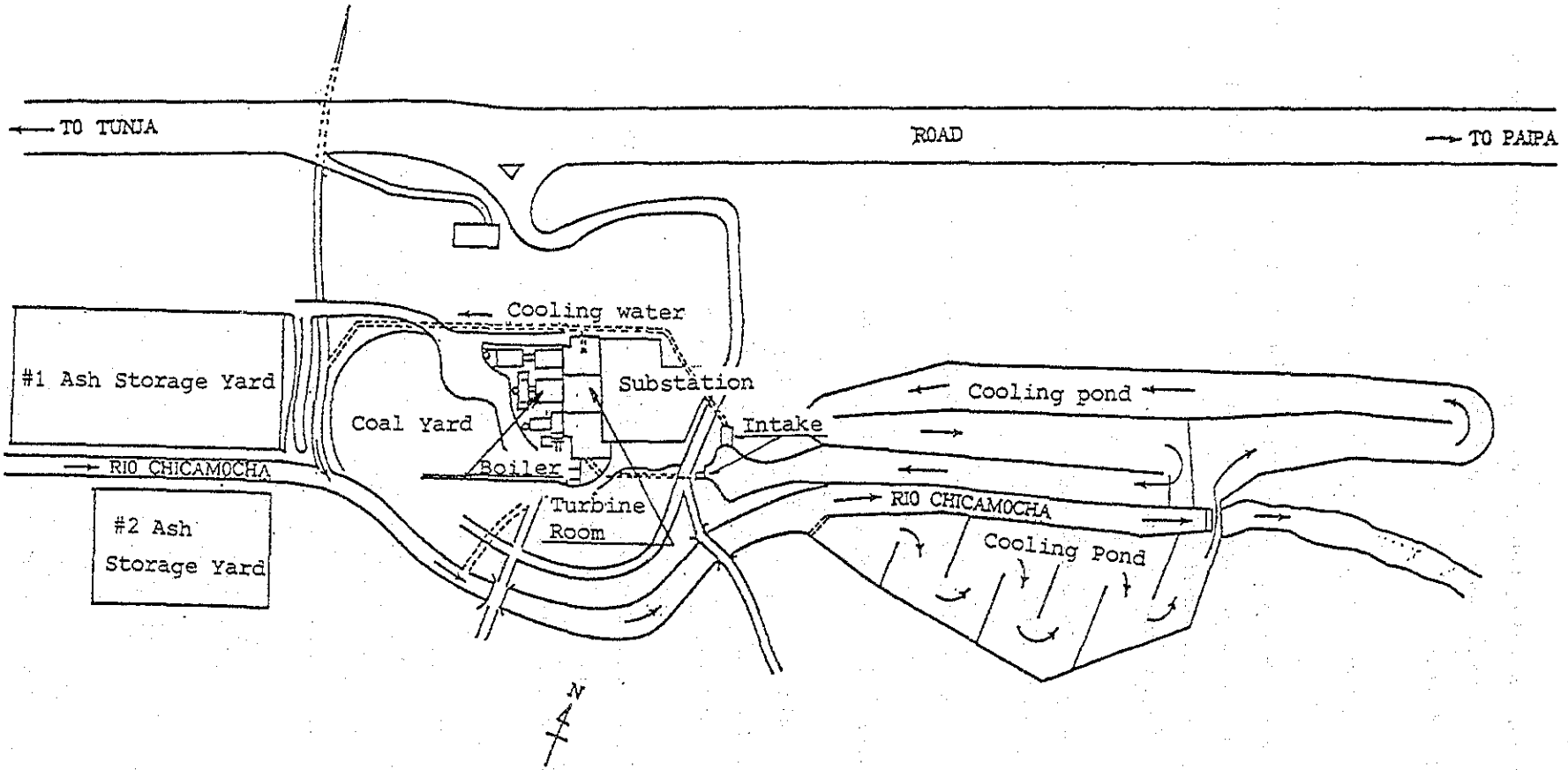

Fig. 4.1 General Layout of Termopaipa Power Plant

4.2 Rehabilitation of Termopalenque Power Plant

In order to improve #4 gas turbine generating unit, it is necessary to inspect in detail not only turbine itself but also all equipment. The items to be inspected are as follows:

(1) Mechanical equipment (detailed items omitted)
(2) Electrical equipment and control devices (detailed items omitted)
(3) Auxiliary equipment (detailed items omitted)

An improvement work cost is assumed to be US$4.64 million at the present stage and the cost per kW is estimated at US$304/kW. This is an approximately by estimated cost and there is no significant difference between new construction cost and improvement cost, because the new construction cost of gas turbine generator having output of 15,000 kW class is estimated at US$366/kW.

4.3 Rehabilitation of Termobarranca Power Plant

#3 unit is to be rehabilitated. The major problem to be solved is damage of equipment due to high turbidity in the cooling water. Turbid water of the river is used as the cooling water.

Therefore, the following two countermeasures are taken to solve the above-mentioned problems.

(1) Open type cooling water system for turbine and generator is changed to closed type one.

This countermeasure has already been examined by ICEL group themselves.

(2) Improvement of automatic condenser-cleaning system

The existing condenser room shall be modified, and three automatic changeover valves shall be provided to control the cooling water of 6,000 m^3/h.

These automatic changeover valves are designed to be opened or closed automatically by using water-pressure difference which generates on both sides of outlet and inlet of condenser.

Preliminary improvement cost is estimated at US$488 thousand, and the cost per output is of US$7.36/kW. If this improvement has been made, the output increase is estimated to be approx. 1 to 2%, and this improvement is useful for improving the thermal efficiency.

5. Rehabilitation Plan of Hydraulic Power Plants

Process of the study for rehabilitation of hydraulic power plants is summarized in the comparison chart as attached hereto.

5.1 Classification of Proposed Power Plants

Prior to formulating the rehabilitation plan, the 62 hydraulic power plants were classified according to the following screening patterns:

Group I : Run-of-River Type Power Plants (57 power plants)

(a) that are kept under the present condition,
(b) that are rehabilitated to the rated output,
(c) that are improved to more than the rated output,
(d) that have been ready for the expansion,
(e) that are expected to be expanded by changing the generating type.

Group - II: Pondage or Reservoir Type Power Plants (5 power plants)

(a) that are kept under the present condition,
(b) that have been ready for the expansion
(c) that are expected to increase the output by expanding.

Power plants for which the rehabilitation plan and conceptional design are conducted in the stage of the Pre F/S belong to (b) and (c) of Group I.

5.2 Candidate Power Plants for Rehabilitation Plan

38 out of 62 power plants are excluded from those requiring the formulation of the rehabilitation plan because of the following realistic reasons.

R-1)	power plants that has already been under repair works	5
R-2)	power plants that are relinquished by public electric companies	1
R-3)	power plants in which ICEL group does not have water right	4
R-4)	power plants in which the river improvement works are included	1
R-5)	power plants for which the feasibility study has already been conducted	5
R-6)	power plants that are maintained in favorable operating conditions	11
R-7)	power plants whose priority order for the rehabilitation is evaluated to be low by the public electric companies	9
R-8)	power plants that are apparently judged to be improper for the rehabilitation as a result of the field reconnaissance	2
	Total	38

Table 5.1 shows the candidate power plants for the rehabilitation plan.

Table 5.1 Candidate Power Plants for Rehabilitation

Code No.	Power Plant	Department	Operation State			River
			Rated Output P_1 (kW)	Available Output Pe (kW)	Pe/P_1 (%)	
201	Caracoli	Antioquia	3,200	2,300	72	Nus
204	Rio Abajo	Antioquia	1,000	600	60	Negro
205	Piedras	Antioquia	458	250	53	Piedras
210	P. Guillermo	Boyaca	1,280	0	0	Suarez
211	San Cancio	Caldas	2,320	1,750	75	Chinchina
212	Intermedia	Caldas	1,120	900	80	Chinchina
213	Municipal	Caldas	2,112	1,400	66	Chinchina
219	Santa Rosa	Risaralda	450	139	31	San Eugenio
221	Bayona	Quindio	1,008	159	16	Quindio
222	Campestre	Quindio	1,120	62	6	Quindio
223	La Union	Quindio	1,000	0	0	Quindio
227	Silvia	Cauca	604	100	17	Piendamo
228	Ovejas	Cauca	900	650	72	Ovejas
232	Florida-I	Cauca	2,300	0	0	Cauca
233	La Vuelta	Choco	2,000	500	25	Andagueda
237	Apulo	Cundinamarca	3,000	0	0	Bogota
238	La Viciosa	Huila	225	0	0	Qd. Viciosa
241	Rio Iquira-I	Huila	4,320	2,230	52	Iquira
242	Rio Iquira-II	Huila	2,400	700	29	Iquira
248	Julio Bravo	Nariño	1,500	0	0	Pasto
251	Zaragoza	Santander	1,560	800	51	Surata
256	Guali	Tolima	1,048	0	0	Guali
258	Mirolindo	Tolima	3,600	1,000	28	Combeima
261	Lagunilla	Tolima	452	0	0	Lagunilla

5.3 Rehabilitation Plan

The main contents of this rehabilitation plan are to replace generating equipment whose functions are stopped or drastically reduced, owing to the fact that the duration of their service is extended and such equipment are deteriorated. This plan also includes the rehabilitation of power plants which are stopped by damaged or worn penstocks, or collapsed headraces.
It is necessary to replace or rehabilitate such facilities as gates, values and screens which are incidental to waterway structures, because they are deteriorated and do not function properly.
Places requiring the rehabilitation of the waterway between diversion weir and surge tank are indicated in Table-1 attached to Summary. In case that the candidate power plants are improved to more than the rated output, the increase of design discharge or effective head would entail the improvement of headraces and penstocks.

The conceptional design for the rehabilitation plan was conducted according to the following study items.

(1) Hydrological regime

Flow-duration curves of rivers in the surrounding area of the candidate power plants are shown in the Appendix IV. These duration curves are tentatively prepared on the basis of daily or monthly record observed for the past three years.

(2) Available discharge

The available discharge for run-of-river type power plants is studied by using the tentative flow-duration curve and characteristics of plant factor. The range of plant factors adopted is around 70 to 80% and the utilization factor of river flow is in a range of 50 to 80%, depending on the hydrological regime.

(3) Selection of types of turbines

Turbines are appropriately selected from among five typical types of Francis, Pelton, Cross Flow, Tubler and Kaplan according to the available discharge and head of each candidate power plant.

(4) Conceptional design of main structures

As shown in the attached drawings, the headrace structures are classified into the following two groups according to the available discharge in order to compare and examine the rehabilitation work cost, and the standard design for such structures is conducted to standardize type, shape and dimensions of structures.

Group A is the power plants that utilize comparatively a great volume of discharge, and Group B is the small-scale power plants with simple structures.

(5) Preliminary estimation of rehabilitation cost

Preliminary rehabilitation cost which is broken down into 1) mechanical and electrical equipment, 2) penstock and 3) civil and architectural works is estimated in Table 5.2.

Table 5.2 Preliminary Estimation Cost

Code No.	Power Plant	Rehabilitation to Nominal Capacity (10^6 US$)				Prospected More Than Nominal Capacity (10^6 US$)			
		Mechanical & Electrical Equipments	Penstock Works	Civil Works	Total	Mechanical & Electrical Equipments	Penstock Works	Civil Works	Total
201	Caracoli	2.93	0	0.94	3.93	-	-	-	-
204	Rio Abajo	1.93	0	0.69	2.62	-	-	-	-
205	Piedras	1.01	0.07	0.56	1.64	-	-	-	-
210	P. Guillermo	2.05	0.16	0.4	2.61	-	-	-	-
211	San Cancio	2.35	0	1.2	3.55	-	-	-	-
212	Intermedia	-	-	-	-	2.35	0.26	0.98	3.59
213	Municipal	-	-	-	-	3.01	0	1.38	4.39
219	Santa Rosa	0.93	0.13	0.7	1.76	-	-	-	-
221	Bayona	0.94	0.11	0.8	1.85	-	-	-	-
222	Campestre	2.11	0.07	0.97	3.15	-	-	-	-
223	La Union	0.98	0.08	1.1	2.16	-	-	-	-
227	Silvia	1.24	0	0.03	1.27	2.9	0.07	1.49	4.46
228	Ovejas	2.88	0.1	1.14	4.12	-	-	-	-
232	Florida-I	3.06	0	2.17	5.23	-	-	-	-
233	La Vuella	4.25	0.06	1.76	6.07	12.76	0.25	6.18	19.19
237	Apulo	5.13	0.1	0.84	6.07	-	-	-	-
238	La Viciosa	0.56	0.06	0.4	1.02	-	-	-	-
241	Rio Iquira-I	0.6	0.08	3.72	4.4	-	-	-	-
242	Rio Iquira-II	0.2	0	0.06	0.26	-	-	-	-
248	Julio Bravo	4.11	0.22	0.76	5.09	4.03	0.26	1.44	5.73
251	Zaragoza	2.49	0.14	1.8	4.43	4.45	0.23	3.65	8.33
256	Guali	2.7	0.03	1.43	4.16	6.67	0.06	5.3	12.03
258	Mirolindo	4.69	0	3.16	7.85	-	-	-	-
261	Lagunilla	1.1	0.1	0.3	1.5	6.47	0.52	0.47	7.46

6. Rehabilitation Plan of Diesel Power Plants

Termotumaco Diesel Power Plant is the candidate for the rehabilitation considering that the imbalance between peak demand and present installed capacity must be solved, and the replacement of the existing deteriorated #3 and #4 units is timely.

Regarding the realization of the rehabilitation plan on this plant, it is necessary to take into account the completion date of a new 230 kV transmission line connected between Pasto and Tumaco city.

6.1 Rehabilitation Plan of Termotumaco Diesel Power Plant

It seems necessary to increase the installed capacity in consideration of the peak demand forecasted two or three years hence from now, in the event the peak demand continues at the present average annual increase rate of about 9%.

An outline of the expansion scheme is as follows:

(1) Space and fuel supply

An adequate space for the expansion is available at the site of the existing power plant. The existing fuel tanks have sufficient capacity.

(2) Outline specification for facilities to be expanded

- Number of diesel generator : 2
- Rated output : 3,000 kW
- Voltage : 4,160 V
- Frequency : 60 Hz
- Phase : 3
- Cooling system : Closed type
- Fuel : Marine diesel oil

7. Priority Order of Candidate Power Plants for F/S

7.1 Evaluation on Priority Order of Thermal Power Plants

(1) Rehabilitation items excluded from evaluation

The following three items are excluded from the evaluation on priority order, because these items have been investigated and examined by ICEL group.

- Change of ash handling system of #3 unit on Termopaipa Power Plant
- Removal of water plant growing in cooling ponds on Termopaipa Power Plant
- Improvement of cooling system for turbine oil and generator of #3 unit on Termobarranca Power Plant

The rehabilitation items of #1 unit on Termopaipa Power Plant may be excluded from such evaluation, because the duration of its service is nearly 29 years.

Revetment work of the Magda Lena River on Termobarrance Power Plant is also excluded because it has no connection with rehabilitation of generating equipment.

(2) Ranking on rehabilitation items

The remaining rehabilitation or improvement items are examined by using 3-point ranking method in order to evaluate contribution to power increase, effects on operation, maintenance and control, urgency of rehabilitation and degree of difficulty in rehabilitation as shown in Table 7.1.

As a result of 3-point ranking, the following four items are evaluated to be high.

1) Increase of turbine output (from 66 to 74 MW) for Termopaipa #2 unit

2) Securing of site for coal ash storage yard for Termopaipa
3) Installation of automatic condenser-cleaning system for Termobarranca #3 unit
4) Recovery of function by replacement of gas turbine parts for Termopalenque #4 unit

Table 7.1 Rating in Priority Order of Thermal Power Plants

Thermal Power Plant	Unit No.	Installed Capacity (MW)	Installed Year	Rehabilitation or Improvement Items	Evaluation Items: Increase of Output	Simplicity of Operation, Maintenance & Control	Urgency of Rehabilitation	Degree of Difficulty in Rehabilitation	Total
Termopaipa	#2	66	1974	Change from penumatic instrumentation system to electric one	1	2	2	1	6
				Increase of turbine output (from 66 to 74 MW)	3	1	3	3	10
	#1, #2, #3			Securing of site for coal ash storage yard	2	2	3	1	8
Termopalenque	#4	15	1972	Recovery of function by replacement of gas turbine parts	3	1	3	1	8
Termobarranca	#3	74	1978	Installation of automatic condenser-cleaning system	2	3	2	2	9
				Improvement of direct current supply system	1	2	2	2	7
				Change from penumatic instrumentation system to electric one	1	2	2	1	6
				Installation of event recorder	1	2	2	1	6

(3) Technical evaluation on countermeasures

Countermeasures for the remaining rehabilitation or improvement items may be divided into the following three classes from technical point of view.

Class- A : Items that are solved in the stage of Pre F/S

Class- B : Items that are solved by ICEL group themselves following Pre F/S

Class- C : Items requiring further detailed study and investigation in order to solve entirely

Table 7.2 Countermeasures for Rehabilitation or Improvement Items

Power Plant	Unit No.	Rehabilitation or Improvement Items	Technical Point of View		
			A	B	C
Termopaipa	#1	Replacement of air-preheater for boiler	o		
Termopaipa	#1	Installation of electrostatic precipitator	o		
Termopaipa	#1, #2	Change from pneumatic instrumentation system to electric one		o	
Termopaipa	#2	Increase of turbine output		o	
Termopaipa	#3	Change of ash disposal system	o		
Termopaipa	#1, #2, #3	Change of cooling water system			o
Termopaipa	#1, #2, #3	Removal of water plant in the cooling ponds	o		
Termopalenque	#4	Functional recovery by replacement of gas turbine parts		o	
Termobarranca	#3	Improvement of cooling system	o		
Termobarranca	#3	Installation of condenser-cleaning system	o		
Termobarranca	#3	Improvement of direct current supply system	o		
Termobarranca	#3	Change from pneumatic instrumentation system to electric one		o	
Termobarranca	#3	Installation of event recorder	o		
Termobarranca	#3	River revetment work		o	

(4) Evaluation on priority order

Based on the result of study of the above items (2) and (3), the priority order of candidate thermal power plants is as follows:

1 Termopaipa
2 Termopalenque
3 Termobarranca

7.2 Evaluation on Priority Order of Hydraulic Power Plants

Among the 62 hydraulic power plants proposed for Pre F/S, 24 ones have been selected as the rehabilitation plan.

The following case studies for the rehabilitation plan of the above 24 plants were conducted:

Case-(1): to be rehabilitated to the rated output ..... 16 plants
Case-(2): to be improved to more than rated output ..... 2 plants
Case-(3): both cases of the above ..... 6 plants

(1) Power plants excluded from priority evaluation

1) The following two power plants were excepted from the evaluation on priority order, because the ownership of these plants are not transferred to ICEL.

Code No.	Power Plant	Department	Installed Capacity (kW)	Property
233	La Vuelta	Choco	2,000	Choco Mining Company
237	Apulo	Cundinamarca	3,000	Private Cement Company

2) The following three power plants which are presently owned by municipalities and where a public electric power company will be established in 1989 were excluded from the evaluation on priority order.

Code No.	Power Plant	Department	Installed Capacity (kW)
221	Boyana	Quindio	1,008
222	Campestre	Quindio	1,120
223	La Union	Quindio	1,000

(2) Comparison of construction cost

As an index for comparing the economical efficiency of the rehabilitation plan, a construction unit price method is applied. This is the method for comparing the construction cost per output (kW) and annually generated energy (kWh). This annualy generated energy is calculated using the generating output and discharge plant factor.

Comparison of construction cost between 22 power plants to be rehabilitated upto the rated output and 8 power plants to be improved to more than the rated output is as follows:

Table 7.3 Construction Cost for Rehabilitation

Code No.	Power Plant	Department	Rated Output Pl (kW)	Rehabilitated Output Pr (kW)	Construction Cost Per Pr (10^3US$/kW)	Rank	Construction Cost Per kWh (US$/kWh)	Rank
201	Caracoli	Antioquia	3,300	1,000	4.0	12	0.14	2
204	Rio Abajo	Antioquia	990	390	6.8	22	0.31	10
205	Piedras	Antioquia	570	320	5.2	18	0.35	11
210	P. Guillermo	Boyaca	1,100	1,100	2.4	4	0.29	7
211	San Cancio	Caldas	2,600	850	4.2	14	0.22	4
219	Santa Rosa	Risaralda	510	371	4.8	16	0.42	20
221	Bayona	Quindio	580	421	4.5	15	0.39	18
222	Campestre	Quindio	1,000	931	3.4	11	0.38	15
223	La Union	Quindio	840	840	2.6	5	0.31	9
227	Silvia	Cauca	360	260	4.9	17	0.43	21
228	Ovejas	Cauca	1,300	650	6.4	21	0.38	16
232	Florida-I	Cauca	2,400	2,400	2.2	2	0.26	5
233	La Vuelta	Choco	2,000	1,500	4.1	13	0.37	14
237	Apulo	Cundinamarca	2,700	2,700	2.3	3	0.30	8
238	La Viciosa	Huila	170	170	6.0	19	0.72	22
241	Rio Iquira-I	Huila	3,700	1,470	3.0	7	0.14	2
242	Rio Iquira-II	Huila	1,900	1,200	0.3	1	0.02	1
248	Juliuo Bravo	Nariño	1,800	1,800	2.9	6	0.34	11
251	Zaragoza	Santander	1,500	700	6.4	20	0.35	13
256	Guali	Tolima	1,300	1,300	3.3	10	0.39	18
258	Mirolindo	Tolima	3,500	2,500	3.2	8	0.27	6
261	Lagunilla	Tolima	470	470	3.2	9	0.38	16

Table 7.4 Construction Cost for Improvement

Code No.	Power Plant	Department	Rated Output Pl (kW)	Rehabilitated Output Pr (kW)	Construction Cost Per Pr (10^3US$/kW)	Rank	Construction Cost Per kWh (US$/kWh)	Rank
212	Intermedia	Caldas	2,500	1,600	2.3	3	0.23	3
213	Municipal	Caldas	3,500	2,100	2.1	2	0.20	1
227	Silvia	Cauca	1,700	1,600	2.8	6	0.37	6
233	La Vuelta	Choco	7,500	7,000	2.8	5	0.37	6
248	Julio Bravo	Nariño	2,300	2,300	2.5	4	0.30	4
251	Zaragoza	Santander	3,500	2,700	3.1	8	0.36	5
256	Guali	Tolima	4,300	4,300	2.8	7	0.40	8
261	Lagunilla	Tolima	4,300	4,300	1.8	1	0.21	2

(3) Selection of candidate power plants for F/S

Power plants whose construction cost per output (kW) and annually generated energy (kWh) is low were selected as the candidate ones for F/S with consideration given to the following points:

(a) To be rehabilitated upto the rated output
- Power plants whose output to be rehabilitated exceeds 1,000 kW.
- Construction cost per output to be rehabilitated is less than US$2,500/kW
- Construction cost per annually generated energy (kWh) is around US$0.3/kWh.

(b) To be improved to more than the rated output
- Construction cost per output is less than US$3,000/kW.
- Construction cost per annually generated energy is around US$0.3/kWh.

Based on the result of the above selection, the following power plants are selected.

- Candidate power plants to be rehabilitated upto the rated output:

Power Plant	Department	Rehabilitated Output (kW)
P. Guillermo	Boyaca	1,000
Rio Iquira-II	Huila	1,200
Florida-I	Cauca	2,400

- Candidate power plants improved to more than the rated output:

Power Plant	Department	Output Increased (kW)
Intermedia	Caldas	1,600
Municipal	Caldas	2,100
Julio Bravo	Nariño	2,300
Lagunilla	Tolima	4,300

Both Intermedia and Municipal Power Plants in Caldas Department form a group with San Cancio Power Plant which is located upper stream of them. These three power plants are picked up as one package. And also Rio Iquira-I and II Power Plants are picked up as one package because the Rio Iquira-II has been operated by using the discharge of Rio Iquira-I.

Caracoli Power Plant (Antioquia Department) whose construction cost per annually generated energy is low and Zaragoza Power Plant (Santander Department) whose output is large are added to the above candidate ones, and the following power plants were selected as the candidate for F/S.

Table 7.5 Candidate Hydraulic Power Plants for F/S

Code No.	Power Plant	Department	Grade	Present Installed Capacity (kW)	Output to be Rehabilitated or Increased (kW)	Rehabilitation Work Cost (10^6 US$)
201	Caracoli	Antioquia	1)	3,200	1,000	3.9
210	P. Guillermo	Boyaca	1)	1,280	1,100	2.6
211	San Cancio	Caldas	1)			
212	Intermedia	Caldas	2)	5,552	4,550	11.5
213	Municipal	Caldas	2)			
232	Florida-I	Cauca	1)	2,300	2,400	5.2
241	Rio Iquira-I	Huila	1)	6,720	2,670	4.7
242	Rio Iquira-II	Huila	1)			
248	Julio Bravo	Nariño	2)	1,500	2,300	5.7
251	Zaragoza	Santander	2)	1,560	2,700	8.3
261	Lagunilla	Tolima	2)	452	4,300	7.5
	Total			22,564	21,020	49.4

1) Rehabilitation 2) Improvement

7.3 Recommendation for Project Formation of Hydraulic Power Plant

The following three power plants are not included in the proposed ones for the rehabilitation in this pre F/S. However, change of the existing facilities in the two power plants would lead to expectation of drastic increase in output. For verification of this realization, basic data such as topographic and geologic conditions, discharge record should be collected and kept in constant readiness.

Code No.	Power Plant	Rated Output (kW)	Available Output (kW)	Expected Rated Output (kW)	Basic Data to be Kept in Readiness
207	Tamesis	1,508	1,140	6,000 (output increase by effective use of head)	1) Aerial photograph for the Rio Frio River basin (S=1:5000) 2) Discharge gauging record at intake
230	Inza	360	Under repair	16,000 (output increase by increase of intake water)	1) Topographic survey for Power Plant 2) Geologic condition on the left bank of the Ullucos River
246	Rio Bobo	4,730	Under repair	15,000 (output increase by changing to a pondage type power plant)	1) Aerial photograph for the junction of Bobo River basin and the Opongo River (S=1:5000) 2) Water level and discharge record observed at a reservoir in the upper stream 3) Geologic condition on the left bank of the Bobo River

La Vuelta Power Plant (in Choco Department), whose ownership has not been transferred to ICEL, is excluded from the proposed power plants for F/S. However, this power plant is considered to be a promising rehabilitation project because the rehabilitation of the power plant is required in terms of power demand-supply, and a ripple effect for regional development as well as rehabilitation effect could be expected.

8. Translation

The Summary is made both in English and Spanish. In case any discrepancy of translation arises between the two languages, the English version shall be employed.

Table 1 The Summary of the Rehabilitation Plan for 62 Power Plants

CODE NO.	POWER PLANT	PRESENT INFORMATION: Design discharge (m^3/sec)	Net head (m)	Installed capacity (kW) "Po"	Turbine type & No. of unit	Passage year from 1988	Available capacity (kW) "Pe"	Pe / Po x 100 (%)	FACTORS TO BE EXCLUDED FROM PRE FEASIBILITY STUDY: R-1) Already under repairing	R-2) Dismissed by electric company	R-3) Water right is out of jurisdiction	R-4) Necessity of discharge canal improvement	R-5) F/S is executing by others	R-6) Under good operating condition	R-7) Low priority by electric company	R-8) Based on the reconnaissance survey	No hydrology gauging station to be available	JUDGMENT OF PRE-F/S	REHABILITATION PLAN – TO BE REHABILITATED TO THE NOMINAL CAPACITY – GENERATING SCHEME: Design discharge (m^3/sec)	Net head (m)	Plant output (kW)	Annual generating power (GWh)	Turbine type No. of unit	SUBJECT OF REHABILITATION – MECHANICAL & ELECTRICAL EQUIPMENTS: Turbine & generator	Control panel	Switchgear	Transformer	Substation	Penstock	CIVIL WORKS: Dam	Intake	Settling basin	Canal	Reservoir	Gate & screen	Power house	ESTIMATION COST: Mechanical & electrical equipments (M¥)	Penstock works (M¥)	Civil works (M¥)	Total (M¥)	INDICES – Cost per installed capacity: Capacity (¥/kW)	Energy (¥/kWh)	Cost per increased capacity: Capacity (¥/kW)	Energy (¥/kWh)	Cost per installed capacity (US$/kW)	Cost per increasing capacity (US$/kW)	Generating cost (US$/kWh) (See Note)	GENERATING: Design discharge (m^3/sec)	Net head (m)	Plant output
201	CARACOLI	5.0	86.0	3,200	P x 1, F x 1	25-53	2,300	72										YES	5.0	86.0	3,300	27.5	C x 2	O	O	O	O	X	X	O	O	O	X	X	O	O	374	0	117	491	149	18	491	59	1,190	4,000	0.023	—	—	—
202	LA REBUSCA	1.0	90.0	700	P x 2	54-56	470	67							X		X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
203	CALERA	1.0	20.0	160	P x 2	30	64	40							X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
204	RIO ABAJO	2.5	51.0	1,000	P x 2	41	600	60										YES	2.5	51.0	990	8.2	C x 2	O	O	O	O	X	X	O	O	X	X	Δ	Δ	O	241	0	86	327	330	40	838	101	2,640	6,800	0.052	—	—	—
205	PIEDRAS	1.5	49.0	450	F x 2	30-53	250	53										〃	1.5	49.0	570	4.7	C x 1	O	O	O	O	X	O	O	O	O	O	O	O	O	126	9	70	205	360	43	641	77	2,070	5,200	0.056	—	—	—
206	SONSON	1.0	536.0	3,600	P x 1	21	3,600	100					X	X				NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
207	TAMESIS	1.2	167.0	1,508	P x 3	27-48	1,160	77						X				〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
208	URRAO	1.5	70.0	824	F x 2	24	430	52	X						X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
209	ABEJORRAL	1.0	135.0	724	P x 2	28	490	68							X		Δ	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
210	P. GUILLERMO	2.6	58.0	1,280	F x 2	25	0	0										YES	2.6	58.0	1,100	9.2	C x 2	O	O	O	O	X	O	X	X	X	X	O	O	O	256	20	50	326	296	36	296	36	2,370	2,400	0.046	—	—	—
211	SAN CANCIO	5.6	59.75	2,320	F x 1, P x 1	41-59	1,750	75										〃	5.6	59.75	2,600	16.2	C x 2	O	O	O	X	X	X	O	Δ	Δ	Δ	Δ	O	O	294	0	150	444	171	27	522	84	1,360	4,200	0.027	—	—	—
212	INTERMEDIA	5.6	59.01	1,120	P x 1	41	900	80										〃	—	—	—	—	—	O	O	O	X	X	O	X	X	Δ	O	X	O	O	—	—	—	—	—	—	—	—	—	—	—	5.6	59.01	2,5
213	MUNICIPAL	5.6	80.57	2,112	P x 2	43	1,400	66										〃	—	—	—	—	—	O	O	O	O	O	X	O	O	Δ	Δ	Δ	O	O	—	—	—	—	—	—	—	—	—	—	—	5.6	80.57	3,5
214	GUACAICA	4.0	67.8	1,120	F x 1	59	0	0	X									NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
215	SALAMINA	0.4	65.0	280	P x 1	45	140	50							X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
216	ANSERMA	← UNKNOWN	→				0	0		X					X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
217	BELMONTE	6.0	115.0	3,760	P x 2	47	3,300	88						X				〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
218	DOS QUEBRADAS	10.0	113.0	8,500	F x 2	33	8,200	96						X				〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
219	SANTA ROSA	1.2	55.0	450	P x 1, F x 1	61	139	31										YES	1.2	55.0	510	4.2	C x 1	O	O	O	X	X	O	Δ	Δ	O	O	O	O	O	116	16	88	220	431	52	593	71	3,450	4,800	0.068	—	—	—
220	EL BOSQUE	4.0	90.0	2,280	P x 1	59	0	0					X					NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
221	BAYONA	2.5	30.0	1,008	F x 1	36	159	16										YES	2.5	30.0	580	4.8	C x 1	O	O	O	X	X	O	O	O	O	O	O	O	O	118	14	100	232	400	48	551	66	3,200	4,500	0.063	—	—	—
222	CAMPESTRE	2.5	54.0	1,120	F x 1	32	62	6										〃	2.5	54.0	1,000	8.3	C x 2	O	O	O	O	O	O	O	Δ	Δ	Δ	Δ	O	O	264	9	121	394	394	47	420	50	3,150	3,400	0.062	—	—	—
223	LA UNION	2.5	43.0	1,000	F x 1	50	0	0										〃	2.5	43.0	840	7.0	C x 1	O	O	O	X	X	O	O	O	O	O	Δ	O	O	123	10	137	270	321	39	321	39	2,570	2,600	0.050	—	—	—
224	SAJANDI	3.0	104.0	2,480	P x 1, F x 2	28	1,640	66						X	X			NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
225	EL PALO	6.0	24.5	1,440	F x 2	24	1,280	89						X				〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
226	MONDOMO	2.0	29.0	600	F x 2	30	470	78						X	X			〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
227	SILVIA	1.5	31.0	604	F x 2	28	100	17										YES	1.5	31.0	360	3.0	C x 1	O	O	O	O	O	X	X	X	X	X	X	X	X	155	0	4	159	442	53	612	73	3,530	4,900	0.069	7.0	31.0	1,7
228	OVEJAS	7.0	24.5	900	F x 1	49	650	72										〃	7.0	24.5	1,300	10.8	C x 2	O	O	O	O	O	O	Δ	O	X	O	X	Δ	O	360	13	143	516	397	48	794	95	3,170	6,400	0.062	—	—	—
229	ASNAZU	1.0	134.0	450	P x 1	56	300	67							X		X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
230	INZA	0.6	72.0	360	F x 1	17	0	0	X									〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
231	TORIBIO	0.5	13.0	63	UNKNOWN	20	35	55							X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
232	FLORIDA-I	6.5	48.0	2,300	F x 2	32	0	0										YES	6.5	48.0	2,400	20.0	C x 2	O	O	O	O	O	X	Δ	Δ	Δ	O	X	O	O	383	0	271	654	273	33	273	33	2,180	2,200	0.043	—	—	—
233	LA VUELTA	54.0	4.8	2,000	F x 2	72	500	25										〃	54.0	4.8	2,000	16.6	T x 2	O	O	O	O	O	O	Δ	O	—	O	—	O	O	531	8	220	759	380	46	506	61	3,030	4,100	0.059	200.0	4.8	7,5
234	LA SALADA	2.3	15.0	280	F x 1	53	0	0								X	X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
235	RIO NEGRO	13.0	78.2	9,600	F x 2	14	4,500	47				X						〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
236	CHOACHI	1.0	45.0	300	F x 1	34	19	6								X	X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
237	APULO	23.0	15.0	3,000	TUBULAR x 3	41-60	0	0										YES	23.0	15.0	2,700	20.2	T x 2	O	O	O	O	O	O	X	X	X	X	X	O	O	641	13	105	759	281	38	281	38	2,240	2,300	0.044	—	—	—
238	LA VICIOSA	0.5	45.5	225	F x 2	38	0	0										〃	0.5	45.5	170	1.4	C x 1	O	O	O	X	X	O	O	O	O	O	O	O	O	70	7	50	127	747	90	747	90	5,970	6,000	0.117	—	—	—
239	LA PITA	0.75	120.5	1,420	F x 2	15-24	1,060	75						X			X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
240	FORTALECILLAS	2.0	28.0	408	F x 1	20	0	0			X							〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
241	RIO IQUIRA-I	2.5	192.4	4,320	P x 3	27-37	2,230	52										YES	2.5	192.4	3,700	30.8	P x 3	X	O	X	X	X	Δ	X	X	X	X	O	Δ	X	75	10	465	550	149	18	374	45	1,180	3,000	0.023	—	—	—
242	RIO IQUIRA-II	2.5	98.4	2,400	F x 1	34	700	29										〃	2.5	98.4	1,900	15.8	F x 1	X	O	X	X	X	X	X	X	X	X	X	Δ	X	25	0	7	32	17	2	27	3	130	300	0.003	—	—	—
243	EL CALVARIO	0.04	60.0	20	P x 1	4	16	80						X			X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
244	SAN JUANITO	0.10	53.0	20	F x 1	2	20	100						X			X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
245	RIO MAYO-II	12.5	218.0	21,000	F x 3	19	20,000	95						X				〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
246	RIO BOBO	1.8	306.0	4,368	P x 3	32	0	0	X								X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
247	RIO SAPUYES	2.0	107.0	1,856	F x 3	32	780	42							X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
248	JULIO BRAVO	2.0	120.0	1,500	P x 3	46	0	0										YES	2.0	120.0	1,600	15.0	F x 2	O	O	O	O	O	O	O	O	O	Δ	O	O	O	514	28	95	637	354	43	354	43	2,830	2,900	0.055	2.5	120.0	2,
249	MULATO	0.5	50.0	168	F x 1	24	0	0			X							NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
250	PALMAS	17.0	150.0	18,000	F x 4	28-38	13,000	72					X					〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
251	ZARAGOZA	6.5	30.0	1,560	F x 3	40-57	800	51										YES	6.5	30.0	1,500	12.5	C x 2	O	O	O	O	X	Δ	O	O	O	Δ	O	O	O	311	17	225	553	369	44	790	95	2,940	6,400	0.058	15.0	30.0	3,
252	CASCADA	18.8	24.5	3,350	F x 3	25-49	1,300	39					X					NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
253	COMODA	1.3	89.0	880	F x 2, P x 2	34-76	0	0					X				X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
254	SERVITA	0.6	169.5	800	F x 2	25	720	90							X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
255	CALICHAL	1.2	26.0	280	F x 2	38	220	79							X		X	〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
256	GUALI (HONDA)	12.0	13.9	1,048	F x 3	33-62	0	0										YES	12.0	13.9	1,300	10.8	C x 2	O	O	O	O	X	O	O	O	Δ	X	O	O	O	337	4	179	520	400	48	400	48	3,200	3,300	0.063	40.0	13.9	4,
257	RIO RECIO	5.0	100.0	4,000	F x 2	28	1,200	30			X				X			NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
258	MIROLINDO	4.7	97.0	3,600	F x 3	42	1,000	28										YES	4.7	97.0	3,500	29.1	F x 2	O	O	O	O	O	X	O	X	Δ	O	O	O	O	586	0	395	981	280	34	392	47	2,240	3,200	0.044	—	—	—
259	PASTALES	3.87	30.0	840	F x 1	41	0	0	X									NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
260	PRADO	112.0	56.0	51,000	F x 4	14	51,000	100						X				〃	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
261	LAGUNILLA	0.5	120.0	452	P x 2	48	0	0										YES	0.5	120.0	470	3.9	P x 1	O	O	O	O	O	O	O	O	O	O	O	O	O	137	12	37	186	396	48	396	48	3,160	3,200	0.062	2.0	280.0	4,
262	VENTANAS	25.3	28.6	6,000	F x 2	30	2,500	42			X				X			NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Symbol X : factor to be excluded

Symbol X : not available
Symbol Δ : data are used as reference

Symbol O : item to be rehabilitated
Symbol X : item not requiring rehabilitation.
Symbol Δ : item to be partially rehabilitated

bilitation Plan for 62 Power Plants

P_g / P_o × 100 (%)	R-1 Already under repairing	R-2 Dismissed by electric company	R-3 Water right is out of jurisdiction	R-4 Necessity of discharge canal improvement	R-5 F/S is executing by others	R-6 Under good operating condition	R-7 Low priority by electric company	R-8 Based on the reconnaissance survey	No hydrology gauging station to be available	Judgment of Pre-F/S	Design discharge (m³/sec)	Net head (m)	Plant output (kW)	Annual generating power (GWh)	Turbine type no. of unit	Turbine generator	Control panel	Switchgear	Transformer	Substation	Penstock	Dam	Intake	Settling basin	Canal	Reservoir	Gate & screen	Power house	Mechanical & electrical equipments (MY)	Penstock works (MY)	Civil works (MY)	Total (MY)	Cost per installed capacity: Capacity (kY/kW)	Cost per installed capacity: Energy (Y/kWh)	Cost per increased capacity: Capacity (kY/kW)	Cost per increased capacity: Energy (Y/kWh)	Cost per installed capacity (US$/kW)	Cost per increasing capacity (US$/kW)	Generating cost (US$/kWh) (See Note)	Design discharge (m³/sec)	Net head (m)	Plant output (kW)	Annual generating power (GWh)	Turbine type & no. of unit	Mechanical & electrical equipments (MY)	Penstock works (MY)	Civil works (MY)	Total (MY)	Cost per installed capacity: Capacity (kY/kW)	Cost per installed capacity: Energy (Y/kWh)	Cost per increased capacity: Capacity (kY/kW)	Cost per increased capacity: Energy (Y/kWh)	Cost per installed capacity (US$/kW)	Cost per increasing capacity (US$/kW)	Generating cost (US$/kWh) (See Note)
	Factors to be excluded from pre feasibility study										Rehabilitation plan: to be rehabilitated to the nominal capacity — Generating scheme					Subject of rehabilitation: Mechanical & electrical equipments						Civil works							Estimation cost				Indices							To be prospected more than nominal capacity — Generating scheme					Estimation cost				Indices						
72										YES	5.0	86.0	3,300	27.5	C x 2	O	O	O	O	X	X	O	O	O	X	X	O	O	374	0	117	491	149	18	491	59	1,190	4,000	0.023	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
67							X		X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40							X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
60										YES	2.5	51.0	990	8.2	C x 2	O	O	O	O	X	X	O	O	X	X	△	△	O	241	0	86	327	330	40	838	101	2,640	6,800	0.052	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
53										·	1.5	49.0	570	4.7	C x 1	O	O	O	O	X	O	O	O	O	O	O	O	O	126	9	70	205	360	43	641	77	2,870	5,200	0.056	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
100					X	X				NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
77						X				·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
52	X						X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
68							X		△	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										YES	2.6	58.0	1,100	9.2	C x 2	O	O	O	O	X	O	X	X	X	X	O	O	O	256	20	50	326	296	36	296	36	2,370	2,400	0.046	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
73										·	5.6	59.75	2,600	16.2	C x 2	O	O	O	X	X	X	O	△	△	△	△	O	O	294	0	150	444	171	27	522	84	1,360	4,200	0.027	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80										·	—	—	—	—	—	O	O	O	X	X	O	X	X	△	O	X	O	O	—	—	—	—	—	—	—	—	—	—	—	5.6	59.01	2,500	15.6	C x 2	294	32	123	449	180	29	281	45	1,430	2,300	0.028
66										·	—	—	—	—	—	O	O	O	O	O	X	O	O	△	△	△	O	O	—	—	—	—	—	—	—	—	—	—	—	5.6	80.57	3,500	21.8	C x 2	376	0	172	548	157	25	261	42	1,250	2,100	0.024
0	X									NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
50							X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0		X					X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
88						X				·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
96						X				·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
31										YES	1.2	55.0	510	4.2	C x 1	O	O	O	X	X	O	△	△	O	O	O	O	O	116	16	88	220	431	52	593	71	3,450	4,800	0.068	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0					X					NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16										YES	2.5	30.0	580	4.8	C x 1	O	O	O	X	X	O	O	O	O	O	O	O	O	118	14	100	232	400	48	551	66	3,200	4,500	0.063	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6										·	2.5	54.0	1,000	8.3	C x 2	O	O	O	O	O	O	O	△	△	△	△	O	O	264	9	121	394	394	47	420	50	3,150	3,400	0.062	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										·	2.5	43.0	840	7.0	C x 1	O	O	O	X	X	O	O	O	O	O	△	O	O	123	10	137	270	321	39	321	39	2,570	2,600	0.050	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
66						X	X			NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
89						X				·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78						X	X			·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17										YES	1.5	31.0	360	3.0	C x 1	O	O	O	O	O	X	X	X	X	X	X	X	X	155	0	4	159	442	53	612	73	3,530	4,900	0.069	7.0	31.0	1,700	12.0	C x 2	362	9	186	557	328	46	348	49	2,620	2,800	0.051
72										·	7.0	24.5	1,300	10.8	C x 2	O	O	O	O	O	O	△	O	X	O	X	△	O	360	13	143	516	397	48	794	95	3,170	6,400	0.062	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
67							X		X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	X									·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
55							X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										YES	6.5	48.0	2,400	20.0	C x 2	O	O	O	O	O	X	△	△	△	O	X	O	O	383	0	271	654	273	33	273	33	2,180	2,200	0.043	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
25										·	54.0	4.8	2,000	16.6	T x 2	O	O	O	O	O	O	△	O	—	O	—	O	O	531	8	220	759	380	46	506	61	3,030	4,100	0.059	200.0	4.8	7,500	51.8	T x 2	1,595	31	772	2,398	320	46	343	50	2,550	2,800	0.050
0								X	X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
47				X						·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6								X	X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										YES	23.0	15.0	2,700	20.2	T x 2	O	O	O	O	O	O	X	X	X	X	X	O	O	641	13	105	759	281	38	281	38	2,240	2,300	0.044	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										·	0.5	45.5	170	1.4	C x 1	O	O	O	X	X	O	O	O	O	O	O	O	O	70	7	50	127	747	90	747	90	5,970	6,000	0.117	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
75						X			X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0			X							·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
52										YES	2.5	192.4	3,700	30.8	P x 3	X	O	X	X	X	△	X	X	X	X	O	△	X	75	10	465	550	149	18	374	45	1,180	3,000	0.023	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
29										·	2.5	98.4	1,900	15.8	F x 1	X	O	X	X	X	X	X	X	X	X	X	△	X	25	0	7	32	17	2	27	3	130	300	0.003	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
80						X			X	NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
100						X			X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
95						X				·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	X								X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
42							X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										YES	2.0	120.0	1,800	15.0	F x 2	O	O	O	O	O	O	O	O	O	△	O	O	O	514	28	95	637	354	43	354	43	2,830	2,900	0.055	2.5	120.0	2,300	19.1	F x 2	504	32	180	716	311	37	311	37	2,490	2,500	0.049
0			X							NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
72					X					·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
51										YES	6.5	30.0	1,500	12.5	C x 2	O	O	O	O	X	△	O	O	O	△	O	O	O	311	17	225	553	369	44	790	95	2,940	6,400	0.058	15.0	30.0	3,500	23.3	C x 3	556	29	456	1,041	297	45	386	58	2,370	3,100	0.046
39					X					NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0					X				X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
90							X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
79							X		X	·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										YES	12.0	13.9	1,300	10.8	C x 2	O	O	O	O	X	O	O	O	△	X	O	O	O	337	4	179	520	400	48	400	48	3,200	3,300	0.063	40.0	13.9	4,300	30.4	T x 2	834	7	662	1,503	350	49	350	49	2,790	2,800	0.055
30			X				X			NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
28										YES	4.7	97.0	3,500	29.1	F x 2	O	O	O	O	O	X	O	X	△	O	O	O	O	586	0	395	981	280	34	392	47	2,240	3,200	0.044	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0	X									NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
100						X				·	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0										YES	0.5	120.0	470	3.9	P x 1	O	O	O	O	O	O	O	O	O	O	O	O	O	137	12	37	186	396	48	396	48	3,160	3,200	0.062	2.0	280.0	4,300	35.8	P x 2	809	65	59	933	217	26	217	26	1,730	1,800	0.034
42			X				X			NO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Symbol X : factor to be excluded

Symbol X : not available
Symbol △ : data are used as reference

Symbol O : item to be rehabilitated
Symbol X : item not requiring rehabilitation.
Symbol △ : item to be partially rehabilitated

(Note)
Generating Cost (US$/kWh) is Calculated,

$$I = \frac{C \cdot \gamma}{8760 \cdot L}$$

I : Generating Cost (US$/kWh)
C : Construction Cost (US$/kW)
γ : Annual Expense Rate (12 %)
L : Capacity Factor (70 %)

1. Description of the Rehabilitation Project

1. DESCRIPTION OF THE REHABILITATION PROJECT

1.1 Outline of Study Areas

There are 82 study areas which consist of 3 thermal power plants, 62 hydraulic power plants and 17 diesel power plants, as candidate power plants for the pre F/S requested by ICEL are shown in APPENDIX I List of Candidate Power Plants for Pre F/S.

The installed capacity by each power plant is as follows.

- Thermal power plants (including gas turbine power plant)
  - Number of power plants ---------- 3
  - Total installed capacity -------- 254,000 kW

- Hydraulic power plants
  - Number of power plants ---------- 62
  - Total installed capacity -------- 192,416 kW

- Diesel power plants
  - Number of power plants ---------- 17
  - Total installed capacity -------- 14,848 kW

As shown below, the study areas are scattered in the 13 departments (Antioquia, Boyaca, Caldas, Risaralda, Quindio, Cauca, Choco, Cundinamarca, Huila, Meta, Nariño, Santander, Tolima) and one intendency (Putumayo). Location maps of study areas by department are shown in APPENDIX II.

No. of Proposed Small-Scale Power Plants

Department	Power Source			Total
	Thermal	Hydraulic	Diesel	
Antioquia	0	9	0	9
Boyaca	1	1	0	2
Caldas	0	6	0	6
Risaralda	0	3	0	3
Quindio	0	4	0	4
Cauca	0	9	0	9
Choco	0	1	9	10
Cundinamarca	0	4	0	4
Huila	0	5	0	5
Meta	0	2	3	5
Nariño	0	4	5	9
Putumayo	0	1	0	1
Santander	2	6	0	8
Tolima	0	7	0	7
Total	3	62	17	82

1.2 Contents of Study

The contents of this pre F/S conducted on the basis of the S/W and minutes of meetings (hereinafter referred to as M/M) concluded between JICA and ICEL on August 6, 1987 are as follows:

(1) Review of previously conducted study result and existing data

Reviews are made on the questionnaire survey report on the study areas for rehabilitation related to this Pre F/S furnished by ICEL, information on the power demand and supply of the ICEL and public electric power companies, the existing Rehabilitation Plan for Small-scale Power Plants - ICEL Group and other related information.

(2) Selection of candidate power plants for reconnaissance survey

The candidate power plants are selected for reconnaissance survey on the criteria of 1) necessity of rehabilitation, 2) rehabilitation effect, and 3) balance of power demand and supply which are based on the result and data of the above study.

(3) Reconnaissance

For the power plants selected in (2) above, the reconnaissance survey carried out to confirm the plants requiring rehabilitation and to conduct the works as described below and formulation of preliminary rehabilitation plan.

(4) Conceptional design

A conceptional design for the pre F/S areas is conducted on the site on the basis of the above preliminary rehabilitation plan.

(5) Preliminary cost estimation for rehabilitation

The unit prices by kind of works are standardized with reference to data on cost estimation and prices for construction materials, and cost estimation examples collected in Colombia, and a preliminary cost estimate for rehabilitation is conducted on the basis of the above conceptional design.

(6) Preliminary economic analysis and evaluation

A preliminary economic analysis and evaluation are conducted for rehabilitation of the candidate power plants for pre F/S.

(7) Evaluation on priority of candidate power plants

The priority of the candidate power plants for the feasibility study is decided by comprehensive consideration of the results of analyses in the field survey and home work in Japan.

(8) Programming for the feasibility study

Concrete study items, contents and schedule, etc. are programmed for the feasibility study for rehabilitation.

1.3 Study Planning

1.3.1 Basic Procedures for Study

The candidate power plants for the feasibility study were selected on the criteria of 1) necessity of rehabilitation, 2) rehabilitation effect and 3) balance of power supply and demand, and based upon review of various conditions obtained through reconnaissance survey.

The basic work flow for selection of candidate power plants for rehabilitation project is shown in Fig. 1.3.1.

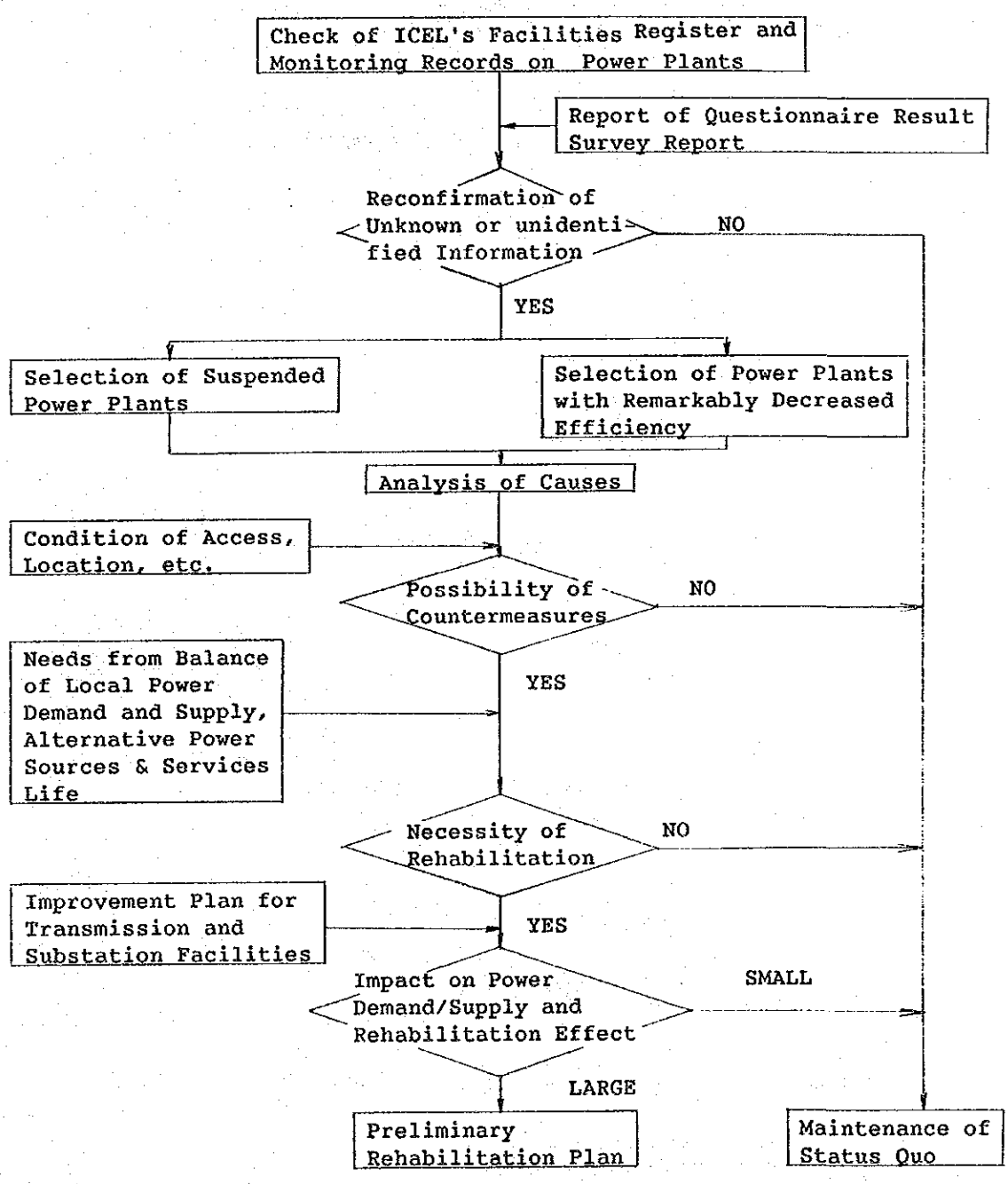

Fig. 1.3.1 Basic Procedures to Select the Candidate Power Plants for Rehabilitation

(1) *Work flow for thermal power plants*

Three Termopaipa, Termopalenque and Termobarranca Thermal Power Plants are study areas. By considering the fact that these power plants have the relatively larger installed capacities and connected to the national power system, the work flow for preparing the rehabilitation plan is simplified as follows:

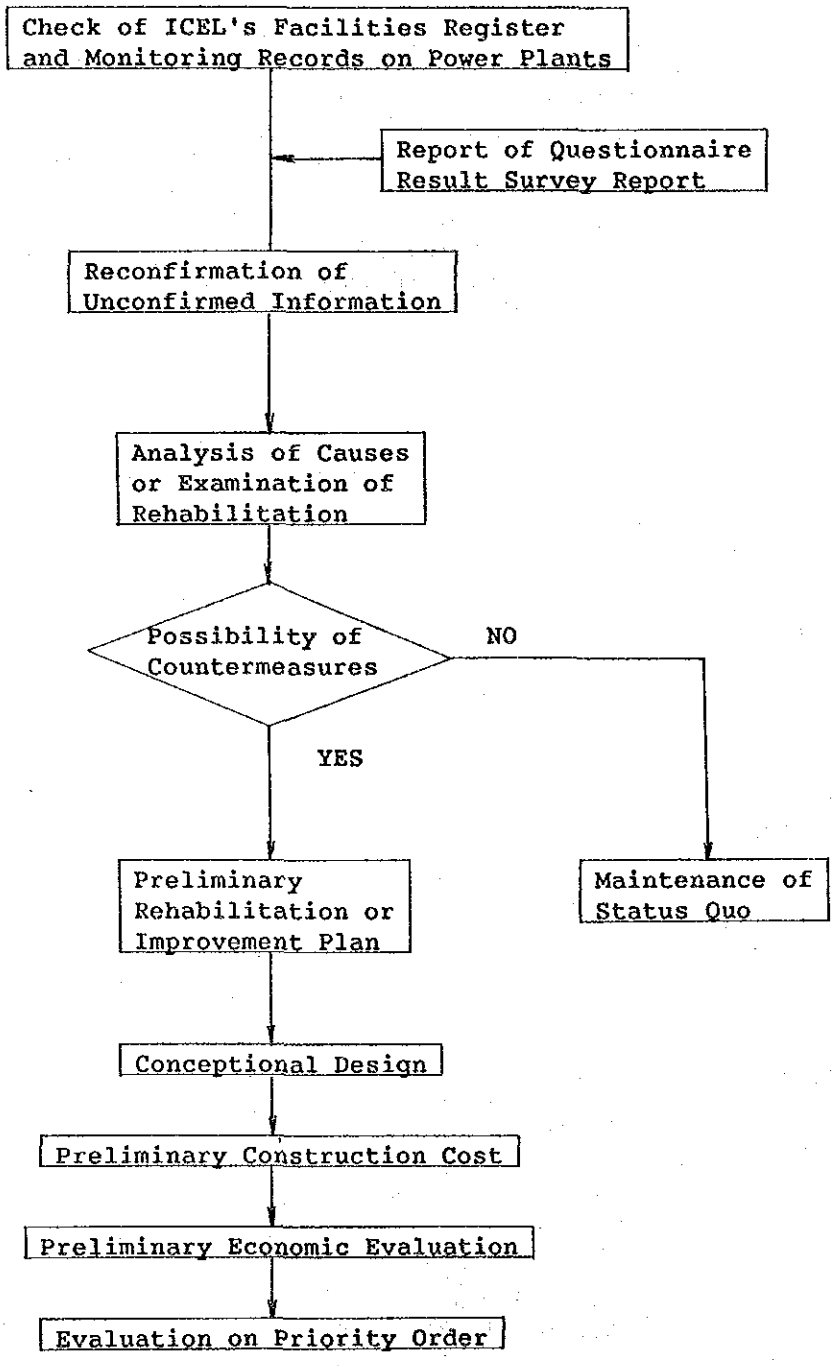

Fig. 1.3.2 Basic Procedure of Pre F/S for Thermal Power Plants

(2) Work flow for hydraulic power plants

In case of hydraulic power plants, particularly run-of-river type ones, the work flow which is divided into the rehabilitation plan, and expansion or improvement plan, as described below, should be considered in the course of the basic work flow according to the progress of the study.

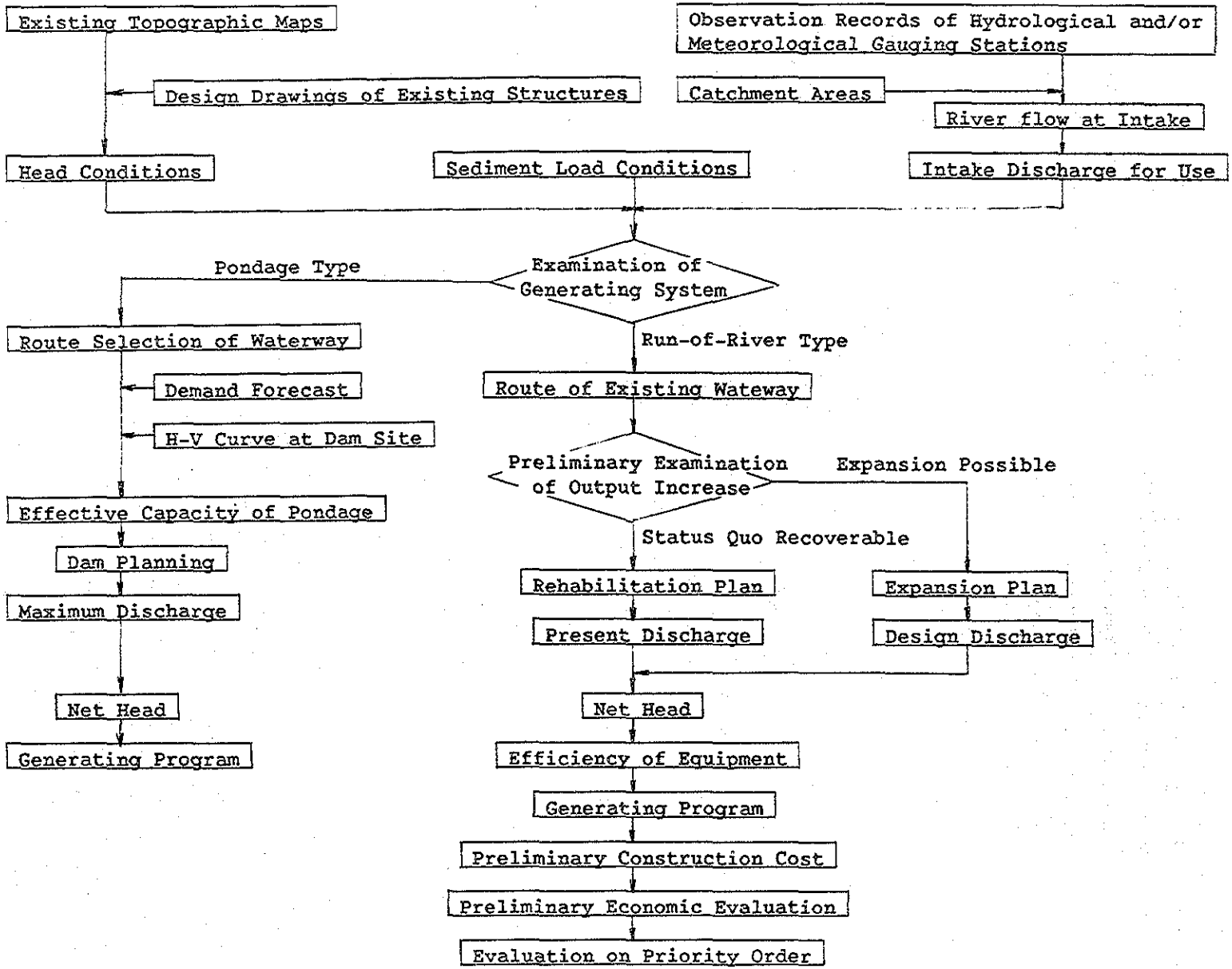

Fig. 1.3.3 Study Flow for Run-of-River Type Hydraulic Power Plants

(3) Work flow for diesel power plants

Most of the study areas for diesel power plants are small-capacity power plants which provide power demand to the communities scattered in the departments of Nariño, Choco and Meta. The rehabilitation plan shall be formulated with consideration given to a special work flow as shown in Fig. 1.3.4.

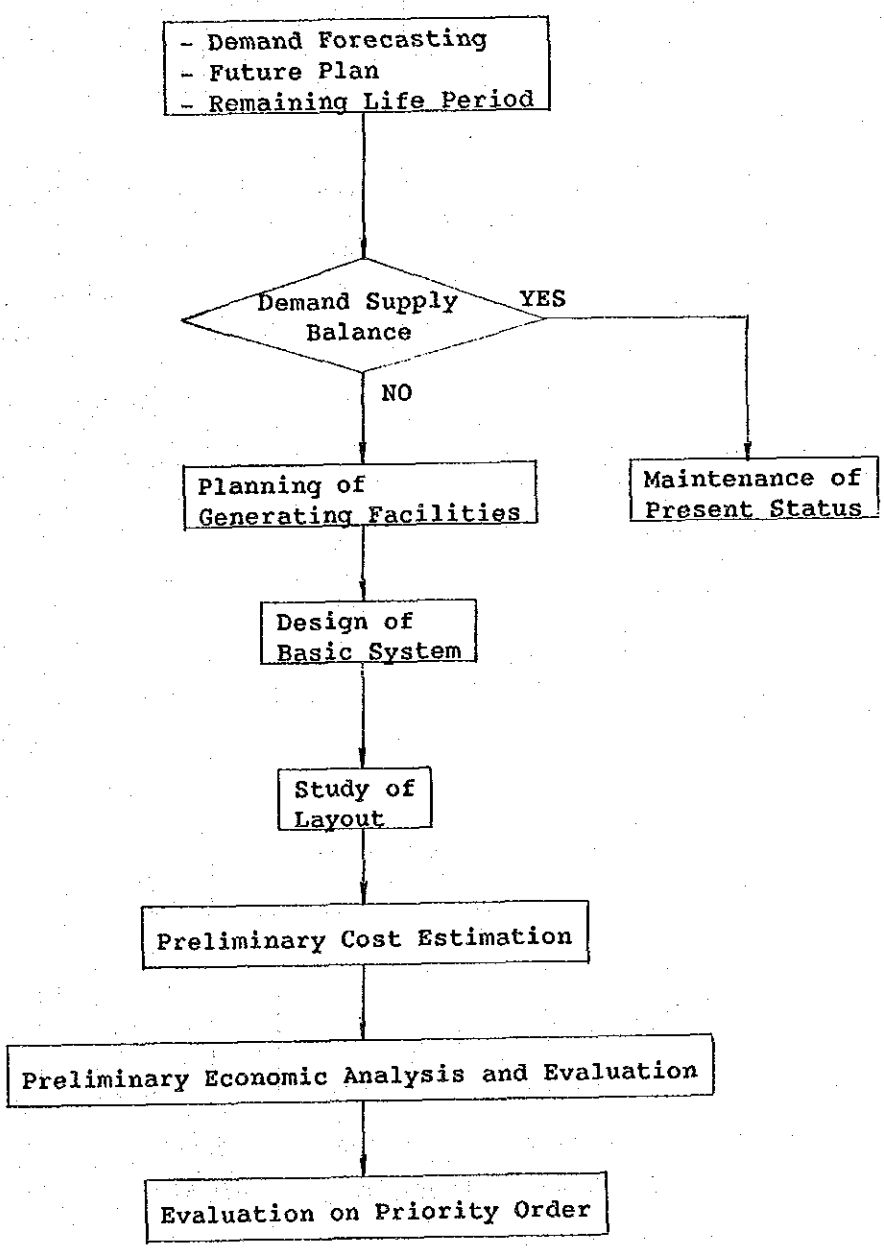

Fig. 1.3.4 Basic Procedure for Diesel Power Plants

1.3.2 Time Schedule for Pre F/S

The pre F/S was divided into the field work in Colombia and homework in Japan, and was conducted according to the time schedule as shown in Table 1.3.1.

Table 1.3.1 Time Schedule for Pre F/S

Year	1987		1988						
Month	1	2	3	4	5	6	7	8	9
Calendar Month	11	12	1	2	3	4	5	6	7
Work Item									
1. Review of existing data			(primary field survey)						
2. Selection of candidate power plants			(primary field survey)						
3. Reconnaissance Survey						(secondary field survey)			
4. Review of preliminary rehabilitation plan						(secondary field survey)			
5. Conceptional design						(secondary field survey)			
6. Approximate cost estimation of rehabilitation									
7. Preliminary economic analysis and evaluation									
8. Evaluation on priority order									
9. Preparation of study plan at the stage of F/S									
Reports									
Inception report	Δ								
Progress report					Δ				
Draft final report								Δ	
Final Report									Δ

Work in Colombia by ICEL's counterpart

Work in Colombia by JICA study team

Work in Japan

Submission of report Δ

1.3.3 Organization of Study Team

This pre F/S was conducted by the study team consisting of the following members, and the ICEL's counterpart in Colombia.

(1) Organization of study team members

Name	Assignment	Title	Company	Department
Masami Ono	Generating plan and civil facility (Civil)	Team Leader	Yachiyo Engineering Co., Ltd.	Vice-President
Yoshio Kawasaki	Generation and civil facility (Civil)	Member	Yachiyo Engineering Co., Ltd.	Industrial Engineering
Masayuki Tamai	Generating equipment, transmission facility (Electrical)	Member	Yachiyo Engineering Co., Ltd.	Industrial Engineering
Hirohito Seto	Diesel power generting facility (Electrical)	Member	Yachiyo Engineering Co., Ltd.	Industrial Engineering
Eiji Shimomura	Thermal power generating facility (Mechanical)	Member	Yachiyo Engineering Co., Ltd.	Industrial Engineering

(2) List of members of ICEL's counterpart

Name	Assignment	Title
Juvenal Panaloza Rosas	Generation and civil engineering	Head of Division of Execution and Coordination of Projects (D.E.C.P.)
Hector J. Guerrero V.	Generation and civil engineering	Division of Execution Coordination of Projects ICEL
Victor Pardo Camelo	Generation and civil engineering	Division of Execution Coordination of Projects ICEL
Jairo González Morales	Generation and civil engineering	Division of Execution Coordination of Projects ICEL
Ilva Lorduy Hernandez	Generation and civil engineering	Division of Execution Coordination of Projects ICEL
Augusto Sanabria Diaz	Mechanical engineering	Division of Execution Coordination of Projects ICEL

(3) List of members of Electric Power Companies

Organization	Name	Title
EADE	Mario Gonzalez	Director of Power Generation Program
	Walter Ospina	Power Generation Program
	Juan C. Viana A.	Power Generation/Transformation Program
E. Boyaca	Francisco Duque	Vice-president
	Omar Miguel B.A.	Power Generation/Civil Engineering Program
	Hector Pulido	Chief of Paipa Power Plant
	Pedro Lesmes	Director of Technical Service Department of Paipa Power Plant
	Fernand Cruz	Director of Electric/Instrumentation Department of Paipa Power Plant
	Avelino Cery	Machinery in Charge of Paipa Power Plant
CHEC	Alberto Naranjo A.	Manager of MIEL-I Project
	Jorge H. Garcia C.	Member of MIEL-I Project
	Claudia M. Agudelo	Member of MIEL-I Project
CEDELCA	Fernand Iragorri	President
	Jose Morales	Director of Technical Department
	Freddy Gaviria	Power Generation Program
	Lorry Guzman M.	Power Generation Program
	Augusto Insuasty	Distribution Department
E. Choco	Juan B. Hinestroza C.	President
	Demonstenes Valencia M.	Technical Department

Organization	Name	Title
E. Huila	Luis Alberto V.	Director of Project Department
	Carlos Linares	Director of Transmission Department
	Juan Jose F.	Program Department
EMSA	Luis Eduardo Solis Bangrero	Director of Technical Department
	Camilo Torres Puentes	Director of Transmission
CEDENAR	Eruesto Orlando Benavides	President
	Diego Delgado Ruiz	Director of Power Generation/ Transmission Program
	Bernardo Castillo	Chief of Tumaco Power Plant
ESSA	Hernado Uribe Nino	President
	Ruben Gelves	Chief of Palanque Power Plant
E. Tolima	Luis Eduardo Quintero	President
	Hugo Neira S.	
	Francisco Corrales	
	Ernesto Triana	Chief of Prado Power Plant
	Antonio Cuartas	Vice-director of Operation/ Maintenance
CRAMSA	Hector Alberto Serna	Vice-president
	Hebert Enrique Soto S.	
	Jose Fernando Aristizabal	
	Rogelio Pena H.	

2. Background of the Study

2. BACKGROUND OF THE STUDY

2.1 Power Condition in ICEL Group

ICEL group consists of ICEL itself as well as public electric power companies existing in the following 13 departments:

The Name of Departments where Public Electric Power Companies of ICEL Group exist

No.	Abbreviation of Electric Power Companies	Department	Remarks
1	EADE	Antioquia	except EPM
2	E. Boyaca	Boyaca	
3	CHEC	Caldas	
4	E. Caqueta	Caqueta	
5	CEDELCA	Cauca	
6	ECSA	Cundinamarca	except EEEB
7	E. Choco	Choco	
8	E. Huila	Huila	
9	EMSA	Meta	
10	CEDENAR	Nariño	
11	CENS	Norte de Santander	
12	ESSA	Santander	
13	E. Tolima	Tolima	

The two main factors to grasp the electric demand are basically 'electric energy' and 'peak demand'. The average annual increase rate in power demand of ICEL group is 7.3% for 6 years from 1981 to 1986. The figure exceeds 6.0% which are the average annual increase in the whole Colombia.

The peak demand in 1986 is 1,268 MW, while the installed capacity of the generating facilities owned by the ICEL group is 918 MW (demand factor of 138%). Among them, the installed capacity of ICEL itself is 342 MW (37%).

Among the generating facilities belonging to ICEL group, a number of isolated power sources (diesel and hydraulic) with their small capacity which are not connected to the national grid, have been found. The great majority of isolated power sources is maintained and operated by a self-governing body.

As for the breakdown of power supply, 56% of the power supply depends on the supply on the supply from other electric power companies, and the remaining 44% are supplied by generating facilities within ICEL group (53% : thermal power, 47% : hydraulic power). Therefore, a public electric power company in each department keeps a demand supply balance since it relies on the supply from the other power companies, although there is a slight difference in such supply amount except the area where it depends on the isolated power source. Some public electric power companies depend on the the other power companies for all their power supply.

Under the above power condition, in June 1987, Bentania Hydraulic Power Plant of 510 MW (170 MW x three units) constructed by ISA/ICEL at the conjunction of Megdalena River and Yaguara River in Huila department was put into operation on a commercial basis. In addition, a 230 kV transmission line linking the power plan with Popayan City in Cauca department has been completed and a 230 kV transmission line linking with Ibague City in Tolima is also being planned, so that the power condition of ICEL Group will substantially be better.

This report describes the power condition in ICEL group in 1986 before the Betania Hydraulic Power Plant had not been completed, since statistical data in 1987 are not available.

2.1.1 Present Generating Facilities

(1) Generating facilities

The transition of installed capacity within ICEL group in the six years from 1981 to 1986 is shown in Table 2.1.1. The capacity of the generating facilities within ICEL group in 1985/86 is 918 MW, of which hydraulic power plant accounts for 383 MW (42%), diesel power plant accounts for 22 MW (2%), and thermal power plant accounts for 513 MW (56%).

The installed capacity of hydraulic power generating facilities is not increased since 1982, while that of diesel power generating facilities is decreased by 4 MW in or before 1984 and that of thermal power generating facilities is decreased by 25 MW in 1985, respectively. On the other hand, the peak demand shows an approx. 5.5% average annual increase.

Table 2.1.1 Installed Capacity and Peak Demand within ICEL Group (1981-1986)

No.	Item	1981	1982	1983	1984	1985	1986	Average Increase Rate (%)
1	Installed Capacity (MW)							
	1) Hydroelectric	380	384	384	384	383		0.2
	2) Diesel	26	25	21	22	22	918	Δ4.0
	3) Thermal	259	379	388	538	513		18.6
	Total	665	788	793	944	918	918	6.6
2	Peak Demand (MW)	969	979	1,058	1,110	1,198	1,268	5.5
3	Demand Factor (%)							
	$\frac{\text{Item-2}}{\text{Item-1}} \times 100$	146	124	133	118	131	138	Δ1.1

(Source: Sistema Electrico del Grupo ICEL 1946-1986)

Table 2.1.2 indicates the breakdown of generating facilities owned by ICEL itself among 918 MW (1986) of installed capacity of generating facilities within ICEL group.

Table 2.1.2 Generating Unit under Property of ICEL (1986)

No.	Department	Power Plant	Unit No.	Capacity (kW)	Generating Method
1	Boyaca	Termopaipa	#3	74,000	Thermal
2	Santander	Termobarranca	#4	32,290	Thermal
3	Santander	Termopalenque	#5	21,770	Thermal
4	Norte de Santander	Termotasajero	#1	163,000	Thermal
5	Tolima	Hidroprado	#1	15,300	Hydroelectric
6	Tolima	Hidroprado	#2	15,300	Hydroelectric
7	Tolima	Hidroprado	#3	15,300	Hydroelectric
8	Tolima	Hidroprado	#4	5,100	Hydroelectric
	Total			342,060	

(2) Transmission and transformer system

Major cities, towns and villages in each department are connected by transmission lines belonging to ICEL group (230 kV or less), ISA (115 kV or above), or municipally operated electric power company and Regional Development Public Corporation. The total length of transmission and distribution lines and total capacity of transformers in 1985 are as follows:

a) Total length of transmission lines (in 1985)

Voltage (kV)	230	115	66	44	34.5	13.2
Total length (km)	675	2,590	20	922	3,409	10,307

b) Total capacity of transformers (in 1985)

Voltage (kV)	230/115	115/66-44-34.5	115/13.2	66/13.2	44/13.2	34.5/13.2
Total length (MVA)	750	1,518	424	18	336	1,034

2.1.2 Balance of Power Demand and Supply

Table 2.1.3 shows the transition of power demand in the recent six years from 1981 to 1986 within ICEL group which is compared with that in the whole Colombia. The annual demand of ICEL group in 1986 is approx. 4,640 GWh, accounting for approx. 23% of the total demand in Colombia.

Table 2.1.3 Transition of Power Demand by Sector (1981-1986)

(Unit: GWh)

Item		1981	(%)	1982	(%)	1983	(%)	1984	(%)	1985	(%)	1986	Average Increase Rate (%)
Residential	ICEL Group	1,768	9.0	1,927	7.6	2,037	11.0	2,301	7.3	2,469	6.2	2,621	8.2
	Colombia	6,964	13.6	7,913	4.2	8,248	6.9	8,814	5.8	9,327	5.9	9,881	7.3
Commercial	ICEL Group	396	2.0	404	1.0	408	5.9	432	4.5	460	4.1	479	3.9
	Colombia	1,808	8.5	1,961	3.4	2,028	Δ0.8	2,012	5.0	2,112	1.6	2,146	3.5
Industrial	ICEL Group	760	8.2	822	4.3	857	10.4	946	7.1	1,013	8.7	1,101	7.7
	Colombia	4,480	4.5	4,682	6.9	5,005	6.4	5,323	2.9	5,477	12.5	6,160	6.6
Others	ICEL Group	333	27.3	424	13.4	481	2.9	495	1.0	500	Δ12.4	438	5.7
	Colombia	2,005	Δ8.7	1,830	9.6	2,006	5.5	2,116	4.5	2,211	0.5	2,222	2.1
Total	ICEL Group	3,257	9.8	3,577	6.8	3,819	9.3	4,174	6.4	4,442	4.4	4,639	7.3
	Colombia	15,257	7.4	16,386	5.5	17,287	5.7	18,265	4.7	19,127	6.7	20,409	6.0

(Source: Sistema Electrico Colombiano Balance Energetico Historico 1971-1986)

The demand for residential, commercial, industrial and other purposes by category of consumers in 1986 is 56%, 24% and 10%, respectively. Compared with the component ratio for the total demand in Colombia (48% for residential, 11% for commercial, 80% for industrial and 11% for other purposes), the demand for residential use is high, while that for industrial use is low.

On the other hand, the transition of electric energy and demand within ICEL group is shown in Table 2.1.4, the average annual increase rate in the six years from 1981 to 1986 is 2.7% and the difference between this rate and average annual increase rate of power demand of 8.8% (including the power loss) is in the neighborhood of 6%. Because of constant power capacity of the hydraulic power generating facilities, the dependency on the thermal power generating facilities has become higher. Power loss rate tends to increase more and more every year. The power loss rate in 1986 accounts for 26%, indicating an extremely high loss.

Table 2.1.4 Transition of Energy and Demand within ICEL Group (1981 - 1986)

(Unit: GWh)

No.	Item	1981	1982	1983	1984	1985	1986	Average Increase Rate (%)
1	Electric Energy							
	1) Hydroelectric	1,390	1,454	1,301	1,485	1,359	1,307	Δ1.2
	2) Diesel	23	27	32	32	33	1,472	9.5
	3) Thermal	1,016	1,304	1,675	1,943	2,243		21.9
	Total	2,429	2,785	3,008	3,460	3,635	2,779	2.7
2	Demand	4,171	4,810	5,159	5,547	6,015	6,341	8.8
3	Loss	773	1,078	1,148	1,167	1,370	1,634	16.2
4	$\frac{\text{Loss}}{\text{Demand}} \times 100$ (%)	19	22	22	21	23	26	6.8

(Source: Sistema Electrico del Grupo ICEL 1946-1986)

2.1.3 Electrificating Rate and Generating Cost

There exists a great difference between electrificating rate (Household with service/whole Household) and generating cost by each department in 1985 as described below. The electrificating rate and generating cost within the ICEL group is described later.

a) Electrificating rate

Max. 62% in Huila department

Min. 18% in Choco department

b) Generating cost

Max. 6.4 peso/kWh in Cauca department

Min. 3.5 peso/kWh in Antioquia department

2.2 Power Condition in Electric Power Companies by Department

The areas to be studied in the pre-feasibility study on Small-scale Power Plants Rehabilitation Project are scattered in 13 departments (Antioquia, Boyaca, Caldas, Cauca, Choco, Cundinamarca, Huila, Meta, Nariño, Santander, Tolima, Quindio, and Risaralda) and one intendancy (Putumayo) of the whole Colombia (24 Departments, 3 Intendancy and 5 Special Districts). In the three departments of Quindio, Risaralda and Putumayo, no public electric power companies exist, but individual self-governing communities supply the power only in some specific areas. In Quindio, the existing four electric power companies will be integrated in 1989 to establish a public electric power company.

On the other hand, two departments of Caqueta and Norte de Santander belonging to ICEL group are not included in the relevant study area.

2.2.1 Power Source Composition

Table 2.2.1 indicates the composition of power source in each department in 1985. Boyaca and Santander have both thermal and hydraulic power sources, while Choco and Meta are isolated from the national grid and depend on the diesel power source. The other departments have only the hydraulic power sources.

Table 2.2.1 Composition of Power Source in 1985

(Unit: MW)

No.	Department	Power Source			Total Capacity
		Hydro-electric	Thermal	Diesel	
1	Antioquia 1)	11.2	0	1.3	12.5
2	Boyaca	1.6	173	0	174.6
3	Caldas	199	0	0	199
4	Cauca	32.8	0	0.6	33.4
5	Cundinamarca 2)	10	0	0	10
6	Choco	0	0	0	0
7	Huila	9	0	5.0	14
8	Meta	0	0	1.6	1.6
9	Nariño	29.4	0	10	39.4
10	Santander	25.7	159	4	188.7
11	Tolima	65.9	0	0	65.9
12	Risaralda 3)	16.8	0	1.8	18.6
13	Quindio 4)	5.4	0	0	5.4
14	Putumayo	0.2	0	0	0.2
	Total	407	332	24.3	763.3

1) Teritory of EPM is not included.
2) Teritory of EEEB is not included.
3) Data of EPP
4) Data of CRQ and E. P. de Armenia

(Source: Informe Estadistico Resumen 1981-1985)