CENTRALES ELECTRICAS DEL CAUCA S.A.

REPUBLIC OF COLOMBIA

REPORT OF PRELIMINARY STUDIES ON JULUMITO HYDRO-ELECTRIC PROJECT

JUNE 1970

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

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OVERSEAS TECHNICAL COOPERATION AGENCY (OTCA)

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June 1, 1970

Dr. Aurelio Iragorri H.
Gerente
Centrales Electricas del Cauca, S.A.
Popayan, Colombia

Sir:

The Government of Japan, in response to the request from the Government of the Republic of Colombia, entrusted the Overseas Technical Cooperation Agency to conduct preliminary studies of the Julumito Hydroelectric Project on the Rio Cauca.

The Overseas Technical Cooperation Agency, in consideration of the importance of the hydro-electric power generation of the project, sent to your country a survey team headed by Yozo Fukutake (Geologist, Electric Power Development Co., Ltd. EPDC), and consisting of Kei Yamamoto (Civil Engineer, EPDC) and Hisanobu Okamoto (Electrical Engineer, Ministry of International Industry and Trade).

The team stayed in your country for two months from February 15, 1970. During their stay in your country the team conducted studies and discussions on the various aspects of the project, reconnoitered the project area and related areas to the project, and collected relevant data and information. During their stay in your country, the team prepared

the draft of the report and after returning to Japan, the team prepared this report under the direction of the Chief Engineer o. EPDC.

In submitting this report, I sincerely wish that this report could contribute to the development of your country and to the promotion of friendly relationship and economic exchange between Colombia and Japan. I also take this opportunity to express my deepest appreciation, on behalf of the Overseas Technical Cooperation Agency, to the officials of the Government of Colombia and the Japanese Embassy and other persons and organizations for their kind hospitality and cooperation extended to the team during their stay in Colombia.

Respectfully yours,

Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency

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CHAPTER I

INTRODUCTION

1.1 AUTHORIZATION AND HISTORY

Centrales Electricas del Cauca S.A. (CEDELCA) in order to cope with the rapidly increasing demand of electricity in the provinces of Cauca and Nariño, has proposed the Julumito project to develop the hydro-electric potential of the Rio Cauca.

CEDELCA requested the Government of Japan, through the Government of Colombia, to conduct a preliminary study of this project.

In response to the request, the Government of Japan sent the following team of engineers to perform the preliminary study of the project.

Hisanobu Okamoto
Electrical Engineer
Ministry of International Trade and Industry

Kei Yamamoto
Civil Engineer
Assistant Manager of Planning Section, General Planning and Research Office
Electric Power Development Co., Ltd.

Yozo Fukutake
Geologist
Assistant Manager of Engineering Services Section, Foreign Activities Department
Electric Power Development Co., Ltd.

This preliminary report has been prepared for CEDELCA and Instituto Colombiana de Energia Electrica (ICEL) on the basis of the preliminary study of the project conducted by the team.

1.2 SCOPE OF THE REPORT

The purpose of this report is to present the results of the preliminary investigations related to the technical and economical possibility of the project, and its time of development. It includes the basic plan of the project, and recommendations for the necessary investigations required for the feasibility study.

The data available, as well as the time given for the preparation of this report were limited. Therefore, the detailed study of the project should be performed in the feasibility study.

The appendix contains the basic data used in the report.

1.3 EXISTING AND BASIC DATA

During 1969 the Julumito project was investigated by CEDELCA. Except for this investigation no other study had been done before.

The basic data which were available comprised of precipitation and river discharge records, topographic maps, energy demand records, etc., and are listed in paragraph 1.4. Besides these data, it was necessary to collect more information during the investigation. However, the existing data is not sufficient for the feasibility study, mainly in geology and soil materials. It is anticipated that these investigations will be executed in the field and by laboratory tests in the near future, to obtain necessary data for the feasibility study.

1.4 BASIC DATA

The main data obtained either from CEDELCA and ICEL or in the course of the field investigations are:

A. Topographic data

(1) *Air-photo topographic maps*
Scale 1 : 10000
Contour lines every 25 meters
Area covering the main part of the project area.

(2) Ground survey maps

Scale 1 : 500

Area: No. 2 dam site and No. 3 powerhouse site.

(3) Cross-sections

Scale 1 : 500

Area: No. 1 and No. 3 dam sites, No. 2 powerhouse site and diversion dam site.

(4) Elevations at project site

B. Hydrologic data

(1) Precipitation data

Monthly records at three sites in the catchment area.

(2) Discharge data

Julumito Gauging Station on the Rio Cauca; Daily flow record from 1964 to 1969.

Malvasa Gauging Station on the Rio Ralacé; Daily flow record from 1961 to 1965.

C. Energy demand and supply data

(1) Estudio sobre el suministro de energia a los sistemas electricos de CEDELCA y CEDENAR. Octubre de 1968.

(2) Manual de electrificacion de la Republica de Colombia.

(3) Information on demand forecast obtained from CEDELCA.

(4) Information on demand forecast obtained from CEDENAR.

(5) Others

1.5 ACKNOWLEDGEMENT

Deepest appreciation is expressed for the wholehearted assistance and cooperation extended to the team, by the officials and staff of the Government of Colombia, ICEL, CEDELCA and CEDENAR, during the investigation and the field trips.

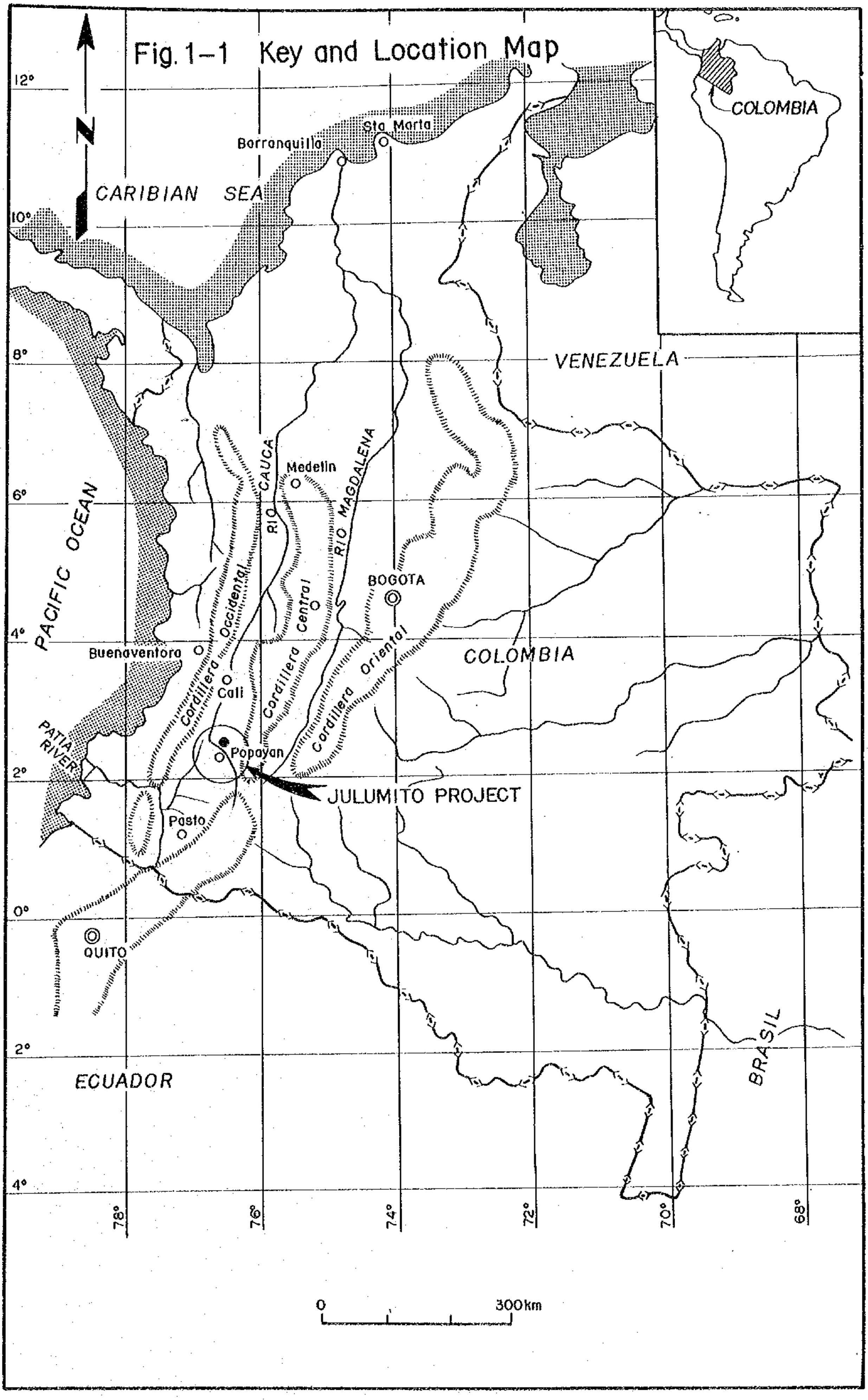


Fig. 1-1 Key and Location Map

CHAPTER II

CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

Aerial topographical maps, hydrologic data and other basic information were made available by CEDELCA and ICEL. Based upon these data, field investigations and preliminary studies of the project were undertaken. As a result, a general outline of the scheme of development, time schedule and economics of the project were established as follows.

A. Scheme and magnitude of the project

(1) The development plan as considered is to construct a dam on the Rio Sate which is a tributary of the Rio Cauca and divert water from the Rio Cauca and the Rio Palacé (in the future) into the reservoir created by the dam. Water stored in the reservoir capable of carry over storage is to be released through a powerhouse back into the Rio Cauca.

(2) For the development pattern of the Julumito project, Plan A, B and C were studied in relation to their engineering and economic possibility. As a result, Plan C (No. 2 dam site and No. 3 powerhouse site) is considered to be the best.

(3) The recommended scale of the project is about 50 MW, judging from the pattern and size of projected future power requirements and economic point of view.

B. Timing of development

It is clear that shortage of power and energy supply capability in CEDELCA and CEDENAR systems is expected around 1975, assuming Florida II begins operation in 1972 as scheduled. Therefore, this project should be developed as soon as possible.

In consideration of the growing energy demand in the region and for economic reasons, it is desirable to divert the flow of Rio Palacé into the reservoir and install an aditional unit in the future.

C. Economics of the project

(1) If the Julumito project is put in service in 1976, it will be possible to meet the demand in CEDELCA system and also to cover the shortage of supply capability in CEDENAR system for a few years.

(2) Julumito hydroelectric project was found to be economically favorable. Comparative studies were alternative sources including a thermal plant and the energy cost in the CVC system. The result showed that the cost of energy of the project, estimated to be about 11.5 ₵/kWh, is less than that of the alternative sources and that the benefit-cost ratio exceeds 1.7.

The interconnection between CVC system and CEDELCA-CEDENAR system which can be considered to a reserve capacity will be very effective for the stabilization of supply capability.

D. Additional benefits

(1) The proposed reservoir with scenic landscape and with its location being very close to the city of Popayan will offer immeasurable recreational benefits.

(2) After water from the Rio Palacé is diverted into the reservoir it will be possible to decrease the acidity of the water diverted from the Rio Cauca into the reservoir and may become possible to establish fish culture.

E. Technical problems

It is appears that there are no unusual engineering problems in the design and construction of the project, at the present stage of the studies.

F. Future investigations

The data available were limited and are far from adequate. Therefore, it is essential that field studies of the project be initiated immediately.

2.2 RECOMMENDATIONS

The Julumito powerhouse should start operation in 1976 in order to meet the estimated future energy demand. Therefore, feasibility study of the project must be completed at the earliest possible time.

In this connection, various preparations as mentioned in CHAPTER IX, mainly collection of additional hydrological data, must be undertaken as soon as possible.

CHAPTER III

OUTLINE OF THE PROJECT

3.1 BASIC ENGINEERING DATA OF THE PROPOSED PROJECT

The basic engineering data and the construction cost of the project appear in the Table 3-1. Reference is also made to the general plan shown in Fig. 3-1.

3.2 CONSTRUCTION SCHEDULE

Construction schedule of the project is indicated on Fig. 3-2. The time required for the project study up to its completion are follows:

Survey and Study: 38 months (From May 1970 to Jun. 1973) including feasibility and definite studies.

Preparation Works: 12 months (From Jan. 1973 to Dec. 1973)

Construction Works: 30 months (From Jan. 1974 to Jun. 1976)

Table 3-1 Basic Data of Proposed Project (Plan-C)

Item	Unit	I Stage	II Stage	Total
Method of Power Generation		Dam → Headrace Tunnel → Powerhouse	{Rio Palacé Diversion / No. 4 unit Installation}	
Catchment Area				
Rio Cauca	km^2	930	-	930
Rio Sate		30	-	30
Rio Palacé and Blanco		-	230	230
Total		I Stage 960	II Stage 230	1190
Reservoir				
Annual Inflow	10^6m^3	Rio Cauca 659, Rio Sate 23 } 682	Rio Palacé 165, (Laguna San Rafael) 48 } 218	900
Reservoir				
Normal High Water Surface Level	m	1715		
Water Surface Area	10^3m^2	4400		
Total Storage Capacity	10^6m^3	60		
Effective Storage Capacity	10^6m^3	50		
Available Drawdown	m	15		
Dam (Main Dam)				
Type		Rock fill		
Height x Crest Length	m	74 x 320		
Volume	10^3m^3	1000		
Waterway				
Headrace (Diameter x Length)	m	4.6 x 1800		
Diversion Water Way	m	(Rio Cauca) Open Channel 2900, Tunnel 300	(Rio Palacé, Blanco) Open Channel 8300, Tunnel 700	
Power Production				
Standard Intake Level	m	1710		
Tailwater Level	m	1577		
Standard effective head	m	124.		
Power Station Discharge				
Maximum	m^3/s	37	13	50
Firm	m^3/s	20	6	26
Output				
Installed Capacity	kW	39,000	13,000	52,000
Annual Energy Production	10^6kWh	200	*65	265
Transmission Line				
Section		P.S - Popayan S.S		
Distance	km	10		
Voltage & (Number or Circuit)	kV(cct)	115 (1)		
Substation				
Location		Popayan S.S.		
Voltage	kV	115/33		
Construction Cost				
Generating End	$10^3$$	255,500	40,000	295,500
Transmission & Substation	$10^3$$	4,500	-	4,500
Total Construction Cost	$10^3$$	260,000	40,000	300,000
Cost of Energy	$/kWh	0.131	0.062	0.115
Benefit - Cost Ratio				1.7

I. Stage

1. Diversion of Rio Cauca
2. Installation of 3 Units (No. 1 - 3 13,000 kW x 3)

II. Stage

1. Diversion of Rio Palacé
2. Increase of Diversion of Rio Cauca due to construction of Laguna San Rafael reservoir
3. Installation of 1. additional unit (No. 4, 13,000 kW)

*	Energy by Rio Palace Diversion	50 x 10^6kWh
	Energy by Increased Diversion of Rio Cauca	15 x 10^6kWh
	Total	65 x 10^6kWh

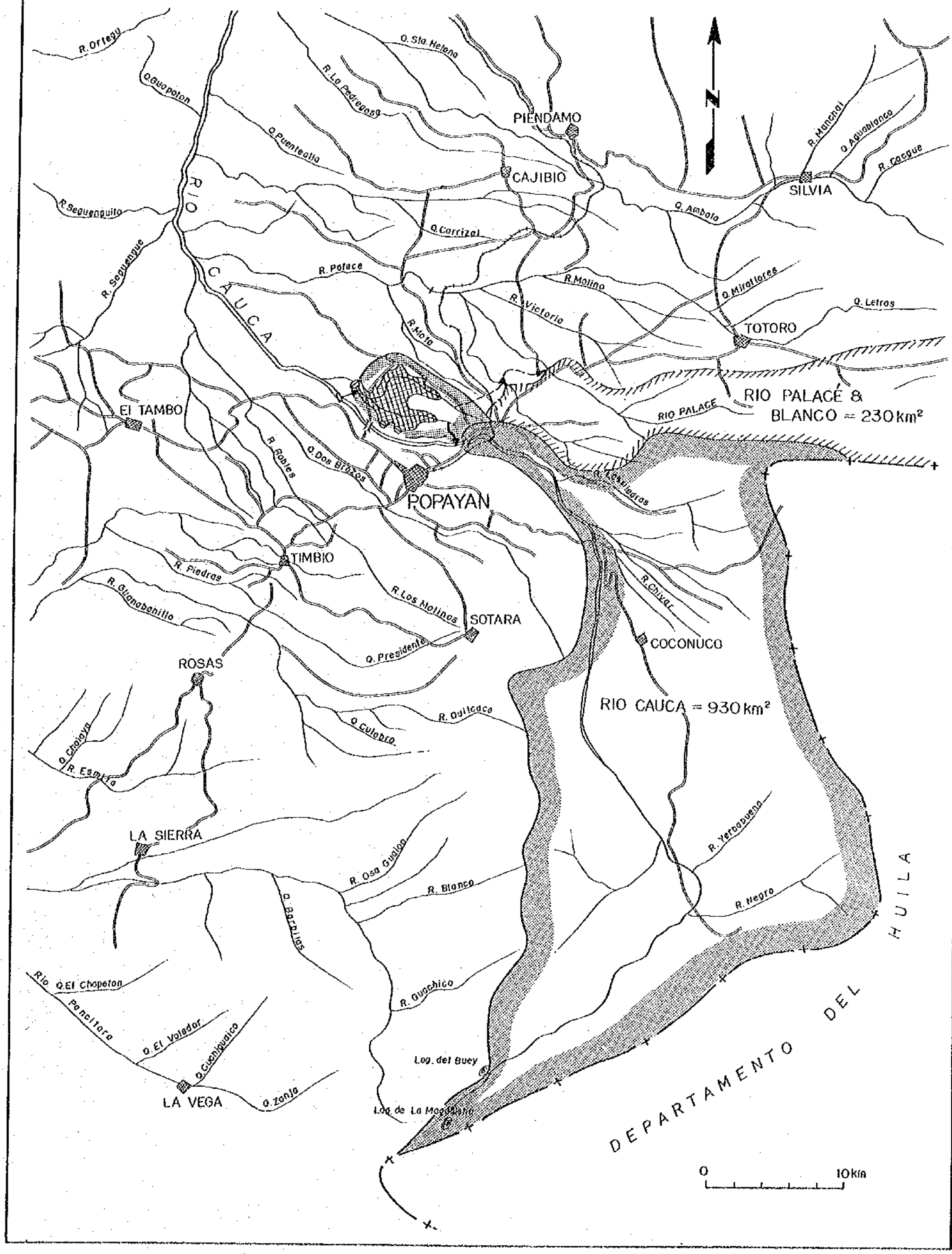
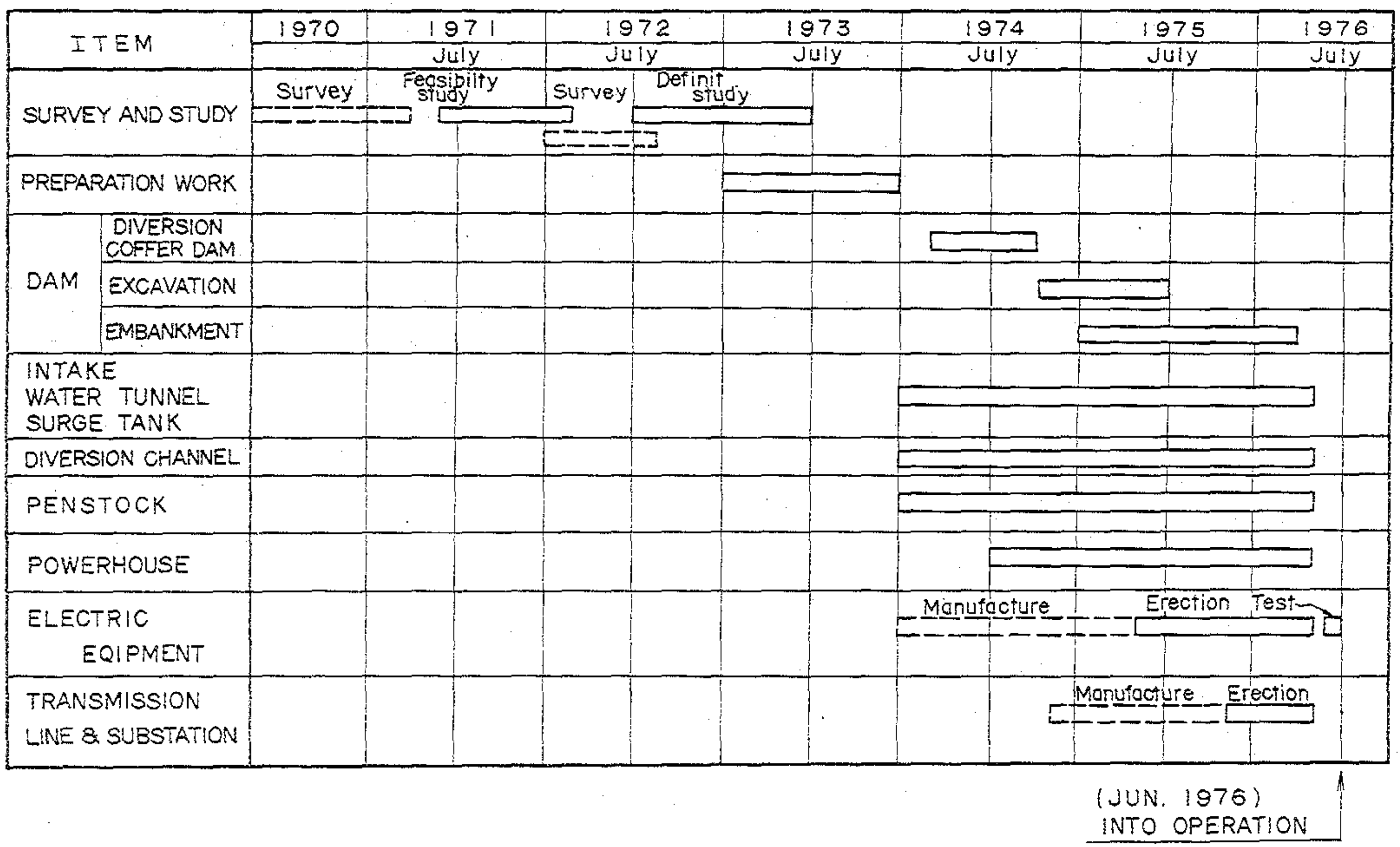


Fig. 3-1 General Plan

Fig.3-2 Construction Schedule of Julumito Project (Plan-C)



CHAPTER IV

LOAD FORECAST

4.1 GENERAL

The Departments of Cauca and Nariño are located in the southwest region of the Republic of Colombia.

The population of Cauca is about 700,000 (1964). Popayan, located on the uppermost part of the Rio Cauca, is the capital of Department of Cauca, with a population of 77,000 (1964) and there is very little industry.

The total electric power demand in Cauca is concentrated in Popayan, with 60%, and 15% in Pt. Tejada and Santander.

Department of Nariño has a population of about 850,000 (1964). Pasto, the capital city, is located in the mountainous area (EL. 2700 m) with 120,000 population (1964).

The total electric power demand in Nariño is concentrated in Pasto with 60% and 10% in Ipiales.

Industries in both Departments are limited to small-scale furniture factories, leather, brick and fertilizer factories and breweries. The main industry is agriculture consisting of barley, wheat, corn, fruit farming and cattle breeding. Mineral resources, such as sulfur, coal and bauxite in Cauca; lead, zinc, copper and limestone in Nariño seem to be abundant and are awaiting future exploitation.

4.2 PRESENT STATUS OF FACILITIES

A. Generating facilities

The total number of power stations and installed capacity of CEDELCA as of March 1970, are 11 and about 9,000 kW respectively. Presently, Florida II Hydroelectric Plant (2 units of 12,000 kW each) is under construction and is scheduled to start operation in the middle of 1972. With the completion of Florida II, the total installed capacity of CEDELCA will increase to 33,000 kW in 1972.

Most of the existing powerhouses of CEDELCA are hydraulic plants, which are less than 2,500 kW in maximum output, and only two diesel plants (530 kW) are under operation.

The power supply capability at present in CEDELCA system is not enough and it has been buying peak energy from Rio Mayo Powerhouse (CEDENAR) since September 1969 and this situation will continue till 1972 when Florida II will start operating.

The shortage of capability will be overcome for few years after the completion of Florida II but it is expected to come again around 1975.

In view of such situation, CEDELCA has been studing Julumito hydroelectric power project on the Rio Cauca.

Besides the above capacity, Coconuco Powerhouse (hydro, installed capacity 1,600 kW) and Sulfur Co. Powerhouse (diesel, 700 kW) are under operation by privates companies in Department of Cauca.

The total power output of the CEDENAR system is about 33,000 kW, including Rio Mayo Powerhouse (7,000 kW x 3 units) which was completed in 1969.

This total consists of 28,000 kW in 5 hydroelectric powerhouses and 5,000 kW in 2 diesel plants in Pasto and Tumaco.

By the completion of Rio Mayo Powerhouse, the shortage of peak power and energy supply capability in CEDENAR service area have been overcome, but a marked shortage of supply in this system is expected within a few years.

In CEDENAR, there is no powerhouse under construction or in the stage of study.

In Pasto district the Julio Bravo e Hijos Company operates a 2,000 kW plant, in addition to the facilities of CEDENAR.

The total generating capacity in CEDELCA and CEDENAR consists of 42,000 kW existing and 24,000 kW under construction as of March 1970, excluding privately owned facilities.

Details of the power facilities are shown in Table 4-1 and Fig. 4-1.

Table 4-1 Generating Facilities in CEDELCA and CEDENAR

Service Area	Powerhouse	Type	Starting Year of Operation	Installed Capacity (kW)	Energy Production in 1969 (10^3 MWh)	Remarks
CEDELCA	Florida I	Hydro	1956	2,210	12.3	
	Sajandi	Hydro	1960	2,400	11.0	
	Rio Palo	Hydro	1964	1,440	5.9	
	Ovejas	Hydro	1939	900	4.5	
	Asunazu	Hydro	1934	450	0.8	
	Silvia	Hydro	1960	640	1.4	
	Mondomo	Hydro	1957	600	3.8	
	Toribio	Hydro	1968	60	0.4	
	San Pablo	Diesel	1967	400	0.1	
	Guapi	Diesel	1960	130	0.7	
	Florida II	Hydro	(1972)	24,000	-	Under Construction
	Inza	Hydro	(1970)	400	-	Under Construction
	Total		(1970)	9,230	40.9	
			(1972)	33,630	-	
	(Coconuco)	Hydro	1927	1,600		
CEDENAR	Rio Mayo	Hydro	1969	21,000	24.0	From Sept. in '69
	Rio Mayo (Old)	Hydro	1958	600	2.3	Until Sept. in '69
	Rio Bobo	Hydro	1938/50/63	4,370	26.3	
	Rio Sapuya	Hydro	1957/58	1,860	8.7	
	Rio Ingenio	Hydro	1959	200	1.0	
	Pasto	Diesel	1965/69	2,860	Included in Bobo	CAT 1,860kW MAN 1,000kW
	Tumaco	Diesel	1961/69	2,040	2.4	CAT 1,400kW BLACKSTONE 640
	Total			32,930	64.7	
	Julio Bravo e Hijos	Hydro		2,000		

B. Transmission lines

The voltages of transmission lines in CEDELCA and CEDENAR systems are either 115 kV or 34.5 kV.

The systems of CEDELCA and CEDENAR had been interconnected by a 115 kV line through Río Mayo Powerhouse.

CEDELCA and CVC are interconnected by a 34.5 kV line between Cali and Popayan. Besides, construction of 115 kV transmission line which will connect these cities is underway.

In CEDENAR there is a plan to connect Pasto to Ipiales by a 115 kV line in the future in addition to the present 34.5 kV line between these cities.

Details of transmission lines in CEDELCA and CEDENAR are shown in Fig. 4-1.

4.3 LOAD FORECAST

A. Basis of forecast

The purpose of demand forecast in this preliminary study is to indicate the time when construction of the Julumito project should be started.

The global estimation method was used for the forecast. Past trends of demand growth, consumption per capita and population growth rates were taken into consideration as well as past development pattern in similar areas with respect to the size and component of demand and the opinions of CEDELCA and CEDENAR.

Therefore, in accordance with changes of economic conditions in the future, the demand forecast will require adjustment, but it is thought that significant revisions of the conclusions of this report will not be required.

The assumptions used in making this demand forecast are as follows:

B. Supply area

CEDELCA and CEDENAR systems were selected for the supply area of the Julumito project in this study, because both systems have been connected by 115 kV transmission line after completion of Rio Mayo Powerhouse and they have been operating as if one supply area.

As the 115 kV transmission line between CVC system and CEDELCA system which is under construction will be completed in the near future, this line was considered to be a system reserve capacity.

C. Period of forecast

Period of forecast was made for the 15 years beginning in 1970.

D. Annual mean rate of load growth

The annual mean rate of growth of energy demand in CEDELCA and CEDENAR areas was about 13.3 % for the past 5 years and 12.9 % during the 9 years before as shown in Table 4-2.

Table 4-2 Record of Annual Mean Rate of Load

(Unit ; %)

Term	Years	CEDELCA	CEDENAR	Compound
1961 - 1970	9	13.5	12.5	12.9
1965 - 1970	5	11.5	15.0	13.3

Note;

	Demand		(MWh)
	CEDELCA	CEDENAR	Total
1961	21,000	27,900	48,900
1965	37,600	39,950	77,550
1970 *-1	65,000	80,000 *-2	145,000

*-1; To calculate a past average grouth rate, taking into consideration of restrained demand in the CEDELCA and CEDENAR systems, the demand in 1970 was estimated based on the record between Sep. and Dec. 1969 after operating Rio Mayo Powerhouse.

*-2; After supplying 20,000 MWh to CEDELCA.

According to past records in CEDELCA and CEDENAR (Table 4-3), the shortages of peak power and energy supply ar conspicuous, especially peak demand has been extremely suppressed.

Table 4-3 Demand Record

CEDELCA

Item	1961	1962	1963	1964	1965	1966	1967	1968	1969
Annual Energy at Demand End (MWh)	14,420	21,040	20,980	25,900	28,700	32,120	33,390	33,680	35,180
Annual Generated Power (MWh)	21,000	21,460	29,402	35,170	37,600	41,920	44,580	47,630	51,240
Annual Growth Rate (%)	-	2.1	37.0	19.6	6.9	11.5	6.3	6.8	7.6
Average Output at Generating End (kW)	2,400	2,500	3,400	4,000	4,300	4,800	5,100	5,500	5,900
Peak Load (kW)	5,000	6,000	6,600	7,000	8,300	8,200	8,400	8,900	11,400
Load Factor (%)	48	42	52	57	52	59	61	62	52
Gross Loss Rate (%)	31	13	29	26	24	23	25	29	31

CEDENAR

Item	1961	1962	1963	1964	1965	1966	1967	1968	1969
Annual Energy at Demand End (MWh)	-	-	20,200	25,770	30,770	35,470	35,470	35,160	45,480
Annual Generated Power (MWh)	27,880	30,020	28,530	33,670	39,950	48,380	47,500	47,690	61,657 (7,000)
Annual Growth Rate (%)	-	-	-	18.0	18.7	21.2	-	0.4	29.3
Average Output at Generating End (kW)	-	-	3,250	3,900	4,500	5,500	5,400	5,500	7,100 (9,500)
Peak Load (kW)	-	-	6,200	8,000	9,200	9,300	9,300	9,400	23,000 (20,000)
Load Factor (%)	-	-	53	49	49	59	58	58	31 (48)
Gross Loss Rate (%)	-	-	29	23	21	25	23	25	26

Notes: Figures in 1969 exclude power and energy supplied to CEDELCA.
( ) indicates figures in Dec. 1969.

Table 4-4 Detail of Annual Energy Consumption

CEDELCA

(MWh)

Item	1965	1966	1967	1968	1969
Residentials	19,329 (67.4)	21,372 (66.7)	22,272 (66.7)	22,478 (66.8)	24,104 (68.5)
Commercials	3,662 (12.7)	3,480 (10.8)	3,489 (10.5)	3,385 (10.1)	3,673 (10.4)
Industrials	2,064 (7.2)	2,964 (9.3)	3,132 (9.3)	3,424 (10.2)	2,900 (8.3)
Officials	2,667 (9.2)	2,776 (8.6)	2,969 (8.9)	2,854 (8.3)	3,031 (8.6)
Publics	1,017 (3.5)	1,523 (4.6)	1,532 (4.6)	1,537 (4.6)	1,472 (4.2)
Total	28,739 (100)	32,115 (100)	33,394 (100)	33,678 (100)	35,180 (100)

CEDENAR

(MWh)

Item	1965	1966	1967	1968	1969
Residentials	23,484 (76.4)	27,173 (76.5)	27,369 (77.1)	27,508 (76.2)	29,202 (64.3)
Commercials	-	-	-	1,142 (3.1)	6,489 (14.3)
Industrials	3,910 (12.6)	4,511 (12.8)	4,318 (12.2)	3,785 (10.5)	5,558 (12.2)
Officials	988 (3.2)	1,097 (3.1)	1,147 (3.2)	1,277 (3.5)	1,815 (4.0)
Publics	2,390 (7.8)	2,688 (7.6)	2,649 (7.5)	2,446 (6.7)	2,420 (5.2)
Total	30,772 (100)	35,469 (100)	35,473 (100)	36,158 (100)	45,484 (100)

Note: ( ) indicats %

On the other hand, the growth rate of consumption per capita in these areas was estimated at about 6%, population growth rate was about 4.5%, and the total growth rate in both areas was about 11%.

Moreover, some existing industrial demand that cannot be satisfied at the present, as well as the future industrial demand were included.

With these factors taken into consideration, the annual mean growth rate of energy demand has been estimated as given in Table 4-6.

Table 4-5 Estimated Load Factor

(Unit ; %)

Load Factor	'70	'75	'80	'85
CEDELCA	← 52 →	← 53 →	← 55 →	
CEDENAR	← 50 →	← 52 →	← 55 →	

Table 4-6 Annual Mean Rate of Load Growth

(Unit ; %)

Item	'70	'75	'80	'85
CEDELCA	← 15 →	← 12 →	← 12 →	
CEDENAR	← 15 →	← 12 →	← 12 →	

Even if a high rate of growth is temporarily registered, this will not necessarily mean that the high rate of growth will continue into the future. The annual mean rate of growth of 15 to 12% for the next 15 years is a conservative estimate and is not believed to be too large.

E. Load factor

Fig. 4-2 and 4-3 show daily load curves and monthly load factors in recent years for CEDELCA and CEDENAR. According to these curves, the peak load occurs around 18.00 to 20.00 o'clock, and daily load factor is estimated to be about 60% for both areas.

A feature of this district is that no fluctuation ocurs in the load curves throughout the year, except for in September 1969 when Rio Mayo started operation.

Fluctuations in load curves between week days and weekends is considered to be also small, because the load is composed mostly of residential demands. This is the reason the shape of the load curve remains substantially unchanged throughout the year, while only the size of load continues to grow.

At present, several hours of service interruption have been recorded in both areas. The interruption of service has been caused by all kinds of damages and by maintenance of the transmission system and the equipment.

Therefore it is considered that the annual load factor is about 50% at present as shown in Table 4-3. After considering a gradual rise of annual load factor due to improvement of several electric equipment and the development of some industries, the estimation of annual load factor was made as shown in Table 4-5.

F. Result of forecast

The annual energy and maximum peak demands have been estimated based on the load factor and annual growth rate as shown in Table 4-5 and 4-6 respectively. Tables 4-7 through 4-8 show the results of these estimations.

Table 4-7 Maximum Peak Demand Forecast for CEDELCA and CEDENAR

(Unit ; MW)

Year	Maximum Power Demand				
	CEDELCA	Load Factor (%)	CEDENAR	Load Factor (%)	Total
1970	14.2		19.0		33.2
1971	16.4		22.0		38.4
1972	18.9	52	24.2	50	43.1
1973	21.7		27.8		49.5
1974	25.0		32.0		57.0
1975	27.9		33.5		61.4
1976	30.8		37.5		68.3
1977	34.3	53	42.1	52	76.4
1978	38.5		47.1		85.6
1979	43.2		52.7		95.9
1980	48.3		55.7		104.0
1981	52.0		62.5		114.5
1982	58.5	55	70.2	55	128.7
1983	65.4		78.5		143.9
1984	73.3		87.8		161.1
1985	82.1		98.3		180.4

Table 4-8 Energy Demand Forecast for CEDELCA and CEDENAR

Year	Average Growth Rate(%)	Average Energy Demand (10^6kWh)			Average Energy Demand (MW)		
		CEDELCA	CEDENAR	Total	CEDELCA	CEDENAR	Total
1970		65.0	80.0	145.0	7.4	9.1	16.5
1971		74.8	92.0	166.8	8.5	10.5	19.0
1972	15	86.0	105.8	191.8	9.8	12.1	21.9
1973		98.9	121.7	220.6	11.3	13.9	25.2
1974		113.7	139.9	253.6	13.0	16.0	29.0
1975		127.3	152.8	280.1	14.5	17.4	31.9
1976		142.6	171.1	313.7	16.3	19.5	35.8
1977		159.7	191.6	351.3	18.2	21.9	40.1
1978		178.9	214.6	393.5	20.4	24.5	44.9
1979	12	200.4	240.4	440.7	22.9	27.4	50.3
1980		224.4	269.2	493.6	25.6	30.7	56.3
1981		251.3	301.5	552.8	28.6	34.4	63.0
1982		281.6	337.8	619.4	32.2	38.6	70.8
1983		315.2	378.1	693.3	36.0	43.2	79.2
1984		353.1	423.6	776.7	40.3	48.3	88.6
1985		395.6	474.5	870.1	45.2	54.1	99.3

4.4 DEMAND AND SUPPLY CAPABILITY

Fig. 4-4 shows the balance between the demand estimated in 4.3 and the supply capability of existing plants and proposed projects.

It is noted from the figure that there will be a deficiency of power supply capability in and after 1975 and deficiency of energy supply capability in and after 1975 (dry year) or 1979 (average year). The energy supply capability of the existing diesel power plants has been estimated at plant factor of 60%.

Fig. 4-1 Electric Power System

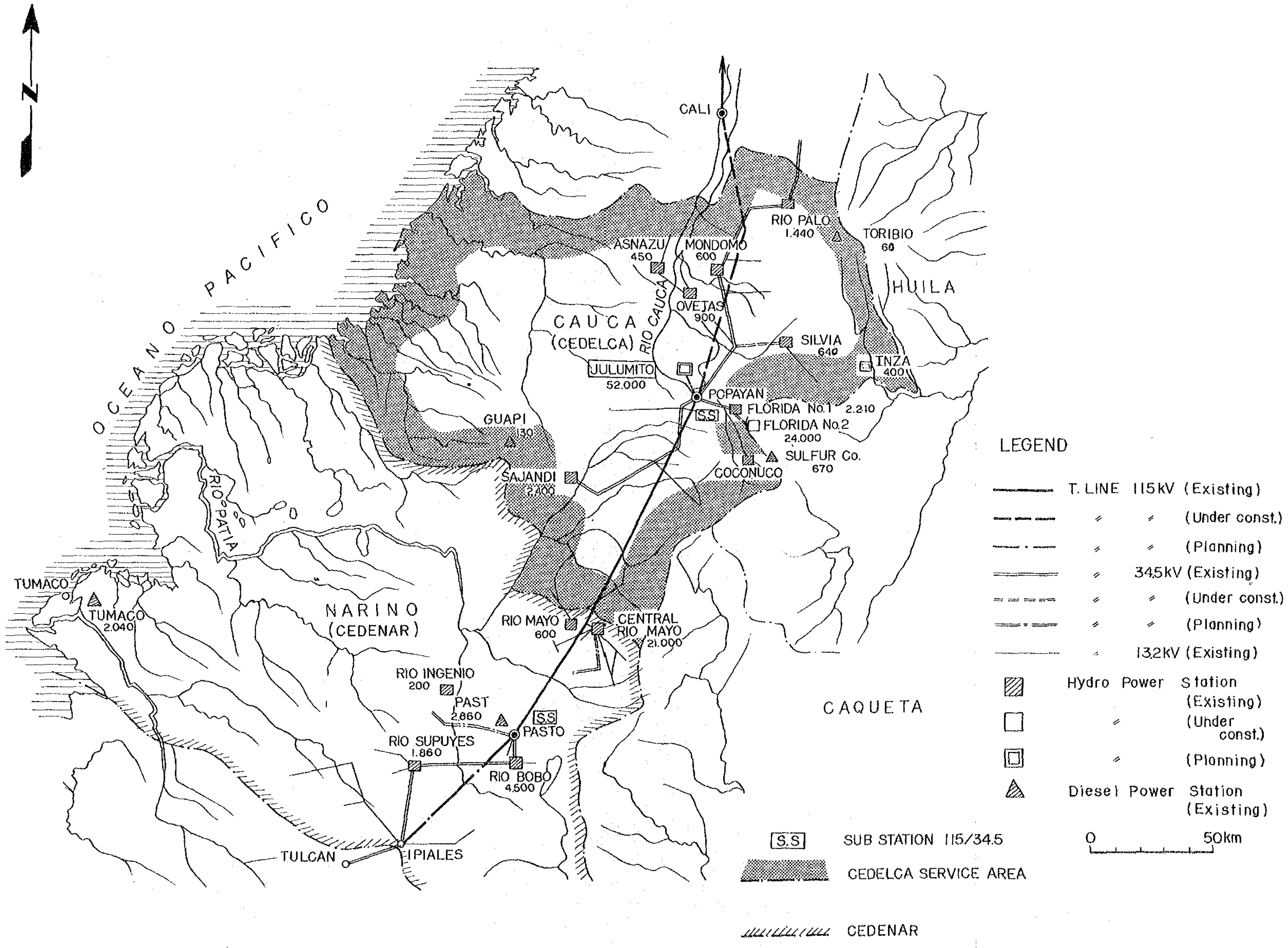


Fig.4-2 CEDELCA Load Curve

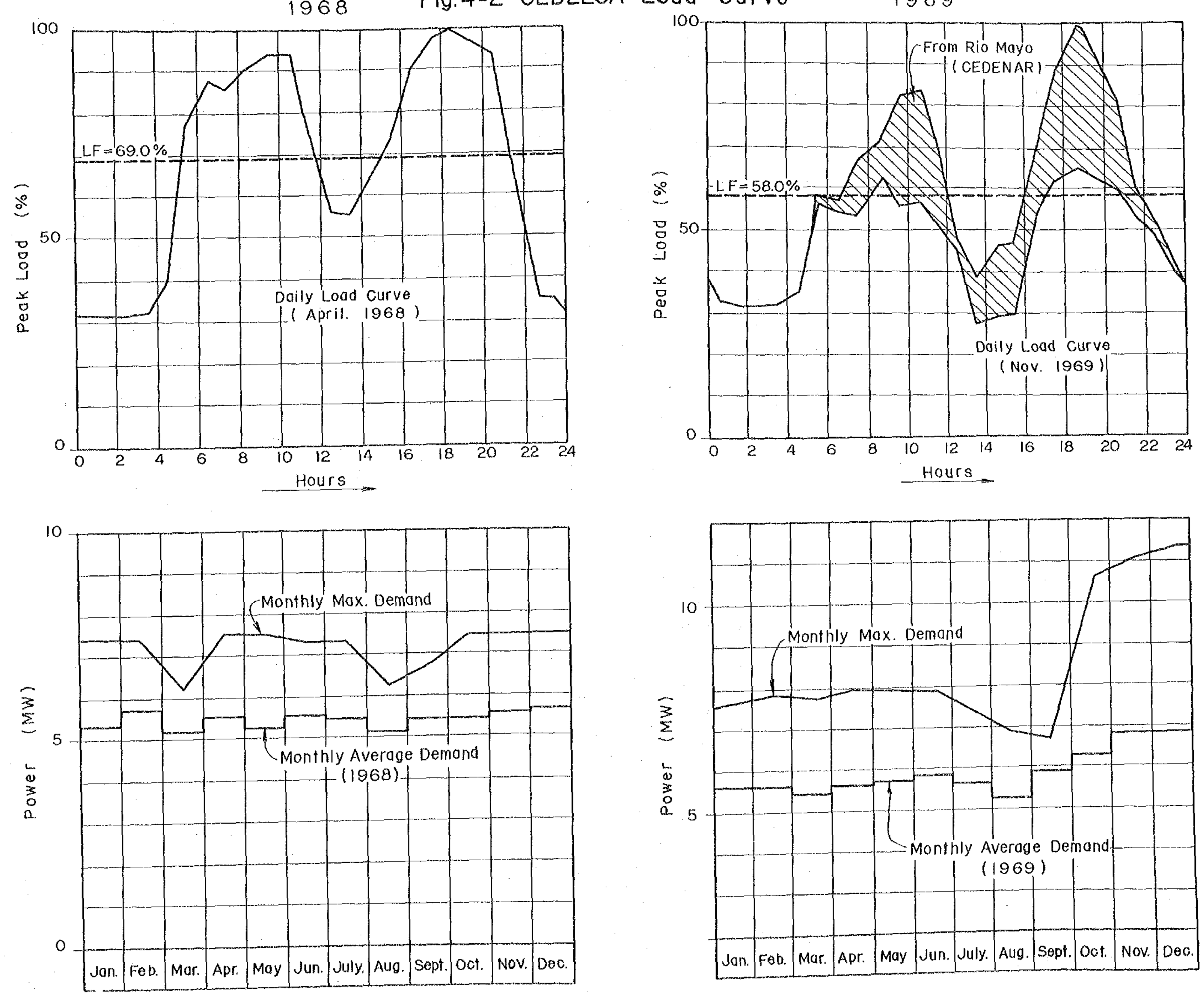


Fig.4-3 CEDENAR Load Curve

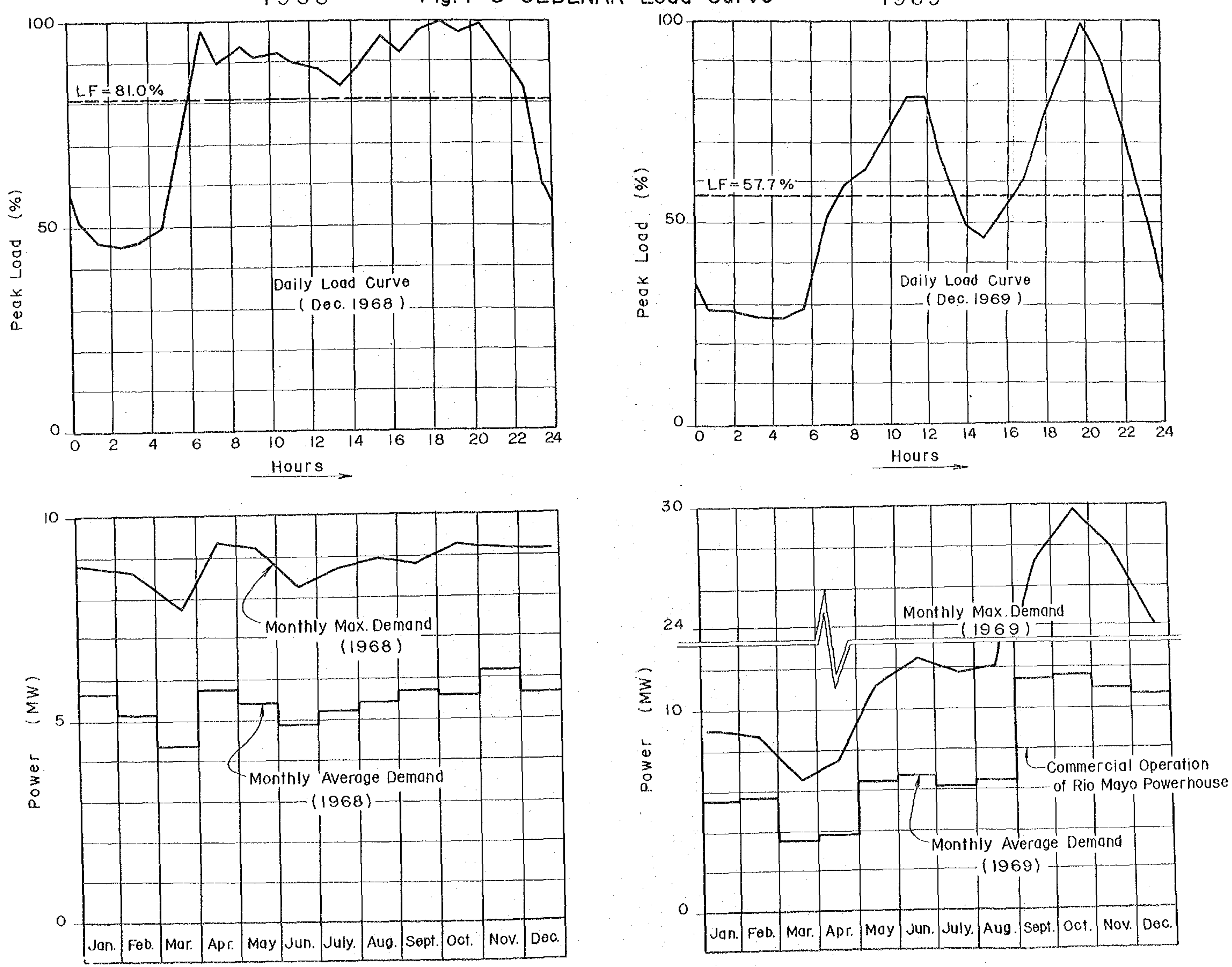
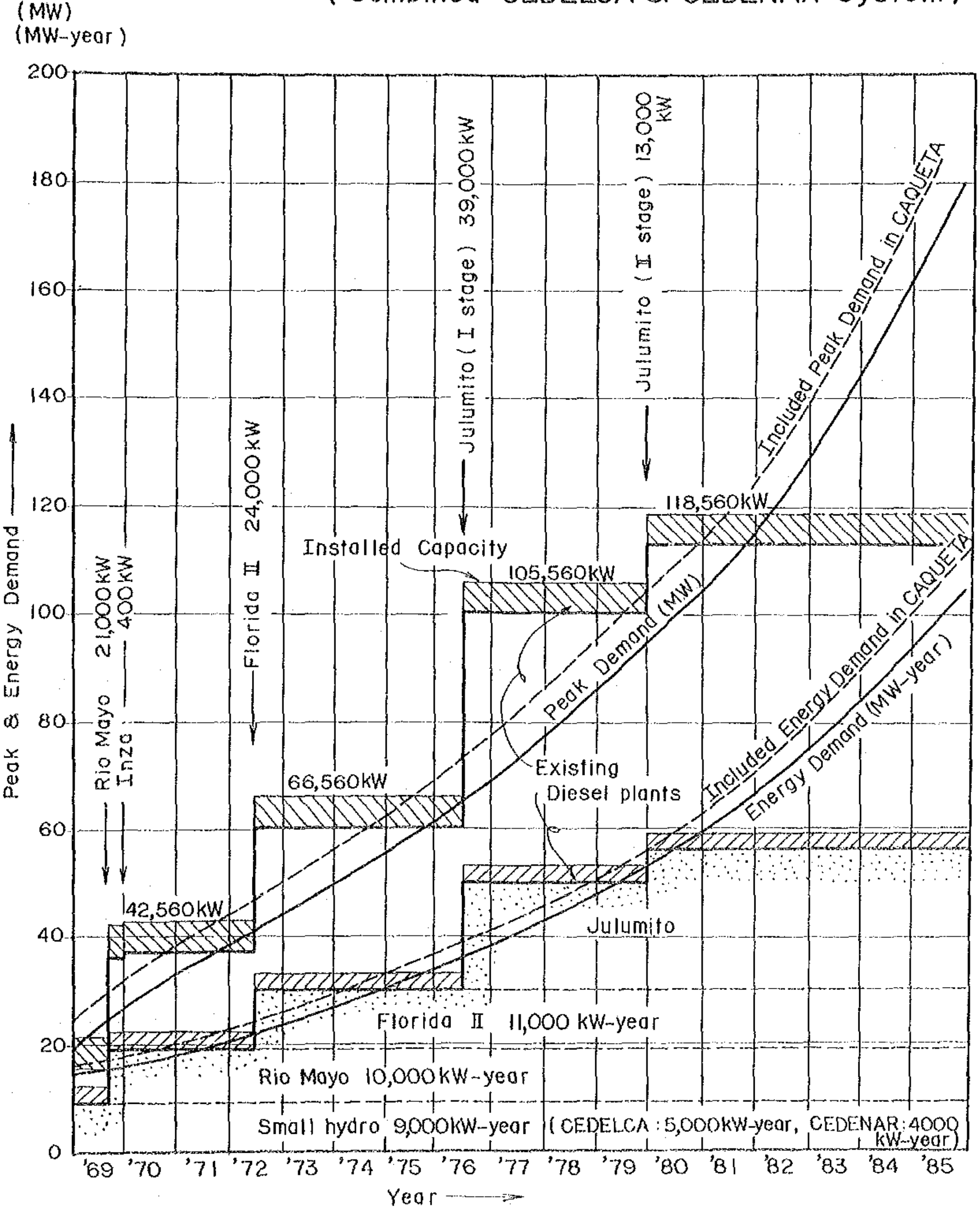


Fig.4-4 kW & kWh Balance
(Combined CEDELCA & CEDENAR System)



CHAPTER V

STUDY OF DEVELOPMENT PLAN

5.1 OUTLINE OF PROJECT AREA

The Rio Cauca originates at Paramo de las Papas in Department of CAUCA, flows from south to north through the basin between Cordillera Occidental and Cordillera Central.

The Julumito project site is located in the upper stream of the Rio Cauca near Popayan City-Latitude N. 2°5', Longitude W. 76°5' — in Cauca Department (see key and location map).

Topography of the project area is represented by a volcanic plateau around Popayan city and the steep mountainous topography higher than elevation 3000 m.

The river is generally a deep V shaped or U shaped gorge with little deposit. The gradient of the Rio Cauca is from 1/100 to 1/200 around Popayan city and about 1/30 to 1/60 on the upstream of the river.

The elevation of the project site is about 1700 m and the catchment area of the Rio Cauca at the proposed diversion dam site is 930 km^2.

According to existing data, the average precipitation of this area varies from 1600 mm to 2200 mm. Particularly, the precipitation at Purace and Coconuco in the mountainous area is large and frequently the annual precipitation is over 3000 mm.

Locally, April and May and October to December are referred to as the rainy seasons and the period from July to September is the dry season. Most of the rainfall are localized strong showers of short duration, and prolonged rainfall is not frequent. The temperature at the project area, which is situated near the equator, is mild because of the high altitude (average temp. 18.4°C.)

Geology of this area mainly consist of lava flow and tuffaceous clay covering the lava flow. Lava flow is the basement rock of the project site and forms the lava plateau. It is presumed that tuffaceous clay was changed from the volcanic ash accumulated on the lava plateau.

Besides the abovementioned volcanic prodr-t, terrace deposit of the Rio Cauca are widly distributed in the area around Popayan city.

The project area, as mentioned above, has favorable natural conditions for hydroelectric development, but, except for the Florida II project which is now under construction, the hydro resources have not been developed.

5.2 STUDY OF DEVELOPMENT PLAN

A. General

Basic scheme of development of the Julumito hydroelectric project as considered is to construct a dam on the Rio Sate which is a tributary of the Rio Cauca, and divert water from the Rio Cauca and the Rio Palacé (in the future) into the reservoir with carryover storage capability. Water stored in the reservoir is to be utilized for power generation by the head between the reservoir and the Rio Cauca. Water discharged through the powerhouse is to be released back into the Rio Cauca.

B. Dam site

Following three dam sites on the Rio Sate as shown in Fig. 5-1 and 5-2 were considered for the project.

No. 1 Dam Site ; Located about 8 km upstream of the confluence with the Rio Cauca

No. 2 Dam Site ; Located about 1.5 km downstream of No. 1 Dam Site

No. 3 Dam Site ; Located about 0.5 km downstream of No. 2 Dam Site

The result of the field reconnaissance of above three dam sites is shown on the following Table 5-1.

Table 5-1 Result of Field Reconnaissance of Dam Site

Dam Site	Topography	Geology	Dam Volume
No. 1	A	C	A
No. 2	A	A	A
No. 3	B	B	C

Note; A ; Good

B ; Comparatively good

C ; Not good

Dam Volume ; At same reservoir capacity, including the volume of dike.

Judging from the above Table 5-1, the best site is No. 2 site, and No. 1 site was considered as an alternative of No. 2 site. No. 3 site is inferior than the other two.

C. Powerhouse site

Field reconnaissance of powerhouse site was made of following four proposed sites.

No. 1 Powerhouse Site ; Above ground
Located about 2.5 km downstream of the Julumito bridge on right bank of the Rio Cauca

No. 2 Powerhouse Site ; Above ground
Located about 2.5 km downstream of No. 1 site on right bank of the Rio Cauca

No. 3 Powerhouse Site ; Above ground
Located about 2 km downstream of No. 2 site on right bank of the Rio Cauca

No. 4 Powerhouse Site ; Located underground near No. 2 Dam site

Table 5-2 Result of Field Reconnaissance of Powerhouse Site

Powerhouse Site	Topography	Geology	Available Head
No. 1	C	B	C
No. 2	B	B	B
No. 3	B	B	A
No. 4	A	Unknown	A

Note; A ; Good

B ; Comparatively good

C ; Not good

Judging from the above Table 5-2, No. 2 and No. 3 powerhouse sites are considered to be comparatively good for an aboveground powerhouse site, and the underground site may be an alternative of No. 2 or 3 site, if the geological condition is good.

D. Plan of development

Following three plans of development for the project were studied taking into consideration the above mentioned results of field reconnaissance.

Table 5-3 Plan of Development

Plan	Dam Site	Powerhouse		Tunnel	Remarks
		Site	Type		
A	No. 2	No. 4	underground	Tailrace	See Fig. 5-1
B	No. 2	No. 2	aboveground	Headrace	See Fig. 5-2
C	No. 2	No. 3	aboveground	Headrace	See Fig. 5-2

Note; In addition to the abovementioned plans, various plans were considered combining dam sites and powerhouse sites, but they were found to be less economical.

5.3 SCALE OF DEVELOPMENT

A. Diversion from Rio Cauca and Rio Palacé

The catchment area at the diversion dam site of the Rio Cauca is about 930 km^2 and the daily river discharge at this site is roughly as follows;

Max. 43 m^3/sec.

Mean 22 m^3/sec.

Min. 13 m^3/sec.

The result of economic evaluations is shown in the following Table 5-4.

Table 5-4 Study of Diversion Channel Capacity

Channel Capacity (m^3/sec)	Discharge (m^3/sec-day)	Ratio of Diverted Discharge (%)	Increment of Energy Generation (10^6 kWh)	Additional Construction Cost (10^3 \$)	Additional Construction Cost (\$/kWh)
25	7055	88	15	2,000	0.13
30	7383	92	9	2,200	0.24
35	7628	95	6	2,500	0.42
40	7710	96	2	3,000	1.50

According to the results of abovementioned study, 35 m^3/sec was considered to be economical and optimum channel capacity.

A capacity of 9 m^3/sec was selected for the Rio Palacé diversion channel (catchment area 230 km^2) as the result of the study.

B. Storage capacity of reservoir

Using the run-off obtained in Chapter VII, mass curve and reservoir operation diagram for the period of five years from May 1964 to April 1969 have been prepared. In estimating the optimum effective storage capacity of the reservoir, a reservoir capacity was determined which can regulate the flow so that the average powerhouse discharge is approximately equal to the average annual inflow of the five years aforementioned. The effective storage capacity so determined is 50×10^6 m^3. The total storage capacity of the reservoir was determined as 60×10^6 m^3 including 10×10^6 m^3 of dead storage.

The required high water surface elevation for the abovementioned capacity is 1715 m. The optimum high water surface level of the Julumito reservoir was found to be between 1717 m and 1712 m from topographic and economic points of views.

Detail study of the high water surface level should be further studied in the feasibility study.

C. Powerhouse discharge

Using the mass curve from May 1964 to April 1969 mentioned in 5.3 B (Fig. 5-3), the firm volume of outflow has been calculated in accordance with the effective storage capacity of 50×10^6 m^3 (571 m^3/sec-day). Then, considering the future trend of load curves in the region, a maximum discharge of 50 m^3/s for an annual load factor of 55% was obtained for the final stage capacity.

D. Installed capacity, firm output and annual energy production

Based on the powerhouse maximum discharge and firm volume of outflow mentioned above, the installed capacity and dependable output has been estimated. The annual energy production has been calculated for the period of May 1964 to April 1969.

These figures are shown in Table 5-5.

5.4 CONSTRUCTION COST

Construction cost of the Julumito project was calculated using the following basic assumptions.

(1) Construction cost have been roughly calculated from a topographical map (Scale of 1/10000) and ground survey maps and cross sections.

(2) Interest rates on investments: 7.5% per annum for foreign currency, 10% annum for domestic currency, weighted average 9.1% per annum.

(3) Unit costs for civil works were used taking into consideration the comments of CEDELCA.

A summary of the estimated construction cost of the respective plans is given in Table 5-6.

5.5 CONCLUSION

The result of above studies is shown in following Table 5-5.

Table 5-5 Result of Study of Development Plan

Item	Plan-A*	Plan-B*	Plan-C*
Powerhouse discharge (m^3/s)	50	50	50
Effective head (m)	126	102	124
Installed capacity (kW)	53,000	43,000	52,000
Annual energy production (10^6kWh)	268	210	265
Construction cost ($10^3$$)	307,000	287,000	300,000
Cost per kWh ($/kWh)	0.115	0.140	0.115

* See Table 5-3.

Table 5-6 Construction Cost

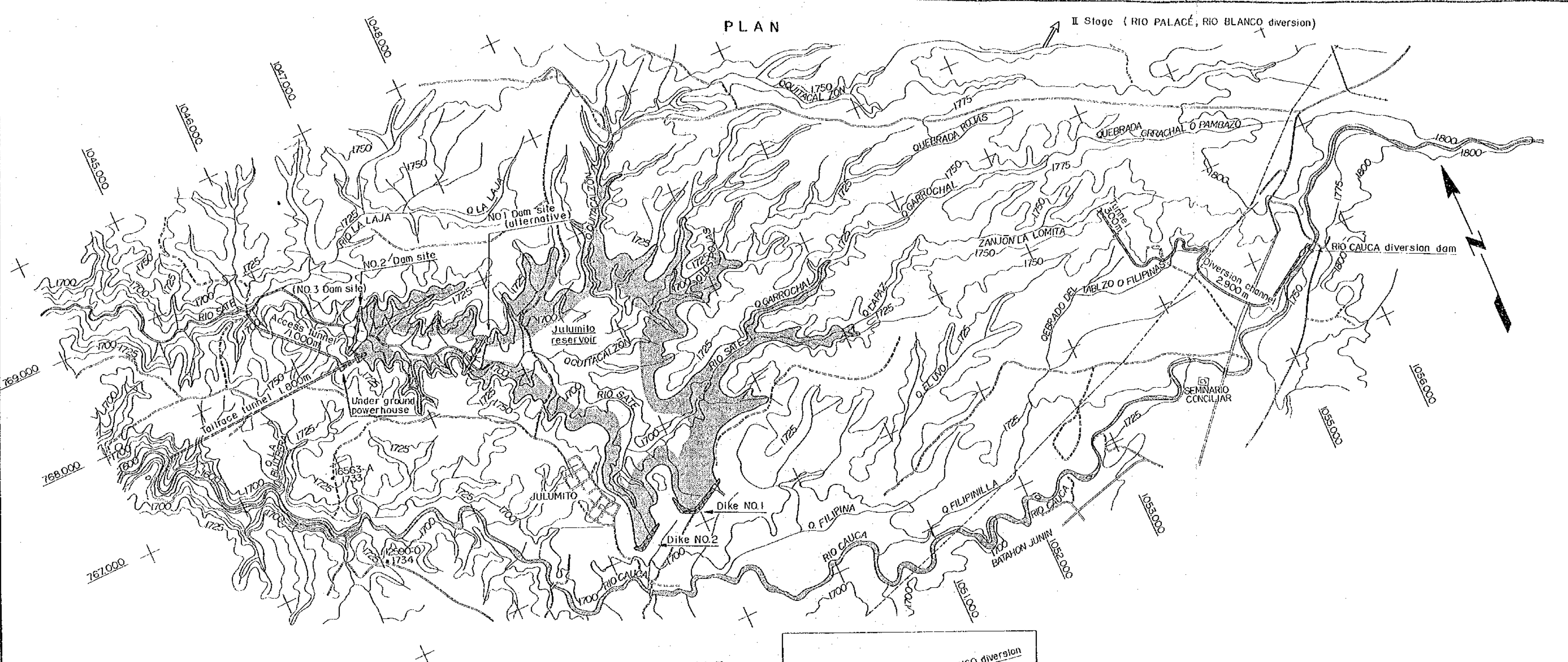
(Unit ; 10^3 $)

Item	Plan-A*	Plan-B*	Plan-C*
I-Stage			
Civil works	143,000	133,000	137,000
Hydraulic and electric equipments	56,500	55,300	58,400
Preliminary works	3,600	3,200	3,300
Compensation	2,200	2,200	2,200
Administration	1,000	1,000	1,000
Transmission line	2,300	2,300	2,300
Sub-station	1,200	1,200	1,200
Engineering	8,000	8,000	8,000
Contingency	26,000	23,000	25,000
Interest during construction	22,200	21,800	21,600
I-Stage total	266,000	251,000	260,000
II-Stage (**)			
Civil works	18,000	18,000	18,000
Hydraulic and electric equipment	14,000	11,000	14,000
Others (Contingency, Interest)	8,000	7,000	8,000
II-Stage total	40,000	36,000	40,000
(I + II) Total	306,000	287,000	300,000

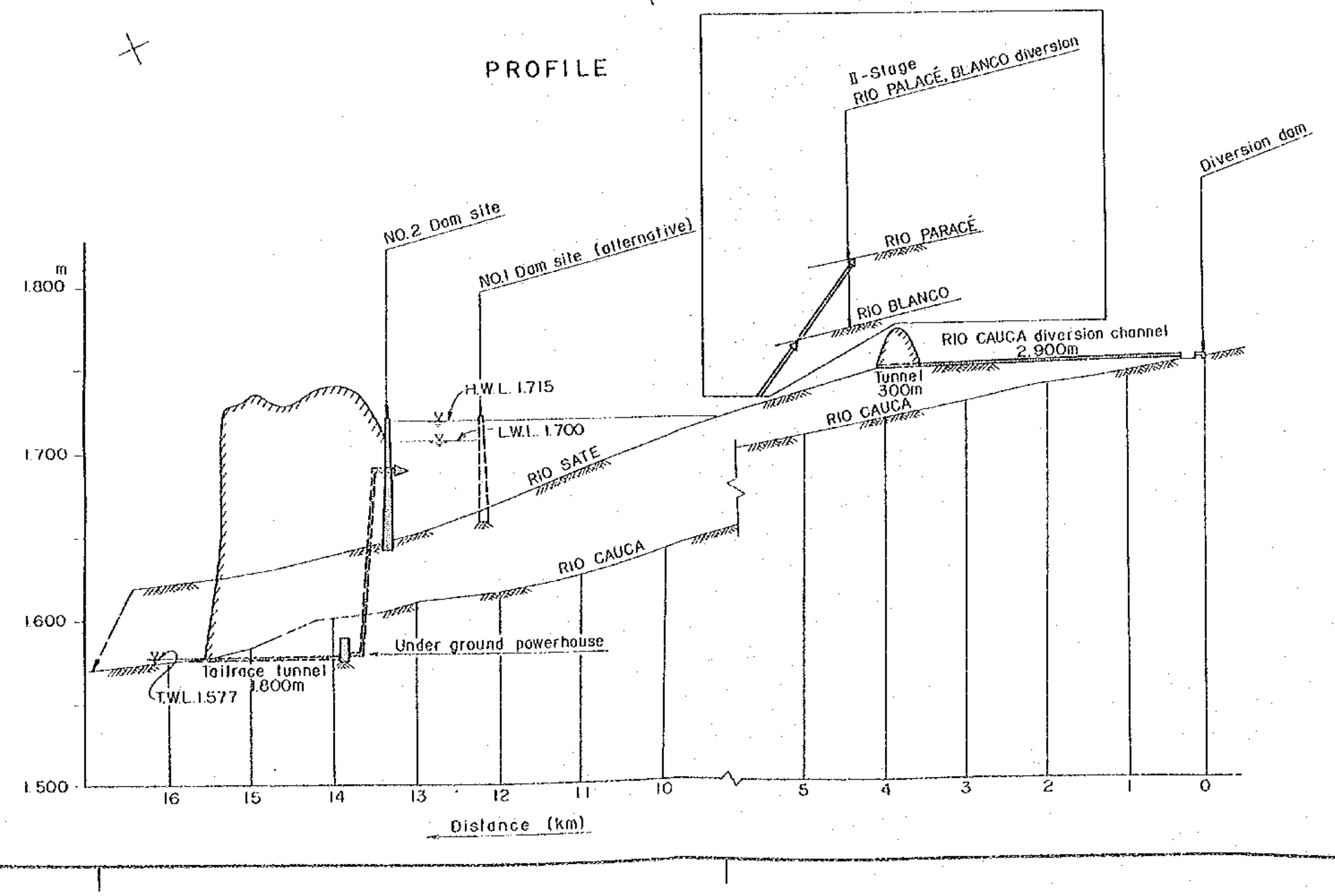
* See Table 5-3

** II-Stage ; Diversion from the Rio Palacé and installation of No. 4 unit (13,000 kW).

PLAN

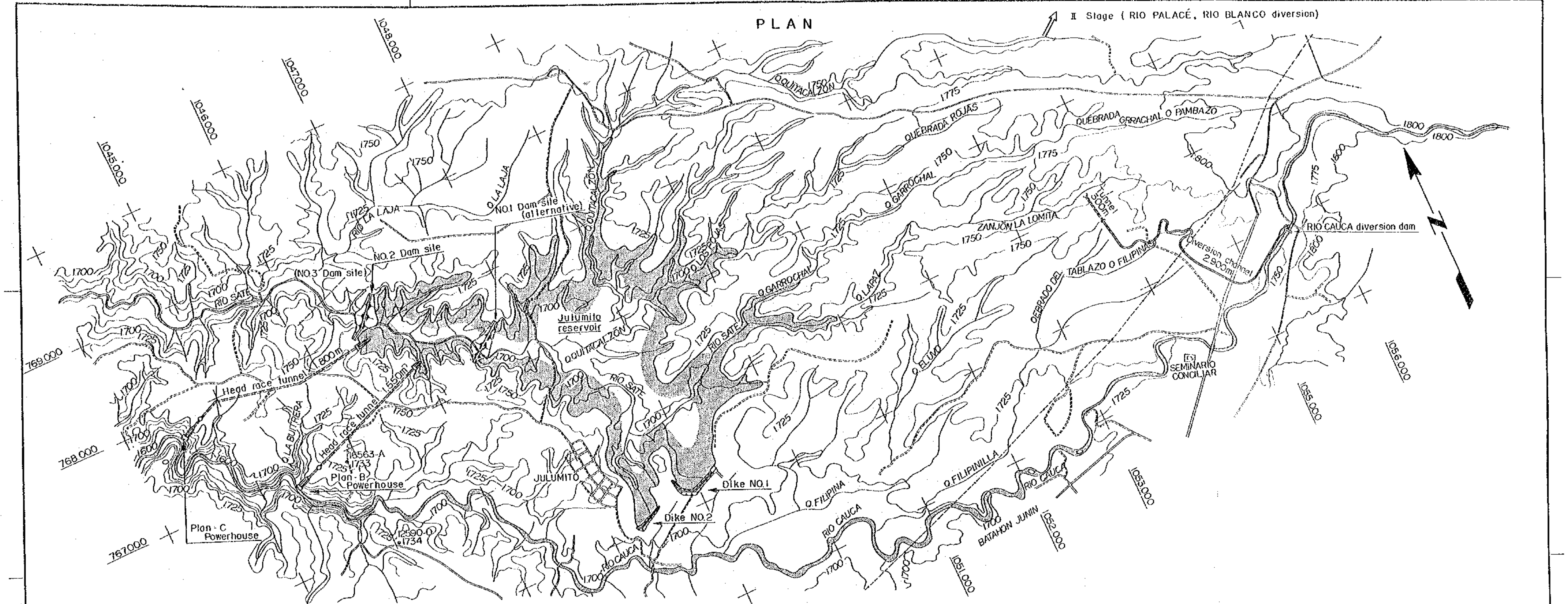


PROFILE



OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO - JAPAN
CENTRALES ELECTRICAS DEL CAUCA S.A.
JULUMITO HYDROELECTRIC PROJECT
GENERAL PLAN AND PROFILE FOR PLAN-A
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO - JAPAN
FIG. 5-1   DATE

PLAN



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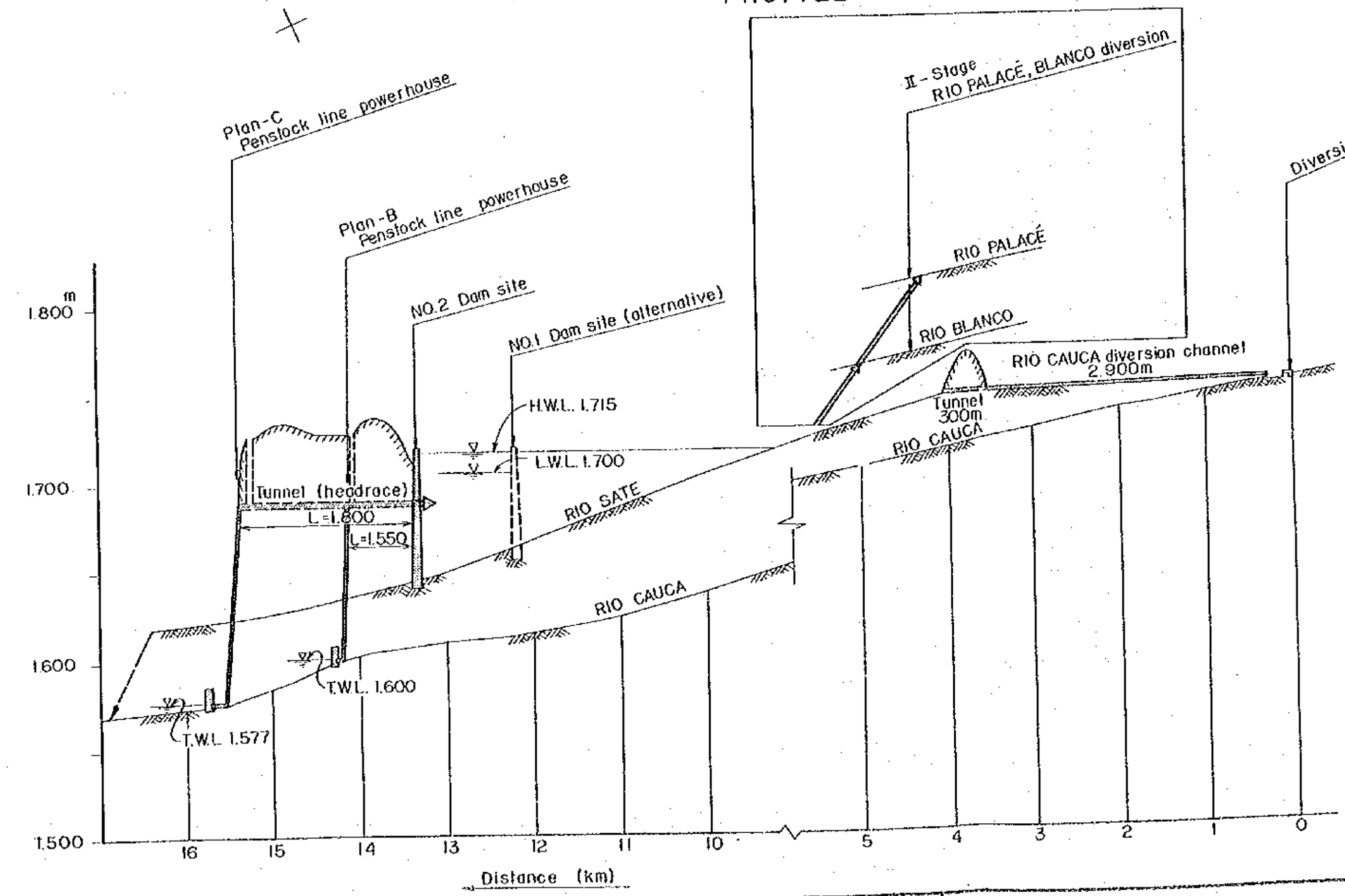
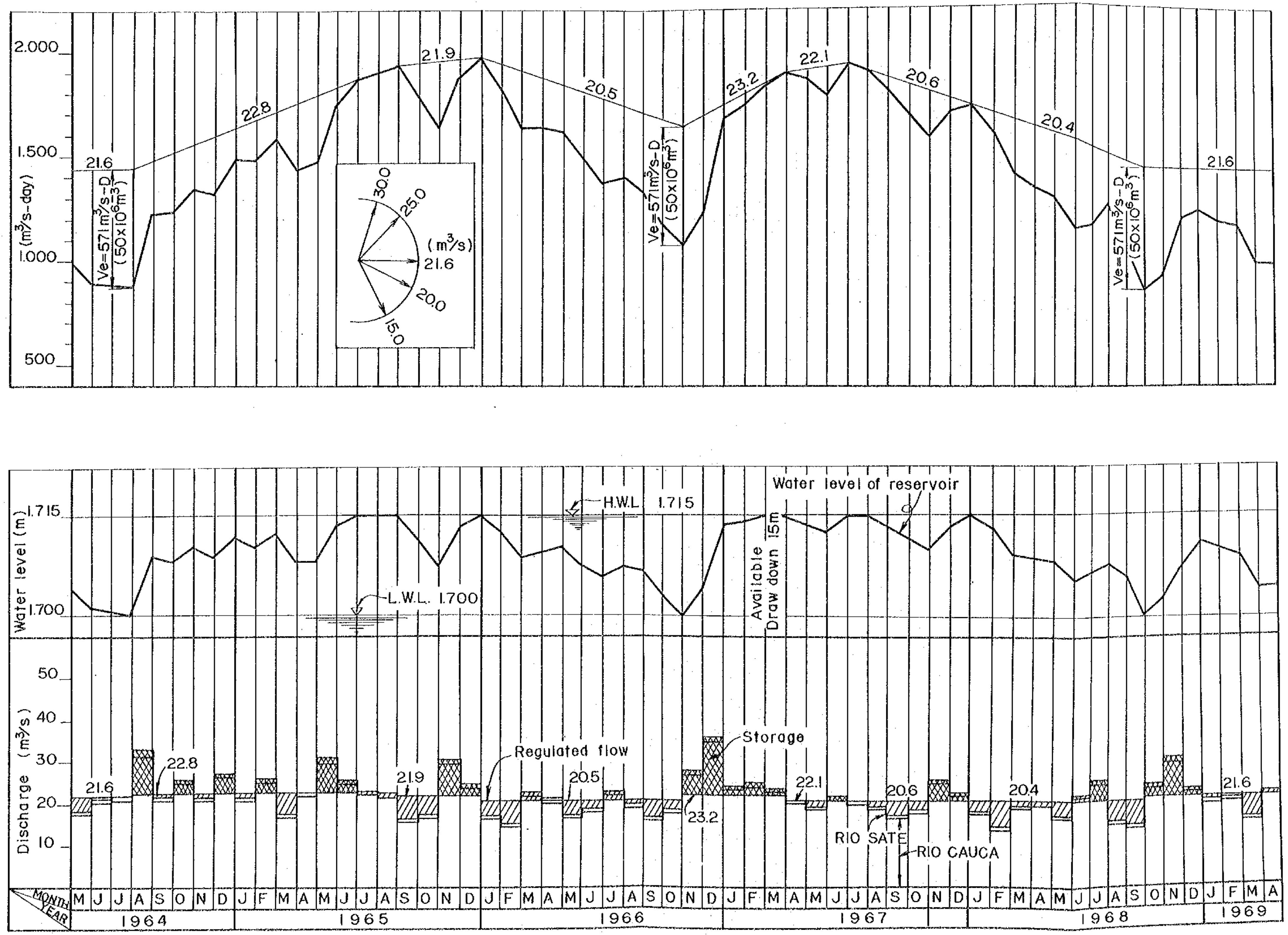


OVERSEAS TECHNICAL COOPERATION AGENCY TOKYO - JAPAN
CENTRALES ELECTRICAS DEL CAUCA S.A.
JULUMITO HYDROELECTRIC PROJECT
GENERAL PLAN AND PROFILE FOR PLAN-B AND C
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO - JAPAN
FIG. 5-2 / DATE

Fig. 5-3 Reservoir Operating Diagram (I Stege)



LEGEND

DISCHARGE OF RIO SATE
INFLOW OF RIO CAUCA
STORAGE
REGURATED FLOW

Note :
This diagram shows the reservoir operation at the I stage development (before the completion of RIO PALACE diversion)

CHAPTER VI

ECONOMIC EVALUATION

The method of evaluation is to compare the project with an alternative thermal plant which can provide equivalent service (kW and kWh) and the cost of energy in the CVC system.

The following paragraphs show the result of economic evaluation on the assumption of complete consumption of power and energy

6.1 ANNUAL COST AND COST OF ENERGY

Annual cost of the project have been calculated on the following assumption.

A. Basis of calculation

(1) Interest rate; 7.5% per annum for foreign currency
10 % per annum for domestic currency
Weighted average 9.1% per annum.
(40% foreign and 60% domestic currency)

(2) Amortization 50 years
0.091 x (Total construction cost)

(3) Replacement
- Hydraulic and mechanical equipment 30 years
  0.114 x 0.077 x (Const. cost of above equipment)
- Electrical equipment 35 years
  0.080 x 0.077 x (Const. cost of electrical equipment)
- Transmission line and substation 30 years
  0.114 x 0.077 x (Const. cost of T.L. and S.S.)

B. Maintenance and operation

(1) Dam

0.0030 x (Const. cost of dam)

(2) Power generating facility

0.010 x (Const. cost of power generating facility)

(3) Transmission line

0.015 x (Const. cost of transmission line)

(4) Substation

0.025 x (Const. cost of substation)

C. Other expenses

0.0050 x (Total construction cost)

Table 6-1 Calculation of Annual Cost and Cost per kWh

(Plan - C)

	Unit	Cost	Remarks
(1) Amortization	10^3\$	27,300	
(2) Replacement	10^3\$	500	
(3) Maintenance and Operation	10^3\$	2,000	
(4) Others	10^3\$	200	
Total annual cost	10^3\$	30,000	
Salable Energy at Substation	10^6kWh	260	loss 2% 265 x 0.98
Cost per kWh at Substation	¢/kWh	11.5	

6.2 ALTERNATIVE SOURCE

For the purpose of benefit-cost studies, a 50,000 kW thermal power plant built near Popayan was assumed as an alternative source. The unit costs of power and energy of the thermal power plant were calculated and the values were used as basic unit prices for the calculation of benefit of the proposed project. Calculations of the basic unit prices are given in Table 6-2.

Basic data of thermal power and unit costs are follows;

Type of alternative thermal plant:	Oil burning
Capacity x Units	25,000 kW x 2
Efficiency	28%
Annual fuel consumption	80 x 10^3 kl
Fuel cost	1.8 $/l
Annual energy production	263 x 10^6 kWh
Initial construction cost	200,000 x $10^3$$

Table 6-2 Annual Cost of Alternative Thermal Plant

(10^3 $)

	Total Annual Cost.	Fixed Cost	Variable Cost
(1) Amortization	16,500	16,500	-
(2) Operation and maintenance	5,400	4,700	700
Wages and salaries	1,550	1,550	-
Repair expense	3,500	2,800	700
Miscellaneous	350	350	-
(3) Administration	500	400	100
(4) Fuel cost	25,200	-	25,200
Total	47,600	21,600	26,000

Note; 1. Serviceable years: 25 years

2. Interest rate; 7.5% annum for foreign currency

10 % annum for domestic currency

3. Cost of transmission line was neglected.

The results are

Unit power benefit: $21,600 \times 10^3\$/50,000$ kW = 432\$/kW

Adjustment of kW: 432\$/kW x 1.2 = 518\$/kW

Unit energy benefit: $26,000 \times 10^3\$/260 \times 10^6$kWh = 0.10\$/kWh

6.3 BENEFIT COST RATIO

The annual benefit and benefit-cost ratio are shown in the following Table 6-3.

Table 6-3 Annual Benefit and Benefit-Cost Ratio

(Plan-C)

	Unit	Cost
Benefit of kW (B_1)	10^3\$	26,000
Benefit of kWh (B_2)	10^3\$	26,000
Benefit ($B=B_1+B_2$)	10^3\$	52,000
Annual cost (C)	10^3\$	30,000
Benefit-cost ratio (B/C)		1.7

Note; Above benefit is simply calculated on the assumption of complete consumption of power and energy.

6.4 COMPARISON WITH COST OF ENERGY IN CVC SYSTEM

The purchase of energy from CVC system is considered to be one alternative source.

The wholesale price of energy at the substation in CVC system, which is more than 22¢ per kWh at present time, may be reduced in the future by the completion of interconnection system and large scale projects in the system.

The estimated energy cost of Julumito project delivered at primary substation is about 11.5¢ per kWh, and seems to be competitive with that of the CVC system, besides the transmission line between CVC and CEDELCA-CEDENAR systems which is under construction will contribute to the stabilization of supply capability as a reserve capacity.

Detail comparative study cost of energy in CVC system should be made in the feasibility study.

CHAPTER VII

HYDROLOGY

7.1 PRECIPITATION DATA

Within the catchment area of the Julumito project, there are several precipitation observation stations. At each station, daily precipitation is being observed over a comparatively long period. Monthly precipitation at these stations is given in Table 7-2.

Table 7-1 Precipitation Record

Gauging Station	Elevation (m)	Period
Popayan (ICEL)	1790	1955 - 1969
Florida	1968	1951 - 1969
Coconuco	2300	1947 - 1969
Puracé	3200	1946 - 1969

Table 7-2 Monthly Average Precipitation in the Catchment Area

(Unit; mm)

Gauging Station	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Popayan	135	161	120	164	119	79	41	48	91	250	275	212	1695
Florida	153	147	168	181	140	98	40	32	89	267	311	287	1913
Coconuco	183	105	157	146	141	88	40	41	43	207	272	168	1591
Puracé	196	87	115	125	177	247	306	197	97	178	159	176	2060

7.2 RUN-OFF DATA

Within the catchment area of the Julumito project, the Julumito gauging station on the Rio Cauca is near the proposed project area. At this station daily regular observations are being carried out by National Meteorological Observation Agency. The records available are for the five years from May 1964 to January 1969. The average monthly run-off of the five years is given in the following Table 7-3.

Table 7-3 Monthly Average Run-off at Julumito Gauging Station

(Unit; m^3/sec)

Item	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max.	45.0	40.1	48.0	53.9	34.0	48.2	61.4	43.2	30.2	54.0	56.7	49.7
Mean	20.8	21.1	20.1	24.0	21.6	25.1	31.2	25.7	18.2	23.9	32.6	27.4
Min.	11.9	12.7	12.1	13.8	14.6	15.3	15.4	15.5	14.1	13.9	16.2	16.5

Note: Catchment Area at Julumito Gauging Station; 1015 km^2
(Measured on the Map "Cauca 1/250000")

Daily records of run-off at Julumito gauging station are shown in the Appendix.

7-3 ESTIMATION OF RUN-OFF AT PROPOSED SITE

The daily run-off records of the aforementioned five years at the Julumito gauging station were used for the study of the Julumito project. The run-off at the proposed site was estimated to be proportional to the run-off at the Julumito gauging station in relation to the respective catchment areas.

During the eleven months from December 1966 to April 1967 and July 1967 to December 1967 daily run-off was not observed at the Julumito gauging station. Therefore, the record for these months were supplemented by the following hydrological analysis.

(1) The correlation between accumulated annual precipitation at

Popayan, Puracé and Coconuco in the catchment area and the accumulated annual run-off at the Julumito gauging station.

(2) The correlation between run-off at Salvajina gauging station (3830 km^2) at the middle stream of the Rio Cauca and run-off of the Julumito gauging station.

The correlation between precipitation and run-off in the catchment area and other hydrological studies should be carried out in more detail during the feasibility study.