(4) Present State of Balance Between Power Demand and Supply Capability

In 1979, the maximum demand recorded for the entire country was 3,690.5 MW, of which 2,902.6 MW corresponding to 78.7% was maximum demand occurring within the interconnected system. This interconnected system covers the three great load centers, the city of Bogota supplied by Bogota Electric Power, the city of Medellin supplied by Medellin Electric Power, and the city of Cali supplied by C.V.C.

The interconnection will be completed in 1982 between the system of Corelca Electric Power, in the north centered at the cities of Barranquilla and Magdalena, and the existing interconnected system, and the maximum demand of the interconnected area in 1981 will become 4,058 MW.

The total output of existing power generating facilities tied up with this interconnected system is 4,238.7 MW consisting of 2,949.4 MW of hydro and 1,289.3 MW of thermal. When new power generating facilities to be commissioned in 1981 (Zipaquira IV, 66 MW; Chivor II, 500 MW: Paipa III, 66 MW; Chinu, 100 MW; total, 732 MW) are added, the total power generating facilities will become 4,970.7 MW, and this will result in a reserve capacity of 913 MW.

However, when reduction in hydro due to drought and repairs of thermal are considered, it is estimated that the maximum reduction of the supply capacity will be 18% so that the dependable supply capacity in the interconnected system will be 4,200 MW, and there will be only 142 MW, or 3.5% allowance above the maximum demand of 4,058 MW. With such a situation, there will be great risk of a shortage in supply capacity, arising in case a fault occurs when an abnormally dry year is encountered.

The states of demand and supply balance for the past 7 years are as shown in table 4-2-2.

Table 4-2-2 kW Balance of Interconnected System (1975∿1981)

Year	Maximum Demand A	Installed Capacity B	Firm Capacity C	B-A	C-A	(C-A)/A
	MW	MW	MW	MW	MW	%
1975	2,111.7	2,498		386.3		
1976	2,264.1	2,630		365.9		
1977	2,381.8	3,130		748.2		
1978	2,680.0	3,165		485.0		
1979	2,902.6	3,460		557.4		
1980	3,116	3,460	2,900		-216	-6.9
1981	*4,058	**4,970.7	4,200		142	3.5

Note: * Including Corelca system.
** Including the power plants which was commissioned in 1981.

The annual growth rates in maximum demand and annual energy consumption of the individual utilities during the past 9-year period (1971∿1979) are as shown in table 4-2-3.
According to this table, the average growth rate in electric power consumption in Colombia has been 9.40%/year, and the highest growth rate was 11.89% which was indicated in 1973.

Table 4-2-3 Annual Growth Rate of Demand (1971∿1979)

Unit: %/year

Utility		1971	1972	1973	1974	1975	1976	1977	1978	1979	Average Growth Rate
E.E.E.B.	E	11.75	10.03	10.93	11.41	10.90	10.47	7.43	10.93	11.66	10.61
	P	9.60	8.28	10.74	7.26	7.88	9.06	7.18	12.63	9.94	9.17
E.P.M.	E	9.41	10.37	9.06	7.11	6.31	10.01	-1.42	13.86	9.21	8.21
	P	13.74	6.87	11.97	5.94	7.75	5.29	3.13	11.82	6.42	8.10
C.V.C.	E	9.63	10.47	10.24	7.90	5.47	11.03	0.79	14.04	8.90	8.72
	P	12.60	5.59	8.48	10.75	7.94	8.44	7.28	6.79	8.33	8.46
ICEL	E	10.25	10.61	13.70	9.66	12.53	11.04	9.56	18.92	10.43	11.85
	P	7.77	10.16	22.00	3.17	16.07	13.44	4.13	14.83	7.35	10.97
CORELCA	E	—	—	10.55	9.93	6.33	13.40	6.42	15.59	12.57	10.68
	P	—	—	4.21	11.24	11.18	10.81	8.42	17.73	6.66	10.03
Total	E	11.07	9.10	11.89	7.14	9.87	9.19	5.78	12.71	7.90	9.40
	P	-	-	-	-	-	-	-	-	-	-

Note: E; Annual Energy Consumption, P; Maximum Demand

(5) Service Type of Electric Power

The service type of electric power in Colombia, as seen from the records for 1979, were 37.07% residential, 24.73% industrial, 10.32% commercial, 3.89% governmental, 1.83% public lighting, 2.22% others, and 19.85% power losses. Seen from the ratios, the extent of power losses is conspicuous and indicates the necessity for improvements in the power transmission and distribution networks. If power losses could be reduced from the present level to 12%, it would mean that approximately 300 MW of supply capability can be economized.

The consumption ratios of electric power by utility are as shown in table 4-2-4.

Table 4.2.4 Service Type of Electric Power

Unit: %

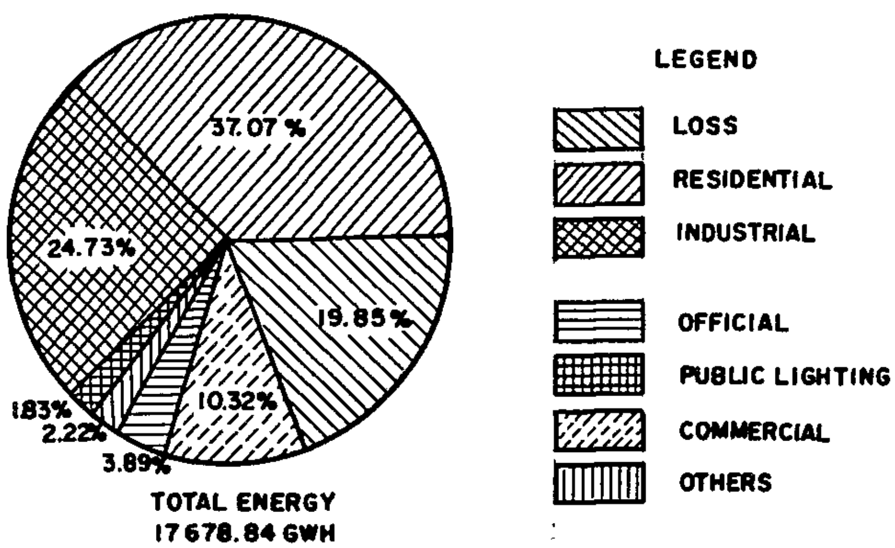
Service Type / Utility	Residential	Industrial	Commercial	Governmental	Public Lighting	Others	Whole-sale	Losses
ICEL	36.05	8.72	16.75	3.85	2.24	3.89	11.1	17.33
ISA	-	-	-	-	-	-	98.54	1.46
E.E.E.B.	31.94	24.05	12.81	5.31	2.39	-	4.78	18.72
E.P.M.	33.63	22.26	5.82	2.17	0.55	1.03		17.90
C.V.C.	33.13	32.30	9.73	-	-	6.25	5.95	13.00
CORELCA	32.72	24.10	10.55	6.15	2.60	-	2.60	21.23
OTHERS	54.90	8.35	9.85	1.60	-	-	-	25.30
Total	37.07	24.73	10.32	3.89	1.83	2.22	-	19.85

Meanwhile, the results of investigations of electric power consumption are as described below. Seen from the population statistics of Colombia, the population of 1975 was 24 million, and the population of 1979 estimated by assuming population growth rate of 3% should have been 27 million.

The maximum demand in that year was 3,690.5 MW and the annual energy consumption 17,679 GWh/year, so that the per capita consumption was 137 W/capita, or 655 kWh/capita/year.

This consumption corresponds to the fifth highest in Latin America after Brazil, Mexico, Argentina and Venezuela. This shows that Colombia has been making considerable efforts for expansion of the electric power sector. Further, as shown in Fig. 4-2-3, electric power for industrial and commercial purposes make up 35.05% of the whole, and the consumption has attained 6,196 GWh/year. It indicates that considerable electrification has progressed.

Fig. 4-2-3 Uses of Electric Power (1979-GWH)

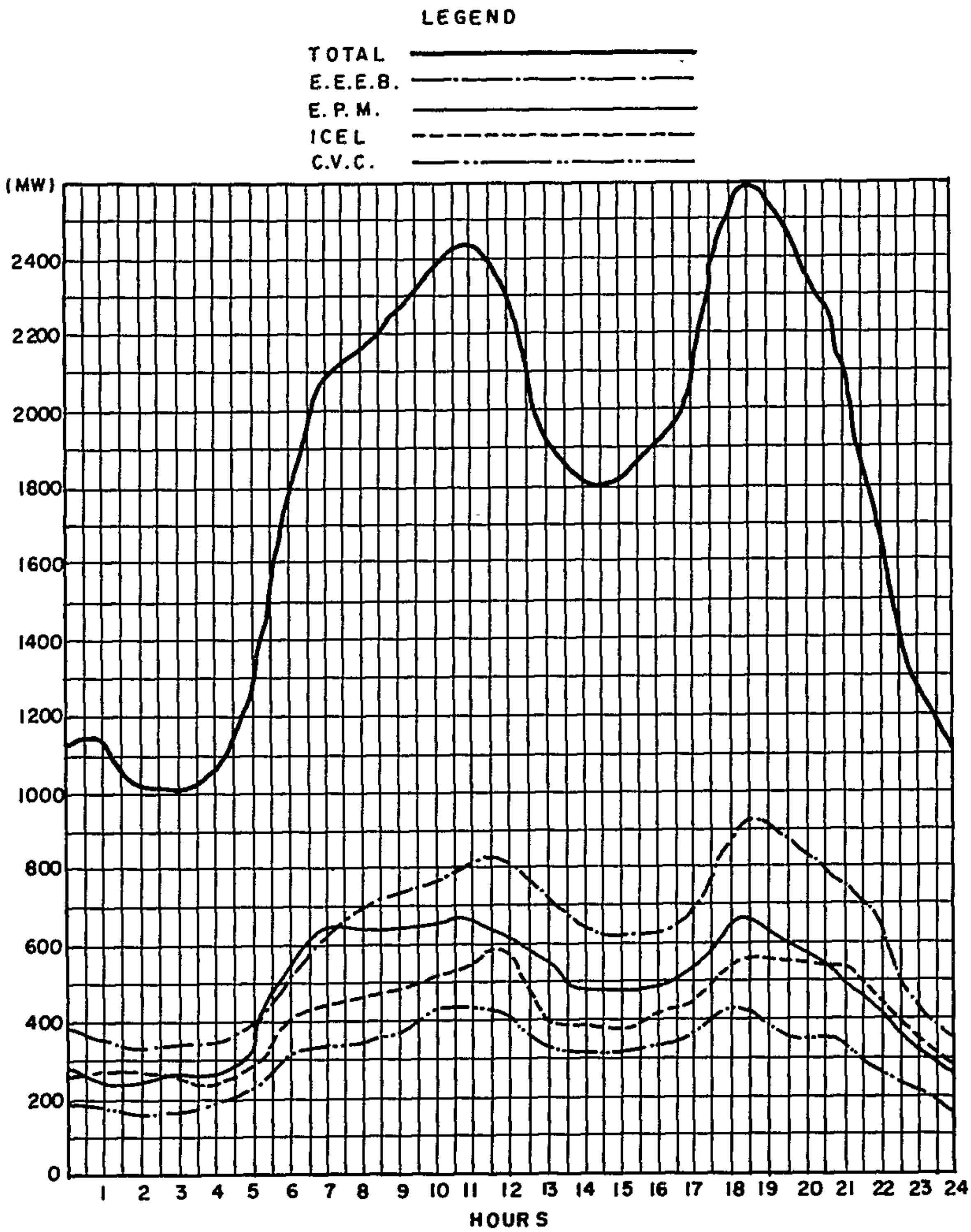


(6) Load Pattern and Reserve Capacity

A typical daily load pattern of the interconnected system in 1979 is as shown in Fig. 4-2-4. This load pattern shows that the maximum load of 2,600 MW in the interconnected system occurs between 6 p.m. to 7 p.m. This is normal for electric power consumption and is due to the peak in residential use. However, there is a load of 2,440 MW (93.8% of maximum load) at 11 a.m. This is an abnormally high value compared with other countries and is because the interconnected system covers tropical, sub-tropical, temperate and sub-arctic temperature zones which differ according to altitude, and the peak for air conditioning is added to electric power for industrial use.

The daily load factor, according to Fig. 4-2-4 is 70.8%, but when days of low load such as Saturdays, Sundays and holidays are considered, the annual average load factor is 59.3%.

Fig. 4-2-4 Typical Daily Load Curve of Interconnected System (1979)



As demand is expanding constantly, the maximum demand increases monthly from January, and becomes maximum in December. This is because there is little variation in air temperature throughout the year and there is no influence according to season. Table 4-2-5 shows the variations in maximum demand by month.

Table 4-2-5 Variations by Month in Maximum Demand of Interconnected System (1979)

Month	Maximum Demand (MW)	Month	Maximum Demand (MW)
Jan.	2,623.4	July	2,727.6
Feb.	2,663.7	Aug.	2,768.5
Mar.	2,680.7	Sep.	2,800.4
Apr.	2,698.0	Oct.	2,859.1
May	2,711.0	Nov.	2,897.4
June	2,708.7	Dec.	2,902.6

The minimum load of the interconnected system at midnight was 1,000 MW according to the records for 1979, or 38.5% of the maximum load of 2,600 MW. This is a low value seen from the level for developed nations, and indicates that electric power is not being used for industrial purposes in the middle of the night.

In general, reserve capacity is contemplated in units of months, and is expressed by the difference between the average power demand of the three heaviest load days of the month and the supply capacity of that month. In the examination of the supply capacity, it is necessary for the drop in output of hydro due to drought, outage of thermal generating facilities for inspection and repairs, and outage due to faulting to be taken into consideration.

On investigation of the discharge conditions of the major rivers of Colombia, for most of the rivers the dry season is seen to be July-October, while the wet season is April-June. However, the discharge in the dry season is reduced only to slightly less than 50% of the discharge in the wet season.

Meanwhile, since the existing or planned hydroelectric power projects are mostly at sites where seasonal regulation is possible, the effect due to dry season is on the small side. However, since hydroelectric power generation makes up 70.3% of the whole, hydro power stations are required to be operated at high load, and if the supply capability is greatly lowered according to the effects of dry years, there will be years when the installed facilities cannot be fully utilized.

(7) Prevailing Electricity Rates

In Colombia, electricity rates are differentiated according to electric power company and according to service type. Also, commodity price escalation is considered and rates are raised at tempos of 1.5-2.5%/month. Rates are divided into basic rates of fixed amounts and rates according to kWh consumption. As for residential-use electric power, a declining metered rate system is applied. The electricity rate in 1979 obtained in terms of average unit price which is calculated by dividing the electricity charge revenue for the entire country by the amount of energy sales was COL$0.84/kWh (US$0.0168/kWh).

This rate is extremely low compared with other countries. The average values of electricity rates in major cities according to service type are as shown below in table 4-2-6.

Table 4-2-6 Tariff Rates of Main Cities by Service Type (July 1979)

Unit: COL$/kWh

Service Type \ City	BOGOTA	MEDELLIN	CALI	BARRANQUILLA
Residential	0.76	0.60	1.10	1.26
Commercial	1.82	1.71	1.40	1.88
Industrial	1.26	1.15	1.85	1.47
Governmental	0.99	0.72	0.87	1.21
Public Lighting	1.03	0.10	0.86	1.18
Average	1.10	0.74	0.92	1.40

Note: The average unit price of the whole country is COL$0.84/kWh.

According to the Table 4-2-6 above, the Medellin Electric Power System applies the cheapest rates, which is indicative of how electric power supply based mainly on hydroelectric power generation acts to stabilize electricity rates at a low level. In comparison, the Corelca System relying on thermal power generation for all of its supply capability is the district with the highest electricity rates, they being approximately twice the rates in the Medellin System. This indicates that thermal power generation in Colombia has the effect of raising electricity rates by the cost of fuel.

In Colombia, the rates for residential use are made cheap, while those for commercial and industrial purposes are set at higher levels. Although this is disadvantageous for nurturing industry, it indicates that an electricity rate policy emphasizing stabilization of the people's livelihood is being pursued. (Note: Latin American countries generally adopt electricity rate policies stressing stabilization of people's livelihood.)

4.2.2 Intermediate Electric Power Development Plan Until 1988

(1) Guiding Principle and Objectives

In Colombia, domestic production has been growing at an annual rate of 5%, and according to the energy demand forecast of ISA, it is assumed that demand growth of about 10% annually will continue in the future.

Table 4-2-7 shows the load forecast values for the interconnected system.

Table 4-2-7 Energy Demand Forecast for Intèrconnected System

Year	Maximum Demand (MW)	Growth Rate (%)	Year	Maximum Demand (MW)	Growth Rate (%)
1980	3,116	7.4	1988	8,094	9.7
1981	4,058	30.2*	1989	8,852	9.4
1982	4,585	13.0	1990	9,697	9.5
1983	5,074	10.7	1991	10,635	9.7
1984	5,584	10.1	1992	11,612	9.2
1985	6,147	10.1	1993	12,706	9.4
1986	6,742	9.7	1994	13,882	9.3
1987	7,377	9.4	1995	15,159	9.2

Note: According to 1981 data of ISA.
*Increase due to interconnection with the Corelca System.

Colombia has decided on construction of 6,620 MW of new electric power generating facilities and 4,988 km of transmission lines during the 8-year period from 1981 through 1988, and has started on construction or on working designs.

As shown in Table 4-2-9, the basic policy of Colombia in electric power development is mainly utilizing water resources which have not yet been developed enough. However, until 1984, 764 MW of thermal power generation and gas turbine power generation are considered to be developed. This is because the amount of hydro power development decided on or projects under construction will not be enough to cope with the increasing electric power demand, and the thermal power development is to be done in the form of supplementary development.

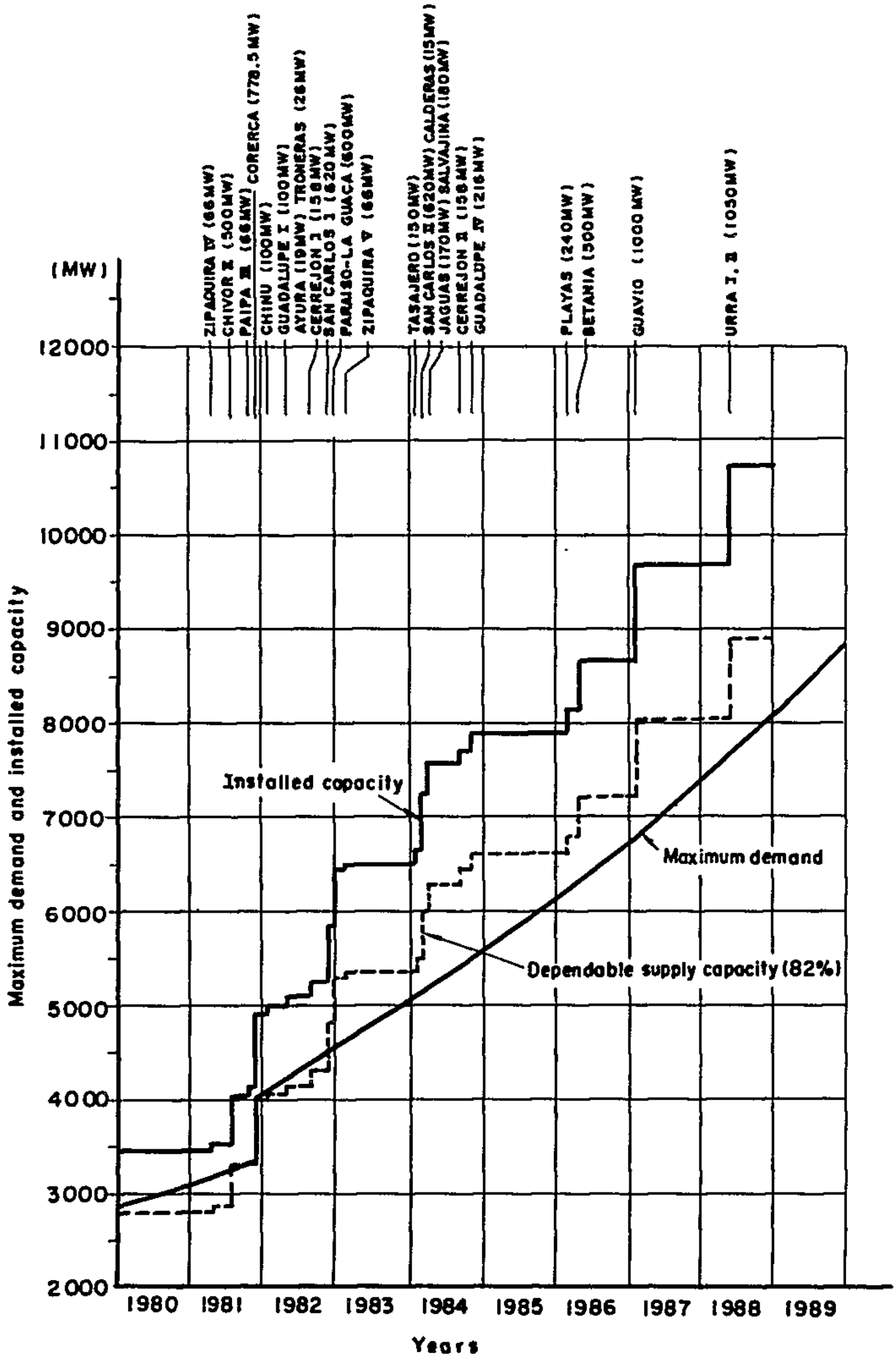
Consequently, when the construction periods for projects in 1988 and after are considered, it is possible for hydroelectric power generation to be made mainly, and this has been amply reflected in the plans.

Meanwhile, in thermal power generation, as shown in the table below, there are large differences in the cost of fuel, and the policy of placing emphasis on thermal power generation using coal which can be domestically produced is taken.

Average Fuel Costs of Thermal Power Plants (1980)

Oil	US$0.05 ∿ 0.10/kWh
Gas	US$0.03 ∿ 0.06 "
Coal	US$0.01 ∿ 0.03 "

Fig. 4-2-5 Estimated Maximum Demand and Installed Capacity of Interconnected System (1980 ~ 1988)



(2) Outline of the Middle-range Electric Power Development Plan

(2)-1 Electric Power Development Plan

As shown in Table 4-2-9, the electric power projects commissioned by 1988 are 5,856 MW of hydro and 764 MW of thermal, hydro making up 88% of the total. The principal ones among hydroelectric power projects will be the seven great projects of San Carlos I and II, 1,240 MW; Paraiso-La Guaca, 600 MW; Playas, 240 MW; Betania, 500 MW; Salvajina, 180 MW; Guavio, 1,000 MW; and Urra I and II, 1,050 MW. Other hydro projects are expansions of existing facilities: 500 MW at Chivor, and 100 MW at Guadalupe.

Meanwhile, thermal power generation will consist of the large-scale projects of Cerrejon Coal-fired Thermal Phases I and II, 158 MW x 2 units, and Tasajero Gas Thermal, 150 MW.

According to the above plans, the power generating facilities which can be commissioned each year are as shown in Table 4-2-8, the average amount of annual increase being 828 MW. The project sites are, as shown in Fig. 4-2-6, concentrated at Medellin.

Table 4-2-8 Annual Increase of Installed Capacity

Year	Annual Increase (MW)	Cumulative Rise (MW)
1981	632	4,870.7
1982	1,623	6,493.7
1983	66	6,559.7
1984	1,509	8,068.7
1985	0	8,068.7
1986	740	8,808.7
1987	1,000	9,808.7
1988	1,050	10,858.7
Total	6,620	—

Table 4-2-9 Construction Schedule of Generating Facilities (1981∿1988)

(According to the data of ISA)

Year	Name of Power Plants	Installed Capacity (MW)		Utility	Year of Opera-tion	Market
		Hydro	Thermal			
1981	ZIPAQUIRA IV		66	ISA-EEEB	1981/4	Bogota
	CHIVOR II	500		ISA	81/7	"
	PAIPA III		66	ICEL	81/10	"
	Sub-total	500	132			
1982	CHINU		100	ISA	1982/1	Barranquilla
	GUADALUPE I (Amp.)	100		EPM	*	Medellin
	AYURA	19		"	82/4	"
	TRONERA (Amp.)	26		"	*	"
	CERREJON I		158	CORELCA	82/8	Barranquilla
	SAN CARLO I	620		ISA	82/11	Medellin
	PARAISO-LA GUACA	600		EEEB	82/12	Bogota
	Sub-total	1,365	258			
1983	ZIPAQUIRA V		66	ISA-EEEB	1983/2	Bogota
	Sub-total	-	66			
1984	SAN CARLOS II	620		ISA	1984/2	Medellin
	JAGUAS	170		"	84/3	"
	CALDERAS	15		"	84/5	"
	TASAJERO		150	ICEL	84/1	Bogota & Medellin
	SALVAJINA	180		CVC	84/3	Cali
	CERREJON II		158	CORELCA	84/8	Barranquilla
	GUADALUPE IV	216		EPM	84/10	Medellin
	Sub-total	1,201	308			
1985	-	-	-	-	-	-
1986	PLAYAS	240		EPM	1986/2	Medellin
	BETANIA	500		ICEL-ISA	86/4	"
	Sub-total	740	-			
1987	GUAVIO	1,000	-	EEEB-ISA	1987/1	Bogota
	Sub-total	1,000	-			
1988	URRA I	340		ISA-CORELCA	1988/5	Barranquilla
	URRA II	710		"	88/5	Medellin
	Sub-total	1,050	-			
	Total	5,856	764			
		6,620				

Note: * 1982/1st half

(2)-2 Transmission Line Expansion Plan

With regard to transmission line expansion plans, it is expected that 524 km, 1-cct line between San Carlos Power Station of the existing interconnected system and Sabanalarga of the Corelca System was completed in 1981 with a design for 500 kV (to be commissioned initially as 220 kV).

As a result, all of the large load centers in Colombia will have become interconnected and the trunk transmission line network completed.

Meanwhile, along with development of hydroelectric power sources, it is being contemplated to expand transmission lines. A 500-kV line 675 km in length with the purposes of development of Urra Hydroelectric power station and interconnection with Corelca system, and 220-kV lines 3,788 km in length, a total of 4,988 km of transmission lines, are being constructed or are being planned for construction by 1988.

When the abovementioned power transmission projects are finished in 1988, the power transmission network shown in Fig. 4-2-6 and Fig. 4-2-7 will have been completed. This power transmission network will make it extremely easy for power stations planned for 1989 and after to be developed.

Table 4-2-10 Construction Schedule of Transmission Lines (1981 ∿ 1988)

(According to the data of ISA)

Year of Operation	Section		Length (km)		No. of Circuits	Voltage (kV)
			500 kV	220 kV		
1981	CHIVOR P.S.			105	2	220
	*SAN CARLOS P.S.	SABANA LARGA	524		1	500
	Sub-total		524	105		
1982	SAN CARLOS	GUATAPE		34	2	220
	SAN CARLOS	BALSILLAS		209.2	1	220
	SAN CARLOS	TORCA		205.2	1	220
	T. CERREJON	SANTA MARTA		75	2	220
	SANTA MARTA	FUNDACION		80	2	220
	PARAISA	LA GUACA		6	2	220
	LA GUACA	LA MESA		5	2	220
	TORCA	CIRCO		24.5	1	220
	PARAISO	CIRCO		66	1	220
	PARAISO	SUR		32	1	220
	***TORCA	TUNAL		44.5	1	220
	TUNAL	SUR		14	1	220
	MARIGUITA P.S.	Branch		-	1	220
	RIO NEGRO	Branch		-	1	220
	Sub-total		-	795.4		
1983	**ESMERALDA	CALI		194.1	2	220
	SAN CARLOS	ANCON SUR		90	2	220
	ANCON SUR	MIRAFLORES		15	1	220
	CERREJON	CUESTECITA		100	2	220
	POPAYAN	JUANCHITO		111.8	1	220
	POPAYAN	YUMBO		126	1	220
	PUERTO BERRIO S.S.	Branch		-	1	220
	Sub-total		-	636.9		
1984	SAN CARLOS	JAGUAS		28	1	220
	SABANA LARGA	FUNDACION		95	1	220
	SALVAJINA	PANCE		50	1	220
	PANCE	JUANCHITO		14.9	1	220
	SALVAJINA	JUANCHITO		64.9	1	220
	GUATAPE	MIRAFLORES		19.0	2	220
	GUADALUPE IV	BARBOSA		45	2	220
	LA MESA	IBAGUÉ		110	2	220
	SABANA LARGA	NUEVA SUBESTACION		38.2	2	220
	BARBOSA S.S.	Branch		19	2	220
	TASAJERO	Branch		-	1	220
	Sub-total		-	484		

Table 4-2-10 Construction Schedule of Transmission Lines (Cont'd)

Year of Operation	Section		Length (km) 500 kV	Length (km) 220 kV	No. of Circuits	Voltage (kV)
1985	BUCARAMANGA	CÚCUTA		121	1	220
	BUCARAMANGA	OCAÑA		140	1	220
	OCAÑA	CÚCUTA		120	1	220
	SAN CARLOS	PUERTO BERRIO - BARRANCA		185	1	220
	BARRANCA	BUCARAMANGA		95.7	1	220
	Sub-total		-	661.7		
1986	PLAYAS	RIO NEGRO		57	1	220
	ANCON-SUR	ESMERALDA		140	2	220
	GUATAPE	PLAYAS		22	1	220
	BETANIA	POPAYAN		180	2	220
	BETANIA	IBAGUÉ		170	2	220
	POPAYAN	PASTO		162	2	220
	SABANA LARGA	TERNERA		80	1	220
	Sub-total		-	811		
1987	ANCON-SUR	ENVIGADO		5	1	220
	GUAVIO	CIRCO		80	2	220
	***GUAVIO	TUNAL		119.3	1	220
	***GUAVIO	CIRCO		89.5	1	220
	GUAVIO CONECTION			-		220
	NOROESTE S.S. CONECCION			-		220
	Sub-total		-	294		
1988	SAN CARLOS	CERROMATOSO	210		1	500
	CHINÚ	SABANA LARGA	181		1	500
	URRÁ II	CERROMATOSO	100		1	500
	URRÁ I	CHINÚ	155		1	500
	URRÁ I	URRÁ II	30		1	500
	Sub-total		676	-		
Total	Total of 500 kV and 220 kV lines		1,200	3,788		
			4,988			

Note: * Operated initially at 220 kV, but to become 500 kV when Urra is completed in 1988.

** One circuit to be tied to Yumbo Substation, the other to Juanchito Substation.

*** Torca-Circo and Torca-Tunal to be cut off when Guavio-Tunal and Guavio-Circo are completed in 1987.

Fig. 4-2-6 Transmission System expected in 1988

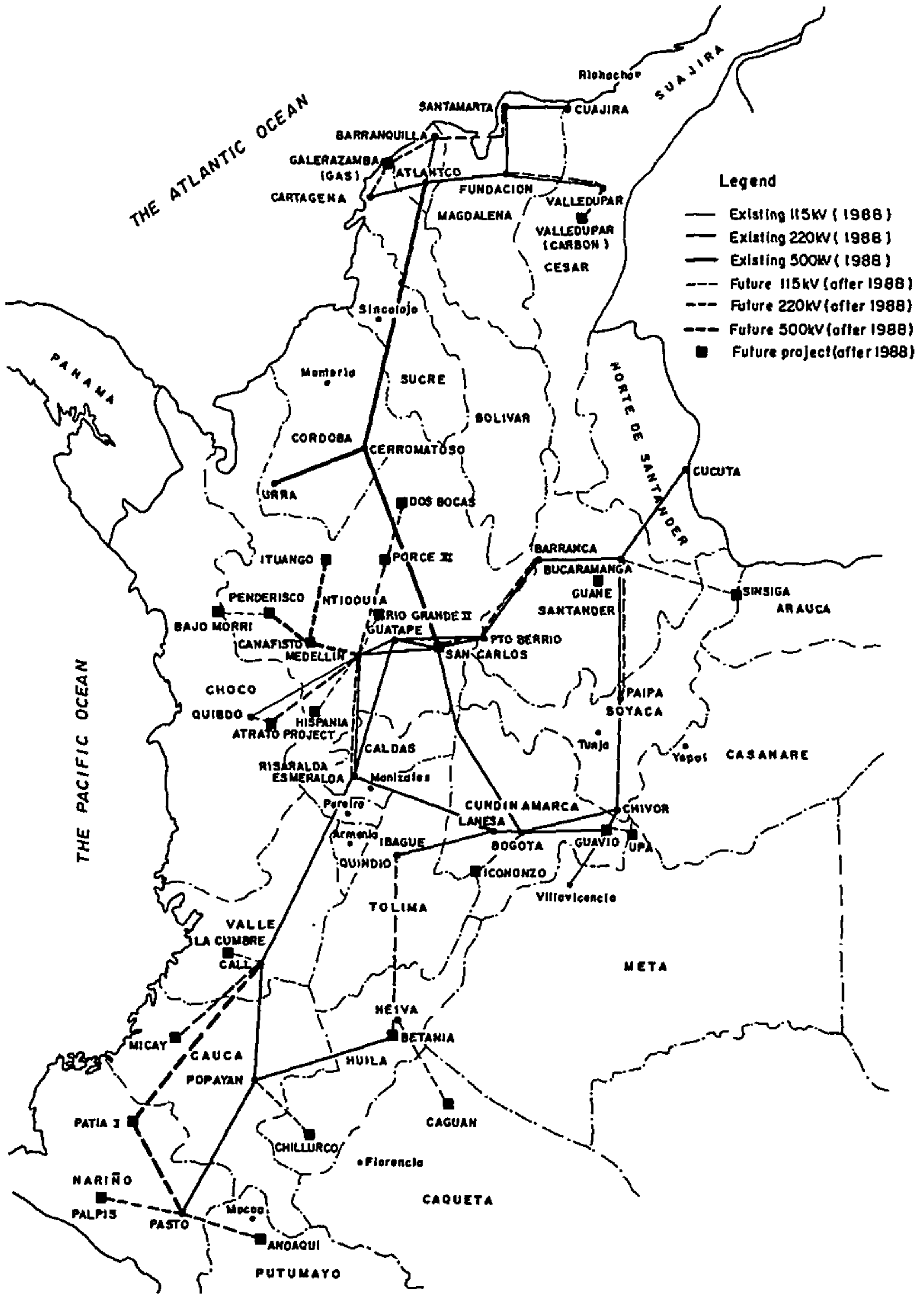
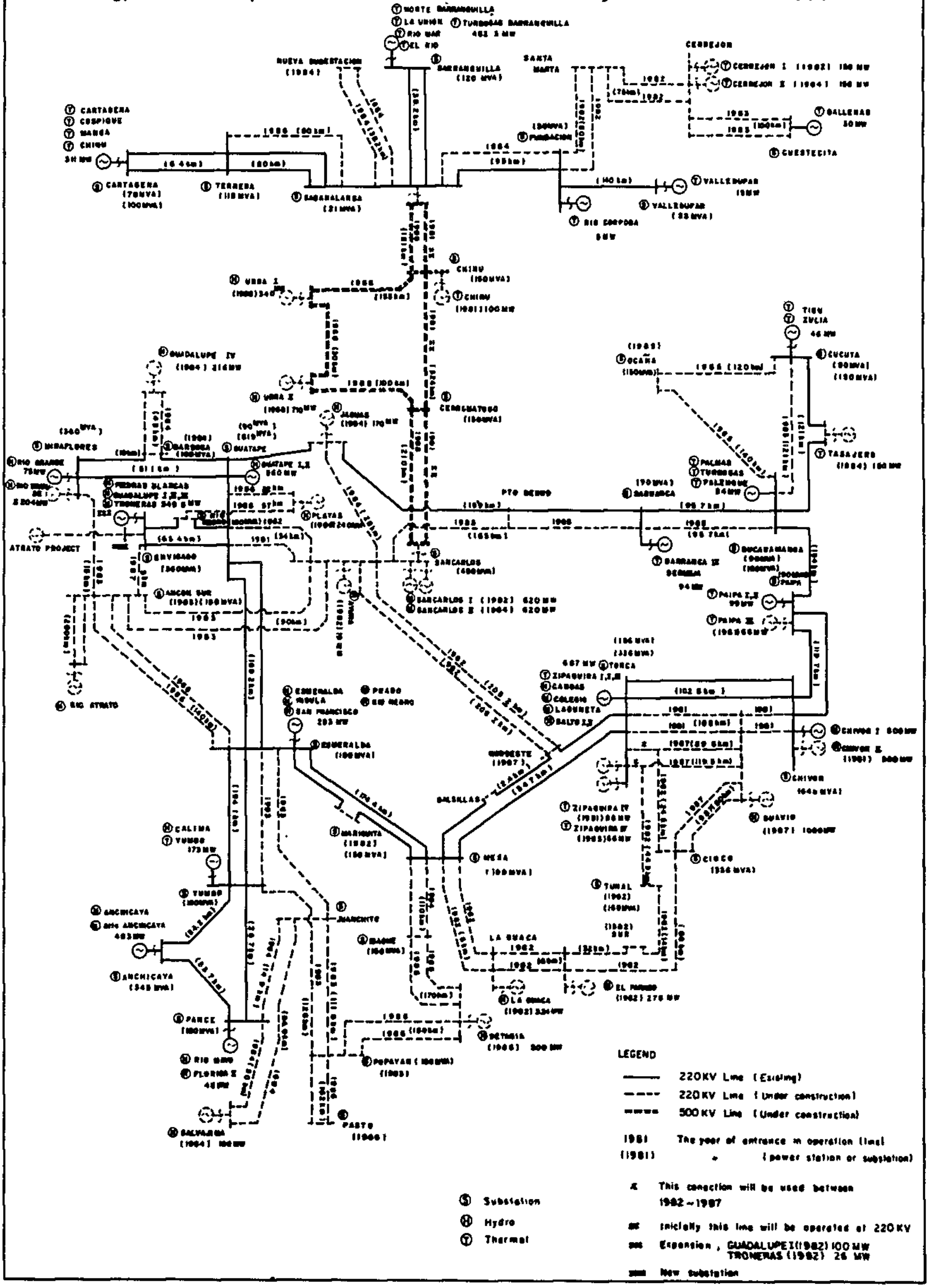


Fig. 4-2-7 Expansion Plan of Transmission System (1980~1981)



(2)-3 Electric Power Demand and Supply Balance According to Middle-range Plan

The condition of balance between the forecast power demand and supply capability according to the middle-range plan described in (2)-2 was examined. The results are as shown in Fig. 4-2-5 and Table 4-2-11.

Table 4-2-11 kW and kWh Balance of Interconnected System (1980～1989)

Year	Name of Power Plants	Installed Capacity Hydro (MW)	Installed Capacity Thermal (MW)	Installed Capacity Cumulative Rise (A) (MW)	Demand Maximum Demand (B) (MW)	Demand Average Demand (MW)	Demand Load Factor (%)	Difference A - B (MW)
1980		-	-	3,460	3,116	1,891	60.7	344
1981	ZIPAQUIRA IV (C)		66					
	CHIVOR II	500						
	PAIPA III (C)		66					
	[Interconnection with CORELCA]		779					
	Sub-total	500	911	4,871	4,058	2,167	53.4	813
1982	CHINU (T.G)		100					
	GUADALUPE I (Amp.)	100						
	AYURA	19						
	TRONERAS (Amp.)	26						
	CERREJON I (C)		158					
	SAN CARLOS I	620						
	PARAISO-LA GUACA	600						
	Sub-total	1,365	258	6,494	4,585	2,807	61.2	1,909
1983	ZIPAQUIRA V (C)		66					
	Sub-total	-	66	6,560	5,074	3,130	61.7	1,486
1984	SAN CARLOS II	620						
	JAGUAS	170						
	CALDERAS	15						
	TASAJERO (C)		150					
	SALVAJINA	180						
	CERREJON II (C)		158					
	GUADALUPE IV	216						
	Sub-total	1,201	308	8,069	5,584	3,430	61.4	2,485

Table 4-2-11 kW and kWh Balance of Interconnected System (Cont'd)

Year	Name of Power Plants	Installed Capacity			Demand			Difference A - B (MW)
		Hydro (MW)	Thermal (MW)	Cumulative Rise (A) (MW)	Maximum Demand (B) (MW)	Average Demand (MW)	Load Factor (%)	
1985		-	-	8,069	6,147	3,774	61.4	1,922
1986	PLAYAS	240						
	BETANIA	500						
	Sub-total	740	-	8,809	6,742	4,132	61.3	2,067
1987	GUAVIO	1,000						
	Sub-total	1,000	-	9,809	7,377	4,514	61.2	2,432
1989	URRA I	340						
	URRA II	710						
	Sub-total	1,050	-	10,859	8,094	4,929	60.9	3,815

Note: (Amp.): Amplification
(C) : Coal
(T.G) : Gas Turbine

4.2.3 Power Development Scheme for 1989 to 1995 (Proposal)

(1) General

A middle-range electric power development plan for the period up to 1988 has been stated in the preceding section. The energy demand forecast for the interconnected system in 1995 according to the prediction of ISA calls for a maximum demand of 15,159 MW and energy consumption of 80,737 GWh/year. In order to meet the demand, 7,065 MW (15,159 MW - 8,094 MW) of electric power development must be carried out during the 7 year period from 1989 through 1995.

The projects presently being investigated and studied are as shown in Table 4-2-12, and the total output becomes 12,284 MW with eleven hydro sites and one thermal site. (See Fig. 4-2-8 for the locations of the sites.)

The priorities of these projects have not yet been decided, but they will be studied including the projects which will be investigated from now on, like Rio Atrato project.

Table 4-2-12 Construction Schedule of Generating Facilities (after 1989)

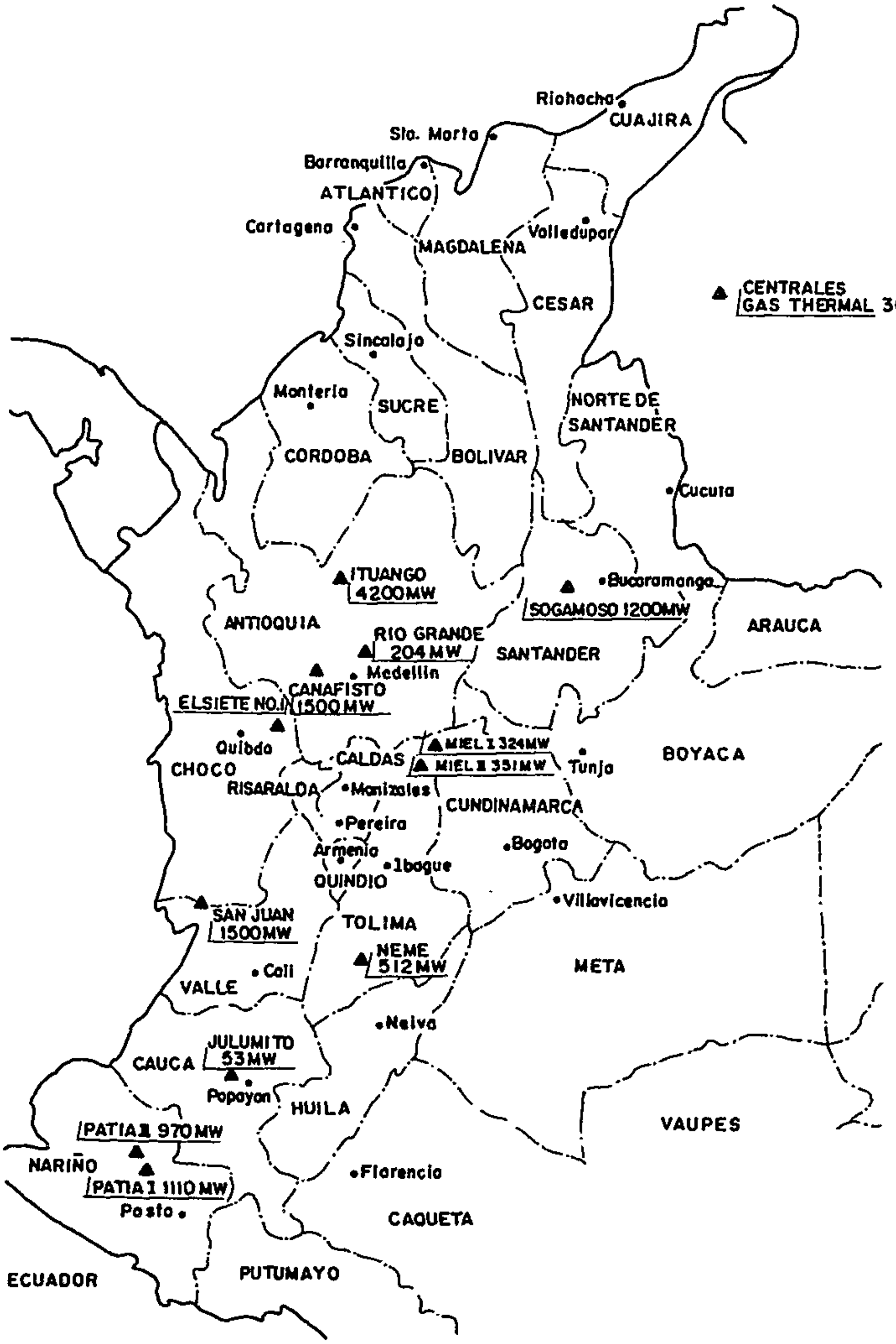
Name of Power Plants	Installed Capacity (MW)	Annual Energy Production (GWH)	Construction Cost (10^6US$)	Cost of Energy per kW (US$/kW)	Cost of Energy per kWh (US$/kWh)	Utility
JULUMITO	53	320	125.4	2,366	0.047	ICEL
MIEL I	384	1,680	266	691	0.019	ICEL
RIO GRANDE II	204	1,390	130.8	641	0.011	EPM
MIEL II	351	2,030	284.6	811	0.017	ICEL
CAÑAFISTO	1,500	7,370	945.2	543	0.015	ISA
SOGAMOSO	1,200	5,820	1,036	863	0.021	ISA
SAN JUAN	1,500	5,850	1,129	753	0.023	ISA
PATIA I	1,110	4,623	760.3	685	0.020	ICEL
PATIA II	970	4,203	575	593	0.016	ICEL
NEME	512	2,550	427.2	834	0.020	ISA
ITUANGO	4,200	18,080	2,206	525	0.015	
TERMICA (Thermal)	300	1,892				
Total	12,284	55,808	7,885.5			

Breakdown: 11,984 MW hydro, 300 MW thermal, 12,284 MW total.

Note: 1) Rio Grande II is being studied by Medellin Electric Power, and is expected to be changed to multi-purpose development including water supply to Medellin City.

2) Construction costs calculated as of 1978.

Fig. 4-2-8 Location of Projectos for Electric Power Development
(1989 ~ 1991)



The gas thermal plant (300 MW) taken up in Table 4-2-12 is to be built in Venezuela at the source gas field and the power is planned to be transmitted to Colombia. It will be a model of international co-operation.

Except for the thermal power plant above, it is the basic policy of the Colombian Government to carry out all power generation by hydro. Meanwhile, it is also a policy of the Colombian Government to develop coal mines, and there is possibility that the project of coal-fired thermal power generation will be taken up in the future.

(2) Hydroelectric Resources

The hydroelectric resources possessed by Colombia, converted into terms of electric power, is estimated to be 118,755 MW. This estimate figure includes existing facilities as well as projects under construction or planned to be developed by 1988.

Even if limited to a selection of projects which are technically feasible and planned to be developed in 1989 or after, the scale of the potential is as large as 83,548 MW. The results of examination of these by region, number of sites, and stage of study are as given in Fig. 4-2-9 and Table 4-2-13.

Classified according to the scale of development and according to construction cost per kW, the results are indicated in Table 4-2-14 and Table 4-2-15, and it is estimated that there are 35,000 MW worth of sites which can be developed at construction cost per kW of not more than US$800.

The electric power required to be developed in Colombia in the 11-year period from 1989 to 2000 is estimated to be 14,200 MW, so the country is in the favorable position that electric power can be supplied by hydro for the time being.

Fig. 4-2-9 Theoretical Hydro Potential by River Basin

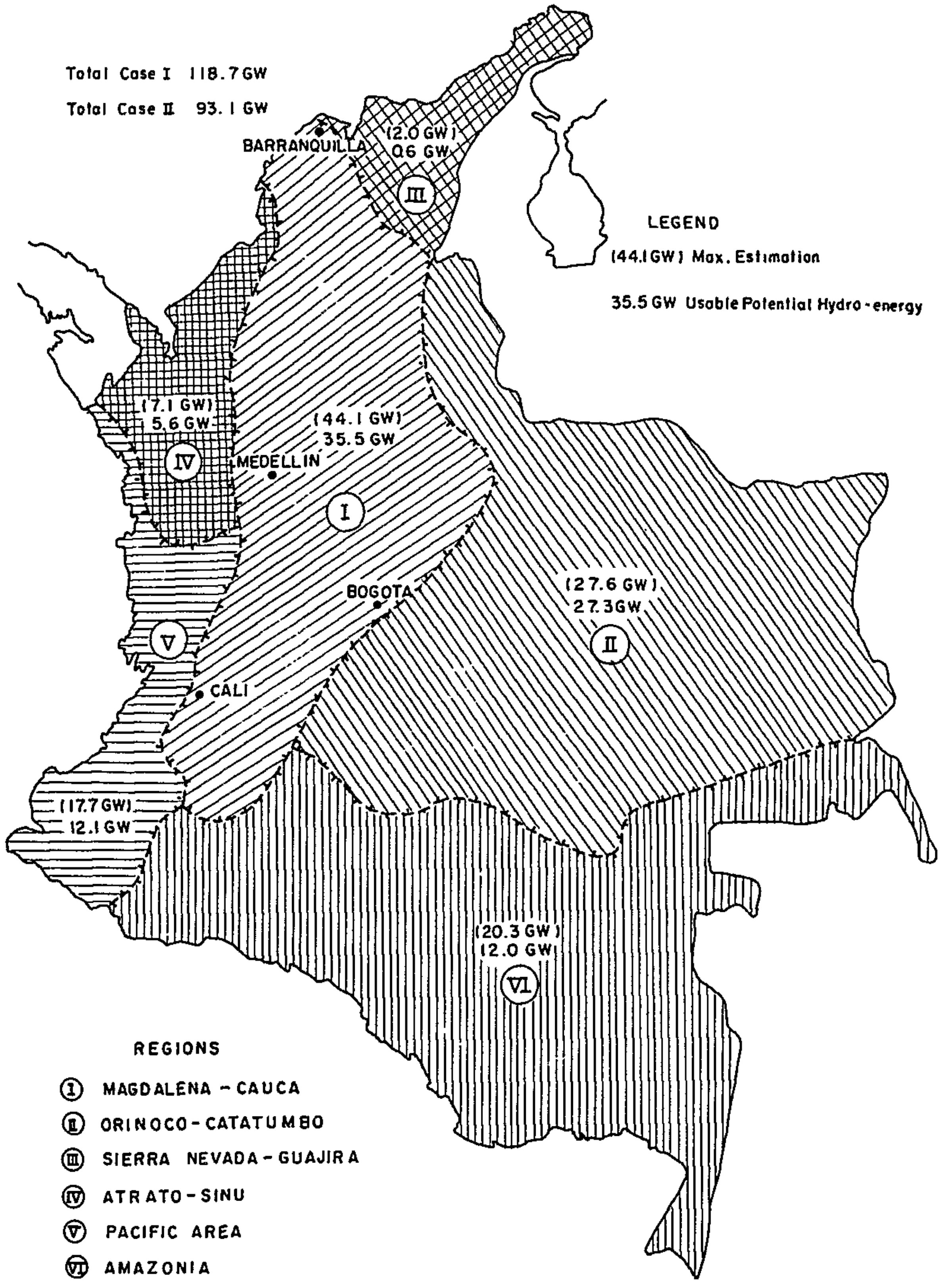


Table 4-2-14 Items according to the Scale of Installed Capacity

Installed Capacity (MW)	Number of Projects		Hydro Potential	
	No.	%	MW	%
Less than 200	157	57	18,800	22
201 ∿ 500	85	31	26,400	32
501 ∿ 1,000	16	6	10,900	13
More than 1,001	16	6	27,400	33
Total	274	100	83,500	100

Table 4-2-15 Items according to the Construction Cost

Construction Cost (US$/kW)	Number of Projects		Hydro Potential	
	No.	%	MW	%
Less than 499	18	7	15,300	18
500 ∿ 800	56	20	19,700	24
801 ∿ 1,200	96	35	26,800	32
More than 1,201	104	38	21,700	26
Total	274	100	83,500	100

4.3 Geology

4.3.1 General

The six hydroelectric power development projects - El Siete No. 1 (160 MW), El Siete No. 2 (124 MW), El Once (167 MW), El Dieciocho No. 1 (252 MW), El Dieciocho No. 2 (261 MW), and El Lloro (147 MW), in order from upstream, are planned in the upper basin of the Rio Atrato. A reconnaissance was recently made for approximately 10 days during July-August 1981 to obtain a concept of the surface geologic condition of the above-mentioned project sites, and the results are as described in this chapter. Since accurate topographical maps adequately covering the project sites were not available, the reconnaissance was carried out referring to existing geological data and using rough maps made from radar imagery. It should be remembered therefore, that the accuracy of the results of surface geological survey is deficient.

Generally speaking, since the project sites are planned along a public road running by the Rio Atrato, it was possible to investigate to an extent the geologic conditions of important project sites through observation of surfaces of road-cut along the public road, and also through observation of outcrops near the channel of the Rio Atrato.

4.3.2 Existing Geological Data and Outline of Reconnaissance

The following geological data were available for the field reconnaissance which was done by JICA Mission in 1981;

(1) Estudio del Sector de Energia Electrica, Inventario de Los Recursos Hidroelectricos, 1979. Published by Departamento Nacional de Planeacion (DNP).

The 1/220,000 geological maps annexed to the above-mentioned report.

(2) Geological Map
Mapa de Geologico de Colombia, 1976, scale 1/1,500,000, published by Instituto Nacional de Investigaciones Geologico-Minas (GEOMINAS).

(3) Land Surface Imagery by Radar
Scales: original, 1/250,000; enlargements, 1/40,000
Note) It's impossible to draw contour lines by using these images.

(4) Topographical Maps

Scale, 1/100,000, published by Instituto Geografico "Agustin Codazzi".

Note) These maps only indicate shapes of rivers and the routes of main roads without contour lines. The accuracy of the locations of rivers and main roads is extremely poor.

A geological reconnaissance was made in the field based on the data listed above. Accordingly, the field survey consisted mostly of observing topographic feature, sampling rocks, examining outcrops at the river bed, and inspecting road-cut exposure. The outlines of geological maps attached to this Report are as follows;

o Geological Map of Planning Area (Drawing - 03)

This map is mainly compiled from the DNP's geological map and partially depending on the result of the recent reconnaissance.

o Lineament Map (Drawing - 04)

The lineament map is prepared for El Siete No. 1 and No and El Once based on aerial photographs (available for stereoscopic observation) taken in 1962 and obtained from the Instituto Geografico. However, since the project areas of El Dieciocho No. 1 and No. 2 were not covered by the aerial photographs, the lineament map of these areas is prepared based on radar imagery and the results of geological reconnaissance.

o Geological Sketched Maps (Plans, Profiles) of Each Damsite (except El Siete No. 2 and Rio Playa Damsite) (Fig. 4.3-1 ∿ 4)

These maps, which were originally made by rough topographical surveying by the civil engineers of the reconnaissance team were prepared for the exploration of geological condition of each site. Accuracies of locations and elevations are slightly inferior.

The recent geological reconnaissance was to obtain the basic geological information for a master plan of the hydroelectric power development project at the upstream part of the Rio Atrato. However the investigations were made with topographical maps which were defective, so that only rough examinations of the individual project sites were undertaken. Accordingly, it was impossible to make up a detail geological map in recent reconnaissance. The scopes of the investigations at the individual sites are described below.

o El Siete No. 1 Site

The El Siete No. 1 site is situated by a public road which runs to Quibdo through Bolivar from Medellin and the damsite could be adequately observed from the public road. Also, since surfaces of road-cuts of the public road could be thoroughly inspected it was possible to grasp an outline of the geology from surface observations.

The waterway route and power station site for the El Siete No. 1 project are located at the opposite bank of the Rio Atrato from the public road and it was possible to view the conditions of the topography and outcrops from a distance. (Details are given in 4.3.4.)

o El Siete No. 2 Site

It is planned for El Siete No. 2 to be provided at the right bank along the beforementioned public road, and it was possible to observe the topographical conditions of the intake site, tunnel route and powerhouse site as well as the types and conditions of rocks at the surface observation. (Details are given in 4.3.4.)

o El Once Site

This site is located along the public road and it was possible to observe the damsite and the power station site. (Details are given in 4.3.5.)

o El Dieciocho No. 1 and No. 2 Sites

The No.1 project damsite is located by the public road and could be observed. As for the two power station sites, which are near to the public road and the river of the Rio Atrato, surface observation was done. But the geological reconnaissance of Playa Dam (No. 2 project) was prevented by absence of mountain path from the public road. And, the accessibility of the tailrace tunnel route of the No. 2 project was extremely poor and it was impossible to make an on-the-spot inspection. (Details are given in 4.3.6.)

o El Lloro Site

It was possible to go to this site from Quibdo by boat and both banks of the river at the damsite could be observed. (Details are given in 4.3.7.)

The surfaces of mountain areas at all of the above project sites are covered with thick forests, and hilly areas are grassy so that it was not possible to obtain adequate geological information by surface observation. But the outline of geologic conditions of the whole project area could be grasped through observation of the road-cut along the public road and outcrops at the river banks.

4.3.3 General Topography and Geology

(1) General Topography

The Project consists of development of the water power resources of the upstream part of the Rio Atrato which flows through Departamento de Choco situated in the northwestern part of the Republic of Colombia. The Rio Atrato rises in the mountainland in the eastern part of Departamento de Choco, flows east, after which it turns northward to flow into the Caribbean Sea. A total length of the Rio Atrato is approximately 600 km and is the third largest river in Colombia. The project area is located between 5°25' - 6°00' north latitude, and 76°35' - 76°06' west longitude.

The eastern mountainland which is the fountainhead of the Rio Atrato comprises the western slope of the Cordillera Occidental, one of the three branches of the Andes Mountain Range consisting of Cordillera Occidental, Cordillera Central and Cordillera Oriental. Elevations of the eastern mountains are from 2,500 to 3,000 m. The Rio Atrato flows at an elevation of 1,800 m near Carmen de Atrato and EL. 280 m at El Dieciocho, the upstream part being an extremely swift stream. While, the stretch from El Dieciocho to El Lloro (EL. 45 m) is an extremely slow stream which meanders about.

The Project consists of development of the above-mentioned swift stream part and El Lloro for hydroelectric power. The mountain mass comprising the rapid stream part is in the mature stage of topography which are relatively rugged, and the Rio Atrato flows down between the mountains forming V-shaped valleys, however at parts there are also wide river terraces.

The vegetation in the vicinity of the level of EL. 1,500 m is a mixed forest of the temperate zone and subtropical flora which completely covers the mountainsides. The forest is primeval one consisted mostly of miscellaneous trees.

Around EL. 1,000 m to 300 m, or the El Once and El Dieciocho project sites, the vegetation is subtropical and the condition of growth is dense requiring considerable felling in order to enter the mountains. This mountain forest is left in its natural state and is not utilized, and there are no mountain paths.

The area below EL. 300 m, or the area between El Dieciocho and El Lloro is a plain completely covered with dense tropical vegetation which has some hilly parts. The appearance at a glance is that of a sea of trees. The Rio Atrato meanders down through this area where river terraces have been formed here and there.

(2) General Geology

The general topography of Colombia is characterized by the geologic structure. The eastern half of Colombia is occupied by the Guiana shield and shows a relatively simple geologic structure. In contrast, the western half consists of the Andes Mountain and has a complex structure of folding.

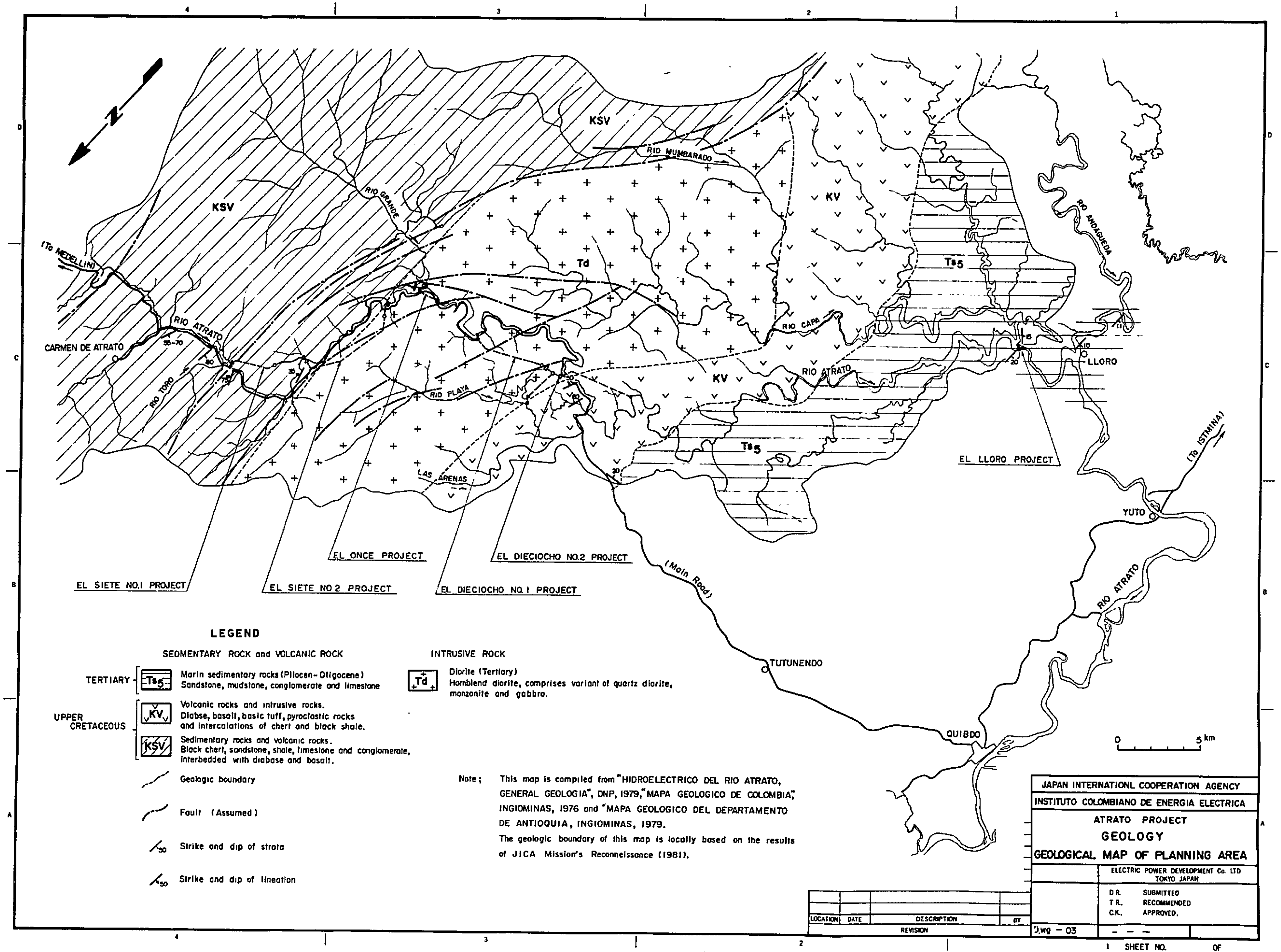
According to the geological map of Colombia (scale, 1/1,500,000; 1976, GEOMINAS), the mountainlands at the upstream part of the project area is occupied by highly folded Cretaceous sedimentary rocks (shale, tuff, chert, etc.) and igneous rocks (basalt, diabase, etc.) through which were intruded by diorite in Tertiary time. At the downstream plain area there are distributions of Tertiary (Oligocene - Pliocene) sedimentary rocks (alternation of sandstone and mudstone, conglomerate) covered with Quaternary deposits. These strata are distributed in belts running in a north-south direction.

Most of the faults in this area run in a north-south direction, which is parallel to the folding axis of Cretaceous formations or trend of stratigraphic distributions. It may be judged that such geological structure was formed on the whole by the orogenic movement of the Andes Mountains.

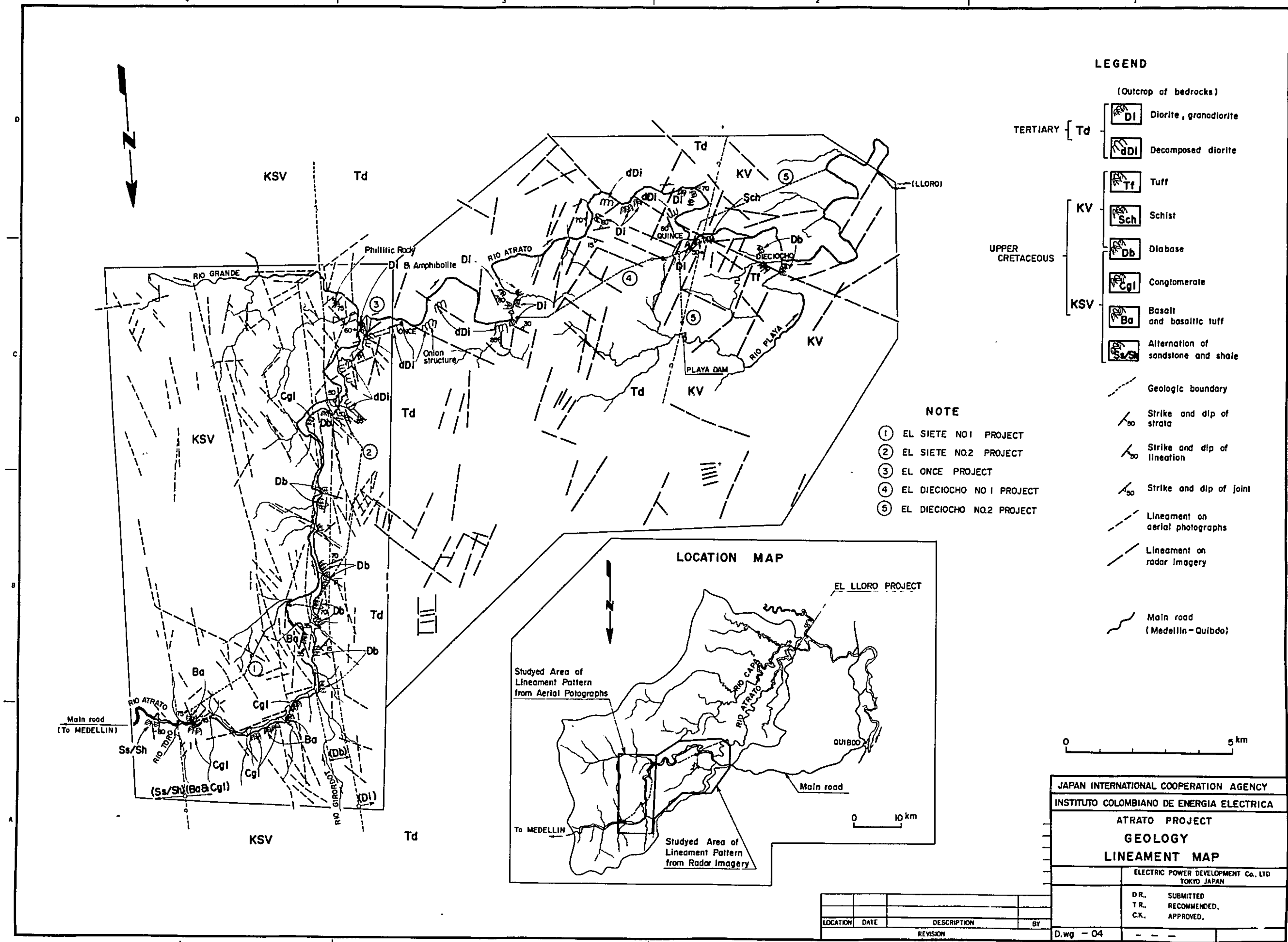
The general geological sequence and rock types of the project area are shown in Table 4-3-1. And the distribution of rocks are indicated in Drawing-03.

Table 4-3-1 General Geologic Sequence and Rock Type of Rio Atrato Basin

Era	Period	Rock Unit	Rock Type	Characteristic	Main Distribution
Cenozoic	Quaternary	Quaternary system	Alluvium, terrace deposits and slope wash.	Unconsolidated deposits consist of gravel, sand, silt, etc.	Along the Rio Atrato.
	Tertiary	Ts5; Marine sedimentary rocks	Alternation of sandstone and mudstone, and conglomerate.	Alternation of sandstone and mudstone interbedded with thin conglomerate beds. Commonly gently dipped beds, and weakly consolidated, somewhat soft in general.	El Lloro project area.
		Td; Intrusive rocks	Diorite.	Medium-to coarse-grained, massive and hard. Joints are regularly spaced in part.	El Siete No.2 project area, El Once project area, El Dieciocho No.1 and No.2 project area.
Mesozoic	Upper Cretaceous	KV; Volcanic rocks and intrusive rocks	Diabase, basalt, basic tuff, pyroclastic rocks and intercalations of chert and black shale.	Diabase and basalt are massive and hard. Basic tuff is massive and rather soft.	El Dieciocho No.2 project area.
		KSV; Sedimentary rocks and volcanic rocks	Black chert, sandstone, shale, limestone and conglomerate, interbedded with diabase and basalt.	Conglomerate, diabase and basalt are massive and hard. Alternation of sandstone and shale is somewhat brittle and strongly folded as a whole.	El Siete No.1 project area.



N
KSV
KV
Td
Ts5
RIO MUMBARADO
RIO GRANDE
RIO ANDAGUEDA
(To MEDELLIN)
RIO ATRATO
CARMEN DE ATRATO
RIO TORO
RIO CAPA
RIO PLAYA
LAS ARENAS
LLORO
YUTO
(To ISTMINA)
EL LLORO PROJECT
EL ONCE PROJECT
EL DIECIOCHO NO.2 PROJECT
EL SIETE NO.1 PROJECT
EL SIETE NO.2 PROJECT
EL DIECIOCHO NO.1 PROJECT
(Main Road)
TUTUNENDO
QUIBDO
0 5 km
LEGEND
SEDMENTARY ROCK and VOLCANIC ROCK
TERTIARY
Ts5 Marin sedimentary rocks (Pliocen-Oligocene) Sandstone, mudstone, conglomerate and limestone
UPPER CRETACEOUS
KV Volcanic rocks and intrusive rocks. Diabse, basalt, basic tuff, pyroclastic rocks and intercalations of chert and black shale.
KSV Sedimentary rocks and volcanic rocks. Black chert, sandstone, shale, limestone and conglomerate, interbedded with diabase and basalt.
INTRUSIVE ROCK
Td Diorite (Tertiary) Hornblend diorite, comprises variant of quartz diorite, monzonite and gabbro.
Geologic boundary
Fault (Assumed)
Strike and dip of strata
Strike and dip of lineation
Note; This map is compiled from "HIDROELECTRICO DEL RIO ATRATO, GENERAL GEOLOGIA", DNP, 1979, "MAPA GEOLOGICO DE COLOMBIA", INGIOMINAS, 1976 and "MAPA GEOLOGICO DEL DEPARTAMENTO DE ANTIOQUIA, INGIOMINAS, 1979.
The geologic boundary of this map is locally based on the results of JICA Mission's Reconneissance (1981).
JAPAN INTERNATIONL COOPERATION AGENCY
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA
ATRATO PROJECT
GEOLOGY
GEOLOGICAL MAP OF PLANNING AREA
ELECTRIC POWER DEVELOPMENT Co. LTD TOKYO JAPAN
DR. SUBMITTED
TR. RECOMMENDED
CK. APPROVED.
LOCATION DATE DESCRIPTION BY
REVISION
Dwg - 03
SHEET NO. OF


LEGEND
(Outcrop of bedrocks)
TERTIARY
Td
Di Diorite, granodiorite
dDi Decomposed diorite
UPPER CRETACEOUS
KV
Tf Tuff
Sch Schist
Db Diabase
KSV
Cgl Conglomerate
Ba Basalt and basaltic tuff
Ss/Sh Alternation of sandstone and shale
Geologic boundary
Strike and dip of strata
Strike and dip of lineation
Strike and dip of joint
Lineament on aerial photographs
Lineament on radar imagery
Main road (Medellin-Quibdo)
NOTE
1 EL SIETE NO1 PROJECT
2 EL SIETE NO.2 PROJECT
3 EL ONCE PROJECT
4 EL DIECIOCHO NO 1 PROJECT
5 EL DIECIOCHO NO.2 PROJECT
LOCATION MAP
EL LLORO PROJECT
Studyed Area of Lineament Pattern from Aerial Potographs
Studyed Area of Lineament Pattern from Radar Imagery
RIO CAPA
RIO ATRATO
QUIBDO
Main road
To MEDELLIN
0 10 km
KSV
Td
KV
RIO GRANDE
Phillitic Rock
Di & Amphibolite
RIO ATRATO
ONCE
Onion structure
QUINCE
DIECIOCHO
PLAYA DAM
RIO PLAYA
(LLORO)
Main road (To MEDELLIN)
RIO TORO
RIO GIRORDOT
0 5 km
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA
ATRATO PROJECT
GEOLOGY
LINEAMENT MAP
ELECTRIC POWER DEVELOPMENT Co., LTD TOKYO JAPAN
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4.3.4 Geology of El Siete No. 1 and No. 2 Sites

(1) General Geology

The El Siete No. 1 and No.2 project sites are located in the Andes Mountain Range (western slope of Cordillera Occidental) which runs north-south and has peaks ranging in altitude from 2,500 to 3,000 m. The Rio Atrato first flows south and turns westward in the vicinity of El Siete No.1 Damsite, and again changes its direction southward at the confluence with the tributary Girordot to reach El Once. The part of the river flowing westward, that is, the portion from El Site No. 1 Damsite to the confluence with the tributary Girordot comprises a V-shaped valley and is a swift stream with a river gradient of 1/18. There are outcrops of bedrock at the river bed and many large boulders can be seen.

On the other hand, the subsequent portion of the Rio Atrato flowing south, where El Siete No. 2 project will be provided, from the tributary Girordot to El Once, is an open U-shaped valley with river terraces in parts. The river gradient of this portion is 1/23 and gentle compared with the part flowing westward, but the flow is still swift compared with ordinary rivers.

This project area is occupied by alternating beds of sandstone and shale, basalt, conglomerate, diabase and diorite. The distribution of rocks is shown in Drawing-03. The properties of the rocks are indicated in Table 4-3-2.

The DNP's geological map indicates that there is an assumed fault extending in the north-south direction passing immediate downstream of the El Siete No. 1 damsite and another assumed fault in the same direction along the Rio Atrato, crossing the route of the waterway of El Siete No. 2, but in the recent surface reconnaissance it was not possible to confirm these faults at field. The exact locations and the characteristics of the faults should be confirmed in future investigations.

(2) Geology of El Siete No. 1 Damsite

This dam is planned as a concrete dam with a height of 55 m and high water level of EL. 1,460 m. River bed elevation is EL. 1,415 m. The valley has a river width of 15 to 20 m, where gravels and boulders are deposited, and bedrock is exposed at both banks. (Fig. 4-3-1) The left bank rises at about 45° from the river up to EL. 1,475 m, and outcrops of bedrock are observable at parts up to the high water level of EL. 1,475 m. While, the right bank rises at 30° up to the road at EL. 1,435 m and at 50° from the road up to EL. 1,470 m, but at around EL. 1,470 m there is a gently-sloped portion of width about 40 m. A reservoir is planned at this site with high water level at EL. 1,460 m, and the dam crest length is 150 m. Consequently, the ratio of dam width to dam height would be 1:2.7, and topographically, this location is suitable as a damsite.

The left bank of the damsite and near the river bed is occupied by Upper Cretaceous basalt, and at the right bank the same basalt and Upper Cretaceous conglomerate crop out at parts.

The basalt is generally black, massive and hard, but there are parts where joints spaced about 10 cm. Prominent weathering is not seen at outcrops.

The conglomerate is dark gray, and slightly soft containing a large proportion of basalt gravels.

Overburden is thin at the left bank of the damsite. Otherwise, there are rather thick distributions of slope wash at the right bank of upstream and downstream of the damsite. There are deposits of boulders 50 to 100 cm in diameter and silt at the river bed, the thickness of which is estimated to be about 2 to 3 m.

Although large-scale faults were not confirmed through the recent reconnaissance, according to the DNP's geological map, there is an assumed fault trending north-south immediate downstream of the damsite.

Joints, those with strike and dip of EW25-45°S, N20°W 75°NE, and N35-50°E 40°NW are developed at spacings of 10 to 100 cm in basalt near the river bed. Of these, joints of EW25-45°S are slightly opened, or thin layers of clay are interspaced in the joints.

It is considered that the bedrock of basalt will have sufficient strength as the foundation for a dam of height of 55 m, if foundation treatment by grouting is performed for water cut-off, and it is estimated that adequate strength will be possessed. However, there is concern about permeability of conglomerate, and it will be necessary to excavate and remove parts of poor quality.

It is necessary for geological maps of 1/1,000 to 1/2,000 scale to be prepared for this damsite in step with other geological work to clarify details of the geologic structure. Also, it is necessary for permeability tests to be carried out with boring holes on the basalt and conglomerate comprising the dam foundation.

(3) Geology of El Siete No. 1 Headrace Tunnel, Penstock and Power Station Sites

The headrace tunnel will be 3.3 km in length with an inner diameter of 4.1 m from an intake to be provided at the left bank of the damsite and running through the mountain at the left bank to reach the power station site.

As shown in Drawing-05, the route of the headrace is in the mountain mass at the left bank of the Rio Atrato. The maximum depth from the ground surface to the tunnel route is 350 m at the middle of the tunnel route. The headrace tunnel will be driven through Upper Cretaceous basalt and conglomerate.

The penstock of 2.3 km in length is to be provided at the ground surface of narrow spur trending south-west at the left bank of the Rio Atrato. This spur is rising at 15° from the river, and there are no landslides or no slope failures at the spur. It is surmised that the bedrock consists of basalt and conglomerate, and detail geological informations cannot be confirmed under present conditions since the ground surface is covered by foliage.

The power station site is planned on the river terrace along the Rio Atrato. There are outcrops of basalt in the river banks about 1 km upstream from the site (Drawing-04). It is not considered that the terrace deposit is so thick to prevent the construction of power station. The underlying rock comprising the powerhouse foundation may be basalt or conglomerate and it is considered there will be no concern about the foundation.

According to the DNP's geological map, faults are not indicated to exist in the vicinities of the headrace tunnel, penstock and powerhouse sites, but upon an overall judgment of the results of the recent reconnaissance and the results of aerial photograph interpretaion, a long lineament crossing the penstock route and striking north can be recognized (Drawing-04). It is necessary to investigate whether the lineament is due to a fault or is caused by lithologic character differences.

(4) Geology of Intake Damsite, Headrace Tunnel, Penstock and Power Station Sites of El Siete No. 2

Intake discharge for the El Siete No. 2 project is to be a maximum of 40 m^3/sec directly from the discharge of El Siete No. 1 Power Station, while since in addition a maximum 20 m^3/sec is to be drawn from the catchment area remaining downstream of El Siete No. 1 Dam, it will be necessary to provide a diversion dam of height of 15 m on the mainstream of the Rio Atrato.

This intake dam would be built immediate upstream of El Siete No. 1 Power Station where the width of the river is approximately 40 m. Since it is expected that basalt is distributed at both banks of this site, it will be possible for a intake dam of height of 15 m class to be constructed.

The headrace tunnel is to be driven along the right bank of the Rio Atrato through a large mountain mass which runs north-south. The maximum depth of the headrace tunnel route will be approximately 280 m from the ground surface, but where the tunnel will cross under three valleys along its route the cover will be about 40 m. Diorite is widely distributed in this area. This diorite has become soft to a depth of 1 - 2 m from the ground surface caused by weathering, but deeper parts of the rock mass are hard.

The slope of spur at which the penstock will be provided is gentle with a gradient of about 30°. There is the bedrock of diorite covered with thin overburden in this route. The bedrock is assumed to be intensely weathered 2 m in depth from the ground surface. However, there will be no problem as the foundation for the penstock, except that the part of the penstock route close to the power station site is covered with gently sloped terrace deposits. Therefore it will be necessary to anchor the penstock to sound bedrock.

Furthermore, the mountainside where the penstocks are to be provided comprises a relatively narrow ridge having small gullies about 20 m deep and at intervals of approximately 80 m laid out in grid from on the slopes, and the causes of these topographic features are supposedly based on the joints pattern of diorite. At any rate, it will be necessary to conduct more detail field investigations for analyzing the geologic structure of this site.

The power station site is also covered with the terrace deposit continuing from the bottom part of the penstock route. The terrace deposit is assumed 2 to 3 m thick, but this should be confirmed by means of boring.

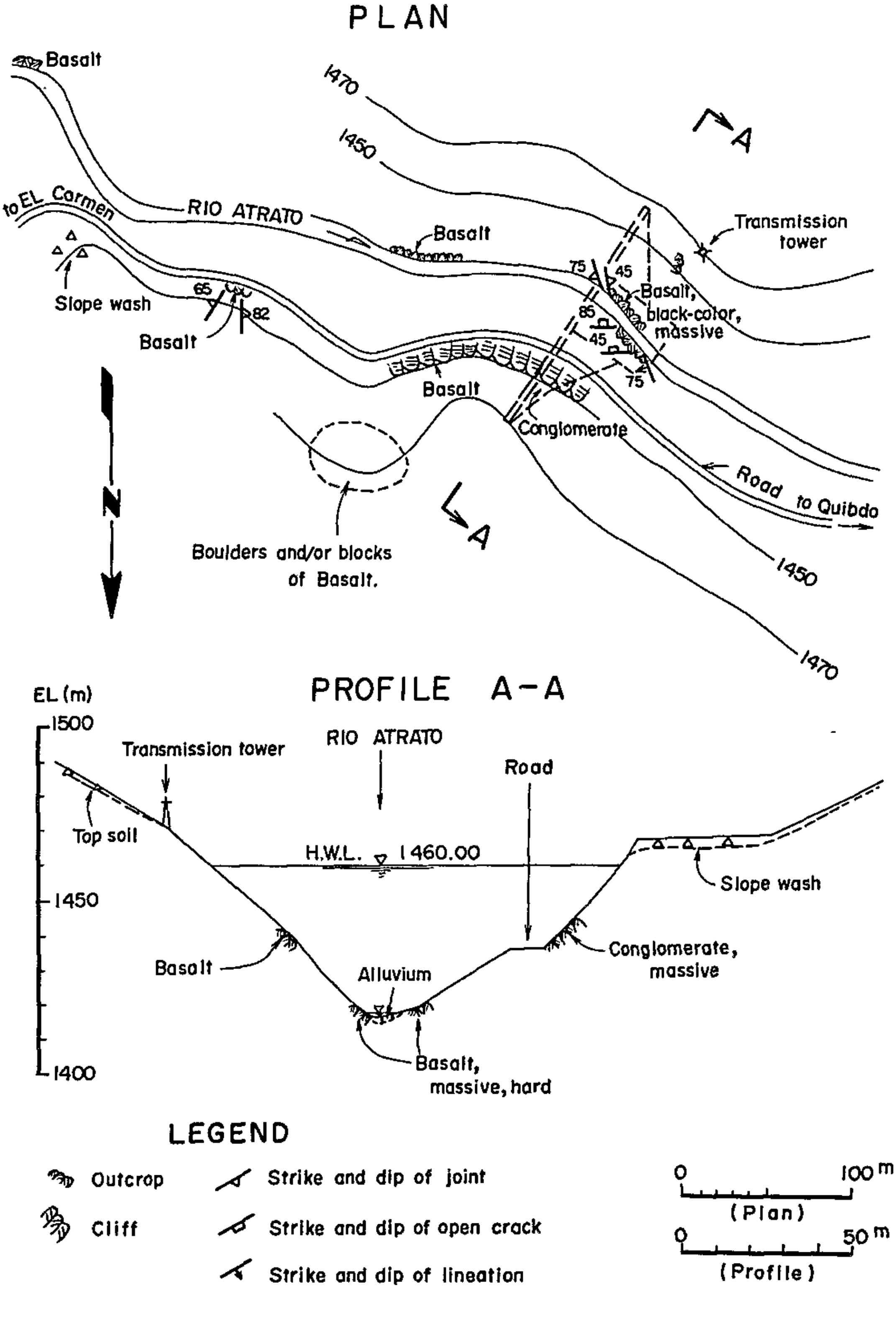
The site of main structures, except intake dam and intake, of the El Siete No. 2 project are situated in the diorite mass which intruded in Tertiary time. The vicinity of the intake is distributed Upper Cretaceous conglomerate, basalt, and a intrusive rock of diorite having a thickness of approximately 1 km. The general properties of these rocks are described in Table 4-3-2, while the distribution is indicated in Drawing-03 and Drawing-04.

One assumed fault exists along the Rio Atrato parallel to the head-race tunnel as seen in the DNP's geological map. Although according to interpretation of aerial photographs there are some lineaments in the north-south direction in this area.. It could not be confirmed in the recent surface reconnaissance that they were faults or not.

Table 4-3-2 Geologic Sequence and Rock Type of El Siete No. 1 and No. 2 Project Area

Period	Rock Unit	Rock Type	Characteristic	Main Distribution
Quaternary		Alluvium, slope wash	Unconsolidated deposits. Many boulders of basalt in Alluvium in general. Slope wash; silty matrix and angular rock fragments (basalt, chert, etc).	Along the Rio Atrato valley.
Tertiary	Td	Diorite	Grayish-white, massive and hard. Decomposed diorite is frequently seen at mountain slopes.	Headrace Tunnel, Penstock and Power Station sites of No. 2 project.
Upper Cretaceous	KSV	Diabase	Gray to dark green, massive and hard. Intruded about 1 km wide. Generally fresh in road-cut.	Upstream part of Head-race Tunnel route of No. 2 project.
		Conglomerate	Black to gray, massive and moderately hard. Many basaltic pebbles with muddy matrix. Joint pattern is not remarkable.	Damsite, Headrace Tunnel, Penstock and Power Station site of No. 1 project. Damsite of No. 2 project.
		Basalt	Black, massive, hard and partially cracky. Basaltic Tuff in local.	
		Alternation of sandstone and shale	Gray to black, thin-bedded. Shaly part is rather brittle. In general slightly sheared along the bedding planes.	Upstream part of the reservoir area of No. 1 project.

Fig.4.3-1 GEOLOGICAL SKETCHED MAP OF EL SIETE NO.1 DAMSITE



4.3.5 Geology of El Once Site

(1) General Geology

This project site is situated at immediate downstream of the confluence of the Rio Atrato and Rio Grande and located at 2.5 km downstream from El Siete No. 2 power station. The Rio Atrato flows south-west near the El Siete No. 2 project site and turns westward at the confluence with Rio Grande. On the both banks of the site, gentle slopes and river terraces are formed at the height of 100 to 150 m and 20 to 30 m above river bed respectively.

The El Once project consists of constructing a dam of height of 110 m for a high water level of EL. 700 m at a relatively narrow part about 300 m downstream of the confluence of the mainstream Rio Atrato and the Rio Grande, with water conducted immediately below by headrace tunnels and penstock lines to a power station.

The rocks distributed in this project area are almost all diorite with a part being diabase. The general properties of the rocks are as described in Table 4-3-3. The states of distribution are as indicated in Drawing-03. The boundary between diabase and diorite is in a north-south direction, and this boundary is assumed to be slightly sheared.

According to the DNP's geological map, although not directly hitting the damsite, there are two assumed faults in the north-east direction crossing the reservoir area and one fault downstream of the power station in the north-northeast direction continuing down from the El Siete No. 2 site (Drawing-03, 04).

(2) Geology of El Once Damsite

The dam is planned as a concrete-faced rockfill dam with a height of 110 m, a high water level of EL. 700 m and a crest length of 710 m.

As shown in Fig. 4-3-2, the damsite has a river bed elevation of 610 m, and a river width of approximately 40 m.

The right bank of damsite rises at a gentle slope of 10° with distributions of terrace deposits from the river up to a road at EL. 685 m, and from there at a slope of 40° to EL. 740 m. Further above (EL. 740 m and higher) there is a flat top of a hilly area and this flat forms the highest peak in the vicinity. On the other hand, the left bank has a slope of 30° from the river bed to a terrace at El. 705 m. The vicinity of EL. 705 m is a flat area covered with terrace deposits which continues on to near the watershed. The valley is shallow and wide, the width being 700 m at high water level (EL. 700 m).

The rock distributed at the dam foundation is diorite which intruded during Tertiary time. Fresh part of diorite is grayish white, massive and hard, and fresh diorite is exposed in the vicinity of the river bed. However, the rock is moderately or highly weathered at both wings of the damsite. Highly weathered part corresponds to residual soil containing relatively hard blocks of diorite. It is assumed that the thickness of the strongly weathered diorite is as much as 3 to 5 m above the public road (Fig. 4-3-2).

Outcrops of diorite can be observed on examination of surfaces of cut slopes of the road at EL. 670 m on the right bank and weathering has progressed to a considerable extent.

In regard to overburden, there are distributions of terrace deposits at the gently sloped portion (below the road) on the right bank of the damsite and the flat area (EL. 705 m) of the mountain on the left bank. The thickness of terrace deposit could not be ascertained. A slight amount of slope wash can be observed at the side of the left bank of the damsite.

Large boulders of diameters 1 to 2 m are deposited at the river bed and it is estimated that fresh bedrock exists at a depth of about 5 m under the river bed.

Although faults were not confirmed in the recent investigation, there are several lineaments (lengths approximately 1.5 km) in the N75°E direction running parallel to the Rio Atrato according to aerial photograph interpretations (Drawing-04).

Joints are observed spacing 30 cm in the two directions. Their strikes and dips are N55°E 90°, and N55°W 50°SW at the right bank near the confluence with the Rio Grande (Fig. 4-3-2).

There is a possibility that the bedrock comprising the dam foundation has a weathered or deteriorated lithological character. Therefore, it is necessary to grasp the permeability of the bedrocks by boring to be made in the next investigation.

Further, some borings will be necessary to confirm the thickness of terrace deposits and weathered zone of bedrocks at the left bank because the terrace of left bank (EL. 705 - 725 m) is located at near high water level (EL. 700 m).

(3) Geology of El Once Headrace Tunnels, Penstocks and Power Station Sites

The intake, headrace tunnels and penstocks will be provided at the ridge trending south-west with flat top (EL. 740 m) on the right bank of the damsite. The two lines of headrace tunnels are planned of 600 m long with the diameter of 5.5 m and two lines of penstocks, 600 m in each length are considered.

This area is occupied by diorite. Generally the surface layer of diorite is moderately to severely weathered to depths of 3 m to 5 m.

The headrace tunnel will be provided at a depth of approximately 40 m from the ground surface. Therefore there is a possibility that the bedrock of tunnel may be weathered and weakened in part.

The penstocks will be provided at the surface of the western slope of the ridge. The bedrock is also strongly weathered at its surface portion.

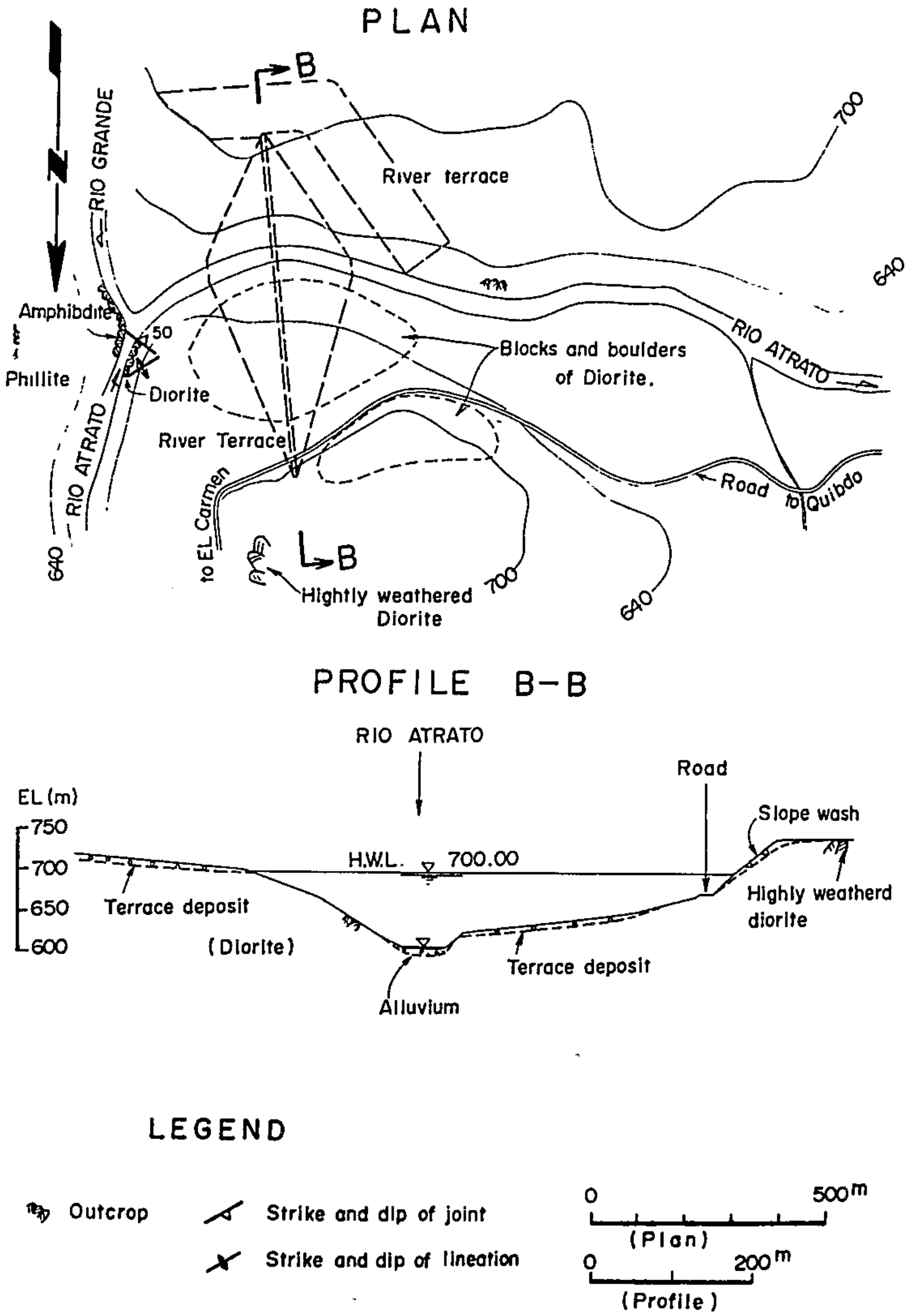
The power station site is located at the gentle slope of the right bank of the shallow, wide valley about 1 km downstream from the damsite. Terrace deposits and river bed deposits are distributed on the surface. It is not considered that the overburden is so thick to prevent the construction of power station. The underlying foundation rock of the powerhouse is diorite, and its surface part is weathered, but

It is necessary for the penstock route and power station site to be investigated the depth of overburden and weathered zone of bedrock by means of drilling.

Table 4-3-3 Geologic Sequence and Rock Type of El Once Project Area

Period	Rock Unit	Rock Type	Characteristic	Main Distribution
Quaternary		Alluvium, terrace deposits	Unconsolidated deposits. Alluvium consists of gravels and boulders (diorite, conglomerate, basalt, etc.).	Along the Rio Atrato valley.
Tertiary	Td	Diorite	Grayish-white, massive and hard. Most of outcrops are strongly weathered and decomposed. Amphibolite locally (at the upstream of damsite).	Damsite, Headrace Tunnel and Power Station sites.
Upper Cretaceous	KSV	Diabase	Gray to dark green, massive and hard. Intruded about 1 km wide. Generally fresh in road-cut.	Upstream part of the Reservoir area of El Once project.

Fig.4.3-2 GEOLOGICAL SKETCHED MAP OF EL ONCE DAMSITE



4.3.6 Geology of El Dieciocho No. 1 and No. 2 Project Sites

(1) General Geology

El Dieciocho No. 1 project consists of a dam with height of 80 m with a high water level of 575 m, which is planned at the Arayanes site 6 km downstream of El Once Dam, from where water is to be conducted to No. 1 Power Station by a headrace tunnel with 7.4 m diameter and 4.5 km length.

Further, the discharge of El Dieciocho No. 1 Power Station, a maximum of 180 m^3/sec, and a maximum of 40 m^3/sec conducted from the Rio Playa are to be combined for use at an underground power station of El Dieciocho No. 2 project to be provided at the El Quince. The water after use there is to be conducted to the Bellavista by a tailrace for discharge into the Rio Atrato.

This is a part of the Rio Atrato where it turns westward and the right bank of the river is a mountain mass of elevation of 900 to 1,000 m. And, river terraces are seen at parts along the river. The river gradient is 1/94 which is gentle compared with the vicinity of El Siete.

The rocks distributed in this area consist mainly of diorite at the El Dieciocho No. 1 project site, and diabase and basalt at the El Dieciocho No. 2 site. The general properties of these rocks are as indicated in Table 4-3-4. Although the boundary condition of these rocks cannot be judged in the recent reconnaissance. The boundary between diorite and schist is probably in a north-south direction and crosses the tailrace tunnel of No. 2 project at an angle of 45°, but is parallel with the Rio Playa water conduct tunnel.

The DNP's geological map shows one fault striking north-northeast, crossing the El Diechiocho No. 1 headrace tunnel route at an angle of 45° and another passing by the site of El Dieciocho No. 1 Power Station site (Drawing-03).

(2) Geology of El Dieciocho No. 1 Damsite

The damsite of El Diechiocho is located at 6 km downstream of El Once Damsite. The type of dam is planned as a concrete dam with a height of 80 m with a high water level of EL. 575 m. The river bed elevation is 505 m and the river width 40 m. The right bank is a slope of 40°, whereas the left bank presents a hilly topography with a slope of 15°, and has a terrace 50 to 70 m wide at EL. 530 m. The dam crest length will be 330 m for a ratio of dam height to crest length of 1:4.2. (See Fig. 4-3-3)

The foundation rock of the damsite is a grayish-white, massive and hard diorite which intruded in Tertiary time. There are joints spaced 20 to 50 cm in local. The surface of the bedrocks has become slightly brittle due to weathering and some of the cracks has intercalations of thin layers of clay. Outcrops at the surface of cut along the road (EL. 530 m) at the right bank are weathered and softened in thickness of 2 to 3 m.

As overburden, it is estimated that terrace deposits are distributed to a depth of approximately 3 to 5 m at the left bank, while at the right bank there is only a small amount of topsoil. As for the river bed portion, outcrops of rock can be seen at the both banks, but there is distribution of gravels 30 to 100 cm in diameter at the river bed surface, and it is estimated that the depth to the bedrock is about 5 m.

Faults could not be confirmed in the recent reconnaissance so far as seen from the ground surface. Meanwhile, with respect to joints, as a result of measurements at the right bank, it was ascertained that there are joints predominant in three directions having strikes and dips of N0°-20°E 60°-80°SE at spacing of 20 to 50 cm, EW 90° at spacing 20 to 30 cm and N10°E 20°NW at wider spacing with some sheared zones (width is 1 to 2 cm in part).

There is a possibility that sheared zones are intercalated in the bedrock, it is necessary for permeability of bedrock to be thoroughly investigated.

(3) Geology of El Dieciocho No. 1 Headrace, Penstock and Power Station Sites

The headrace of El Dieciocho No. 1 will be provided from the intake to be constructed at the right bank of the damsite, pass through the mountains at the right bank of the Rio Atrato, and short-cut the winding river. The tunnel length will be 4.5 km with diameter 7.4 m.

As shown in Drawing-06, the route of the headrace tunnel has been selected to go through the center of the mountainland at the right bank of the Rio Atrato so that there will be cover of 300 to 450 m in thickness, and no large valleys crosses the tunnel route. This route consists of diorite according to the geological map.

Upon examination of the diorite exposed along the road from the dam to the No. 1 power station, many parts where weathering has progressed can be seen so that care will be needed where the tunnel cover is thin.

According to the DNP's geological map, there is an assumed fault which crosses the tunnel at an angle of 45° at a point 1 km from the intake, but it was not possible to confirm this from the ground surface along the road (Drawing-03). While, as a result of interpretation of radar imagery, there are several lineaments running for 2 to 3 km in the N10-20°E direction at the route of the headrace tunnel route (Drawing-04). It is impossible to determine by the radar imagery whether these are faults or not. However, the lineaments in this direction have the same direction as joints observed in outcrops along the road, and there is a possibility that joints are sheared.

The penstocks are to be provided utilizing the surface of the ridge at the end of the mountain running continuously parallel to the Rio Atrato at its right bank. Since this part has no mountain paths and the entire surface is covered with foliage it was not possible to observe the geologic condition, but on looking at rocks exposed at vallays and surfaces of cuts for the road, it is assumed that the bedrock is chiefly diorite and its surface is weathered at least 2 to 3 m deep. However, there will be no problem about providing the penstocks at the ground surface.

The power station is to be provided at the surface by developing a lot utilizing a valley. Outcrops of bedrock can be observed at parts of this valley, and it is assumed that the foundation of the powerhouse can be provided on bedrock consisting of diorite.

(4) Geology of El Dieciocho No. 2 Penstock, Power Station and Tailrace Tunnel Sites

El Dieciocho No. 2 Power Station is to be constructed with an underground powerhouse in the continuous mountain of elevation of 600 m on the right bank of the Rio Atrato from El Dieciocho No. 1 Power Station to Dieciocho Village, which sandwich El Quince Valley. The discharge water from El Dieciocho No. 1 Power Station and intaking water from Rio Playa reservoir are to be conducted to El Dieciocho No. 2 Power Station by a headrace tunnel and penstock.

The inclined shaft-type penstocks and the underground power station are to be provided at a depth of 0 m to 300 m from the ground surface inside the mountain consisting of diorite which is continuous from the vicinity of El Dieciocho No. 1 Power Station. The geologic condition of this mountainland can only be assumed from the surfaces of slopes cut for the road, and diorite and schist are distributed at these surfaces (Drawing-04). Fresh parts of these rock are massive and hard and it is surmised that the underground powerhouse location at 300 m depth is of the same quality of Diorite. However, there is a necessity for thorough studies to be made in further investigations whether faults and sheared zones exist or not. Investigation with drillholes is effective for this purpose.

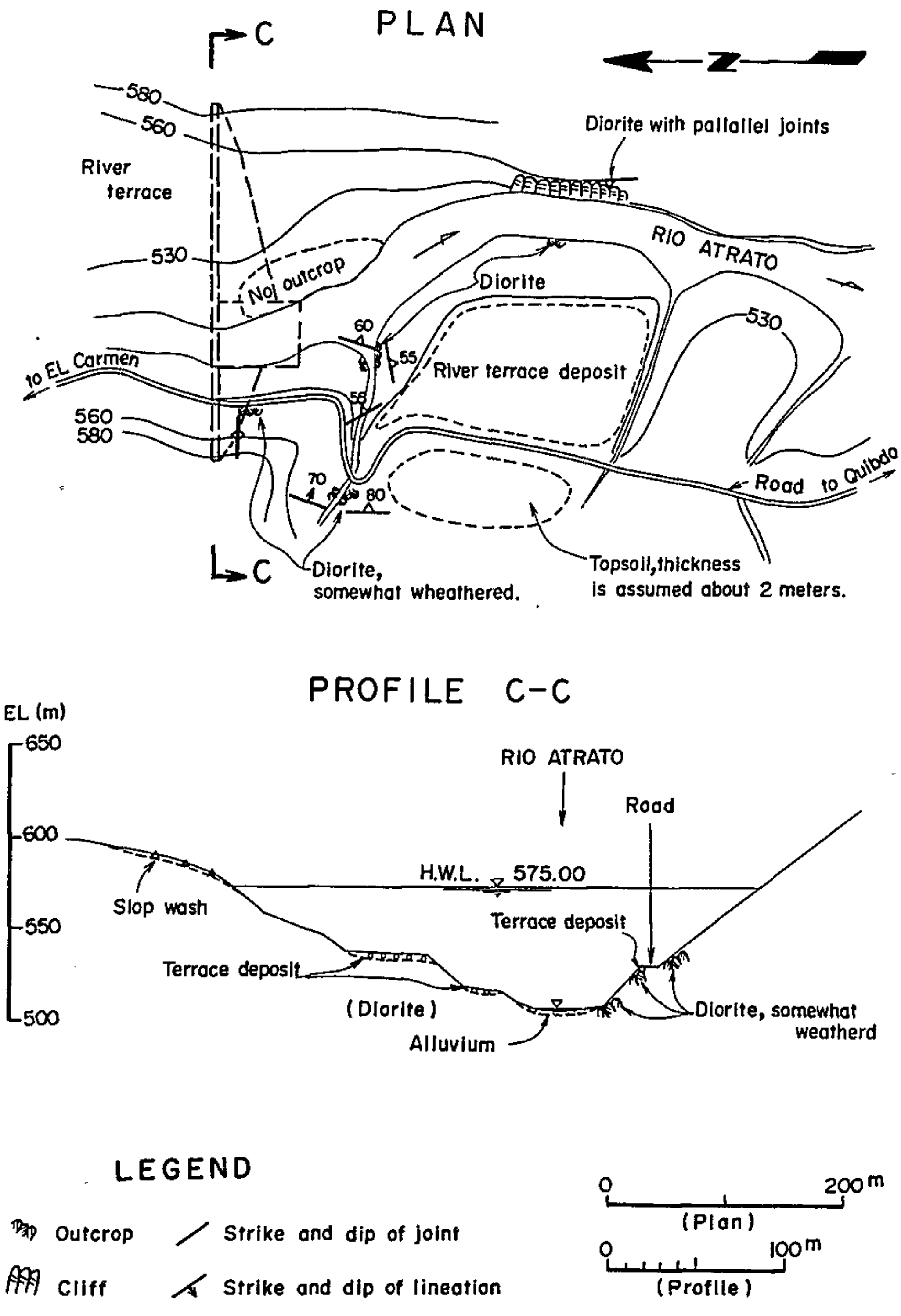
The geological reconnaissance of the Rio Playa dam and the water conduct tunnel route of 2.0 km long were prevented by absence of mountain path. Consequently, geological informations of these sites can only be obtained from the DNP's geological map or interpretations of radar imagery. Playa Dam is planned to be constructed on the schist near the boundary between diorite and schist. Since the plan is for a dam height of 40 m, it is thought there will be few difficulty from the standpoint of geology. However, this area could not be entered at all in the recent reconnaissance, and geological study should be made by a future investigation. The provision of an access road, which will be adequate even if only of mountain-path, is a precondition for such an investigation.

The tailrace tunnel will be designed (diameter, 8.4 m; length, 4.9 km) for discharging a maximum 220 m^3/sec after power generation, it is to first cross the mainstream Rio Atrato 100 m under the river bed immediately downstream of the powerhouse, conducting the water to Bellavista where it is to be discharged into the Rio Atrato. The topography of this tunnel route is that of a hilly area with the geology consisting of diorite and schist near the power station, with most of the remainder comprising diabase and tuff. The general geology is as shown in Table 4.3-4. At present the entire surface has a dense growth of tropical vegetation and the geologic condition cannot be judged from the ground surface, but judging by the condition of rocks exposed along the mainstream Rio Atrato, it will be possible to provide the tailrace tunnel in the schist, diabase and tuff. Faults are not indicated in the DNP's geological map. The depth of the tailrace tunnel from the ground surface is a maximum of 300 m and it is assumed that most of the route will not pose any problem in excavation, but the minimum cover at a valley along the way will be about 30 m. It will be necessary for thorough care to be exercised at parts of thin cover since there is concern that weathering may have reached down to the tunnel section.

Table 4-3-4 Geologic Sequence and Rock Type of El Dieciocho No. 1 and No. 2 Project Area

Period	Rock Unit	Rock Type	Characteristic	Main Distribution
Quaternary		Alluvium, Terrace deposits	Unconsolidated deposits. Many big boulders of diorite in Alluvium in general. Terrace deposits consist of gravels and sand.	Along the Rio Atrato valley.
Tertiary	Td	Diorite	Grayish-white, massive and hard.	Damsite, Headrace Tunnel and Power Station site of No. 1 project. Power Station site of No. 2 project.
Upper Cretaceous	KV	Diabase	Gray to dark green, massive and hard. Generally fresh in road-cut.	Upstream part of Tailrace Tunnel route of No. 2 project.
		Tuff	Gray, massive and generally rather soft. Some outcrops are strongly weathered and decomposed.	Some part of Tailrace Tunnel route of No. 2 project.
		Schist	Gray, massive, hard and locally like sandstone schist (containing coarse grained quartz). Generally fresh in road-cut.	Upstream part of Tailrace Tunnel route of No. 2 project.

Fig.4.3-3 GEOLOGICAL SKETCHED MAP OF EL DIECIOCHO DAMSITE



4.3.7 Geology of El Lloro Project Site

(1) General Geology

This project is located at the lowest part in the upper stream basin of Rio Atrato. A dam of 50 m in height is planned in relative narrow valley of the immediate downstream from the confluence of the Rio Atrato and Río Capa. A power station will be provided immediately below the dam body (so-called "dam-type power generation").

The project area presents a hilly topography with elevations of 100 to 150 m through which the Rio Atrato and the Rio Capa possessing river widths of around 150 to 250 m, meander and generally flow down to southwest direction. After meeting of the two rivers the flow turns westward. River terraces are seen here and there along the rivers, while the hills are entirely covered with tropical flora down to the river banks, and the appearance is that of a jungle area.

The bedrocks in this area are Tertiary (Oligocene - Pliocene) alternation of sandstone and mudstone, and conglomerate (Drawing-03). The general strike and dip of the strata are N15°W 10°SW. The general properties of these rocks are described in Table 4-3-5.

(2) Geology of El Lloro Dam and Power Station Site

The dam is planned as a concrete-faced rockfill dam with a height of 50 m and high water level at EL. 75 m. The river width at the damsite is approximately 150 m, and the water level of the river flow at the time of the reconnaissance was 44 m in elevation (Fig. 4 3-4).

The left bank of the damsite consists of two terraces at elevations of 50 m and 57 m, and the part higher above is a hill of EL. 100 to 125 m. Outcrops of bedrock cannot be seen at the ground surface, which is covered with overburden. However, some outcrops were observable at the cliff of the hill, and it is assumed that the core of the hill consists mainly of alternation of sandstone and mudstone.

The other hand, the right bank presents a steep slope of in height from the river bed at 36 m up to an elevation of 80 m, and outcrops of bedrock consisting of alternations of mudstone and sandstone can be observed at the surface. The top of the hill between EL. 75 m and

EL. 100 m shows comparatively flat. The width of the valley at high water level of EL. 75 m is 320 m, and the shape is that of a wide U.

The dam foundation is composed of Tertiary alternating beds of mudstone and midium-to coarse-grained sandstone, and their colors are commonly gray or black. The alternating bed with intercalations here and there of thin beds of conglomerate (30 to 40 cm thick), range in thickness 2 to 10 cm of mudstone and 10 to 20 cm of sandstone. These rocks are both weakly consolidated and soft, and their fragments are easily broken by hand.

Conglomerate which is found at places presents a black color and can be divided into parts with a large proportion of gravels of diameters of 1 cm and under, and parts with a large proportion of gravels of diameters 2 to 10 cm. These gravels consist of chert, andesite and diorite. The matrix is argillaceous and although the appearance is that of tightness, its degree of consolidation is poor.

In regard to overburden, there are distributions of terrace deposits of thickness of approximately 6 m at the right bank immediately below the damsite, and topsoil of 1 to 2 m.

Meanwhile, on the left bank also, there are distributions of topsoil 1 to 2 m in thickness and underlying terrace deposits although the thickness of the latter is unknown. The river bed portion has a large width of 150 m with water flowing down the entire breadth. The water is deep and the depth could not be measured, and seen from the conditions upstream and downstream, it is assumed that alluvium mainly consisting of gravels of diameters 10 to 20 cm are relatively thick.

As previously mentioned, the strikes of the foundation rocks at the damsite are NS-N15°W, which cross with the channel of the Rio Atrato at 30 to 45°. Further, the dips of strata are 10-18°W and gently sloped in the downstream direction. No fault was observable at the ground surface in the recent reconnaissance. However, joints exist in part of the mudstone alternating with sandstone, the direction of which is parallel to the channel of the Rio Atrato. There was also a number of joints seen in the N45°E - 85°SE direction.

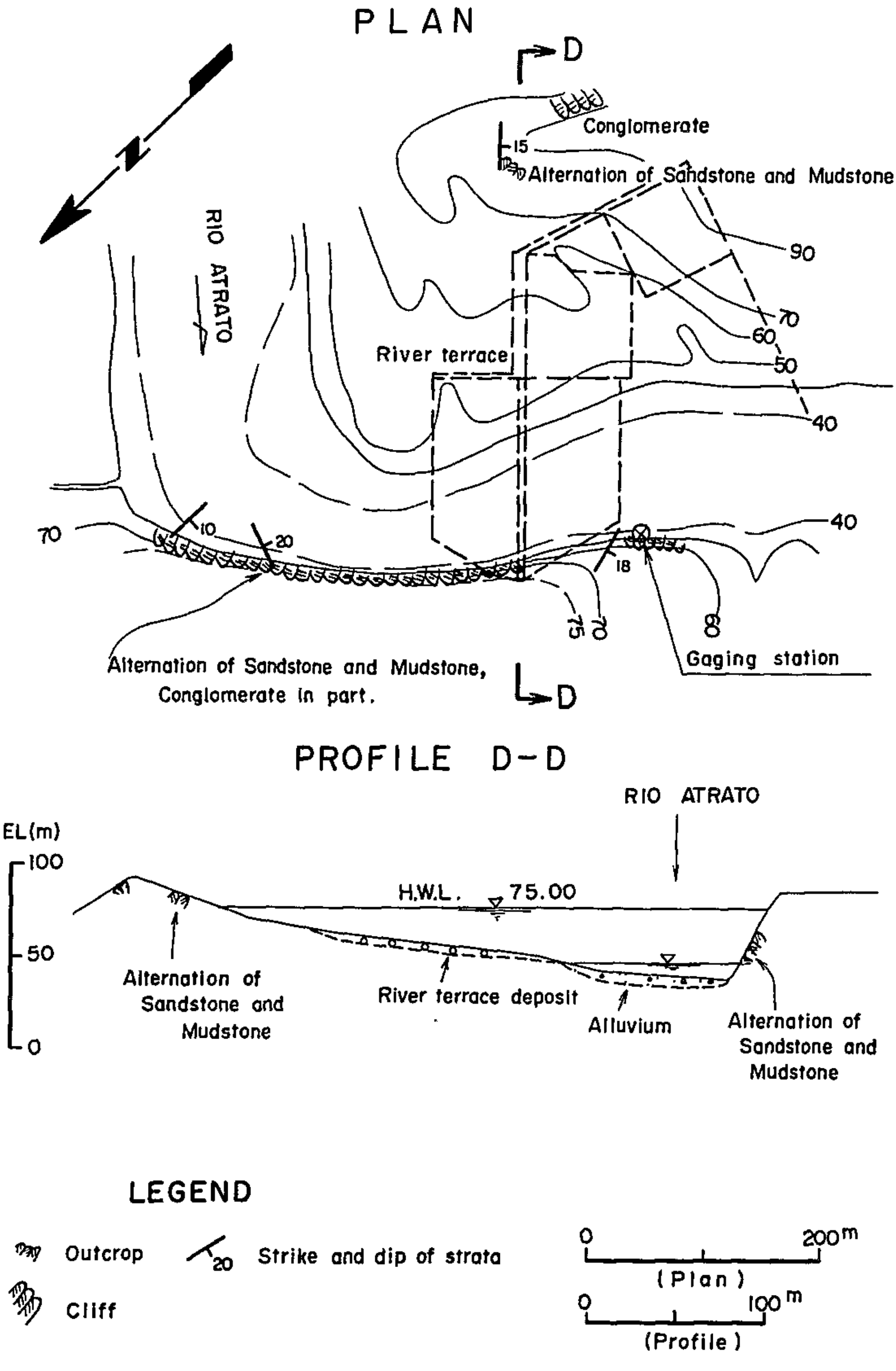
The lithological characters of the abovementioned rocks were generally soft for a high dam foundation, and although there is no concern with regard to bearing strength of a low rockfill-type dam of 50 m class, there will be a problem in the aspect of permeability, and it is necessary for considerable foundation treatment to be provided.

In case that a high water level of this dam is applied at EL. 75 m, there will be two places having some risky factors for water leakage problems from a topographical stand point of view. One is a saddle with lowest elevation of about 85 m at 1 km downstream of the damsite on the left bank and the another is a rather flat ridge in elevation of about 85 m on the right bank of the damsite. Sufficient investigations are to be required in order to confirm their hydrogeological conditions. Also, there is a possibility that the beforementioned foundation rock may fail or be softened by permeation of water upon impoundment, and it is necessary for the stability of the bedrock to be confirmed carrying out absorption tests using test pieces.

Table 4-3-5 Geologic Sequence and Rock Type of El Lloro Project Area

Period	Rock Unit	Rock Type	Characteristic	Main Distribution
Quaternary		Alluvium	Unconsolidated deposits. Mainly gravel, sandstone and silt.	River bed of the Rio Atrato.
		Terrace deposits	Unconsolidated deposits. Mainly pebble with sandy or silty matrix.	On the river terrace of Damsite.
Tertiary	Ts_5	Alternation of sandstone and mudstone, partially interbedded with conglomerate.	Mainly alternation of sandstone and mudstone, partially interbedded with conglomerate. Mudstone; black to gray, 2 ∿ 10 cm thick bedding. Sandstone; black, medium to coarse grained, 10 ∿ 20 cm thick bedding. Conglomerate; pebbles and cobbles of chert, andesite, diorite, etc. with muddy matrix, 30 ∿ 40 cm thick bedding. Consolidation degree of alternating beds is not so strong and these beds are generally soft and brittle.	Damsite and Power Station site.

Fig.4.3-4 GEOLOGICAL SKETCHED MAP OF EL LLORO DAMSITE



4.4 Hydrology

4.4.1 General Meteorological Conditions

The project area is situated from 5°30' to 6°00' north latitude and is near the equator. Consequently, places at low elevations such as Quibdo and El Lloro generally have tropical climates. However, the El Siete No. 1 project site is at about El. 1,500 m and the climate changes to sub-tropical or Temperate.

Generally speaking there's much rainfall at the western slope of the Cordillera Occidental.

The precipitation exceeds 12,000 mm/year at Quibdo and Tutunendo in certain years, and this is said to be the heaviest rainfall area in the world. As for mountain areas, 7,000 to 10,000 mm/year are recorded in some years at the western slope of the Cordillera Occidental. Consequently, this area has high-temperature, high-humidity with lowlands comprising jungle areas where tropical plants flourish.

Temperatures at lowland Quibdo are between a daily maximum of 28 to 30°C and a daily minimum of 22°C, while the diurnal variation is from 7 to 8°C and such condition does not change throughout the year. On the other hand, at La Mansa in the highlands (about EL. 2,000 m), the daily maximum is 20°C and the minimum 13°C for a difference of 7°C, and similarly to the lowlands such condition does not change throughout the year.

In general, there is little difference between the rainy and dry seasons. However it can be said from the precipitation records, the 3-month period of January-March is the dry season and the remaining period from April to December is the rainy season, in which October and November have greatest amounts of precipitation. The maximum daily precipitation in those two months is 150 to 200 mm/day, while maximum monthly precipitation from 1,000 to 1,500 mm/month has been recorded.

(1) Temperature

The airport at Quibdo and La Mansa Observatory are the only places in the project area where temperatures are being measured, and the monthly temperatures of years which are considered representative are shown in table 4-4-1 and 4-4-2.

Table 4-4-1 Monthly Temperature at Quibdó Observatory (Year 1970)

Unit: °C

Month	1 Max. daily average	2 Min. daily average	3 1 - 2	4 Monthly maximum	5 Monthly minimum	6 4 - 5
Jan.	32.1	22.4	9.7	34.0	19.0	15.0
Feb.	31.6	23.2	8.4	35.0	22.0	13.0
Mar.	31.5	23.2	8.3	34.0	21.0	13.0
Apr.	32.3	23.1	9.2	35.0	20.5	14.5
May	31.3	22.7	8.6	34.0	21.0	13.0
June	32.3	22.4	9.9	35.0	17.0	16.0
July	30.8	22.1	8.7	34.0	23.0	11.0
Aug.	31.3	-	-	33.3	-	-
Sep.	30.6	22.0	8.6	34.0	21.0	13.0
Oct.	31.1	22.3	8.8	34.0	22.0	12.0
Nov.	30.7	22.1	8.8	34.0	22.0	12.0
Dec.	30.4	22.3	8.1	33.0	21.0	12.0
Average	31.3	22.6	8.7	35.0	19.0	16.0

Table 4-4-2 Monthly Temperature at La Mansa Observatory (Year 1977)

Unit: °C

Month	1 Max. daily average	2 Min. daily average	3 1 - 2	4 Monthly maximum	5 Monthly minimum	6 4 - 5
Jan.	21.9	12.5	9.4	23.4	10.6	12.8
Feb.	21.8	13.1	8.7	24.4	11.2	13.2
Mar.	22.5	13.5	9.0	26.0	11.4	14.6
Apr.	21.4	13.6	7.8	24.4	11.4	13.0
May	20.4	13.6	6.8	23.4	12.2	11.2
June	20.7	13.0	7.7	23.6	14.2	9.4
July	21.6	12.5	9.2	23.8	10.6	13.2
Aug.	21.0	12.6	8.4	23.6	11.0	12.6
Sep.	21.0	12.5	8.6	23.8	10.8	13.0
Oct.	20.6	13.4	7.2	22.8	12.0	10.8
Nov.	20.5	13.2	7.4	23.2	10.8	12.4
Dec.	20.6	13.6	7.1	22.8	11.6	11.2
Average	21.2	13.1	8.1	23.8	11.5	12.3

Based on the above, and assuming that temperature varies with elevation, the temperatures at the each project site is as shown in Table 4-4-3.

Table 4-4-3 Temperature at Each Project Site

Unit: °C

Project Sites	Max. daily average	Min. daily average	Annual max.	Annual min.	Elevation level (m)
El Siete No.1	24.0	15.7	28.5	12.4	1,460
El Siete No.2	26.5	18.1	30.7	14.0	970
El Once	27.9	19.4	32.0	14.8	700
El Dieciocho No.1	28.6	20.0	32.5	15.3	570
El Dieciocho No.2	29.4	20.8	33.3	15.8	400
El Lloro	31.1	22.4	34.8	16.9	75

(2) Humidity

Humidity, as may be understood from the records below, is very high and shows almost no variation throughout the year, while there is not much variation according to difference in elevation, and it can be assumed that the each project site will have the same conditions.

Table 4-4-4 Annual Humidity at Quibdo & La Mansa Station

Unit: %

Station	Hour			Annual average	Annual maximum	Annual minimum	Year
	07	13	19				
Quibdo	98	75	90	80	99	74	1970
La Mansa	95	78	92	88	96	77	1974

(3) Wind Speed

Wind speed measurements in the project area are only available at the Quibdo Airport. According to the measurements, wind speeds are as shown in Table 4-4-5.

Table 4-4-5 Annual Average Wind Velocity at Quibdo Station

Unit: m/s

Annual average (hour)			Monthly average	Average of monthly maximum	Maximum
07	13	19			
0.5	1.6	0.6	0.9	5.2	10.3

These wind speed measurements are applicable to the various project sites in view of the topography of the project area.

(4) Precipitation

The only observatories available for providing information on precipitation at project sites are those of La Mansa, Carmen de Atrato, El Piñon, Tutunendo, Quibdo and La Vuelta. This, seen from the catchment area of 4,870 km^2 at the Quibdo site, corresponds to one observation stations to each 800 km^2, which can be said to be an extremely small number of observation stations. However, it is possible to learn about precipitation characteristics of the project area from the data of these observation stations. If precipitation stations around the project area were to be added, there would be a total of 28 stations, and it is possible to draw an approximate annual isohyetal map of the area.

Isohyetal maps were drawn for the 12 year period from 1968 to 1979. As a result, it was shown that the same trend existed every year, and the representative isohyetal distribution was the data for 1974, which are as shown in Fig. 4-4-1.

According to the map, the Quibdo and Tutunendo districts have the greatest amounts of precipitation in the Rio Atrato Basin with 9,000 to 12,000 mm recorded annually. The three sites of El Lloro, El Dieciocho No. 1, and El Dieciocho No. 2 are in areas of 7,500 - 8,000 mm/year. El Once and El Site No. 2 are represented by El Piñon station and have 5,000 - 8,000 mm/year, while El Siete No. 1 is in an area of 3,000 - 4,000 mm/year. The middle stream part of the Rio Atrato is in an area of 3,000 mm/year, and the part further downstream has still less 2,500 mm/year. Therefore, the Upstream Rio Atrato Basin is shown to belong to an area with the highest amounts of precipitation.

Table 4-4-6 and Table 4-4-7 give the precipitation records of the Rio Atrato Basin and surrounding areas.

As seen in Table 4-4-6, the monthly precipitation shows that the La Mansa and Carmen de Atrato stations can be clearly distinguished to be in a dry season for the 3-month period of January - March. On the other hand in El Piñon, Tutunendo, Quibdo and La Vuelta, rainy and dry seasons cannot be distinguished throughout the year, and it can be said to be the rainy season all the year around. It is because of this that precipitations of 9,000 to 12,000 mm annually are recorded.

Accordingly, the upstream part of the Rio Atrato basin is a stream of extremely good run-off duration conditions. And although the El Siete No. 1 project site is affected by a dry season in January - March, El Siete No. 2 and its downstream are relatively uninfluenced by dry season and have uniform run-off throughout the year, as can be judged by precipitation records.

Maximum daily precipitation are given in Table 4-4-9 with the heaviest rainfalls 110 mm/day recorded at Carmen de Atrato, 268 mm/day at El Piñon, 203 mm/day at Tutunendo and 301 mm/day at Quibdo. These maximum rainfalls have occurred between July and October. Such heavy rainfalls do not continue for days, but occur singularly in a day as seen from the records.

Table 4-4-6 Annual Pricipitation at Each Pricipitation Station in Departamento de Choco

Unit: mm

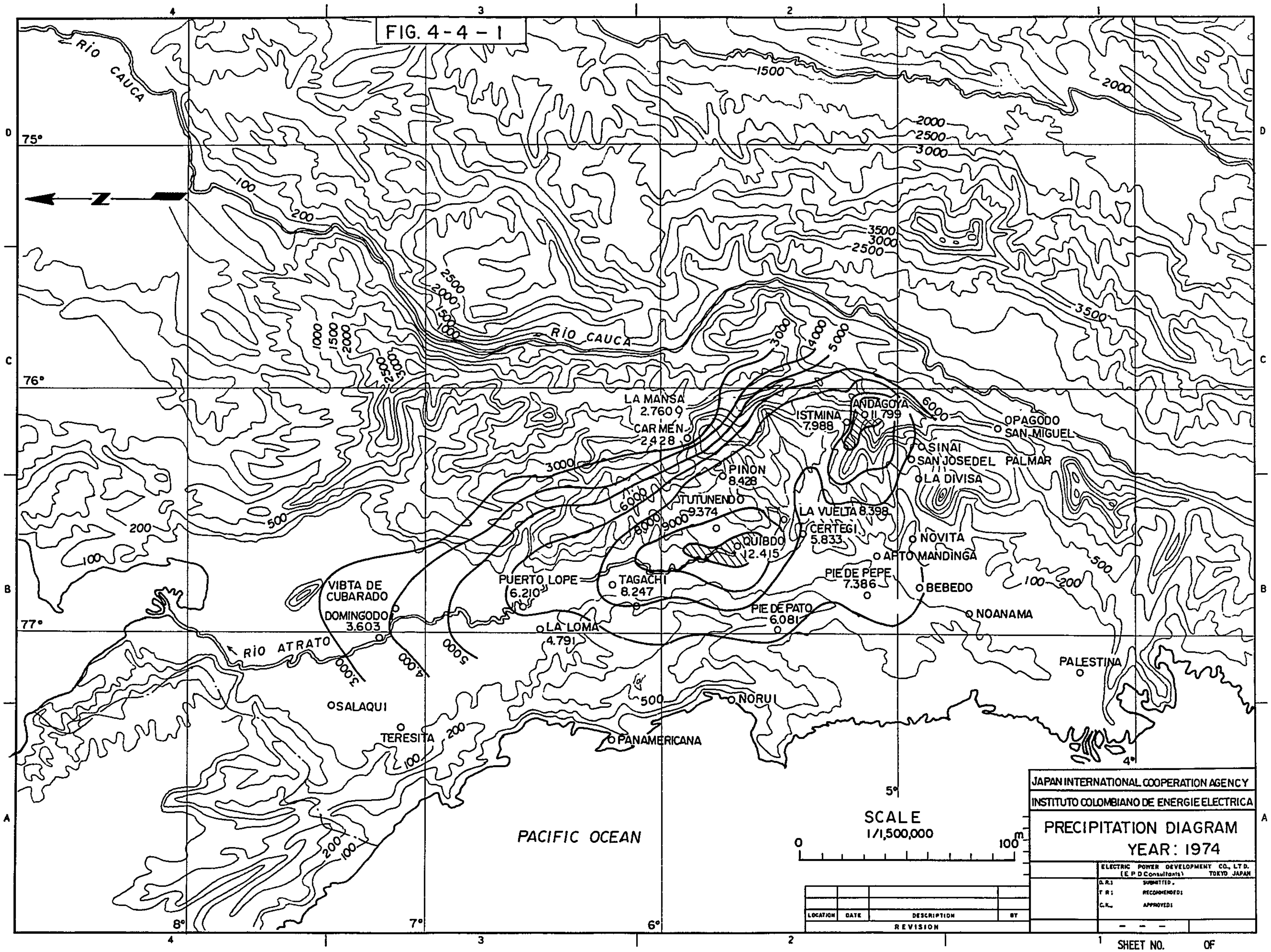
Station	Mark	Annual Precipitation			Period
		Maximum	Mean	Minimum	
SALAQUI	G.2.4	-	2,613	-	74 ∿ 79
DOMINGODO	G.2.6	4,659	3,823	2,736	67 ∿ 80
VISTA DE CUBARADO	G.3.17	29,635		8,981	72 ∿ 80
TERESITA	G.2.7	3,040	2,737	2,460	72 ∿ 78
PUERTO LOPE	H.3.8	6,210	5,360	4,522	70 ∿ 79
LA LOMA	H.3.10	7,507	5,473	4,944	67 ∿ 79
TAGACHI	H.3.16	8,247	6,535	4,814	67 ∿ 80
PANAMERICANA	H.2.4	7,128	5,660	4,177	39 ∿ 77
LA MANSA	I.3.2	7,892	3,834	2,005	70 ∿ 77
CARMEN DE ATRATO	I.3.3	3,437	2,642	1,826	58 ∿ 80
EL PINON	I.3.7	11,316	7,511	5,579	58 ∿ 80
TUTUNENDO	I.3.5	12,666	10,574	8,671	67 ∿ 80
QUIBDO	I.3.8	12,428	7,734	3,625	47 ∿ 77
LA VUELTA	I.3.11	10,955	8,661	7,086	63 ∿ 80
CERTEGI	I.3.13	10,543	6,887	4,165	67 ∿ 80
PIE DE PATO	I.3.9	10,597	7,390	4,981	71 ∿ 80
NOVITA	J.3.3	14,183	8,612	6,366	67 ∿ 80
ISTMINA	I.3.16	9,389	7,717	6,787	67 ∿ 80
ANDAGOYA	I.3.19	11,799	7,487	5,975	18 ∿ 80
APTO MANDINGA	I.3.20	-	-	-	67 ∿ 79
PIE DE PEPE	I.3.17	7,830	6,636	5,753	73 ∿ 80
SAN JOSE DEL PALMAR	J.3.2	6,213	4,825	3,449	67 ∿ 80
SINAI	J.3.6	7,106	6,090	4,337	67 ∿ 80
LA DIVISA	J.3.5	6,213	4,825	3,449	67 ∿ 80
BEBEDO	J.3.4	9,180	7,720	6,749	73 ∿ 80
NOANAMA	J.3.12	9,030	7,947	6,801	66 ∿ 70
OPAGODO SAN MIGUEL	J.3.21	9,399	7,410	5,231	67 ∿ 80
PALESTINA	J.2.3	-	7,405	-	66 ∿ 70

Table 4-4-7 Annual Precipitation in Atrato Area

Unit: mm

Stations	Marks	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
SALAQUI	G.2.4	-	-	-	-	-	-	-	-	-	-	-	2,613	-
DOMINGODO	G.2.6	3,757	-	3,757	4,162	4,231	-	-	3,603	3,409	-	-	4,069	2,736
VISTA DE CUBARADO	G.3.17	-	-	-	-	-	-	-	-	-	-	-	8,981	-
TERESITA	G.2.7	-	-	-	-	-	-	-	-	3,040	2,705	2,460	-	-
PUERTO LOPE	H.3.8	-	-	-	-	5,649	-	5,413	6,210	5,320	5,048	4,522	-	-
LA LOMA	H.3.10	7,507	-	5,194	5,737	5,768	5,700	-	4,791	5,808	5,075	4,944	5,849	-
TAGACHI	H.3.16	7,835	-	5,935	-	8,040	5,092	5,979	8,247	7,288	6,503	4,814	6,370	5,786
PANAMERICANA	H.2.4	-	-	-	-	-	4,177	7,128	6,162	6,565	4,267	-	-	-
LA MANSA	I.3.2	-	-	-	-	7,892	5,054	-	2,760	3,123	2,170	2,005	-	-
CARMEN DE ATRATO	I.3.3	3,437	-	2,728	3,363	3,518	2,311	2,222	2,428	2,858	1,972	1,826	2,546	-
EL PINON	I.3.7	6,275	5,579	-	-	-	5,640	8,593	8,428	10,206	7,124	8,047	8,199	7,679
TUTUNENDO	I.3.5	12,100	-	11,071	10,505	12,704	8,671	10,629	9,374	12,666	10,113	8,736	11,382	8;931
QUIBDO	I.3.8	-	7,399	6,647	8,948	7,442	-	-	12,415	12,428	-	-	-	-
LA VUELTA	I.3.11	9,527	9,091	9,900	9,595	10,955	7,670	8,489	8,398	-	7,086	8,021	7,662	7,799
CERTEGI	I.3.13	-	-	9,487	9,939	10,543	6,660	4,165	5,833	7,224	6,199	-	4,650	4,168
PIE DE PATO	I.3.9	-	-	10,597	9,255	9,116	7,457	6,481	6,081	7,480	-	-	-	5,058
NOVITA	J.3.3													
ISTMINA	I.3.16	6,856	6,899	7,864	8,139	8,933	7,647	-	7,988	6,798	6,787	7,710	7,591	9,389
ANDAGOYA	I.3.19	7,607	-	8,462	-	8,879	7,671	9,379	11,799	10,595	-	5,975	-	6,375
APTO MANDINGA	I.3.20	-	-	10,314	-	14,183	7,001	8,256	-	9,366	6,366	7,040	-	6,370
PIE DE PEPE	I.3.17	-	-	-	-	-	-	-	7,386	7,830	5,753	6,011	6,463	6,373
SAN JOSE DE PALMAR	J.3.2	-	-	-	-	-	-	-	-	4,184	4,969	3,438	-	3,698
SINAI	J.3.6	6,311	6,665	5,665	6,428	6,565	4,337	6,142	6,080	7,106	-	5,599	-	-
LA DIVISA	J.3.5	5,361	-	4,333	-	5,573	4,626	6,157	6,213	-	3,449	4,470	4,233	3,839
BEBEDO	J.3.4	-	-	-	-	-	-	-	-	17,566	9,180	7,232	-	6,749
NOANAMA	J.3.12	9,093	-	6,801	-	-	-	-	-	-	-	-	-	-
OPAGODO SAN MIGUEL	J.3.21	6,808	-	8,102	-	9,399	6,810	-	7,927	7,475	5,231	8,406	-	6,532
PALESTINA	J.2.3													

FIG. 4-4-1


RIO CAUCA
RIO ATRATO
PACIFIC OCEAN
Z
75°
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77°
4°
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6°
7°
8°
LA MANSA 2.760
CARMEN 2.428
ISTMINA 7.988
ANDAGOYA 11.799
OPAGODO
SAN MIGUEL
SINAI
SAN JOSE DEL PALMAR
LA DIVISA
PINON 8.428
TUTUNENDO 9.374
LA VUELTA 8.398
CERTEGI 5.833
QUIBDO 12.415
NOVITA
APTO MANDINGA
PIE DE PEPE 7.386
BEBEDO
NOANAMA
PUERTO LOPE 6.210
TAGACHI 8.247
PIE DE PATO 6.081
LA LOMA 4.791
VIBTA DE CUBARADO
DOMINGODO 3.603
PALESTINA
SALAQUI
TERESITA
NORUI
PANAMERICANA
SCALE
1/1,500,000
0
100 km
JAPAN INTERNATIONAL COOPERATION AGENCY
INSTITUTO COLOMBIANO DE ENERGIE ELECTRICA
PRECIPITATION DIAGRAM
YEAR: 1974
ELECTRIC POWER DEVELOPMENT CO., LTD.
(E P D Consultants) TOKYO JAPAN
SUBMITTED
RECOMMENDED
APPROVED
LOCATION
DATE
DESCRIPTION
BY
REVISION
SHEET NO.
OF

Table 4-4-8 Monthly Precipitation at Project Area

Unit: mm/month

Month	Station	LA MANSA	CARMEN DE ATRATO	PIÑON	TUTUNENDO	QUIBDO	LA VUELTA
Jan.	Maximum	403	325	1,095	1,440	1,188	1,002
	Average	189	133	618	708	550	573
	Minimum	15	50	138	222	141	186
Feb.	Maximum	533	371	672	1,049	1,056	853
	Average	266	129	444	620	424	448
	Minimum	79	25	150	93	78	137
Mar.	Maximum	343	303	710	1,183	1,005	1,312
	Average	315	163	455	618	473	526
	Minimum	124	62	210	142	162	215
Apr.	Maximum	691	491	1,182	1,373	856	1,042
	Average	422	249	641	816	546	663
	Minimum	147	122	301	306	84	394
May	Maximum	706	417	1,585	1,502	1,229	1,154
	Average	358	264	769	970	657	787
	Minimum	219	132	448	395	118	367
Jun.	Maximum	814	426	870	1,624	1,530	1,405
	Average	406	273	650	1,075	703	811
	Minimum	182	181	186	691	187	524
Jul.	Maximum	824	522	1,256	1,506	1,441	1,176
	Average	330	233	577	967	770	814
	Minimum	196	58	299	350	140	567
Aug.	Maximum	907	450	1,251	1,940	2,030	1,438
	Average	365	245	643	1,044	839	998
	Minimum	108	104	352	436	159	649
Sep.	Maximum	877	418	1,005	1,700	1,129	1,044
	Average	354	226	723	922	671	815
	Minimum	83	112	388	108	493	545
Oct.	Maximum	686	411	1,445	1,886	938	1,141
	Average	361	263	920	1,141	578	827
	Minimum	152	28	516	766	165	408
Nov.	Maximum	455	329	1,398	2,037	1,985	1,259
	Average	269	226	899	1,007	674	754
	Minimum	142	89	395	103	351	369
Dec.	Maximum	312	316	1,409	1,384	1,222	1,165
	Average	161	178	882	886	654	667
	Minimum	18	40	308	612	326	326
Annual	Maximum	7,892	3,518	11,316	12,666	12,428	10,955
	Average	3,834	2,642	8,169	10,574	7,734	8,661
	Minimum	2,005	1,826	5,579	8,671	5,533	7,086
Period		71∿77	59∿81	59∿80	67∿80	47∿77	63∿80

Table 4-4-9 Maximum Daily Precipitation at Each Year

Unit: mm

Station / Year	CARMEN DE ATRATO	PIÑON	TUTUNENDO	QUIBDO
1959	52	134	-	207
60	94	268	-	158
61	42	180	-	181
62	80	190	-	113
63	60	153	-	179
64	62	134	-	190
65	110	154	-	208
66	78	120	-	163
67	90	100	203	206
68	100	132	-	178
69	60	120	199	194
70	61	230	150	185
71	65	205	186	141
72	47	104	176	142
73	50	153	154	188
74	51	129	176	301
75	57	153	150	273
76	61	134	160	176
77	55	154	150	157
78	48	193	156	-
79	75	136	135	-

4.4.2 Existing Run-off Gaging Stations and Their Run-off Data

There are eleven run-off gaging stations located at the upstream and middle stream part of the Rio Atrato, El Siete, Puente de Sanchez, Los Arayanes, El Lloro, Agua Sal, San Isidro, Quibdo, Tagachi, Bellavista and Domingodo from the upstream.

However, gaging stations which have carried out measurements for relatively long periods are only the three of Tagachi, Bellavista and Quibdo. And all three of these are at the middle part of the Rio Atrato. San Isidro and Domingodo have many blank periods, and therefore, have not carried out effective observations.

Gaging stations on the upstream part of the Rio Atrato are the five of El Siete, Puente de Sanchez, Los Arayanes, El Lloro and Agua Sal. However, considered from the periods of measurement, Puente de Sanchez is the only one which can be considered as effective. Of the others, only El Siete possesses records for a 2-year period, while the three stations of Los Arayanes El Lloro and Agua Sal have only been in existence for less than a year. Consequently, Puente de Sanchez is the only gaging station which can be used effectively for the hydroelectric power development plan of the upstream Rio Atrato. The records of this gaging station can be effectively applied for planning the El Siete No. 1, No. 2 Hydroelectric Power Project since the station is 1 km upstream of the El Siete No. 1 damsite. However, the station is only carrying out periodic measurements of water level, and since run-off measurements are not being made, there are no rating curves and it is not possible to determine run-off.

Meanwhile, Los Arayanes Gaging Station is located 2 km upstream of the El Dieciocho No. 1 damsite and is effective for the power generation projects of El Once, El Dieciocho No. 1 and El Dieciocho No. 2. However, the observation period is for less than a year and data can be used only for reference. This gaging station also measures water level only and is still not making measurements of run-off, and therefore, run-off data cannot be obtained.

Accordingly, the Survey Mission used current meters which were furnished ICEL by JICA in September 1981 to measure run-off at the three gaging stations of El Siete, Puente de Sanchez and Los Arayanes, and together with carrying out surveys of the run-off cross section, rating curves were prepared. Although these curves do not have enough accuracy because these rating curves were prepared based on data from one time measurement. In the present study for formulation of a master plan, it could not be helped using these curves, by which daily run-off was calculated. Through this operation it became possible to obtain the run-off conditions for the El Siete No. 1, No. 2 projects. Further measurements should be made at least eleven times a year including flood observations to improve accuracy and also to adjust rating curves.

Still further, with regard to the two gaging stations of El Lloro and Agua Sal, the data are only of water level measurements made for less than one year, and these could not be applied to the present study. In the future, these operation of gaging stations should be continued, and it will be only after data for a 5-year period or more has been obtained that application can be made to the El Lloro Project.

It can be seen from the above that run-off data are lacking on the whole, and it may be said that the only two project sites for which a feasibility study can be started are the El Siete No. 1, No. 2 projects on the view point of existing run-off data.

The relation between the locations of these gaging stations and the projects are as shown in Fig. 4-4-2, the number of years records have been collected being as shown in Fig. 4-4-3.

The records of monthly run-off of the two gaging stations of Puente de Sanchez and Los Arayanes are shown in Table 4-4-11 and Table 4-4-12, and a run-off duration in Table 4-4-15.

On examination of these tables, the average run-off for the 5 year period of 1976 to 1980 at Puente de Sanchez Gaging Station was 16.8 m^3/sec, and the unit run-off per 100 km^2 was 8.2 m^3/sec. Meanwhile, the maximum run-off was 73.9 m^3/sec and the ratio to average run-off 4.39 (maximum run-off /annual average run-off). This figure cannot be said to have been the past maximum run-off in view of the daily maximum precipitation in this area.

As for the minimum run-off , this occurs in February or March according to the records, and the average for the 5-year period was 6.1 m^3/sec, and the ratio to average run-off was 0.37 (minimum run-off/annual average run-off).

In contrast, to look at Table 4-4-14, the run-off duration for Puente de Sanchez Gaging Station, although the records are for only a 5-year period, there is little variation in annual run-off duration. Based on this run-off duration and with annual average run-off as 1.00, the ratios of the various number of days of run-off duration are as follows:

Table 4-4-10 Run-off Duration at Puente de Sanchez G.S.

Unit: m^3/sec.

Duration day	Run-off	Ratio
Maximum	51.5	3.07
35 days	27.4	1.63
95 days	20.6	1.23
185 days	15.4	0.92
275 days	11.2	0.67
355 days	7.2	0.43
Minimum	6.1	0.37
Average	16.8	1.00

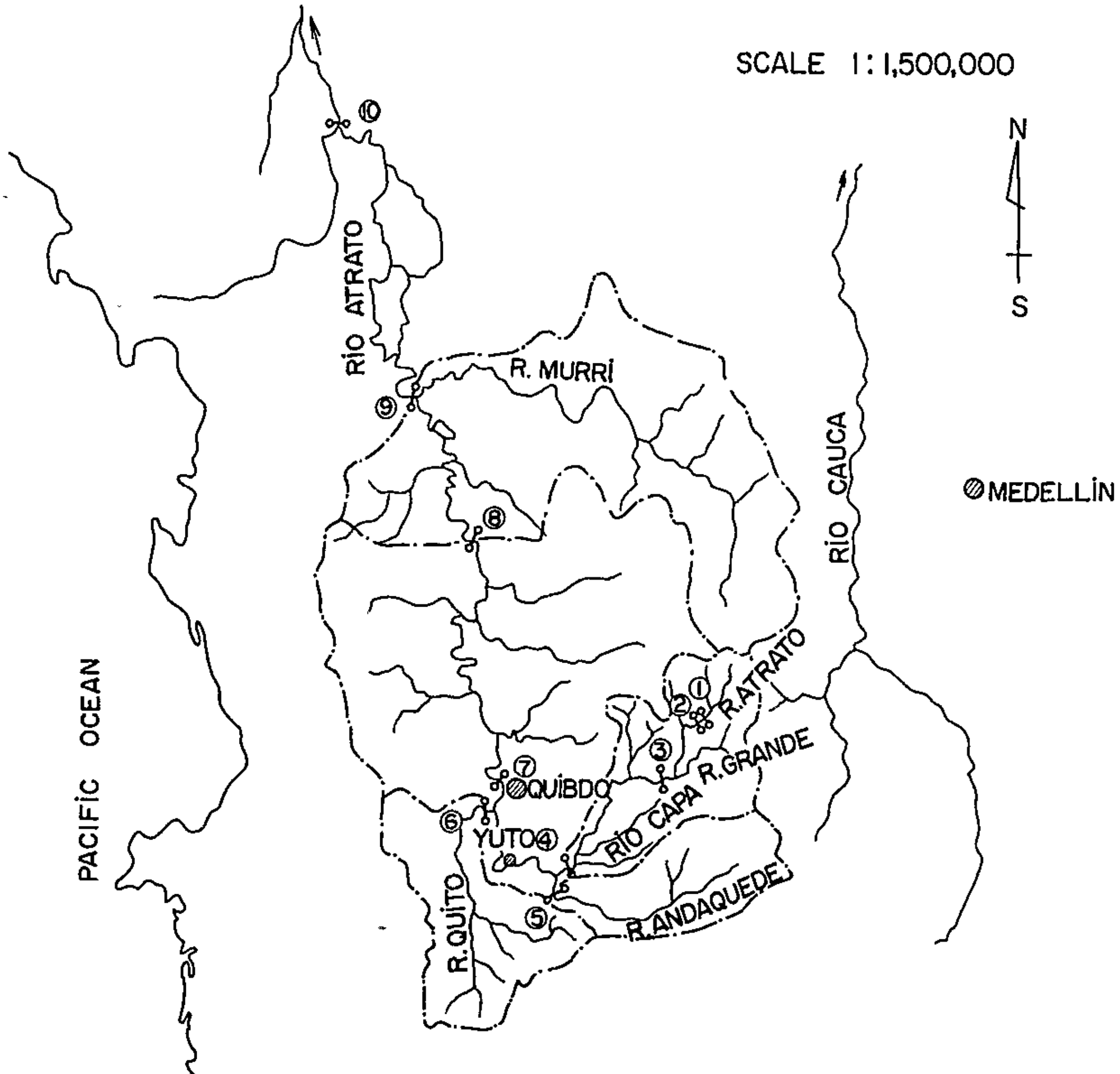
According to these run-off duration ratios, the condition of run-off at Puente de Sanchez Gaging Station is extremely good compared with other rivers, and although perhaps it may not be possible for seasonal control to be performed, it is indicated that this is a river on which considerable effective of power generation can be performed.

Regarding the two gaging stations of El Siete and Los Arayanes, the periods recorded are still short, it is difficult to apply the records to the planning while the climatic conditions also differ considerably from Puente de Sanchez so that correlations based only on catchment area ratios will involve numerous contradictions, it is also difficult to apply these correlations between Puente de Sunchez gaging station and El Once, El Dieciocho No. 1 and No. 2 project sites. Therefore, run-off gaging should be continued further, and when at least 5-years have elapsed it will be possible to apply the data to planning, especially for the El Dieciocho No. 1 and No. 2 projects.

As for the El Lloro project the existing El Lloro and Agua Sal Gaging Stations will be extremely effective. Regrettably, however, these are gaging stations with only short periods of recording performed having been installed in May 1981 and their data cannot be used for the recent study. Therefore, in order to estimate the run-off at the El Lloro site, it is necessary to make a study referring to the records of Tagachi Gaging Station as indicated in Fig. 4-4-2.

The monthly run-off of Tagachi Gaging Station are as given in Table 4-4-13. To examine this, the average run-off for a 9-year period was 1,740 m^3/sec, and the unit run-off per 100 km^2 was 17.2 m^3/sec. Comparing this with Puente de Sanchez Gaging Station, it is a very large figure. However, as described in 4.4.1(4) on precipitation, the fact that the remaining catchment area centered at Quibdo is the area of highest precipitation all the year around is the reason for the difference. The run-off duration is as given in Table 4-4-16, indicating the run-off duration to be extremely good for utilization in power generation.

Fig. 4-4-6 LOCATION MAP OF GAGING STATION IN RIO ATRATO



Gaging Station	Catchment Area (km^2)
① EL SIETE	160
② PUENTE DE SANCHEZ	205
③ ARAYANES	610
④ LLORO	1,600
⑤ AGUA SAL	998
⑥ SAN ISIDRO	1,623
⑦ QUIBDO	4,870
⑧ TAGACHI	10,124
⑨ BELLAVISTA	15,127
⑩ DOMINGODO	—

Fig. 4-4-3 REGISTRATED DATA OF HYDROLOGICAL GAGING STATION IN ATRATO RIVER

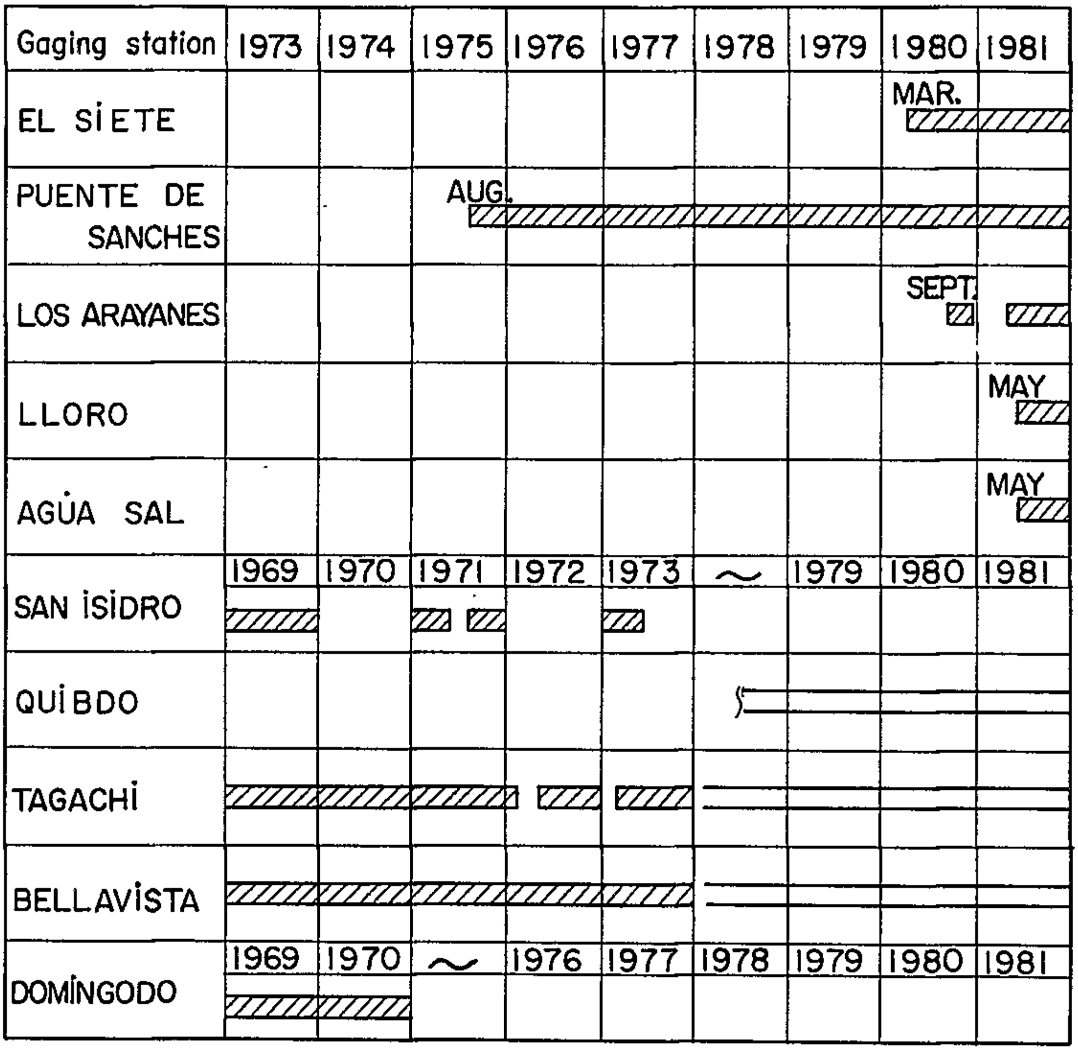


Table 4-4-11 Monthly Run-off at Puente de Sanchez Gaging Station

Catchment Area: 205 km^2

Unit: m^3/s

Month	Year	1975	1976	1977	1978	1979	1980	1981
Jan.	Ave.	-	17.6	9.4	10.5	13.6	14.7	9.6
	Max.		34.5	12.5	15.6	16.4	20.9	12.0
	Min.		11.3	7.6	8.3	11.7	12.0	7.6
Feb.	Ave.	-	12.6	8.1	8.5	8.5	13.0	8.8
	Max.		25.3	11.5	10.9	11.3	20.9	17.0
	Min.		9.4	7.0	7.6	5.1	10.2	7.6
Mar.	Ave.	-	13.4	7.3	11.2	9.3	9.3	11.7
	Max.		18.7	12.9	28.7	15.1	15.1	18.5
	Min.		8.6	6.1	7.6	6.3	7.6	7.6
Apr.	Ave.	-	16.8	8.9	37.2	15.5	11.5	14.4
	Max.		31.4	15.6	73.9	46.8	35.4	28.7
	Min.		10.5	6.6	20.9	8.3	7.3	8.6
May	Ave.	-	17.0	17.7	29.1	19.0	22.6	15.7
	Max.		23.6	47.5	43.3	26.9	44.7	25.8
	Min.		11.7	10.9	21.5	14.2	12.5	11.7
June	Ave.	-	24.3	17.3	18.3	27.1	26.1	24.2
	Max.		39.6	28.7	26.9	44.7	43.3	59.4
	Min.		15.1	13.4	12.0	21.5	17.5	13.8
July	Ave.	-	15.9	15.9	15.2	23.4	14.8	14.9
	Max.		26.4	25.3	24.1	34.8	27.5	21.5
	Min.		9.7	11.3	12.0	17.5	11.3	10.2
Aug.	Ave.	33.7	8.9	19.8	11.3	18.1	16.7	12.7
	Max.	47.5	17.3	28.7	26.9	32.9	22.1	19.5
	Min.	20.9	6.1	11.7	8.3	12.5	12.5	9.0
Sep.	Ave.	28.9	7.5	13.0	15.3	20.6	12.1	13.5
	Max.	46.4	16.0	20.9	24.7	26.4	17.9	24.7
	Min.	15.7	4.6	9.0	9.4	15.6	9.7	9.7
Oct.	Ave.	24.4	15.9	24.4	21.2	27.0	16.2	-
	Max.	39.3	23.4	33.6	28.7	45.3	22.6	
	Min.	20.3	7.3	16.4	15.6	12.9	12.0	
Nov.	Ave.	26.9	21.2	23.2	27.3	26.5	16.1	-
	Max.	64.5	44.7	34.8	45.3	39.3	20.0	
	Min.	20.0	13.8	15.6	14.7	20.5	11.7	
Dec.	Ave.	50.8	13.9	16.9	19.9	20.1	13.7	-
	Max.	192.8	22.3	25.3	30.4	36.7	20.0	
	Min.	22.6	11.3	12.0	12.5	14.7	11.3	
Annual	Ave.	-	15.4	15.2	18.8	19.1	15.6	-
	Max.		44.7	47.5	73.9	46.8	44.7	
	Min.		4.6	6.1	7.6	5.1	7.3	

Note: Above data are calculated from the Puente de Sanchez Gaging Stations data by catchment area ratio.

Table 4-4-12 Monthly Run-off at Arayanez Gaging Station

Catchment Area: 613 km^2

Unit: m^3/s

Month	Year	1980	1981
Jan.	Ave.	-	-
	Max.		
	Min.		
Feb.	Ave.	-	-
	Max.		
	Min.		
Mar.	Ave.	-	-
	Max.		
	Min.		
Apr.	Ave.	-	-
	Max.		
	Min.		
May	Ave.	-	-
	Max.		176.0
	Min.		46.9
June	Ave.	-	104.7
	Max.		261.0
	Min.		52.2
July	Ave.	-	55.8
	Max.		129.1
	Min.		18.1
Aug.	Ave.	-	106.8
	Max.		182.8
	Min.		39.7
Sep.	Ave.	47.1	76.4
	Max.	151.0	134.6
	Min.	25.8	35.6
Oct.	Ave.	47.5	-
	Max.	68.0	
	Min.	27.5	
Nov.	Ave.	87.3	-
	Max.	352.6	
	Min.	39.0	
Dec.	Ave.	-	-
	Max.	232.0	
	Min.	37.3	
Annual	Ave.	-	-
	Max.		
	Min.		

Table 4-4-13 Monthly Run-off at Tagachi Gaging Station

Catchment Area: 10,124 km^2

Unit: m^3/s

Month	Year	1969	1970	1971	1972	1973	1974	1975	1976	1977
Jan.	Ave.	1,390	1,951	2,516	2,292	768	2,221	1,399	1,627	663
	Max.	1,910	2,737	3,041	2,542	1,568	2,664	1,909	2,003	1,448
	Min.	880	1,211	1,680	2,010	438	1,840	787	1,400	165
Feb.	Ave.	1,186	1,619	2,488	1,414	492	2,210	1,367	1,102	1,220
	Max.	1,780	2,407	2,795	2,622	650	2,843	2,034	1,618	1,644
	Min.	530	741	2,026	543	413	1,358	748	752	715
Mar.	Ave.	1,329	1,353	2,138	1,059	1,181	1,826	900	839	728
	Max.	2,150	2,076	2,787	1,563	1,838	2,625	1,377	1,395	1,279
	Min.	690	634	1,163	462	410	724	505	163	375
Apr.	Ave.	1,971	2,027	2,084	1,126	1,396	1,281	1,023	773	1,269
	Max.	2,460	2,986	2,744	1,710	1,843	1,908	1,527	1,624	2,072
	Min.	1,260	1,186	1,579	628	1,012	730	651	149	378
May	Ave.	1,925	2,483	1,898	1,601	1,673	1,725	1,957	1,177	2,092
	Max.	2,490	2,979	2,235	2,158	2,208	2,268	2,715	1,604	2,389
	Min.	1,290	1,639	1,073	892	1,114	1,208	1,247	637	1,618
June	Ave.	1,920	2,036	2,141	1,837	2,129	1,879	2,093	1,436	1,603
	Max.	2,370	2,826	2,580	2,590	2,657	2,395	2,856	1,784	2,201
	Min.	1,240	1,258	1,572	926	1,543	1,223	1,457	884	783
July	Ave.	1,390	1,397	2,393	1,096	1,922	2,188	2,017	963	1,756
	Max.	2,300	2,039	2,932	1,597	2,483	2,542	2,676	1,772	2,182
	Min.	580	755	1,676	671	1,202	1,797	1,249	213	802
Aug.	Ave.	2,267	2,098	2,065	1,157	1,961	2,022	2,607	1,017	1,881
	Max.	2,550	2,564	2,641	2,037	2,936	2,612	2,923	1,503	2,246
	Min.	1,160	1,500	1,364	499	1,200	1,202	1,845	166	1,238
Sep.	Ave.	2,021	2,113	2,127	1,978	2,326	2,087	2,015	761	1,520
	Max.	2,410	2,785	2,641	2,315	2,939	2,590	2,801	1,228	2,040
	Min.	1,390	1,509	1,425	1,407	1,733	1,245	1,292	315	697
Oct.	Ave.	2,263	2,119	1,947	1,488	2,686	2,376	2,591	1,055	2,179
	Max.	2,930	2,516	2,362	2,285	2,833	2,686	2,843	1,492	2,533
	Min.	1,640	1,654	1,490	631	2,539	1,958	1,595	351	1,812
Nov.	Ave.	2,004	2,175	2,074	1,799	2,848	2,148	2,644	1,249	1,606
	Max.	2,360	2,561	2,609	2,235	3,060	2,593	2,958	2,169	2,018
	Min.	1,540	1,714	1,299	1,356	2,689	1,726	1,581	174	752
Dec.	Ave.	2,187	1,856	1,621	1,174	2,401	1,603	2,447	797	1,453
	Max.	2,760	2,696	2,378	1,669	3,003	2,430	2,779	1,614	2,012
	Min.	1,580	1,312	1,075	474	1,945	958	2,015	139	668
Annual	Ave.	1,824	1,936	2,122	1,500	1,822	1,963	1,926	1,066	1,500
	Max.	2,930	2,986	3,041	2,622	3,060	2,843	2,958	2,169	2,533
	Min.	530	634	1,073	462	410	724	505	139	165

Table 4-4-14 Annual River Run-off Duration at Puente de Sanchez Gaging Station

Catchment Area: 205 km^2

Unit: m^3/s

	1976	1977	1978	1979	1980	Average
Maximum	44.7	47.5	73.9	46.8	44.7	51.5
35 days	24.0	25.0	34.0	30.0	24.0	27.4
95 days	19.0	19.0	23.0	24.0	18.0	20.6
185 days	14.0	15.0	16.0	18.0	14.0	15.4
275 days	11.0	9.0	11.0	13.0	12.0	11.2
355 days	6.0	7.0	8.0	7.0	8.0	7.2
Minimum	4.6	6.1	7.6	5.1	7.3	6.1
Average	15.4	15.2	18.8	19.1	15.6	16.8

Table 4-4-15 Annual River Run-off Duration at El Siete No. 1 Dam

Catchment Area: 240 km^2

Unit: m^3/s

	1976	1977	1978	1979	1980	Average
Maximum	52.3	55.6	86.5	54.8	52.3	60.9
35 days	28.1	29.3	39.8	35.1	28.1	32.1
95 days	22.2	22.2	26.9	28.1	21.1	24.1
185 days	16.4	17.6	18.7	21.1	16.4	18.0
275 days	12.9	10.5	12.9	15.2	14.0	13.1
355 days	7.0	8.2	9.4	8.2	9.4	8.4
Minimum	5.4	7.1	8.9	5.9	8.5	7.2
Average	18.0	17.8	22.0	22.4	18.3	19.7

Note: Above data are calculated from The Puente de Sanchez Gaging Stations data by catchment area ratio.

Table 4-4-16 Annual River Run-off Duration Curve at Tagachi Gaging Station

Catchment Area: 10,124 km^2

Unit: m^3/s

	1969	1970	1971	1972	1973	1974	1975	1976	1977	Average
Maximum	2,930	2,986	3,041	2,622	3,060	2,843	2,958	2,169	2,533	2,794
35 days	2,460	2,587	2,705	2,290	2,792	2,505	2,830	1,618	2,167	2,439
95 days	2,220	2,310	2,433	1,929	2,488	2,354	2,525	1,393	1,958	2,179
185 days	1,840	1,980	2,125	1,487	1,840	2,078	1,935	1,064	1,629	1,775
275 days	1,460	1,575	1,833	1,100	1,288	1,546	1,394	786	1,006	1,332
355 days	810	873	1,285	551	449	1,070	729	198	417	709
Minimum	530	634	1,073	462	410	724	505	139	165	516
Average	1,824	1,936	2,122	1,500	1,822	1,963	1,926	1,066	1,500	1,740

Table 4-4-17 Annual River Run-off Duration Curve Par 100 km^2 at Tagachi Gaging Station

Unit: m^3/s

	1969	1970	1971	1972	1973	1974	1975	1976	1977	Average
Maximum	29.0	29.0	30.0	26.0	30.0	28.0	29.0	21.0	25.0	27.4
35 days	24.0	26.0	27.0	23.0	28.0	25.0	28.0	16.0	21.0	24.2
95 days	22.0	23.0	24.0	19.0	25.0	23.0	25.0	14.0	19.0	21.6
185 days	18.0	20.0	21.0	15.0	18.0	21.0	19.0	11.0	16.0	17.7
275 days	14.0	16.0	18.0	11.0	13.0	15.0	14.0	8.0	10.0	13.2
355 days	8.0	9.0	13.0	5.0	4.0	11.0	7.0	2.0	4.0	7.0
Minimum	5.0	6.0	11.0	5.0	4.0	7.0	5.0	1.0	2.0	5.1
Average	18.0	19.1	21.0	14.8	18.0	19.4	19.0	10.5	14.8	17.2

4.4.3 Run-off Analyses of Project Sites

As described in 4.4.2, Puente de Sanchez is the only run-off gaging station which can be used in formulating power generation plans for the upstream part of the Rio Atrato, and the project site to which the data of this gaging station is applicable are El Siete No. 1 and No. 2 projects

The three gaging stations of Los Arayanes, El Lloro and Agua Sal which would be effective for projects from El Once down to El Lloro have inadequate lengths of observation periods and cannot be applied at the present time.

Accordingly, it was decided to apply the daily run-off measurements at Puente de Sanchez to the El Siete No. 1 and No. 2 projects, while for the other projects the Thiessen Method was applied, where rainfall intensities within the catchment areas were obtained, run-off converted from rainfall quantities were computed from the above figures, and monthly run-off was estimated giving consideration to river run-off coefficients.

As seen from precipitation observation data, it is possible to compute run-offs converted from precipitation figures for the 22-year period from 1959 through 1980, and it can be said abovementioned 22-year period is long enough for this Study.

Since figures for Colombia which would be of reference were not available regarding run-off coefficients, it was decided to estimate river run-off coefficient for the two gaging stations of Puente de Sanchez and Tagachi obtaining correlations between run-off converted from precipitation and measured run-off concerning periods for which there were run-off records.

Regarding monthly run-off durations, it was decided to estimate the conditions of run-off durations preparing models corresponding to monthly average run-off from measured run-off durations of the two gaging stations of Puente de Sanchez and Tagachi.

To obtain run-off converted from precipitation, 1/100,000 topographic maps published by the Instituto Geograficos were used to obtain the catchment areas of the various project sites. However, these topographic maps were of extremely rough accuracies, and errors at parts were found compared even with radar imagery. Notwithstanding, because of the lack of any alternative topographic maps, it was necessary to use these maps.

4.4.3.1 Analysis Method

The present study is for the purpose of formulating a master plan for hydroelectric power development at the upstream part of the Rio Atrato and it was aimed at this time to gain a rough concept of run-off conditions. So the study left detailed analyses to the stage of a feasibility study after adequate run-off records have been obtained.

Since the observation periods of existing gaging stations at the upstream part of the Rio Atrato are still short, it is not possible to carry out hydrological analyses of high accuracies. Therefore, it was decided that hydrological analyses in this study would be made applying the simplified method described below.

4.4.3.2 River Run-Off Coefficient

The upstream part of the Rio Atrato, although small in number, precipitation observation stations have data on 22 years from 1959 to 1980. And using these data the areas of influence of the precipitation observation stations were obtained by the Thiessen Method, and the monthly run-off at the each project site was estimated taking into consideration run-off coefficient.

Table 4-4-18 and Table 4-4-19 show the monthly and annual river run-off coefficients of the Puente de Sanchez and Tagachi run-off gaging stations, respectively, for each's period of observation. These tables show, naturally, that there are fluctuations from month to month. Seen by year, however, the values fall in a range of 0.75 to 0.85 in case of Puente de Sanchez and 0.65 to 0.75 except 1976 in case of Tagachi, and the ranges of variation are not wide. Therefore, it is judged that predicted values would not be greatly erroneous. It was decided that monthly run-off estimates would be computed with average values of run-off coefficients being 0.814 for the El Siete No. 1 project and 0.729 for the remaining catchment area of El Siete No. 2, El Once, El Dieciocho No. 1, El Dieciocho No. 2, and El Lloro projects.

Fig. 4-4-4 and Fig. 4-4-5 give comparisons of measured run-off and monthly estimated run-off calculated from precipitation amounts applying the abovementioned run-off coefficients for the Puente de Sanchez and

Tagachi gaging stations. Although partial differences can be seen in some months, there is good coincidence from the long term run-off duration.

Although this is an extremely simplistic comparison, the present situation is that there are only one or two precipitation observatories in the catchment area of a project site, so that it was judged to be impossible for analysis to be made by severe method, and it was unavoidable for the technique of simply estimating run-off from precipitation to be applied.

The equations used in the study are as given below.

(1) Puente de Sanchez Gaging Station

$$\overline{Q}_1 = \overline{R}_1 \times f_1$$

$$\overline{R}_1 = R_1 \cdot \alpha_1 + R_2 \cdot \alpha_2$$

where:

$\overline{Q}_1$: Calculated monthly run-off from precipitation at Puente de Sanchez gaging station (m^3/sec.)

$\overline{R}_1$: Monthly average precipitation of catchment area (mm)

f_1: Run-off coefficient for Puente de Sanchez gaging station = 0.814

R_1: Monthly precipitation at Carmen de Atrato station (mm)

R_2: Monthly precipitation at EL Piñon station (mm)

α_1: Weight of Carmen de Atrato station = 0.82

α_2: Weight of EL Piñon station = 0.18

(2) Tagachi Gaging Station

$$\overline{Q}_2 = \overline{R}_2 \times f_2$$

$$\overline{R}_2 = R_1 \cdot \alpha_1 + \ldots\ldots + R_8 \alpha_8$$

where:

$\overline{Q}_2$: Calculated monthly run-off discharge from precipitation at Tagachi gaging station (m^3/sec.)

$\overline{R}_2$: Monthly average precipitation of catchment area (mm)

f_2: Run-off coefficient for Tagachi gaging station = 0.724

R_1: Monthly precipitation at Carmen de Atrato station (mm)

R_2: Monthly precipitation at EL Piñon station (mm)

R_3: Monthly precipitation at Tutunendo station (mm)

R_4: Monthly precipitation at Quibdo station (mm)

R_5: Monthly precipitation at La Vuelta station (mm)

R_6: Monthly precipitation at Cartegi station (mm)

R_7: Monthly precipitation at Pie de Pato station (mm)

R_8: Monthly precipitation at Tagachi station (mm)

α_1: Weight of Carmen de Atrato station = 0.10

α_2: Weight of EL Piñon station = 0.15

α_3: Weight of Tutunendo station = 0.10

α_4: Weight of Quibdo station = 0.15

α_5: Weight of La Vuelta station = 0.10

α_6: Weight of Cartegi station = 0.10

α_7: Weight of Pie de Pato station = 0.10

α_8: Weight of Tagachi station = 0.20

Location of gagings and precipitation stations are shown in Fig. 4-4-7.

Table 4-4-18 Coefficient of River Run-off at Puente Sanchèz Gaging Station

Catchment Area: 205 km^2

Year / Month	1976	1977	1978	1979	1980	Average
January	1.948	1.085	1.046	1.229	1.235	1.309
February	0.784	0.913	0.826	1.264	0.831	0.924
March	1.353	0.886	0.448	0.895	1.365	0.989
April	0.838	0.503	0.764	0.543	0.461	0.622
May	0.700	0.485	1.007	0.824	0.758	0.755
June	0.842	0.953	0.964	0.848	1.089	0.939
July	1.292	0.769	1.129	1.485	0.814	1.098
August	0.561	0.811	1.007	0.913	0.918	0.842
September	0.435	0.691	0.518	1.192	0.387	0.742
October	0.613	0.731	0.649	0.748	0.683	0.694
November	0.759	1.527	0.983	0.920	0.778	0.951
December	0.760	0.939	0.936	0.780	0.739	0.943
Average	0.821	0.794	0.810	0.886	0.739	0.814

Table 4-4-19 Coefficient of River Run-off at Tagachi Gaging Station

Catchment Area: 10,124 km^2

Month \ Year	1969	1970	1971	1972	1973	1974	1975	1976	1976	Average
January	0.586	0.789	0.557	0.937	0.662	0.854	0.664	0.789	0.693	0.718
February	0.865	0.722	0.775	1.008	1.040	0.998	0.697	0.725	0.825	0.866
March	0.711	0.640	0.541	0.843	0.564	0.808	0.611	0.727	0.602	0.665
April	0.894	0.618	0.674	0.717	0.752	0.639	0.624	0.388	0.666	0.698
May	0.720	0.671	0.698	0.739	0.731	0.842	0.636	0.491	0.630	0.708
June	0.716	0.779	0.511	0.758	0.867	0.701	0.576	0.510	0.723	0.704
July	0.712	0.651	0.627	0.899	0.760	0.692	0.779	0.428	0.726	0.731
August	0.628	0.675	0.589	0.548	0.731	0.704	0.574	0.362	0.752	0.650
September	0.605	0.763	0.678	0.805	0.890	0.759	0.736	0.407	0.836	0.758
October	0.898	0.729	0.636	0.708	0.914	0.700	0.818	0.456	0.805	0.776
November	1.050	0.814	0.781	0.823	0.687	0.725	0.692	0.482	0.856	0.804
December	0.707	0.472	0.747	0.843	0.939	0.895	0.835	0.430	0.968	0.801
Average	0.737	0.683	0.636	0.792	0.772	0.766	0.685	0.499	0.757	0.729

Fig. 4-4-4 CORRELATION BETWEEN AVERAGE PRECIPITATION OF CATCHMENT AREA AND RUN-OFF DISCHARGE AT PUENTE DE SANCHEZ GAGING STATION

CATCHMENT AREA : 205 km²

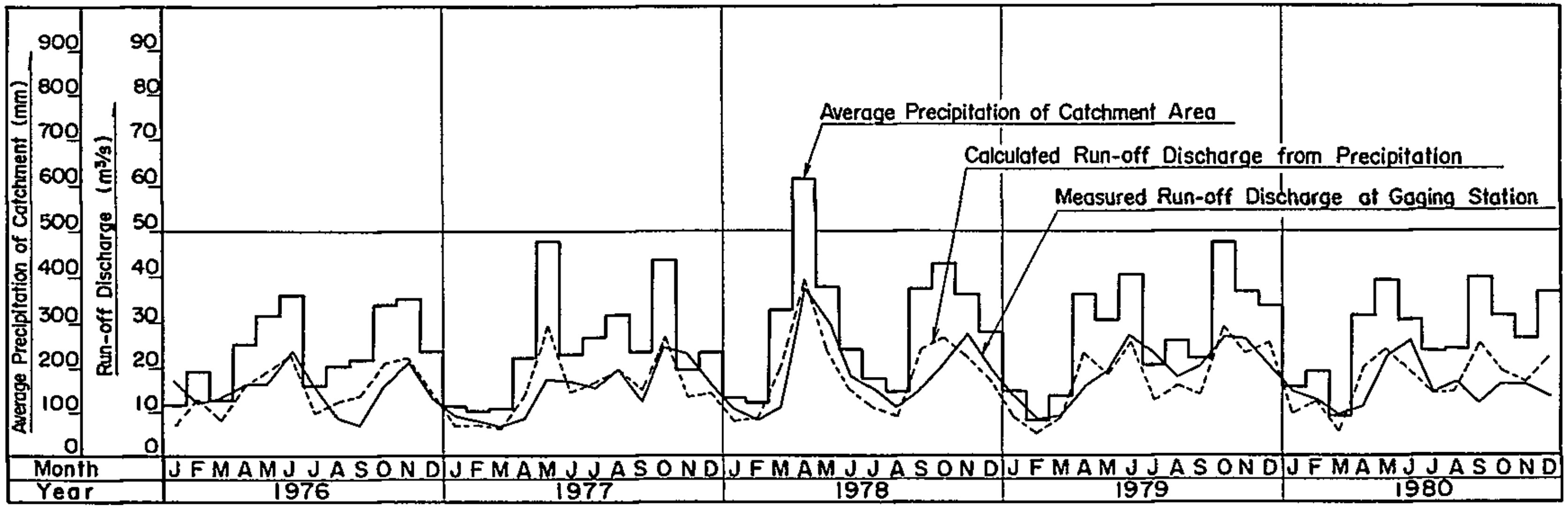
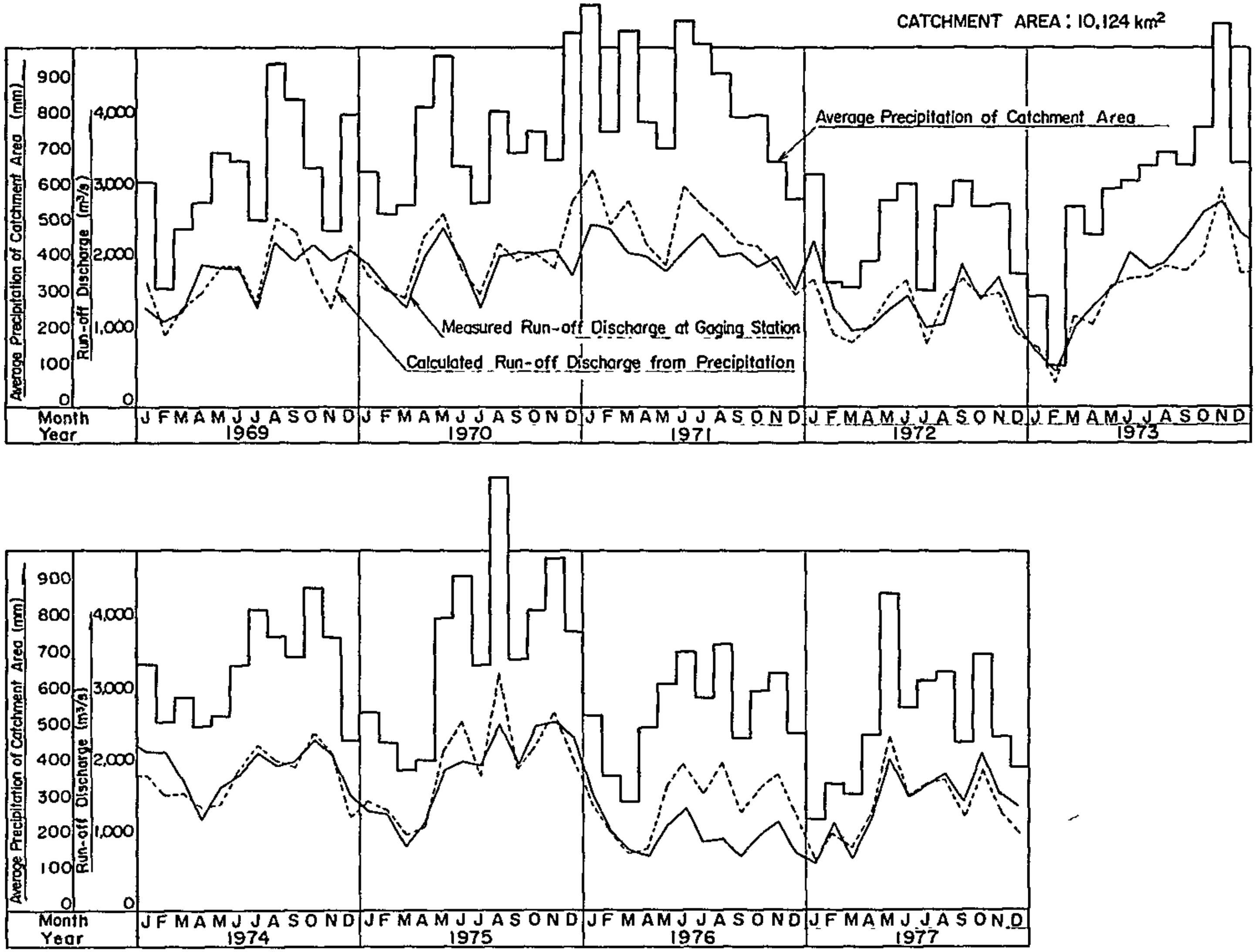


Fig. 4-4-5 CORRELATION BETWEEN AVERAGE PRECIPITATION OF CATCHMENT AREA AND RUN-OFF DISCHARGE AT TAGACHI GAGING STATION



4.4.3.3 Run-off at Each Project Site

The estimated values of monthly run-off for the 22-year period from 1959 to 1980 at the each project site was calculated employing the technique described in 4.4.4.3 and applying the formulae below.

(1) El Siete No. 1 Project

$$Q_1 = \frac{(R_1 \cdot \alpha_1 + R_2 \cdot \alpha_2) A_1 \times 1{,}000}{(\text{Days in Month}) \times 86{,}400 \text{ sec.}} \times f_1 \quad (m^3/\text{sec.})$$

where,

Q_1: Monthly run-off at El Siete No. 1 Dam (m^3/sec.)

R_1: Monthly precipitation at Carmen de Atrato Station (mm)

R_2: Monthly precipitation at El Piñon Station (mm)

α_1: Weight of Carmen de Atrato Station = 0.82

α_2: Weight of El Piñon Station = 0.18

A_1: Catchment area of project El Siete Dam = 240 km^2

f_1: Run-off coefficient = 0.814

Note: From August 1975 to December 1980 the values were obtained by catchment area ratio (240/205 = 1.1707) from the measured run-offs of Puente de Sanchez Gaging Station.

(2) El Siete No. 2 Project

$$Q_2 = Q_1 + \left[\frac{R_2 \cdot \Delta A_2 \times 1{,}000 \times f_2}{(\text{Days in Month}) \times 86{,}400 \text{ sec.}}\right] \quad (m^3/\text{sec.})$$

where,

Q_2: Monthly run-off at El Siete No. 2 intake dam

R_2: Monthly precipitation at El Piñon Station (mm)

ΔA_2: Remaining catchment area between El Siete No. 1 Dam and El Siete No. 2 Intake Dam = 70 km^2

f_2: Run-off coefficient = 0.729

(3) El Once Project

$$Q_3 = Q_2 + \left[\frac{R_2 \cdot \Delta A_3 \times 1{,}000 \times f_2}{(\text{Days in Month}) \times 86{,}400 \text{ sec.})}\right] \ (m^3/\text{sec.})$$

where,

Q_3: Monthly run-off at El Once Dam (m^3/sec.)

R_2: Monthly precipitation at El Piñon Station (mm)

ΔA_3: Remaining catchment area between El Siete No. 2 Intake Dam and El Once Dam = 280 km^2

f_2: Run-off coefficient = 0.729

(4) El Dieciocho No. 1 Project

$$Q_4 = Q_3 + \left[\frac{R_4 \cdot \Delta A_4 \times 1{,}000 \times f_2}{(\text{Days in Month} \times 86{,}400 \text{ sec.})}\right] \ (m^3/\text{sec.})$$

where,

Q_4: Monthly run-off at El Dieciocho No. 1 Dam Site (m^3/s)

R_4: Precipitation at Quibdó Station

ΔA_4: Remaining catchment area between El Once Dam and El Once Dam and El Dieciocho No. 1 Dam = 30 km^2

f_2: Run-off coefficient = 0.729

(5) El Dieciocho No. 2 Project

$$Q_5 = Q_4 + \left[\frac{(R_2 \cdot \alpha_1 + R_4 \cdot \alpha_2)\Delta A_5 \times 1{,}000 \times f_2}{(\text{Days in Month}) \times 86{,}400 \text{ sec.}}\right] \ (m^3/\text{sec.})$$

where,

Q_5: Monthly run-off at El Dieciocho No. 2 Project Site (m^3/sec.)

R_2: Precipitation at El Piñon Station (mm)

R_4: Precipitation at Quibdó Station (mm)

ΔA_5: Catchment area of Rio Playa Dam Site = 100 km^2

f_2: Run-off coefficient = 0.729

α_1: Weight of El Piñon Station = 0.8

α_2: Weight of Quibdo Station = 0.2

(6) El Lloro Project

$$Q_6 = Q_5 + \left[\frac{(R_2 \cdot \alpha_1 + R_4 \cdot \alpha_2 + R_5 \cdot \alpha_3)\Delta A_6 \times 1,000 \times f_2}{(\text{Days in Month}) \times 86,400 \text{ sec.}}\right] \ (m^3/\text{sec.})$$

where,

Q_6: Monthly run-off at El Lloro Dam (m^3/sec.)

R_2: Precipitation at El Piñon Station (mm)

R_4: Precipitation at Quibdo Station (mm)

R_5: Precipitation at La Vuelta Station (mm)

α_1: Catchment area weight of El Piñon Station = 0.4

α_2: Catchment area weight of Quibdo Station = 0.2

α_3: Catchment area weight of La Vuelta Station = 0.4

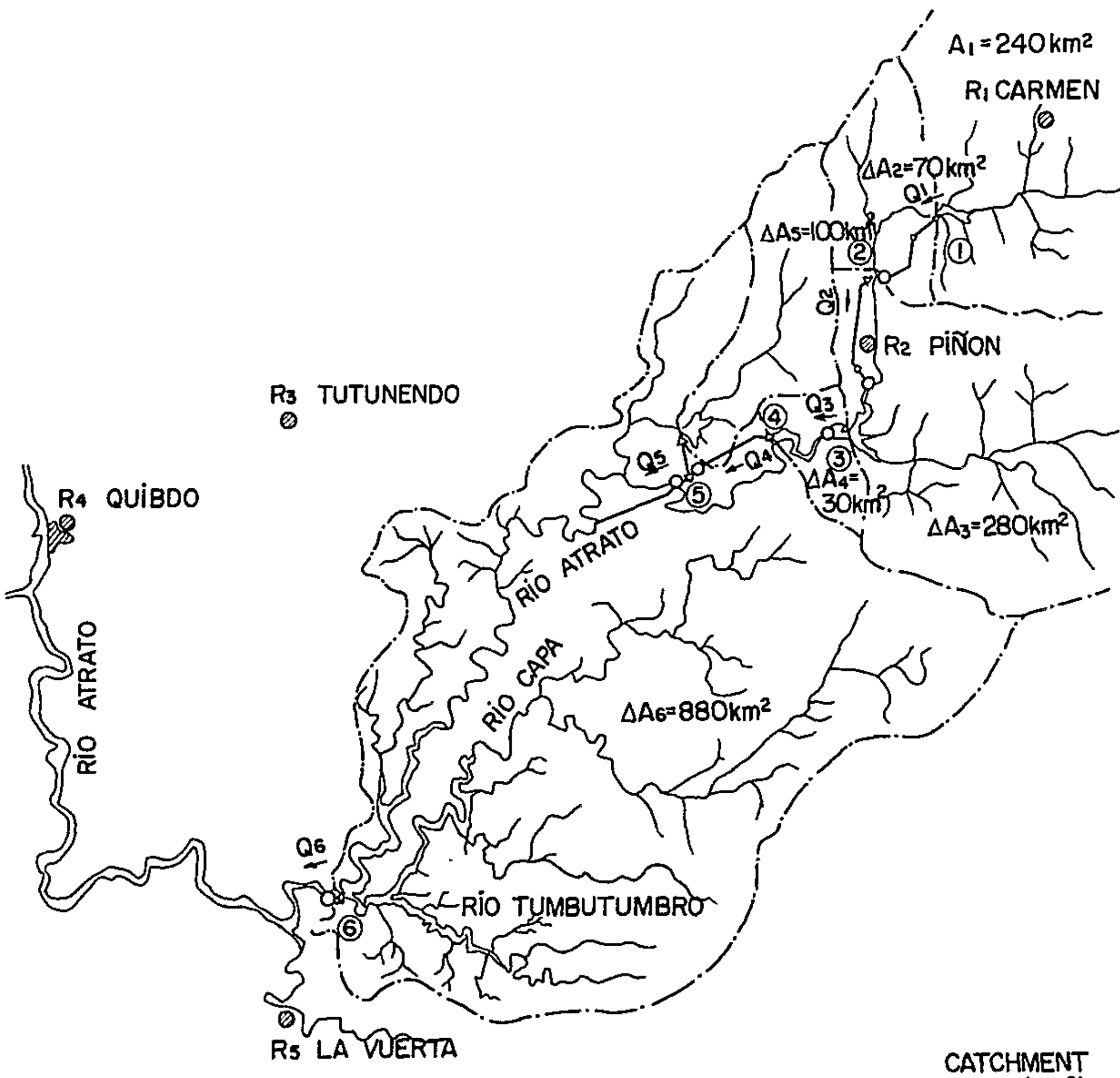
ΔA_6: Remaining Catchment area between El Dieciocho No. 2 Project and El Lloro Dam = 880 km^2

f_2: Run-off coefficient = 0.729

The results obtained for the estimated monthly average run-off of the various projects based on the above calculation formula are as shown in Table 4-4-20 to Table 4-4-25.

However, it should be paid attention that these are estimated run-offs obtained utilizing measurements of precipitation stations. and are inferior in accuracies. In the El Siete No. 1 and El Siete No. 2 projects, the most reliable run-off figures are the data for the 5-year period from 1976 to 1980 for which the measured values of Puente de Sanchez Gaging Station are applied.

Fig. 4-4-6 LOCATION MAP OF PRECIPITATION OBSERVATION STATION AND PROJECTS SITES



	DISCHARGE	CATCHMENT AREA (km^2)
① EL SIETE NO. 1	Q_1	240
② EL SIETE NO. 2	Q_2	310
③ EL ONCE	Q_3	590
④ EL DIECIOCHO NO. 1	Q_4	620
⑤ EL DIECIOCHO NO. 2	Q_5	720
⑥ LLORO	Q_6	1,600

Table 4-4-20 Monthly Run-off at El Siete No. 1 Dam

Catchment Area: 240 km^2

Unit: m^3/s

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average	Maximum	Minimum
1959	9.5	5.4	14.5	25.8	21.4	29.5	21.5	26.3	21.5	30.4	25.2	13.0	243.9	20.3	30.4	5.4
1960	25.4	20.4	18.2	25.2	27.8	32.8	32.2	21.3	19.1	25.9	28.7	34.0	310.9	25.9	34.0	18.2
1961	11.1	7.7	13.3	25.4	19.4	22.1	21.5	16.1	25.8	22.9	36.3	19.8	241.3	20.1	36.3	7.7
1962	10.9	17.2	16.5	15.7	27.5	20.6	18.4	21.3	18.0	29.4	13.6	16.4	225.6	18.8	29.4	10.9
1963	11.1	24.0	10.2	27.8	18.3	27.0	23.6	17.7	11.7	13.1	22.7	12.5	219.8	18.3	27.8	10.2
1964	11.4	12.4	9.1	32.9	20.0	30.7	26.6	19.7	25.0	27.8	18.5	26.1	260.3	21.7	32.9	9.1
1965	27.0	7.6	6.8	7.8	16.4	4.8	6.7	17.6	27.0	30.0	24.3	24.3	200.3	16.7	30.0	4.8
1966	11.9	18.0	23.2	20.2	36.2	36.6	28.3	29.5	21.8	28.5	29.9	21.3	305.3	25.4	36.6	11.9
1967	21.7	33.3	9.9	24.0	23.4	20.5	37.3	28.7	18.3	30.9	29.4	18.2	295.5	24.6	37.3	9.9
1968	6.4	10.0	19.1	25.4	25.2	23.8	14.7	19.1	17.5	21.2	30.5	13.1	226.0	18.8	30.5	6.4
1969	18.4	10.6	19.9	22.9	22.7	23.0	11.3	27.7	34.4	36.3	11.4	8.5	247.2	20.6	36.3	8.5
1970	12.6	4.4	11.3	19.7	25.0	15.9	16.9	18.4	26.0	28.8	35.3	55.6	269.8	22.5	55.6	4.4
1971	52.3	37.8	45.7	31.9	36.6	49.2	37.2	51.0	43.4	37.8	34.4	25.5	482.9	40.2	52.3	25.5
1972	20.0	4.6	11.0	19.1	26.8	21.8	9.2	22.5	24.2	23.8	22.0	11.5	216.4	18.0	26.8	4.6
1973	4.7	4.6	15.6	16.7	20.7	23.7	19.8	22.0	27.4	34.7	34.5	26.1	250.6	20.9	34.7	4.6
1974	26.6	23.4	17.7	18.8	17.1	18.8	28.1	22.0	22.5	31.7	27.7	7.8	262.2	21.8	31.7	7.8
1975	17.7	19.8	14.7	19.3	25.1	26.7	26.2	35.6	33.8	28.5	31.5	59.5	338.4	28.2	59.5	14.7
1976	20.6	14.8	15.7	19.7	20.0	28.4	18.6	10.5	8.8	18.6	24.8	16.3	216.7	18.1	28.4	8.8
1977	11.0	9.4	8.5	10.4	20.8	20.3	18.6	23.2	15.2	28.6	27.2	19.8	212.9	17.7	28.6	8.5
1978	12.3	10.0	13.1	43.5	34.1	21.4	17.8	13.2	17.9	24.8	31.9	23.3	263.4	21.9	43.5	10.0
1979	16.0	10.0	10.9	18.1	22.3	31.7	27.5	21.2	24.2	31.6	31.1	23.5	267.8	22.3	31.7	10.0
1980	17.2	15.2	10.8	13.4	26.5	30.6	17.3	19.6	14.2	19.0	18.8	22.7	225.3	18.8	30.6	10.8
Total	375.9	320.5	335.9	483.7	533.1	559.8	479.1	504.1	497.7	604.2	589.7	498.8	5,782.5	481.6		
Average	17.1	14.6	15.3	22.0	24.2	25.4	21.8	22.9	22.6	27.5	26.8	22.7	262.8	21.9		
Maximum	52.3	37.8	45.7	43.5	36.6	49.2	37.3	51.0	43.4	37.8	36.3	59.5				
Minimum	4.7	4.4	6.8	7.8	16.4	4.8	6.7	10.5	8.8	13.1	11.4	7.8				

Table 4-4-21 Monthly Run-off at El Siete No. 2 Dam

Catchment Area: 310 km^2

Unit: m^3/s

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average	Maximum	Minimum
1959	18.9	8.6	20.4	40.4	36.9	46.7	29.2	37.8	34.2	48.2	41.7	22.9	386.0	32.2	48.2	8.6
1960	43.6	34.1	31.7	43.5	45.4	49.6	56.2	39.8	33.4	45.3	52.2	55.8	530.8	44.2	56.2	31.7
1961	20.8	9.9	21.3	38.2	27.9	32.3	31.1	25.8	39.0	40.2	64.0	35.7	386.2	32.2	64.0	9.9
1962	21.1	25.6	23.3	27.5	41.6	30.4	28.3	29.2	32.6	45.8	23.7	30.9	360.2	30.0	45.8	21.1
1963	19.8	37.8	16.6	41.1	32.2	37.9	35.5	24.5	18.6	22.9	36.8	22.0	345.6	28.8	41.1	16.6
1964	20.3	17.2	14.8	45.4	30.5	45.4	34.4	31.0	35.4	44.6	26.4	43.9	389.3	32.4	45.4	14.8
1965	42.0	13.1	11.9	13.8	28.9	8.5	11.7	24.8	39.8	48.5	35.9	38.0	316.8	**26.4	48.5	8.5
1966	18.4	27.9	30.2	27.2	52.4	51.2	36.5	40.2	31.8	43.5	51.5	34.6	445.5	37.1	52.4	18.4
1967	32.6	45.7	14.6	36.0	36.7	27.9	45.9	36.7	27.2	42.0	43.5	29.4	418.2	34.8	45.9	14.6
1968	9.1	17.1	24.9	33.8	38.0	35.2	20.4	26.8	25.2	37.3	47.9	19.0	334.7	27.9	47.9	9.1
1969	29.0	17.4	25.4	32.9	37.5	32.7	22.6	45.3	54.3	53.2	17.8	24.4	392.6	32.7	54.3	17.4
1970	27.0	16.9	22.3	36.6	46.4	31.2	27.5	37.5	42.7	45.4	56.8	113.3	501.5	41.8	111.3	16.9
1971	99.8	70.3	85.6	56.8	59.9	83.7	71.2	85.7	77.7	68.6	68.0	44.0	871.3	*72.6	99.8	44.0
1972	37.1	9.0	15.8	30.0	36.4	29.6	14.7	31.8	37.6	33.6	31.4	18.9	325.9	27.2	37.6	9.0
1973	8.1	8.1	24.9	24.2	32.5	39.8	33.2	34.5	44.1	62.3	60.2	45.4	417.6	34.8	62.3	8.1
1974	47.5	34.9	30.6	26.2	30.3	28.0	40.6	34.3	35.4	54.9	47.8	15.7	426.2	35.5	54.9	15.7
1975	29.3	30.5	22.8	26.0	42.1	41.8	37.9	59.6	48.7	53.6	58.3	86.5	536.9	44.7	86.5	22.8
1976	27.9	24.4	20.9	31.4	33.3	43.8	26.9	19.1	21.4	35.2	38.6	32.7	355.5	29.6	43.8	19.1
1977	18.4	18.0	14.0	21.8	51.1	28.5	29.3	34.5	28.3	48.8	40.3	36.2	369.3	30.8	51.1	14.0
1978	20.5	17.0	26.7	66.9	48.7	31.5	26.2	19.7	34.9	46.1	47.6	37.2	423.1	35.3	66.9	17.0
1979	22.8	14.8	16.4	34.9	36.9	45.2	36.2	34.0	36.9	49.6	47.4	42.2	417.2	34.8	49.6	14.8
1980	24.6	27.6	14.9	32.0	38.1	44.1	26.0	28.9	35.3	33.1	33.9	39.5	377.9	31.5	44.1	14.9
Total	638.7	526.0	529.9	766.8	863.7	844.8	721.6	781.5	814.7	1,002.8	971.4	868.2	9,328.3	777.3		
Average	29.0	23.9	24.1	34.9	39.3	38.4	32.8	35.5	37.0	45.6	44.2	39.5	424.0	35.3		
Maximum	99.8	70.3	85.6	66.9	59.9	83.7	71.2	85.7	77.7	68.6	68.0	113.3				
Minimum	8.1	8.1	11.9	13.8	27.9	8.5	11.7	19.1	18.6	22.9	17.8	15.7				

Table 4-4-22 Monthly Run-off at El Once Dam

Catchment Area: 590 km^2

Unit: m^3/s

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average	Maximum	Minimum
1959	56.6	21.3	44.3	99.1	98.9	115.5	60.0	83.7	85.0	119.4	107.9	62.2	954.0	79.5	119.4	21.3
1960	116.5	89.1	85.8	117.0	116.0	116.7	152.4	113.9	90.7	123.1	146.0	142.9	1,410.1	117.5	152.4	85.8
1961	59.9	18.9	53.6	89.1	62.2	73.1	69.3	64.4	92.0	109.1	174.6	99.6	965.8	80.5	174.6	18.9
1962	62.0	59.5	50.2	74.6	98.2	69.5	67.9	60.9	91.1	111.7	64.0	88.7	898.4	74.9	111.7	50.2
1963	54.7	93.0	41.8	94.4	87.7	81.5	82.7	51.4	46.1	62.4	93.2	60.1	849.0	70.7	94.4	41.8
1964	56.2	36.2	37.6	95.7	72.2	104.1	65.9	75.8	76.8	111.6	57.6	115.2	905.0	75.4	115.2	36.2
1965	101.8	35.3	32.4	37.6	78.7	23.2	31.9	53.6	90.9	122.7	82.2	92.5	782.8	65.2	122.7	23.2
1966	44.1	67.4	57.9	55.6	117.1	109.8	69.5	83.3	71.8	103.8	137.8	87.9	1,006.0	83.8	137.8	44.1
1967	76.0	95.5	33.6	84.3	90.0	57.6	80.5	68.8	62.7	86.3	99.9	73.8	908.9	75.7	99.9	33.6
1968	19.7	45.7	47.9	67.4	89.0	81.0	43.3	57.9	55.9	101.7	117.4	42.6	769.5	64.1	117.4	19.7
1969	71.5	44.4	47.4	73.1	96.5	71.4	68.0	115.7	133.8	120.9	43.3	88.2	974.1	81.2	133.8	43.3
1970	84.4	66.9	66.3	104.3	132.0	92.3	70.0	113.8	109.9	111.8	142.9	333.8	1,428.5	119.0	333.8	66.3
1971	290.0	200.1	245.3	156.2	153.2	221.4	207.3	224.7	214.8	191.5	202.4	118.2	2,425.2	202.1	290.0	118.2
1972	105.3	26.5	35.1	73.8	74.9	60.7	36.6	69.1	91.4	73.1	69.1	48.6	764.3	63.7	105.3	26.5
1973	21.7	22.1	62.1	54.3	79.9	104.3	86.9	84.7	110.8	173.0	162.9	122.7	1,085.3	90.4	173.0	21.7
1974	131.4	81.1	82.0	55.9	83.3	64.7	90.4	83.3	86.9	148.0	128.3	47.1	1,082.3	90.2	148.0	47.1
1975	75.7	73.3	55.0	52.8	109.9	102.1	84.6	155.3	108.4	153.8	165.2	194.3	1,330.6	110.9	194.3	52.8
1976	56.9	62.9	41.8	78.0	86.8	105.2	59.9	53.5	71.7	101.3	94.1	98.1	910.3	75.9	105.2	41.8
1977	48.1	52.5	35.6	67.2	172.5	61.5	72.3	80.0	81.0	129.5	92.6	101.7	994.6	82.9	172.5	35.6
1978	53.2	45.2	81.1	160.4	107.4	71.7	59.8	45.5	103.2	131.3	110.4	93.0	1,062.1	88.5	160.4	45.2
1979	50.3	34.0	38.1	102.1	95.4	99.2	71.3	85.2	87.7	121.8	112.5	117.0	1,014.7	84.6	121.8	34.0
1980	54.0	77.0	30.9	106.2	84.5	98.4	60.7	66.5	119.9	89.5	94.1	106.1	987.9	82.3	119.9	30.9
Total	1,690.0	1,348.2	1,306.0	1,899.1	2,186.0	1,985.1	1,691.3	1,891.1	2,082.7	2,597.2	2,498.3	2,334.3	23,509.4	1,959.0		
Average	76.8	61.3	59.4	86.3	99.4	90.2	76.9	86.0	94.7	118.1	113.6	106.1	1,068.6	89.0		
Maximum	290.0	200.1	245.3	160.4	172.5	221.4	207.3	224.7	214.8	191.5	202.4	333.8				
Minimum	19.7	18.9	30.9	37.6	62.2	23.2	31.9	45.5	46.1	62.4	43.3	42.6				

Table 4-4-23 Monthly Run-off at El Dieciocho No. 1 Dam

Catchment Area: 620 km^2

Unit: m^3/s

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average	Maximum	Minimum
1959	60.6	22.6	46.9	105.4	105.5	122.9	63.3	88.6	90.5	127.0	114.9	66.4	1,014.9	84.6	127.0	22.6
1960	124.3	95.0	91.6	124.8	123.6	123.8	162.7	121.9	96.8	131.5	156.1	152.2	1,504.3	125.4	162.7	91.6
1961	64.0	19.9	57.1	94.6	65.9	77.5	73.5	68.5	97.7	116.4	186.4	106.4	1,027.9	85.7	186.4	19.9
1962	66.4	63.2	53.1	79.7	104.2	73.7	72.2	64.3	97.4	118.7	68.3	94.9	956.1	79.7	118.7	53.1
1963	58.4	98.9	44.5	100.1	93.6	86.2	87.8	54.3	49.1	66.7	99.2	64.2	902.9	75.2	100.1	44.5
1964	60.1	38.3	40.1	101.1	76.7	110.4	69.3	80.6	81.3	118.7	61.0	122.8	960.3	80.0	122.8	38.3
1965	108.2	37.7	34.6	40.2	84.1	24.8	34.1	56.7	96.4	130.6	87.1	98.4	832.7	69.4	130.6	24.8
1966	46.9	71.7	60.8	58.6	124.0	116.1	73.1	87.9	76.1	110.2	147.0	93.6	1,066.0	88.8	147.0	46.9
1967	80.6	100.8	35.7	89.5	95.7	60.8	84.2	72.2	66.5	91.0	106.0	78.6	961.5	80.1	106.0	35.7
1968	20.8	48.8	50.4	71.0	94.5	86.0	45.8	61.2	59.2	108.6	124.9	45.1	816.1	68.0	124.9	20.8
1969	76.0	47.3	49.7	77.4	102.8	75.5	72.8	123.2	142.3	128.1	46.0	95.0	1,036.4	86.4	142.3	46.0
1970	90.5	72.3	71.0	111.6	141.2	98.9	74.6	122.0	117.1	118.9	152.1	357.6	1,527.8	127.3	357.6	71.0
1971	310.4	214.0	262.4	166.9	163.2	236.2	221.8	239.6	229.5	204.7	216.8	126.1	2,591.6	216.0	310.4	126.1
1972	112.6	28.4	37.2	78.5	79.0	64.1	38.9	73.1	97.1	77.4	73.2	51.8	811.2	67.6	112.6	28.4
1973	23.1	23.6	66.1	57.5	84.9	111.2	92.7	90.0	118.0	184.8	173.9	131.0	1,156.9	96.4	184.8	23.1
1974	140.4	86.1	87.5	59.0	89.0	68.7	95.8	88.5	92.4	158.0	136.9	50.4	1,152.7	96.1	158.0	50.4
1975	80.6	77.9	58.5	55.7	117.2	108.6	89.6	165.0	114.8	164.5	176.7	205.9	1,415.7	118.0	205.9	55.7
1976	60.0	67.0	44.1	83.0	92.5	111.7	63.5	57.2	77.1	108.4	100.0	105.1	969.7	80.8	111.7	44.1
1977	51.3	56.1	37.9	72.1	185.5	65.1	77.0	84.9	86.7	138.1	98.3	108.7	1,061.6	88.5	185.5	37.9
1978	56.7	48.3	86.9	170.4	113.6	76.0	63.4	48.3	110.5	140.4	117.1	98.9	1,130.6	94.2	170.4	48.3
1979	53.3	36.1	40.5	109.3	101.7	105.0	75.0	90.7	93.1	129.5	119.5	125.0	1,078.7	89.9	129.5	36.1
1980	57.2	82.3	32.7	114.2	89.4	104.2	64.4	70.6	128.9	95.5	100.5	113.2	1,053.2	87.8	128.9	32.7
Total	1,802.6	1,436.3	1,389.1	2,020.5	2,327.7	2,107.3	1,795.1	2,010.0	2,218.6	2,768.1	2,661.9	2,491.6	25,010.8	2,085.9		
Average	81.9	65.3	63.1	91.8	105.8	95.8	81.6	91.4	100.8	125.8	121.0	113.3	1,136.9	94.8		
Maximum	310.4	214.0	262.4	170.4	185.5	236.2	221.8	239.6	229.5	204.7	216.8	357.6				
Minimum	20.8	19.9	32.7	40.2	65.9	24.8	34.1	48.3	49.1	66.7	46.0	45.1				

Table 4-4-24 Monthly Run-off at El Dieciocho No. 2 Power Station

Catchment Area: 720 km^2

Unit: m^3/s

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average	Maximum	Minimum
1959	73.9	27.8	56.4	127.6	128.6	150.3	77.4	107.0	111.9	151.5	136.6	82.4	1,231.3	102.6	151.5	27.8
1960	149.5	115.1	111.3	149.9	150.2	148.0	197.6	150.1	118.8	159.4	188.8	181.5	1,820.2	151.7	197.6	111.3
1961	81.2	25.4	71.0	115.6	82.1	95.8	91.0	87.3	116.6	140.2	223.7	129.8	1,259.7	105.0	223.7	25.4
1962	80.7	73.7	62.1	93.8	121.2	85.6	89.2	79.2	118.4	140.5	84.2	115.5	1,144.3	95.4	140.5	62.1
1963	69.5	115.3	53.6	116.4	110.6	102.3	103.1	63.7	60.4	79.2	118.9	80.9	1,073.9	89.5	118.9	53.6
1964	72.7	47.3	47.8	119.6	93.2	134.3	83.6	102.0	100.2	141.9	74.7	147.9	1,165.1	97.1	147.9	47.3
1965	132.2	48.4	43.2	50.0	102.9	34.9	44.2	72.2	116.0	154.8	104.4	117.5	1,020.6	85.1	154.8	34.9
1966	59.2	87.9	71.1	70.8	147.5	137.4	89.2	104.8	92.4	130.1	176.4	115.2	1,282.0	106.8	176.4	59.2
1967	97.3	120.9	43.7	108.1	115.7	74.4	98.5	89.0	83.0	111.1	130.1	97.5	1,169.2	97.4	130.1	43.7
1968	25.2	61.7	62.8	84.3	114.2	103.2	57.9	76.4	72.3	131.9	148.4	57.3	995.8	83.0	148.4	25.2
1969	96.1	57.3	59.8	95.2	125.4	91.2	89.3	150.3	172.0	151.6	57.1	118.9	1,264.0	105.3	172.0	57.1
1970	110.7	91.2	88.8	136.9	172.6	120.9	90.6	146.2	140.8	144.0	181.4	427.3	1,851.2	154.3	427.3	88.8
1971	371.8	257.5	312.8	203.1	194.0	282.4	269.0	284.5	274.6	245.2	260.6	151.1	3,106.5	258.9	371.8	151.1
1972	136.6	37.1	43.5	92.7	94.8	78.9	47.1	87.3	119.3	93.0	90.8	63.7	984.8	82.1	136.6	37.1
1973	29.2	28.2	83.2	72.5	106.7	135.3	113.7	109.6	141.5	220.8	209.1	156.9	1,406.6	117.2	220.8	28.2
1974	167.4	102.9	104.8	70.6	106.3	83.1	116.2	106.3	112.0	194.9	164.2	63.5	1,392.3	116.0	194.9	63.5
1975	96.4	94.1	70.4	66.7	142.7	132.7	108.2	203.6	140.0	200.9	214.9	242.3	1,712.9	142.7	242.3	66.7
1976	72.1	81.1	52.0	100.3	113.5	135.8	77.7	73.3	96.3	132.4	121.6	128.3	1,184.4	98.7	135.8	52.0
1977	62.2	71.0	47.1	88.9	224.4	79.7	94.7	103.3	102.4	166.3	117.3	131.7	1,289.0	107.4	224.4	47.1
1978	67.3	58.6	104.6	203.3	136.2	96.6	80.0	60.7	135.2	170.9	140.7	122.4	1,376.5	114.7	203.3	58.6
1979	63.8	45.8	50.9	131.6	122.8	126.0	90.4	110.2	112.4	156.6	138.7	149.7	1,299.1	108.3	156.6	45.8
1980	70.7	99.4	40.8	138.8	108.5	128.7	81.2	88.5	162.7	120.1	129.3	137.2	1,306.0	108.8	162.7	16.0
Total	2,185.6	1,747.7	1,681.6	2,436.6	2,814.2	2,557.7	2,189.7	2,455.5	2,699.3	3,337.4	3,211.8	3,018.3	30,335.4	2,528.0		
Average	99.3	79.4	76.4	110.8	127.9	116.3	99.5	111.6	122.7	151.7	146.0	137.2	1,378.9	114.9		
Maximum	371.3	257.5	312.8	203.3	224.4	282.4	269.0	284.5	274.6	245.2	260.6	427.3				
Minimum	25.2	25.4	40.8	50.0	82.1	34.9	44.2	60.7	60.4	79.2	57.1	57.3				

Table 4-4-25 Monthly Run-off at El Lloro Dam

Catchment Area: 1,600 km^2

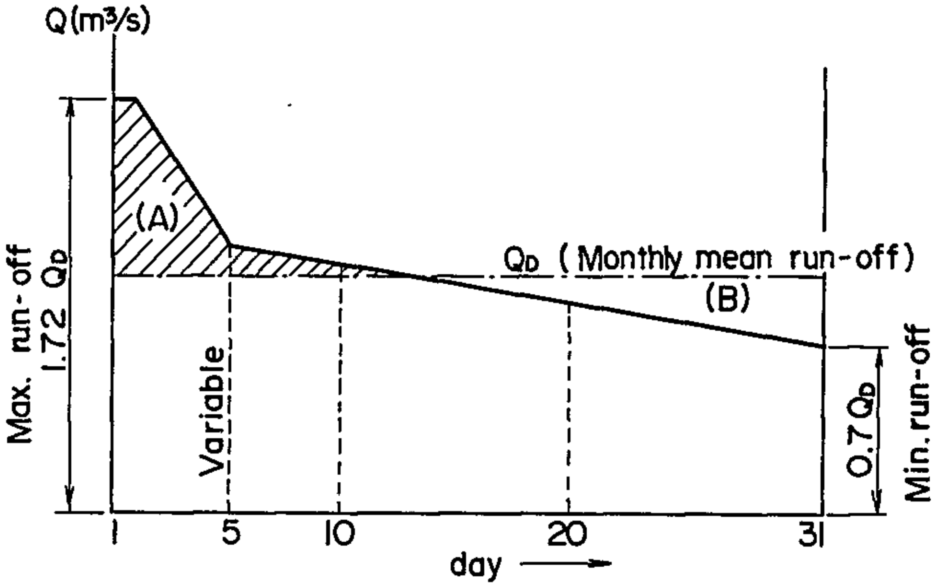
Unit: m^3/s

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Average	Maximum	Minimum
1959	177.2	76.4	145.3	318.5	323.1	406.1	231.2	278.7	327.7	330.7	279.4	234.7	3,129.0	260.8	406.1	76.4
1960	335.4	279.2	273.4	330.8	380.7	340.8	481.5	395.9	314.8	382.3	436.9	385.3	4,337.1	361.4	481.5	273.4
1961	260.5	102.2	212.5	320.2	264.3	293.1	282.4	305.8	265.9	316.0	486.9	322.6	3,432.5	286.0	486.9	102.2
1962	189.5	135.8	123.9	167.1	211.3	151.9	263.5	245.9	286.9	286.8	232.0	277.7	2,572.2	214.4	286.9	123.9
1963	166.7	281.2	178.3	265.5	277.6	260.7	238.0	201.4	210.4	178.8	289.8	241.8	2,790.2	232.5	289.8	166.7
1964	193.4	134.7	140.4	289.5	260.2	365.7	283.0	323.7	305.6	320.0	217.8	326.9	3,160.8	263.4	365.7	134.7
1965	351.7	178.5	143.6	177.2	271.8	193.2	168.1	258.5	303.7	348.5	314.0	273.5	2,982.2	248.5	351.7	143.6
1966	204.9	241.8	166.3	191.5	342.0	319.8	282.4	262.4	264.7	313.0	387.8	292.3	3,268.9	272.4	387.8	166.3
1967	257.1	281.4	111.8	267.2	335.5	296.0	252.8	270.0	260.6	333.3	347.2	300.2	3,313.1	276.1	347.2	111.8
1968	87.6	180.3	179.7	237.2	300.2	264.1	222.1	284.3	236.0	355.2	348.0	223.3	2,918.1	243.2	355.2	87.6
1969	280.2	171.9	160.9	289.4	342.1	273.0	257.5	438.3	416.6	329.5	184.9	361.0	3,505.3	292.1	438.3	160.9
1970	272.2	247.4	246.3	377.7	439.3	297.1	250.1	366.3	342.1	389.2	398.3	844.0	4,470.1	372.5	844.0	246.3
1971	769.4	539.8	682.7	487.3	436.8	605.9	603.0	610.1	578.1	532.6	559.2	350.8	6,755.7	563.0	769.4	350.8
1972	340.9	138.2	116.4	202.1	261.3	232.0	146.0	259.8	324.3	255.8	265.4	168.3	2,710.5	225.9	340.9	116.4
1973	104.7	65.5	241.3	216.5	291.8	341.6	288.4	314.0	347.2	493.8	514.7	374.4	3,593.7	299.5	514.7	65.5
1974	318.0	217.5	242.6	192.6	227.2	265.7	332.9	311.6	323.6	480.6	397.9	187.9	3,498.2	291.5	480.6	187.9
1975	234.8	213.3	162.8	176.8	368.2	358.0	301.9	526.4	357.5	504.9	502.5	515.2	4,222.3	351.9	526.4	162.8
1976	218.6	210.4	133.4	265.5	271.8	328.1	219.3	259.6	255.7	322.7	303.5	281.1	3,069.8	255.8	328.1	133.4
1977	146.4	202.5	136.0	229.1	498.5	220.4	301.1	296.3	264.9	402.0	309.4	282.7	3,289.2	274.1	498.5	136.0
1978	150.9	150.3	236.8	452.0	328.8	352.6	246.6	213.7	338.5	396.1	307.6	314.2	3,488.0	290.7	452.0	150.3
1979	160.9	140.7	173.4	301.8	323.0	294.9	264.0	329.0	305.7	378.7	262.5	314.3	3,249.0	270.8	378.7	140.7
1980	208.8	227.1	151.9	320.7	289.4	350.1	200.5	246.6	459.9	317.7	339.5	327.2	3,439.3	286.6	459.9	151.9
Total	5,429.7	4,416.2	4,359.7	6,076.2	7,045.0	6,810.7	6,116.4	6,998.3	7,090.4	7,967.9	7,685.1	7,199.4	77,195.2	6,433.1		
Average	246.8	200.7	198.2	276.2	320.2	309.6	278.0	318.1	322.3	362.2	349.3	327.2	3,508.9	292.4		
Maximum	769.4	539.8	682.7	487.3	498.5	605.9	603.0	610.1	578.1	532.6	559.2	844.0				
Minimum	87.6	65.5	111.8	167.1	211.3	151.9	146.0	201.4	210.4	178.8	184.9	168.3				

4.4.3.4 Available Discharge for Each Project

Available discharge for each project (which average available discharge) and average available discharge for lowest five days in a month were estimated applying the model of monthly run-off duration. This monthly run-off duration model was prepared judging that a single model would be sufficiently representative upon analysing the measured run-off at the existing gaging stations of Puente de Sanchez and Tagachi.

Fig.4-4-7 MONTHLY DURATION CURVE'S MODEL



Note) Since the number of days in a month varies among 28-31 days the 5th-day run-off is obtained for individual months so that the areas of (A) and (B) is equal.

4.4.4 Design Flood Discharge of Each Project Site

Flood flow observations have not been made as yet on the upstream Rio Atrato. Consequently, there are only the daily maximum rainfalls (R_{24}) at the each precipitation station as data for estimating flood. The precipitation observatories which can be used for that purpose are the four of Carmen de Atrato, El Piñon, Tutunendo and La Vuelta.

It was decided to apply the Rational Formula normally used for computation of flood discharge.

The Rational Formula is as follows:

$$Q = \frac{1}{3.6} \times f \times R_{td} \times A$$

where,

R_{ta} (rainfall intensity) = $\frac{R_{24}}{24} \times (\frac{24}{T_a})^{2/3}$ (mm/hour)

T_a (flood concentration time) = $\frac{L}{20 \times (\frac{H}{L})^{0.6}}$ (hour)

f: Run-off coefficient = 1.0

A: Catchment area (km^2)

H: Difference of elevation (m)

L: River channel length (m)

For computation of return periods and daily maximum rainfalls (R_{24}), the weights influencing the basins of the various each site and the applicable precipitation stations were assumed as shown in Table 4-4-27, the daily maximum rainfalls by year were obtained applying the equations below, and the return periods and daily maximum rainfalls were calculated by the Gumbel Method. The results are as shown in Table 4-4-27.

R_{24} (El Siete No. 1) = $0.82R_1 + 0.18R_2$

R_{24} (El Siete No. 2) = $0.63R_1 + 0.37R_2$

R_{24} (El Once) = $0.32R_1 + 0.67R_2$

R_{24} (El Dieciocho No. 1) = $(0.33R_1 + 0.67R_2) \times \frac{620 \text{ km}^2}{590}$

R_{24} (Rio Playa) = $0.80R_2 + 0.20R_3$

R_{24} (El Lloro) = $0.12R_1 + 0.54R_2 + 0.12R_3 + 0.22R_4$

where,

R_1: Daily precipitation at Carmen de Atrato Station (mm)

R_2: Daily precipitation at El Piñon Station (mm)

R_3: Daily precipitation at Tutunendo Station (mm)

R_4: Daily precipitation at La Vuelta Station (mm)

Table 4-4-26 Weight Coefficient of Precipitation at Each Project Site

Project Site \ Station	EL CARMEN	EL PIÑON	TUTU-NENDO	LA VUETRA	Total
EL SIETE NO. 1 dam	0.82	0.18	—	—	1.00
EL SIETE NO. 2 intake dam	0.63	0.37	—	—	1.00
EL ONCE dam	0.33	0.67	—	—	1.00
EL DIECIOCHO NO. 1 dam	0.32	0.68	—	—	1.00
RIO PLAYA dam	—	0.80	0.20	—	1.00
EL LLORO dam	0.12	0.54	0.12	0.22	1.00

Table 4-4-27 Estimated Maximum Daily Precipitation at Each Project Site

Unit: mm

Project / Year	EL SIETE NO. 1 DAM SITE	EL SIETE NO. 2 INTAKE DAM SITE	EL ONCE DAM SITE	EL DIECIOCHO NO. 1 DAM SITE	RIO PLAYA DAM SITE	EL LLORO DAM SITE
1959	45.28	53.66	89.78	91.12	—	—
1960	78.88	114.88	182.08	184.32	—	—
1961	52.48	70.38	122.58	124.32	—	—
1962	66.32	70.30	127.30	129.20	—	—
1963	65.58	71.47	103.17	104.68	—	—
1964	54.80	58.64	93.74	94.96	—	—
1965	117.92	126.28	139.48	139.92	—	—
1966	84.66	91.69	102.79	103.16	—	—
1967	74.94	62.21	69.79	70.16	90.00	89.78
1968	97.84	95.56	91.96	91.84	105.60	102.42
1969	61.26	63.46	85.35	86.40	110.80	85.10
1970	57.82	101.79	181.89	184.56	216.00	150.16
1971	68.02	122.93	209.63	212.52	256.00	178.00
1972	49.18	58.87	74.17	74.68	101.20	68.86
1973	51.78	65.27	104.16	105.64	128.40	92.76
1974	59.82	69.34	102.16	103.64	132.80	102.74
1975	58.62	79.33	112.03	113.12	146.40	111.54
1976	69.82	79.13	100.67	101.68	113.00	90.84
1977	55.72	70.70	109.45	110.80	127.40	97.86
1978	66.78	89.77	129.31	131.24	160.80	111.84
1979	68.70	70.16	97.77	99.08	126.80	93.34
1980	66.00	79.40	116.54	118.16	136.00	103.80

The results in obtaining return period flood discharges for the each project sites by the Rational Formula using the data above are as shown in Table 4-4-28.

Table 4-4-28 Estimated Flood Discharge in Rio Atrato Project

Project Sites	Return Period (years)	Catchment Area (km^2)	Difference of elevation H (m)	River Length L (m)	Maximum Daily Rainfall R_{24} (mm/day)	Intensity of Rainfall R_{Ta} (mm/hr)	Flood Concentration Time Ta (hr)	Flood Discharge at Project Site Qf (m^3/s)	Specific Flood Discharge per km^2 q (m^3/s)	Adopted Flood Discharge for Project Q (m^3/s)	Remarks
El Siete No.1 dam site	100 200 500 1,000 10,000	240	580	19,000	128.28 138.69 152.43 162.81 197.59	26.78 28.95 31.82 33.99 44.62	2.14	1,786 1,930 2,122 2,266 2,975	7.4 8,0 8.8 9.4 12.4	1,800 for concrete gravity dam	Adopted formula is as shown follows: $Ta = \frac{L}{20(\frac{H}{L})^{0.6}}$ $R_{Ta} = \frac{R_{24}}{24}(\frac{24}{Ta})^{\frac{2}{3}}$
El Siete No.2 intake dam site	100 200 500 1,000 10,000	310	1,030	26,000	157.00 170.02 187.20 200.19 243.11	29.47 31.91 35.14 37.58 45.63	2.51	2,538 2,748 3,026 3,236 3,929	8.2 8.9 9.8 10.4 12.7	2,600 for concrete gravity dam	$Qf = \frac{1}{3.6} \cdot f \cdot R_{Ta} \cdot A$ where, Ta : Flood concentration time (hr.)
El ONCE dam site	100 200 500 1,000 10,000	590	Rio Atrato 1,380 Rio Grande 380	 36,000 25,000	246.03 268.14 297.30 319.35 392.73	34.37 37.46 41.53 44.61 54.86	3.54 4.28 mean 3.91	5,633 6,139 6,806 7,311 8,991	9.5 10.4 11.5 12.4 15.2	9,000 for rockfill dam	L : River length (m) H : Difference of elevation (m) R_{24}: Max. daily rainfall (mm/day)
El Dieciocho No.1 dam site	100 200 500 1,000 10,000	620	-	-				5,919 6,451 7,152 7,683 9,447	9.5 10.4 11.5 12.4 15.2	6,000 for concrete gravity dam	R_{Ta}: Intensity of rainfall (mm/hr.) f : Coefficient of discharge A : Catchment area (km^2) Qf : Flood discharge (m^3/sec.)
Rio Playa dam site	100 200 500 1,000 10,000	100	940	21,000	316.14 345.87 385.10 414.74 512.81	71.95 78.72 87.65 94.39 116.71	1.88	1,999 2,186 2,435 2,622 3,242	20.0 21.9 24.4 26.2 32.4	3,300 for rockfill dam	Rio Atrato (1) To Rio Playa confluence L'_1=56,000m, H'_1=1,725m, Ta'_1=6.28hr, L'_2=27,500m, H'_2=1,025m, Ta'_2=2.75hr Ta'_1=(Ta'_1+Ta'_2)/2=4.52hr
El Lloro dam site	100 200 500 1,000 10,000	1,600	1,960	85,000	212.87 230.90 254.70 272.68 332.16	15.05 16.32 18.00 19.28 23.48	10.86	6,689 7,254 8,000 8,569 10,436	4.2 4.5 5.0 5.4 6.5	10,500 for rockfill dam	(2) From Rio Playa confluence to El Lloro L'_3=29,000m, H'_3=235m, Ta'_3=7.24hr Ta_A=Ta'_1+Ta'_3=11.76hr Rio Capa L'_4=60,000m, H'_4=960m, Tac=9.96hr Ta=(Ta_A+Tac)/2=10.86hr

As design flood discharges of the each project site, 100-year return period flood discharges were used for concrete gravity dams and probable maximum floods (10,000-year return period) for rockfill dams. As a result, the various design flood discharges are as shown in Table 4-4-29.

Table 4-4-29 Design Flood Discharge at Each Project Site

Project site	Design flood discharge (m^3/sec.)	Return period (Year)
EL SIETE NO. 1 dam	1,800	100
EL SIETE NO. 2 intake dam	2,600	100
EL ONCE dam	9,000	10,000
EL DIECLOCHO NO. 1 dam	6,000	100
RIO PLAYA dam	3,300	10,000
EL LLORO dam	10,500	10,000

Comparisons of these values were made with existing dams and other projected sites in Colombia. The results are shown in Table 4-4-30.

Table 4-4-30 Compared Design Flood Discharge between Rio ATRATO PROJECT and Other Project in Colombia

Project	Catchment area (km²)	Design flood discharge (m³/sec.)	Specific flood discharge (m³/sec./km²)	Dam type
ALTO ANCHICAYA	550	4,600	8.36	R.F
BAJO ANCHICAYA	750	5,000	6.67	C.G
CALIMA	315	441	1.40	—
SALVAJINA				R.F
SAN JUAN	15,000	5,700	0.38	R.F
SOGAMOSO	122,500	12,680	0.56	R.F
CAÑA FISTO	34,335	13,700	0.40	R.F
EL SIETE NO. 1	240	1,800	7.50	C.G
EL SIETE NO. 2	310	2,600	8.39	C.G
EL ONCE	590	9,000	15.25	R.F
EL DIECIOCHO NO. 1	620	6,000	9.68	C.G
RIO PLAYA	100	3,300	33.00	R.F
EL LLORO	1,600	10,500	6.56	R.F

Note) R.F: Rockfill
C.G: Concrete gravity

According to the above table, the existing sites with similar meteorological conditions are the two of Alto Anchicaya and Bajo Anchicaya. And seen from precipitation conditions, the design flood discharges estimated here for the each Atrato project site are slightly on the high side but are judged to be reasonable values, and it was decided to use them in the current project study.

4.5 Examination of Development Schemes

4.5.1 Concepts of Development Schemes

The upstream part of the Rio Atrato possesses an undeveloped head of 1,415 m from the intake level of EL. 1,460 m at EL Siete No. 1 project to the tail water level of EL. 45 m at EL Lloro project. The following matters were clarified as a result of recent field reconnaissances regarding topography, river gradients and geology within this stretch:

1) In original development scheme in which the head of 760 m from the intake level of 1,460 m at El Siete to high water level of 700 m at El Once reservoir developed in one step by a headrace tunnel of 8 km had been adopted. But this time, it was clearly determined that there is no mountain mass, on the left bank of the Rio Atrato through which water could be conducted in one step by the headrace tunnel from an intake level of 1,460 m as in the abovementioned plan after judging based upon data obtained from observations of topography in the field, checks of the topography through rough surveying, and mapping of aerial photographs. As a result, it was concluded unavoidable for the El Siete project to be developed dividing the head into two steps.
   If it were to be insisted on El Siete being utilized for power generation developed in one step, it will be necessary for water to be conducted by a headrace tunnel of approximately 19 km going along the right bank of the Rio Atrato and making a wide detour of the Rio Girordot to reach the powerhouse site of El Siete No. 2 (the present project). The length of the headrace tunnel in this case would be extremely great, and it was judged to be clearly uneconomical even if it were possible to obtain a total head of 750 m.

   Consequently, as described in 3.2.2 and 3.2.3, the original El Siete project is to have its head divided into two steps, with the El Siete No. 1 project, the first step, to have its intake level at 1,460 m and its tail water level at 970 m for development of a gross head of 490 m. El Siete No. 2, the second step, would be developed with its intake level at 970 m and tail water level at 710 m for a gross head of 260 m.

   The merits of such a division of head are that headrace tunnel length can be shortened, and that El Siete No. 2 project can add the run-off (average available) of 12.4 m^3/sec. from the remaining catchment area of 70 km^2, and utilize it for power generation.

Further, whereas with the original plan it would have been unavoidable for an underground powerhouse to be provided with tailrace to the reservoir of El Once Project by means of a tunnel, the powerhouses of El Siete No. 1 and No. 2 Project both can be planned to be ground surface types. It was judged that the development in two steps was more economical than the development in one step. As a result of study, whether El Siete No. 1 Project should be a daily regulation type or a run-of-river type, although it was considered that the potential could be amply utilized by a run-of-river type since the river flow conditions are extremely good, a daily regulation type would provide with a dam height of 55 m, the reservoir would be able to serve as a sedimentation basin, while the kW-value of power generation could be enhanced, and so it was judged that this development scheme should be adopted. This regulating capacity would be effective not only for El Siete No. 1 Project, but also El Siete No. 2 Project. Further, with the proposal for dividing the head into two steps, it would be possible for both powerhouses to be provided along an existing road so that new construction of access roads would be made unnecessary, while still further, since an existing 115-kV transmission line passes very closely by the suggested sites of the powerhouses, obtaining electricity supplements for construction would be extremely uncomplicated. Also, both powerhouse sites have plain spaces close by making it easy for temporary facilities for construction work to be provided, and it was judged that this would help to decrease the cost of construction.

This will make it possible for the preparation period for the work to be shortened, and since accessibilities of the sites are good, these two projects can be developed at the earliest stage among the sites on the upstream part of the Rio Atrato.

2) With regard to the El Once Project site, at present it is inconceivable for it to be developed as other than a dam type. Seen from the aspects both of topography and geology, the high water level of El Once dam will be limited at a EL. 700 m. Therefore, it was planned this time to be developed as a same scheme as the original plan.

3) The original plan regarding the El Dieciocho Project was for intake at a level of EL. 575 m at the same damsite as in the present plan, the conduction of water by a headrace tunnel to El Dieciocho Village (confluence of Rio Atrato mainstream and tributary Rio Playa) to a tail water level of 285 m for a total head of 290 m to be utilized for power generation. However, as the result of a check of the topographical condition made by rough surveying, the mountain mass to accommodate the route of the headrace tunnel terminates in the vicinity of El Quince to form a saddle of elevation approximately 480 m, while further, at the mountain mass from El Quince to El Dieciocho Village there would not be sufficient covering of the natural ground for a tunnel conducting the water at high water level of 575 m. It was therefore judged that the original plan would not be feasible since the height of the mountain mass is low, while there is a low saddle along the tunnel route. Furthermore, with regard to utilization of the tributary Rio Playa, the length of the waterway would become great since the site of intake at a level of EL. 575 m would be a considerable distance upstream while the catchment area would become smaller, so that the feasibility would be diminished. Consequently, it was concluded that it would not be possible for the project to be contemplated based on the original plan.

This time, 1/25,000 topographical maps were prepared based on the results of radar imagery and rough field surveying. On examination of the topographical maps, it was judged unavoidable for the head according to the original plan to be divided into two steps for development with the first step having its intake water level at EL. 575 m and tail water level at EL. 400 m for a gross head of 175 m, and the second step having its intake water level at EL. 400 m making it possible for the run-off (average available) of 19.6 m^3/sec. of the Rio Playa to be utilized, with outlet at EL. 250 m conducting water by a tailrace to Bellavista. The gross head of the second step would be 150 m.

Regarding this second step, the site of outlet in the original plan was at EL. 285 m at El Dieciocho Village, but if it were to be planned there, the gross head would be 115 m to impair the economy of scale, and a problem about the economics would arise. In contrast, site of outlet at EL. 250 m at the Bellavista would be possible with an extension of the tailrace tunnel of 1.9 km, and in the new scheme it is planned to utilize the head down to Bellavista. Through this measure, an increase in output of 56 MW over the case of site of outlet at El Dieciocho Village can be expected with the second step, the El Dieciocho No. 2 project.

Because of the above, the Bellavista project in the original plan is to be cancelled. The Bellavista project in the original plan was economically problematic, while even with a 3.3 km of headrace tunnel only a total head of 30 m would have been obtained. Therefore, in the present plan, it was judged that a plan as previously described of providing a tailrace tunnel in the El Dieciocho No. 2 project and utilizing the head is judged to be more economical.

4) The El Lloro project, seen from topography, geology and condition of the river, cannot be considered to be other than a dam type. The old plan was also for development as a dam type, and the new planning was done following that original plan. The problem in case of the El Lloro site is the high water level of reservoir, and seen from the topography and geology, it will not be possible to make it higher than EL. 75 m. Meanwhile, the tail water level is at EL. 45 m so that this is a low-head of only 30 m.

With this kind of development site the cost of care of river during construction will generally be high, so that there will be a tendency for the economics of the entire project to be impaired. This project site is no exception, and it will be necessary for a construction method capable of handling flood of 3,300 m^3/sec. during the construction to be applied, while a result impairing the economics will be produced.

Considering the above points, the development scheme for the upstream Rio Atrato will consist of the following sites El Siete No. 1, 160 MW; El Siete No. 2, 124 MW; El Once, 176 MW; El Dieciocho No. 1, 252 MW, El Dieciocho No. 2, 261 MW; and El Lloro, 147 MW, a total of 1,120 MW from the upstream.

Of these, the projects which are estimated to be economically feasible are El Siete No. 1, El Siete No. 2, El Dieciocho No. 1, and El Dieciocho

No. 2, with the total output being 797 MW.

Of the above, the project sites for which it was possible to improve the accuracies of studies even the slightest degree as a result of the recent investigations were the four of El Siete No. 1, El Siete No. 2, El Once and El Lloro. For these sites simple mapping was done utilizing aerial photographs taken in 1962, whereas the El Dieciocho No. 1 and El Dieciocho No. 2 sites were not covered by existing aerial photographs and the topographic maps made by radar imagery so that the accuracies were inferior.

However, the present study of the master plan can adequately withstand scrutiny concerning the priorities of above six projects and selection of project site which is to be subjected to feasibility study.

4.5.2 Energy Production

According to the results of run-off analyses of the each project made in 4.4, the run-off conditions of discharge for power generation are as shown in Table 4-5-1.

Table 4-5-1 Power Discharge at Each Project

Unit: m^3/s

Items \ Project sites	El Siete NO. 1	El Siete NO. 2	El Once	El Dieciocho NO. 1	El Dieciocho NO. 2	El Lloro
1. Maximum available discharge	40	60	170	180	220	600
2. Average available discharge	21.3	33.7	85.2	90.6	110.2	287.1
3. *	16.0	25.6	64.5	68.5	83.2	213.3
4. Output factor (2/1) %	53.3	56.2	50.1	50.3	50.1	47.9

*: Average available discharge for lowest five days in a month.

The annual energy production (kWh) can be computed by 9.8 x [efficiency of turbine (η_t)] x [efficiency of generator (η_g)] x [average available discharge (m^3/sec.)] x [effective head (m)] x 8,760 (hour). The combined efficiency (9.8 x η_t x η_g) is taken to be 8.4. In this calculation formula, the results of the annual energy productions obtained for the each project are as shown in Table 4-5-2.

Table 4-5-2 Annual Energy Production at Each Projects

Item \ Project	El Site NO. 1	El Siete NO. 2	El Once	El Dieciocho NO. 1	El Dieciocho NO. 2	El Lloro	Total
Annual energy production (GWh)	735	608	753	1,091	1,115	592	4,894
Annual average output (MW)	83.9	69.4	85.9	124.6	127.3	67.5	558.7
Annual plant factor (%)	52.4	56.0	48.8	49.4	48.8	45.9	49.9

The total amounts of the annual energy productions for the above six projects is 4,894 GWh/year, the average output of which is 558.7 MW. The plant factor is 49.9%.

As for the four sites of El Siete No. 1, El Siete No. 2, El Dieciocho No. 1 and El Dieciocho No. 2, in effect, the project sites providing good economy, the total annual energy production was 3,549 GWh/year.

The monthly energy productions obtained for the above project sites are as shown in Table 4-5-3 to Table 4-5-8.

According to these tables, it is shown that at the project sites in the upstream Rio Atrato, dry months are December, January and February and wet months July, August and September.

Whereas many of the existing hydroelectric power stations and the hydroelectric power stations expected to be completed by 1988 have the characteristic of being in the dry season in July - September, this means that the project sites along the Rio Atrato are conversely in the wet season, indicating that the power stations in upstream Rio Atrato are necessary to stabilize the energy supply throughout the year by the hydroelectric power.

At El Siete No. 1 the average, available discharge for lowest five days in a month is 10.7 m^3/sec. in February. However, it is possible for El Siete No. 1 Power Station to secure a peak operation of 6.4 hour/day, and by utilization as a peaking power station even in a dry month the electric power facilities can be used in full. The same can be said for El Siete No. 2 Power Station down to El Lloro Power Station.

Consequently, the electric energy of 4,894 GWh/year which can be produced at the Upstream Rio Atrato is effective electric energy which can all be sold in the market without becoming secondary power.

Table 4-5-3 Energy Production at El Siete No. 1 Project

Month	Average available discharge (m^3/s)	Effective head (m)	Average power output (MW)	Energy production (GWH)	Maximum power output (MW)	Plant factor (%)	* Dis-charge (m^3/sec)	** Out-put (MW)
Jan.	16.5	472	65.0	48.4	160	40.6	12.5	49.2
Feb.	14.5	472	57.1	38.4	160	35.7	10.7	42.2
Mar.	14.9	472	58.7	43.7	160	36.7	11.2	44.1
Apr.	21.5	472	84.7	61.0	160	52.9	16.1	63.4
May	23.9	472	94.2	70.1	160	58.9	17.7	69.7
June	24.6	472	96.9	69.8	160	60.6	18.6	73.3
July	21.4	472	84.3	62.7	160	52.7	15.9	62.6
Aug.	22.2	472	87.5	65.1	160	54.7	16.8	66.2
Sept.	22.1	472	87.1	62.7	160	54.4	16.6	65.4
Oct.	26.7	472	105.2	78.3	160	65.8	20.1	79.2
Nov.	26.1	472	102.8	74.0	160	64.3	19.6	77.2
Dec.	20.7	472	81.5	60.6	160	50.9	16.4	64.6
Total	21.3	472	83.9	735.0	160	52.4	16.0	63.0

* Average available discharge for lowest five days in a month (m^3/s)

** Average available hydropower for lowest five days in a month (MW)

Table 4-5-4 Energy Production at El Siete No. 2 Project

Month	Average available discharge (m^3/s)	Effective head (m)	Average power output (MW)	Energy production (GWH)	Maximum power output (MW)	Plant factor (%)	* Dis-charge (m^3/sec)	** Out-put (MW)
Jan.	27.1	245	55.8	41.5	124	45.0	20.7	42.6
Feb.	23.5	245	48.4	32.5	124	39.0	17.6	36.2
Mar.	22.9	245	47.1	35.0	124	38.0	17.5	36.1
Apr.	34.0	245	70.0	50.4	124	56.5	25.5	52.5
May	38.4	245	79.0	58.8	124	63.7	28.7	59.1
June	36.7	245	75.5	54.4	124	60.9	28.1	57.8
July	31.9	245	65.7	48.9	124	53.0	24.0	49.4
Aug.	34.0	245	70.0	52.1	124	56.5	25.9	53.3
Sept.	35.8	245	73.7	53.1	124	59.4	27.1	55.8
Oct.	43.6	245	89.7	66.7	124	77.3	33.4	68.7
Nov.	42.0	245	86.4	62.2	124	69.7	32.4	66.7
Dec.	34.4	245	70.8	52.7	124	57.1	26.9	55.4
Total	33.7	245	69.4	607.9	124	56.0	25.6	52.7

* Average available discharge for lowest five days in a month (m^3/s)

** Average available hydropower for lowest five days in a month (MW)

Table 4-5-5 Energy Production at El Once Project

Month	Average available discharge (m^3/s)	Effective head (m)	Average power output (MW)	Energy production (GWH)	Maximum power output (MW)	Plant factor (%)	* Dis-charge (m^3/sec)	** Out-put (MW)
Jan.	71.0	122	71.6	53.2	176	40.7	54.4	54.8
Feb.	60.2	122	60.7	40.8	176	34.5	45.0	45.4
Mar.	55.9	122	56.3	41.9	176	32.0	43.1	43.4
Apr.	85.1	122	85.8	61.8	176	48.7	63.3	63.8
May	97.7	122	98.5	73.3	176	56.0	72.7	73.3
June	87.5	122	88.2	63.5	176	50.1	66.1	66.6
July	74.6	122	75.2	55.9	176	42.7	56.3	56.8
Aug.	82.7	122	83.4	62.0	176	47.4	62.8	63.3
Sept.	92.0	122	92.7	66.8	176	52.7	69.4	70.0
Oct.	113.9	122	114.8	85.4	176	65.2	86.4	87.1
Nov.	108.4	122	109.3	78.7	176	62.1	83.2	83.9
Dec.	92.4	122	93.1	69.3	176	52.9	71.3	71.9
Total	85.2	122	85.9	752.6	176	48.8	64.5	65.0

* Average available discharge for lowest five days in a month (m^3/s)

** Average available hydropower for lowest five days in a month (MW)

Table 4-5-6 Energy Production at El Dieciocho No. 1 Project

Month	Average available discharge (m^3/s)	Effective head (m)	Average power output (MW)	Energy production (GWH)	Maximum power output (MW)	Plant factor (%)	* Dis-charge (m^3/sec)	** Out-put (MW)
Jan.	75.7	165	104.0	77.4	252	41.3	57.8	79.4
Feb.	64.1	165	88.0	59.2	252	34.9	47.9	65.8
Mar.	59.4	165	81.6	60.7	252	32.4	45.9	63.0
Apr.	90.6	165	124.4	89.6	252	49.4	67.3	92.4
May	104.0	165	142.8	106.3	252	56.7	77.4	106.3
June	92.9	165	127.6	91.9	252	50.0	70.2	96.4
July	79.1	165	108.6	80.8	252	43.1	59.7	82.0
Aug.	87.9	165	120.7	89.8	252	47.9	66.9	91.9
Sept.	98.0	165	134.6	96.9	252	53.4	73.9	101.5
Oct.	121.3	165	166.6	123.9	252	66.1	92.1	126.5
Nov.	115.5	165	158.6	114.2	252	62.9	88.7	121.8
Dec.	98.5	165	135.3	100.6	252	53.7	76.0	104.4
Total	90.7	165	124.6	1,091.2	252	49.4	68.6	94.2

* Average available discharge for lowest five days in a month (m^3/s)

** Average available hydropower for lowest five days in a month (MW)

Table 4-5-7 Energy Production at El Dieciocho No. 2 Project

Month	Average available discharge (m^3/s)	Effective head (m)	Average power output (MW)	Energy production (GWH)	Maximum power output (MW)	Plant factor (%)	* Dis-charge (m^3/sec)	** Out-put (MW)
Jan.	92.1	140	106.3	79.1	261	40.7	70.3	81.2
Feb.	78.2	140	90.3	60.7	261	34.6	58.3	67.3
Mar.	72.2	140	83.3	62.0	261	31.9	55.6	64.2
Apr.	109.3	140	126.2	90.9	261	48.4	81.2	93.8
May	125.8	140	145.3	108.1	261	55.7	93.6	108.1
June	113.0	140	130.6	94.0	261	50.0	85.2	98.4
July	96.6	140	111.6	83.0	261	42.8	72.8	84.1
Aug.	107.7	140	124.3	92.5	261	47.6	81.7	94.4
Sept.	119.4	140	137.9	99.3	261	52.8	89.9	103.8
Oct.	146.6	140	169.4	126.0	261	64.7	111.0	128.2
Nov.	139.7	140	161.4	116.2	261	61.8	107.0	123.6
Dec.	119.9	140	138.4	103.0	261	53.0	92.2	106.5
Total	110.2	140	127.3	1,114.8	261	48.8	83.2	96.1

* Average available discharge for lowest five days in a month (m^3/s)

** Average available hydropower for lowest five days in a month (MW)

Table 4-5-8 Energy Production at El Lloro Project

Month	Average available discharge (m^3/s)	Effective head (m)	Average power output (MW)	Energy production (GWH)	Maximum power output (MW)	Plant factor (%)	* Dis-charge (m^3/sec)	** Out-put (MW)
Jan.	238.9	29	56.2	41.8	147	38.2	180.7	42.5
Feb.	201.1	29	47.3	31.8	147	32.2	147.4	34.7
Mar.	193.4	29	45.5	33.8	147	31.0	145.1	34.1
Apr.	274.5	29	64.6	46.5	147	43.9	202.4	47.5
May	318.1	29	74.8	55.7	147	50.9	234.4	55.1
June	306.6	29	72.1	51.9	147	49.0	226.9	53.4
July	274.6	29	64.6	48.1	147	44.0	203.5	47.9
Aug.	313.3	29	73.7	54.8	147	50.1	232.9	54.8
Sept.	319.2	29	75.1	54.1	147	51.1	236.2	55.6
Oct.	357.0	29	84.0	62.5	147	57.1	265.1	62.4
Nov.	343.3	29	80.7	58.1	147	54.9	256.0	60.2
Dec.	300.5	29	70.7	52.6	147	48.1	228.4	53.7
Total	287.1	29	67.5	591.5	147	45.9	213.3	50.1

* Average available discharge for lowest five days in a month (m^3/s)

** Average available hydropower for lowest five days in a month (MW)

4.5.3 Studies of Maximum Available Discharge and Maximum Output for Each Project

In general, to study the maximum available discharge for a project means to estimate the maximum output of that project. Seen from the present electric power load factor (annual average load factor 59.3%) and the existing power supply capability (hydro facilities 70.3% of the whole) of Colombia, it is desirable for the hydroelectric power project sites contemplated hereafter to be planned as power stations having plant factors of approximately 50%. This means that during the year the power station group of the upstream Rio Atrato will have the role of supplying the peak load during January-March and base load in July-September, while at the level of master plan preparation, since there will be the matter of comparisons with other projects, it was decided that planning should be done with equipment plant factor at around 50%.

The annual energy productions, plant factors, and maximum output at various maximum available discharges were determined for the each project site. The results are as shown in Table 4-5-9 to Table 4-5-14.

Table 4-5-9 Comparison of Annual Energy Production for Various Maximum Available Discharge at El Siete No. 1 Project

Items \ Maximum available discharge	20	25	30	35	40*	45	50
Average available discharge (m^3/sec.)	16.9	18.9	20.2	20.9	21.3	21.5	21.7
Effective head (m)	472	472	472	472	472	472	472
Maximum power output (MW)	80	100	120	140	160	180	200
Annual energy production (GWH)	644	655	696	721	735	743	749
Average power output (MW)	73.5	74.8	79.5	82.3	83.9	84.8	85.5
Annual plant factor (%)	91.9	74.8	66.3	58.8	52.4	47.1	42.8
*Average available L-5 discharge (m^3/sec.)	14.8	15.6	15.8	15.9	16.0	16.0	16.0

* Average available discharge for lowest five days in a month

According to the above table, increases in annual energy production can be looked forward to from maximum available discharge of 20 m^3/sec. to 40 m^3/sec., but when the maximum available discharge becomes 45 m^3/sec. and 50 m^3/sec., proportional increases cannot be expected so much.
As for plant factor it would be 52.4% in the case of maximum available discharge of 40 m^3/sec., and this case was adopted in this plan.

Table 4-5-10 Comparison of Annual Energy Production for Various Available Discharge at El Siete No. 2 Project

Items \ Maximum available discharge	35	40	45	50	55	* 60	70
Average available discharge (m^3/sec.)	28.5	30.3	31.6	32.5	33.2	33.7	34.2
Effective head (m)	245	245	245	245	245	245	245
Maximum power output (MW)	73	83	93	104	114	124	145
Annual energy production (GWH)	513	547	569	586	598	608	617
Average power output (MW)	58.6	62.4	65.0	66.9	68.3	69.4	70.4
Annual plant factor (%)	80.3	75.2	69.9	64.3	59.9	56.0	48.5
*Average available L-5 discharge (m^3/sec.)	24.2	24.8	25.1	25.4	25.5	25.6	25.7

* Average available discharge for lowest five days in a month

The above table shows the run-off conditions of the catchment area remaining below El Siete No. 1 to be extremely good, and since with the same available discharge as El Siete No. 1 of 40 m^3/sec. the plant factor would be 75.2% and very high, it was planned for the run-off from the remaining catchment area of a maximum 20 m^3/sec. to be drawn for a maximum available discharge of El Siete No. 2 of 60 m^3/sec. The plant factor in such case will be 56%.

Table 4-5-11 Comparison of Annual Energy Production for Various Maximum Available Discharge at El Once Project

Items \ Maximum available discharge	110	140	160	170	180	200	220
Average available discharge (m^3/sec.)	79.5	82.5	84.5	85.2	85.9	86.8	87.4
Effective head (m)	122	122	122	122	122	122	122
Maximum power output (MW)	114	145	166	176	186	207	228
Annual energy production (GWH)	703	729	747	753	759	766	772
Average power output (MW)	80.1	83.2	85.2	85.9	86.6	87.5	88.1
Annual plant factor (%)	70.3	57.4	51.3	48.8	46.6	42.2	38.6
*Average available L-5 discharge (m^3/sec.)	62.9	63.8	64.4	64.5	64.6	64.8	64.9

* Average available discharge for lowest five days in a month

According to the above table it can be seen that incremental electric energy can be counted on up to maximum available discharge of 170 m^3/sec., but when this discharge is exceeded the rate of increase is abruptly slowed down. Meanwhile, the plant factor is 48.8% for the case of 170 m^3/sec. and this was adopted for the new plan. Since dam type development has been selected for this project site, it would be possible for the maximum available discharge to be increased slightly more for development at a scale of about 200 MW, but the unit cost per kWh will become higher to result in a problem about the economic effect.

Table 4-5-12 Comparison of Annual Energy Production for Various Maximum Available Discharge at El Dieciocho No. 1 Project

Items \ Maximum available discharge	120	140	160	180	190	200	220
Average available discharge (m^3/sec.)	83.0	86.6	89.0	90.6	91.3	91.8	92.5
Effective head (m)	165	165	165	165	165	165	165
Maximum power output (MW)	168	196	224	252	266	280	308
Annual energy production (GWH)	1,000	1,043	1,071	1,091	1,099	1,105	1,114
Average power output (MW)	114.0	118.9	122.2	124.6	125.4	126.1	127.0
Annual plant factor (%)	67.9	60.7	54.6	49.4	47.1	45.0	41.2
*Average available L-5 discharge (m^3/sec.)	66.4	67.5	68.3	68.6	68.7	68.8	69.0

* Average available discharge for lowest five days in a month

The above table shows that incremental energy production is provided at a high rate up to maximum available discharge of 180 m^3/sec. Incremental energy production is small at a higher available discharge so that for this plan 180 m^3/sec. at which the plant factor would be 49.4% was adopted. This means that a maximum 10 m^3/sec. of run-off can be additionally drawn at El Dieciocho No. 1 Project from the catchment area remaining between it and El Once Project.

Table 4-5-13 Comparison of Annual Energy Production for Various Available Discharge at El Dieciocho No. 2 Project

Items \ Maximum available discharge	160	180	200	220	230	240	260
Average available discharge (m^3/sec.)	102.6	106.1	108.5	110.2	110.8	111.3	112.1
Effective head (m)	140	140	140	140	140	140	140
Maximum power output (MW)	190	214	238	261	273	285	309
Annual energy production (GWH)	1,038	1,074	1,098	1,115	1,121	1,126	1,134
Average power output (MW)	118.5	122.6	125.3	127.3	128.0	128.5	129.5
Annual plant factor (%)	62.4	57.3	52.6	48.8	46.9	45.1	41.9
*Average available L-5 discharge (m^3/sec.)	81.0	82.1	82.9	83.2	83.3	83.4	83.6

* Average available discharge for lowest five days in a month

If a maximum 40 m^3/sec. were to be drawn from the Rio Playa, since the maximum discharge of El Dieciocho No. 1 Project is 180 m^3/sec., the maximum available discharge of El Dieciocho No. 2 Project will be 220 m^3/sec. and the plant factor at that discharge will be 48.8%. In this case, it was judged that if the maximum available discharge is made too large, a problem would arise about the economic effect since the tailrace length is great.

Table 4-5-14 Comparison of Annual Energy Production for Various Available Discharge at El Lloro Project

Items \ Maximum available discharge	400	450	500	550	600	700	800
Average available discharge (m^3/sec.)	270.0	277.1	281.8	284.9	287.1	289.5	290.7
Effective head (m)	29	29	29	29	29	29	29
Maximum power output (MW)	98	110	123	135	147	172	197
Annual energy production (GWH)	556	571	581	587	592	596	599
Average power output (MW)	63.5	65.2	66.3	67.0	67.5	68.1	68.4
Annual plant factor (%)	64.8	59.3	53.9	49.6	45.9	39.6	34.7
*Average available L-5 discharge (m^3/sec.)	210.9	212.0	212.6	213.0	213.3	213.3	213.3

* Average available discharge for lowest five days in a month

According to the above table, a maximum available discharge can be expected up to 600 m^3/sec. and the maximum available discharge in this plan was thus made 600 m^3/sec. The plant factor at that available discharge will be 45.9%.

Fig. 4-5-1 Flow Chart of Power Discharge