INSTITUTO DE APROVECHAMIENTO DE

AGUAS Y FOMENTO ELECTRICO

REPUBLIC OF COLOMBIA

RECONNAISSANCE REPORT

OF

PUENTE COLAUTE SITE ON THE RIO GUAITARA

SEPTEMBER 1967

GOVERNMENT OF JAPAN

INSTITUTO DE APROVECHAMIENTO DE

AGUAS Y FOMENTO ELECTRICO

REPUBLIC OF COLOMBIA

RECONNAISSANCE REPORT

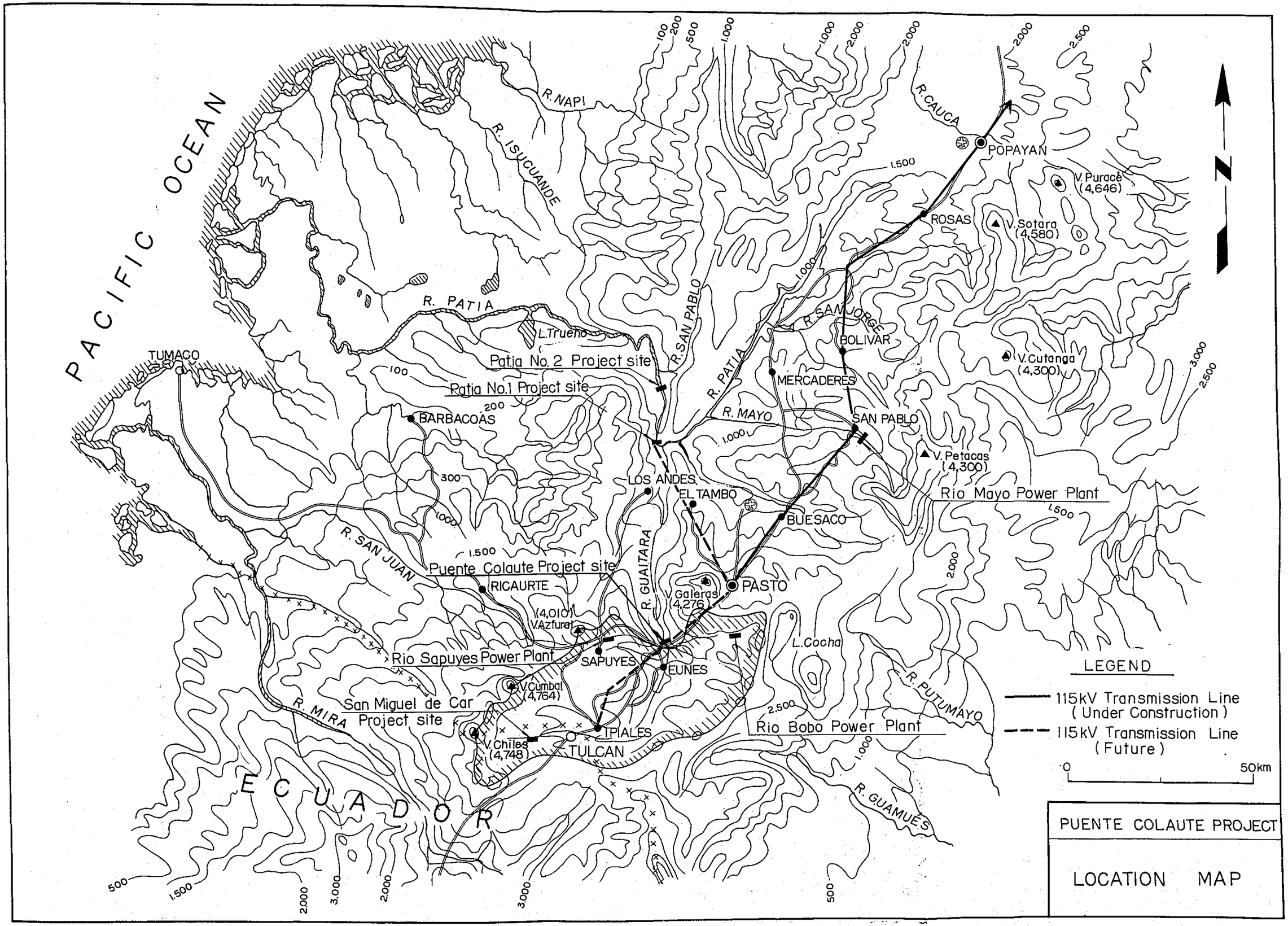
OF

PUENTE COLAUTE SITE ON THE RIO GUAITARA

SEPTEMBER 1967

GOVERNMENT OF JAPAN

CONTENTS


PACIFIC OCEAN
R. NAPI
R. ISUCUANDE
R. PATIA
L. Trueno
Patia No. 2 Project site
Patia No.1 Project site
TUMACO
BARBACOAS
R. SAN JUAN
Puente Colaute Project site
RICAURTE
(4,010) V. Azufral
Rio Sapuyes Power Plant
SAPUYES
V. Cumbal (4,764)
San Miguel de Car Project site
R. MIRA
V. Chiles (4,748)
TULCAN
IPIALES
EUNES
LOS ANDES
EL TAMBO
R. GUAITARA
PASTO
V. Galeras (4,276)
BUESACO
L. Cocha
R. PUTUMAYO
Rio Bobo Power Plant
R. GUAMUES
ECUADOR
R. SAN PABLO
R. SAN JORGE
BOLIVAR
MERCADERES
R. MAYO
SAN PABLO
V. Petacas (4,300)
Rio Mayo Power Plant
R. CAUCA
POPAYAN
ROSAS
V. Sotara (4,580)
V. Puracé (4,646)
V. Cutanga (4,300)
N
LEGEND
115kV Transmission Line (Under Construction)
115kV Transmission Line (Future)
0
50km
PUENTE COLAUTE PROJECT
LOCATION MAP

I. PREFACE

Pursuant to the agreement for technical cooperation between the Governments of Colombia and Japan, the Electric Power Development Company, Ltd. dispatched a team of five enginees to Colombia for a period of three months from January 1967 for the purpose of conducting preliminary investigations of Rio Patia scheme. Although the principal object of the investigations was the Media Patia, the Team, upon consultation with INSTITUTO as well as CEDENAR, carried out studies of tributaries of the said river to examine the possibility of development of hydro-electric power to supply the demand within the CEDENAR system.

For this purpose, reconnaissance investigations were made by the Team of the Rio Guaitara for five days from February 3 with the cooperation of Sr. Alfredo Montenegro, Gerente of CEDENAR and Ing. Ricardo Vargas of INSTITUTO.

The Rio Guaitara is believed to be the most favorable tributary of the Rio Patia from the view point of hydro-electric power development. Along with the reconnaissance investigations, studies were made on the demand and supply balance of CEDENAR system based on data made available to the Team by Dr. Jose Felix Guerrero, Primer Suplente of CEDENAR. Exchange of opinions in connection with the basic concept of the tributary development was also made with Dr. Francisco Forero, chief of the Hydro-electric Division of INSTITUTO. As a result of further studies made by

the Team after return to Japan, Puente Colaute site was selected as the most feasible project for hydro-electric power on the tributaries which is worth further investigations.

2. SUMMARY AND RECOMMENDATION

The proposed Puente Colaute project is still in the preliminary stage since data now available of the project site are not sufficient to establish a concrete plan. However, according to the result of studies made so far, the project is believed to be promising. Natural conditions at the site, such as run-off, topography and geology provide firm ground to believe the project is favorable in addition to the reasonable size of the power plant in comparison with the demand of energy, easy accessibility and advantageous locality for connection into the existing transmission system. The process of the studies is described in the following chapters. Summary of the studies and our recommendations on how to proceed with the further investigations are as follows:

(1) The Puente Colaute preject is located downstream of the confluence of the Rio Guaitara and the Rio Bobo. The general features of the project are as follows:

Scheme of development	With storage reservoir and headrace tunnel
Height of dam:	60 to 100 m
Effective head:	100 to 150 m

Maximum discharge:	30 to 40 m^3/sec
Installed capacity:	25,000 to 50,000 kW
Dependable peak output:	22,000 kW
Annual energy production:	150,000 to 290,000 MWh

(2) the total construction cost of the project is estimated to be within a range of US$8.5 to 16 million according to the capacity to be installed, and the energy cost including transmission lines is 5.5 US mills per KWh approximately. The estimate of the construction cost includes a sizeable amount of contingencies because of many unknown factors at this stage. Therefore, it would be possible that the construction cost might be appreciably less than the present estimate along with the progress of detailed investigations. Even with the present estimate, this project is highly economical compared with the energy cost of alternative thermal power plant which is in the vicinity of 9.5 US mills/KWh.

(3) The supply capability of CEDENAR system is far short of demand, and if potential demand is considered the present capacity is thought to be able to meet only one third of the demand. Furthermore, the government of the Departamento de Narino has established an industrialization program as part of the socio-economic development plan for the frontier district. In view of such situations, it is conceivable that the supply capability of the system even after completion of Rio Mayo Power Station would fall short again after 1970.

Power supply may be expected from CEDELCA system in the three

years of 1970 through 1972. In 1973, however, it is antisipated that the CEDELCA system will not able to supply power in view of the rapid growth in power demand in its system. In addition, the year of 1973 would be the peak period of construction works at Patia scheme which will require about 10,000 KW of power. Therefore, there would be a need to complete another power plant in 1973 to cover such shortage, and the Puente Colaute project is believed to be most suitable project for this purpose.

(4) In order to complete the Puente Colaute project in 1973, construction should start in 1970 considering three years for construction period. To keep up with this schedule, the following procedures should be taken prior to start of construction works. Gaging of river flow, topographical survey and exploratory boring which require considerable time for execution should be started as soon as possible.

- early 1969	Completion of feasibility report
- mid 1969	Start of definite studies
- mid 1970	Completion of tender documents (specifications, drawings, etc.)
- late 1970	Award of contracts

(5) Due consideration should be made in determining the 115 KV transmission line route and equipments to be used therefor so that the Puente Colaute project can be economically connected to the line.

(6) The dam site is situated between Pasto and Ipiales where the Pan

American Highway is proposed to be constructed. Therefore, if the crest of the dam is utilized for crossing the Río Guaitara, the cost of the bridge can be essentially saved. In this case, however, negotiation should be held between the organizations concerned in respect to allocation of the construction cost. At the same time, the advantage that the dam can serve as a bridge should be emphasized in order to promote the materialization of the project.

(7) Construction work of the dam and power plant will require a great deal of labor power. Employment of local laborers will boost the average income in the Departamento de Narino, and thereby contribute to the enhancement of the living standard of the district. Such contribution would be in concordance with the aim of the Inter-American Development Bank or other international financing institutions.

3. POWER SITUATION

Population in Departamento de Narino is approximately 800,000 (1964). Principal cities are Pasto, capital of the Departamento with population of 117,000 (1966) and Ipiales of which inhabitants are about 34,000. The Peunte Colaute project site is located between these two cities. Both cities are situated at an elevation of about 2,700 m. Industries of the Departamento consist chiefly of agriculture, such as, barley, wheat, maize and fruits. Besides agriculture, there are small scale manufacturing industries, such as, furniture, leather, brick, fertilizer and beer breweries. Departamento

de Narino, in pursuance of the socio-economic development plan for the frontier district supported by IDB, has launched an industrialization program with a total investment of 96,653,000 Pesos aiming at the establishment of fourteen factories including cement, brick, cold meat storage, processing of agricultural products, fish cannery, confectionery, dairy, etc. Besides these industrialization programs, large oil resources were discovered recently in the Alto Putumayo, and oil pipe line is under construction between Putumayo and Tumaco to develop the said resources. In the Departamento there are also deposits of limestone, lead, zinc, manganese, copper and gold which promise the future development of industries in the Departamento.

3.1 EXISTING POWER FACILITIES AND THEIR SUPPLY CAPABILITIES

In Departamento de Narino, there are four independent hydro-electric power systems respectively on the Rio Bobo, Rio Sapuyes, Rio Mayo (old) and Rio Ingenio, and two diesel power plants one each in Pasto and Tumaco. In addition, in Pasto there is an industrial power plant owned by Julio Brave e Higas Company. The total installed capacity of hydro-electric power plants is 7,000 KW approximately and that of the diesel power plants is about 3,600 KW. At present, new Rio Mayo Power Station is under construction along side of the old Rio Mayo Power Station. The new plant will have an installed capacity of 14,000 KW in two units in 1968, and the third unit, also 7,000 KW, will be installed in 1969. 115 KV transmission lines will be constructed in the near future to interconnect between Cali, Popayan,

Rio Mayo, Pasto and Ipiales. Also proposed are transmission lines between Ipiales and Puerto Asis and between Ipiales and northern Ecuador.

Current supply capability is far short of demands, and it is assumed that the supply capability is about one half of the demand. Therefore, load control measures are taken to a large extent by means of restrictions of new consumers, voltage drop and supply rationing. Actual load in 1966 was about 10,000 KW at the sending end, and annual energy production was about 49 million KWh (39 million KWh at consuming end). Total energy loss in transmission, transformation and distribution is as high as 22% approximately. Load factor in recent years was extremely high ranging about 70%, which is atributable to the shortage in supply capability. If sufficient capabilities are provided, it would be around 48 to 50%.

3.2 LOAD FORECAST AND TIMING OF DEVELOPMENT OF PUENTE COLAUTE PROJECT

According to the data made available, it is estimated that the power demand would amount to 79 million KWh in 1966 at the consuming end in the CEDENAR system if no restriction on consumption is imposed. As the actual load was 39 million KWh, 40 million KWh can be considered as the latent demand. In addition to this latent demand, it is foreseen that about 4,450 KW of power will be required for the factories to be built in accordance with the industrialization program previously mentioned. Assuming 60% load factor for the factories, annual energy consumption of the new factories would be about 24 million KWh.

Based on IDB data, the annual rate of growth in demand considered for the vicinity is 10% from 1950 through 1963. In the recent three years, however, it has been 23% annually according to "Informe Annual" of INSTITUTO. Taking into consideration the overall rate of growth in southwestern Colombia, covering CVC-CHEC and CEDELCA systems which the Team had investigated, the annual rate of growth in CEDENAR system may be estimated to be about 15% on the average in several years to come. This growth rate is considered to continue until about 1970. Then, it will drop to 11% in three years and remain at the same rate thereafter. The estimated growth in demand is shown in Table 3.1. From Table 3.2 which shows the future supply and demand balance it will be noted that the supply capability will be deficient after 1970 even if the Rio Mayo Power Station is put in operation.

As mentioned previously, construction of transmission lines is of urgency between Cali, Popayan, Rio Mayo, Pasto and Ipiales. In the CEDELCA system, Florida No. 2 Power Station is expceted to start operation in 1971 with an installed capacity of 20,000 KW. Therefore, some energy may be expected from CEDELCA system to supplement the shortage in the CEDENAR system. However, such receipt of energy cannot be expected after 1972 in view of the demand and supply situation in the CEDELCA system.

In 1973, if construction progresses as scheduled, the Patia scheme will be in the peak period of construction works and will require about 10,000 KW for construction. Therefore, it is considered necessary to

develop new power resources in the CEDENAR system by that time. As an alternative, a thermal power plant can be thought at Puerto Asis which is near Alto Putumayo oil field, but the transmission line to Ipiales would be almost 150 km long. However, as described in 5.2, unit cost of electricity at Puente Colaute Power Station will be about 60% of the alternative thermal power. As regards transmission, the 115 KV transmission line proposed to interconnect the systems will pass near the power station, therefore transmission cost will be extremely low as compared with the alternative. Therefore, preparatory works and necessary procedures are recommended to be taken for the completion of Puente Colaute Power Station by 1973.

Table 3.1 Load Forecast in CEDENAR System

Year	Demand at Consuming End (10^6kWh)				Growth Rate (%)	Loss Factor (%)	Load Factor (%)	Demand at Generating End	
	Actual Consumer	Latent Consumer	New Factories	Total				Annual Energy (10^6 kWh)	Peak Load (MW)
1966	39			39	–	22	48	49	10
7	45			45	15	"	"	58	14
8	52	20		72	"	"	"	93	22
9	59	23+20		102	"	"	"	131	30
1970	68	53	10	131	"	"	"	168	39
1	77	59	11	147	13	20	50	184	42
2	87	67	12	166	12	"	"	207	46
3	96	75	14	185	11	"	"	231	54
4	107	83	15	205	"	"	"	256	60
5	119	92	17+14	242	"	"	"	304	69
6	132	102	35	269	"	18	"	328	75
7	146	113	39	298	"	"	"	364	83
8	162	125	43	330	"	"	"	402	92
9	180	139	48	367	"	"	"	450	103
1980	200	155	53	408	"	"	"	500	114

Table 3.2 Demand and Supply Balance in CEDENAR System

(Power: MW, Energy: 10^6 KWh)

Year	Demand		Capability								Difference	
			Existing		Rio Mayo P.S.		Puente Colaute P.S.		Total			
	Peak Load	Annual Energy	Power	Energy	Power	Energy	Power	Energy	Power	Energy	Power	Energy
1966	10	49	10	50					10	50	—	—
7	14	58							10	50	- 4	- 8
8	22	93			14	114			24	164	2	71
9	30	131			21				31	164	1	33
1970	39	168							31	164	- 8	- 4
1	42	184							31	164	-11	-20
2	46	207							31	164	-15	-43
3	54	231					50	290	81	454	27	223
4	60	256							81	454	21	198
5	69	304							81	454	12	150
6	75	328							81	454	6	126
7	83	364							81	454	- 2	90
8	92	402							81	454	-11	52
9	103	450							81	454	-22	4
1980	114	500							81	454	-33	-46

4. PUENTE COLAUTE PROJECT

4.1 TOPOGRAPHY AND GEOLOGY

The proposed site is located at Puente Colaute where a triburary called the Río Bobo drains into the Río Guaitara. Catchment area at the site is 2,560 km^2. The Rio Guaitara, 20 to 40 m in width at the site, forms a "U" shaped narrow gorge more than 100 m deep which is very favorable for dam construction. There is a highway bridge across the gorge at a place about 80 m above the river water (El. 1,726 m). The highway is connecting Pasto and Ipiales. The Pan American Highway to be constructed in the near future will also have a bridge across the same gorge.

Aerophoto maps and other topographical maps of the Rio Guaitara basin are not available so far. Therefore, reconnaissance of the site was made with use of barometers. The river bed at Puente Colaute is at an elevation of about 1,600 m, and the river gradient around there is estimated to be about 1/40. Near Ancuya Gaging Station which is about 20 km downstream of the dam site, the river bed is about 1,100 m above sea level and flowing down on a slope of presumably 1/40 to 1/50. Further downstream where the Rio Pacual, another tributary, joins the river, the river flow becomes gentle and the gradient is estimated to be 1/80.

The geological formation at the dam site consists of rocks called "Toba" of volcanic origin. Technically, they are conglomerate and tuff that are tightly solidified. However, cracks were observed with wide openings.

It is thought technically feasible to construct a concrete dam to a height of 100 m. However, it is necessary to conduct detailed geological investigations on the permeability and bearing capacity of the foundation. Geology along the possible route of headrace tunnel is probably the same as the dam site since the geology in the vicinity of the dam site appears homogeneous.

4.2 RUN-OFF AND MAXIMUM DISCHARGE

The Rio Guaitara originates in the Volcan Chiles near the border of Ecuador and flows north after collecting waters in the hight land about 3,000 m about sea level which is surrounding Ipiales, and drains into the Rio Patia at a point 1 km upstream of the proposed Patia No. 1 dam site. The river is about 140 km long and has a catchment area of about km^2 at the confluence with the Rio Patia.

Two gaging stations were established and records are available since 1964. One is Ancuya Gaging Station (3,058 km^2 in catchment area) in the reaches of the Rio Guaitara and the other is Carlosama Gaging Station (120 km^2 in catchment area) on the Rio Blanco, a tributary draining into the upper reaches of Rio Guaitara. There are eight meteorological stations in the river basin. According to the data compiled at the stations, annual rainfall is 1,500 mm approximately, and the run-off at Ancuya Gaging Station is as follows:

Table 4.1 Run-off at Ancuya Gaging Station

(average in 1964 to 1965)

95 days run-off	185 days run-off	275 days run-off	355 days run-off	Annual Averrage
58.4	42.5	30.9	20.8	48.6

Table 4.2 Firm Run-off (355 days run-off) at Ancuya Gaging Station

(m^3/sec)

1964	1965	1966	Averrage in 3 years
14.1	23.9	24.3	20.8

Run-off at Puente Colaute has been estimated by proportioning the run-off at Ancuya Gaging Station according to the catchment areas; 2,560 km^2 at Puente Colaute and 3,058 km^2 at Ancuya Gaging Station. The run-off at Puente Colaute thus obtained is as follows:

Table 4.3 Run-off at Puente Colaute

(average in 1964 to 1965)

(m^3/sec)

95 days run-off	185 days run-off	275 days run-off	355 days run-off	Annual average	Total annual
49.5	35.6	25.9	17.4	41.0	$1,290 \times 10^6 m^3$

Table 4.4 Firm (355 days run-off) Run-off at Puente Colaute

			(m^3/sec)
1964	1965	1966	Average in 3 years
11.8	20.0	20.4	17.4

Taking into consideration the facts (1) that run-off in dry season is 17.4 m^3/sec. (2) that run-off can be regulated to some exant by a reservoir and (3) that the load factor of CEDENAR system is around 48 to 50%, it is reasonable to determine the maximum discharge of power to be within a range of 30 to 40 m^3/sec.

4.3 POWER DEVELOPMENT PLAN

A high head will be obtained by constructing a dam and headrace tunnel. Water utilized for power generation will be discharged back into the Rio Guaitara. Puente Colaute dam will be a 60 to 100 m high concrete or fill type structure. However, in order to determine the height and type of dam, thorough studies should be made on the storage capacity, topography and geology of the dam site, possibility of land slide within the reservoir, etc. In any case, the merit of using the dam crest for the river crossing of the Pan American Highway should not be neglected. There would be the following merits if the dam serves as a bridge of the highway.

(1) Construction cost of bridge can be reduced considerably.

(2) Energy cost after cost allocation to the bridge will be lower.

(3) The accessibility to the reservoir will become good, and the the reservoir which is 1,600 m above sea level may serve as a pleasant resort place.

Available data are not sufficient to determine the headrace route and location of powerhouse. The river profile and other topographical maps are required. However, the average river gradient around the project site which was mentioned previously gives ground to presume that 100 to 150 m of effective head can be created economically by constructing a headrace tunnel of reasonable length.

Upon these consederations, the principal features of the project which is conceivable at this stage fall in the following range.

	Minimum	Maximum
Installed capacity	25,000 KW	50,000 KW
Dependable peak output	22,000 KW	46,000 KW
Annual energy production	150 million KWh	290 million KWh

4.4 TRANSMISSION LINE PLAN

In the CEDENAR system, a 115 KV transmission line from Popayan (CEDELCA system) to Ipiales via Rio Mayo and Pasto has been proposed

and tenders for the construction and supply of materials were already called. This transmission line is scheduled to be completed on time with the start of operation of Rio Mayo Power Station which will have an installed capacity of 21,000 KW in the ultimate stage.

Power produced at Puente Colaute Power Station will be supplied to Pasto and Ipiales through the said transmission line. This arrangement might be quite advantageous from the economical point of view because the distance from the power station to the load centers are respectively about 30 km 40 km. The construction works of the Patia scheme requirs about 10,000 KW of power. Since there is no suitable power source in the vicinity of the project site, it is advantageous to utilize the power produced by the Puente Colaute scheme through a transmission line between Patia and Pasto (115 KV single circuit) which is to be constructed prior to the start of construction works of the Patia scheme.

4.5 CONSTRUCTION COST

Data available for Puente Colaute Project are far from enough to estimate the construction cost. Therefore, very rough estimate was made based on the preliminary investigations. The estimates include engineering fee, interest during construction and contingencies. It is believed that actual construction costs will not be more than the following estimates unless unexpectedly large escallation takes place.

	Installed capacity
US$ 8.5 million	25,000 KW
US$ 16.0 million	50,000 KW

In other words, the present estimate may well be curtailed if results of detailed investigations are obtained. If results of geological investigations prove the technical feasibility of constructing an arch dam at the site, for instance, construction cost of the dam would be reduced remarkably. Furthermore, the cost allocation to the highway bridge is not considered in the present estimate.

5. ECONOMIC ANALYSIS

5.1 ASSUMPTIONS

The rate of interest is assumed to be 6% for foreign loans and 10% for domestic loans. The ratio of foreign currency requirement and domestic currency requirement is assumed to be 6 to 4. Serviceable life of Hydroelectric power plant is estimated to be 50 years and that of a thermal power to be 25 years. Based on the criteria approved by the Interconnection Comittee for the estimation of personnel expenses, maintenance costs, administrative costs, insurance premium, etc., the equalized annual cost factor of Puente Colaute Power Station is estimated to be 10.4% against the initial investment. As an alternative project, a thermal power plant having

a 25,000 KW unit, US$ 230 per KW in construction cost and reserve capacity of 20% with a thermal efficiency of 30% is considered. The equalized annual cost factor is estimated to be 13.5% against the initial investment. Fuel costs, as data are not available of the local price of oil, were estimated at 3.8 US mills/KWh taking into account prices of other districts.

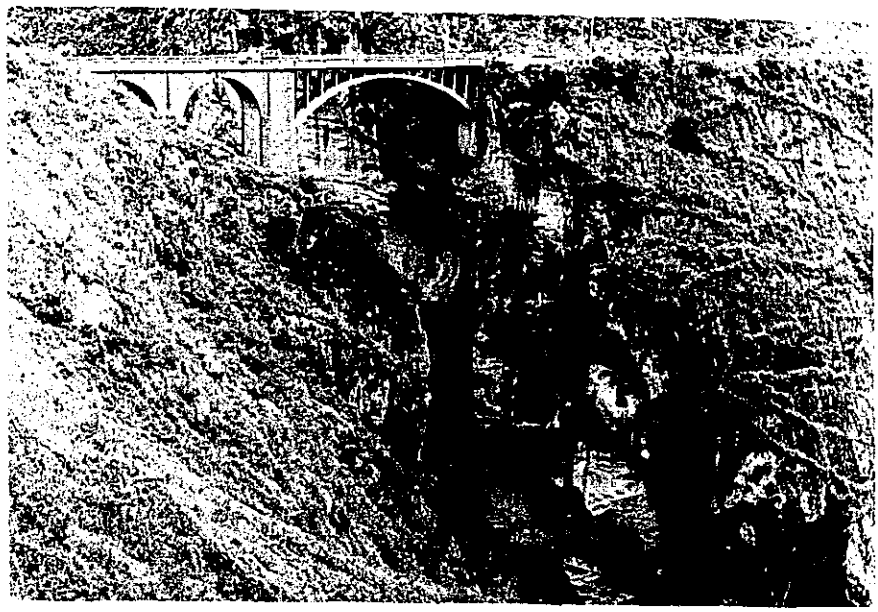
5.2 RESULTS OF ANALYSIS

Based on the assumptions described in the foregoing, costs of energy for the Puente Colaute project, as well as, the alternative thermal are as follows:

Puente Colaute Project	5.5	US mills/KWh
Alternative Thermal Power Plant	9.5	US mills/KWh

The energy cost calculated of Puente Colaute project is almost 60% of the alternative energy. It is probable that the alternative energy may be produced at a less cost if the power plant is built near the oil refinery and the fuel is available at lower price than the estimate. Even if such is the case, energy cost at consuming end is believed to be unchanged because of long distance transmission. At the present stage, energy cost of Patia scheme is estimated to be about 4.8 US mills/KWh which is lower than that of Puente Colaute project. However, the construction schedule of Patia scheme which is much larger in scale should be determined taking into

consideration the demands and supply balance of the whole southwestern Colombia. Our studies on the Patia scheme have revealed that the date of operation of Patia scheme should be around the end of 1976. Therefore, the shortage of supply capability anticipated in 1973, can be supplemented by the Puente Colaute project. As a supplementary project to the Patia scheme, it is believed that the Puente Colaute project is indispensable in view of the growth of power demand in the district.



View of bridge from upstream

right: Rio Guaitara
left: Rio Bobo
Upstream view from bridge

Downstream view from bridge

View of right bank from bridge