INSTITUTO ECUATORIANO DE ELECTRIFICACION

REPUBLIC OF ECUADOR

SAN MIGUEL DE CAR PROJECT

FEASIBILITY REPORT
HYDRO-ELECTRIC POWER DEVELOPMENT

SEPTEMBER 1966

GOVERNMENT OF JAPAN

FOREWORD

The Government of Japan, at the request of the Government of the Republic of Ecuador, entrusted the feasibility studies of the San Miguel de Car Hydroelectric Power Project to the Overseas Technical Cooperation Agency. The Agency dispatched a survey team headed by Mr. M. Koike and consisted of four members.

The team left Tokyo on the 24th of February, 1966 to Ecuador, where it stayed for about one and a half months. During this period, the survey team carried out the specific studies, discussed the Project to examine its feasibility, conducted field investigations, and collected the available data necessary for planning of the Project.

The Government of Ecuador rendered much valuable assistance and cooperation to the survey team so that the survey result in a considerable success and its results be presented in this report.

The Overseas Technical Cooperation Agency, as an executive organization of the Government of Japan, has been performing such technical cooperation by providing consulting services, dispatch of experts and receiving of technical trainees from developing countries.

Nothing would be more gratifying to us, if this report could contribute to the promotion of the Project as well as to the furtherance of the friendship and economic relations between the Republic of Ecuador and Japan.

September 1966

S. Shibusawa

SHIN-ICHI SHIBUSAWA
Director General
Overseas Technical
Cooperation Agency

Mr. Shinichi Shibusawa, Director General

Overseas Technical Cooperation Agency
Tokyo

Sir:

As Chief of the Japanese Government Survey Team for the San Miguel de Car Hydro-electric Power Project of the Republic of Ecuador, the undersigned has the honor of submitting herewith the report of the studies carried out by the Team.

The Survey Team visited Ecuador for approximately one and a half months from February 24, 1966 to conduct investigations of the topography and geology of the project area, and to collect data and information concerning the electric power situation, hydrological and meteorological conditions and information required to estimate the construction cost of the Project.

Upon return to Japan, the Team conducted various studies, based on the data and information collected, under the direction of the Chief Engineer of the Electric Power Development Co., Ltd. (EPDC) which is the parent organization of the Survey Team.

The San Miguel de Car Hydro-electric Power Project will consist of the construction of a power station with an installed capacity of 3,000 KW which will produce 19,999,000 KWH annually, a 34.5 KV transmission line approximately 80 km long and sub-stations with a total transforming capacity of 5,400 KVA to satisfy the power demands of Tulcan City, San Gabriel, El Angel, Ibarra and nearby districts.

In order to meet the ever growing power demands in the above districts, it is essential that the Project be completed and start operation in 1972.

A period of approximately two years will be required to construct the power station, and the construction cost including the transmission line and sub-stations will amount to approximately 44,000,000 Sucres. However, in comparison with a diesel power plant as an alternative, the benefit-cost ratio of this Project is greater than 1.23, which gives a positive reason to believe that the Project is economically sound and justifiable.

It is our earnest hope that this report will be of value in the development of the hydroelectric resources of Ecuador, and will contribute to the promotion of goodwill and friendship, and also in advancing the economic relationship between Ecuador and Japan.

September 1966

Respectifully submitted,

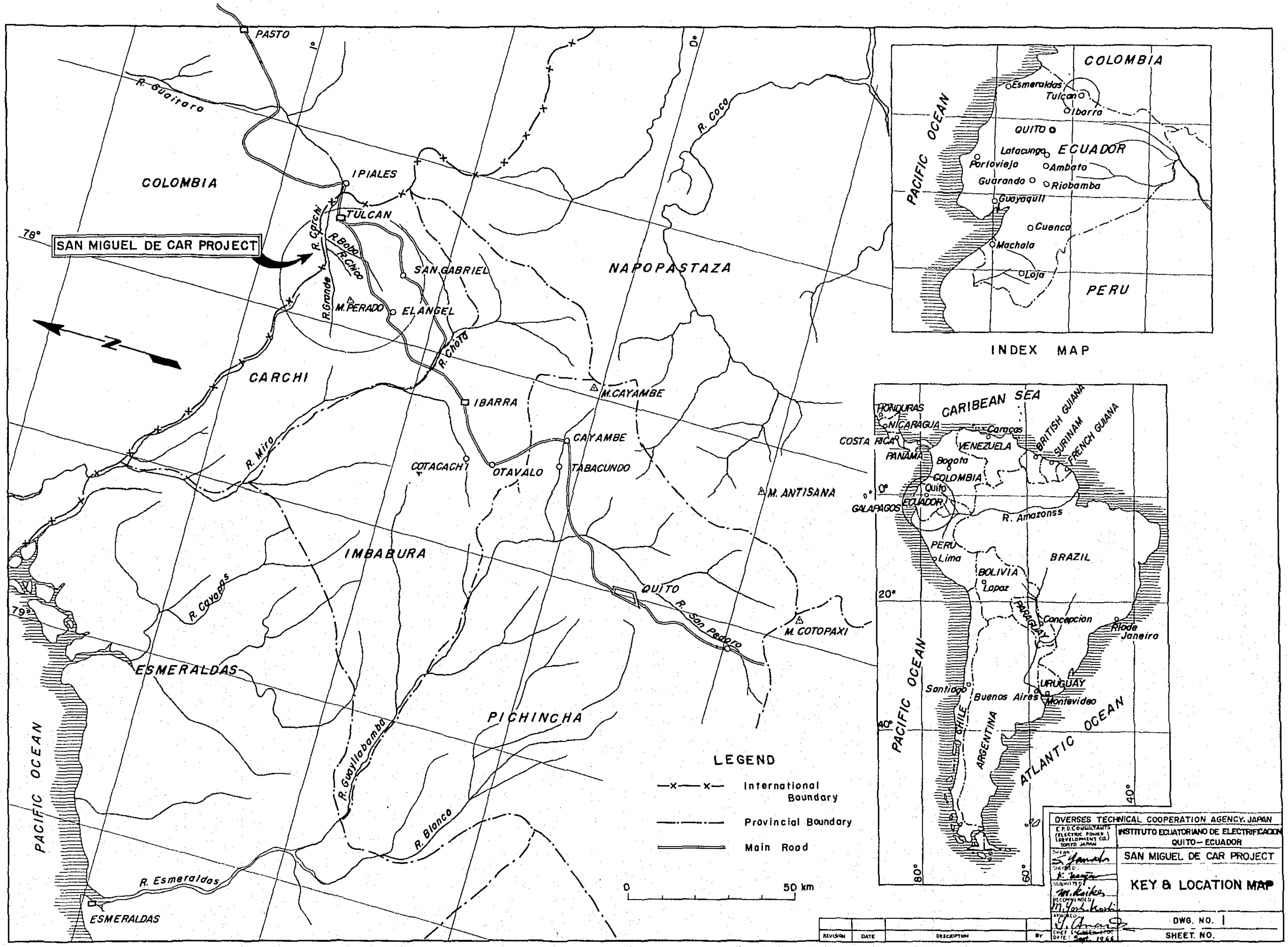
Masashi Koike

Masashi Koike, Chief
Japanese Government Survey Team
for the San Miguel de Car Hydroelectric Power Project

Electrical Engineer, Electric Power
Development Co., Ltd.

C O N T E N T S

1. INTRODUCTION



PASTO
R. Guaitara
COLOMBIA
IPIALES
TULCAN
78°
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R. Carchi
R. Bobo
R. Chico
R. Grande
M. PERADO
SAN GABRIEL
EL ANGEL
R. Chota
CARCHI
IBARRA
NAPOPASTAZA
R. Coca
M. CAYAMBE
CAYAMBE
TABACUNDO
COTACACHI
OTAVALO
M. ANTISANA
R. Mira
IMBABURA
R. Cavapas
79°
ESMERALDAS
QUITO
R. San Pedoro
M. COTOPAXI
PICHINCHA
R. Guayllabamba
R. Blanco
R. Esmeraldas
ESMERALDAS
PACIFIC OCEAN
LEGEND
International Boundary
Provincial Boundary
Main Road
0
50 km
COLOMBIA
Esmeraldas
Tulcan
Ibarra
QUITO
Latacunga
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Bogota
COLOMBIA
Quito
ECUADOR
GALAPAGOS
R. Amazonss
PERU
Lima
BRAZIL
BOLIVIA
Lapaz
20°
PARAGUAY
Concepcion
Riode Janeiro
PACIFIC OCEAN
Santiago
Buenos Aires
URUGUAY
Montevideo
CHILE
ARGENTINA
ATLANTIC OCEAN
40°
80°
60°
OVERSES TECHNICAL COOPERATION AGENCY, JAPAN
E.P.D.CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO.) TOKYO JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION QUITO—ECUADOR
SAN MIGUEL DE CAR PROJECT
KEY & LOCATION MAP
DWG. NO. 1
SHEET NO.
REVISION
DATE
DESCRIPTION
BY
DATE: Sept. 1966

1. INTRODUCTION

1.1 HISTORY AND AUTHORIZATION

The San Miguel de Car Hydroelectric Power Project was originally planned by Instituto Ecuatoriano de Electrificacion (hereinafter called INECEL), and was brought up by Junta Nacional de Planificacion y Coordinacion Economica de Ecuador (hereinafter called JUNTA) to the Consultative Group on External Financing General Economic and Social Development Plan of Ecuador, sponsored by the Inter-American Development Bank (hereinafter called IDB).

At the time of a visit of engineers of Electric Power Development Company (hereinafter called EPDC) to Ecuador in September 1965, technical cooperation from Japan for this project was requested by INECEL, and according to the understanding reached by INECEL, JUNTA and the Japanese Ambassador to Ecuador in the same year, the Government of the Republic of Ecuador officially requested the Government of Japan for technical cooperation and to dispatch an engineering team to Ecuador in order to establish a development plan.

In response to this request, the Government of Japan decided to cooperate in the promotion of the economic and technical development projects of Ecuador, and sent to Ecuador an engineering team consisting of 5 EPDC engineers through the Overseas Technical Cooperation Agency in February 1966.

Prior to the field studies conducted by the team, some investigations including topographical survey had been made for this project according to INECEL's scheme by Empresa Electrica "Tulcan" S.A. in Tulcan City, Carchi Provincia.

1.2 SCOPE OF PROJECT

This report concerns the technical and economic feasibility of the San Miguel de Car Hydro-electric Power Development Project.

The scope of the project covered by the feasibility study is limited to the area encompassing Tulcan City, supplied with electricity by Empresa Electrica "Tulcan" S.A., who will be the owners of the San Miguel de Car Power Station, and San Gabriel, El Angel, etc. served by municipalities. The studies were made up to the primary sub-stations. This scope of the project differs from that in the project report (Document No. 116-No. 1) submitted by the JUNTA to the IDB. Consideration was given to inter-connection with the Ibarra Power System in determining the scale and time of development of the project.

1.3 SURVEY AND STUDY

The team visited Ecuador from February 24, 1966 for a period of about one and one-half months to consult with officials of the Government of Ecuador in connection with the project scheme and scope of field surveys, and conducted field studies and collected relevant information and data.

The team was headed by Masashi Koike, an electrical engineer of EPDC and comprised of 2 civil engineers, 1 geologist and 1 electrical engineer of the said firm.

From April 10, 1966, after the team returned to Tokyo, analysis of hydrological data, demand estimates, power generation schemes, preliminary design of structures, economic studies of the project, etc. were conducted or prepared with the cooperation of engineers of EPDC under the direction of its Chief Engineer. This is a feasibility report incorporating the results of the studies.

1.4 DATA SOURCE

Basic data and information used in preparation of the project plan are those made available to the team during its stay in Ecuador by INECEL, Servicio Nacional de Meteorologia e Hidrologia and Empresa Electrica "Tulcan" S.A. and data sent by INECEL to the team after its return to Tokyo.

These data and information are listed in the appendix to this report.

1.5 ACKNOWLEDGEMENT

The team takes this opportunity to express its sincere appreciation to the officials of the Government of Ecuador, INECEL, Servicio Nacional de Meteorologia e Hidrologia and other offices concerned, as well as Empresa Electrica "Tulcan", S.A. who have freely extended to the team all facilities and assistance without which the team could not have accomplished its mission.

2. CONCLUSION AND RECOMMENDATION

2. CONCLUSION AND RECOMMENDATION

2.1 CONCLUSION

As a result of studies of the San Miguel de Car Hydroelectric Power Project the following conclusions are reached.

(1) The area with Tulcan City as the center is maintaining a balance between demand and supply capability in the dry season at present by means of load restrictions. In view of the La Programa de Integracion Economica Fronteriza Colombo-Ecuatoriana to be carried out in the near future, it is evident that some expansion in power supply facilities is essential.

(2) In order to cope with this increasing demand for power, a transmission line interconnection between Tulcan and Ibarra is essential.

(3) Following this work, the development of the San Miguel de Car Power Station is necessary.

(4) There are no unusual engineering problems in the design and construction of the project.

(5) The San Miguel de Car Project consists of the construction of San Miguel de Car Power Station, Tulcan Sub-station and the transmission line between the power station and the sub-station. In addition to these works, the project includes the construction of San Gabriel and El Angel Sub-stations, transmission lines to interconnect these sub-stations with Tulcan Sub-station, and an interconnecting transmission line between San Gabriel Sub-station and Ibarra Sub-station (one half of the cost of this line is

allocated to the San Miguel de Car Project). The estimated total construction cost of the Project is approximately 44,000,000 Sucres. Of this cost, the required foreign currency is estimated to be about 24,000,000 Sucres and the remaining approximate 20,000,000 Sucres is domestic currency.

(6) The cost of effective energy of the San Miguel de Car Power Station is estimated to be 0.25 Sucres/KWH delivered at the primary sub-station. Future rates of service, in consideration of the present rates of service of Empresa Electrica Ibarra, is estimated to be around 0.6 Sucres per KWH. As the distribution cost of the Empresa Electrica Tulcan is 0.24 Sucres per KWH, it is judged that the cost of energy to the consumer at the primary sub-station is 0.35 Sucres per KWH. In view of this cost, it is judged that the San Miguel de Car Project is economically sound and justified.

(7) The benefit/cost ratio of the San Miguel de Car Project as compared with that of an alternative diesel power plant is 1.23 so that the Project can be said to be favorable.

(8) The average cost of power of the Tulcan Power System including San Miguel de Car, La Playa, San Gabriel and El Angel Power Stations, in approximate years (1968 through 1979) is estimated to be 0.30 Sucres/KWH delivered at the primary sub-station.

(9) Repayment schedule prepared on the basis of revenues of 0.35 Sucres per KWH at the primary sub-station revealed that the project will produce adequate revenues to meet debt obligations.

2.2 RECOMMENDATIONS

On the basis of the abovementioned conclusions the following recommendations are made.

(1) The San Miguel de Car Power Station should be developed as a run-of-river type power station with a regulating pond making possible daily regulation, and the maximum capacity of the plant should be 3,000 KW (1,500 KW x 2 units) utilizing 3.0 m3/s of discharge under an effective head of 122 m.

(2) In consideration of future demands, the San Miguel de Car Project should be developed in two stages of 1,500 KW each as follows:

Complete in 1968:	Transmission line between Tulcan and Ibarra (34.5 KV, 1 circuit)
Complete in 1972:	The First Stage of San Miguel de Car Power Station (1,500 KW x 1)
	Transmission line between San Miguel de Car and Tulcan (34.5 KV, 1 circuit)
Complete in 1974:	The Second Stage of San Miguel de Car Power Station (additional 1,500 KW x 1)

(3) Definite studies of the San Miguel de Car Power Station should be started in 1968, and preparations such as securing of construction funds, invitations for bids, etc. should be made in 1969. This schedule is based on the condition that the interconnecting transmission line between Tulcan and Ibarra is completed in 1968.

3. MARKET SURVEY AND LOAD FORECAST

3. MARKET SURVEY AND LOAD FORECAST

3.1 MARKET SURVEY

3.1.1 Background

The power produced at San Miguel de Car Power Station will be transmitted to the area in Carchi Provincia supplied by Empresa Electrica Tulcan and to Espejo County and Montufar County. Adjacent to this power system there is the Ibarra Power System which supplies Inbaburra Provincia and Pedro Moncayo and Cayambe Counties in Pichincha Provincia.

For the purpose of identification, the area including Tulcan, San Gabriel, El Angel, etc. in Carchi Provincia will be called Zone A and the area including Ibarra, Otavalo, Cotacachi, Atuntaqui, Cayambe, Tabacundo, etc. in Inbaburra Provincia and Pichincha Provincia will be called Zone B.

As described in Chapter 7, it has been found that it will be more economical to interconnect the systems of Zone A and Zone B rather than to operate them independently so that the area to be supplied by San Miguel de Car Power Station will consist of Zones A and B.

The Pan American Highway connecting Guayaquil, Quito and Tulcan runs through these zones. There is a population of about 130,000 in approximately 50 communities at an elevation of 2,500 m or higher. Estimated from the national census of 1962 the populations of principal municipalities are as follows:

Tulcan	17,500
San Gabriel	6,900
El Angel	4,000
Ibarra	27,700
Atuntaqui	9,800
Cotacachi	4,300
Otavalo	8,700
Tabacundo	2,600
Cayambe	8,200

The economy of this region is based chiefly on agriculture and stockfarming with some domestic industry.

The La Programa de Integracion Economica Fronteriza Colombo-Ecuatoriana signed between Ecuador and Columbia on March 13, 1966 is expected to bring about a great expansion of this region in the future. This plan, with the aid of the Inter-American Development Bank, is being executed with the object of economic development and improvement of social conditions, and includes 71 projects. The total funds for the plan is approximately 100 million dollars. Industrialization, which will have a direct connection with power demand will be mainly in Esmeralda Provincia on the Pacific Coast, but construction of meat refrigerating facilities is planned for Tulcan City.

3.1.2 Pattern of Power Supply

Power supply in the areas concerned is now being undertaken by electric utility companies established by joint investments of INECEL founded in May, 1961 as a state organ and the major municipalities. Power is also supplied by some municipalities since 1945 pursuant to municipal law.

In the Tulcan-Ibarra Power System to which San Miguel de Car Power Station will be connected, there are the two companies, Empresa Electrica Tulcan and Empresa Electrica Ibarra. Besides these two, there are also Empresa Electrica Montufar and municipalities which distribute power directly to various communities independently. As of 1966, the total installed capacity in these areas was 5,784 KW, the estimated annual energy production approximately 18,500 MWH, and the annual per capita energy consumption approximately 142 KWH. Although construction of SanMiguel de Car Power Station will be undertaken by Empresa Electrica Tulcan, the necessary funds will be procured by INEGEL as agent for Empresa Electrica Tulcan in the form of a government guarantee.

3.1.3 Present State of Supply and Demand

The estimated demand of 1,900 KW in 1955 has increased to an estimated 4,700 KW in 1962 during which time generating capacity has been doubled. However, since 1962 up to the present, the only new installation has been 360 KW of diesel power. Because of this, although in the wet season the balance between supply and demand is generally maintained, in the dry season there is a shortage of supply capability with some differences according to districts. Especially in the cities of Ibarra and Tulcan, load restrictions are enforced due to drops in voltage during the dry season. In Tulcan, there has been a case where only 440 KW could be supplied against a demand close to 800 KW whereas the installed capacity is 1,320 KW.

Electricity rates are fixed by the respective areas. The rates of Empresa Electrica Tulcan are shown in Table 3-1.

Table 3-1 Electricity Rates of Empresa Electrica Tulcan

Classification	Basic energy	Contracted Amperes	Basic rate	Remarks
	KWH	A	Sucres	
Residential T	20	5	7.00	0.35 Sucres for each KWH in excess of the basic energy
A	20	10	10.00	
R	20	15	12.00	
I	20	20	15.00	
F	20	25	18.00	
A	20	30	25.00	
S	50	50	50.00	
Industrial	20	20	10.00	0.3 Sucres for each KWH in excess of the basic energy and 0.25 Sucres for each KWH in excess of 1,000 KWH.
	20	30	10.00	
	30	50	30.00	

The number of contracts and the energy sales in February 1966 of Empresa Electrica Tulcan is as shown in Table 3-2.

Table 3-2 Number of Contracts and Energy Sales of Empresa Electrica Tulcan

	Number of contracts	Energy	Revenues
		KWH	Sucres
Residential	2,308	131,975	52,738.20
Industrial	55	17,757	5,425.10
Street lighting and municipal lighting	1	50,710	10,516.10
Total	2,364	200,442	68,679.40

The existing generating facilities of the project area are as shown in Table 3-3. The installed capacity as of 1966 is 5,784 KW which will be increased to 12,780 KW in 1968.

Table 3-3 Existing Generating Facilities

	1966 - 1967					1968 -				
	Installed Capacity	Annual Energy Output		Dry Season Output		Installed Capacity	Annual Energy Output		Day Season Output	
		Firm	Secondary	Firm Capacity	Energy		Firm	Secondary	Firm Capacity	Energy
	KW	MWH	MWH	KW	MWH	KW	MWH	MWH	KW	MWH
A-Zone										
La Playa	1,320	8,760	2,097	1,000 1/	24.0	1,320	8,760	2,097	(1,320) 2/ 1,000	24.0
Small Hydro-Plants	644	5,168	354	590	14.2	500 3/	3,854	393	440	10.6
El Angel (extension)						200	1,752	0	200	4.8
Sub-total	1,964	13,928	2,451	1,590	38.2	2,020	14,366	2,490	(1,960) 1,640	39.4
B-Zone										
Small Hydro-Plants	2,860	18,352	5,012	2,095	50.3	1,800	8,672	5,307	990	23.8
El Ambi						8,000	15,760 4/	5,897 5/	(8,000) 4/ 1,800	43.2
(Sub-total)	2,860	18,352	5,012	2,095	50.3	9,800	24,432	11,204	(8,990) 2,790	67.0
Diesel	960	8,410	0	960	23.0	960	8,410	0	960	23.0
Sub-total	3,820	26,762	5,012	3,055	78.3	10,760	32,842	11,204	(9,950) 3,750	90.0
(A+B) Zone										
Hydro-Plants	4,824	32,280	7,463	3,685	88.5	11,820	38,798	13,694	(10,950) 4,430	106.4
Diesel Plant	960	8,410	0	960	23.0	960	8,410	0	960	23.0
Total	5,784	40,690	7,463	4,645	111.5	12,780	47,208	13,694	(11,910) 5,390	129.4

Note 1/ Firm discharge $= 1.5\ m^3/s \times \frac{244\ km^2 \text{ (catchment area of La Playa Intake site)}}{183\ km2 \text{ (catchment area of San Miguel de Car site)}} = 2.0\ m^3/s$

head = 65 m Therefore firm output is 1,000 KW.

2/ The regulating pond for La Playa Power Station (hereinafter called equalizing reservoir) to be constructed simultaneously with Second Stage of San Miguel de Car Project. Therefore the firm peak available discharge of La Playa will be 2.7 m^3/s and the firm peak output 1,320 KW. All values in parentheses indicate firm peak output.

3/ Retirement of small hydro-plants will be made in 1968.

4/ Source INECEL information No. 6605 LHL 1139

5/ 1.5 times the dry season run-off is assumed to be the average run-off available for power generation during wet season (assumed to be 9 months).

3.2 LOAD FORECAST

3.2.1 Area of Supply

The area to be supplied with power from San Miguel de Car Power Station will be Zones A and B described in 3.1.

3.2.2 Load Forecast

The load forecast is made separately for Zone A and Zone B, but since Zone B is not included in the scope of the present survey, figures provided by INECEL will be used. This forecast has been made in detail by INECEL and may be considered to be reasonable.

The demand in Zone A will be divided into the two classifications below and a forecast will be made for each classification for the period from 1966 to 1982.

a. Lighting (including existing demands of cottage industries)
b. New industrial power demand

3.2.2.1 Forecast of Size of Demand

a. Lighting Demand

The load forecast is based on the past figures of Tulcan City which consumes half of the power in the Zone. As records are not available for other areas in the Zone, the forecast is based on consumption at Tulcan in the past from which estimates were made according to population increase and per capita power consumption.

The maximum monthly demand at Tulcan from 1961 to 1965 is as shown in Fig. 3-1. According to this graph, the demand is small in the dry season, but this can be considered to be caused by load restrictions enforced due to shortage of supply capability. In contrast, it will be seen that in December, the wet season when there is adequate supply capability, the demand is large. Therefore, for the maximum demand during a year the figures for December will be adopted. The average rate of growth of demand calculated from maximum demand of each year is 7 percent annually. The maximum demand for Tulcan from 1966 to 1982 was estimated by applying this growth rate. The estimated demand for the said period and the maximum demand per capita are as shown in Table 3-4-1.

Fig 3-1 Actual and Estimated Trend of Demand in Tulcan City

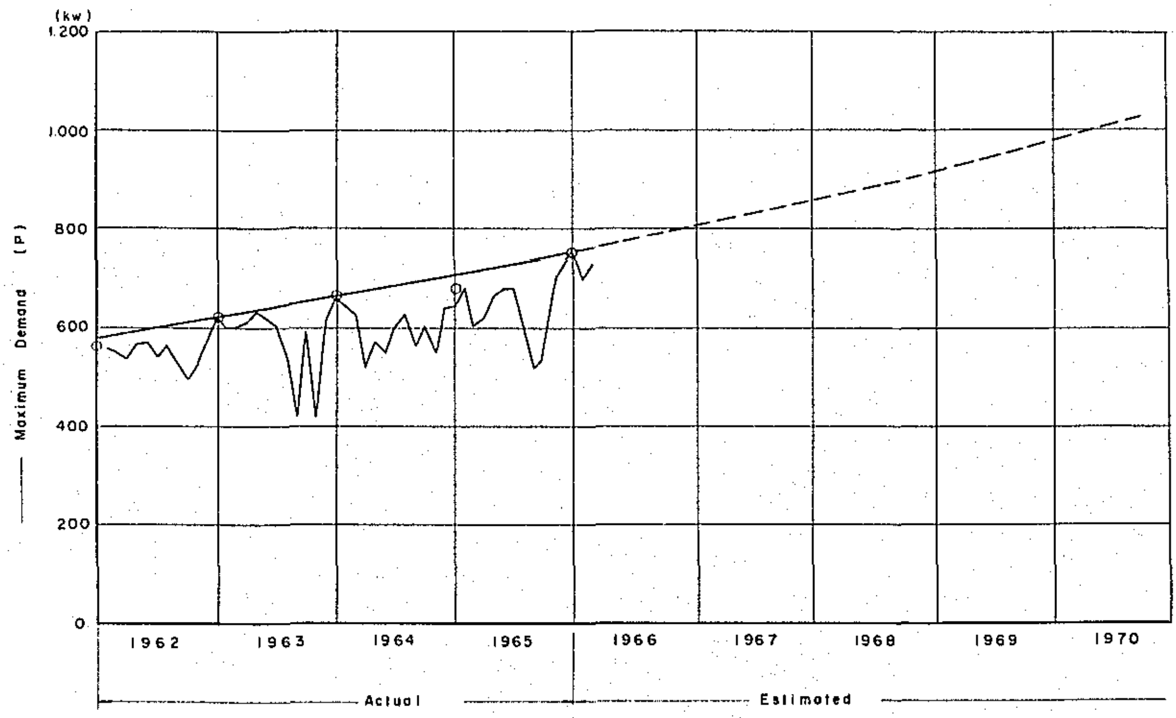


Table 3-4-1 Maximum Demand, Population and Per Capita Power Consumption of Tulcan City

Year	Maximum demand (KW)	Population 1/	Per capita consumption (W)
1962	620	16,535	37.5
1963	660	16,861	39.1
1964	680	17,193	39.6
1965	750	17,524	42.8
1966	800	17,984	44.5
1967	850	18,451	46.1
1968	910	18,927	48.1
1969	980	19,415	50.5
1970	1,050	19,874	52.9
1971	1,120	20,609	54.3
1972	1,200	21,320	56.3
1973	1,280	22,056	58.0
1974	1,370	22,817	60.0
1975	1,470	23,591	62.3
1976	1,570	24,250	64.8
1977	1,680	24,930	67.5
1978	1,800	25,630	70.2
1979	1,920	26,350	73.0
1980	2,060	27,090	76.0
1981	2,200	27,850	79.0
1982	2,360	28,630	82.2

Note 1/ Based on Proyeccion de la Poblacion Urbana Cantonal y de las Cabeceras Parroquiales 1962-1975, Junta Nacional de Planification. The annual rate of increase from 1976 estimated at 2.8 percent.

In districts other than Tulcan City, such as San Gabriel, El Angel and Parroquias, it was considered that economic activity and living standards are lower than in Tulcan, and the maximum demand was estimated between 80 and 90 percent of the per capita annual consumption in Tulcan on the basis of assumed population. The estimated demand is given in Table 3-4-2.

Table 3-4-2 Per Capita Power Consumption, Population and Maximum Demand of San Gabriel, El Angel and Parroquias in Zone A.

Year	Per capita consumption (W)	Population 1/	Maximum demand (KW)
1966	35.6	21,471	760
1967	37.4	21,629	810
1968	39.4	21,788	860
1969	42.4	21,948	930
1970	44.4	22,108	980
1971	47.2	22,272	1,050
1972	50.7	22,438	1,140
1973	52.2	22,606	1,180
1974	54.0	22,774	1,230
1975	56.1	22,942	1,280
1976	58.3	23,115	1,350
1977	60.8	23,289	1,410
1978	63.2	23,465	1,480
1979	65.7	23,643	1,550
1980	68.5	23,821	1,630
1981	71.1	24,002	1,700
1982	74.0	24,184	1,790

Note 1/ Data source: up to 1975 - Proyeccion de la Poblacion Urbana Cantonal y de las Cabeceras Parroquiales 1962-1975.

Population figures for Parroquias other than San Gabriel and El Angel were missing in part and these were supplemented based on data "Tulcan-Ibarra-Cayambe Power System" compiled by INECEL.

b. New Industrial Power Demand

As previously stated, it is anticipated that new demands will be created by the La Programa de Integracion Economica Fronteriza Colombo-Ecuatoriana and the agricultural and livestock products processing plan under the Plan Carchi, 1962, Junta Nacional de Planificacion. It is estimated that these demands shown in the table below may be created by 1975.

	Maximum demand (KW)	Demand during hours of illumination (KW)
Meat products refrigerating facilities	350	350
Dairy products processing	150	70
Machinery repair shops	200	100
Agricultural products processing plants	100	50
Water pumps	50	50
Other medim-and small-sized plants	350	150
Total	1,200 KW	770 KW

It was assumed that these demands of new industries will register an annual growth rate of 20 percent from 1967 to 1976, 18 percent from 1976 to 1979 and 16 percent in and after 1979. These estimated demands are shown in Table 3-5.

c. Integrated Maximum Demand

The integrated lighting and new industrial demands estimated in the preceding paragraph are shown in Table 3-5.

Table 3-5 Maximum Demand in Zone A

Unit : KW

Year	Tulcan	Areas other than Tulcan	New industrial demand	Total
1966	800	760	0	560
1967	850	810	170	1,830
1968	910	860	210	1,980
1969	980	930	250	2,160
1970	1,050	980	290	2,320
1971	1,120	1,050	350	2,520
1972	1,200	1,140	430	2,770
1973	1,280	1,180	520	2,980
1974	1,370	1,230	620	3,220
1975	1,470	1,280	770	3,520
1976	1,570	1,350	930	3,850
1977	1,680	1,410	1,100	4,190
1978	1,800	1,480	1,300	4,580
1979	1,920	1,550	1,540	5,010
1980	2,060	1,630	1,770	5,460
1981	2,200	1,700	2,070	5,970
1982	2,360	1,790	2,390	6,540

d. Estimated Trend of Demand on Sub-stations

The demands on the Tulcan, San Gabriel and El Angel Sub-stations were estimated from the population in the service territory of the respective sub-stations and on the assumption that industrialization will be concentrated in the city of Tulcan. The estimated demands on the respective sub-stations are given in Table 3-6.

Table 3-6 Maximum Demand of Sub-stations in Zone A

Unit : KW

Year	Tulcan	San Gabriel	El Angel	Total
1966	800	450	310	1,560
67	1,020	480	330	1,830
68	1,120	510	350	1,980
69	1,230	550	380	2,160
70	1,340	580	400	2,320
71	1,470	620	430	2,520
72	1,580	700	490	2,770
73	1,710	740	530	2,980
74	1,840	810	570	3,220
75	2,030	870	620	3,520
76	2,230	940	680	3,850
77	2,420	1,030	740	4,190
78	2,650	1,120	810	4,580
79	2,890	1,230	890	5,010
80	3,170	1,320	970	5,460
81	3,480	1,440	1,050	5,970
82	3,800	1,580	1,160	6,540

3.2.2.2 Load Factor

The annual load factor of Tulcan City from 1961 to 1965 fluctuated between 38 and 42 percent because of load restrictions principally due to shortages in supply capability in the dry season, but in 1968, when the transmission line connection between Tulcan and Ibarra is completed and the power distribution network is expanded, it is estimated that the load factor will be about 40 percent. For San Gabriel, El Angel and other districts besides Tulcan City, the annual load factor is also estimated to become about 40 percent.

It is assumed that this annual load factor will continue up to 1970, and thereafter increase to 50 percent by 1976 with the growth in demand from new industries.

However, since industries, such as chemical industries which consume power during the night-time are not planned, it is assumed that the annual load factor will continue to be 50 percent even after 1976.

3.2.2.3 Load Forecast for Zones A and B

The energy demand of Zone A is obtained from the maximum demand and load factor estimated in 3.2.2.1 and 3.2.2.2. Table 3-7 which follows gives the total of demands of Zones A and B.

The estimated annual growth rates of power and energy demand are 11 percent and 12 percent respectively. If, export of power to Colombia is considered, these growth rates will be even greater. At present, Ipiales in Colombia bordering Ecuador, is experiencing an acute shortage of electric power and from August 1966, part of the surplus power of La Playa Power Station is to be transmitted to Ipiales. However, since it is difficult to forecast the long-term export of power at this stage, transmission of power to Colombia is not considered in the forecast.

3.2.2.4 Estimated Load Curve

The weekday load curve from 1964 to 1965 of Tulcan and Ibarra which are the representative communities in the area to be supplied from San Miguel de Car Power Station are shown in Fig. 3-2. The load factor is a little over 40 percent. On the assumption that the holiday load is 80 percent of the weekday load, the weekday load of the system as a whole for each year was estemated from the KW demand and annual load factor given in Table 3-7. . Reference was made to the actual loads mentioned above in the estimate of load factors which are given in Table 3-8 below.

Table 3-7 Load Forecast for Zones A and B

	Zone A			Zone B			Total (Zones A+B)		
	Maximum demand (KW)	Annual electric energy (MWH)	Annual load factor (%)	Maximum demand (KW)	Annual electric energy (MWH)	Annual load factor (%)	Maximum demand (KW)	Annual electric energy (MWH)	Annual load factor (%)
1966	1,560	5,470	40	3,620	12,680	40	5,180	18,150	40
1967	1,830	6,410	40	3,860	13,530	40	5,690	19,940	40
1968	1,980	6,900	40	4,480	15,750	40	6,460	22,650	40
1969	2,160	7,560	40	5,050	17,700	40	7,210	25,260	40
1970	2,320	8,120	40	5,690	19,980	40	8,010	28,100	40
1971	2,520	9,220	42	6,260	23,080	42	8,780	32,300	42
1972	2,770	10,600	44	6,950	26,010	42	9,720	36,610	43
1973	2,980	12,170	46	7,680	28,930	43	10,660	41,100	44
1974	3,220	13,460	48	8,520	32,840	44	11,740	46,300	45
1975	3,520	15,010	49	9,460	37,290	45	12,980	52,300	46
1976	3,850	16,730	50	10,440	42,020	46	14,290	58,800	47
1977	4,190	18,350	50	11,520	47,750	47	15,710	66,100	48
1978	4,580	20,060	50	12,730	54,340	48	17,310	74,400	49
1979	5,010	21,940	50	14,040	61,320	50	19,050	83,260	50
1980	5,460	23,910	50	15,490	67,850	50	20,950	91,760	50
1981	5,970	26,150	50	17,080	74,810	50	23,050	100,960	50
1982	6,540	28,650	50	18,810	82,380	50	25,350	110,030	50

Note. Part of the demand from 1966 to 1967 will be potential demand as the transmission line connection between Tulcan, San Gabriel and El Angel will not be completed.

Fig 3-2 Load Curve

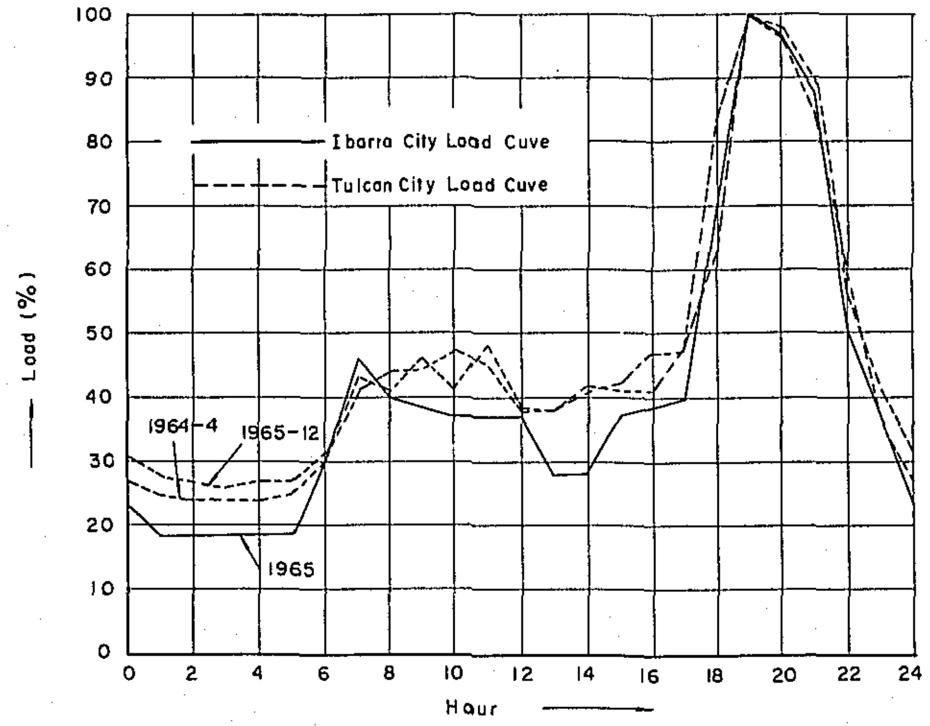


Fig 3-3 Typical System Week-Day Load Curve

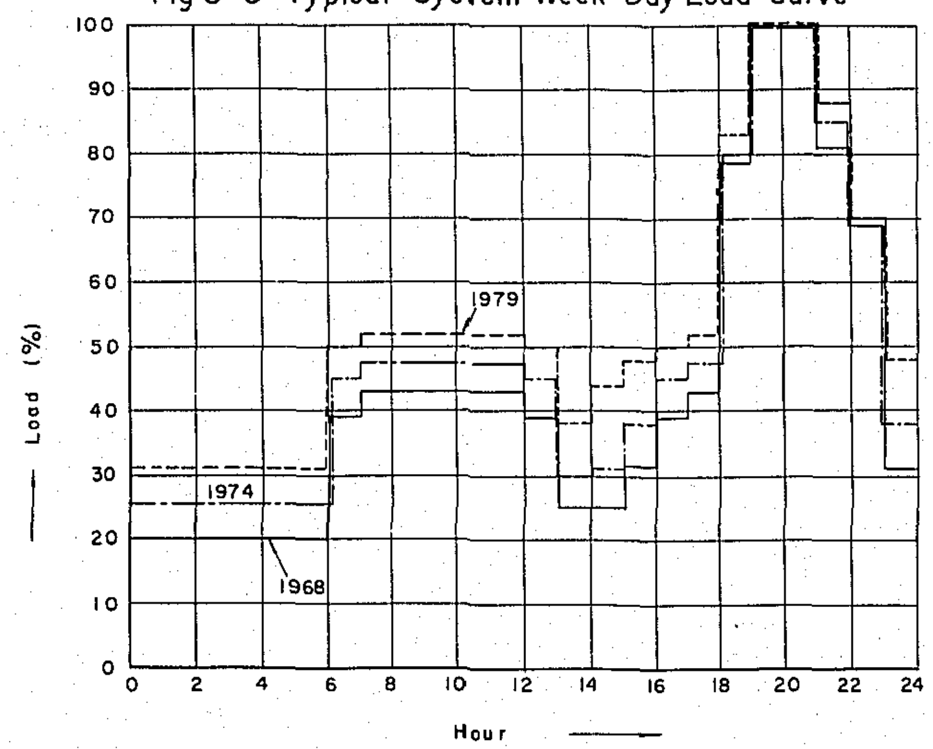


Table 3-8 Annual Load Factor and Weekday Load Factor

	1968	1969	1970	1971	1972	1973
Annual load factor (%)	40	40	40	42	43	44
Weekday load factor (%)	42.4	42.4	42.4	44.5	45.6	46.6

	1974	1975	1976	1977	1978	1979
Annual load factor (%)	45	46	47	48	49	50
Weekday load factor (%)	47.7	48.8	49.9	50.9	52.0	52.9

	1980	1981	1982
Annual load factor (%)	50	50	50
Weekday load factor (%)	52.9	52.9	52.9

The estimated weekday load curve of the entire system for 1968, 1974 and 1979 corresponding to the load factors given in Table 3-8 are as shown in Fig. 3-3.

3.3 BALANCE OF SUPPLY AND DEMAND

3.3.1 KW Balance

The month in which the maximum demand occurs on the system is December while the hydroelectric power supply capability is the smallest in September of the dry season. In view of the fact that these two conditions occur within a few months, the KW balance will be based on maximum demand in December and power supply capability in September. The period covered by the study is the 12 years from 1968 to 1979.

The supply capability in 1968 of power stations in Zones A and B is shown in Table 3-3. The KW balance based on the dry season supply capability and the December maximum demand is depicted in Fig. 3-6. It will be noted from the figure that there will exist a shortage of KWH supply capability in 1972. Even if the El Ambi Power Station is operated at its full capacity and that there is the need to have the San Miguel de Car Project in operation.

Fig. 3-4 depicts the shortage of supply capability if the San Miguel de Car Project is not in operation, while 3-5 gives the KW supply capability situation in 1972 and 1974 on the assumption that the San Miguel de Car Project is developed in two stages. Table 3-9 gives the yearly demand and supply capability and installed capacity in Zones A and B. The KW demand and supply capability table was prepared on the premise that the base load will be supplied by existing small hydro plants, that the peak load will be supplied by El Ambi Power Station which will regulate output within the maximum capability (50,000 m^3, 19,200 KWH) of its storage pond on the basis of an average natural run-off (1.3 m^3/sec, 1,800 KW) during the dry season, and that the San Miguel de Car Project will supply that part of the demand which can not be satisfied by the aforementioned sources.

In and after 1975, when there will be a shortage of supply capability, the deficiency is to be made up with diesel power. In this case, it was assumed that diesel power will be used to supply the base load in order to reduce to the minimum the capacity addition of diesel power.

The deficiency in supply capability which will be created after the San Miguel de Car Project is developed is estimated to be as follows: in 1975, 960 KW of existing stand by diesel power will be required, in and after 1976, new diesel capacity will be required and in 1979 the required diesel capacity will be approximately 4,500 KW. Therefore, before such time comes, it would be economical to develop new hydro sources in the system or to receive power from another power system.

3-3-2 Energy Balance

The annual energy requirement is also shown in Table 3-9. The energy supply capability against demand during the dry season is computed from Fig. 3-6. Required energy supply capability during the wet season is to be furnished by small hydro plants, El Ambi Power Plant and by small hydro plants, El Ambi Power Plant and by San Miguel de Car Project. If the demand can not be satisfied from these sources, then diesel power is to be employed. In the computation of energy requirement fluctuation of demand between weekdays and week-ends is taken into consideration. The results of computations shown in Table 3-9 are the basis for determining the effective energy output of San Miguel de Car Project described in Chapter 7, Power Production.

Table 3-9 Annual Maximum Power Demand and Dry Season Supply Capability, and Annual Energy Demand and Supply Capability

			1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
	Maximum demand	(KW)	6,960	7,210	8,010	8,780	9,720	10,660	11,740	12,980	14,290	15,710	17,310	19,050
	Total annual demand	(MWH)	22,650	25,260	28,100	32,300	36,610	41,100	46,300	52,300	58,800	66,100	74,400	83,260
	Supply capability power													
1.	Existing													
1.1	Hydroelectric	(KW)	2,430	2,430	2,430	2,430	2,430	2,430	2,750	2,750	2,750	2,750	2,750	2,750
1.2	Diesel	(KW)	0	0	0	0	0	0	0	400	960	960	960	960
	Sub total	(KW)	2,430	2,430	2,430	2,430	2,430	2,430	2,750	3,150	3,710	3,710	3,710	3,710
2.	New projects													
2.1	El Ambi	(KW)	3,830	4,580	5,380	6,150	6,940	6,830	7,170	7,330	7,500	7,590	7,680	7,700
2.2	El Angel (extension)	(KW)	200	200	200	200	200	200	200	200	200	200	200	200
2.3	San Miguel de Car	(KW)	-	-	-	-	150	1,200	1,620	2,300	2,650	3,000	3,000	3,000
2.4	Diesel	(KW)	-	-	-	-	-	-	-	-	230	1,210	2,720	4,440
	Sub total	(KW)	4,030	4,780	5,580	6,350	7,290	8,230	8,990	9,830	10,580	12,000	13,600	15,340
	Total	(KW)	6,460	7,210	8,010	8,780	9,720	10,660	11,740	12,980	14,290	15,710	17,310	19,050
	Supply capability energy													
1.	Hydroelectric													
1.1	San Miguel de Car	(MWH)	-	-	-	-	160	893	1,927	3,688	5,969	10,113	14,147	17,226
1.2	Other Hydroelectric	(MWH)	22,650	25,260	28,100	32,300	36,450	40,207	44,373	47,975	50,947	52,017	52,488	52,488
2	Diesel	(MWH)	-	-	-	-	-	-	-	637	1,884	3,970	7,765	13,546
	Total (year)	*(MWH)*	*22,650*	*25,260*	*28,100*	*32,300*	*36,610*	*41,100*	*46,300*	*52,300*	*58,800*	*66,100*	*74,400*	*83,260*
	Installed capacity													
1.	Existing													
1.1	Hydroelectric	(KW)	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620	3,620
1.2	Diesel	(KW)	960	960	960	960	960	960	960	960	960	960	960	960
	Sub total	(KW)	4,580	4,580	4,580	4,580	4,580	4,580	4,580	4,580	4,580	4,580	4,580	4,580
2.	New projects													
2.1	El Ambi	(KW)	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
2.2	El Angel (extension)	(KW)	200	200	200	200	200	200	200	200	200	200	200	200
2.3	San Miguel de Car	(KW)	-	-	-	-	1,500	1,500	3,000	3,000	3,000	3,000	3,000	3,000
2.4	Diesel	(KW)	-	-	-	-	-	-	-	-	500	1,500	3,000	5,000
	Sub total	(KW)	8,200	8,200	8,200	8,200	9,700	9,700	11,200	11,200	11,700	12,700	14,200	16,200
	Total	(KW)	12,780	12,780	12,780	12,780	14,280	14,280	15,780	15,780	16,280	17,280	18,780	20,780

Fig 3-4 Maximum Demand and Dry Season Output Before Completion of San Miguel de Car Project

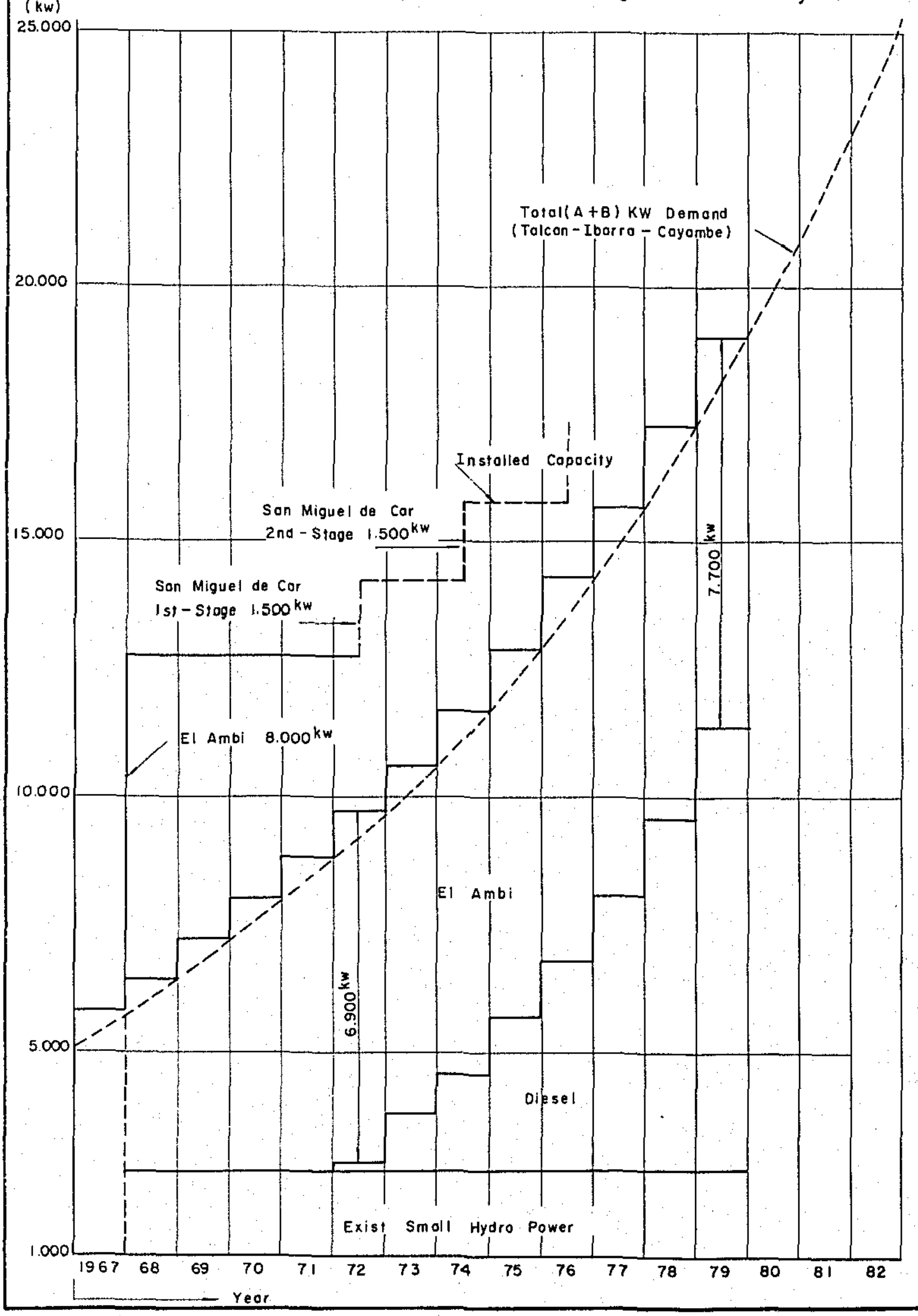


Fig 3-5 Maximum Demand and Dry Season Output After Completion of San Miguel de Car Project

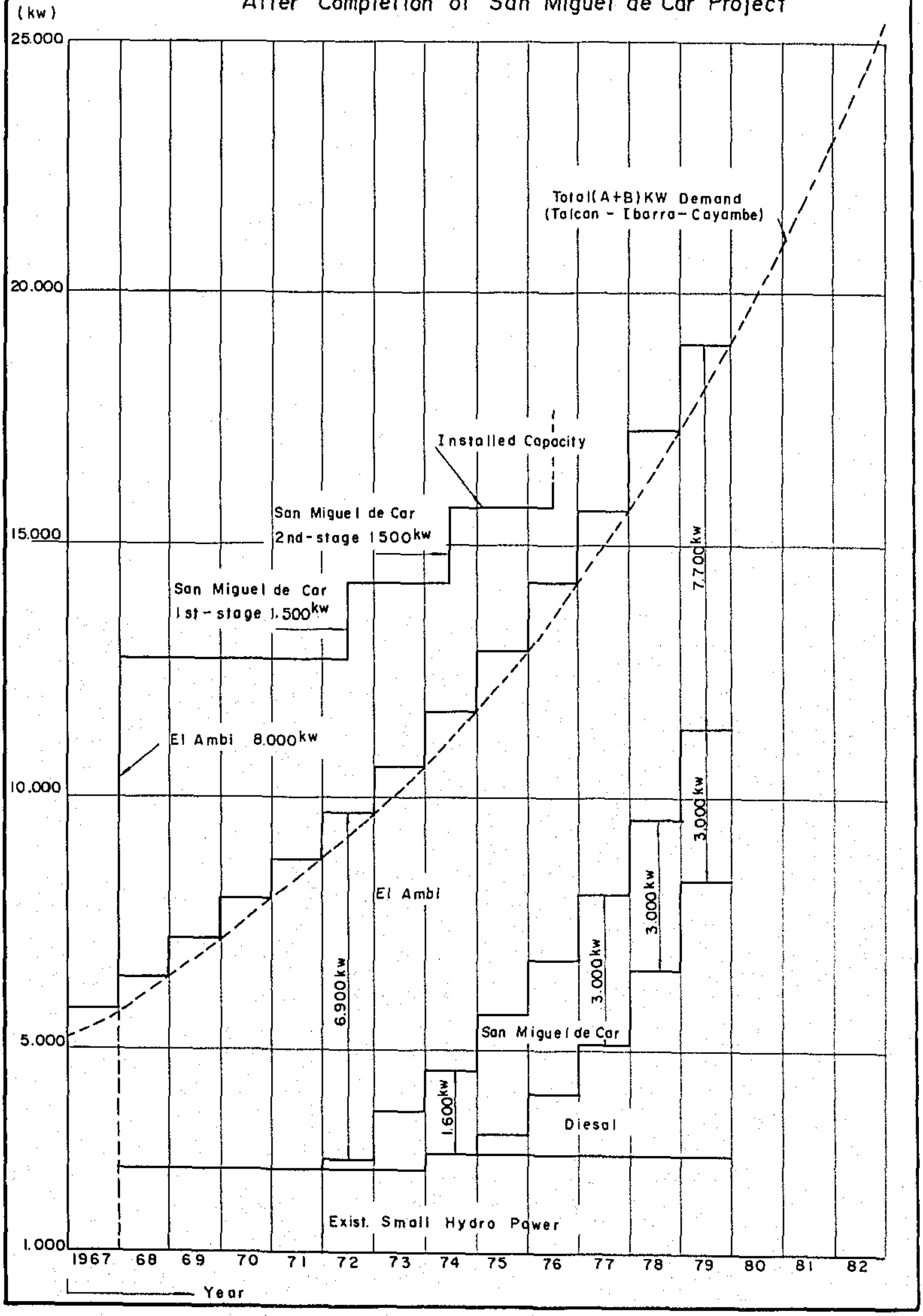
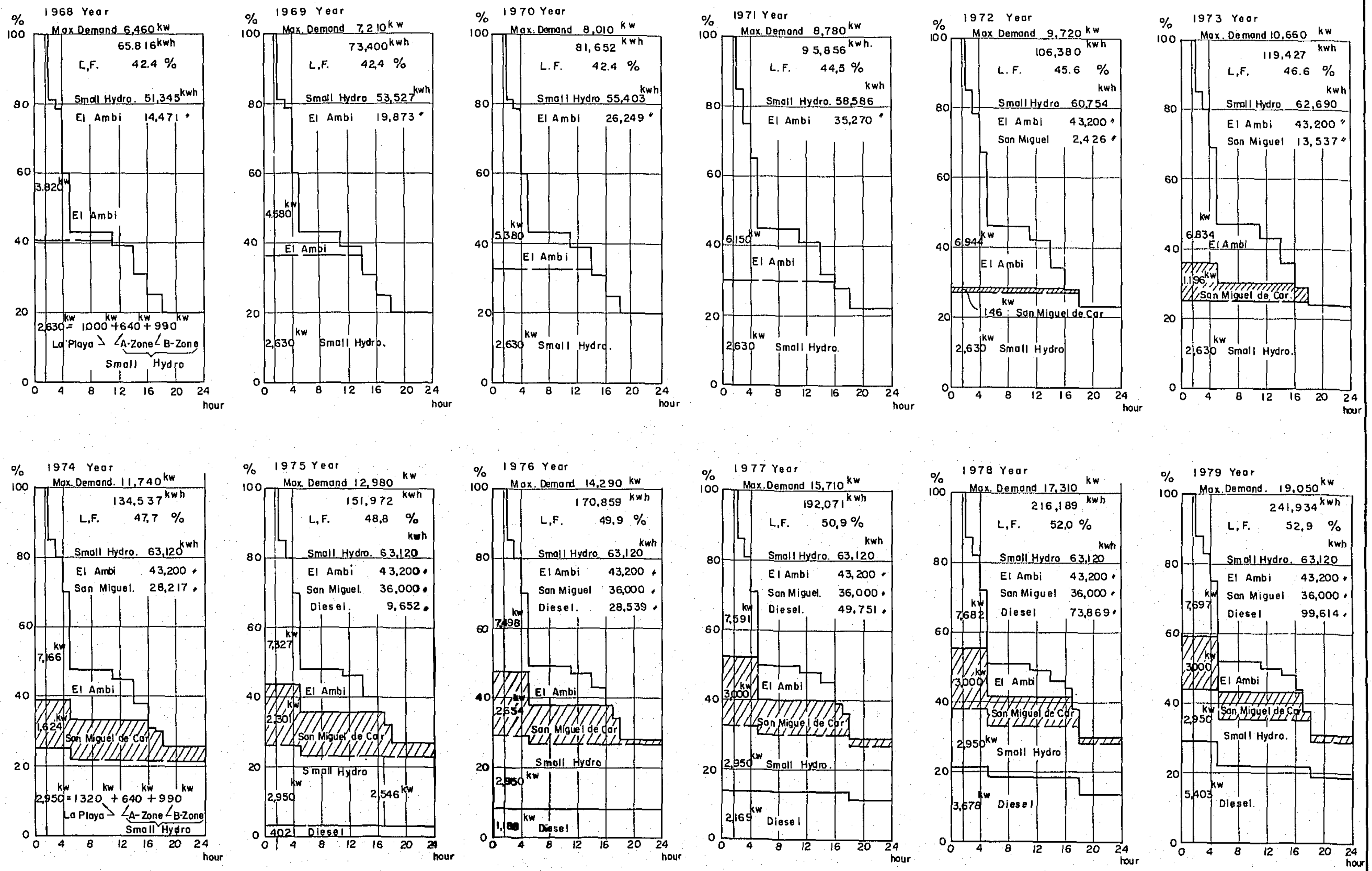


Fig 3-6 Estimated Maximum Power and Energy Demand 1968 to 1979 and Dry Season Supply Copability



3.4 TIMING OF DEVELOPMENT

It will be understood from the foregoing study that with the supply capability of hydroelectric capacity existing at the beginning of 1968 it will become necessary to operate diesel plant to supplement the deficiency of supply capability which will arise in the dry season of 1972. Therefore, in order to avoid the operation of high energy cost diesel plant, it is essential to construct the San Miguel de Car Project so that power will be available from it in 1972 at the latest. This project will also provide reserve capacity which is essential for an electric utility enterprise.

It will be most economical to develop the San Miguel de Car Project in 2 stages corresponding with the growth of demand. The first stage development of 1, 500 KW should be on the line in 1972 and the second stage development of 1, 500 KW ready for operation in 1974.

The output of the San Miguel de Car Project by natural flow during the dry season is 1, 500 KW. When the first stage 1, 500 KW of the project is developed, it can be used to supply the base load and the El Ambi Power Station will be able to fully function as a peaking station. By the time there is anticipated to arise a deficiency in peaking capacity, the second stage 1, 500 KW of the San Miguel de Car Project will be ready. With the project developed to its ultimate capacity, it will be able to regulate output corresponding to demand and thereby utilize effectively the water resources of the river. In addition to this benefit, the following are judged to be important merits of having two major plants, in different river basins, with capability of regulating output.

(1) When there is variation of time in the dry run-off season between the two stations, it will be possible for the plants to supplement each other the deficiency of supply capability during the dry season.

(2) Even in the case transmission interconnection between the two station is interrupted, it will be possible for each station to regulate output corresponding to the load within its own system.

(3) In the case either of the stations or other stations in the system are out of service, the two stations have reserve capacity which can be immediately utilized.

4. GENERAL DESCRIPTION OF PROJECT

4. GENERAL DESCRIPTION OF PROJECT

4.1 GENERAL DESCRIPTION OF PROJECT AREA

The project area is located in the Rio Carchi basin flowing through Carchi Provincia which is in the northern part of Ecuador bordering on Colombia.

The Rio Grande, Rio Chico and Rio Bobo, tributaries of the Rio Carchi, from which water will be drawn, originate from ridges between Mt. Chiles and Mt. El Pelado and flow down to join the Rio Carchi. The Rio Carchi flows past the vicinity of Tulcan City in Carchi Provincia after which it enters Colombia to become the Rio Guaitara and later the Rio Patia and, finally drains into the Pacific Ocean.

The catchment area of this river at the confluence with the Rio Bobo is approximately 350 km^2. The precipitation within the catchment area is approximately 1,000 mm annually. The mountains and hilly areas are covered with vegetation and are not bare, but there is very little growth of trees.

The river does not become completely dry in the dry season and the run-off is relatively constant.

The river gradient of the Rio Bobo upstream from the vicinity of San Miguel de Car site is approximately 1/30 while from this point downstream to the junction with the Rio Carchi the gradient is 1/130.

On the Rio Bobo, downstream of the San Miguel de Car site, La Playa Power Station with a maximum output 1,320 KW has already been developed. This power station was originally constructed by Tulcan City, but it is presently owned by Empresa Electrica Tulcan. In order to increase the dry season run-off at La Playa Power Station, Empresa Electrica

Tulcan is presently constructing a waterway to divert the waters of the Rio Grande and Rio Chico neighboring the Rio Bobo to La Cofradia. This diversion work is scheduled to be completed in August 1966.

4.2 SCHEME OF DEVELOPMENT

4.2.1 Power Station

The San Miguel de Car Hydroelectric Power Project consists of diverting the flow from a catchment area of approximately 67 km^2 of the headwaters of the Rio Bobo to a combining tank at La Cofradia by a waterway approximately 3.7 km in length, and combining this with the run-offs of a catchment area of approximately 71 km^2 of the Rio Grande and a catchment area of approximately 45 km^2 of the Rio Chico which are to be diverted to the Rio Bobo. The San Miguel de Car Power Station will have an installed capacity of 3,000 KW and generate approximately 19,900,000 KWH annually utilizing 3.0 m3/s of water under a head of 122 m. This power station will be a run-of-river type plant provided with a regulating pond capable of daily regulation.

The intake dam of the Rio Bobo will be constructed at a point where andesite is exposed at the river bed approximately 4 km upstream from the La Cofradia site. The waterway between the intake dam and the combining tank will be an open canal approximately 3,500 m long and a tunnel of approximately 220 m.

In order to provide daily regulation, a regulating pond with an effective storage capacity of approximately 28,900 m^3 at a drawdown of 3 m will be constructed. The regulating pond will be constructed on relatively gently sloping ground to the left of the Rio Bobo near La Cofradia.

The route of the penstock line and the location of the powerhouse were selected as shown in in Drawing No. 5 upon consideration of the topography and geological conditions.

In order to re-regulate the discharge of San Miguel de Car Power Station for La Playa Power Station when more than 2,700 KW is generated at San Miguel and in order to accommodate for time lag an equalizing reservoir with high water surface level at El. 2,900 m, total storage capacity of 390,000 m^3, and effective storage capacity of 30,000 m^3 at a drawdown of 0.60 m will be constructed. The site of this equalizing rerervoir will be at a point approximately 1.5 km upstream of the intake of La Playa Power Station where the river gradient of the Rio Bobo is extremely gentle and the required storage capacity can be easily secured.

The above scheme will be constructed in two stages corresponding with growth in power demand. The description of the work is as follows:

First Stage (Completion: 1972)

1. Diversion works to divert flow of the Rio Grande and Rio Chico to the Rio Bobo. (These works are presently under way in order to increase the output of the existing La Playa Power Station and scheduled to be completed in August 1966)

2. Waterway between Rio Bobo intake dam and head tank. Hydraulic structures such as combining tank, regulating pond, head tank, penstock line, powerhouse, tailrace, etc. (The regulating pond is included in the First Stage in view of the topography of the site and the fact that the Second Stage is scheduled to be completed only two years after the First Stage.)

3. Turbine and generator, No. 1 unit (output 1,500 KW) and appurtenant facilities.

Second Stage (Completion: 1974)

1. Turbine and generator, No. 2 unit and appurtenent facilities.

2. Equalizing reservoir.

4.2.2 Transmission System

The energy produced at San Miguel de Car Power Station, which will have an output of 3,000 KW, will be transmitted to Tulcan Sub-station for distribution in Tulcan City, and interconnection with the Tulcan - San Gabriel - Ibarra Transmission Line will be made at Tulcan Sub-station in order to supply electricity to San Gabriel, El Angel, etc. in Carchi Provincia and Ibarra, etc. in Inbaburra Provincia.

The transmission system is indicated in Fig. 4-1, and a description of the proposed transmission lines is given below.

(1) San Miguel de Car Power Station - Tulcan

The transmission line from San Miguel de Car Power Station to Tulcan will be a 34.5 KV single circuit line 9 km long. The route of the transmission line will pass the hilly area on the right bank of the Rio Bobo in a roughly straight line.
The topography of this area is gently sloping hills with few trees. The road to Tulcan crosses the transmission line route at several places and this is convenient for the construction and maintenance of the line.

(2) Tulcan - San Gabriel - El Angel

The Transmission line from Tulcan to El Angel via San Gabriel will be 1 circuit 46 km long with a voltage of 34.5 KV. The route of the transmission line will be planned to run parallel with the Pan American Highway which is thought to be optimum from the viewpoint of construction and maintenance.

(3) San Gabriel - Ibarra

The transmission line from San Gabriel to Ibarra will be a single circuit 34.5 KV line 50 km long. No detailed studies have especially been made regarding the route of the line, but from the viewpoint of construction and maintenance it would appear it should be planned along the Pan American Highway. This line is for the purpose of interchange of power between Zone A and Zone B, and it cannot be said to be a part of the San Miguel de Car Project. However, as this report is based on the premise of interconnection with the El Ambi Power Plant, one half of the cost of the transmission line is allocated to the San Miguel de Car Project.

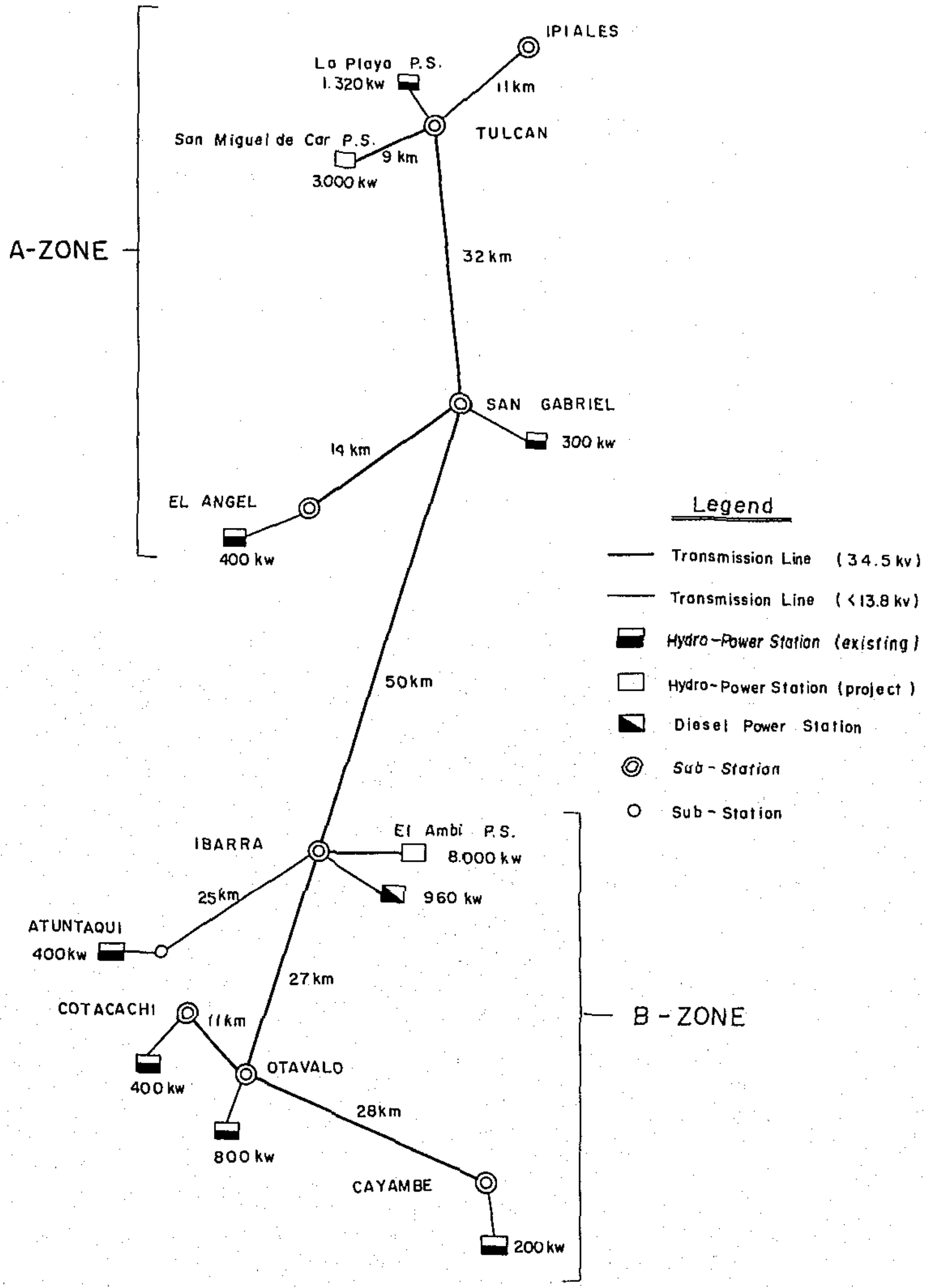
(4) Sub-stations

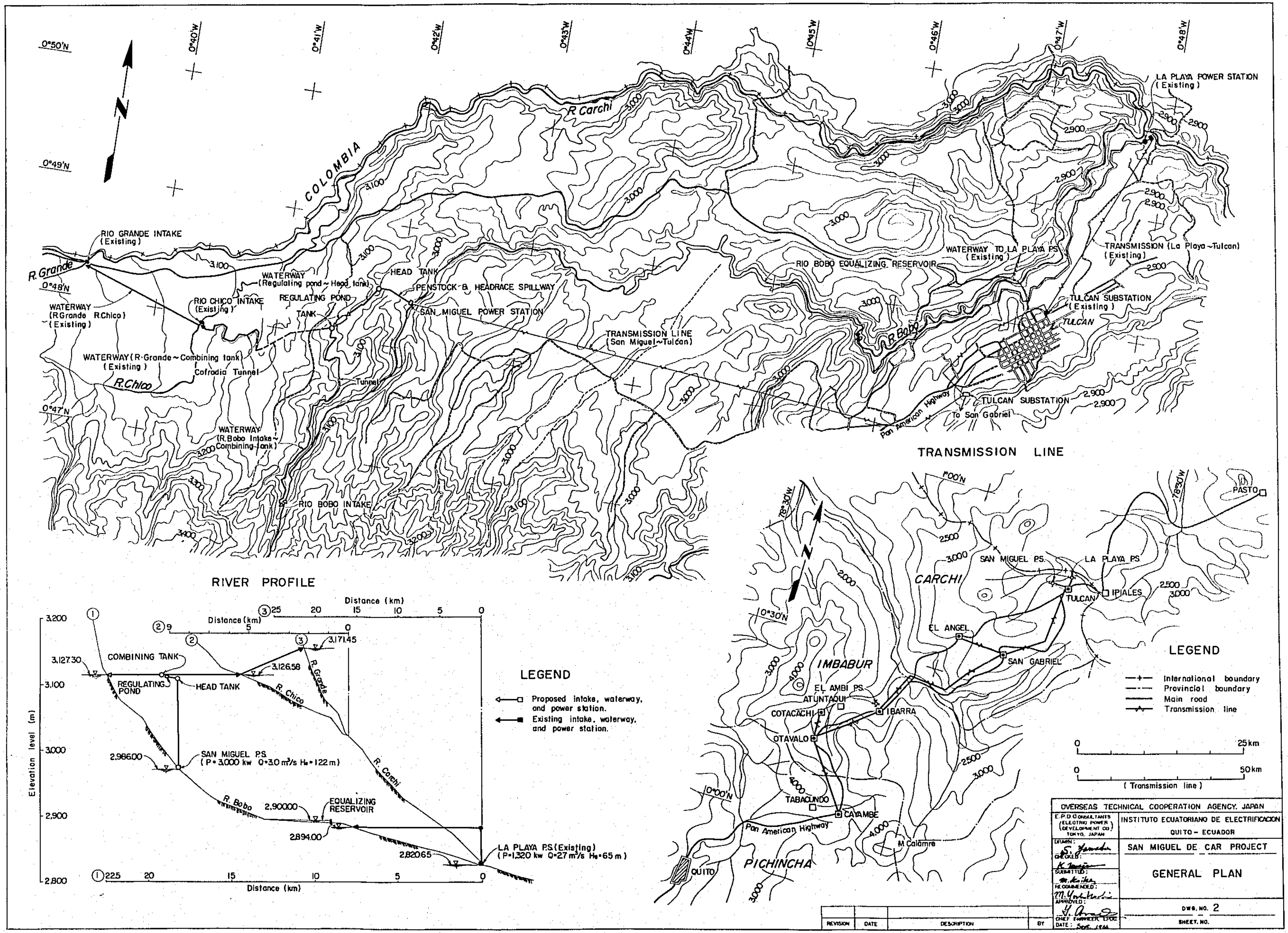
Sub-stations will be constructed at Tulcan, San Gabriel and El Angel. In 1968, when the interconnection between Tulcan and Ibarra will be made, transformers of 1,500 KVA x 1 unit, 500 KVA x 1 unit and 300 KVA x 1 unit will be installed at Tulcan, San Gabriel and El Angel Sub-stations respectively. In 1972, a 500 KVA transformer will be added at San Gabriel Sub-station and in 1975 a 300 KVA transformer will be added at El Angel Sub-station while in 1977, a 1,500 KVA transformer will be added at Tulcan Sub-station. In 1979, transformers of 500 KVA x 1 unit and 300 KVA x 1 unit respectively will be added at San Gabriel and El Angel Sub-stations.

4.2.3 Communication System

Power line carrier telephones will be installed at San Miguel de Car Power Station and Tulcan, San Gabriel, El Angel, Ibarra Sub-stations, etc. Tulcan Sub-station will be the main station and the others will be branch stations.

Fig 4-1 Transmission Network





LA PLAYA POWER STATION (Existing)
R. Carchi
COLOMBIA
R. Grande
RIO GRANDE INTAKE (Existing)
WATERWAY (Regulating pond ~ Head tank)
HEAD TANK
PENSTOCK & HEADRACE SPILLWAY
SAN MIGUEL POWER STATION
REGULATING POND
TANK
RIO CHICO INTAKE (Existing)
WATERWAY (R.Grande R.Chico) (Existing)
WATERWAY (R.Grande ~ Combining tank) (Existing)
Cofradia Tunnel
R. Chico
Tunnel
WATERWAY (R.Bobo Intake ~ Combining tank)
RIO BOBO INTAKE
TRANSMISSION LINE (San Miguel ~ Tulcan)
RIO BOBO EQUALIZING RESERVOIR
WATERWAY TO LA PLAYA P.S. (Existing)
TRANSMISSION (La Playa ~ Tulcan) (Existing)
TULCAN SUBSTATION (Existing)
TULCAN
R. Bobo
Pan American Highway
TULCAN SUBSTATION
To San Gabriel
TRANSMISSION LINE
RIVER PROFILE
Distance (km)
Elevation level (m)
COMBINING TANK
REGULATING POND
HEAD TANK
R. Grande
R. Chico
R. Carchi
R. Bobo
SAN MIGUEL P.S. (P=3,000 kw Q=3.0 m³/s He=122 m)
EQUALIZING RESERVOIR
LA PLAYA P.S. (Existing) (P=1,320 kw Q=2.7 m³/s He=65 m)
LEGEND
Proposed intake, waterway, and power station.
Existing intake, waterway, and power station.
PASTO
CARCHI
SAN MIGUEL P.S.
LA PLAYA P.S.
TULCAN
IPIALES
EL ANGEL
SAN GABRIEL
IMBABUR
EL AMBI P.S.
ATUNTAQUI
COTACACHI
IBARRA
OTAVALO
TABACUNDO
CAYAMBE
Pan American Highway
M. Calamre
PICHINCHA
QUITO
LEGEND
International boundary
Provincial boundary
Main road
Transmission line
(Transmission line)
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
E.P.D.C. CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO.) TOKYO, JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION QUITO - ECUADOR
SAN MIGUEL DE CAR PROJECT
GENERAL PLAN
DWG. NO. 2
SHEET NO.
REVISION
DATE
DESCRIPTION
BY

5. HYDROLOGY

5. HYDROLOGY

5.1 RUN-OFF GAGING STATIONS AND METEOROLOGICAL STATIONS

The locations of meteorological stations and run-off gaging stations in the catchment area and surrounding areas of the San Miguel de Car Hydroelectric Power Project are shown in Fig. 5-1, and the records of run-off and precipitation are shown in Table 5-1 and Table 5-2.

The Tulcan Station is the only precipitation observatory near the project catchment area. However, besides being close to the project area, the daily precipitation records of a period of over 15 years is available, and these data can be considered to be useful for preparation of the power development scheme.

Run-off gaging stations in the project basin are established on three rivers, namely the Rio Grande, Rio Chico and Rio Bobo. However, available recorded data of run-off cover only several observations and also water level observations cover only a period of a few months. Therefore, the data available at these stations can merely serve as references.

However, data of electricity generated for 4 years from 1962 at the La Playa Power Station which draws water from the Rio Bobo are available and these data can be considered to be extremely valuable for the purpose of this project. In addition, the data available at run-off gaging stations outside of the project catchment area, though almost all of them cover only short periods, are helpful in assuming the run-off in the wet season which has not been recorded at the La Playa Power Station. An analysis of run-off and flood flow at the proposed site of the project is made herein.

TABLE 5-1 Existing Data on River Run-off

Legend: —— Run-off; ---- Water Level

			Catchment Area (sq. km)	Distance of River (km)	Altitude (m)	Number of Index	Period '54	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66
Guaitara	La Playa Intake	Bobo	128	30	2,896	-	Generating Record of La Playa P.S.											
	R. Grande	Carchi (Grande)	70	35	3,160	-												
	R. Chico	Chico	36	18	3,120	-												
	R. Bobo	Bobo	46	30	2,930	-												
Mira	Fst FF.CC Carchi	Mira	4,140	180	1,240	2-a-1									Oct.		Jan.	Jan.
	Des. Lazo San Pablo	Peguche	205	231	2,675	2-c-1									Jul.		Jan.	Jan.
	D.J. Rio Cariyacu	Ambi	700	213	2,015	2-b-1									Aug.		Sep.	Sep.
	D.J. Rio Minas	Apaqui	385	240	2,750	2-g-1									Aug.		Jan.	Jan.
	A. Gruta Rumichaca	"	860	221	2,410	2-g-2									Sep.			
	Hotel Chicapam	Lago San Pablo	160	232	2,680	2-h-1									Jul.			
		Mira				2-a-2									Sep.		Sep.	
Esmeraldas	A.J. Guachala	Granobles	410	237	2,750	13-g-1								Apr.		Sep.	Sep.	
	A.J. Granobles	Guachala	360	238	2,740	13-h-1	Apr.											
	Apuelo	Intag	160	181	1,500	13-i-1								Sep.		Jan.		

Table 5-2 Existing Data on Precipitation

Station	Longtude o '	Latitude o '	Altitude m	Province	'50	'51	'52	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66
Tulcan	77 42 w	00 49 N	2,950	Carchi	Jan.			Daily	Records												
El Angel	77 56 w	00 37 N	3,055	"													Nov.				
San Gabriel	77 50 w	00 36 N	2,860	"													Nov.				
Salinas-Imababura	78 06 w	00 30 N	1,730	Imbabura																	
Ibarra	78 08 w	00 21 N	2,228	"																	
Atuntaqul	78 13 w	00 20 N	2,350	"													Mar				
Sigsicunga	78 21 w	00 15 N	3,111	"													May				
Otavalo	78 16 w	00 14 N	2,556	"														Jun			
San Pablo	78 16 w	00 12 N	2,680	"																	
Tabacundo	78 13 w	00 03 N	2,876	Pichincha																	
Jerusalen	78 07 w	00 01 N	2,300	"														Apr.			
Quito Observatorio	78 30 w	00 13 N	2,812																		

5.2 PRECIPITATION

This area located in the Andes Mountain zone, is far from the rain front in the winter season of June through September and has little precipitation, the average being 30 to 40 mm monthly. In the summer season of October through July, however, the rain front covers the mountainous region and brings a considerable amount of precipitation averaging 70 to 100 mm monthly, and at times almost 300 mm monthly. (See Fig. 5-3)

The annual pattern of precipitation recorded at the Tulcan Station which is near the proposed project area is shown in Fig. 5-2. As observed in this figure the annual precipitation of the recent 4 or 5 years is approximately the average precipitation of the past 15 years, which is about 700 mm.

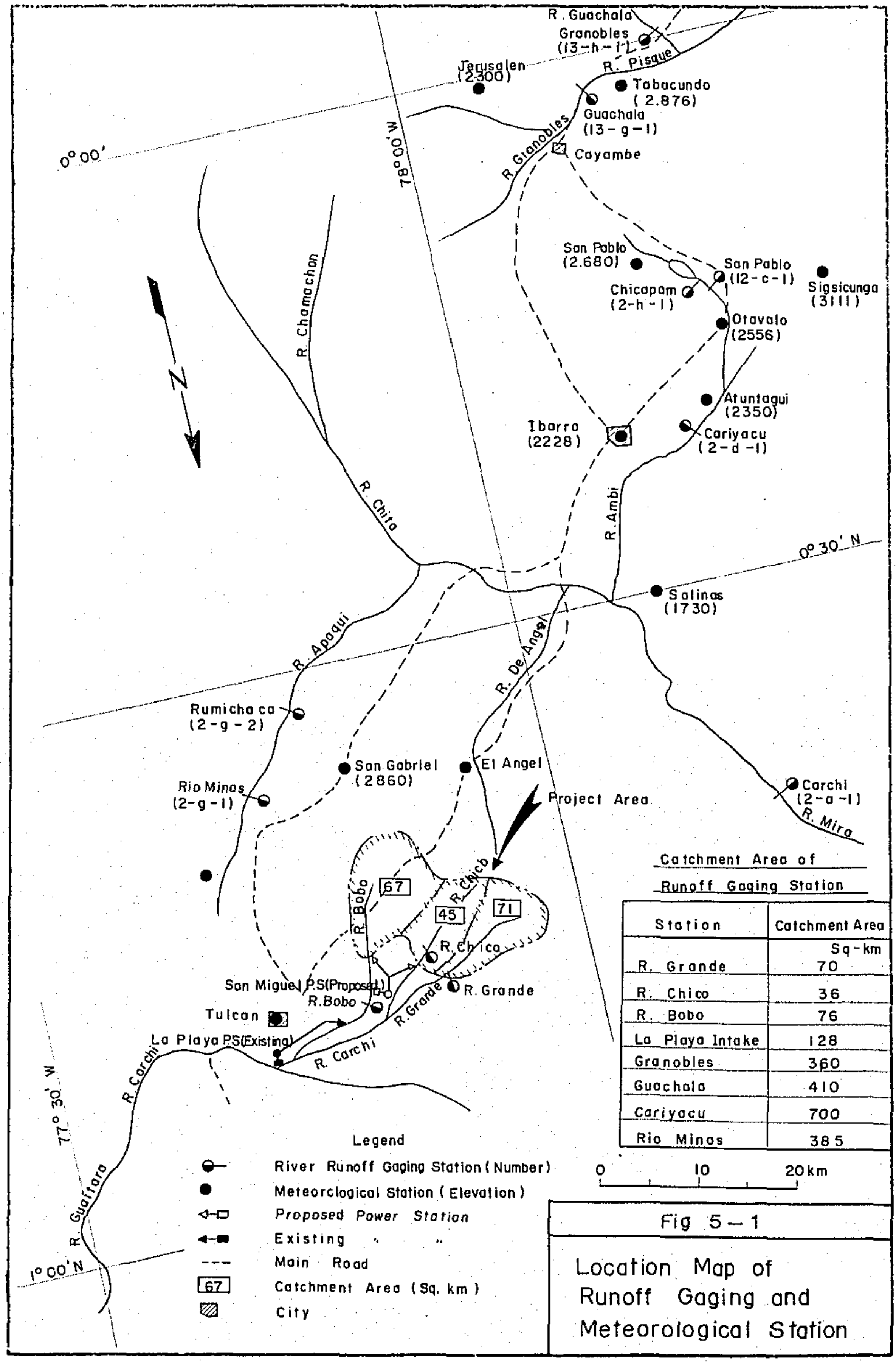
Studying the distribution of precipitation according to areas from the isohyetal map of annual precipitation prepared by Servicio Nacional de Meteorologia e Hidrologia based upon the precipitation data of 1964, the proposed project area has an annual precipitation of approximately 1,000 mm, which is 200 to 300 mm more than in Tulcan City, as it lies on a higher elevation than Tulcan. (See Fig. 5-4)

5.3 RIVER RUN-OFF

5.3.1 Treatment of Run-Off Data

5.3.1.1 Record of Power Generation of La Playa Power Station

Detailed records of daily power generation at the La Playa Power Station for the period of 1962 through 1965 are available. By the use of Fig. 5-5 these records of power generation can be converted into the run-off taken in at the La Playa Intake Dam. The maximum intake



Catchment Area of Runoff Gaging Station

Station	Catchment Area
	Sq-km
R. Grande	70
R. Chico	36
R. Bobo	76
La Playa Intake	128
Granobles	360
Guachala	410
Cariyacu	700
Rio Minas	385

Fig 5-1

Location Map of Runoff Gaging and Meteorological Station

Fig 5-2 Annual Precipitation

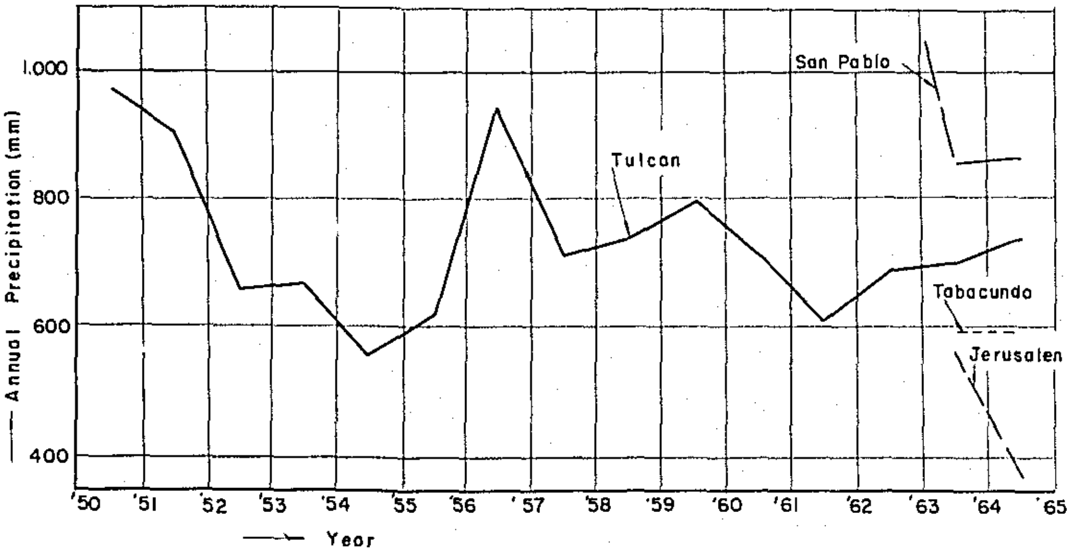


Fig 5-3 Monthly Precipitation at Tulcan (1950 to 1965)

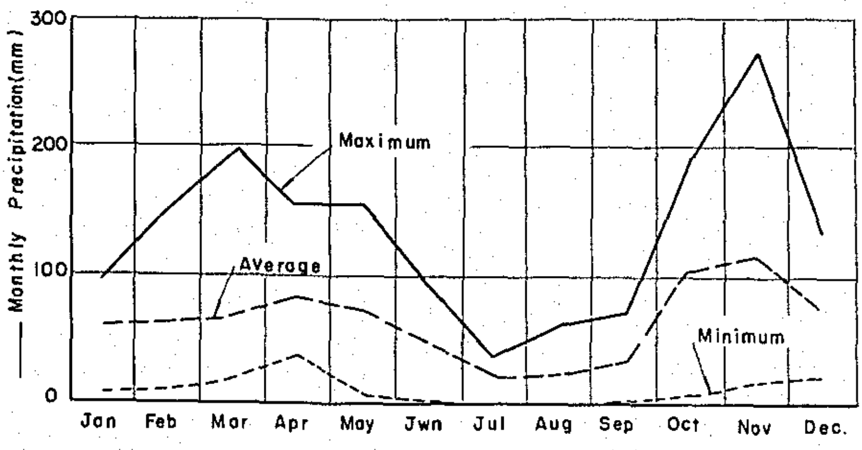


Fig 5-4 Annual Isohyetal Map(1964)

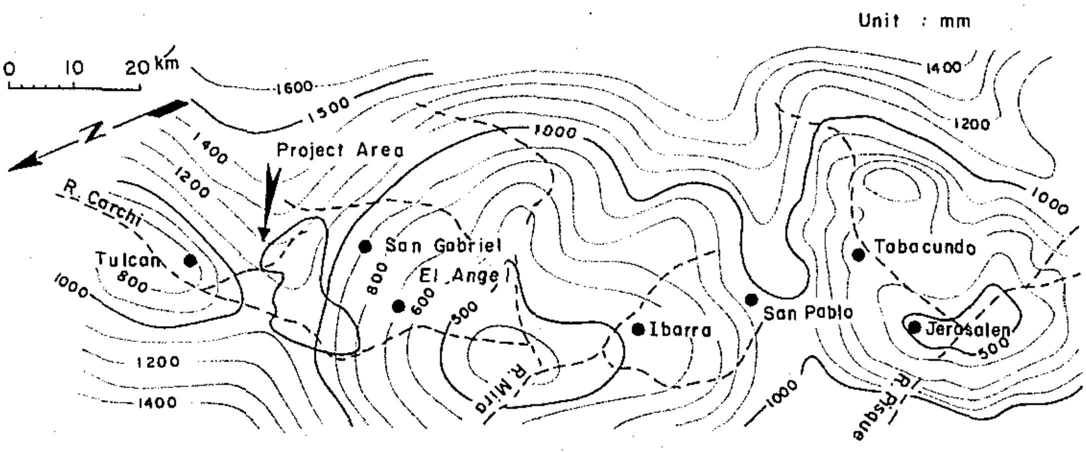
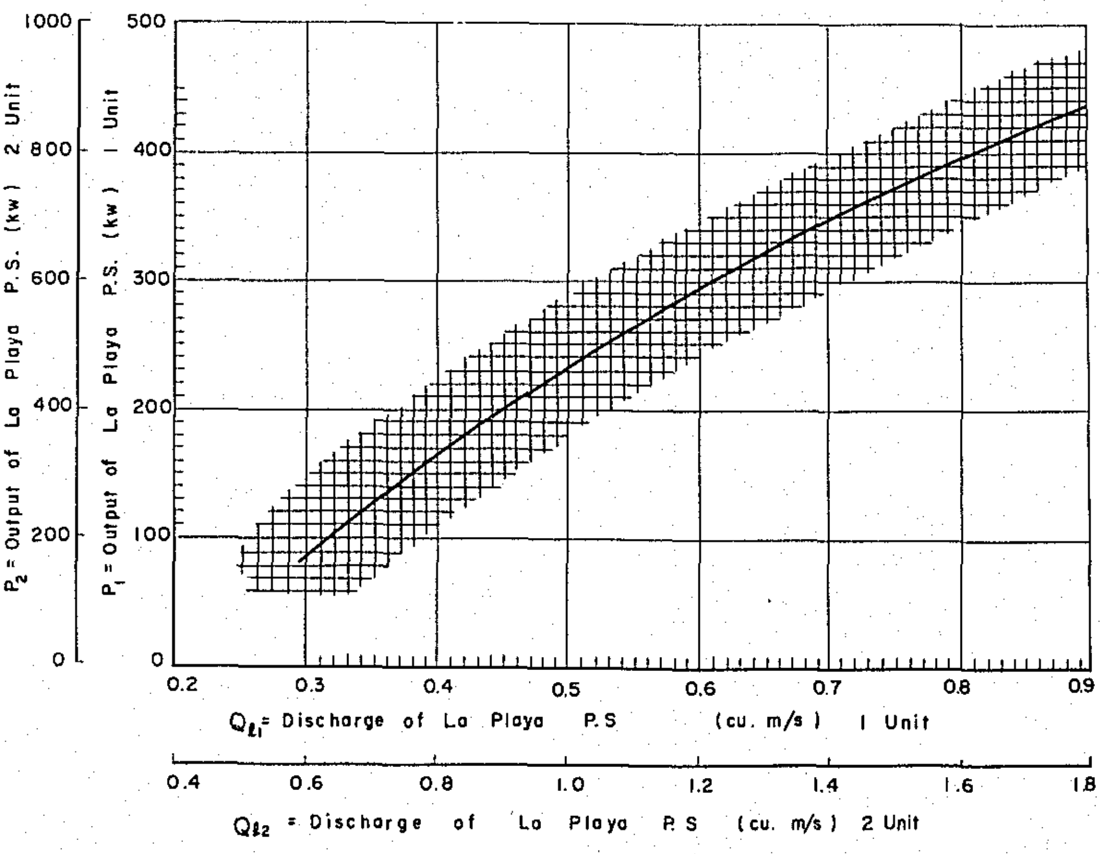


Fig 5-5 Relation Betwean Output and Discharge of La Playa Power Station



of the La Playa Intake is 2.70 m^3/s, and any run-off in excess of this amount is spilled over the overflow weir into the Rio Bobo. The amount of spilled water has not been recorded, but the run-off in the dry season of June through September hardly exceeds 2.70 m^3/s, and therefore, the run-off converted from the recorded power generation can be considered to represent the run-off of the Rio Bobo at the site of La Playa Intake.

5.3.1.2 Gaging Stations Outside of Catchment Area (Granobles, Guachala, R. Minas and Cariyacu)

As described in the preceding paragraph, the run-off in the dry season can be obtained from the recorded power generation of La Playa Power Station. Further, in order to obtain the run-off in the wet season, reference was made to available data of gaging stations outside of the catchment area of San Miguel de Car.

The catchment area of San Miguel de Car resembles the basin of the Rio Pisque, where the Granobles and Guachala Gaging Stations are located, and the basin of the Rio Apaqui where the Minas Gaging Station exists, in distribution of precipitation (see Fig. 5-4) and also in topography.

The Granobles Station has daily records of run-off for more than 10 years, which are dependable as the station is well equipped with gaging instruments. Data of Guachala Station in the same basin covers a short period of only 2 or 3 years, but since the frequency of measurements is high, these are also reliable.

Although the only available data at the Minas Station are the records of water level for the period of 1964 through 1965, a fairly reliable rating curve can be drawn from recorded run-off data. Thus, it is possible to calculate the run-off at Minas for 1964 and 1965, and these values can be used as reference because they are data of a gaging station in a basin adjacent to the proposed project area. In addition to this, available data at the Cariyacu Gaging Station, a relatively reliable gaging station in the basin of the Rio Ambi, can also be useful as a reference, although it is in an area with less precipitation in comparison to the proposed project area.

5.3.2 Method of Estimating Run-Off

A flow-duration curve is essential as run-off data to determine the scale of the San Miguel de Car Project and to calculate the electric energy to be generated. The duration curve is obtained through the methods described in the following sub-paragraphs.

5.3.2.1 Run-Off in the Dry Season (June - September)

The run-off per 100 sq.km at the La Playa Intake Dam site, converted from the recorded power generation at the La Playa Power Station by the use of Fig. 5-5, is shown in Table 5-3 below.

Table 5-3 Specific Run-off During Dry Season

(m3/s per 100 km^2)

Year	June	July	August	September
1962	0.90	0.90	0.87	0.84
1963	0.99	0.93	0.74	0.62
1964	1.00	0.99	0.92	0.96
1965	1.06	1.02	0.89	0.85
Average	0.98	0.96	0.86	0.82

The figures in the above Table 5-3 represent the values for the Rio Bobo. These values are also applicable to the basins of the Rio Grande and the Rio Chico because the conditions of the basins of these two rivers are judged to be practically the same as in the catchment area of the Rio Bobo.

Therefore, the duration curve for 4 months in the dry season can be obtained from the daily run-off at the La Playa Power Station on the basis of ratio of catchment area. The curve thus obtained for the 4 dry months fits into the period between the 243rd day and 365th day of Fig. 5-6.

5.3.2.2 Run-Off of the Wet Season (October - May)

A flow-duration curve for the wet season can be obtained from the duration curves of the four nearby gaging stations mentioned in 5.3.1.2. The hydrograph per unit area at each of these 4 gaging stations differs from each other, but on the assumption that the 243-day run-off at each station is equal to that for the same period at San Miguel de Car for the purpose of grasping the shape of the flow duration-curve, the duration-curve in the wet season would be as shown in Fig. 5-6. These duration curves are approximately similar. Therefore, the stable line of Fig. 5-6 which roughly represents the mean value of these curves is assumed to be the flow duration-curve for the wet season of the San Miguel de Car catchment area, taking a safety factor into consideration.

Since the effect of run-off in the wet season will not have a great bearing on the determination of the scale of development and energy output, the run-off of the wet season assumed in the manner described above should be adequate for the purpose of this project.

Apart from estimating run-off as described above from the duration curves of the nearby gaging stations, the correlations between run-off at each station and precipitation within each station's catchment areas were obtained and these were applied to the San Miguel de Car Project in order to estimate run-off from precipitation records, but reliable results could not be obtained for the purpose of the project study due to limited availability of precipitation and run-off data.

The run-off at the proposed site of the San Miguel de Car Project was estimated from data available for the period of 4 years from 1962 to 1965. As described in 5.2, the average annual precipitation in the past 15 years is approximately 730 mm, whereas the average of these 4 years recorded in Tulcan City is about 690 mm annually. Since the average for the 4 years is approximate to the 15 years average and on the conservative side, it is judged that the run-off estimated from the 4 years average may be used for the purpose of this project.

5.3.3 Run-Off at the Proposed Project Site

The flow-duration curve at each intake site of San Miguel de Car Project, namely, Rio Grande (CA - 71 km^2), Rio Chico (CA-45 km^2) and Rio Bobo (CA-67 km^2), as obtained by the method described in the preceding paragraph is shown in Fig. 5-7, and the average annual run-off at each intake site calculated from the curve tabulated in Table 5-4 below.

Table 5-4 Average Annual Run-off

River	Catchment Area (km^2)	Average Annual Run-off (m3/s)
Rio Grande	71	0.99
Rio Chico	45	0.63
Rio Bobo	67	0.93
Total	183	2.55
Rio Bobo at La Playa Intake	(128)	(1.58)

Table 5-5 represents the monthly run-off at the San Miguel de Car Project site. The values for the 4 months of the dry season are run-off converted from the records of power generation at the La Playa Power Station, and the values for the other months are the total annual run-off obtained from the aforementioned flow-duration curve, less the run-off of the 4-month dry season, which have been distributed in proportion to the ratio of monthly precipitation recorded in Tulcan City.

Table 5-5 Monthly Distribution of Run-off

	Run-off in m3/s				Remark	
Month	R. Grande (71 sq.km)	R. Chico (45 sq.km)	R. Bobo (67 sq.km)	Total (183 sq.km)	Specific * run-off	Precipitation of Tulcan in mm **
					cu.m/s/ 100 sq.km	
Jan.	0.90	0.57	0.84	2.31	-	61.4
Feb.	0.91	0.58	0.86	2.35	-	62.2
Mar.	0.98	0.62	0.93	2.53	-	67.3
Apr.	1.23	0.78	1.15	3.16	-	84.1
May	1.04	0.66	0.98	2.68	-	71.2
June	0.70	0.44	0.66	1.80	0.98	(46.2)
July	0.68	0.43	0.64	1.75	0.96	(24.0)
Aug.	0.61	0.39	0.58	1.58	0.86	(25.9)
Sep.	0.58	0.37	0.55	1.50	0.82	(31.8)
Oct.	1.48	0.94	1.39	3.81	-	101.1
Nov.	1.70	1.08	1.60	4.38	-	116.5
Dec.	1.05	0.66	0.99	2.70	-	71.7
Annual Average	0.99	0.63	0.93	2.55	-	79.5***

Note: * See Table 5-3.

** Average of 15 years precipitation.

*** The values in parenthesis are not included.

Fig 5-6 Flow-Duration Curve of San Miguel de Car Project

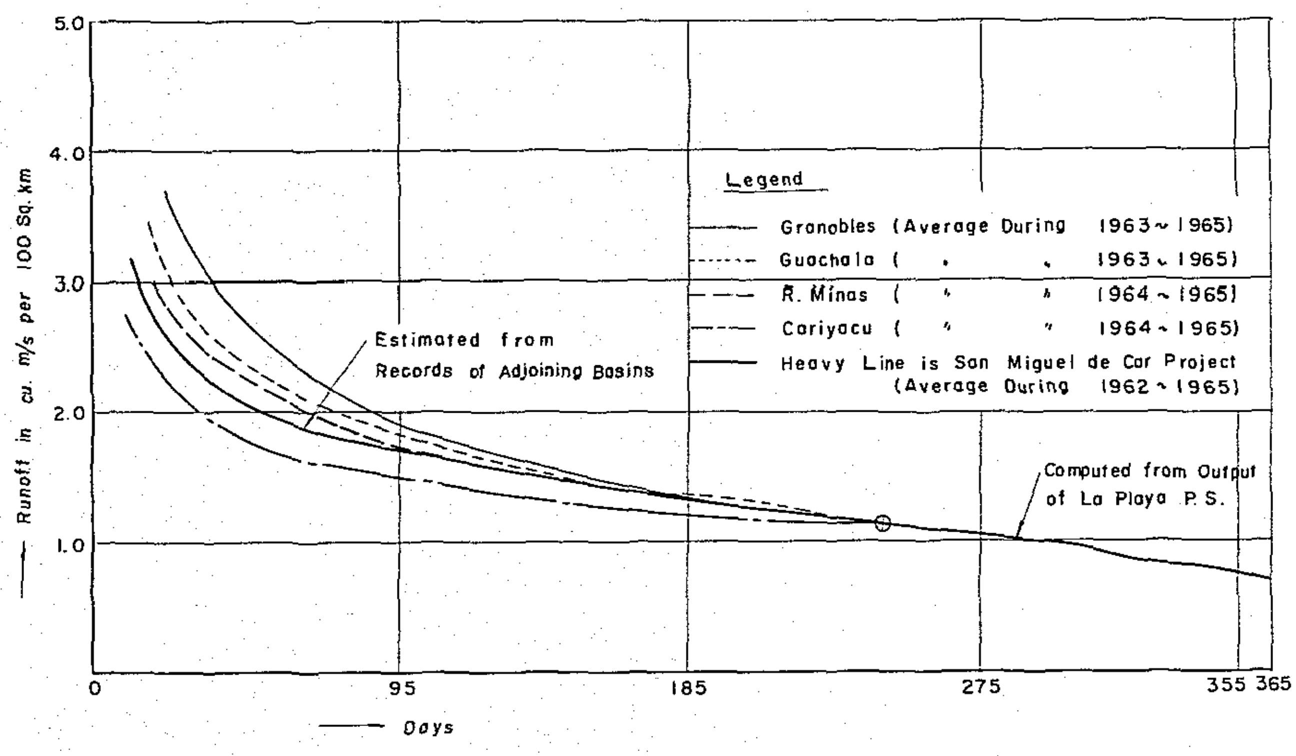
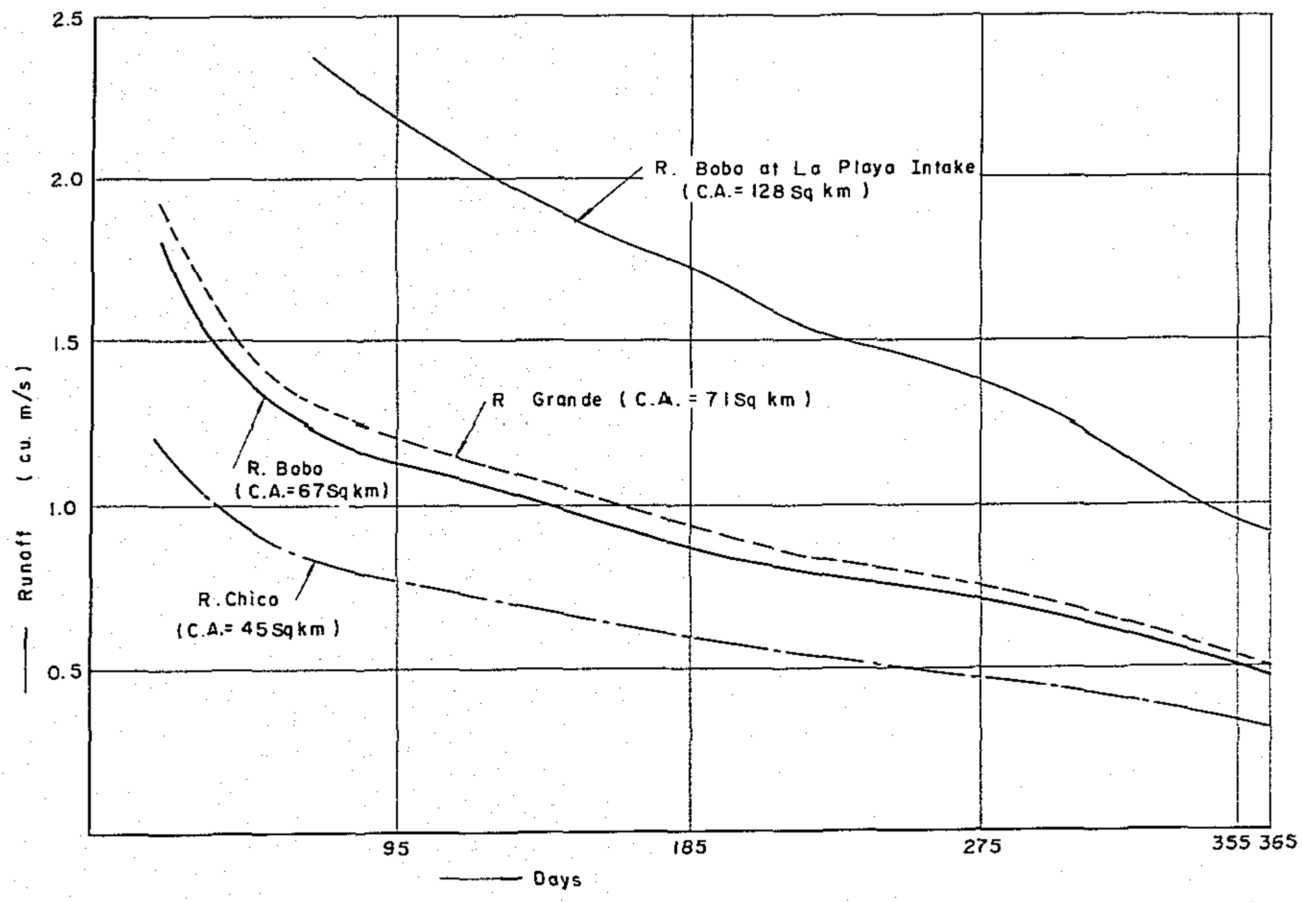


Fig 5-7 Flow - Duration Curve of San Miguel de Car Project



5.4 FLOOD FLOW

5.4.1 Method of Estimating Flood Flow

There are no records of flood flows at the gaging stations on the Rio Grande, Rio Chico and Rio Bobo mentioned in 5.1.1. It is normally possible to estimate flood flow from precipitation by various formulae in the absence of recorded data. However, it is impossible to estimate flood flow in the case of this project as there is no precipitation observation station located at a suitable place in the catchment area. Therefore, the design flood flow for the La Playa Intake Dam is taken as a basis of calculating flood flow.

The design flood flow for the La Playa Intake Dam is assumed to be about 80 m^3/s in view of the shape of the structure and other factors, or 0.62 m^3/s per km^2 expressed in terms of specific run-off. However, to be on the safe side, a specific run-off of 2.5 times of the above specific run-off, namely 1.50 m^3/s per km^2, was applied for this project.

5.4.2 Design Flood Flow

The design flood flow at each point of the project obtained by using the above specific run-off of 1.5 m^3/s per km^2 is tabulated in Table 5-6 below.

Table 5-6 Design Flood Flow

Station	Catchment Area	Design Flood Flow
Rio Bobo Intake Dam	67 km^2	100 m^3/s
San Miguel Power Station	80 "	120 "
Equalizing Dam	115 "	180 "

5.5 SEDIMENTATION

Deposits of sand are found at numerous places in the Rio Bobo. It is necessary, therefore, to estimate probable deposition of sediment if regulation of run-off is to be made by construction of an equalizing reservoir. According to field observation of sedimentation in the river made by the team, it is estimated on the basis of our experience, that the annual sedimentation rate is about 100 m^3 per km^2. Deposition of sediment in the equalizing reservoir was estimated using this value.

5.6 EVAPORATION, TEMPERATURE, ETC.

According to the data of the Tulcan observatory, the annual evaporation is about 1,200 mm. However, evaporation loss need not be considered as the regulating pond or equalizing reservoir is for daily regulation of flow.

The recorded maximum temperature at Tulcan City is 23°C while the recorded minimum is minus 1°C, and the average temperature about 10°C. There temperatures will not present any problem in the execution of construction works.

6. GEOLOGY

6. GEOLOGY

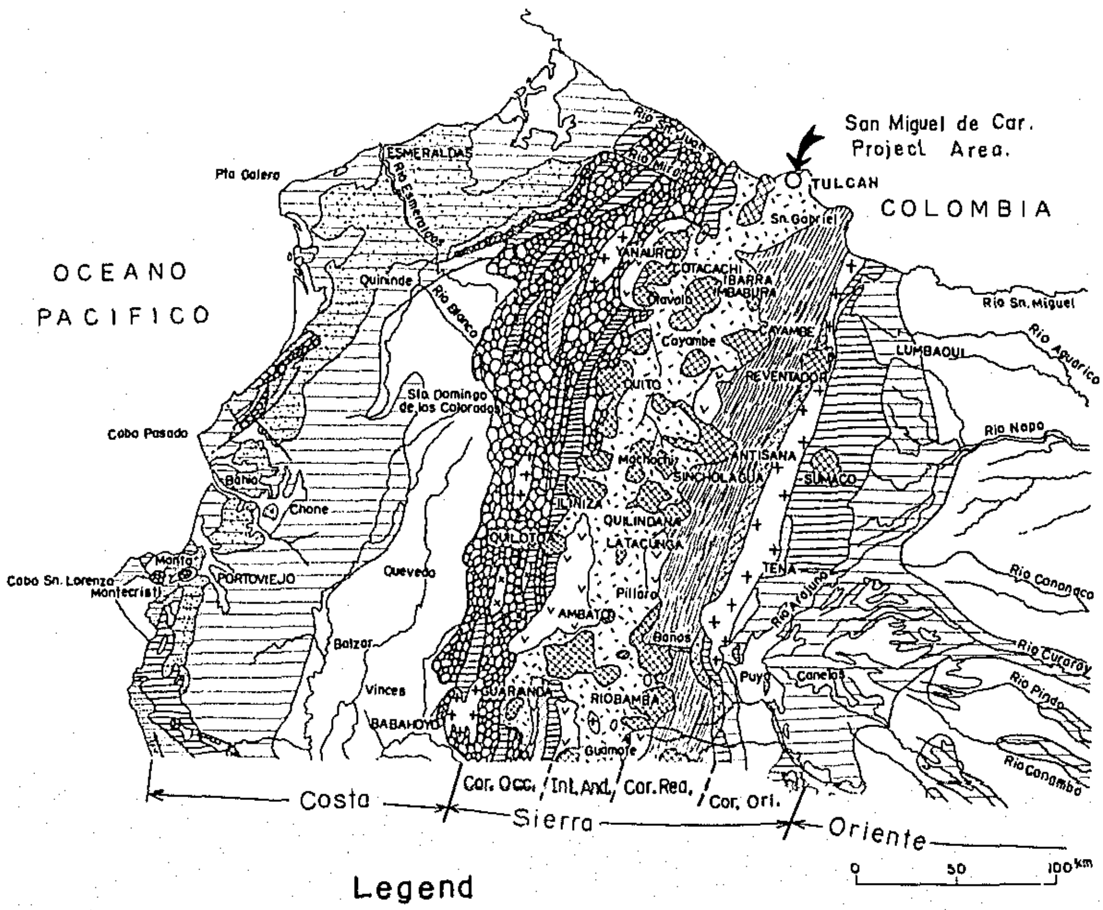
6.1 GEOLOGY OF PROJECT AREA

Ecuador can be divided roughly into 3 morphologic provinces, Sierra (Andes) running through the central part of the country from north to south, Costa on the west side, and Oriente on the east side. The Sierra can be further divided into 3 zones, namely, Cordillera Occidental, Depresion Interandina and Cordillera Real. The geology of the morphologic provinces are different from each other as shown in Fig. 6-1. The project area is located at the northern part of the Depresion Interandina.

The Depresion Interandina is a huge graben of 30 to 40 km wide and 300 km long north to south lying between mountain ranges on the east and west. The elevation is generally 2,200 to 3,000 m although there are some high peaks like Mt. Imbabura (El. 4,630 m), and the zone is further divided into several basins. The Depresion Interandina is covered with lava and pyroclastic deposits, having complex conditions of distribution and deposits due to epirogenetic movements, volcanic activities and glaciation which took place in the Quarternary Period.

The order of strata spread throughout the project area is from top to bottom aeolian Cangagua formation, fluvio-glacial deposit, lacustrine Cangagua formation and lava flow of andesite.

Fig, 6-1 Geological Map of Northern Ecuador



Legend

	Legend	Legend
Quaternary	Terrigenous deposits	Basalt, Andesite
	Pyroclastic deposits	
Tertiary	Marine deposits of Plio-Miocene	Volcanic rocks of Pliocene
	Marine deposits of Oligocene	Granite, Granodiorite
	Marine deposits of Eocene	Diorite
Cretaceous	Marine deposits of upper Cretaceous	Diabase, Porphyrite
	Marine deposits of lower Cretaceous	
Jurassic	Limestone of upper Jurassic	Limestone of lower Jurassic
Paleozoic ~ Cambrian	Marine deposits of Carboniferous ~ pre-Caboniferous	Metamorphic rocks of pre-Cambrian
	Semi metamorphic rocks (Era unknown)	

by Dr, Walter Sauer
Quito, Feb. 1950.

Aeolian Cangagua Formation

This formation widely covers the project area. Although its thickness varies from place to place, it is generally about 5 m. This formation consists of an enormous amount of deposited volcanic ash, which was ejected by fierce volcanic eruptions during the Post Glacial Age immediately following the Fourth Glacial Age. The formation can be classified into 3 layers according to the difference in components. The uppermost layer comprising the surface soil is black humus of 30 to 100 cm thickness, which is an organic soil belonging to OL or Pt of the Unified Soil Classification Method. Because of this soil, unpaved roads turn into muddy puddles when it rains and rivers become a turbid black color. The second layer consists of fine grained yellow sand with a thickness of 20 to 60 cm, belonging to SM or ML of the said Classification Method. This sand layer, although missing in parts, is distributed parallel to the surface widely throughout the hilly area, and some of this material is used for concrete aggregate. The component minerals are mostly quartz, containing small quantities of feldspar, biotite and hornblende, and somewhat resemble sand being derived from weathered granite. The third layer underlying the second is a clay layer 2 to 4 m thick, and the clay is high in dry strength and plasticity, belonging to CH or OH of the same Classification Method. In places it is an alternate layer of dark brown and orange clay, indicating repeated volcanic activity.

Fluvio-glacial Deposit

This formation is distributed in fan shape at elevations of 3,300 to 3,100 m between the Rio Grande and the Rio Chico. It consists of irregular mixtures of large and small sand and gravel, and it can be observed at the exposed surface of the banks of the Rio Grande and the excavated surface of the existing canal connecting the Rio Grande and the Rio Chico. Boulder gravels with glacial striae are found around Panecillo Hill (El. 3,415 m) at the starting point of the fan, which reveals that the hill is a glacial terminal moraine. Judging from such surrounding topographical and geological conditions, the fan can be assumed to be a frontal apron of fluvio-glacial deposits formed towards the end of the Fourth Glacial Age.

Lacustrine Cangagua Formation

This formation is distributed in the plateau where the project area is located, but it is difficult to grasp the whole picture of the strata as it is covered with aeolian Cangagua formation. The deposit is assumed to had been made towards the end of either the Second or Third Glacial Age.

The formation consists mainly of volcanic ash, and contains a small amount of pumice. At some places it also contains boulder gravel. It is yellow or orange in color and is generally well solidified having turned into tuff or partly tuffaceous silt-stone with well developed bedding planes.

Lava Flow of Andesite

This rock is the lava ejected prior to the beforementioned lacustrine Cangagua formation and in the project area it is spread around the intake dam of the Río Bobo. There are two types of andesite, namely, dark grey basaltic andesite which consists of fine grained phenocryst of olivine, augite and hornblende, and grey hornblende-andesite which consists of fine to medium grained phenocryst of feldspar, hornblende and augite. The former seems to be an earlier lava flow than the latter. Basaltic andesite is exposed for a distance of 1.2 km along the canal route from the site of the intake dam of the Rio Bobo, whereas hornblende-andesite is exposed at a higher elevation along the water supply canal. Both andesites are dense and hard, but cracks have developed on the surface.

6.2 GEOLOGY OF RIO BOBO INTAKE DAM SITE

An intake dam about 4.0 m in height is planned for this site. The foundation rock of the dam is basaltic andesite.

Left Bank

The Left bank about 3 m above the water surface is a steep slope with an inclination of 60°, beyond which the valley wall is a gentle slope of 20 to 30° inclination. At both upstream and downstream sides of the dam site exposed basaltic andesite can be observed, but at the dam site it is covered with fairly thick topsoil. According to the result of a pit (P-1) excavated at a distance of 5 m from the bank, the first 35 cm from the surface consists of black humus, the next 35 to 110 cm of dark brown clay, while the final 110 to 130 cm is a sand bearing gravel bed. The total depth of topsoil is assumed to be 3 to 4 m.

Right Bank

Up to about 10 m from the water surface, there is a steep slope with an inclination of 45° where basaltic andesite is exposed. There is practically no covering topsoil, and even where there is any, it is very thin. The andesite is a blackish grey and is dense and hard, but has scattered wide cracks on its surface.

River Bed

The width of the river is approximately 8 m. The deposit of gravel with an estimated thickness of about 2 m covers the river bed, and boulder gravel is scattered on the deposits. The bed rock underneath the gravel bed is assumed to be basaltic andesite.

6.3 GEOLOGY OF WATERWAY AND REGULATING POND SITE

The proposed waterway from the intake dam of the Rio Bobo to the San Miguel de Car Power Station and the regulating pond are planned to be constructed along the mountainside on the left-side bank of the Rio Bobo. For a distance of 1.2 km from the intake dam site the mountain slope is steep, and lava flow of andesite is spread throughout the distance. The slope between the 1.2 km point and the site of the head tank, including the regulating pond, is fairly moderate, and aeolian Cangagua formation is distributed over the underlying lacustrine Cangagua formation.

Andesite

Although the andesite here has large cracks on the surface, fresh portions are dense and hard. This andesite is exposed at many places forming a steep cliff, and on the existing canal passing nearby there are sections where this andesite has been excavated almost vertically.

Aeolian Cangagua Formation

The order of layers of aeolian Cangagua formation is from surface to bottom, black humus with a thickness of 30 to 100 cm, fine grained yellow sand with a thickness of 20 to 60 cm and orange or dark brown clay 2 to 4 m thick, the total thickness being estimated to be approximately 5 m. Of these layers black humus and fine grained yellow sand are considered to be unsuitable for bases of structures, but the clay layer is suitable as a base of a waterway. According to the result of a simple field permeability test conducted at the site of the regulating pond, the coeffecient of permeability of this clay layer was 10^{-6} cm/s. This aeolian Cangagua formation and the underlying lacustrine Cangagua formation (tuff) contact each other almost parallel with the ground surface, and it is highly probable that landslides may occur along the boundary plane. Actually, there are instances of such landslides at damaged points of the ruined waterway. Leakage from the waterway is considered to have caused this, and therefore, due caution should be exercised in design and construction of the waterway to prevent leakage especially at steep slopes.

Lacustrine Cangagua Formation

The Laçustrine Cangagua formation is soft tuff. The tunnel 220 m long planned between the intake dam on the Rio Bobo and the regulating pond is expected to pass through this formation except for the vicinity of the tunnel portal. The foundation of the dike for the regulating pond is also planned to be excavated down to this formation. In excavation of the existing La Cofradia Tunnel, also passing this formation, it is reported that no blasting was necessary. Judging from the records of the above tunnel, the proposed tunnel route is thought to pass few faults, and seepage is expected to be very small.

6.4 GEOLOGY OF PENSTOCK LINE AND POWERHOUSE SITE

These sites lie in a hilly area, and the inclination of the ridge along which the penstock line will run is 8° between the head tank site and El. 3,100 m, 20° between El. 3,100 and 3,010 m and 30° between El. 3,010 and 2,995 m. A strip 50 m wide between the end of the penstock and the river bank is a moderate slope, where the powerhouse and tailrace are to be constructed.

Around these sites are distributed lacustrine Cangagua formation (tuff) underlying aeolian Cangagua formation (clay and sand). Tuff is found exposed at the landslide on the upstream slope of the ridge along which the penstock line is planned and around a pond constructed to store seeped water 50 m northwest of the powerhouse site. Therefore, the depth of aeolian Cangagua formation is assumed to be about 5 m at the ridge where the penstock is planned to pass and 0 to 2 m at the site of the powerhouse. Tuff of the lacustrine Cangagua formation offers no problem in bearing strength, but as it is not sufficiently solidified and is somewhat soft, resistance against erosion by running water is not great.

The abovementioned landslide is 25 m high and 20 m wide, and was caused by permeation of water leaked from the irrigation canal, causing a sliding of the contact plane between clay of the aeolian Cangagua formation and tuff of the lacustrine Cangagua formation. This landslide might influence the stability of the ridge where the penstock is to be installed, but it is considered that it will not have any effect on the safety of the penstock as it will be installed about 30 m away from the landslide and the foundation will be constructed on tuff. The spring mentioned above is a small quantity of water seeping from the boundary between the claylayer and the tuff, but will be of no problem in the stability of the structure to be constructed.

6.5 GEOLOGY OF EQUALIZING DAM SITE

At this site a concrete dam of about 8 m in height is planned. The basal rock around this site is lacustrine Cangagua formation covered with aeolian Cangagua formation.

The left abutment is planned on a ridge protruding between gullies and the slope of ridge is about 30°. On the right bank there is a flat table of land about 25 m wide about 3 m above the river water level and the slope thereabove has an inclination of about 20°. The depth of the aeolian Cangagua formation is assumed to be 3 to 4 m on the left bank and 0.5 to 4 m on the right bank. The width of the river is about 6.5 m and muddy deposits about 2 m thick are estimated to lie on the river bed.

Lacustrine Cangagua formation of the foundation rock of the dam is of poorly solidified soft tuff, but so far as bearing strength and permeability are concerned, it can be judged to present no problem as a foundation for a concrete dam 8 m in height.

6.6 MATERIALS

6.6.1 Aggregate

a Coarse Aggregate

There are no river deposits of gravel usable as coarse aggregate for concrete around the project area. Up to the present, therefore, coarse aggregate was quarried from Mt. Las Peñas.

Mt. Las Peñas is a dome-shaped volcano, 3,396 m above sea level located about 7 km south of Tulcan City. It is shaped in an ellipse with a major axis of 1 km and a minor axis of 500 m, and has a height of 200 m from the foot to the top. All aggregates required for the San Miguel de Car Project can be quarried from the mountain. The rock is augite bearing hornblende andesite, its property is dense and hard and is good quality rock for coarse aggregate.

b Fine Aggregate

There is scarcely any river sand usable as fine aggregate in the project area. The sand layer in the aeolian Cangagua formation has been excavated and used for concrete works in the vicinity of Tulcan City. Currently the sand is taken at the east foot of Mt. Las Penas and at several locations between Tulcan City and San Gabriel along the Pan American Highway, all located about 8 to 9 km south of Tulcan City. At these locations the sand is collected after removing the overlying topsoil 0.5 to 1.0 m thick, and the depth of sand layer is estimated to be 2 to 4 m thick. Since this layer is widely distributed, there seems to be no trouble in obtaining the required quantity of fine aggregate for the project.

The component mineral of this sand is predominantly quartz, containing a small amount of feldspar and mafic minerals, and resembles sand made of weathered granite. According to the result of analysis of the sand layer in the aeolian Cangagua formation taken from around the site of the equalizing reservoir for the La Playa Power Station (See Table 6-1, Pit No. 2, Stratum No. 2) it contains a considerable percentage of clay. Sand now being excavated near Mt. Las Peñas has a better fineness modulus than this based on visual observation. At any rate, proper mix designs should be selected based on test results.

6.6.2 Soil Material

a Distribution

The regulating pond of the San Miguel de Car Power Station is planned to be built by excavating a moderate slope and using the excavated earth for the embankment. The amount of excavation is estimated to be approximately 130,000 m^3, of which approximately 28,000 m^3 will be necessary for the embankment.

In this area, aeolian Cangagua formation is distributed overlying lacustrine Cangagua formation. According to the result of two test pits (dug with a hand-auger for 2 m in addition to the pit of 2 m) it was found that the depth of 90 to 150 cm from the surface consisted of humus, followed by a fine grained sand layer of 40 to 50 cm and a clay stratum of more than 2 m thickness. The base of the pit at 4 m did not reach the lacustrine Cangagua formation, but the thickness of the aeolian Cangagua formation is assumed to be about 5 m.

b Properties of Earth Material

Material test was conducted of the soil near the equalizing reservoir site for the La Playa Power Station. Three pits were excavated on the left bank, reaching basal rock of lacustrine Cangagua formation at depths of 3.7 m, 2.58 m and 3.86 m. The test was performed on the clay and sand of volcanic ash origin, comprising the aeolican Cangagua formation. The order of sedimentation and properties of aeolian Cangagua formation in this area resemble those of the regulating pond site of the San Miguel de Car Power Station.

One specimen sample from the fine grained yellow sand layer and three specimen samples from the different colored clay layers were taken. The laboratory test was conducted by INECEL, the results of which are as shown in Table 6-1. The results involve some questions and problems, but the earth can be used for embankment, if precautions are taken in the design and construction, such as to make the slope gradient gentle, to provide an inner facing, and to avoid rainy days for embankment work.

Although soil of the regulating pond site of the San Miguel de Car Power Station and that of the site of the equalizing reservoir for La Playa Power Station are almost the same in property, soil tests must be conducted before executing the work. In addition, as it is probable that the property of earth material can be improved by mixing it with lacustrine Cangagua formation, it is necessary to carry out investigations and tests in order to determine the distribution and properties of lacustrine Cangagua formations.

6.7 EARTHQUAKE

Ecuador is located on the Circum-Pacific Earthquake Belt and has been affected by seismic disturbances many times in the past. According to "Breve Historia de los Principales Terremotos en la Republica del Ecuador" compiled in 1959 by Comiti del Ano Geofisico Internacional del Ecuador, there has been as many as 315 great earthquakes between 1534 and April 1958, and of these quite a number have taken place in the Depresion Interandina and the Pacific Ocean coast, especially in the northern parts of these zones.

The project area is located in the northern part of the Depresion Interandina, which is frequently affected by earthquakes.

According to the data compiled by the said Committee, severe earthquakes with epicenters within a radius of 100 km from Tulcan City have been experienced in the 100 years between 1855 and 1954, i.e. there have been 6 earthquakes of seismic intensity I, 8 of intensity II and also 8 of intensity III. The seismic intensity is divided into 3 classes: I being mediano, II fuerte and III destructor, and although the relation with the Modified Mercalli Intensity Scale is not clear, it is judged that intensity I is equivalent to MM IV - VI, II equivalent to MM VI - VIII and III equivalent to MM VIII - IX.

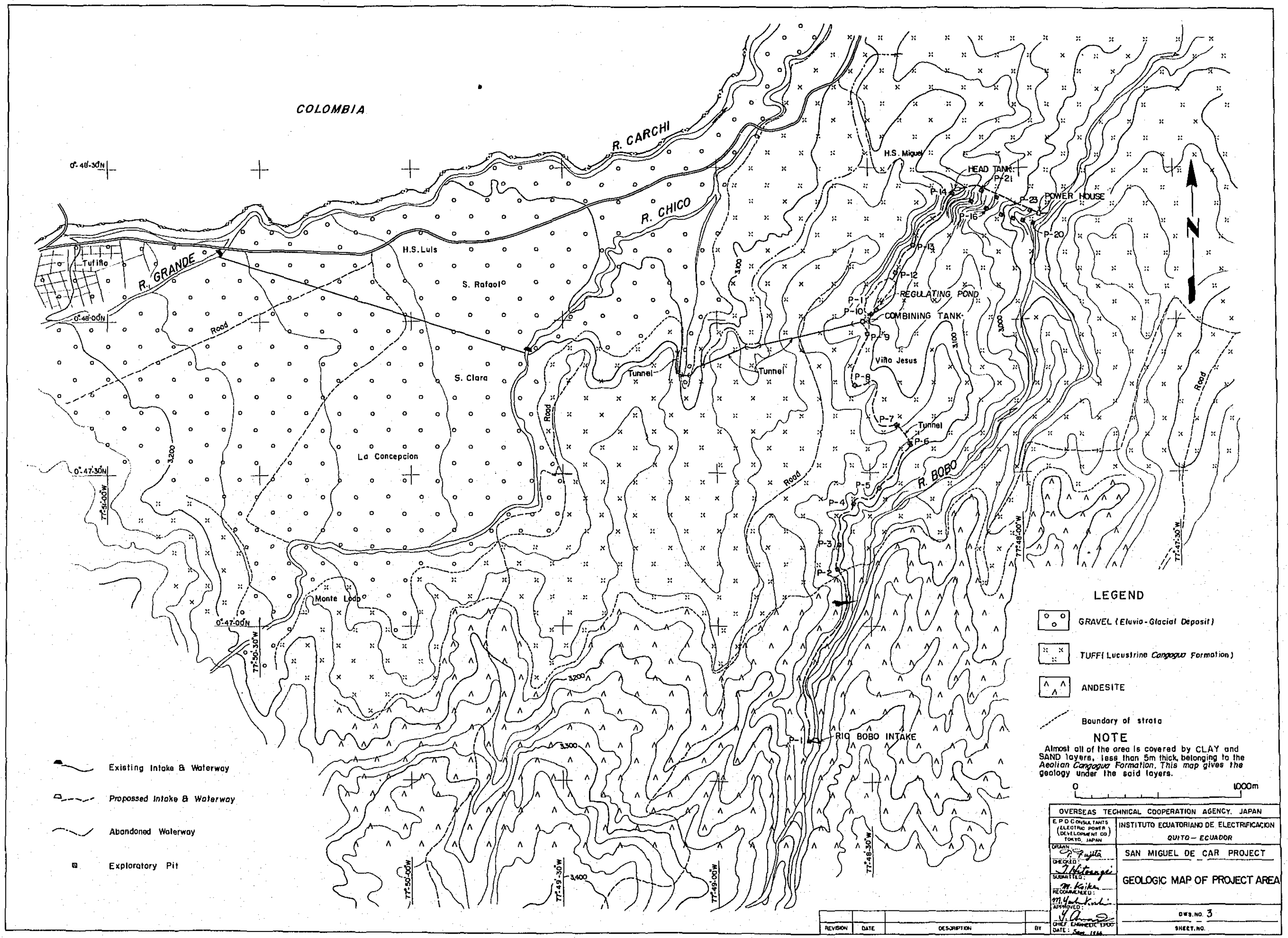
In designing the structures for the San Miguel de Car Project, it should therefore be taken into consideration that the project area and its vicinity is located in an active earthquake zone.

Table 6-1 Laboratory Tests on Soil Material

			No 1		No 2		Note
Number of Test Pit			No 1		No 2		Note
Number of Stratum			No 3	No 4	No 2	No 4	
Name by Unified Soil Classification Method			OH	HO	ML	OH	
Natural watercontent			86.81	57.32	23.92	78.10	ASTM D2216-63T
Specific gravity			2.30	2.41	2.31	2.36	
Grain size analysis	Maximum grain size	mm	2.0	2.0	4.8	4.8	ASTM D422-63
	-4.8mm	%	100.0	100.0	100.0	100.0	
	-0.075 mm	%	86.3	72.0	27.8	83.6	
	-0.050 mm	%	78.0	67.0	23.5	77.5	
	-0.005 mm	%	33.0	50.3	5.7	38.5	
Organic content		%	24.61	18.84	3.63	32.62	
Atterberg limits 1/	LL	%	77.50 (49.00)	59.90 (45.00)		65.70 (58.18)	ASTM D428-61
	LP	%	44.41 (43.53)	42.21 (35.08)		46.41 (40.38)	D424-59
	IL	%	33.09 (5.47)	17.69 (9.92)		19.29 (17.29)	
Proctor conpaction Test	Optimum moisture content	%	50.00	37.93	24.80	49.11	ASTM D698-64T
	Maximum dry density	g/cm^3	1.11	1.33	1.43	1.08	method A
	Moisture content		54.8	38.2	25.6	55.2	
	Cohesion	kg/cm^2	0.178	0.244	0.027	0.465	
	Angle of internal friction	(o)	10°25'	12°45'	42°05'	2°30'	
Permiability		(cm/sec)	(impermiable)	(impermiable	2.61×10^{-6}	(impermiable)	

Note: 1/ This test was performed on two kinds of samples - one is a sample with a water content lower than natural but not air dried, and the other is an oven dried sample.

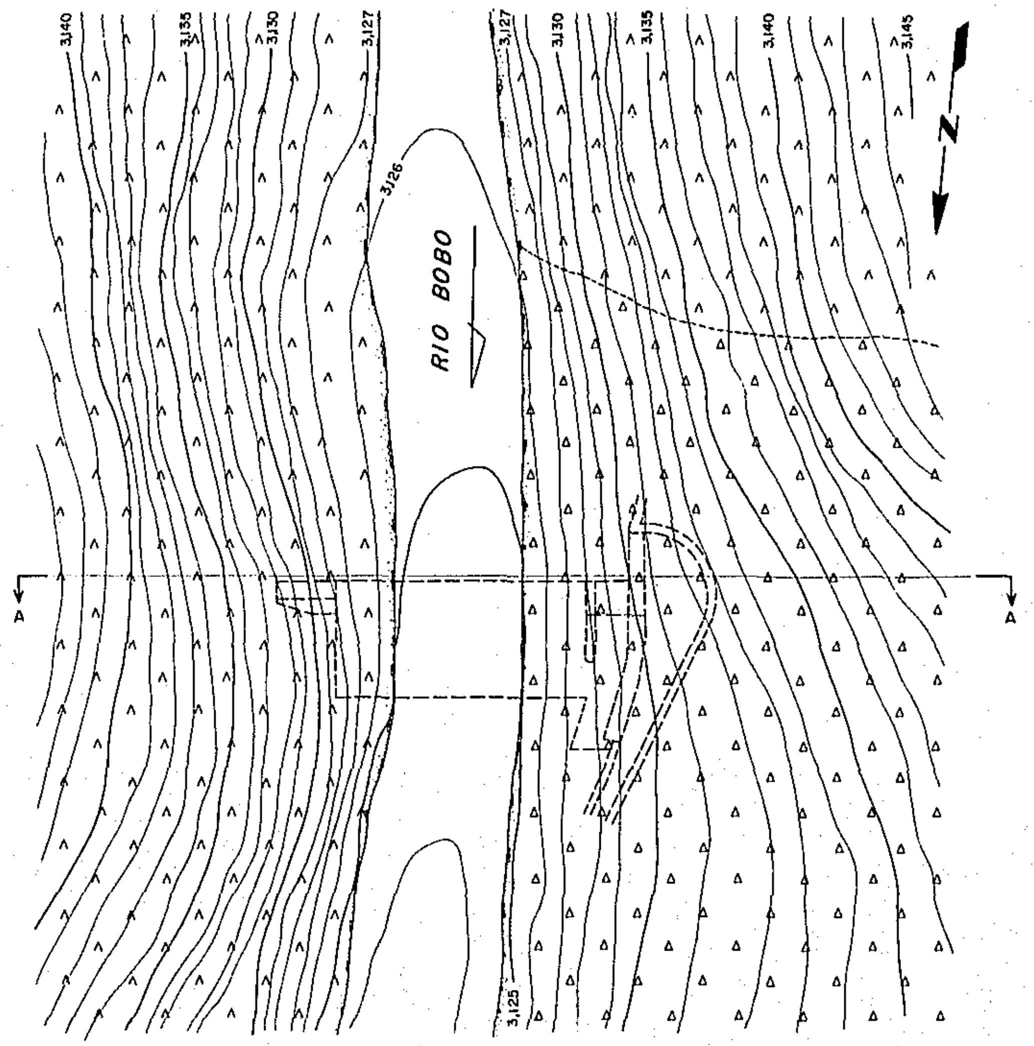
Figures in parenthesis show the values of air dried sample.



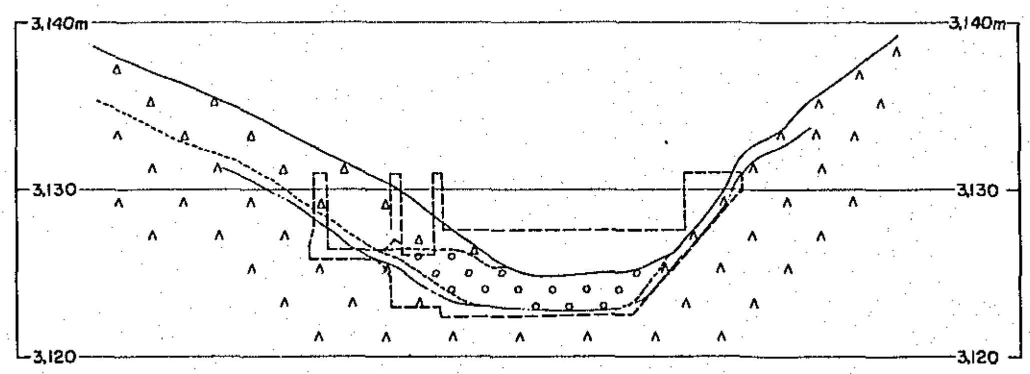
COLOMBIA
R. CARCHI
R. CHICO
R. GRANDE
R. BOBO
Tufiño
H.S. Luis
S. Rafael
S. Clara
La Concepcion
Monte Lodo
Viño Jesus
H.S. Miguel
HEAD TANK
POWER HOUSE
REGULATING POND
COMBINING TANK
RIO BOBO INTAKE
Tunnel
Road
P-1
P-2
P-3
P-4
P-5
P-6
P-7
P-8
P-9
P-10
P-11
P-12
P-13
P-14
P-16
P-20
P-21
P-23
0°-48'-30"N
0°-48'-00"N
0°-47'-30"N
0°-47'-00"N
77°-51'-00"W
77°-50'-30"W
77°-50'-00"W
77°-49'-30"W
77°-49'-00"W
77°-48'-30"W
77°-48'-00"W
77°-47'-30"W
3,100
3,200
3,300
3,400
N
Existing Intake & Waterway
Proposed Intake & Waterway
Abandoned Waterway
Exploratory Pit
LEGEND
GRAVEL (Eluvio-Glacial Deposit)
TUFF (Lucustrine Cangagua Formation)
ANDESITE
Boundary of strata
NOTE
Almost all of the area is covered by CLAY and SAND layers, less than 5m thick, belonging to the Aeolian Cangagua Formation. This map gives the geology under the said layers.
0
1000m
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
E P D CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO) TOKYO, JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION
QUITO — ECUADOR
DRAWN: T. Fujita
CHECKED: T. Hitosugi
SUBMITTED: M. Koike
RECOMMENDED: M. Yoshikoshi
APPROVED: Y. Amano
CHIEF ENGINEER EPDC
DATE: Sep. 1966
SAN MIGUEL DE CAR PROJECT
GEOLOGIC MAP OF PROJECT AREA
DWG. NO. 3
SHEET. NO.
REVISION
DATE
DESCRIPTION
BY

RIO BOBO INTAKE DAM SITE

PLAN

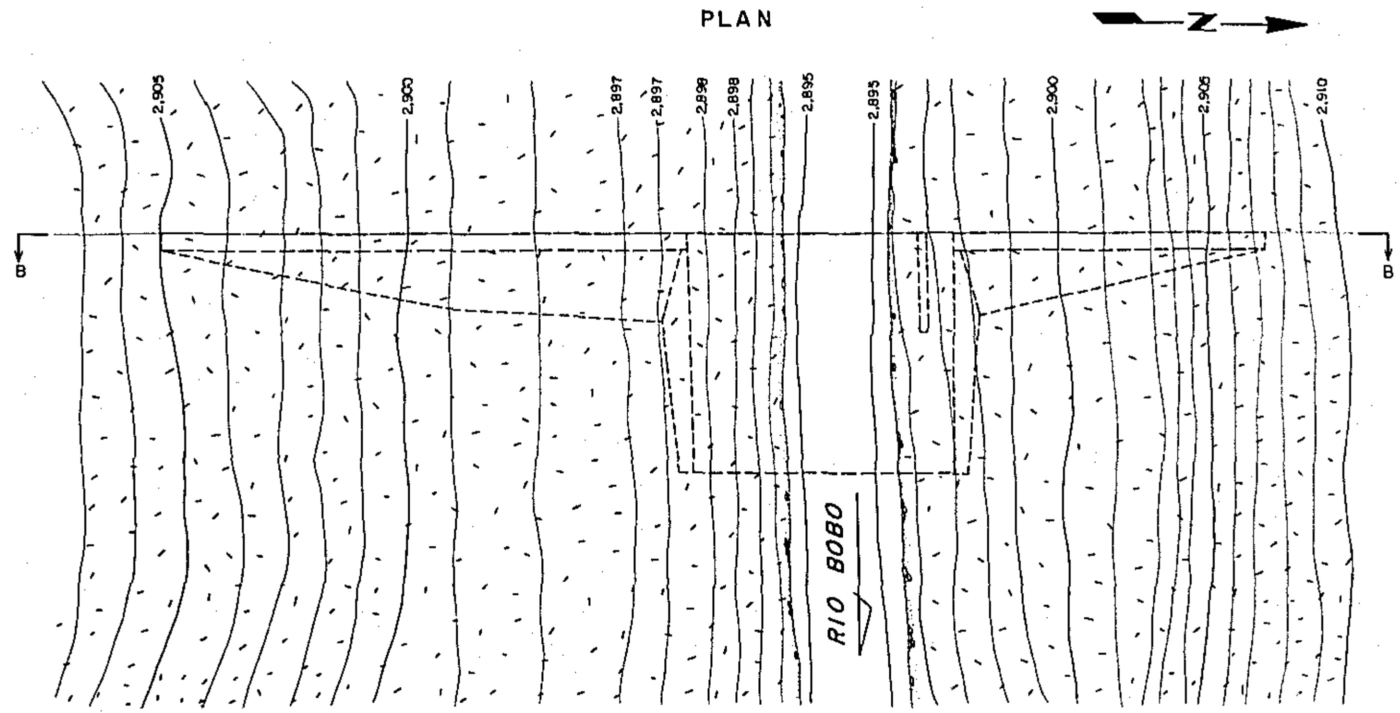


SECTION A-A

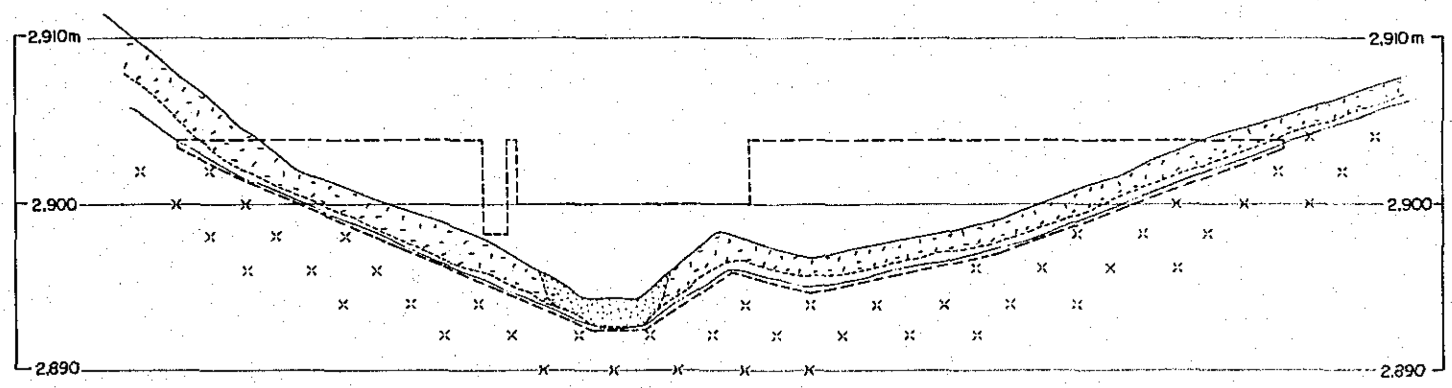


RIO BOBO EQUALIZING DAM SITE

PLAN



SECTION B-B



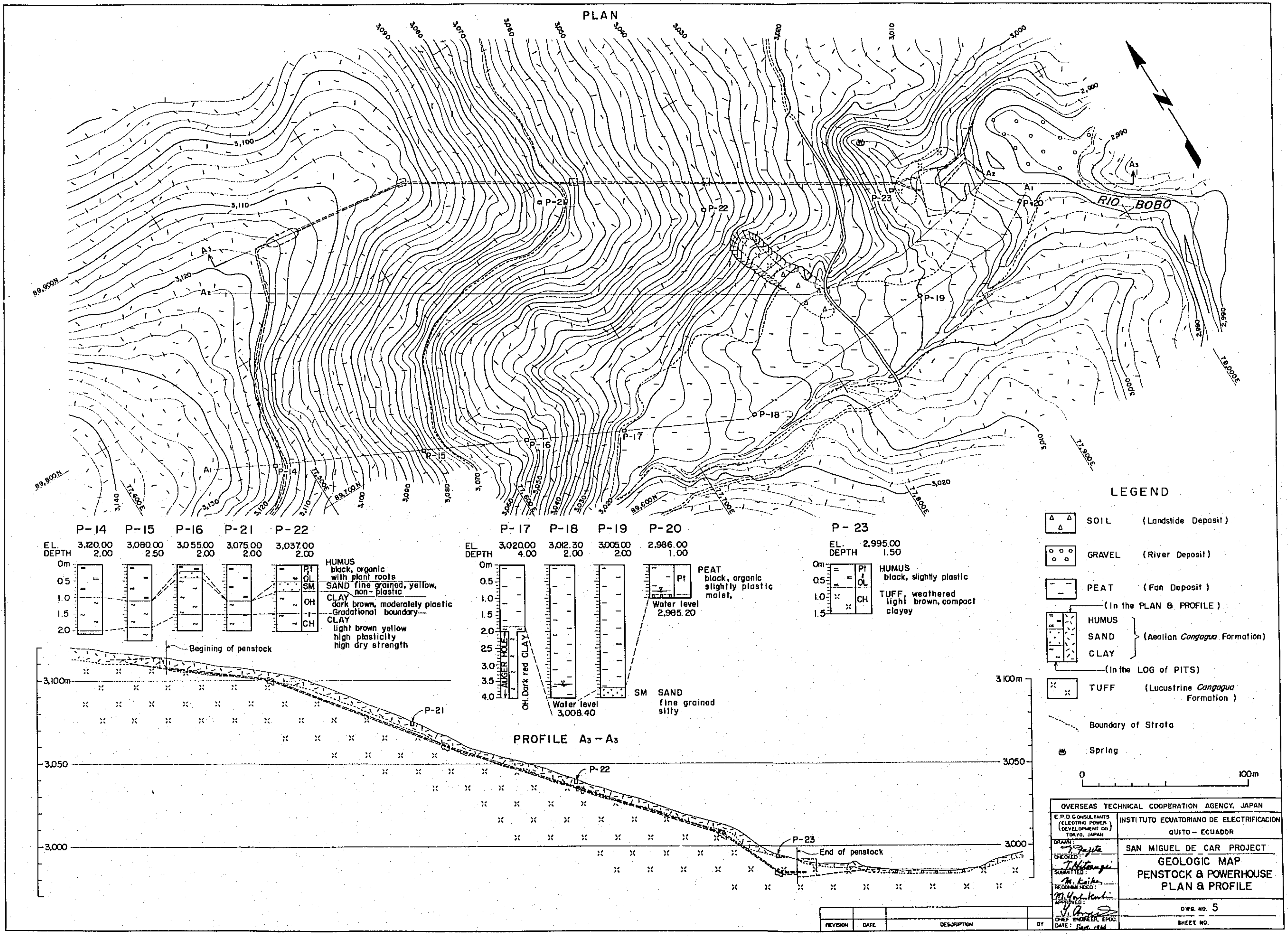
LEGEND

- TOPSOIL
- GRAVEL / SAND (Rirer Deposit)
- CLAY and SAND (Aeolian *Cangagua* Formation)
- TUFF (Lucustrine *Cangagua* Formation)
- ANDESITE
- Boundary of Strata
- Assumed Sound Rock Surface

0 — 20m

REVISION	DATE	DESCRIPTION	BY

OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN	
E.P.D. CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO) TOKYO, JAPAN	INSTITUTO ECUATORIANO DE ELECTRIFICACION QUITO – ECUADOR
DRAWN:	SAN MIGUEL DE CAR PROJECT
CHECKED:	GEOLOGIC MAP
SUBMITTED:	INTAKE DAM & EQUALIZING DAM
RECOMMENDED:	PLAN & SECTION
APPROVED: CHIEF ENGINEER, EPDC	DWG. NO. 4
DATE: Sept. 1966	SHEET NO.



PLAN
RIO BOBO
P-14
P-15
P-16
P-17
P-18
P-19
P-20
P-21
P-22
P-23
89,900N
89,800N
89,700N
89,600N
77,400E
77,500E
77,600E
77,700E
77,800E
77,900E
78,000E
EL. DEPTH
3,120.00 2.00
3,080.00 2.50
3,055.00 2.00
3,075.00 2.00
3,037.00 2.00
HUMUS black, organic with plant roots
SAND fine grained, yellow, non-plastic
CLAY dark brown, moderately plastic
Gradational boundary
CLAY light brown yellow high plasticity high dry strength
3,020.00 4.00
3,012.30 2.00
3,005.00 2.00
2,986.00 1.00
AUGER HOLE
OH. Dark red CLAY
Water level 3,008.40
SM SAND fine grained silty
PEAT black, organic slightly plastic moist.
Water level 2,985.20
EL. 2,995.00 DEPTH 1.50
HUMUS black, slightly plastic
TUFF, weathered light brown, compact clayey
Begining of penstock
End of penstock
PROFILE A3 - A3
3,100m
3,050
3,000
LEGEND
SOIL (Landslide Deposit)
GRAVEL (River Deposit)
PEAT (Fan Deposit)
(In the PLAN & PROFILE)
HUMUS
SAND
CLAY
(Aeolian Cangagua Formation)
(In the LOG of PITS)
TUFF (Lucustrine Cangagua Formation)
Boundary of Strata
Spring
0
100m
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
E.P.D.CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO.) TOKYO, JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION QUITO - ECUADOR
SAN MIGUEL DE CAR PROJECT
GEOLOGIC MAP
PENSTOCK & POWERHOUSE
PLAN & PROFILE
DWG. NO. 5
SHEET NO.
REVISION
DATE
DESCRIPTION
BY
DRAWN:
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:
CHIEF ENGINEER, EPDC
DATE:

7. POWER PRODUCTION

7. POWER PRODUCTION

7.1 BASIC CONDITIONS FOR DETERMINATION OF SCALE OF DEVELOPMENT

The basic conditions considered in connection with the determination of the output of the San Miguel de Car Project are as follows:

a. As stated in Chapter 3, the area with which this project is related contains two power systems, the Empresa Electrica Tulcan System to which the San Miguel de Car Power Station belongs, and the Ibarra Power System centered around El Ambi Power Station. Two cases are conceivable, i.e. Alternative-1, in which the power of San Miguel de Car Power Station is supplied only to the Empresa Electrica Tulcan System (hereinafter called A-1) and, Alternative-2, in which Tulcan and Ibarra systems are interconnected with a transmission line and the power is supplied to both systems (hereinafter called A-2).

The scale of development of San Miguel de Car Power Station and the timing of the development depends to a great deal on which of the above alternatives is selected and therefore both cases were studied.

b. Of the existing and planned power stations within the two systems, El Ambi Power Station of the Ibarra Power System is the only station with a regulating pond capable of peak load operation. Therefore, in consideration of future power demands it would be desirable for San Miguel de Car Power Station to have a regulating pond to supply part of the peak load. Thus in both alternatives A-1 and A-2, studies were made in which regulating ponds are constructed for daily regulation of output. In alternative A-2, a study was also made of a development with no regulating pond.

c. The capacity of the regulating pond of San Miguel de Car Power Station was determined based on the following concepts. In the case of alternative A-1, should a shortage in supply capability occur during the dry seasons between 1966 and 1982, in order to minimize the installation cost of additional capacity to cover this shortage, the energy output required to be regulated at San Miguel de Car Power Station was calculated on the condition that the least capacity as possible would be installed. The required energy output for each year was obtained under this condition and the largest value was then converted into regulating capacity which was considered the required storage capacity of the regulating pond of San Miguel de Car Power Station.

The required regulating capacity for alternative A-2 to secure supply capability in the dry seasons between 1968 and 1979, were based on the same thinking as in alternative A-1. The regulating capacity of the regulating pond of El Ambi Power Station was taken to be 50,000 m^3.

d. The run-off used in planning the project was the average of the four years from 1962 to 1965 described in Chapter 5, and the run-off for determination of dependable output was based on below average run-off during the dry season of the same period.

e. Maximum available discharge was determined based on a constant standard effective head as the standard intake level and the tail water level are approximately constant.

f. Varying scales of development of San Miguel de Car Power Station were studied to estimate the benefit (V) and the annual cost (C) and the case in which the V/C is the largest was considered the economically optimum scale of development.

g. The annual costs of alternative A-1 include the expenses of San Miguel de Car Power Station, the transmission line from the power station to El Angel via Tulcan and San Gabriel and the substations at Tulcan, El Angel and San Gabriel. In alternative

A-2, one-half of the expense for the interconnecting transmission line between San Gabriel and Ibarra are included in addition to those expenses considered in alternative A-1.

h. The benefits of San Miguel de Car Power Station were assumed to be the sum of KW and KWH costs of a diesel installation of the same capacity. It was assumed that the power and energy output San Miguel de Car Power Station would supply demands which cannot be supplied by existing facilities. Therefore, during the initial period of operation when supply capability exceeds demand, a part of the power and energy output of San Miguel de Car Power Station will not be effective.

7.2 DETERMINATION OF OUTPUT AND AVAILABLE DISCHARGE

In order to determine the maximum discharge for the most economical installed capacity, the 3 cases of 3.0, 3.5 and 4.0 cubic meters per second (3,000, 3,500 and 4,000 KW) for alternative A-1 and the 6 cases of 1.5 (no regulating pond), 2.0, 2.5, 3.0, 3.5 and 4.0 cubic meters per second for alternative A-2 (1,500, 2,000, 2,500, 3,000, 3,500 and 4,000 KW) were considered. The available discharge, output, energy production, approximate construction cost, etc., the factors for determination of maximum discharge and output of each case considered are shown in Table 7-1.

The ratio (V/C) of benefit (V) and annual cost (C) calculated for each case is given in Table 7-2 and Fig. 7-1. It will be noted in the table and graph that A-2 which include a transmission line interconnection is more economical. However, in alternative A-2 run-of-river type development without a regulating pond is evidently uneconomical. Where regulating ponds are provided, there is not much difference economically, but the case of maximum discharge of 3.0 m^3/s is the most economical. Therefore, an installed capacity of 3,000 KW and maximum discharge of 3 m^3/s have been adopted for the project.

Table 7-1 Basic Data for Determination of Maximum Available Discharge

					Construction Cost in 1979 Generating End				
	Qmax	Pmax	Pfirm	Ph	(1) Total	Per KW	Per KWH	(2) Transmission & Substation	Total ((1) + (2))
	cu.m/s	KW	KW	1000 KWH	1000 Sucre	Suc/KW	Suc/KWH	1000 Sucre	1000 Sucre
Alternative-1	4.0	4,000	1,500	21,000	33,270	8,300	1.59	10,490	43,760
	3.5	3,500	"	20,500	32,270	9,200	1.58	10,490	42,760
	3.0	3,000	"	19,900	31,170	10,400	1.57	10,490	41,660
Alternative-2	4.0	4,000	1,500	21,000	34,440	8,600	1.64	12,490	46,930
	3.5	3,500	"	20,500	32,620	9,000	1.59	12,490	45,110
	3.0	3,000	"	19,900	31,170	10,400	1.57	12,490	43,660
	2.5	2,500	"	18,700	28,470	11,400	1.52	12,100	40,570
	2.0	2,000	"	16,600	26,470	13,300	1.60	12,080	38,550
	1.5	1,500	"	13,100	22,670	15,200	1.74	12,030	34,700

Legend:
- Qmax: Maximum Discharge for Power
- Pmax: Installed Capacity
- Pfirm: Firm Output
- Ph: Annual Energy Production at Generating End

Table 7-2 Benefit-Cost Ratio for Each Case

Alternative	Qmax	Pmax	Annual Benefit (V)	Annual Cost (C)	V/C
	cu.m/s	KW	1000 Sucre	1000 Sucre	
A-1	4.0	4,000	4,420	4,087	1.08
	3.5	3,500	4,260	4,003	1.06
	3.0	3,000	4,098	3,899	1.05
A-2	4.0	4,000	5,470	4,489	1.21
	3.5	3,500	5,292	4,296	1.22
	3.0	3,000	5,060	4,130	1.23
	2.5	2,500	4,755	3,877	1.22
	2.0	2,000	4,220	3,666	1.15
	1.5	1,500	3,413	3,322	1.03

The relation between inflow and available discharge for the maximum discharge selected is shown in Table 7-3, Fig. 7-2 and Fig. 7-3.

Table 7-3 Average Monthly Inflow and Available Discharge

cu.m/s

Month	Inflow				Available Discharge
	R. Grande	*R. Chico*	*R. Bobo*	*Total*	
Jan.	0.90	0.57	0.84	2.31	2.21
Feb.	0.91	0.58	0.86	2.35	2.25
Mar.	0.98	0.62	0.93	2.53	2.43
Apr.	1.23	0.78	1.00	3.01	2.90
May	1.04	0.66	0.98	2.68	2.58
June	0.70	0.44	0.66	1.80	1.73
July	0.68	0.43	0.64	1.75	1.68
Aug.	0.61	0.39	0.58	1.58	1.52
Sep.	0.60	0.38	0.57	1.55	1.50
Oct.	1.48	0.94	1.00	3.42	3.00
Nov.	1.70	1.08	1.00	3.78	3.00
Dec.	1.05	0.66	0.99	2.70	2.60
Annual Average	0.99	0.63	0.84	2.46	2.27

In respect of the values for Rio Bobo in Table 7-3, the monthly maximum values are 1.0 even though there are months in which the run-off (see Chapter 5, Table 5-5) exceed 1.0 m^3/s. Available discharge was calculated as 96% of inflow considering intake efficiency and losses in in the waterway. The maximum available discharge was taken as 3.0 m^3/s.

7.3 PERTINENT DATA CONCERNING INSTALLED CAPACITY

Pertinent data for the maximum discharge determined in 7.2 are given below:

Standard intake level (at head tank)	3,113.5 m
Tail water level	2,986.0 m
Total head	127.5 m
Head loss	5.5 m
Effective head (He)	122.0 m
Turbine and generator efficiency (η)	
$\eta 1 \times \eta 2 = 0.88 \times 0.95 =$	84%
Maximum discharge (Qmax)	3.0 m^3/s
Installed capacity	
(P_{max} 9.8 x 0.84 x 122 x 3.0)	3,000 KW

7.4 ENERGY PRODUCTION

The monthly energy production of San Miguel de Car Power Station is shown in Table 7-4 and Fig. 7-4. According to these, the annual energy production will be 19,900,000 KWH.

As described in Chapter 3, for some period after completion of the power plant, the demand will be smaller than supply capability so that there will be a number of years when all of the output will not be effective.

Fig 7-1 Benefit-Cost Ratio

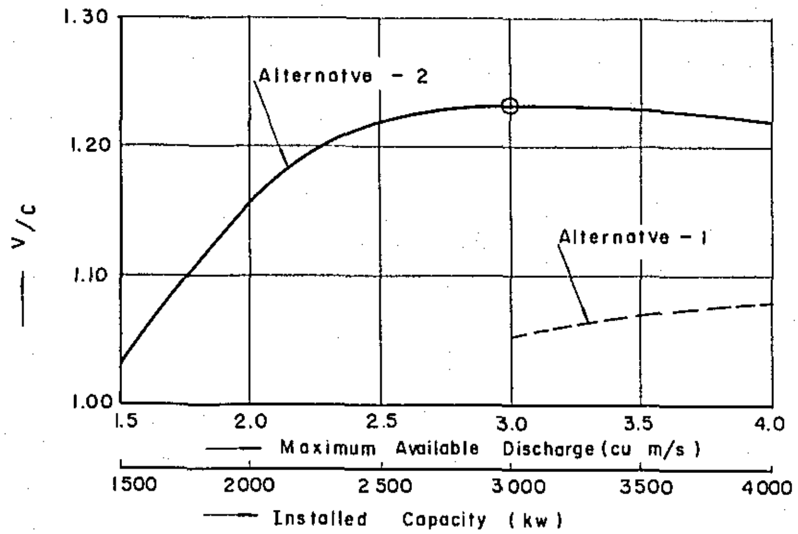


Fig 7-2 Average Monthly Inflow Available Discharge For Power and Spilled Water Including Loss

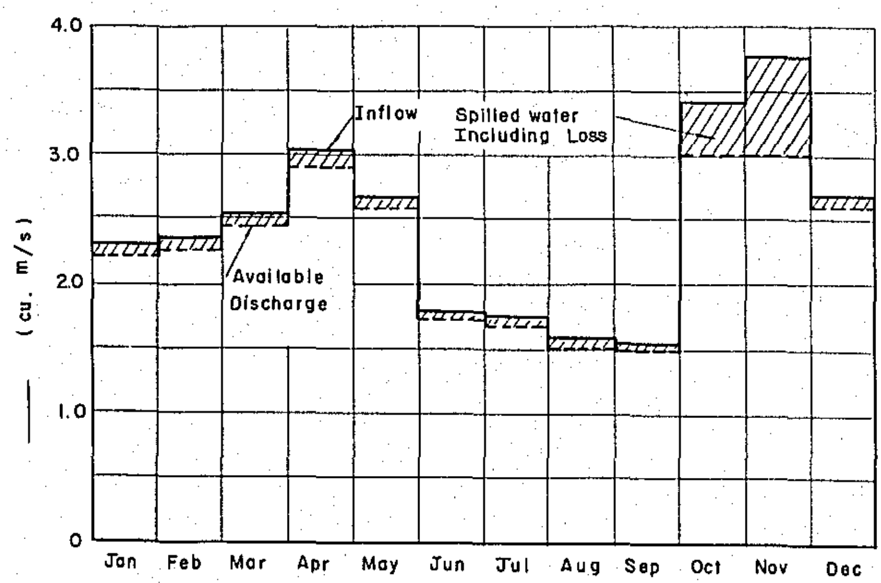


Fig 7-3 Duration Curve for Determination of Available Discharge of San Miguel de Car Power Station

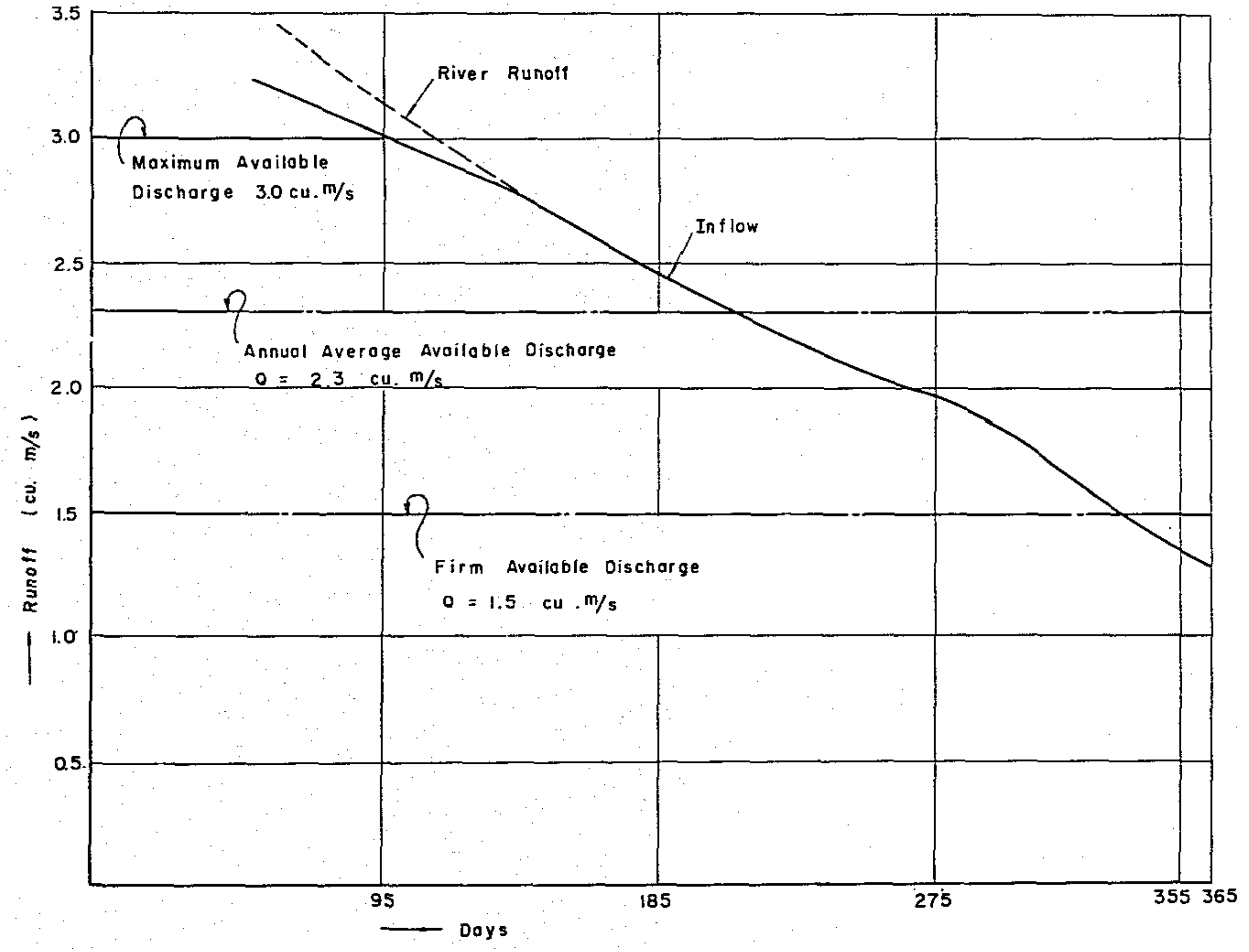


Fig 7-4 Monthly Energy Production

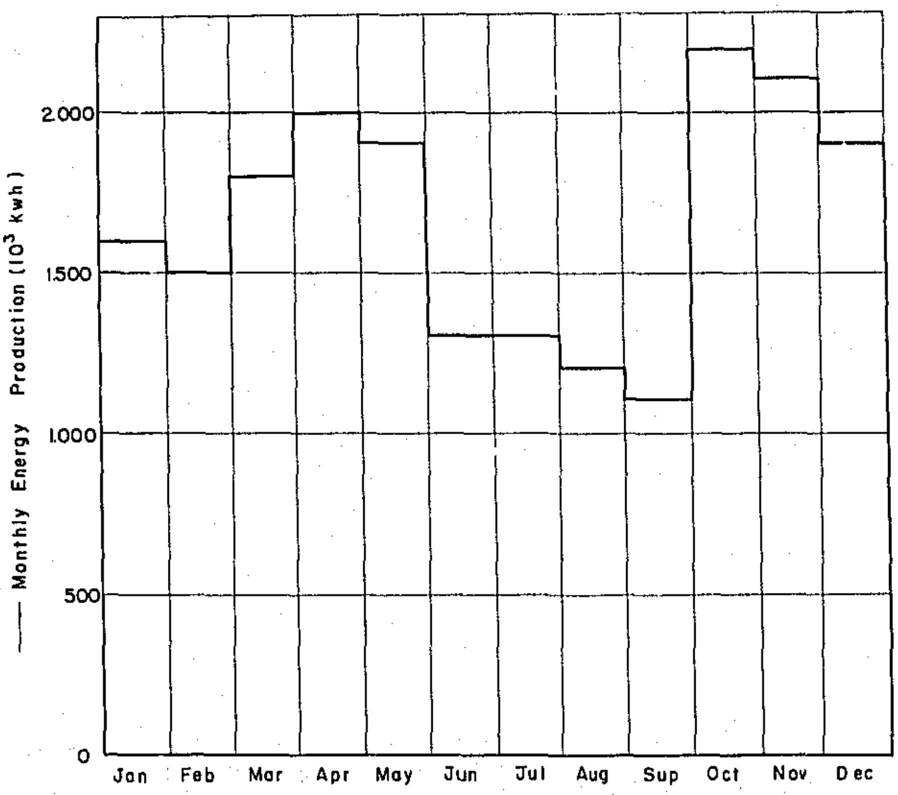


Table 7-5 Effective Energy and Power Output

Year	Effective Annual Energy Production	Effective Output	Remark
	kwn	kw	
1972	160,000	146	Transmission Loss
1973	893,000	1,196	(1) : Energy -6%
1974	1.927,000	1,624	
1975	3.688,000	2,210	(2): Power - 4%
1976	5.969, 000	2,550	
1977	10.113,000	2,890	
1978	14.147,000	2,890	
1979	17.226,000		
1980	18.600,000		
1981	18.800,000		
1982	18.800, 000		
↓	↓	↓	
40 Years Average.	16.200.000	2.710	

Taking this into consideration, the effective energy and effective power for the economic life (40 years) of the project were calculated. In this case, station use and transmission losses of 6 percent for energy and 4 percent for power were included. The results are shown in Table 7-5. According to the calculation the average annual effective electric energy for the economic life of 40 years would be 16,200,000 KWH and the average annual effective power 2,710 KW.

If transmission loss up to Tulcan Sub-station only is considered, the value may be one half of the percentage given above. However, in view of the fact that future variation in energy consumption at centers of demand and station service uses are not known, adequate allowance has been included to be on the safe side.

Table 7-4 Monthly Energy Production

Month	Available Discharge	Average Monthly Output	Monthly Energy Production
	cu.m/s	KW	1000 KWH
January	2.21	2,210	1,600
February	2.25	2,250	1,500
March	2.43	2,430	1,800
April	2.90	2,900	2,000
May	2.58	2,580	1,900
June	1.73	1,730	1,300
July	1.68	1,680	1,300
August	1.52	1,520	1,200
September	1.50	1,500	1,100
October	3.00	3,000	2,200
November	3.00	3,000	2,100
December	2.60	2,600	1,900
Annual Average	2.27	2,270	19,900

8. PRELIMINARY DESIGN

8. PRELIMINARY DESIGN

8.1 DESCRIPTION OF STRUCTURES

8.1.1 Hydraulic Structures

The hydraulic structures of the San Miguel de Car Power Station consist of the intake dam on the Rio Bobo, waterway, combining tank, head tank, penstock, powerhouse, tailrace, regulating pond, and equalizing dam.

a. Intake Dam on Rio Bobo

The intake dam on the Rio Bobo is to be constructed at a location about 4 km upstream of La Cofradia. It is a concrete gravity dam with an overflow spillway having a design discharge capacity of 100 m^3/s as described in Chapter 5.

Excess run-off due to rise in water level at times of flood will be discharged over a side overflow weir constructed in the intake waterway and released into the Rio Bobo. A stoplog gate will be installed near the entrance of the waterway.

b. Headrace

The headrace is comprised of about 4.1 km of open canal, about 0.3 km of culvert and about 0.2 km of tunnel. The gradient is to be 1/600 and 1/1,000. Three types of cross-section are considered; rectangle, trapezoid and tunnel. The section of the open canal about 1.2 km downstream from the intake dam runs through sound bedrock and in order to minimize the volume of excavation it is designed to be a rectangular cross-section. The walls and floor will be lined with a thin coat of concrete to prevent leakage and weathering. The section to be constructed in clay zone is to be of a trapezoidal cross-section with stone masonry lining. In consideration of the safety of the slopes against possible sliding by seepage of water, the width of the riverside dike of canal is approximately 3 m. In addition slope protection will be provided by stone lining. A side overflow weir is to be constructed part way down the canal.

The sections through clay zone at about 1 km and 0.4 km upstream of the confluence with the existing waterway are to be culverts and backfilled about the structure.

The geological condition of the tunnel section is assumed to be the same as that of the existing La Cofradia Tunnel, and therefore, it is anticipated that blasting will not be required in the excavation of the tunnel. Since the ground water level is low, there is no concern of seepage of water. However, as rock in this area softens when it absorbs water, the tunnel will be concrete-lined throughout the whole section in order to prevent possible failure.

c. Combining Tank

The combining tank is to be constructed at the confluence of the existing and newly planned waterways.

A maximum flow of 3 m^3/s from the existing waterways of the Rio Grande and the Rio Chico and 1 m^3/s maximum from the waterway of the Rio Bobo are to be combined in the tank and conducted to the head tank through a waterway. An overflow-type spillway with stoplogs is to be built in the combining tank and water is to be released into a gully through a trapezoidal waterway 40 m long.

d. Head Tank

The head tank is to be built cn a table of land at the end of the waterway. It is designed to hold 360 m^3 of water which is a volume for 2 minutes at the maximum discharge of 3 m^3/s. A gate is to be installed at the exit of the tank.

The spillway will be an overflow-type to be built at the side of the head tank, and its designed capacity will be large enough to discharge excess water safely even in case of complete stoppage of the power plant. Water discharged from the spillway will be conducted through a steel pipe installed parallel with the steel penstock and released into the river downstream of the powerhouse.

e. Penstock

With respect to the route of the penstock, three alternatives A-1, A-2 and A-3 (See attached Drawing No. 5) were studied. Route A-1 passes through a thick deposit of humus so that a large volume of excavation will be necessary about the powerhouse site. In addition, as the ground water level is high, difficulty will also be encountered in the construction of the tailrace.

In alternative A-2, judging from the topographical and geological conditions of the proposed route, there is the danger of sliding of the slope.

For the above mentioned reasons alternatives A-1 and A-2 are judged to be unsuitable for the penstock route.

However, in alternative A-3, the proposed route will present no problem topographically, and only a few meters of excavation of aeolian Cangagua formation consisting of clay and sand will uncover bed rock consisting of tuff. Anchor blocks and saddles constructed on this bedrock will safely support the penstock. This route is more suitable than the other two alternatives, and therefore alternative A-3 is adopted.

The penstock will be installed above ground, connecting the head tank and powerhouse with a single pipe 403 m long designed for a maximum discharge of 3.0 m^3/s. It will bifurcate into two pipes at the powerhouse to serve two turbines.

As the excavated surface of the penstoke route may be eroded by rain, it will be protected with a stone lining.

f. Powerhouse

The powerhouse is to be a semi-underground type built on bedrock in consideration of the tailrace water level and geological and topographical conditions, and the control room and office rooms are to be built above ground.

Access to the powerhouse will be by an existing road which will be repaired and improved. Powerhouse equipment is to be unloaded with a crane to be installed on the roof of the powerhouse and delivered to the erection bay inside the powerhouse.

A stoplog is to be provided at the draft tube exit.

The direction of the tailrace is to be determined taking into account the river flow, and training walls, concrete floor and slope protection will be constructed where necessary.

g. Regulating Pond

Two sites for the regulating pond were studied - one site near the combining tank and other at the upper part of the penstock. As a result of studies, the site near the combining tank was adopted.

As described in Chapter 6. Geology, at this proposed site the surface stratum is aeolian Cangagua formation consisting of sand and clay and the underlying formation is lacustrine Cangagua formation (tuff). The aeolian Cangagua formation will be excavated and removed, and the regulating pond will be constructed on the underlying formation as there is danger of the aeolian Cangagua formation sliding when saturated with water.

The excavated material will be used to construct an earth dam about 7 m high and about 250 m long on the river side. For the dam foundation, the surface soil will be stripped, and the core will be constructed on bedrock. The slopes and floor of the pond will be lined with asphalt in order to prevent leakage of water.

As there may be the possibility of reducing the volume of excavation by moving the site of the regulating pond towards the river side, further detailed studies by conducting permeability test and material test of embankment material are necessary.

h. Dam for Equalizing Reservoir

Two types of dams can be considered. A concrete structure and an earth. However, since more than one half of the dam will be an overflow spillway section, there would be very little economic merit if the non-overflow section is an earth dam. Therefore, a concrete gravity dam about 11 m high with a center overflow section about 66 m long is adopted. The capacity of the spillway as described in Chapter 5 is for a design flood flow of 180 m^3/s. The overflow section is to be constructed in the center of the dam, and a gate is to be installed at the left of the overflow section for the purpose of intake of water and flashing of sand.

8.1.2 Turbines and Generators

a. Number of Main Equipment

The San Miguel de Car Project which will have a total installed capacity of 3,000 KW is to be developed in two stages of 1,500 KW each in consideration of growth of demand, in order to prevent the decrease of combined efficiency of turbine and generator when operated under partial load during midnight hours, and in consideration of the influence to the power system when the station is stopped due to accident or for daily maintenance or overhauling.

b. Type of Turbine

The effective head of this power station is approximately 122 m and the discharge per turbine is a maximum of 1.5 m^3/s. The turbine meeting these conditions would be the Francis type and the Pelton type. However, in case of the Pelton type, the number of revolutions would be about 50% of the Francis type (namely, Pelton 514.3 rpm vs. Francis 1,200 rpm), and consequently the weight of the machinery will be heavier, the price more expensive, the effective head smaller and the space required for installation is greater. It is obviously disadvantageous compared to the Francis type. Therefore, horizontal shaft Francis turbines are adopted taking into account simplicity of maintenance and operation.

The generators to be directly coupled to the turbines are horizontal shaft rotary-field open type.

c. Main Transformer

In view of recent technical improvements and greater reliability and in view of the relatively small capacity required, one main transformer will be installed to serve the two units of turbine-generators.

8.1.3 Transmission Line, Sub-station and Communication Facilities

a. Transmission Line

Two voltages - 13.8 KV and 34.5 KV - for the transmission line between the San Miguel de Car Power Station and Tulcan Sub-station, were studied, but in view of voltage drop, the 34.5 KV line was adopted.

Studies of the operating voltage conditions of power stations and sub-stations in the power systems of Zones A and B between Tulcan and Cayambe by means of an analog computor revealed that the voltage fluctuation in the power systems during peak and off-peak hours can be controlled to within ± 5% by regulation of reactive power at the respective power station, and consequently, there will be no need to install a phase modifier. The assumed maximum power flow on the transmission line between Ibarra and Cayambe up to 1979 is approximately 4, 000 KW, and no need is recognized for a 69 KV transmission line.

Results of studies of operating voltage conditions and power flow from 1972 to 1979 also conducted with an analog computor are shown in Fig. 8-1 and Fig. 8-2.

The tentatively planned transmission voltage to El Angel is 34. 5 KV by directly connecting into the 34. 5 KV transmission line between Tulcan and San Gabriel. However, a 13. 8 KV line from San Gabriel to El Angel can be considered to supply local loads. Therefore, this transmission line should be studied in more detail and a decision made before the definite study of the project.

From the standpoint of economy, the transmission lines of the power systems are to be directly grounded, and in the insulation design internal abnormal voltage by switching surge and resistance to lightning have been taken into consideration. Three sizes of ACSR conductors - 64 mm^2, 58 mm^2 and 48 mm^2 - were studied for the transmission line and as a result of the studies, the 58 mm^2 ACSR conductor was adopted. Supports for the transmission line will be reinforced concrete pole which is being manufactured in the city of Tulcan. The standard span is 120 m. Single poles will be used for suspension sections and H poles where tension will act on the supports.

b. Sub-stations

The main transformers and switching equipment of the Tulcan Sub-station are to be installed outdoors which is a standard outdoor type sub-station controlled from the switchboard room. The San Gabriel Sub-station and the El Angel Sub-stations will have the switching equipment for the 34.5 KV line installed outdoors and those for the 13.8 KV line placed inside cubicles. The stations will be controlled from outdoor control panels, and switchboard rooms will not be constructed.

c. Communication Facilities

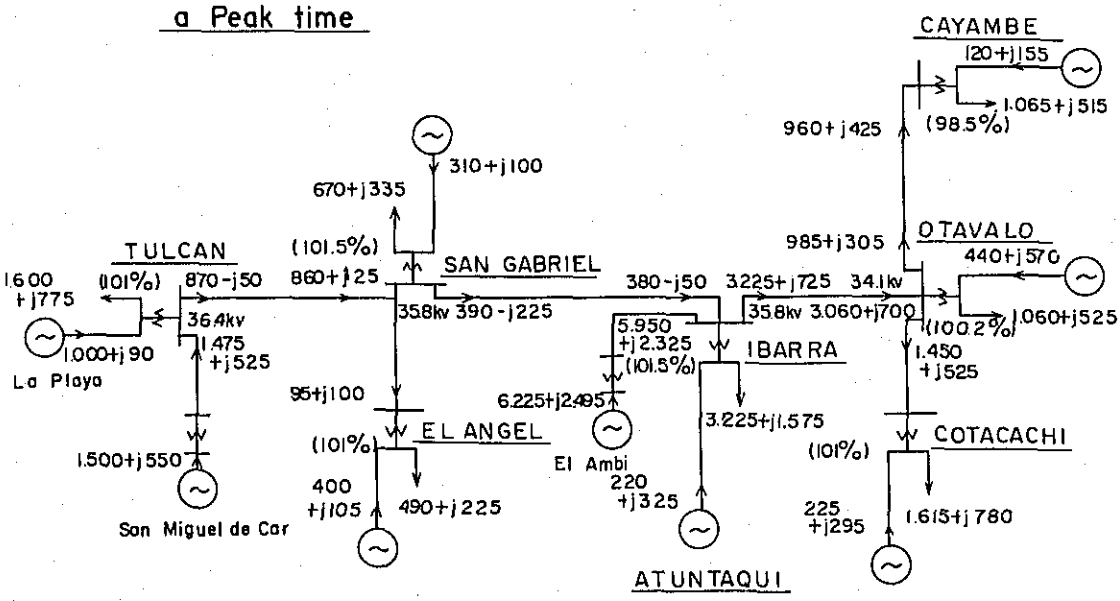
As communication channels for load dispatching a terminal exchange for power line carrier system is to be installed at the San Miguel de Car Power Station and substation in Zone A, and a direct exclusive channel is to be provided between the Ibarra and Tulcan Sub-stations in Zone B.

8.1.4 Principal Features

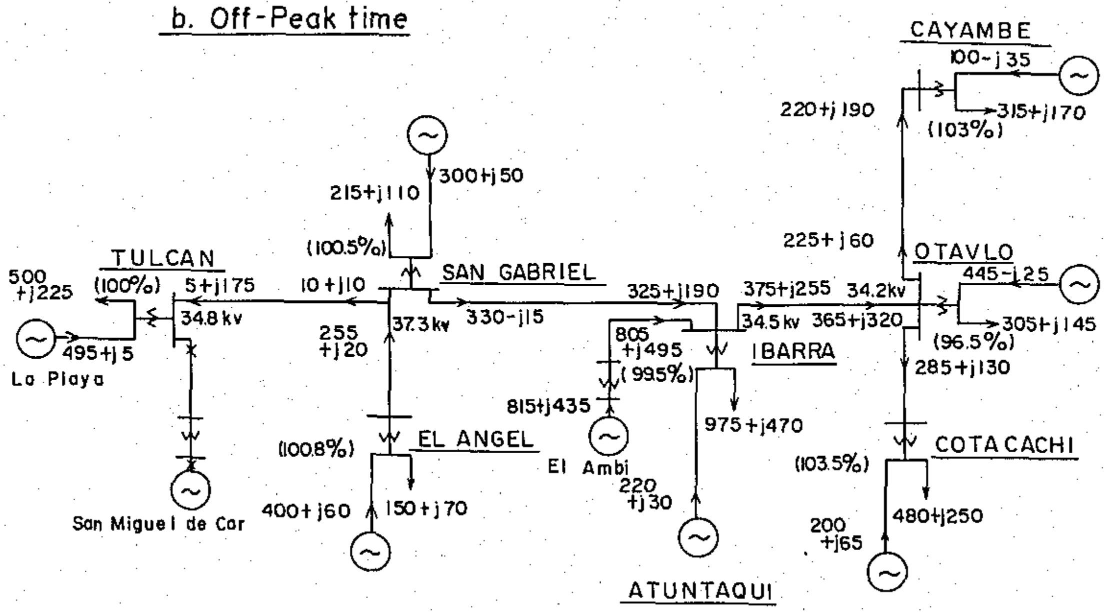
The principal features of the San Miguel de Car Project are as follows:

Fig. 8-1. Power Flow Diagram in 1972

a Peak time

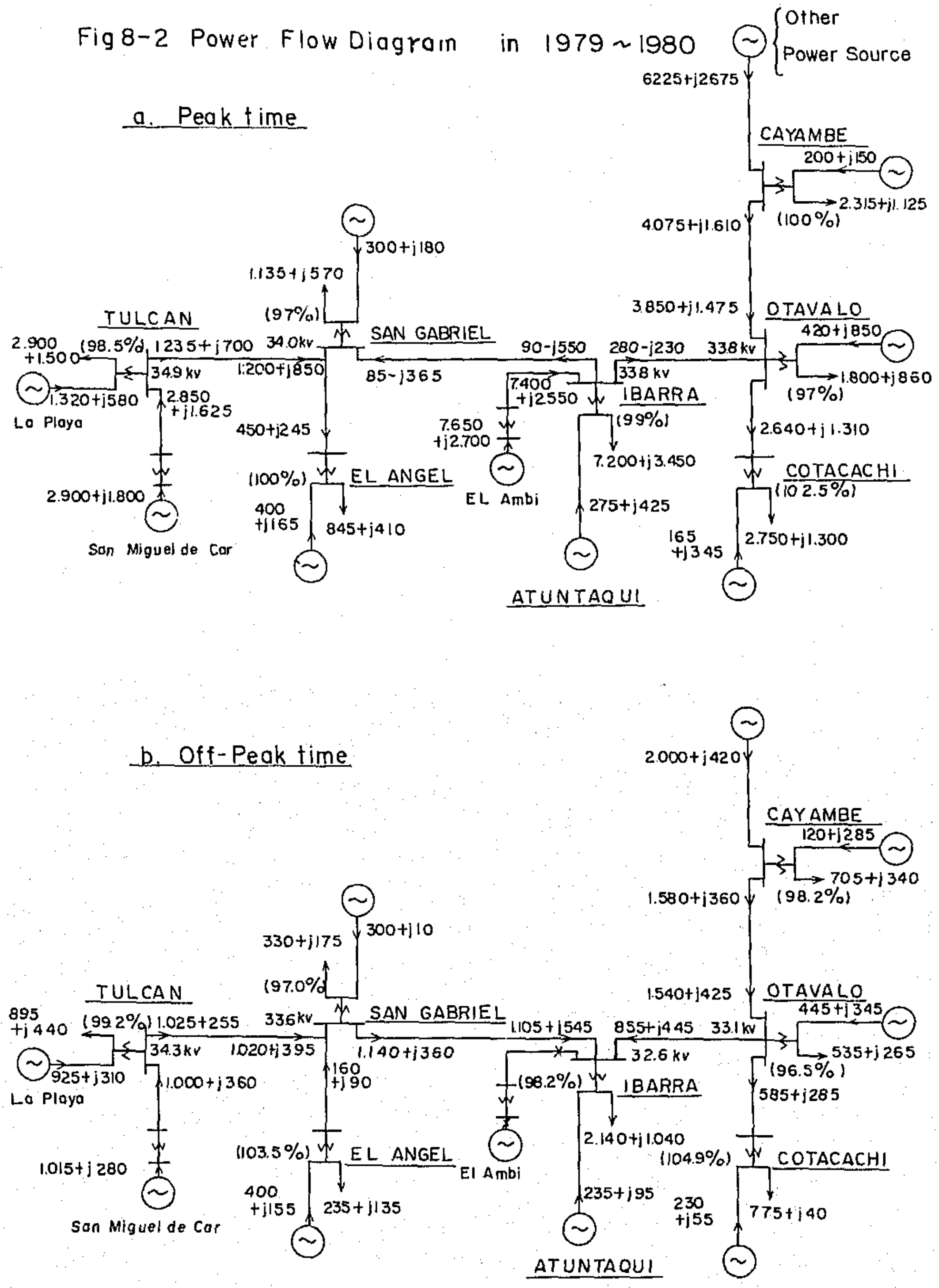


b. Off-Peak time



Note ; ( ) : Percent of Voltage

Fig 8-2 Power Flow Diagram in 1979 ~ 1980



Note; ( ) : Percent of Voltage

Name of Works	Pertinent Data	
Intake Dam		
	Type:	Concrete gravity dam with overflow spillway
	Elevation of Dam Crest:	3,127.6 m
	Length of Dam Crest:	21.5 "
	Height:	4.5 "
	Volume:	350 m^3
	Design Flood Flow:	100 m^3/s
Headrace	Total Length:	4,560 m
	Type:	Open channel and tunnel
	Shape:	Rectangular canal, trapezoidal canal and tunnel
	Cross-section:	Depth(m) x Width(m)
	Type I rectangular canal	0.90 x 0.90
	Type II trapezoidal canal	0.65 x 1.20
	Type III trapezoidal canal	1.30 x 2.20
	Type IV trapezoidal canal	1.20 x 2.00
	Tunnel	0.45 x 1.80
	Maximum Discharge	1.0 m^3/s
Combining Tank		
	Capacity:	30 m^3
	Dimensions: (Length) x (Width)	4.5 m x 3 m
Head Tank		
	Capacity:	360 m^3
	Dimensions: (Length) x (Width)	23 m x 6 m

Headrace Spillway

Type:	Steel pipe	
Diameter:		0.500 m
Length:		430 m

Penstock

Material:	Welded steel pipe	
Length:		403 m
Number of lines:		1
Inside Diameter:		0.8 - 1.0 m

Tailrace

Length		26 m
Type:	Open channel	

Regulating pond

Effective capacity:		28,900 m^3
Dimensions:	(Length) x (Width) x (Depth)	245 m x 65 m x 5 m

Equalizing reservoir

Effective capacity:		30,000 m^3
Type:	Concrete gravity dam with over flow spillway	
Elevation of Dam Crest:		2,904 m
Length of Dam Crest:		66.0 m
Height:		11.0 m
Volume:		1,240 m^3
Design Flood Discharge		180 m^3/s

Powerhouse

Building	Type:	Semi-underground type

Turbine	Type:	Horizontal shaft, single runner, single discharge Francis type water turbine
	Output:	1,600 KW
	Maximum Discharge:	3.0 m^3/s
	Revolutions:	1,200 rpm
	Number of Units:	2
Generator		
	Type:	Three-phase, synchronous generator, horizontal shaft, rotary field, open type
	Capacity:	1,800 KVA
	Voltage:	3.3 KV
	Frequency:	60 cycles
	Number of Units:	2
Main Transformer		
	Type:	Three-phase, outdoor, oil-immersed, self-cooled type
	Capacity:	3,600 KVA
	Voltage:	3.3 KV / 36.0 / 34.5 / 33.0 KV
	Number of Units:	1
Outdoor Switchyard		
	Ground area	270 m^2
Transmission Line		
	Length of each route:	
	San Miguel de Car - Tulcan	9 km
	Tulcan - San Gabriel - El Angel	46 km

San Gabriel - Ibarra — 50 km 1/

Voltage:		34.5 KV
Number of Circuits:		1 cct
Conductor:		ACSR 58 sq. mm
Insulator:	Line post insulator with specially designed clamp	
Supports:	Reinforced concrete pole	
Note: 1/	One half of construction cost to be borne by San Miguel de Car Project	

Tulcan Sub-station

Building	Space		150 m^2
Transformer	Type:	Three-phase, oil immersed, self-cooled auto-transformer	
	Capacity:	1500/1500/450 KVA Y—Y—△	
	Voltage:		36.0 KV / 34.5 / 33.0 — 13.8 KV
	Number of Units:	1st stage (1968)	1
		2nd stage (1977)	1

San Gabriel Sub-station

(Unit sub-station system)

Appurtenant Equipment:		Compressor	
Transformer	Type:	Three-phase, oil immersed, self-cooled auto-transformer	
	Capacity:	500/500/150 KVA Y—Y—△	
	Voltage:		36.0 KV / 34.5 / 33.0 — 13.8 KV
	Number of Units:	1st stage (1968)	1
		2nd stage (1972)	1

3rd stage (1979) 1

El Angel Substation

(Unit sub-station system)

Appurtenant Equipment:		Compressor
Transformer	Type:	Three-phase, oil immersed, self-cooled auto-transformer
	Capacity:	300/300/90 KVA Y-Y-Δ
	Voltage:	36.0 / 34.5 / 33.0 KV / 13.8 KV
	Number of Units:	
		1st stage (1968) 1
		2nd stage (1975) 1
		3rd stage (1979) 1

Communication

Kind:	Power line carrier system
Number of Circuits:	The main exchange will be installed in Tulcan Sub-station, and 1 channel each between Sub-stations.

8.2 CONSTRUCTION SCHEDULE AND CONSTRUCTION METHOD

8.2.1 Construction Schedule

As already described, the San Miguel de Car Project is to be constructed in two stages corresponding to the growth of demand.

Power generation of the first stage must start at the beginning of 1972 and that of the second stage at the beginning of 1974. Therefore, the field works of the first stage shall have to be begun in January 1970 and that of the second stage in January 1973. In consideration of the scale of the project, the method of construction and quantities of work, a construction schedule as shown in Fig. 8-3 was prepared, according to which the construction period for the first stage is assumed to require 24 months, and for the second stage 12 months.

The construction of sub-stations is to be carried simultaneously with the construction of the transmission line between Tulcan and Ibarra as they are required to be in operation in 1968, and the addition of transformers thereafter will be made as shown in the construction schedule.

8.2.2 Construction Method

a. Transportation Route

The Pan American Highway passes through a distance of approximately 608 km between Guayaquil and Tulcan via Quito and there is a road from Tulcan to Tufino. The existing road to the power station site branches out from this road, but there are narrow sections and sharp curves on the way which require repair and improvement. As the road from the power station site to the Rio Bobo intake site is only partially negotiable by jeep, a new road will have to be constructed.

Construction materials and electrical equipment are to be transported to the site by the route above mentioned. Imported materials and machinery are to be unloaded at the port of Guayaquil and hauled by truck by the above route.

b. Procurement of Labor and Materials

Labor for construction works is to be employed domestically. Cement and timber will be procured in Ecuador, but steel materials such as reinforcing steel and other steel, explosives, steel penstock, turbines, generators, transformers, and transmission line conductors, etc. are to be imported.

Aggregate for concrete is planned to be taken from the site near Las Peñas, about 7 km south of Tulcan City, as described in Chapter 6.

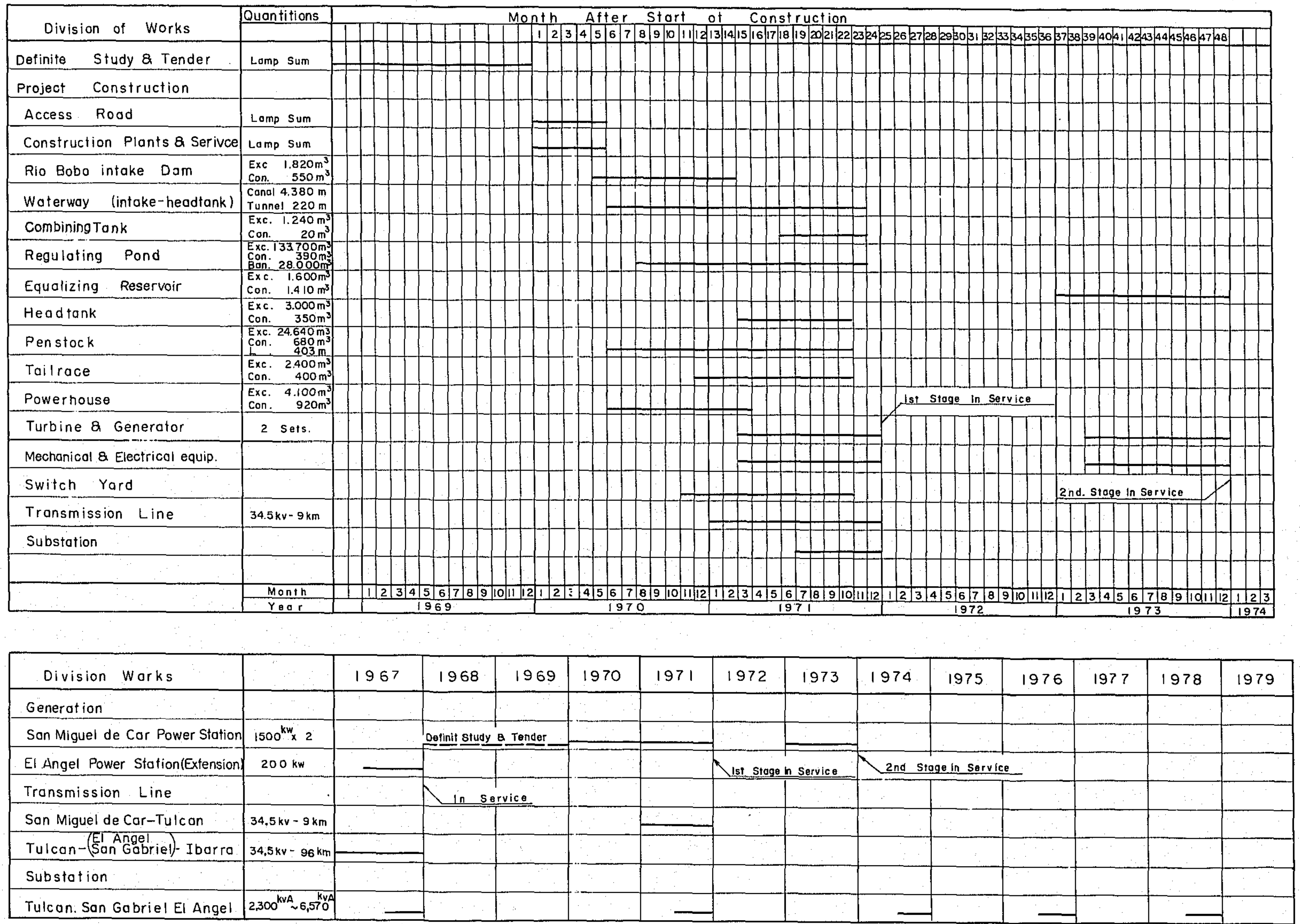
Power for construction will be partly received from the power generated at the La Playa Power Station and small-size diesel generators are to be installed for the rest of the requirements.

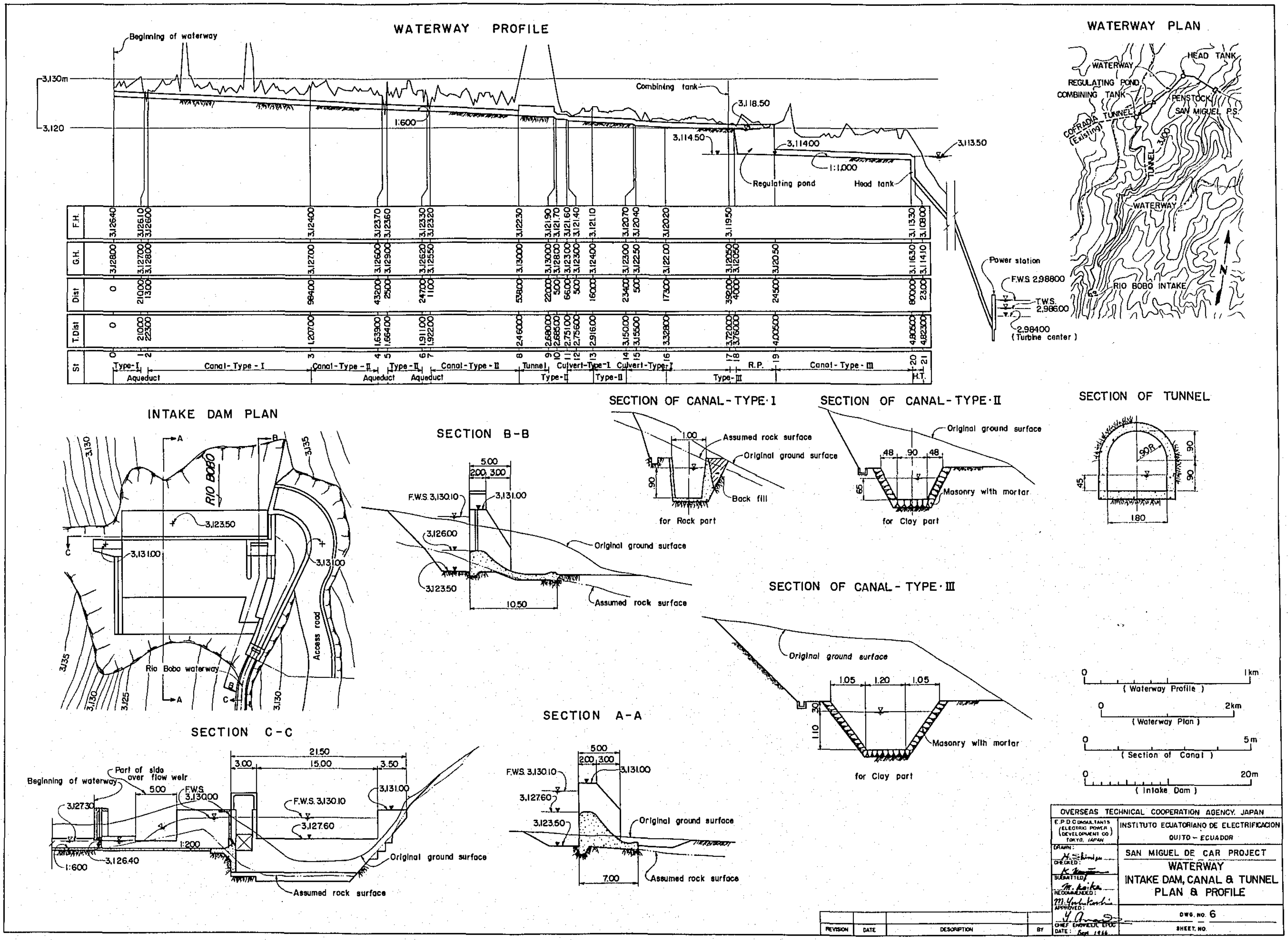
c. Construction Methods

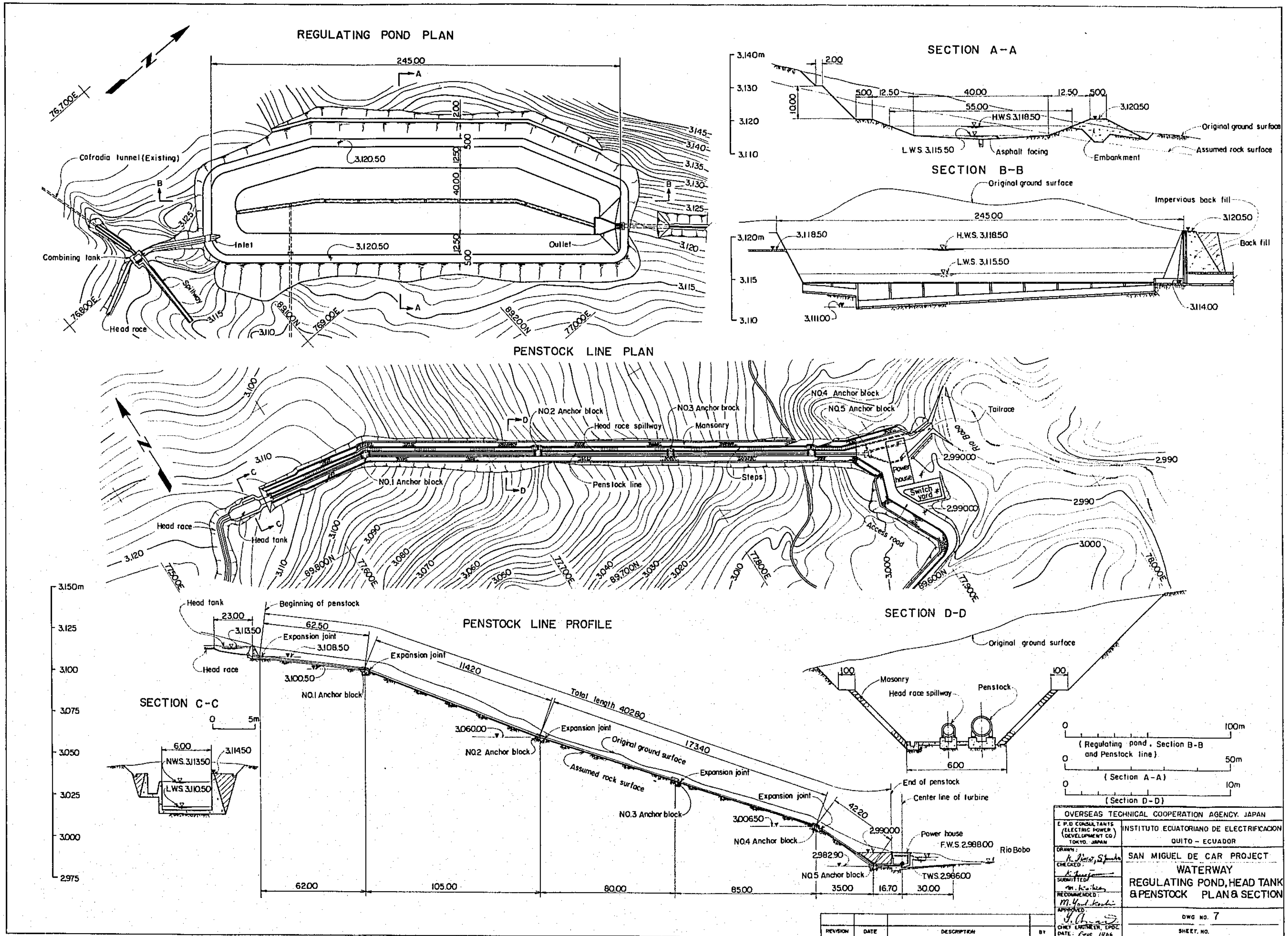
With respect to the construction method for this project there are no special problems expected in view of the types and scale of the works. Attention, however, must be paid to the following points:

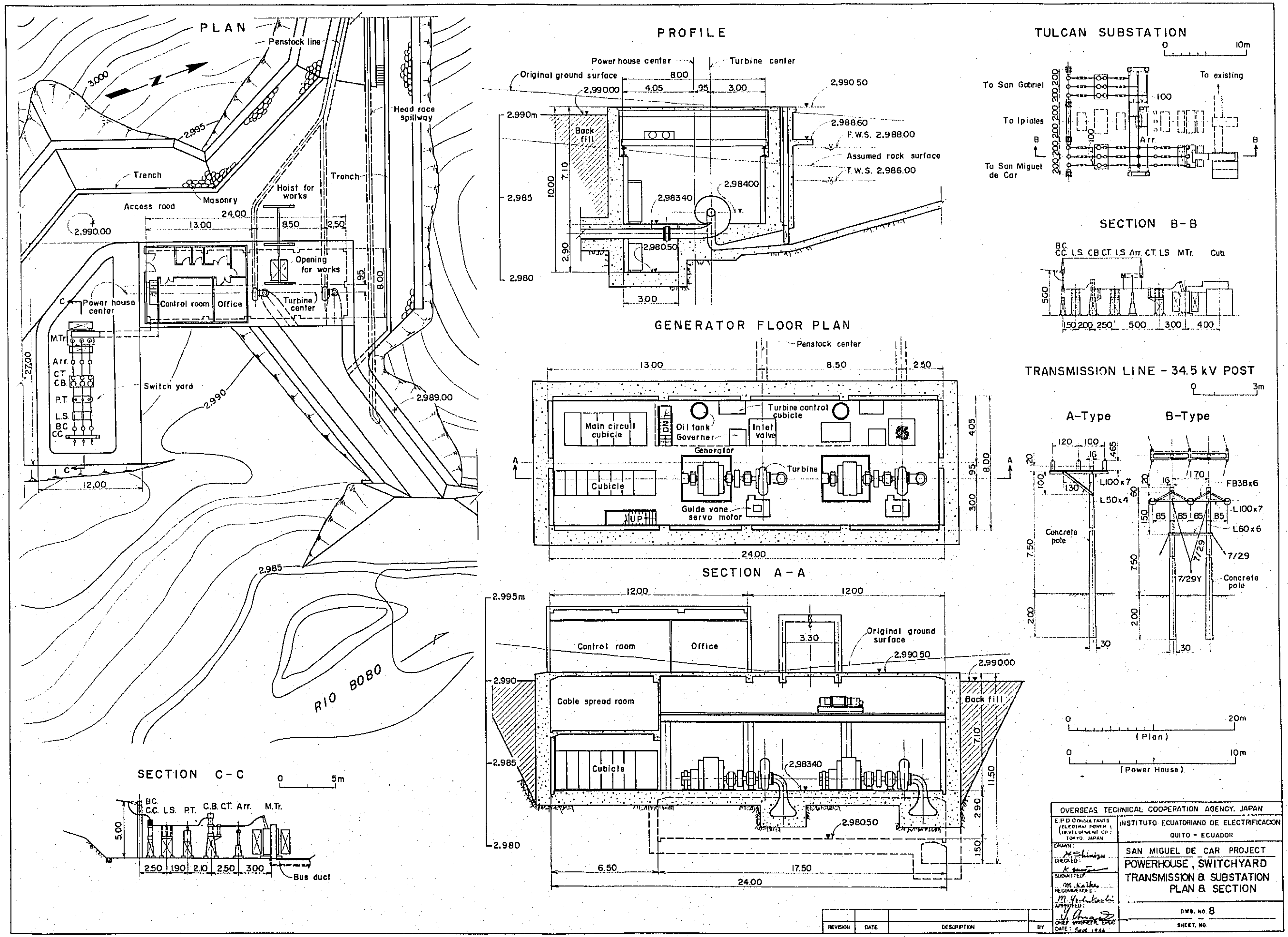
In connection with the geology of the waterway route of approximately 3.5 km from a point about 1 km downstream of the Rio Bobo Intake Dam site to the powerhouse site, the surface is covered with volcanic ash. As there are the possibility of sliding of materials in the waterways due to seepage of water, special caution must be taken in lining work of open canals, although much consideration has been given in the determination of the route of the waterway.

Fig 8-3 Construction Schedule

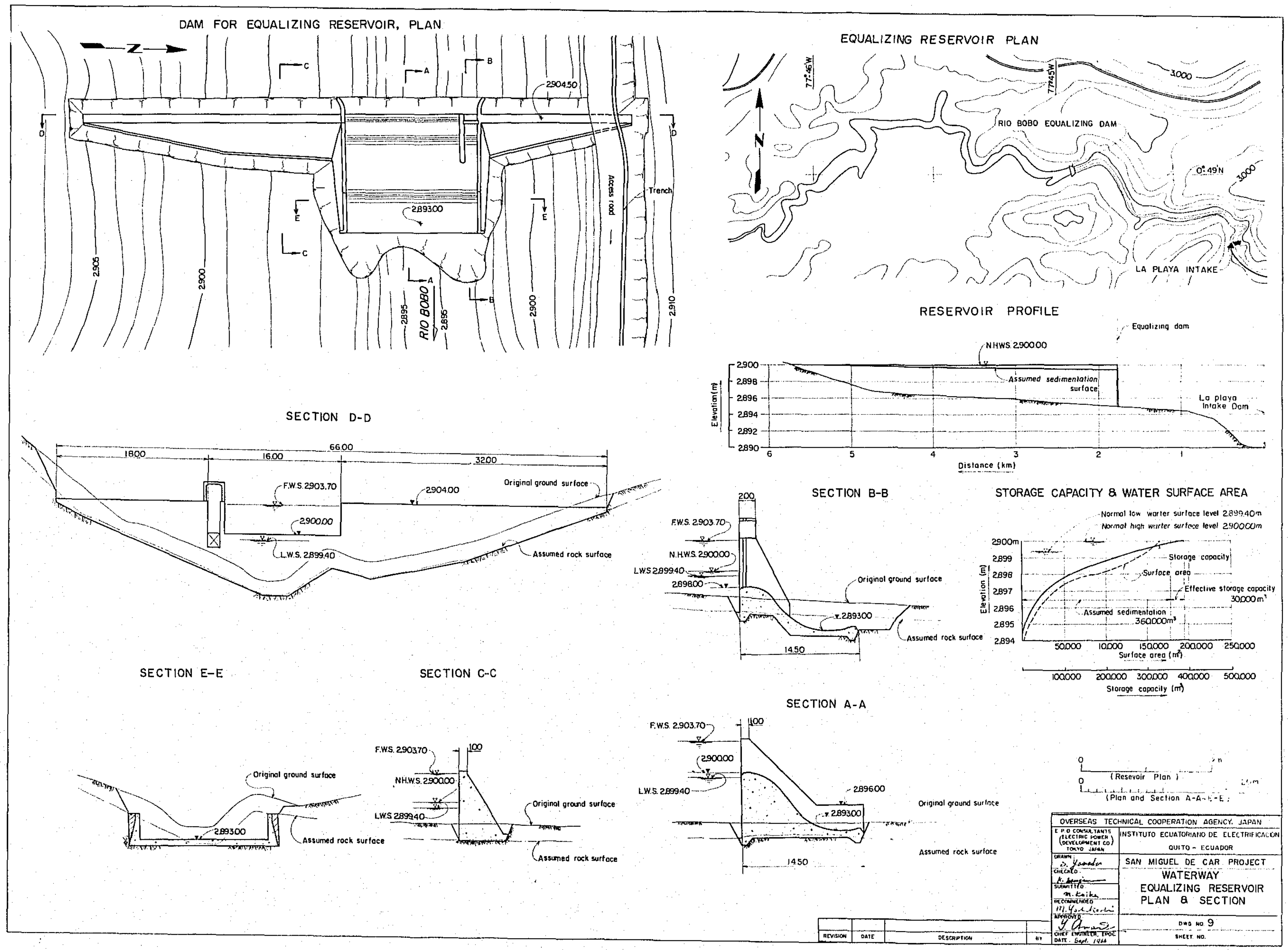



WATERWAY PROFILE
Beginning of waterway
3,130m
3,120
Combining tank
3,118.50
1:600
3,114.50
3,114.00
3,113.50
1:1,000
Regulating pond
Head tank
Power station
F.W.S. 2,988.00
T.W.S. 2,986.00
2,984.00 (Turbine center)
F.H.
G.H.
Dist
T.Dist
St
Type-I Aqueduct
Canal-Type-I
Canal-Type-II
Type-II Aqueduct
Type-II Aqueduct
Canal-Type-II
Tunnel
Culvert-Type-I
Type-II
Culvert-Type-I
Type-II
Culvert-Type-I
Type-III
R.P.
Canal-Type-III
H.T.
WATERWAY PLAN
WATERWAY
HEAD TANK
REGULATING POND
COMBINING TANK
PENSTOCK
SAN MIGUEL P.S.
COFRADIA TUNNEL (Existing)
TUNNEL
WATERWAY
RIO BOBO INTAKE
INTAKE DAM PLAN
RIO BOBO
3,123.50
3,131.00
3,131.00
Access road
Rio Bobo waterway
SECTION B-B
5.00
2.00
3.00
F.W.S. 3,130.10
3,131.00
3,126.00
3,123.50
Original ground surface
10.50
Assumed rock surface
SECTION OF CANAL-TYPE·I
1.00
Assumed rock surface
Original ground surface
Back fill
for Rock part
SECTION OF CANAL-TYPE·II
Original ground surface
.48 .90 .48
Masonry with mortar
for Clay part
SECTION OF TUNNEL
90R
1.80
SECTION OF CANAL-TYPE·III
Original ground surface
1.05 1.20 1.05
Masonry with mortar
for Clay part
SECTION C-C
21.50
3.00 15.00 3.50
Beginning of waterway
Part of side over flow weir
5.00
F.W.S. 3,130.00
F.W.S. 3,130.10
3,127.60
3,131.00
3,127.30
3,126.40
1:200
1:600
Original ground surface
Assumed rock surface
SECTION A-A
5.00
2.00 3.00
F.W.S. 3,130.10
3,131.00
3,127.60
3,123.50
Original ground surface
7.00
Assumed rock surface
(Waterway Profile) 0 1km
(Waterway Plan) 0 2km
(Section of Canal) 0 5m
(Intake Dam) 0 20m
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
E.P.D.C. CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO.) TOKYO, JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION QUITO - ECUADOR
SAN MIGUEL DE CAR PROJECT
WATERWAY
INTAKE DAM, CANAL & TUNNEL
PLAN & PROFILE
DRAWN:
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:
CHIEF ENGINEER, OTCA
DATE:
DWG. NO. 6
SHEET NO.
REVISION DATE DESCRIPTION BY

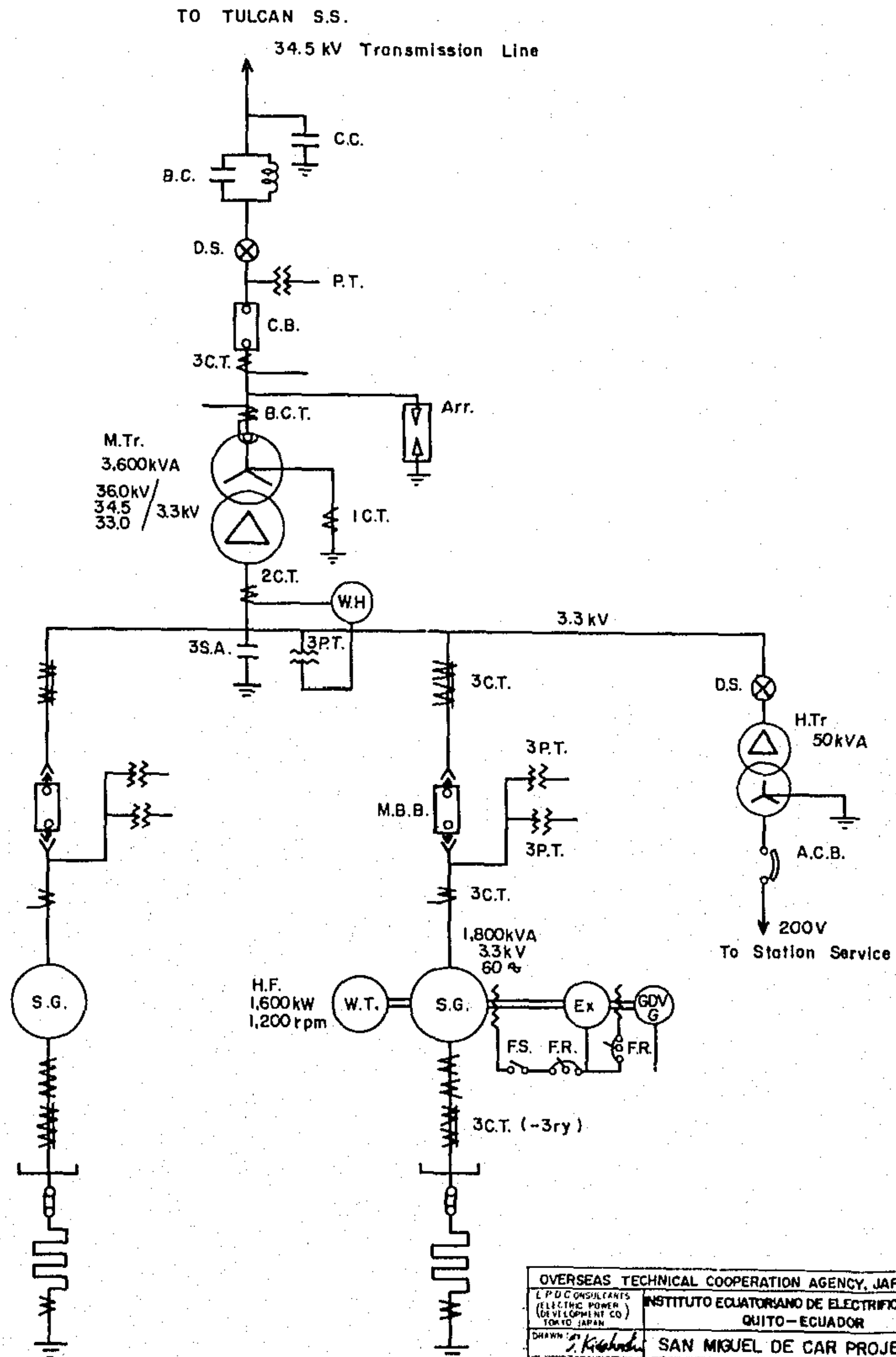

REGULATING POND PLAN
245.00
Cofradia tunnel (Existing)
Combining tank
Head race
Spillway
Inlet
Outlet
3,120.50
SECTION A-A
H.W.S. 3,118.50
L.W.S. 3,115.50
Asphalt facing
Embankment
Original ground surface
Assumed rock surface
SECTION B-B
Impervious back fill
Back fill
PENSTOCK LINE PLAN
NO.1 Anchor block
NO.2 Anchor block
NO.3 Anchor block
NO.4 Anchor block
NO.5 Anchor block
Head race spillway
Mansonry
Penstock line
Steps
Head tank
Tailrace
Power house
Switch yard
Access road
Rio Bobo
PENSTOCK LINE PROFILE
Beginning of penstock
Expansion joint
Total length 402.80
Original ground surface
Assumed rock surface
End of penstock
Center line of turbine
F.W.S. 2,988.00
T.W.S. 2,986.00
SECTION C-C
N.W.S. 3,113.50
L.W.S. 3,110.50
SECTION D-D
Masonry
Penstock
(Regulating pond, Section B-B and Penstock line)
(Section A-A)
(Section D-D)
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
E.P.D CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO) TOKYO, JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION QUITO - ECUADOR
SAN MIGUEL DE CAR PROJECT
WATERWAY
REGULATING POND, HEAD TANK & PENSTOCK PLAN & SECTION
DWG NO. 7
SHEET NO.
REVISION
DATE
DESCRIPTION
BY



PLAN
Penstock line
Head race spillway
Trench
Masonry
Access road
Hoist for works
Opening for works
Control room
Office
Turbine center
Power house center
Switch yard
M.Tr.
Arr.
CT
CB.
P.T.
L.S.
BC
CC
RIO BOBO
SECTION C-C
B.C.
C.C. L.S. P.T. C.B. C.T. Arr. M.Tr.
Bus duct
PROFILE
Power house center
Turbine center
Original ground surface
Back fill
F.W.S. 2,988.00
Assumed rock surface
T.W.S. 2,986.00
GENERATOR FLOOR PLAN
Penstock center
Main circuit cubicle
Oil tank
Governor
Inlet valve
Turbine control cubicle
Generator
Turbine
Cubicle
Guide vane servo motor
UP
SECTION A-A
Control room
Office
Original ground surface
Cable spread room
Back fill
Cubicle
TULCAN SUBSTATION
To San Gabriel
To Ipiales
To San Miguel de Car
To existing
SECTION B-B
BC.
CC. LS. CB. CT. LS. Arr. CT. LS. MTr. Cub.
TRANSMISSION LINE - 34.5 kV POST
A-Type
B-Type
Concrete pole
L100x7
L50x4
FB38x6
L60x6
7/29
7/29Y
(Plan)
(Power House)
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION
QUITO - ECUADOR
SAN MIGUEL DE CAR PROJECT
POWERHOUSE, SWITCHYARD
TRANSMISSION & SUBSTATION
PLAN & SECTION
DWG. NO 8
SHEET. NO.
REVISION DATE DESCRIPTION BY

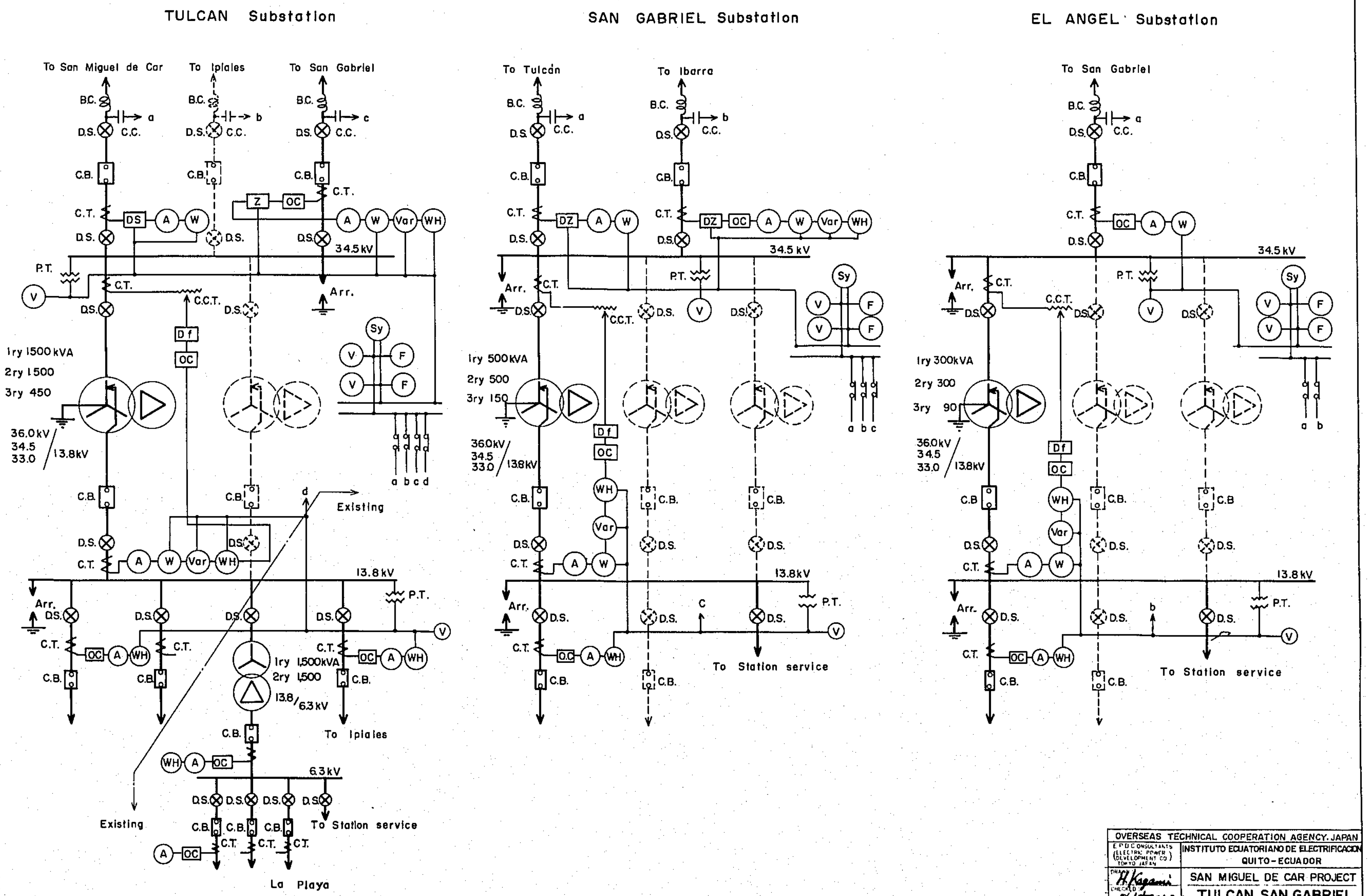


DAM FOR EQUALIZING RESERVOIR, PLAN
2,904.50
2,893.00
Access road
Trench
RIO BOBO
2,905
2,900
2,895
2,910
EQUALIZING RESERVOIR PLAN
77°46'W
77°45'W
3,000
RIO BOBO EQUALIZING DAM
0°49'N
LA PLAYA INTAKE
RESERVOIR PROFILE
Equalizing dam
N.H.W.S. 2,900.00
Assumed sedimentation surface
La playa Intake Dam
Elevation (m)
Distance (km)
SECTION D-D
18.00
16.00
66.00
32.00
F.W.S. 2,903.70
2,904.00
Original ground surface
2,900.00
L.W.S. 2,899.40
Assumed rock surface
SECTION B-B
2.00
F.W.S. 2,903.70
N.H.W.S. 2,900.00
L.W.S. 2,899.40
2,898.00
Original ground surface
2,893.00
Assumed rock surface
14.50
STORAGE CAPACITY & WATER SURFACE AREA
Normal low warter surface level 2,899.40m
Normal high warter surface level 2,900.00m
Storage capacity
Surface area
Effective storage capacity 30,000 m³
Assumed sedimentation 360,000m³
Surface area (m²)
Storage capacity (m³)
SECTION E-E
Original ground surface
2,893.00
Assumed rock surface
SECTION C-C
F.W.S. 2,903.70
1.00
N.H.W.S. 2,900.00
L.W.S. 2,899.40
Original ground surface
Assumed rock surface
SECTION A-A
F.W.S. 2,903.70
1.00
2,900.00
L.W.S. 2,899.40
2,896.00
2,893.00
Original ground surface
Assumed rock surface
14.50
(Reservoir Plan)
(Plan and Section A-A~E-E)
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
E.P.D. CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO.) TOKYO JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION
QUITO - ECUADOR
SAN MIGUEL DE CAR PROJECT
WATERWAY
EQUALIZING RESERVOIR
PLAN & SECTION
DRAWN
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
CHIEF ENGINEER, EPDC
DWG NO 9
SHEET NO.
REVISION
DATE
DESCRIPTION
BY



OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN	
EPDC CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO.) TOKYO JAPAN	INSTITUTO ECUATORIANO DE ELECTRIFICACION QUITO-ECUADOR
DRAWN:	SAN MIGUEL DE CAR PROJECT
CHECKED: SUBMITTED: RECOMMENDED:	POWER PLANT SINGLE-LINE DIAGRAM
APPROVED: CHIEF ENGINEER	DWG. NO. 10
DATE: Sept. 1972	SHEET NO.

REVISION	DATE	DESCRIPTION	BY



OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN

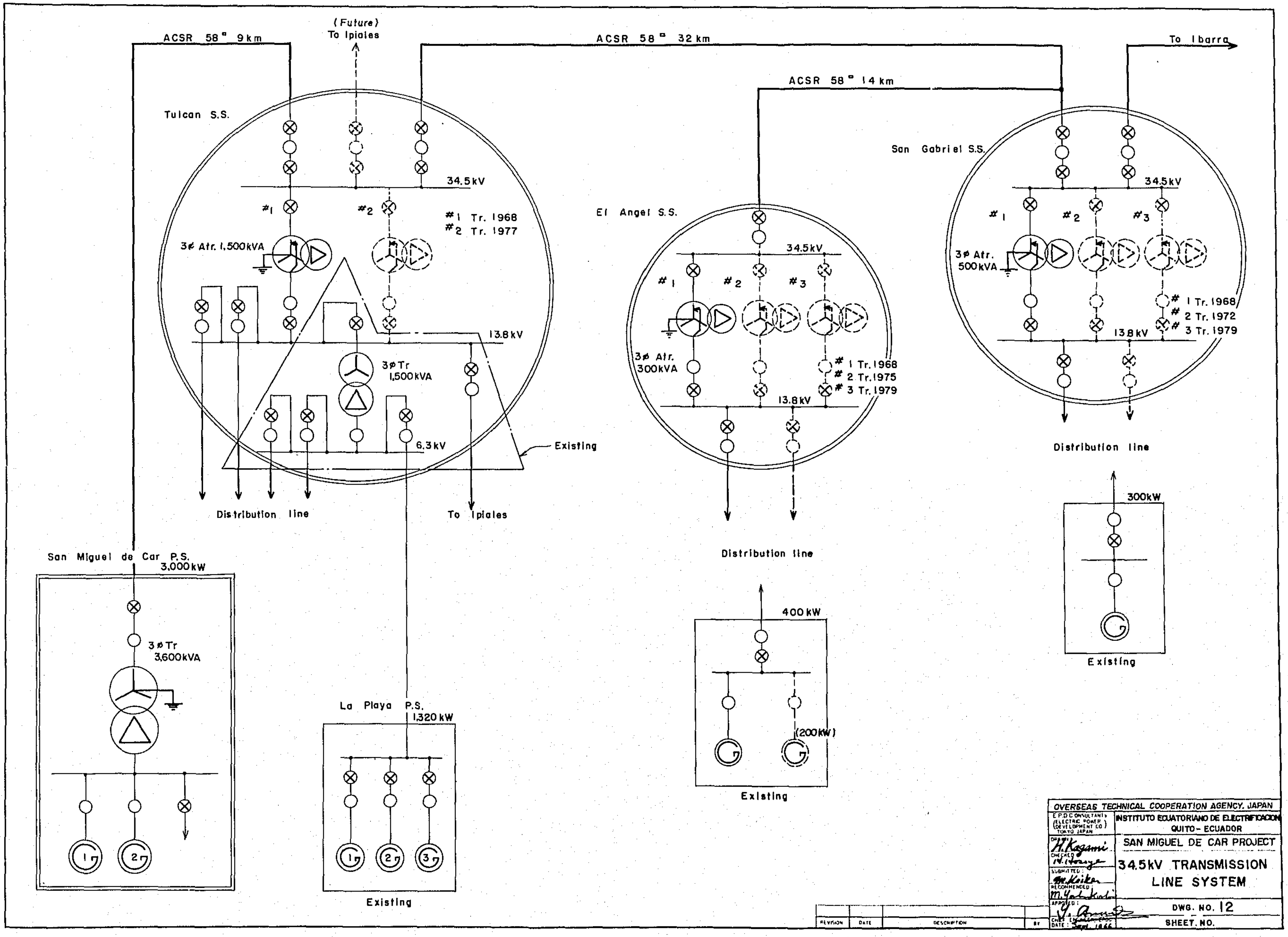
INSTITUTO ECUATORIANO DE ELECTRIFICACION
QUITO-ECUADOR

SAN MIGUEL DE CAR PROJECT

TULCAN, SAN GABRIEL & EL ANGEL SUBSTATION SINGLE-LINE DIAGRAM

DWG. NO. 11

SHEET. NO.


ACSR 58□ 9km
(Future)
To Ipiales
ACSR 58□ 32km
To Ibarra
ACSR 58□ 14km
Tulcan S.S.
34.5kV
#1
#2
#1 Tr. 1968
#2 Tr. 1977
3ø Atr. 1,500kVA
13.8kV
3ø Tr
1,500kVA
6.3kV
Existing
Distribution line
To Ipiales
El Angel S.S.
34.5kV
#1
#2
#3
3ø Atr.
300kVA
#1 Tr.1968
#2 Tr.1975
#3 Tr.1979
13.8kV
Distribution line
San Gabriel S.S.
34.5kV
#1
#2
#3
3ø Atr.
500kVA
#1 Tr. 1968
#2 Tr. 1972
#3 Tr. 1979
13.8kV
Distribution line
300kW
Existing
San Miguel de Car P.S.
3,000kW
3ø Tr
3,600kVA
La Playa P.S.
1,320kW
Existing
400kW
(200kW)
Existing
OVERSEAS TECHNICAL COOPERATION AGENCY, JAPAN
E.P.D.C. CONSULTANTS (ELECTRIC POWER DEVELOPMENT CO.) TOKYO JAPAN
INSTITUTO ECUATORIANO DE ELECTRIFICACION
QUITO - ECUADOR
SAN MIGUEL DE CAR PROJECT
34.5kV TRANSMISSION
LINE SYSTEM
DRAWN:
CHECKED:
SUBMITTED:
RECOMMENDED:
APPROVED:
DWG. NO. 12
SHEET. NO.
REVISION
DATE
DESCRIPTION
BY

9. COST ESTIMATE

9. COST ESTIMATE

9.1 BASIC ASSUMPTIONS

Cost estimates of the project were made under the following basic assumptions.

(1) Estimates of the costs of the project include the San Miguel de Car Power Station, transmission line from San Miguel to El Angel via Tulcan and San Gabriel, one half of the cost of the line between San Gabriel and Ibarra, and the Tulcan, San Gabriel and El Angel Sub-stations. Although the cost of the San Gabriel - Ibarra Transmission Line should be allocated to Zone A and Zone B systems after detailed analysis of power flow and other factors, for the purpose of this estimate one half of the construction cost of the transmission line is allocated in the cost of the San Miguel de Car Project.

(2) Labor cost and unit prices of construction materials are based on 1966 figures.

(a) Labor cost

			Remarks
Common labor	sucres/day	12	8 hours/day & 44 hours/week
Skilled labor	"	25	"
Carpenter	"	30	"
Mason	"	25	"
Electrician	"	35	"
Mechanic	"	50	"
Operator	"	35	"

(b) Materials

Domestically available materials (prices delivered at field)

Portland cement	sucres/ton	625
Wooden form	sucres/m^2	28
Gasoline	sucres/gallon	4.7
Asphalt	"	6.0
Diesel oil	"	3.5

Imported materials (CIF prices)

Reinforcing steel	sucres/ton	3,400
Mobile oil	sucres/gallon	25
Dynamite	sucres/kg	7
Detonators	sucres/piece	0.4

(3) Quantities of work were estimated from the preliminary designs attached to this Report.

(4) The construction cost is divided into domestic currency requirement and foreign currency requirement.

Domestic currency is to be used for payment of wages of domestic labor, domestically procurable materials such as cement, lumber, oil and lubricants, etc., and inland freight charges.

Payments for others than the above will be covered with foreign currency.

(5) The works are to be carried out by contract, and engineering and supervision are to be provided by a consulting engineer under contract to INECEL, the owner of this Project.

Field works are to be executed by Ecuadorian contractors, while installation works of steel structures and electrical equipment are to be handled by foreign contractors. Engineering and supervision are to be provided by a foreign consulting engineering firm.

(6) The costs of water tank gate, penstock, turbines and generators and other electrical equipment, transmission lines, sub-station and communication equipment have been separately estimated for transportation and installation works and for costs of materials and fabrication.

(7) The costs of roads, camps and buildings, furniture and fixtures and vehicles, etc. are included in access road and others.

(8) Costs of acquisition of land and compensation include cost of purchase of land necessary for the works and land to be submerged by construction of an equalizing reservoir.

(9) A contingency of about 20% for civil works and steel structure, about 5% for electrical equipments, and about 10% for transmission line and sub-station is included in the estimate.

(10) Interest of during construction of 8% on domestic currency and 5.75% on foreign currency are included in the estimate.

(11) Imported materials and equipment are to be duty-free. However, 0.1% of CIF values have been included in transportation and installation costs for custom clearance charges.

(12) The cost of the existing diversion works on the Rio Grande and the Rio Chico to increase the available flow of the La Playa Power Station is about 4,468,560 Sucres. Of the cost 2,270,000 Sucres has been allocated to the San Miguel de Car Project.

(13) 200,000 Sucres is included as working capital.

(14) 1 US$ = 18.18 Sucres

9.2 SUMMARY TABLE OF CONSTRUCTION COSTS

The construction costs are as shown in the following table.

SUMMARY TABLE OF CONSTRUCTION COST (Unit: 1,000 Sucres)

No.	Item	Time of Connecting Transmission Line (1967-1969)			First Stage (1970-1972)			Second Stage (1973)			Time of Sub-station Expansion (1974-1979)			Total		
		Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total
1	Land Acquisition and Compensation	-	34	34	-	500	500	-	-	-	-	-	-	-	534	534
2	Access road and others	-	620	620	252	478	730	48	82	130	-	-	-	300	1,180	1,480
3	Civil works & equipment installation cost															
-1	Givil works	-	318	318	1,266	7,423	8,689	59	675	734	-	-	-	1,325	8,416	9,741
-2	Installation of gate, screen & penstock	-	-	-	490	154	644	-	1	1	-	-	-	490	155	645
-3	Installation of turbine, generator & other electrical equipment	-	-	-	740	303	1,043	590	74	664	-	-	-	1,330	377	1,707
-4	Construction of transmission lines	-	1,732	1,732	-	204	204	-	-	-	-	-	-	-	1,936	1,936
-5	Installation of sub-station and communication equipment	213	172	385	-	42	42	-	-	-	-	120	120	213	334	547
	Sub-Total	213	2,222	2,435	2,496	8,126	10,622	649	750	1,399	-	120	120	3,358	11,218	14,576
4	Materials and machinary & equipment															
-1	Gate, screen & penstock	-	-	-	1,337	-	1,337	5	-	5	-	-	-	1,342	-	1,342
-2	Turbine, generator & accessories	-	-	-	5,017	-	5,017	2,326	-	2,326	-	-	-	7,343	-	7,343
-3	Materials of transmission lines	1,420	497	1,917	180	47	227	-	-	-	-	-	-	1,600	544	2,144
-4	Materials of sub-station & communication facilities	3,129	-	3,129	325	-	325	-	-	-	888	-	888	4,342	-	4,342
	Sub-Total	4,549	497	5,046	6,859	47	6,906	2,331	-	2,331	888	-	888	14,627	544	15,171
5	Overhead															
-1	Engineering & supervisory costs	455	-	455	1,196	84	1,280	234	16	250	-	-	-	1,885	100	1,985
-2	Administration	-	360	360	445	464	909	151	39	190	-	49	49	596	912	1,508
-3	Working Capital	-	-	-	-	160	160	-	40	40	-	-	-	-	200	200
	Sub-Total	455	360	815	1,641	708	2,349	385	95	480	-	49	49	2,481	1,212	3,693
6	Contingency	649	422	1,071	1,116	1,645	2,761	176	166	342	84	19	103	2,025	2,252	4,277
7	Interest during construction	135	134	269	548	724	1,272	83	35	118	-	-	-	766	893	1,659
8	Total (1 - 7)	6,001	4,289	10,290	12,912	12,228	25,140	3,672	1,128	4,800	972	188	1,160	23,557	17,833	41,390
9	Existing diversion works	-	2,270	2,270	-	-	-	-	-	-	-	-	-	-	2,270	2,270
10	Grand Total	6,001	6,559	12,560	12,912	12,228	25,140	3,672	1,128	4,800	972	188	1,160	23,557	20,103	43,660

3. DETAILED CONSTRUCTION COST OF CIVIL WORKS AND EQUIPMENT INSTALLATION (Unit; 1,000 Sucres)

3-1. DETAILED COST OF CIVIL WORKS

No.	Item	Time of Connecting Transmission Line (1967-1969)			First Stage (1970-1972)			Second Stage (1973)			Time of Substation Expansion After Second Stage (1974-1979)			Total		
		Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total	Foreign Currency	Domestic Currency	Total
3-1-1	Intake Dam				55	327	382							55	327	382
3-1-2	Headrace - 1 (Open Canal)				146	1,704	1,850							146	1,704	1,850
3-1-3	Headrace - 2 (Tunnel)				69	661	730							69	661	730
3-1-4	Combining tank				8	85	93							8	85	93
3-1-5	Head tank				38	227	265							38	227	265
3-1-6	Penstock				73	633	706							73	633	706
3-1-7	Tailrace				19	195	214							19	195	214
3-1-8	Regulating pond				549	2,220	2,769							549	2,220	2,769
3-1-9	Equalizing reservoir				-	-	-	59	675	734				59	675	734
3-1-10	Powerhouse				307	1,343	1,650							307	1,343	1,650
3-1-11	Switchyard foundation				2	28	30							2	28	30
3-1-12	Sub-station foundation	-	318	318	-	-	-							-	318	318
	Total	-	318	318	1,266	7,423	8,689	59	675	734				1,325	8,416	9,741

10. ECONOMIC EVALUATION

10. ECONOMIC EVALUATION

10.1 ECONOMIC EVALUATION OF SAN MIGUEL DE CAR POWER STATION

10.1.1 Saleable Electric Energy and Saleable Output

The saleable energy and power are identical to the effective energy and power tabulized in Table 7-5, Chapter 7 and according to this the annual average saleable energy during the life of project (40 years) is 16,200,000 KWH and the annual average saleable power is 2,710 KW.

10.1.2 Annual Cost and Energy Cost per KWH

10.1.2.1 Annual Cost

a Basis of Calculation

The calculation of annual cost is based on the following conditions which have been commonly used by INECEL and were judged to be acceptable in the studies made by EPDC.

a-1 Interest Rate

An interest rate of 5.75% per annum for foreign currency and 8% for domestic currency are assumed for interest rates on construction costs. However, in this economic evaluation an interest rate of 8% per annum for both foreign and domestic currencies will be applied, which is the rate normally used in calculations by INECEL.

a-2 Capital Investment

The capital investment required for this project is as shown in Table 9-1. The present worth of the above investment as of 1972, in which the first stage of the San Miguel de Car Power Station is scheduled to start operation, at an interest rate of 8% per annum is as shown in Table 10-1. However, interest charges from 1968 to 1972 on investments to be made in 1968 for the transmission line and sub-stations are to be borne by other power stations in the system and are not included in the cost of the San Miguel de Car Project.

Table 10-1 Total Investment (Present worth at 1972)

Facility	Investment
	Sucres
Generation	30, 181, 000
Transmission	5, 920, 000
Sub-station	6, 180, 000
Total	42, 281, 000

a-3 Serviceable Life

The average serviceable life are 40 years for hydraulic generating equipment and 33 years for transmission lines and sub-stations.

a-4 Interest and Amortization

The uniform annual cost over the 40 years serviceable life of the project to amortize the cost with interest of the project by the sinking fund method was calculated.

The cost factors are as follows:

Generating equipment	8. 4%
Transmission line and sub-stations	8. 7%

However, in this case the residual after the 40 years life and the replacement costs for facilities of life less than 40 years are not considered.

a-5 Maintenance and Operating Costs

Generating equipment:	80 Sucres/KW per year
Transmission lines:	1, 300 Sucres/km per year
Sub-stations:	12 Sucres/KVA per year

a-6 Administrative Cost

The administrative cost is assumed to be 35% of the maintenance and operating costs.

a-7 Insurance

The insurance premium is estimated at 0. 1% of the capital investment for facilities.

b Annual Costs

The annual costs calculated on the basis of the above assumptions is 4, 130, 000 Sucres as shown in detail in Table 10-2 below.

Table 10-2 Annual Costs of San Miguel de Car P. S.

Unit: 1000 Sucres

Item	Generation	Transmission	Sub-station	Total
Interest and amortization	2, 531	512	537	3, 580
Operation and Maintenance	216	105	54	375
Administration	76	37	19	132
Insurance	31	6	6	43
Total	2, 854	660	616	4, 130

10. 1. 2. 2 *Unit Cost of Energy of San Miguel de Car Power Station*

Dividing the annual cost of 4, 130, 000 Sucres of the San Miguel de Car Power Station obtained in the preceding sub-paragraph by the effective saleable energy of 16, 200, 000 KWH, the cost per KWH delivered at sub-station is 0. 254 Sucres.

10. 1. 3 Comparison with Alternative Source

As a result of various studies of an alternative source of power in the system, a diesel generating power plant of equivalent capacity is considered.

10. 1. 3. 1 Specification of Alternative Source

Alternative Source:	Diesel Plant (It is assumed that diesel plants will be installed at centers of load. Therefore, transmission lines and sub-station were considered not necessary.)
Output:	500 KW x 6 units

Utilization Factor:	61.5%
Annual Energy Production:	16,200,000 KWH
KW Adjustment Factor:	15%
Heat Value of Fuel:	148,000 B.T.U./gallon
Unit Price of Fuel:	3.5 Sucres/gallon
"	0.25 Sucres/KWH
Construction Cost: (Capital Investment for Facilities)	9,900,000 Sucres (3,300 Sucres/KW)

10.1.3.2 Annual Costs and Energy Cost per KWH

a Basis of Calculation

The calculation of annual costs of the alternative diesel power plant is based on the following conditions:

a-1 Interest Rate

An interest rate of 8% per annum is assumed.

a-2 Serviceable Life

The average serviceable life is assumed to be 15 years.

a-3 Interest and Amortization

The uniform annual cost over the 15 years life is calculated. The annual cost factor is 11.7%.

a-4 Maintenance and Operation Costs

This is estimated at 180 Sucres/KW per year.

a-5 Administrative Cost

This is estimated at 35% of the above maintenance and operation costs.

a-6 Insurance

This is estimated at 0.1% of the capital investment for facilities.

b Annual Costs

The annual costs calculated on the basis of the above assumptions are shown in Table 10-3 below.

Table 10-3 Annual Costs of Diesel Plant

Unit: Sucres

Item		Annual Cost	Total of Annual Cost
Fixed Cost	Interest and Amortization	1,158,300	
	Operation and Maintenance	540,000	
	Administration	189,000	
	Insurance	9,900	
	Sub-Total	1,897,200	
	KW Adjustment	284,550	
	Total	2,181,750	2,181,750
	Cost per KW	728	
Variable Cost	Fuel and Lubricant	4,050,000	
	Total	4,050,000	4,050,000
	Cost per KWH	0.25	
	Grand Total		6,231,750

c Unit Cost of Energy of the Alternative Diesel Plant

Dividing the annual cost of 6,231,750 Sucres of the alternative diesel plant obtained in the preceding section by the annual energy of 16,200,000 KWH, the cost of 0.385 Sucres per KWH is obtained.

10.1.4 Benefit-Cost Ratio

10.1.4.1 Benefit

The costs per KW and KWH of the alternative diesel plant obtained in the preceding sub-paragraph are considered to be the benefit per KW and KWH of the San Miguel de Car Power Station.

The annual effective energy and power given in Table 7-5 of Chapter 7 are multiplied by the above unit costs to obtain the annual benefit throughout the serviceable life of the project. This is shown in Table 10-4. These annual benefits throughout the serviceable years converted to present worth in 1972 and their total uniformly distributed over the year are the annual benefit. This is given in Table 10-4, and the annual benefit is 5,060,000 Sucres.

10.1.4.2 Benefit-Cost Ratio

The ratio (V/C) between the above annual benefit (V) of 5,060,000 Sucres and the annual cost (C) of 4,130,000 described in sub-paragraph 10.1.2.1 is 1.23.

As described above, transmission line and sub-stations are not included in the alternative diesel plant, though they are included in the San Miguel de Car Project. The transmission line and sub-stations will be extremely important, for both Zones A and B, for system reliability and operation. However, these merits are not included in the benefit, and a simple comparison only was made with the output of the alternative diesel plant, but even under this condition, the San Miguel de Car Project is economically justifiable.

Table 10-4 Annual Benefit of San Miguel de Car Project

Year	(1) Saleable Annuel Energy	(2) Salable Average Annual Output	Annual Benefit (3) for KWH (1) x 0.25	(4) for KW (2) x 728	Total ((3) + (4))
	KWH	KW	1000 Sucres	1000 Sucres	1000 Sucres
1972	160,000	146	40	106	146
1973	893,000	1,196	223	870	1,093
1974	1,927,000	1,624	482	1,180	1,662
1975	3,688,000	2,210	925	1,610	2,535
1976	5,969,000	2,550	1,490	1,860	3,350
1977	10,113,000	2,890	2,530	2,100	4,630
1978	14,147,000	2,890	3,540	2,100	5,640
1979	17,226,000	.	4,310	.	.
1980	18,600,000	.	4,650	.	.
1981	18,800,000	.	4,700	.	.
1982	18,800,000	.	4,700	.	.
.	.	.	.	.	.
.	.	.	.	.	.
2012	18,800,000	2,890	4,700	2,100	6,800
Present Worth at 1972	-	-	22,189	38,210	60,399
Annual Benefit for 40 Years	-	-	1,860	3,200	5,060

10. 2 AVERAGE ENERGY COST OF APPROXIMATE FUTURE YEARS IN ZONE A

10. 2. 1 Saleable Energy

The saleable energy of the power stations in Zone A is the total demand of Zone A and the energy to be supplied to Zone B. However in some years Zone A will receive energy from Zone B, but as the cost of this energy to be purchased from Zone B is not known, this cost could not be included in the cost estimate. Therefore, the energy to be purchased from Zone B was subtracted from the energy to be supplied to Zone B.

The saleable energy of the power stations in Zone A is shown in Table 10-7.

10. 2. 2 Annual Costs and Unit Cost of Energy

a Basis of Calculation

a-1 Cost Factor

In the calculation of the annual costs the cost factors shown in Table 10-5 are applied.

Table 10-5 Cost Factors

	Depreciation %	Interest & Return %	Operation & Maintenance Sucre/KW/% year	Administration % of O. M.	Insurance %
Generation					
Existing					
La Playa	2.0	5.0	100	15	0.1
Small Hydro	2.5	5.0	160	15	0.1
New Project					
Extension-El Angel	2.5	8.0	160	35	0.1
San Miguel de Car	2.5	8.0	80	35	0.1
Transmission			Sucre/km/year		
La Playa-Tulcan(exist)	3.0	5.0	1,000	15	0.1
San Miguel-Tulcan -San Gabriel -El Angel	3.0	8.0	1,300	35	0.1
Sub-station			Sucre/KVA/year		
Tulcan (exist)	3.0	5.0	20	15	0.1
Tulcan, El Angel San Gabriel	3.0	8.0	12	35	0.1

Note: The cost factors for the La Playa Power Station are those from data - , Ofc. No. 2294. - of INECEL.

a-2 Capital Investment

The capital investments for the San Miguel de Car Project are as described in Chapter 9, and investments for generating facilities other than the above are those taken from data - Ofc. No. 2294 and No. 660 SLHL 1139 - compiled by INECEL. The capital investment includes one half of the cost of the transmission line between San Gabriel and Ibarra in addition to the investments for the generating facilities in Zone A.

b Annual Costs and Unit Cost of Energy

The annual costs and unit cost of energy in each year of the approximate future years (1968 - 1979) are shown in Table 10-7. For the period of 1968 through 1979, the average unit cost of energy is as shown in Table 10-6 below.

Table 10-6 Energy Cost of Zone A

Unit: Sucres/KWH

Period	Zone A
1968 - 1976	0.380
1968 - 1977	0.352
1968 - 1978	0.324
1968 - 1979	0.300

Table 10-7 Estimated Annual Investment and Cost of Energy of Zone A Power System

	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
1 Investment												
1 Generation												
1 Existing												
a) La Playa	12,475	12,475	12,475	12,475	12,475	12,475	12,475	12,475	12,475	12,475	12,475	12,475
b) Small Hydro-Plants	2,680	2,680	2,680	2,680	2,680	2,680	2,680	2,680	2,680	2,680	2,680	2,680
2 Project												
a) El Angel (extension)	600	600	600	600	600	600	600	600	600	600	600	600
b) San Miguel de Car	-	-	-	-	26,370	26,370	31,170	31,170	31,170	31,170	31,170	31,170
Sub-total	15,755	15,755	15,755	15,755	42,125	42,125	46,925	46,925	46,925	46,925	46,925	46,925
2 Transmission												
1 La Playa-Tulcan	174	174	174	174	174	174	174	174	174	174	174	174
2 San Miguel-Tulcan	-	-	-	-	620	620	620	620	620	620	620	620
3 Tulcan-El Angel-San Gabriel	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300	3,300
4 San Gabriel-Ibarra	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Sub-total	5,474	5,474	5,474	5,474	6,094	6,094	6,094	6,094	6,094	6,094	6,094	6,094
3 Substation												
1 Tulcan (exist)	104	104	104	104	104	104	104	104	104	104	104	104
2 Tulcan, El Angel, San Gabriel	4,990	4,990	4,990	4,990	5,410	5,410	5,410	5,650	5,650	6,080	6,080	6,570
Sub-total	5,094	5,094	5,094	5,094	5,514	5,514	5,514	5,754	5,754	6,184	6,184	6,674
4 Total Investment	26,323	26,323	26,323	26,323	53,733	53,733	58,533	58,733	58,733	59,203	59,203	59,693
2 Accumulated Depreciation												
1 Generation												
1 Existing												
a) La Playa	1,322	1,572	1,822	2,072	2,322	2,572	2,822	3,072	3,322	3,572	3,822	4,072
b) Small Hydro-Plants	871	838	1,005	1,072	1,139	1,206	1,273	1,340	1,407	1,474	1,541	1,608
2 Project												
a) El Angel (extension)	0	15	30	45	60	75	90	105	120	135	150	165
b) San Miguel de Car	-	-	-	-	0	659	1,318	2,097	2,876	3,655	4,434	5,213
Sub-total	2,193	2,425	2,857	3,189	3,521	4,512	5,503	6,614	7,725	8,836	9,947	11,058
2 Transmission												
1 La Playa-Tulcan	30	35	40	45	50	55	60	65	70	75	80	85
2 San Miguel-Tulcan	-	-	-	-	0	19	38	57	76	95	114	133
3 Tulcan-El Angel-San Gabriel	0	99	198	297	396	495	594	693	792	891	990	1,089
4 San Gabriel-Ibarra	0	60	120	180	240	300	360	420	480	540	600	600
Sub-total	30	194	358	522	686	869	1,052	1,235	1,418	1,601	1,784	1,967
3 Substation												
1 Tulcan (exist)	18	21	24	27	30	33	36	39	42	45	48	51
2 Tulcan, El Angel, San Gabriel	0	150	300	450	600	762	924	1,086	1,256	1,426	1,609	1,792
Sub-total	18	171	324	477	630	795	960	1,125	1,298	1,471	1,657	1.843
4 Total Accumulated Depreciation	2,241	2,790	3,539	4,188	4,837	6,176	7,515	8,974	10,441	11,908	13,388	14,868

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				1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
3			Net Investment	24,082	23,533	22,784	22,135	48,896	47,557	51,018	49,799	48,332	47,295	45,815	44,825
4			Production Expenses												
	1		Depreciation												
		1	Generation												
			a) La Playa	250	250	250	250	250	250	250	250	250	250	250	250
			b) Small Hydro-Plants	67	67	67	67	67	67	67	67	67	67	67	67
			c) El Angel (extension)	15	15	15	15	15	15	15	15	15	15	15	15
			d) San Miguel de Car	-	-	-	-	659	659	779	779	779	779	779	779
			Sub-total	332	332	332	332	1,027	1,027	1,111	1,111	1,111	1,111	1,111	1,111
		2	Transmission												
			a) La Playa-Tulcan	5	5	5	5	5	5	5	5	5	5	5	5
			b) San Miguel-Tulcan	-	-	-	-	19	19	19	19	19	19	19	19
			c) Tulcan-El Angel-San Gabriel	99	99	99	99	99	99	99	99	99	99	99	99
			d) San Gabriel-Ibarra	60	60	60	60	60	60	60	60	60	60	60	60
			Sub-total	164	164	164	164	183	183	183	183	183	183	183	183
		3	Substation												
			a) Tulcan (exist)	3	3	3	3	3	3	3	3	3	3	3	3
			b) Tulcan, El Angel, San Gabriel	150	150	150	150	162	162	162	170	170	183	183	197
			Sub-total	153	153	153	153	165	165	165	173	173	186	186	200
		4	Total Depreciation	649	649	649	649	1,375	1,375	1,459	1,467	1,467	1,480	1,480	1,494
	2		Interest & Return												
		1	Generation												
			a) La Playa	558	545	533	520	508	495	483	470	457	446	433	420
			b) Small Hydro-Plants	90	87	84	81	78	75	72	69	66	63	60	57
			c) El Angel (extension)	48	47	46	45	43	42	41	40	39	37	36	35
			d) San Miguel de Car	-	-	-	-	2,110	2,057	2,388	2,326	2,264	2,201	2,139	2,077
			Sub-total	696	679	663	646	2,739	2,669	2,984	2,905	2,826	2,747	2,668	2,589
		2	Transmission												
			a) La Playa-Tulcan	7	7	7	6	6	6	6	5	5	5	5	5
			b) San Miguel-Tulcan	-	-	-	-	50	48	47	45	44	42	41	39
			c) Tulcan-El Angel-San Gabriel	264	256	248	240	232	224	216	208	200	193	184	177
			d) San Gabriel-Ibarra	160	155	150	146	141	136	131	126	122	117	112	107
			Sub-total	431	418	405	392	429	414	400	384	371	357	342	328
		3	Substation												
			a) Tulcan	5	4	4	4	4	4	3	3	3	3	3	3
			b) Tulcan, El Angel, San Gabriel	400	387	375	364	385	372	360	365	351	372	358	382
			Sub-total	405	391	379	368	389	376	363	368	354	375	361	385
		4	Total Interest & Return	1,532	1,488	1,447	1,406	3,557	3,459	3,747	3,657	3,651	3,479	3,371	3,302

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			1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
3		Operation & Maintenance												
	1	Generation												
		a) La Playa	132	132	132	132	132	132	132	132	132	132	132	132
		b) Small Hydro-Plant	80	80	80	80	80	80	80	80	80	80	80	80
		c) El Angel (extension)	32	32	32	32	32	32	32	32	32	32	32	32
		d) San Miguel de Car	-	-	-	-	120	120	240	240	240	240	240	240
		Sub-total	244	244	244	244	364	364	484	484	484	484	484	484
	2	Transmission												
		a) La Playa-Tulcan	6	6	6	6	6	6	6	6	6	6	6	6
		b) San Miguel-Tulcan	-	-	-	-	12	12	12	12	12	12	12	12
		c) Tulcan-El Angel-San Gabriel	60	60	60	60	60	60	60	60	60	60	60	60
		d) San Gabriel-Ibarra	33	33	33	33	33	33	33	33	33	33	33	33
		Sub-total	99	99	99	99	111	111	111	111	111	111	111	111
	3	Substation												
		a) Tulcan (exist)	33	33	33	33	33	33	33	33	33	33	33	33
		b) Tulcan, El Angel, San Gabriel	28	28	28	28	34	34	34	37	37	55	55	65
		Sub-total	61	61	61	61	67	67	67	70	70	88	88	98
	4	Total Operation & Maintenance	404	404	404	404	542	542	662	665	665	683	683	693
4		Administration												
	1	Generation												
		a) La Playa	20	20	20	20	20	20	20	20	20	20	20	20
		b) Small Hydro-Plant	12	12	12	12	12	12	12	12	12	12	12	12
		c) El Angel (exist)	11	11	11	11	11	11	11	11	11	11	11	11
		d) San Miguel de Car	-	-	-	-	42	42	84	84	84	84	84	84
		Sub-total	43	43	43	43	85	85	127	127	127	127	127	127
	2	Transmission												
		a) La Playa-Tulcan	1	1	1	1	1	1	1	1	1	1	1	1
		b) San Miguel-Tulcan	-	-	-	-	4	4	4	4	4	4	4	4
		c) Tulcan-El Angel-San Gabriel	21	21	21	21	21	21	21	21	21	21	21	21
		d) San Gabriel-Ibarra	12	12	12	12	12	12	12	12	12	12	12	12
		Sub-total	34	34	34	34	38	38	38	38	38	38	38	38
	3	Substation												
		a) Tulcan (exist)	5	5	5	5	5	5	5	5	5	5	5	5
		b) Tulcan, El Angel, San Gabriel	10	10	10	10	12	12	12	13	13	19	19	23
		Sub-total	15	15	15	15	17	17	17	18	18	24	24	28
	4	Total Administration	92	92	92	92	140	140	182	183	183	189	189	193
5		Insurance												
	1	Generation												
		a) La Playa	12	12	12	12	12	12	12	12	12	12	12	12
		b) Small Hydro-Plant	2	2	2	2	2	2	2	2	2	2	2	2
		c) El Angel (extension)	1	1	1	1	1	1	1	1	1	1	1	1
		d) San Miguel de Car	-	-	-	-	26	26	31	31	31	31	31	31
		Sub-total	15	15	15	15	41	41	46	46	46	46	46	46

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				1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
	2	Transmission													
		a) La Playa-Tulcan		1	1	1	1	1	1	1	1	1	1	1	1
		b) San Miguel-Tulcan		-	-	-	-	1	1	1	1	1	1	1	1
		c) Tulcan-El Angel-San Gabriel		3	3	3	3	3	3	3	3	3	3	3	3
		d) San Gabriel-Ibarra		2	2	2	2	2	2	2	2	2	2	2	2
		Sub-total°		6	6	6	6	7	7	7	7	7	7	7	7
	3	Substation													
		a) Tulcan (exist)		1	1	1	1	1	1	1	1	1	1	1	1
		b) Tulcan, El Angel, San Gabriel		5	5	5	5	5	5	5	5	5	5	5	5
		Sub-total		6	6	6	6	6	6	6	6	6	6	6	6
	4	Total Insurance		27	27	27	27	54	54	59	59	59	59	59	59
6		Total Production Expenses		2,704	2,660	2,619	2,578	5,667	5,570	6,109	6,031	5,925	5,890	5,782	5.741
7		Energy													
1		Available Energy Production of Stations in Zone A		16,856	16,856	16,856	29,956	36,756	36,756	36,756	36,756	36,756	36,756	36,756	36,756
2		Saleable Energy	(MWH)	6,900	7,560	8,120	9,220	11,124	13,853	15,353	17,451	22,076	26,495	31,003	34,082
	1	Demand of Zone A	(MWH)	6,900	7,560	8,120	9,220	10,600	12,170	13,460	15,010	16,730	18,350	20,060	21,940
	2	Receipt from Zone B	(MWH)	(45)	(132)	(230)	(406)	0	0	0	0	0	0	0	0
	3	Sales to Zone B	(MWH)	0	0	0	(172)	569 (45)	1,797 (132)	2,123 (230)	2,675 (234)	5,345	8,145	10,943	12,142
3		Energy Loss (6.0% MWH)		414	454	487	553	667	831	921	1,047	1,325	1,590	1,860	2,045
4		Energy at Low-voltage Bus (13.8KV) of Sub-station	(MWH)	6,486	7,106	7,633	8,667	10,457	13,022	14,432	16,404	20,750	24,905	29,143	32,037
8		Unit Cost of Energy	(Sucre/KWH)	0.417	0.374	0.343	0.297	0.542	0.428	0.423	0.368	0.286	0.236	0.198	0.179
9		*Average Unit Cost of* Energy	(Sucres/KWH)	←						0.380		→			
				←							0.352		→		
				←								0.324		→	
				←									0.300		→
10		Accumulated Total Production Expenses		2,704	5,364	7,983	10,561	16,228	21,798	27,907	33,938	39,863	45,753	51,535	57,276
11		Accumulated Energy at Low-voltage Bus (13.8 KV) of Sub-station	(MWH)									104,957	129,862	159,005	191,042

Note: All values are in units of 1,000 Sucres unless otherwise noted.

11. FINANCIAL PROGRAM

11. FINANCIAL PROGRAM

11.1 FUND REQUIREMENTS

The estimated total construction cost of this Project, as described in detail in Chapter 9, is 43,660,000 Sucres consisting of 23,557,000 Sucres in foreign currency and 20,103,000 Sucres in domestic currency. The annual fund requirement is shown in Table 11-1.

11.2 FINANCING OF FUNDS

11.2.1 Source of Funds

As the sources of funds, there can be thought of loans from foreign governments, and international financial institutions, issue of capital stocks and debentures, and appropriation of depreciation reserves of existing facilities and internal reserves. The financial program for the project was prepared on the assumption that foreign currency requirements would be secured by loans from international financing institutions and domestic currency requirements by domestic loans.

11.2.2 Interest and Term of Repayment

a. Foreign Currency

Foreign currency borrowings were assumed under the following conditions.

Interest: 5.75% per annum

Repayment Term: 17 years from beginning of operation in uniform annual installments of principal plus interest. However, for investments in construction of transmission lines in 1967, repayment of principal is to be deferred until 1972 which is the year the San Miguel de Car Power Station will begin to operate.

b Domestic Currency

Since the minimum attractive return for this type of financing program in Ecuador is said to be 8 percent, the interest rate for domestic currency was calculated at this percentage. Regarding repayment terms, it was assumed that repayment of principal plus interest would be made in uniform annual payments over the serviceable lives of the respective components of the Project.

Investment in power generation facilities:

To be repaid in 40 years from beginning of operation in uniform annual payments of principal plus interest. However, for the construction cost of the diversion works which are to be completed in 1967, repayment is to be deferred until the beginning of operation of San Miguel de Car Power Station in 1972.

Investments in transmission lines and sub-stations:

To be repaid in 33 years from beginning of operation in uniform annual payment of principal plus interest. However, for the construction cost of the transmission line to be completed in 1967, repayment is to be deferred until the beginning of operation of San Miguel de Car Power Station in 1972.

11.3 REPAYMENT CAPABILITY

11.3.1 Operating Revenues

a Unit Cost of Power Delivered at Primary Sub-station

As the scope of this Project covers the works up to the primary sub-station, it will not be appropriate to calculate the revenues from this Project from the unit sales price of power to consumers. Therefore, the revenues from this Project are calculated by multiplying the estimated unit cost to consumers at the primary sub-station by the energy delivered at the primary sub-station.

The current average sales rate of Empresa Electrica Tulcan is 0.34 Sucres per KWH, which may be raised in the future with the expansion of power generation and transmission facilities. The average sales rate of Empresa Electrica Ibarra which is in the service territory of San Miguel de Car Power Station is 0.6 Sucres/KWH. Therefore, it was assumed that 0.6 Sucres per KWH could be applied to Empresa Electrica Tulcan after the San Miguel de Car Project is constructed. The average distribution cost of Empresa Electrica Tulcan is 0.24 Sucres/KWH. Therefore, cost of energy of the San Miguel de Car Project delivered at the primary sub-station is considered to be 0.35 Sucres per/KWH.

b Electric Energy Delivered at Primary Sub-station

The electric energy delivered at the primary sub-station is as described in Chapter 7.

c Revenues

The estimated revenues from the energy sales of San Miguel de Car Power Station at the primary sub-station is as shown in Table 11-2, "Statement of Income."

11.3.2 Charge for Transmission of Electricity

The transmission lines between Tulcan, San Gabriel and El Angel (46 km) and between San Gabriel and Ibarra (25 km) are to be constructed in 1967 which is before the commencement of operation of San Miguel de Car Power Station in 1972. This is because power will be purchased from the Ibarra Power System until the San Miguel de Car Power Station is in operation. Therefore, the operating cost of the transmission lines during this period, i.e., interest, depreciation, maintenance and operation, etc. cannot be charged to the San Miguel de Car Power Station. Therefore, in the Statement of Income, an amount equal to this operating cost was entered as revenues from transmission of electricity.

11.3.3 Maintenance and Operation Expenses

The maintenance and operation expenses of San Miguel de Car Power Station were estimated at 80 Sucres per KW and the amount corresponding to the installed capacity was included. As for the transmission lines, the maintenance and operation expenses were considered to be 1,300 Sucres per km while for the sub-stations it was calculated at 12 Sucres per KVA, and amounts corresponding to the length of transmission line and sub-station capacity are included in the Statement of Income.

11.3.4 Administration Cost and Insurance Premium

Other than the direct expenses for operation of the project mentioned above, 35 percent of the annual maintenance and operation expenses were included as administrative expense to defray part of the expenses of INECEL Headquarters. It was assumed there would be insurance coverage against loss and damage of installations and the premium was estimated at 0.1 percent of capital cost of the installations.

11.3.5 Depreciation Expense

Depreciation was based on the serviceable lives shown below and was calculated by the straight line method.

Power generation facilities	40 years
Transmission lines	33 years
Sub-stations	33 years

11.3.6 Net Income

The annual revenues of the Project based on the above conditions were calculated and from the revenues maintenance and operation, administration, insurance premium, depreciation and interest charges on foreign currency loans and domestic loans were deducted to arrive at the net income which is shown in Table 11-2.

11.4 REPAYMENT SCHEDULE

Repayment of borrowings will be made from the net income from operations and the depreciation reserve.

The annual repayments of foreign currency loans and domestic loans based on the conditions described in 11.2.2 are shown in Table 11-3, Amortization Schedule.

Table 11-4, Statement of Cash Flow shows the sources of funds and repayment of borrowing. According to the statement, for the six years from 1972, when the operation of San Miguel de Car Power Station will begin, until 1977, there will be a deficiency of 3,526,000 Sucres at the maximum and 910,000 Sucres at the minimum for repayment of principal including interest. Therefore, INECEL will be required to cover this shortage by separate borrowings or other sources of its own. However, if part of the domestic currency requirement of the construction cost is covered by equity financing or by appropriation of internal reserves the amount of deficit financing would be about 2, 000, 000 Sucres, which is a sum that can be met by INECEL from its annual resources, but in this case returns on the equity and internal reserve invested cannot be anticipated until such time there is sufficient income from operation after servicing debts

Year	Yearly deficiency in cash balance	Amount to be deferred	Amount required to be financed for debt service
	Sucres	Sucres	Sucres
1972	3, 696, 000	1, 590, 000	2, 106, 000
1973	3, 440, 000	1, 590, 000	1, 850, 000
1974	3, 526, 000	1, 684, 000	1, 842, 000
1975	3, 094, 000	1, 688, 000	1, 406, 000
1976	2, 296, 000	1, 688, 000	608, 000
1977	910, 000	910, 000	

Deducting the above amounts to be deferred, the accrued total matured debt obligations will reach 15, 938, 000 Sucres, but from 1978 there will be a surplus of revenues and the accrued obligations can be retired by 1986. There will be a shortage of funds for 6 years from the time of beginning of operation of San Miguel de Car Power Station, but this shortage can be covered within the financial resources of INECEL and the accrued deficiency can be recovered in the following 8 years. Therefore, it can be said that this Project is financially feasible.

Table 11-1 Annual Investment Requirement by Currencies

Unit: 1,000 Sucres

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	Total
Domestic Currency															
Generation	2,270			(146) 4,710	(562) 7,065		(35) 1,128								(743) 15,173
Transmission line															
San Miguel-Tulcan					(16) 386										(16) 386
Tulcan-San Gabriel-El Angel	(65) 2,082														(65) 2,082
San Gabriel-Ibarra	(42) 1,338														(42) 1,338
Sub-station	(27) 869				67			41		66		81			(27) 1,124
Total	(134) 6,559			(146) 4,710	(578) 7,518		(35) 1,128	41		66		81			(893) 20,103
Foreign Currency															
Generation				(56) 2,465	(486) 9,860		(83) 3,672								(625) 15,997
Transmission line															
San Miguel-Tulcan					(6) 234										(6) 234
Tulcan-San Gabriel-El Angel	(27) 1,218														(27) 1,218
San Gabriel-Ibarra	(15) 662														(15) 662
Sub-station	(93) 4,121				353			199		364		409			(93) 5,446
Total	(135) 6,001			(56) 2,465	(492) 10,447		(83) 3,672	199		364		409			(766) 23,557
Grand Total	(269) 12,560			(202) 7,175	(1,070) 17,965		(118) 4,800	240		430		490			(1,659) 43,660

Note: Figures in parentheses indicatc interest during construction.

Table 11-2 Statement of Income (San Miguel de Car Project)

Unit : 1000 Sucres

Item	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
(A) Revenues																								
Effective saleable energy (10^3KWH)						160	893	1,927	3,688	5,969	10,113	14,147	17,226	18,600	18,800	18,800								
Revenues from power sales (0.35 Sucres/KWH at primary sub-station)						56	312	674	1,291	2,089	3,540	4,951	6,029	6,510	6,580	6,580								
Revenues from transmission of electricity		1,144	1,144	1,144	1,144																			
Gross Operating Revenues		1,144	1,144	1,144	1,144	56	312	674	1,291	2,089	3,540	4,951	6,029	6,510	6,580	6,580	6,580	6,580	6,580	6,580	6,580	6,580	6,580	6,580
(B) Expenses																								
A. Maintenance and operating expense		122	122	122	122	258	258	258	382	382	400	400	409	409	409	409								
Generating expense (80 Sucres/KW)						120	120	120	240	240	240	240	240	240	240	240								
Transmission expense (1,300 Sucres/km)		94	94	94	94	104	104	104	104	104	104	104	104	104	104	104								
Transforming expense (12 Sucres/KVA)		28	28	28	28	34	34	34	38	38	56	56	65	65	65	65								
B. Administration cost (A x 35%)		43	43	43	43	91	91	91	134	134	140	140	143	143	143	143								
C. Insurance (0.1% of capital cost)		10	10	10	10	38	38	43	43	43	44	44	44	44	44	44								
D. Depreciation		281	281	281	281	902	902	902	1,010	1,017	1,029	1,029	1,042	1,042	1,042	1,042								
Total Operating Costs		456	456	456	456	1,289	1,289	1,294	1,569	1,576	1,613	1,613	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638	1,638
(C) Operating Income (A-B)		688	688	688	688	31,233	-977	-620	-278	513	1,927	3,338	4,391	4,885	4,942	4,942	4,942	4,942	4,942	4,942	4,942	4,942	4,942	4,942
(D) Financial Expenses																								
Interest		(688)	(688)	(688)	(688)	2,587	2,543	2,796	2,749	2,686	2,643	2,570	2,522	2,438	2,351	2,265	2,157	2,051	1,938	1,820	1,693	1,560	1,418	1,369
Foreign currency (5.75%)		(345)	(345)	(345)	(345)	1,084	1,048	1,217	1,176	1,121	1,084	1,021	978	907	833	753	669	581	487	388	283	173	56	34
Domestic currency (8%)		(343)	(343)	(343)	(343)	1,503	1,495	1,579	1,573	1,565	1,559	1,549	1,544	1,531	1,518	1,502	1,488	1,470	1,451	1,432	1,410	1,387	1.362	1,335
Power station						1,124	1,119	1,205	1,199	1,194	1,187	1,181	1,173	1,165	1,157	1,147	1,138	1,127	1,115	1,103	1,089	1,075	1,059	1,042
Transmission lines, sub-station		(343)	(343)	(343)	(343)	379	376	374	374	371	372	368	371	366	361	355	350	343	336	329	321	312	303	293
(E) Net Income (C-D)		0	0	0	0	-3,820	-3,520	-3,416	-3,027	-2,173	-716	768	1,869	2,447	2,591	2,687	2,785	2,891	3,004	3,122	3,249	3,382	3,524	3,573

Table 11-3 Amortization Schedule

Unit: 1000 Sucres

Year	Foreign currency loans					Domestic currency loans (Transmission line and Sub-station)					Domestic currency loans (Power station)				
	Invest-ment	Interest	Repayment of principal	Principal plus interest	Balance outstand-ing	Invest-ment	Interest	Repayment of principal	Principal plus interest	Balance outstand-ing	Invest-ment	Interest	Repayment of principal	Principal plus interest	Balance outstand-ing
1967	6,001				6,001	4,289				4,289	2,270				2.270
68		345	-	345	6,001		343	-	343	4,289					2.270
69		345	-	345	6,001		343	-	343	4,289					2.270
70		345	-	345	6,001		343	-	343	4,289					2,270
71	12,912	345	-	345	6,001	453	343	-	343	4,289	11,775				14.045
72		1,084	691	1,775	18,222		379	33	412	4,709		1,124	54	1,178	13,991
73	3,672	1,048	727	1,775	21,167		376	36	412	4,673	1,128	1,119	59	1,178	15,060
74	199	1,217	907	2,119	20,459	41	374	38	412	4,676		1,205	67	1,272	14,993
75	199	1,176	962	2,138	19,497		374	42	416	4,634		1,199	73	1,272	14,920
76	364	1,121	1,017	2,138	18,844	66	371	45	416	4,655		1,194	78	1,272	14,842
77		1,084	1,088	2,172	17,756		372	50	422	4,605		1,187	85	1,272	14,757
78	409	1,021	1,151	2,172	17,014	81	368	54	422	4,632		1,181	91	1,272	14,666
79		978	1,232	2,210	15,782		371	58	429	4,574		1,173	99	1,272	14,567
80		907	1,303	2,210	14,479		366	63	429	4,511		1,165	107	1,272	14,460
81		833	1,377	2,210	13,102		361	68	429	4,443		1,157	115	1,272	14,345
82		753	1,457	2,210	11,645		355	74	429	4,369		1,147	125	1,272	14,220
83		669	1,541	2,210	10,104		350	79	429	4,290		1,138	134	1,272	14,086
84		581	1,629	2,210	8,475		343	86	429	4,204		1,127	145	1,272	13,941
85		487	1,723	2,210	6,752		336	93	429	4,111		1,115	157	1,272	13,784
86		388	1,822	2,210	4,930		329	100	429	4,011		1,103	169	1,272	13.615
87		283	1,927	2,210	3,003		321	108	429	3,903		1,089	183	1,272	13,432
88		173	2,037	2,210	966		312	117	429	3,786		1,075	197	1,272	13,235
89		56	379	435	587		303	126	429	3,660		1,059	213	1,272	13,022
90		34	57	91	530		293	136	429	3,524		1,042	230	1,272	12,792
91															

(6.001 + 12.912) x 0.093836 = 1.775
3672 x 0.093836 + 1775 = 2119
199 x " + 2119 = 2138
364 x " + 2138 = 2172
409 x " + 2172 = 2210

(4289 + 453) x 0.08685163 = 412
41 x 0.08685163 + 412 = 416
66 x " + 416 = 422
81 x " + 422 = 429

14045 x 0.08386016 = 1178
1128 x 0.08386016 + 1178 = 1272

Table 11-4 Cash Flow Statement

Unit: 1000 Sucres

	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Cash from Income		281	281	281	281	2,918	2,618	2,514	2,017	1,156	313	1,797	2,911	3,489	3,633	3,729	3,827	3,933	4,046	4,164	4,294	4,424	4,566	4,615
Net income						3,820	3,520	3,416	3,027	2,173	716	768	1,869	2,447	2,591	2,687	2,785	2,891	3,004	3,122	3,249	3,382	3,524	3,573
Depreciation		281	281	281	281	902	902	902	1,010	1,017	1,029	1,029	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042
Borrowings	(2,270) 10,290			7,175	17,965		4,800	240		430		490												
Foreign loans	6,001			2,465	10,447		3,672	199		364		409												
Domestic loans	(2,270) 4,289			4,710	7,518		1,128	41		66		81												
Total	(2,270) 10,290	281	281	7,456	18,246	2,918	2,182	2,274	2,017	726	313	2,287	2,911	3,489	3,633	3,729	3,827	3,933	4,046	4,164	4,291	4,424	4,566	4,615
Capital Expenditure																								
Construction cost	(2,270) 10,290			7,175	17,965		4,800	240		430		490												
Repayment of loans																								
Foreign currency						691	727	907	962	1,017	1,088	1,151	1,232	1,303	1,377	1,457	1,541	1,629	1,723	1,822	1,927	2,037	379	57
Domestic currency						87	95	105	115	123	135	145	157	170	183	199	213	231	250	269	291	314	339	366
Power station						54	59	67	73	78	85	91	99	107	115	125	134	145	157	169	183	197	213	230
Transmission lines, sub-stations						33	36	38	42	45	50	54	58	63	68	74	79	86	93	100	108	117	126	136
Total	(2,270) 10,290			7,175	17,965	778	5,622	1,252	1,077	1,570	1,223	1,786	1,389	1,473	1,560	1,656	1,759	1,860	1,973	2,091	2,212	2,351	718	423
Cash Balance	0	281	281	281	281	3,696	3,440	3,526	3,092	2,296	910	501	1,522	2,016	2,073	2,073	2,068	2,073	2,073	2,073	2,079	2,073	3,848	4,192

Table 11-5 Depreciation (San Miguel de Car Project)

Unit: 1000 Sucres

Item		1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Investment																			
	(serviceable life)																		
Generation	(40 yrs)	2, 270				24, 109		4, 800											
Substation	(30 yrs)	4, 990				420			240		430		490						
Transmission	(33 yrs)	5, 300				620													
Sub-total		10, 290				1, 040			240		430		490						
Total		12, 560				25, 140		4, 800	240		430		490						
Depreciation																			
	(year of invest.)																		
Generation	1971						593	593	593	593	593	593	593	593	593	593	593	593	593
Generation	1973								108	108	108	108	108	108	108	108	108	108	108
	(0. 0225/year)																		
Substation & Transmission	1967		281	281	281	281	281	281	281	281	281	281	281	281	281	281	281	281	281
Substation & Transmission	1971						28	28	28	28	28	28	28	28	28	28	28	28	28
Substation & Transmission	1974									7	7	7	7	7	7	7	7	7	7
Substation & Transmission	1976											12	12	12	12	12	12	12	12
Substation & Transmission	1979													13	13	13	13	13	13
	(0. 02727/year)																		
Total			281	281	281	281	902	902	1, 010	1, 017	1, 017	1, 029	1, 029	1, 029	1, 042	1, 042	1, 042	1, 042	1, 042

APPENDIX

A P P E N D I X

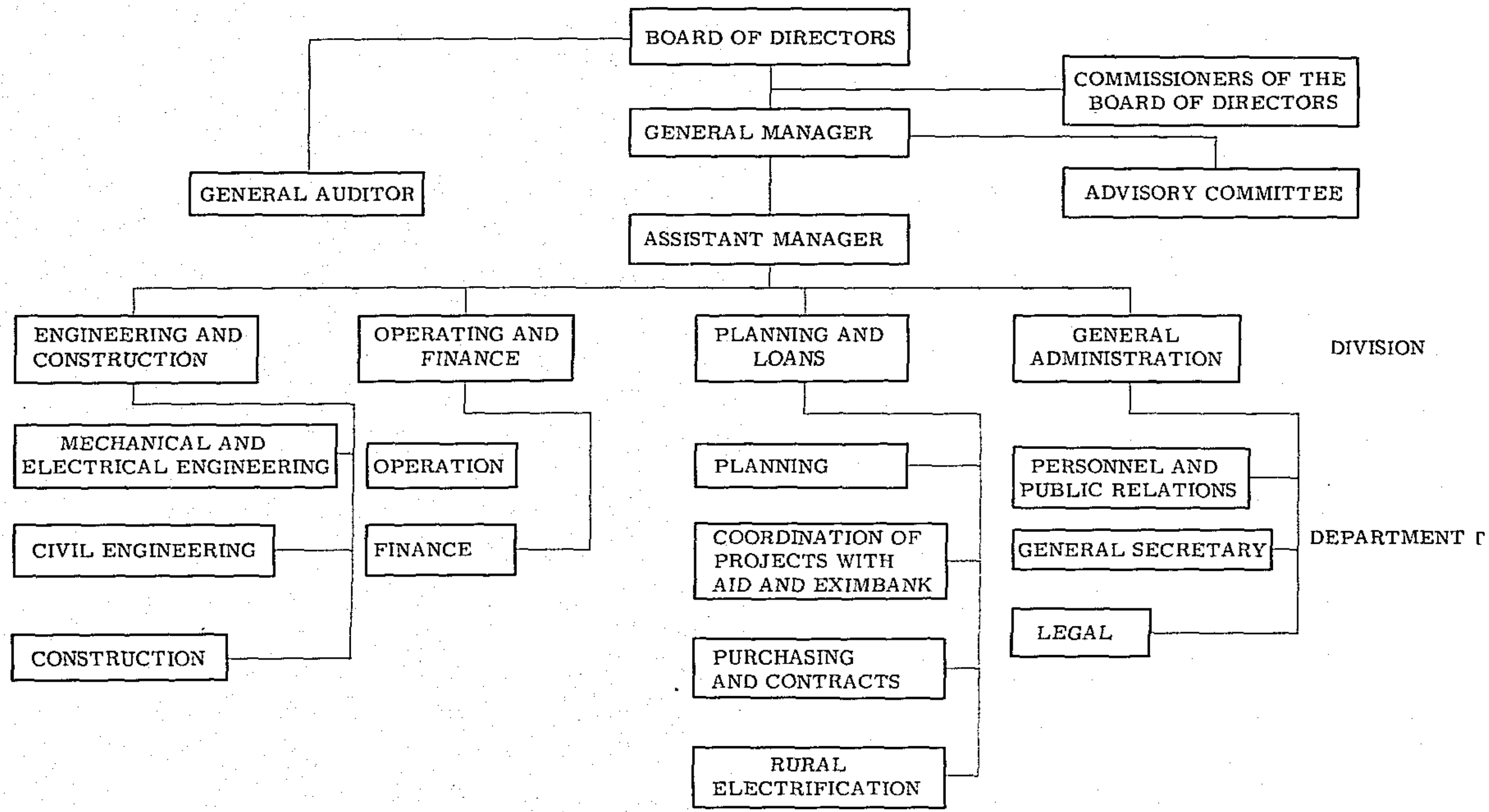
1. Organization of INECEL and

   Empresa Electrica Tulcan S.A.

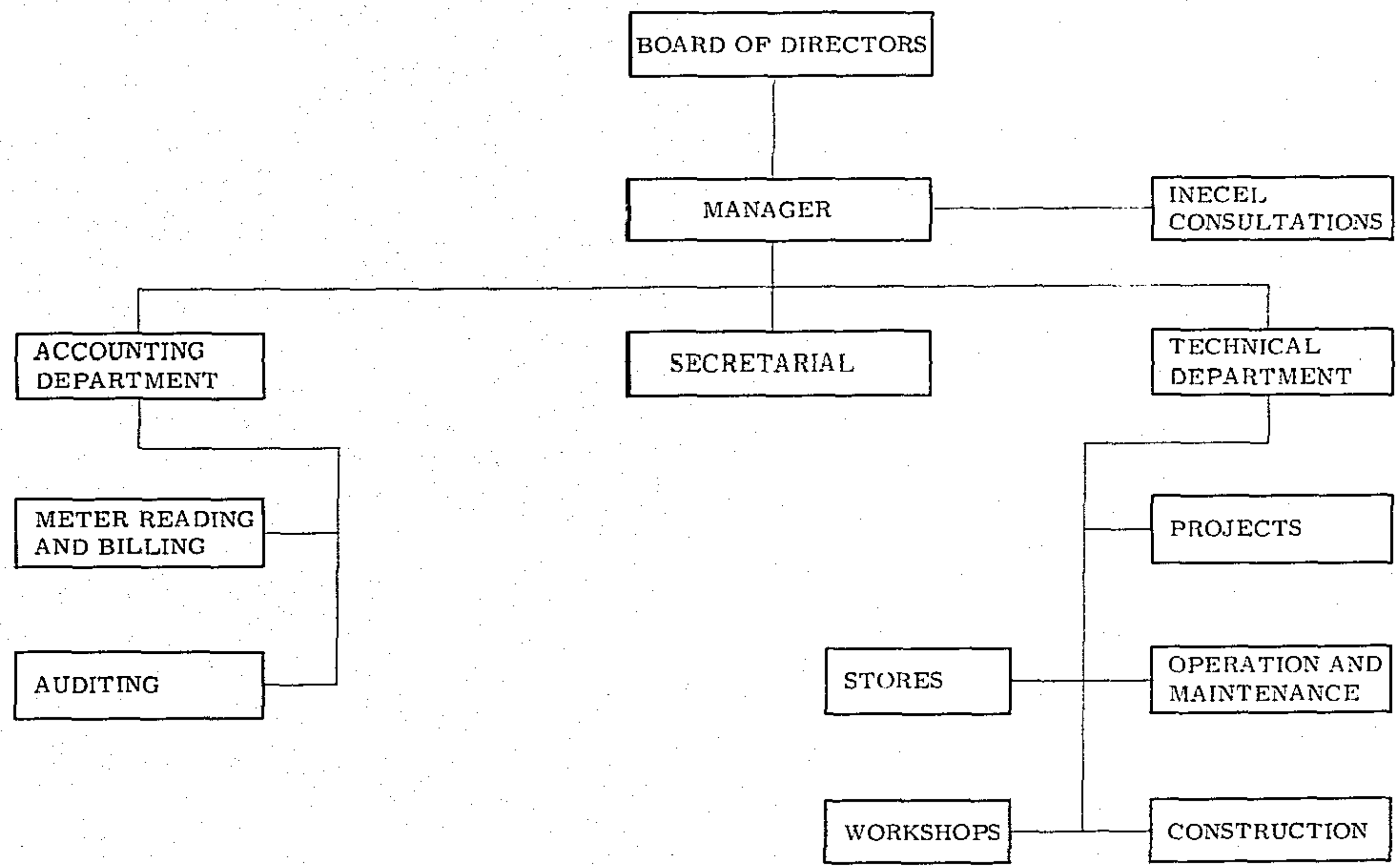
2. Basic Data List

3. Hydrological Data

APPENDIX 1-1 ORGANIZATION OF INECEL (OCTOBER - 1965)



APPENDIX 1-2 ORGANIZATION OF EMPRESA ELECTRICA TULCAN S. A.



Appendix - 2 Basic Data List

2-1 Topographic Map and Reference Map

(1) Aerial photographic map

1/1, 000, 000 - whole Ecuador

1/25, 000 - project area

(2) Survied map

1/1, 000 - Intake dam, Waterway, Penstock, Power house site

Equalizing pond site - Profile and cross section

(3) Reference map

Intake dam of Rio Grande - Plan & Section

Intake dam of Rio Chico - Plan & Section

Longitudinal section of waterway to La Cofradia from intake dam of Rio Grande

Intake dam of La Playa Power Station

2-2 Meteorology and Hydrology

(1) Boletin Climatologico No. 1 - No. 46

Servico Nacional de Meterologia e Hidrogia

(2) Anuario Hidrologico No. 1 - No 2

Servico Nacional de Meterologia e Hidrogia

(3) Isoyetas Anuales En Milmetros 1963 - 1964

2-3 Geology

(1) El Mapa Geologico del Ecuador

Ing. Dr. Walter Saver

1957, Editorial Universitaria

(2) Geologia del Ecuador

Dr. Walter Saver

1965 Editorial del Ministerio de Educacion

(3) Breve Historia de las Principales Terremotos en la Republica del Ecuador

1959 Publicacion del Comite del

Ano Geofisico Internacional del Ecuador

2-4 Electricity

(1) Primer Censo Nacional de Electrificacion
(Direccion General de Recursos Hidraulicos y
Electrificacion de Ministerio de Fomento

(2) Tarifas (Empresa Electrica Tulcan S. A.)

(3) Resultados de Generacion
(La Playa Power Station Empresa Electrica Tulcan S. A.)

(4) Energia (Junta Nacional de Planificacion)

(5) Curva de Carga en Ecuador (INECEL)

(6) Empresa Electrica Tulcan S. A. Estudio de Tarifa
(Departmento de Tarifa de INECEL)

(7) Energia
Abastecimiento de energia en las regionas fronteriza
(Junta Nacional de Planificacion)

2-5 Report

(1) Manabi Steam Generating Plant - Feasibility Report
INECEL 12-1965

(2) Programacion zona Tulcan - Ibarra - Cayambe INECEL

(3) Plan de Electrificacion del Ecuador Sistema
Tulcan - Ibarra - Cayambe INECEL

(4) Program of Expansion, Feasibility Study,
Empresa Electria Tulcan S. A.

2-6 Others

(1) Memoria del Gerente General de Banco Central del Ecuador

(2) Plan Carchi (Junta Nacional de Planificacion)

(3) Projection de la Poblacion Urbana Cantonal y de las Cabeceras
Parroguiales 1962 - 1975
(Junta Nacional de Planificacion)

(4) Precios Unitarios - Presupuestos Valores Tabulados

(5) *Los Datos de INECEL Ofc. No. 2294 y No. 6605 LHL1139*

(6) Memo No 6604GN822

(7) Texto del Acto Rumichaca

(El Comercio 13-March-1966)

Appendix - 3. Hydrological Data

1.	Precipitation Data
1-1.	Tulcan
1-2	Ibarra
1-3	Otavalo
1-4	San Pablo Del Lago
1-5	Tabacundo
1-6	Jerusalen
1-7	Sigusicunga
1-8	*Atuntaqui*
2	River Run-off Data
2-1.	A. J. R. Guachala (13-g-1)
2-2.	A. J. R. Granobles (13-h-1)
2-3.	A. J. R. Cariyacu (2-d-1)
2-4.	D. J. R. Minas (2-g-1)
3.	Output and Discharge at Intake of La Playa P. S. (1962 - 1963)
4.	Temperature and Evaporation of Tulcan.

1-1 PRECIPITATION STATION TULCAN CATCHMENT AREA ______ sq.km SAN MIGUEL DE CAR, ECUADOR

______ RIVER, IN THE BASIN OF ______ ELEVATION 2,950 m UNIT mm N 00° 49' W 77° 42'

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'49-'50					92.9	106.9	198.6	138.1	153.6	78.4	24.1	33.0	-
'50-'51	45.3	76.3	130.6	111.3	99.0	79.1	114.5	81.2	139.4	32.5	38.0	24.0	971.2
'51-'52	0	95.8	278.4	75.7	45.5	76.9	54.2	71.7	39.5	28.4	32.6	10.0	808.7
'52-'53	15.9	43.0	128.5	71.5	51.6	80.1	67.7	48.4	68.0	67.7	10.9	4.0	657.3
'53-'54	69.1	190.8	21.8	35.1	43.5	11.0	47.3	77.2	51.3	54.5	13.8	61.4	676.8
'54-'55	10.4	162.6	45.1	90.4	73.8	50.3	54.1	54.2	7.2	3.8	3.5	2.5	557.9
'55-'56	1.6	9.1	113.0	91.0	8.4	60.2	70.0	125.6	35.6	58.8	27.8	16.9	618.0
'56-'57	69.3	168.0	137.6	98.1	54.6	23.2	101.6	113.3	141.9	19.2	6.5	14.8	948.1
'57-'58	15.5	90.7	*116.5	*71.1	*61.4	54.6	30.9	91.3	42.6	44.6	31.6	68.0	718.8
'58-'59	19.2	110.9	97.6	37.9	58.2	24.5	58.3	69.0	131.8	47.0	27.1	54.4	735.9
'59-'60	22.9	106.3	172.1	45.8	80.3	153.6	*67.3	38.9	51.4	14.8	29.3	12.2	794.9
'60-'61	49.9	104.6	90.1	23.2	41.0	77.0	84.6	102.1	38.3	51.4	35.2	20.1	717.5
'61-'62	28.5	78.5	96.5	29.3	99.7	46.1	37.9	46.5	52.9	55.1	17.2	22.1	610.3
'62-'63	40.4	86.7	81.7	73.1	85.8	40.4	47.9	72.9	67.8	75.3	16.3	2.9	691.2
'63-'64	9.9	89.2	161.5	51.6	14.1	97.2	18.4	73.9	21.0	93.2	32.8	43.3	706.1
'64-'65	51.2	76.6	55.0	106.2	74.2	14.3	24.7	159.8	96.0	13.6	38.3	25.7	735.6
'65-'66	59.3	132.8	139.7	128.0									
AVERAGE	31.8	101.1	116.5	71.1	61.4	62.2	67.3	84.1	71.2	46.2	24.0	25.9	732.0

Note: * marks are average of 15 years

1-2 PRECIPITATION STATION IBARRA CATCHMENT AREA sq. km SAN MIGUEL DE CAR, ECUADOR

RIVER, IN THE BASIN OF ELEVATION m UNIT mm S ° ′ W ° ′

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'55-'56	15.7	49.7	51.1	89.4	52.9	78.4	84.8	120.5	39.6	64.9	25.0	7.2	679.2
'56-'57	83.6	164.9	-	-	-	33.9	87.3	153.7	109.3	7.3	0.8	0	-
'57-'58	3.2	44.5	-	-	97.1	16.9	26.7	56.4	25.2	50.6	0	34.9	-
'58-'59	7.2	-	-	84.8	22.9	17.2	19.3	62.0	108.0	75.4	0.9	27.8	-
'59-'60	15.4	49.6	75.6	65.6	13.6	54.4	27.6	25.4	27.2	6.6	17.7	20.2	398.9
'60-'61	10.4	63.0	-	30.1	-	22.6	49.1	104.8	5.5	38.8	-	1.0	-
'61-'62	7.4	158.2	64.1	15.5	29.8	55.9	87.3	64.4	57.0	85.9	1.1	6.2	632.8
'62-'63	25.9	38.8	107.9	37.6	74.5	177.1	77.0	104.4	20.6	0	0.5	0	664.3
'63-'64	0.7	61.1	166.5	50.8	2.3	18.2	2.5	94.1	58.9	116.4	13.3	31.6	616.4
'64-'65	12.0	38.1	64.7	48.2	21.0	11.5	13.1	84.7	46.5	7.6	2.3	5.3	355.0
'65-'66	13.7	90.7	149.3	42.3	-	-	-	-	-	-	-	-	-
AVERAGE	17.7	75.9	97.0	51.5	39.2	48.6	47.5	87.0	49.8	45.4	6.9	13.4	558.0

1-3 PRECIPITATION STATION OTAVALO CATCHMENT AREA sq. km SAN MIGUEL DE CAR, ECUADOR

RIVER, IN THE BASIN OF ELEVATION 2,556 m UNIT mm N 00 ° 14' W 78 ° 16 '

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'63-'64	-	-	-	-	0	29.4	12.6	174.6	57.8	59.4	26.8	1.0	-
'64-'65	23.3	76.8	78.0	62.3	16.7	4.0	50.6	171.1	69.0	9.9	3.3	0	565.0
'65-'66	10.8	68.4	180.8	92.6	-	-	-	-	-	-	-	-	-
AVERAGE	17.1	72.6	129.4	77.5	8.4	16.7	31.6	172.9	63.4	34.7	15.1	0.5	565.0

1-4 PRECIPITATION STATION SAN PABLO DEL LAGO CATCHMENT AREA ______ sq. km SAN MIGUEL DE CAR, ECUADOR

RIVER, IN THE BASIN OF ______ ELEVATION 2,680 m UNIT mm N/S 00° 12' W 78° 11'

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'61-'62	-	-	-	-	-	-	-	-	-	160.5	0.2	0	-
'62-'63	49.0	141.8	151.3	62.2	80.5	201.2	239.5	298.3	55.2	216.9	20.6	1.3	1,517.8
'63-'64	5.1	58.7	130.6	109.6	15.1	84.4	22.6	185.4	49.7	120.3	23.2	54.0	858.7
'64-'65	39.7	77.2	172.1	135.4	42.7	32.9	29.2	207.4	109.7	9.1	2.8	4.5	862.7
'65-'66	81.6	111.1	233.5	106.3	-	-	-	-	-	-	-	-	-
AVERAGE	43.9	97.2	171.9	103.4	46.1	106.2	97.1	230.4	71.5	126.7	11.7	19.9	1,079.7

1-5 PRECIPITATION STATION TABACUNDO CATCHMENT AREA ______ sq. km SAN MIGUEL DE CAR, ECUADOR

______ RIVER, IN THE BASIN OF ______ ELEVATION 2,876 m UNIT mm S/N 00° 03' W 78° 13'

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'62-'63	-	-	-	-	118.8	121.3	119.3	78.0	60.7	51.3	4.6	0	-
'63-'64	22.9	59.3	87.9	99.4	12.8	65.7	22.0	109.7	19.9	59.7	19.2	20.3	598.8
'64-'65	43.2	69.1	74.7	10.0	67.6	27.8	47.9	174.8	62.1	6.0	0.9	9.9	594.0
'65-'66	52.3	91.8	226.1	62.8	-	-	-	-	-	-	-	-	-
AVERAGE	39.5	73.4	129.6	67.4	66.4	71.6	63.1	120.8	47.6	39.0	7.2	10.1	596.4

1-6 PRECIPITATION STATION JELUSALEN CATCHMENT AREA ____ sq. km SAN MIGUEL DE CAR, ECUADOR

RIVER, IN THE BASIN OF ____ ELEVATION 2,300 m UNIT mm N/S 00° 01' W 78° 07'

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'62-'63	-	-	-	-	-	-	-	39.0	52.8	51.9	4.5	1.8	-
'63-'64	26.1	66.4	76.4	43.2	0	58.5	27.3	151.0	60.5	30.9	10.1	16.7	567.1
'64-'65	4.9	45.4	54.0	40.1	20.5	5.5	8.9	154.0	27.9	11.2	0	1.3	373.7
'65-'66	41.1	91.9	-	47.0	-	-	-	-	-	-	-	-	-
AVERAGE	24.0	67.9	65.2	43.4	10.3	32.0	18.1	114.7	47.1	31.3	4.8	6.6	470.4

1-7 PRECIPITATION STATION SIGUSICUNGA CATCHMENT AREA sq. km SAN MIGUEL DE CAR, ECUADOR

RIVER, IN THE BASIN OF ELEVATION 3,111 m UNIT mm S/N 00° 15' W 78° 21'

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'62-'63	-	-	-	-	-	-	-	-	119.3	44.1	38.1	5.3	-
'63-'64	44.4	90.7	139.2	150.0	10.2	131.6	36.6	319.2	100.1	127.9	52.6	36.6	1,239.1
'64-'65	68.1	94.6	290.9	165.9	86.9	1.4	37.8	83.0	27.5	9.6	0.2	1.6	867.5
'65-'66	78.6	55.2	21.4	68.4	-	-	-	-	-	-	-	-	-
AVERAGE	63.7	76.8	150.5	128.1	48.6	66.5	37.2	201.1	82.3	60.5	30.3	14.5	1,053.3

1-8 PRECIPITATION STATION ATUNTAQUI CATCHMENT AREA ____ sq. km SAN MIGUEL DE CAR, ECUADOR

RIVER, IN THE BASIN OF ____ ELEVATION 2,350 m UNIT mm S/N 00° 20' W 78° 13'

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'62-'63	-	-	-	-	-	-	56.1	138.9	115.8	25.2	8.9	11.3	-
'63-'64	2.5	33.0	100.7	53.8	0.7	28.9	5.6	89.3	43.6	100.2	5.2	27.5	491.0
'64-'65	27.3	45.2	112.7	87.3	30.1	18.3	32.7	153.1	98.5	3.9	6.1	1.5	616.6
'65-'66	34.2	100.4	220.3	97.2	-	-	-	-	-	-	-	-	-
AVERAGE	21.4	59.5	144.6	79.4	15.4	23.6	31.5	127.1	86.0	43.1	6.7	13.4	553.8

2-1 River Run-off STATION A.J. RIO GUACHLA 13-g-1 CATCHMENT AREA 410 sq.km SAN MIGUEL DE CAR, ECUADOR

GRANOBLES RIVER, IN THE BASIN OF ESMERALDAS ELEVATION 2,750 m UNIT cu.m/s S ° ' W ° '

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'61-'62	-	-	-	-	-	-	-	-	6.3	8.4	5.2	3.2	-
'62-'63	1.8	4.2	3.9	4.7	3.4	5.7	3.7	2.9	3.1	4.9	1.7	1.3	3.4
'63-'64	0.8	1.1	2.6	2.5	1.7	1.2	2.0	3.4	2.9	8.5	3.6	3.8	2.8
'64-'65	6.1	2.6	3.0	3.0	2.6	1.6	1.2	4.2	10.9	5.6	4.5	4.3	4.1
'65-'66	2.6	3.3	14.7	5.7	-	-	-	-	-	-	-	-	-
AVERAGE	2.6	2.8	6.1	4.0	2.6	2.8	2.3	3.5	5.8	6.9	3.8	3.2	3.4

RIVER RUN-OFF STATION GUACHALA SAN MIGUEL DE CAR, ECUADOR

CRANOBLES RIVER. IN THE BASIN OF ESMERALDAS ELEVATION 2,750 m UNIT cu.m/s YEAR 1963

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	2.82	3.13	8.02	2.51	4.89	1.28	2.10	3.26	0.85	0.71	2.70	1.45	
2	2.64	3.38	8.02	2.38	4.81	1.50	1.92	1.88	0.88	0.67	2.57	1.45	
3	2.10	3.95	6.40	3.52	5.62	1.41	1.71	1.37	0.80	0.58	3.13	1.37	
4	2.47	5.32	5.51	4.23	5.33	1.22	1.67	1.22	0.80	0.57	3.58	1.50	
5	5.87	4.22	5.84	4.16	4.40	1.22	1.62	1.25	0.80	0.57	3.90	1.50	
6	3.90	3.46	4.98	5.15	3.72	1.19	1.50	1.22	0.91	0.74	5.77	1.25	
7	2.64	3.63	4.39	3.80	3.46	1.17	1.54	2.89	0.85	0.77	3.26	1.25	
8	2.14	3.32	3.72	3.26	3.85	1.17	1.28	1.88	0.91	0.71	2.51	1.37	
9	2.01	2.82	3.55	2.76	4.22	9.42	1.32	1.28	0.82	0.77	2.26	4.48	
10	2.45	2.82	3.55	2.26	4.05	6.22	1.45	1.11	0.77	0.69	2.84	4.89	
11	2.45	3.67	3.72	1.97	6.16	9.14	1.41	1.02	0.82	0.69	4.40	3.97	
12	2.33	4.04	3.72	2.05	3.80	6.00	1.37	1.05	1.56	0.69	2.88	2.95	
13	2.43	3.07	3.55	2.05	3.72	4.64	1.32	0.88	0.82	0.71	2.39	2.14	
14	2.88	2.76	3.72	2.62	3.38	13.20	1.22	0.77	0.69	0.88	2.64	1.80	
15	3.90	2.70	3.38	2.64	3.26	5.28	1.22	0.77	0.69	0.67	2.39	1.58	
16	3.63	2.45	3.00	2.62	3.21	4.64	1.22	1.22	0.67	0.62	2.05	1.37	
17	3.55	2.39	3.00	1.97	3.19	10.70	1.17	2.10	0.64	0.64	2.05	1.28	
18	3.19	5.52	3.00	1.84	2.88	12.90	1.05	2.30	0.69	0.62	1.97	1.32	
19	4.61	8.61	2.88	2.26	2.70	16.70	1.11	1.62	0.64	0.67	1.54	1.45	
20	4.22	5.86	2.64	3.97	2.26	9.68	1.02	1.32	0.64	0.71	1.37	1.54	
21	3.80	5.21	2.39	3.07	1.97	5.06	1.02	1.11	0.66	0.71	1.92	1.41	
22	3.32	7.73	2.14	2.51	1.80	3.72	1.05	1.11	0.71	0.67	2.64	1.32	
23	3.19	14.80	2.14	2.26	1.67	3.13	1.02	1.00	0.80	0.69	3.72	1.89	
24	2.82	8.08	3.56	3.55	1.62	2.70	1.17	0.97	0.82	0.82	3.26	4.56	
25	2.57	16.10	4.19	3.72	2.05	2.39	1.08	0.97	0.80	1.70	2.51	3.72	
26	3.94	8.31	3.20	3.07	2.14	2.14	1.05	1.00	0.80	1.70	2.05	3.19	
27	4.70	11.20	2.92	3.00	1.80	1.97	1.00	1.00	0.67	1.50	1.88	2.51	
28	5.00	11.70	2.26	3.13	1.62	1.80	1.38	0.88	0.60	2.42	1.80	2.26	
29	4.64		1.88	2.64	1.32	1.84	4.39	0.88	0.60	2.59	1.71	2 57	
30	4.54		2.05	2.88	1.19	2.05	6.94	0.88	0.75	4.31	1.50	5.31	
31	3.26		2.14		1.25		4.12	0.80		2.88		8.11	
TOTAL	104.01	160.25	115.46	87.85	97.34	145.48	52.44	41.01	23.46	33.67	79.19	76.76	
Ave.	3.36	5.72	3.72	2.93	3.14	4.85	1.69	1.32	7.80	1.09	2.64	2.48	

ANNUAL TOTAL ( ) 1016.92

RIVER RUN-OFF STATION GUACHALA SAN MIGUEL DE CAR ECUADOR

GRANOBLES RIVER, IN THE BASIN OF ESMERALDAS ELEVATION 2,750 m UNIT cu. m/s YEAR 1964

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	4.95	0.88	1.58	1.17	4.72	3.00	6.51	1.45	2.26	2.68	1.71	2.26	
2	3.88	0.91	1.17	0.94	4.39	3.84	6.40	1.22	2.14	2.64	1.97	2.14	
3	3.00	0.88	1.08	0.82	3.88	3.93	7.29	1.54	29.30	2.64	1.97	1.80	
4	2.51	0.88	0.88	1.22	3.55	6.29	6.18	1.62	8.30	2.05	2.39	1.71	
5	2.56	0.77	0.94	1.97	4.39	6.74	5.51	1.62	5.51	1.88	4.14	1.62	
6	3.13	0.69	0.82	1.62	3.72	4.75	5.06	1.80	5.51	1.71	2.80	2.00	
7	1.88	0.67	0.94	2.05	3.26	11.60	6.40	1.71	7.29	1.54	5.62	3.38	
8	1.80	0.67	0.94	3.37	2.88	6.18	7.07	1.22	6.84	1.37	4.39	3.42	
9	1.71	0.80	0.94	6.84	2.64	5.95	6.18	1.17	6.40	1.37	4.05	2.88	
10	1.58	0.91	0.94	5.51	2.76	5.59	5.28	1.11	5.51	1.45	2.88	2.14	
11	1.45	1.67	0.88	3.38	2.39	6.00	3.88	11.60	13.10	1.37	3.13	2.64	
12	1.45	1.77	0.82	2.64	2.39	4.39	3.38	9.00	14.40	1.88	2.64	2.51	
13	1.37	2.68	0.71	2.51	2.14	3.97	3.13	15.00	12.80	3.14	2.64	2.14	
14	1.28	2.37	0.94	3.13	4.47	4.05	3.72	12.40	8.25	2.99	2.88	1.88	
15	1.28	1.62	7.26	3.72	3.88	4.72	3.38	7.87	7.07	2.76	3.38	1.71	
16	1.37	1.58	14.00	3.88	4.14	3.80	3.00	4.89	6.18	4.54	3.00	1.54	
17	1.78	1.54	5.12	6.62	2.76	3.72	2.14	3.55	6.40	9.40	3.38	1.37	
18	1.37	1.41	3.13	4.56	2.51	12.60	2.14	3.13	5.06	6.40	3.38	1.45	
19	1.50	1.25	1.71	3.38	2.14	21.60	2.14	2.88	4.05	4.39	2.88	2.39	
20	1.37	1.17	1.62	3.00	1.88	23.50	2.05	3.67	3.55	3.26	2.88	3.73	
21	1.19	1.19	2.51	3.13	1.71	19.70	1.88	5.28	3.13	2.39	2.39	3.38	
22	1.08	1.11	1.71	2.39	2.23	18.50	1.97	3.55	2.76	2.05	2.64	3.00	
23	1.06	1.08	1.45	2.51	2.26	13.80	2.05	2.05	2.05	1.88	2.39	4.05	
24	1.11	1.11	1.37	3.13	2.14	8.45	1.71	2.39	2.14	1.80	2.64	3.38	
25	1.00	1.11	1.00	2.64	2.26	6.84	1.71	1.88	2.51	1.88	2.88	3.38	
26	1.02	1.08	1.05	4.89	1.97	10.10	1.45	2.14	2.39	1.88	2.64	4.84	
27	1.14	1.08	1.05	6.09	2.05	11.30	2.30	2.88	2.51	1.54	2.26	5.73	
28	1.08	1.11	1.05	4.05	2.10	6.96	2.64	2.26	2.14	1.37	2.64	7.28	
29	1.08	1.08	0.94	3.13	2.76	5.95	2.21	1.88	1.71	1.37	2.51	4.72	
30	1.05		1.05	6.84	3.11	6.29	1.80	2.14	1.77	1.88	2.88	3.88	
31	0.88		1.11		3.44		1.54	2.14		1.54		3.38	
TOTAL	52.91	35.07	60.71	101.13	90.92	254.11	112.10	117.04	183.03	79.04	87.98	91.73	-
Ave.	1.71	1.21	1.96	3.37	2.93	8.47	3.62	3.78	6.10	2.55	2.93	2.96	

ANNUAL TOTAL ( ) 1265.77

RIVER RUN-OFF STATION GUACHALA 13-g-1 SAN MIGUEL DE CAR, ECUADOR

GRANOBLES RIVER, IN THE BASIN OF ESMERALDAS ELEVATION 2,750 m UNIT cu. m/s YEAR 1965

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	3.00	3.38	1.08	1.00	9.70	4.30	2.05	1.71	3.38	4.82	4.05	5.28	
2	2.76	2.51	1.00	1.00	9.60	4.22	2.46	1.71	2.76	3.13	3.13	6.84	
3	2.51	2.64	1.05	1.19	8.74	11.30	2.94	1.45	2.51	2.26	3.13	6.84	
4	2.39	2.26	1.17	1.42	10.80	11.10	2.95	1.25	2.64	2.05	3.38	5.51	
5	2.05	1.97	2.00	1.22	7.58	5.95	4.22	2.84	3.13	1.80	3.38	4.89	
6	1.97	1.80	1.80	1.72	7.02	5.28	9.26	3.02	2.51	1.62	4.72	4.39	
7	3.90	1.62	1.45	3.55	5.06	6.62	5.04	1.97	2.05	1.45	4.56	4.72	
8	2.76	1.62	1.50	3.77	16.00	4.98	3.80	1.71	2.14	1.45	7.29	6.18	
9	2.88	1.28	1.45	3.00	8.47	9.55	2.76	2.27	2.05	1.37	17.00	7.29	
10	2.88	1.28	1.25	3.88	7.70	15.50	2.20	3.74	1.97	1.45	30.80	16.20	
11	2.05	1.22	1.22	3.72	7.39	7.47	4.93	2.95	1.71	1.62	17.50	9.04	
12	1.88	1.22	1.22	3.19	9.76	5.73	11.30	4.06	1.62	1.62	20.10	6.84	
13	2.04	1.28	1.25	3.13	9.91	4.89	9.54	3.64	1.84	1.80	9.04	6.40	
14	3.55	1.45	1.37	3.13	9.42	3.88	4.72	2.39	1.71	2.64	14.80	5.73	
15	3.13	1.62	1.54	4.82	12.10	3.26	3.26	1.88	1.88	6.40	44.50	5.06	
16	2.76	1.62	1.22	9.09	18.00	5.74	3.00	3.72	1.71	5.95	13.20	5.06	
17	2.14	1.62	1.11	9.91	9.06	14.30	2.51	2.88	1.54	11.30	13.20	7.29	
18	1.88	1.37	1.08	7.91	6.62	5.73	2.26	3.13	1.71	6.40	11.70	5.51	
19	1.80	1.28	1.11	12.00	6.18	4.39	2.51	3.13	2.70	5.51	22.30	5.06	
20	2.95	1.28	1.17	6.84	5.95	4.55	4.79	5.73	2.26	3.72	62.20	4.72	
21	2.39	1.28	1.14	6.40	5.51	3.55	16.50	29.00	2.89	3.13	17.50	4.05	
22	1.97	1.28	1.22	4.10	5.28	3.38	8.79	2.88	3.46	2.88	38.10	3.55	
23	1.88	1.17	1.22	4.39	6.81	3.13	5.17	2.51	3.55	2.39	17.50	3.38	
24	2.05	1.05	1.17	4.39	7.29	4.39	4.22	1.97	3.00	2.26	13.20	3.38	
25	1.80	1.17	1.00	3.72	5.62	3.22	4.22	1.88	2.39	2.39	11.70	4.39	
26	2.59	1.11	0.88	3.88	5.73	2.39	3.80	5.85	2.26	2.14	8.74	5.73	
27	2.51	0.97	0.94	3.88	5.73	2.14	2.64	3.25	2.10	4.39	7.29	4.56	
28	2.14	1.00	1.11	3.26	6.18	2.05	2.05	3.13	2.10	4.22	7.07	3.88	
29	1.97		1.19	3.38	6.40	1.84	1.71	14.70	6.16	4.39	5.95	3.88	
30	2.33		1.05	5.84	5.51	1.88	1.88	8.62	6.13	3.55	5.28	4.89	
31	6.41		1.05		4.89		1.88	4.72		3.55		4.72	
TOTAL	79.32	43.35	38.01	128.73	250.01	166.71	139.36	133.69	77.86	103.65	442.31	175.26	
Ave.	2.56	1.55	1.23	4.29	8.06	5.56	4.50	4.31	2.59	3.34	14.78	5.65	

ANNUAL TOTAL ( ) 1778.26

2-2 River Run-off STATION A.J. RIO GRANDOBLES 13-h-1 CATCHMENT AREA 360 sq.km SAN MIGUEL DE CAR, ECUADOR

GUACHALA RIVER, IN THE BASIN OF ESMERALDAS ELEVATION 2,740 m UNIT cu.m/s S ° ' W ° '

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'54-'55	10.2	13.1	11.0	13.2	19.9	10.5	12.3	15.4	14.5	14.3	22.5	15.2	14.3
'55-'56	8.0	8.8	7.4	11.1	13.8	9.6	17.1	25.5	10.6	32.9	20.2	12.5	14.8
'56-'57	10.5	5.9	2.8	6.9	5.4	4.8	5.7	11.0	11.0	10.7	10.9	-	-
'57-'58	-	-	-	-	-	-	-	7.1	7.1	14.0	8.5	11.5	-
'58-'59	6.1	5.4	6.4	3.8	4.0	4.7	4.7	5.7	9.2	9.7	19.3	9.4	7.4
'59-'60	-	-	-	-	-	-	-	-	-	-	-	-	-
'60-'61	6.4	4.2	3.3	3.8	3.4	3.9	7.0	5.8	6.8	8.8	9.5	7.2	5.9
'61-'62	5.9	7.5	4.7	3.3	3.8	-	-	-	9.0	-	-	8.2	-
'62-'63	-	-	-	-	-	5.0	4.5	4.2	4.2	8.4	5.0	5.5	-
'63-'64	2.9	2.8	3.9	4.7	3.1	2.7	4.2	4.5	4.4	14.2	7.8	9.2	5.4
'64-'65	11.8	4.5	3.8	3.1	3.3	2.9	3.1	4.3	8.2	9.9	10.4	7.5	6.1
'65-'66	4.7	4.5	10.3	6.2	-	-	-	-	-	-	-	-	-
AVERAGE	7.4	6.3	6.0	6.2	7.1	5.5	7.3	9.3	8.5	13.7	12.7	9.6	9.0

RIVER RUN-OFF STATION GRANOBLES 13-h-1 SAN MIGUEL DE CAR, ECUADOR

GUACHALA RIVER, IN THE BASIN OF EMERLDAS ELEVATION 2,740 m UNIT cu. m/s YEAR 1963

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	3.54	3.86	8.20	3.27	4.44	2.81	5.26	7.26	2.76	2.51	3.99	2.86	
2	3.54	5.19	7.89	2.96	5.18	3.54	5.10	5.35	2.76	2.56	3.99	2.86	
3	6.58	5.60	6.63	4.12	4.12	2.91	4.38	5.02	2.76	2.38	4.51	3.27	
4	6.17	4.94	5.76	5.84	6.26	2.86	5.69	4.12	2.76	2.46	4.38	2.86	
5	8.86	4.51	6.26	5.84	4.94	2.81	4.58	4.06	2.71	2.71	5.43	2.86	
6	5.14	3.99	5.35	4.94	3.99	2.81	3.80	6.34	2.76	2.66	5.43	2.76	
7	3.92	3.99	4.85	4.18	3.92	2.91	3.80	12.20	2.71	2.71	4.51	3.73	
8	3.66	4.51	4.18	3.80	3.80	2.86	3.60	6.42	2.76	2.56	3.86	3.73	
9	4.50	3.92	4.12	3.47	3.92	6.18	3.73	5.26	2.76	2.61	3.60	12.00	
10	4.94	3.86	4.06	2.91	4.50	16.20	3.86	4.51	2.81	2.71	3.73	10.60	
11	4.64	3.99	4.77	2.86	6.20	7.01	3.73	3.99	4.50	2.42	4.94	8.10	
12	4.12	4.06	4.12	2.86	4.85	15.20	3.80	3.99	3.86	2.38	5.10	5.60	
13	3.80	3.73	4.06	2.96	3.99	6.58	3.66	3.92	3.22	2.35	3.73	4.51	
14	3.99	3.60	4.06	3.42	3.73	18.70	3.22	4.06	2.76	2.42	3.60	3.73	
15	3.86	3.37	3.99	2.91	5.50	12.80	2.86	6.26	2.76	2.35	4.25	3.73	
16	4.06	2.91	3.86	2.86	5.51	8.10	2.91	13.00	2.71	2.38	3.73	2.86	
17	3.99	2.96	3.86	3.22	7.29	15.40	2.91	13.40	3.38	2.94	3.60	4.23	
18	3.92	5.40	4.44	2.91	4.51	25.40	2.86	7.47	3.32	3.41	2.96	3.27	
19	4.85	4.94	5.10	2.91	3.92	28.10	2.76	6.01	2.81	2.02	3.60	2.96	
20	3.92	4.44	4.06	5.10	3.86	15.60	2.76	5.18	2.76	2.76	2.86	2.86	
21	3.86	3.99	3.73	3.99	3.27	8.78	2.76	4.51	2.76	2.66	3.27	2.86	
22	3.86	4.64	3.60	3.60	2.91	7.05	3.37	3.92	3.42	2.66	3.73	3.95	
23	4.18	11.60	3.27	5.05	2.96	5.76	7.55	3.73	3.41	2.61	3.99	8.18	
24	3.99	8.00	3.27	5.73	2.96	5.26	6.04	3.66	2.96	2.27	4.64	7.26	
25	3.73	6.73	3.60	7.05	4.44	5.10	6.95	3.60	2.76	3.76	3.99	5.26	
26	3.73	6.84	3.73	6.74	3.92	4.77	4.51	5.31	2.76	2.81	3.60	5.26	
27	5.10	5.92	3.32	5.18	3.22	4.77	5.06	4.51	2.66	2.66	3.73	4.51	
28	5.60	7.84	3.92	6.01	2.91	3.99	9.94	3.80	2.56	3.37	3.27	3.99	
29	4.94		4.44	4.51	2.86	3.66	10.80	3.54	2.46	3.66	3.17	3.73	
30	5.10		3.73	4.44	2.86	4.44	13.60	2.86	2.46	4.94	2.86	6.45	
31	4.12		3.54		2.81		8.91	2.86		4.06		5.43	
TOTAL	140.21	139.33	139.77	125.64	129.55	252.36	154.76	170.12	87.84	86.76	118.05	146.26	
AVE.	4.52	4.98	4.51	4.19	4.18	8.41	4.99	5.49	2.93	2.80	3.94	4.72	

ANNUAL TOTAL ( ) 1690.65

RIVER RUN-OFF STATION GRANOBLES 13-h-1 SAN MIGUEL DE CAR, ECUADOR

GUACHALA RIVER, IN THE BASIN OF ESMERALDAS ELEVATION 2,740 m UNIT cu. m/s YEAR 1964

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	4.94	2.46	3.27	3.73	5.10	3.73	9.04	3.73	6.72	4.85	4.25	2.76	
2	4.51	2.46	2.66	2.86	3.99	3.60	12.70	4.94	8.19	5.84	4.62	2.76	
3	3.73	2.56	2.46	4.20	3.73	4.64	15.80	6.04	24.20	5.02	3.67	2.76	
4	3.73	2.56	2.46	5.20	3.60	6.98	11.70	7.54	11.60	3.86	3.80	2.76	
5	3.00	2.46	2.46	3.99	3.47	7.01	9.55	8.78	7.99	3.86	4.78	2.86	
6	3.17	2.66	2.31	3.47	3.47	10.70	9.04	5.35	10.50	3.73	5.02	2.76	
7	3.27	2.66	2.46	2.86	3.27	8.46	20.80	4.44	18.80	3.47	5.82	3.60	
8	3.27	2.66	2.56	4.25	2.86	7.18	16.50	3.92	12.60	3.47	6.38	2.86	
9	3.27	2.66	2.66	5.26	3.73	7.47	13.60	26.10	11.90	2.96	4.70	2.76	
10	2.96	2.46	2.46	5.43	3.73	6.17	10.60	25.70	11.00	2.81	3.92	2.56	
11	2.86	2.66	2.56	4.51	4.20	5.26	8.10	35.80	33.60	3.61	3.86	2.56	
12	3.17	2.86	2.76	3.73	4.12	4.94	6.84	26.00	26.90	5.35	3.54	2.51	
13	2.86	2.66	3.27	3.47	5.80	4.18	6.84	16.80	28.40	6.25	3.66	2.51	
14	2.86	2.66	6.26	3.47	8.78	6.18	7.05	10.90	16.30	5.10	3.60	2.46	
15	3.07	2.66	12.70	4.94	6.17	8.48	6.84	8.10	15.60	5.26	3.73	2.42	
16	2.66	2.66	21.70	3.86	5.76	6.09	5.26	7.26	12.50	6.72	3.47	2.46	
17	3.17	2.66	6.92	6.72	4.64	12.10	5.10	7.47	12.50	12.10	3.47	2.42	
18	3.73	2.56	4.51	5.43	4.38	33.60	5.10	10.50	10.60	7.97	3.27	2.35	
19	2.86	2.66	3.99	3.73	3.66	38.20	4.77	7.05	8.91	5.26	3.98	2.46	
20	2.86	2.66	5.42	4.51	3.79	55.80	4.51	5.60	7.26	4.51	3.73	2.46	
21	2.66	2.66	5.42	5.10	3.66	35.90	3.99	5.18	6.52	3.86	3.47	3.45	
22	2.66	2.76	3.47	3.99	5.26	33.10	4.51	5.02	5.43	3.66	3.73	3.27	
23	2.66	2.66	2.86	4.64	5.43	18.80	5.43	5.26	5.10	3.27	3.47	3.07	
24	2.66	2.66	2.86	4.94	5.39	11.40	4.64	5.26	7.47	4.19	3.27	3.54	
25	2.56	2.66	3.17	4.38	4.90	10.10	3.73	4.85	8.66	4.25	2.86	3.12	
26	2.46	2.56	3.17	5.10	3.73	26.80	3.86	5.10	6.20	3.73	2.76	2.86	
27	2.66	2.56	2.86	7.24	3.73	12.30	6.19	5.35	5.26	3.60	2.76	2.98	
28	2.46	2.66	2.86	5.10	3.73	12.80	7.05	5.02	5.10	2.96	2.76	4.57	
29	2.46	3.96	2.86	4.38	3.54	13.30	5.26	4.44	4.44	2.96	2.76	4.17	
30	2.56		2.76	5.10	3.07	10.30	3.80	4.06	3.99	3.27	2.76	4.50	
31	2.46		2.76		5.16		3.60	5.08		2.91		4.64	
TOTAL	94.21	77.44	130.90	135.59	135.85	425.57	241.80	286.64	354.24	140.66	113.87	93.22	
AVE.	3.04	2.67	4.22	4.52	4.38	14.19	7.80	9.25	11.81	4.54	3.80	3.01	

ANNUAL TOTAL ( ) 2229.99

RIVER RUN-OFF STATION GRANOBLES 13-h-1 SAN MIGUEL DE CAR. ECUADOR

GUACHALA RIVER, IN THE BASIN OF ESMERALDAS ELEVATION 2,740 m UNIT cu. m/s YEAR 1965

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	4.38	3.27	2.86	3.18	18.40	6.42	6.04	5.92	5.60	3.73	4.77	8.00	
2	3.92	2.86	2.91	3.86	7.10	6.63	8.26	5.49	4.94	3.47	3.99	9.68	
3	3.22	2.86	3.50	3.47	6.94	21.70	7.01	4.94	4.64	2.96	3.99	9.55	
4	3.91	2.86	4.38	2.76	9.25	18.90	6.26	4.94	4.94	2.86	5.10	6.84	
5	3.22	2.76	4.77	3.15	8.00	9.55	9.74	16.20	4.77	2.66	4.77	5.60	
6	2.96	2.66	3.27	3.17	7.36	10.40	15.40	9.92	4.51	2.66	5.60	4.77	
7	2.64	2.66	2.86	3.87	5.26	11.40	9.70	5.60	4.51	2.66	5.10	4.77	
8	2.72	2.46	3.37	4.94	10.00	8.60	8.16	4.94	4.51	2.66	5.10	8.79	
9	2.81	2.46	2.96	4.79	6.77	12.40	6.09	5.56	4.51	2.66	7.47	10.80	
10	2.61	2.46	2.76	4.51	6.35	18.20	5.43	7.96	4.51	2.66	17.90	12.80	
11	2.71	2.31	2.86	4.51	6.68	10.30	10.90	7.26	4.51	2.66	10.40	8.42	
12	3.27	2.46	2.96	4.12	5.60	8.52	21.60	8.71	4.51	2.66	9.42	6.63	
13	3.32	2.46	3.37	3.73	6.49	7.05	21.90	10.00	4.51	3.73	11.40	7.26	
14	2.91	4.12	3.47	3.60	6.86	6.42	9.65	7.01	4.51	6.09	9.61	5.76	
15	5.35	3.86	3.17	4.25	7.94	6.26	7.05	5.10	4.51	6.84	27.80	5.26	
16	5.10	3.17	2.76	6.35	8.82	8.95	7.68	4.94	4.51	6.09	13.60	5.43	
17	4.12	2.86	2.86	7.14	6.94	20.40	8.10	4.64	4.51	6.84	18.20	8.27	
18	3.80	2.86	2.96	4.77	6.09	10.80	6.84	4.51	5.92	7.68	14.40	5.43	
19	3.22	3.47	2.86	6.01	11.40	9.05	6.09	4.51	4.77	6.09	18.00	5.10	
20	2.96	2.86	2.76	4.94	8.46	11.10	12.00	4.51	4.94	4.51	13.80	4.64	
21	2.86	2.86	2.86	4.64	6.63	8.31	34.20	6.21	6.09	3.73	13.10	4.51	
22	2.86	2.86	3.27	4.64	6.26	7.47	18.40	5.10	5.60	3.73	20.40	4.51	
23	2.66	2.86	3.73	4.38	8.08	9.64	9.92	4.51	6.49	5.43	14.20	4.38	
24	2.66	3.17	4.12	4.12	10.40	12.20	11.60	4.51	5.26	3.99	10.30	4.64	
25	2.66	2.86	3.27	4.12	8.10	7.75	11.90	6.65	4.77	3.60	8.52	4.64	
26	3.37	2.76	2.86	4.12	9.87	6.42	8.63	17.80	3.99	3.47	7.26	4.51	
27	3.73	3.73	2.76	4.25	9.86	5.76	6.42	6.08	3.27	4.25	6.42	4.51	
28	3.22	3.22	2.66	4.12	11.80	5.26	5.26	9.28	3.60	3.99	6.09	4.51	
29	2.86		2.66	3.86	8.44	5.10	5.60	21.50	4.25	10.60	5.76	4.51	
30	2.91		2.86	4.40	7.89	5.10	8.93	10.40	3.86	5.10	6.86	4.51	
31	3.50		2.86		6.98		6.63	6.84		7.89		4.51	
TOTAL	102.44	82.06	97.58	129.77	255.02	296.06	321.39	231.54	141.82	137.95	309.33	193.54	
AVE.	3.30	2.93	3.15	4.33	8.23	9.87	10.37	7.47	4.73	4.45	10.31	6.24	

ANNUAL TOTAL ( ) 2298.50

2-3 River Run-off

AMBI RIVER, IN THE BASIN OF MIRA

STATION D.J. RIO CARIYACU 2-d-1 CATCHMENT AREA 700 sq.km SAN MIGUEL DE CAR, ECUADOR

ELEVATION 2015 m UNIT cu.m/s S ° ' W ° '

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'63-'64	1.9	1.8	3.2	2.3	2.1	1.6	1.3	2.9	3.0	4.7	2.9	2.1	2.5
'64-'65	2.1	2.7	4.7	4.7	4.4	2.8	2.2	6.0	8.0	2.4	1.5	1.5	3.6
'65-'66	1.4	3.7	10.4	4.5	-	-	-	-	-	-	-	-	-
AVERAGE	1.8	2.7	6.1	3.8	3.3	2.2	1.8	4.5	5.5	3.5	2.0	1.8	3.1

RIVER RUN-OFF STATION CARIYACU 2-d-1 SAN MIGUEL DE CAR, ECUADOR

AMBI RIVER, IN THE BASIN OF MIRA ELEVATION 2,015 m UNIT cu. m/s YEAR 1964

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	4.70	1.40	1.34	1.40	5.17	2.50	4.00	2.00	2.00	2.30	3.60	4.00	
2	4.00	1.40	1.27	1.40	4.30	3.68	4.30	1.90	2.00	2.70	2.50	4.00	
3	3.60	1.40	1.25	1.30	4.30	5.59	3.60	2.00	2.70	2.30	2.60	3.40	
4	2.70	1.50	1.20	1.60	4.38	4.70	3.80	2.00	2.30	2.30	2.20	5.40	
5	2.50	1.50	1.20	1.62	4.70	4.70	3.60	2.00	2.20	2.40	3.20	3.15	
6	2.30	1.40	1.25	1.60	4.00	9.52	3.60	2.00	2.30	2.25	3.20	2.55	
7	2.30	1.40	1.25	2.20	3.60	7.10	3.60	2.00	2.30	2.30	5.27	3.15	
8	2.30	1.40	1.23	3.13	3.60	6.20	3.60	2.00	2.20	2.30	5.10	4.90	
9	2.00	1.50	1.25	3.20	3.20	5.50	3.40	2.00	2.20	2.30	3.95	4.30	
10	2.20	1.50	1.25	2.30	3.20	5.50	3.05	2.00	2.20	2.10	3.40	3.05	
11	2.20	1.80	1.25	2.20	3.20	5.90	3.20	2.00	2.00	2.25	3.80	3.20	
12	2.14	1.80	1.25	2.14	2.90	5.50	3.20	2.00	2.00	2.50	3.20	3.60	
13	2.20	1.80	1.25	3.11	2.90	5.10	3.20	2.00	2.20	2.60	3.20	3.40	
14	2.00	1.70	1.30	3.83	3.20	5.10	3.05	2.00	2.00	2.70	3.95	3.40	
15	2.00	1.89	1.24	3.93	2.90	5.10	2.85	2.00	2.00	2.80	8.80	2.80	
16	2.00	1.69	1.25	4.00	2.60	4.70	2.85	2.00	2.00	3.05	11.80	2.80	
17	1.90	1.80	1.25	2.70	2.50	4.00	2.50	2.20	1.90	4.90	7.25	2.60	
18	2.00	1.70	1.25	2.70	2.30	4.00	2.40	2.20	2.00	4.25	5.77	2.50	
19	1.85	1.50	1.25	2.50	2.30	4.00	2.40	2.20	1.90	3.60	7.47	2.50	
20	1.84	1.40	1.28	2.50	2.30	4.70	2.30	2.20	1.90	3.05	4.70	4.90	
21	1.80	1.50	1.25	2.30	2.30	4.00	2.25	2.00	1.90	2.90	4.00	4.90	
22	1.80	1.50	1.24	2.30	2.30	4.30	2.40	2.20	2.00	2.80	4.00	4.90	
23	1.70	1.73	1.25	2.30	2.30	4.00	2.30	2.20	1.80	2.70	4.00	4.35	
24	1.60	1.70	1.25	2.30	2.30	3.60	2.20	2.20	2.00	2.70	5.50	5.70	
25	1.60	2.50	1.30	2.90	2.30	3.60	2.20	2.20	2.00	2.60	5.50	6.10	
26	1.54	1.40	1.40	6.01	2.30	3.60	2.20	2.99	2.00	2.30	4.00	7.35	
27	1.60	1.40	1.35	5.89	2.30	3.60	2.20	2.90	2.57	2.30	4.36	8.08	
28	1.60	1.40	1.40	4.30	2.00	3.60	2.20	2.30	2.30	2.50	4.00	8.80	
29	1.50	1.40	1.32	4.30	2.00	3.60	2.20	2.20	2.30	2.70	5.45	10.40	
30	1.40		1.40	5.37	2.03	3.60	2.20	2.00	2.20	2.80	4.45	9.00	
31	1.40		1.40		3.39		2.00	2.20		2.70		9.05	
TOTAL	66.27	46.01	39.62	87.33	93.07	140.59	88.85	66.09	63.37	83.95	140.22	146.23	
AVE.	2.14	1.59	1.28	2.91	3.00	4.69	2.87	2.13	2.11	2.71	4.67	4.72	

ANNUAL TOTAL ( ) 1061.60

RIVER RUN-OFF — STATION CARIYACU 2-d-1 — SAN MIGUEL DE CAR, ECUADOR

AMBI RIVER, IN THE BASIN OF MIRA — ELEVATION 2,015 m — UNIT cu. m/s — YEAR 1965

DATE	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	DATE
1	6.70	3.85	1.60	2.00	17.80	4.00	1.75	1.35	1.35	1.50	7.70	5.70	
2	6.20	4.70	1.60	1.90	17.60	4.00	1.80	1.35	1.35	1.45	7.70	5.30	
3	6.70	4.00	1.70	1.90	8.80	3.20	1.80	1.40	1.40	1.40	7.90	4.90	
4	5.50	4.00	2.00	2.20	7.50	3.20	1.70	1.45	1.50	1.45	7.90	4.00	
5	4.70	4.00	2.30	2.00	7.10	3.60	1.70	1.40	1.50	1.40	8.10	3.40	
6	4.70	3.60	2.30	2.70	6.20	3.60	1.70	1.35	1.45	1.45	8.55	3.05	
7	4.30	4.70	2.50	4.00	6.20	3.20	1.65	1.45	1.40	1.36	8.55	4.00	
8	4.70	3.20	2.00	4.00	7.10	2.70	1.65	1.50	1.35	1.28	6.70	4.45	
9	4.00	2.70	2.50	6.40	7.50	2.70	1.70	1.50	1.35	1.28	11.50	4.00	
10	4.00	2.70	2.70	8.80	7.90	2.70	1.70	1.50	1.40	1.30	11.40	4.00	
11	4.70	2.30	2.50	7.10	7.10	2.50	1.60	1.45	1.45	1.28	12.10	4.00	
12	4.00	2.30	2.70	7.10	12.50	2.30	1.65	1.55	1.40	1.35	5.50	4.20	
13	3.20	2.20	2.60	6.20	10.50	2.30	1.65	1.60	1.30	1.45	5.66	4.20	
14	3.20	2.70	2.50	6.20	11.70	2.25	1.60	1.50	1.45	2.30	7.42	4.20	
15	3.20	2.20	2.70	9.70	10.60	2.20	1.55	1.40	1.40	3.60	9.70	4.20	
16	3.20	2.00	2.50	8.80	15.00	2.25	1.50	1.45	1.40	2.80	7.30	4.80	
17	4.30	2.00	2.30	7.90	9.20	2.10	1.50	1.50	1.40	3.64	8.80	4.80	
18	3.20	2.00	2.50	7.90	8.30	2.00	1.55	1.45	1.45	3.80	14.50	4.80	
19	3.20	2.00	2.20	7.50	7.50	1.90	1.45	1.50	1.35	3.20	36.10	4.80	
20	2.70	2.70	2.30	7.10	7.10	1.95	1.40	1.55	1.35	2.50	15.80	5.10	
21	3.00	2.20	2.00	7.10	6.20	1.90	1.45	1.55	1.50	2.30	14.40	5.10	
22	3.60	2.00	2.00	6.20	6.20	1.85	1.35	1.50	1.60	2.40	13.60	5.10	
23	4.70	2.00	2.00	5.50	6.20	1.80	1.35	1.55	1.50	10.00	18.00	4.70	
24	4.30	2.00	2.00	5.50	5.90	1.85	1.40	1.55	1.35	7.50	11.10	4.70	
25	2.70	2.00	2.00	5.50	5.50	1.80	1.40	1.55	1.35	6.70	9.45	4.70	
26	5.50	1.80	2.00	5.50	5.10	1.80	1.35	1.50	1.30	6.20	8.30	4.70	
27	5.50	2.00	2.00	4.70	4.70	1.80	1.35	1.40	1.30	7.30	7.50	4.50	
28	4.70	2.30	2.00	5.50	4.00	1.80	1.35	1.45	1.40	8.30	7.10	4.50	
29	4.00		2.00	7.90	4.70	1.85	1.35	1.40	1.50	8.75	6.70	4.50	
30	5.10		2.20	15.80	7.10	1.78	1.45	1.40	1.55	7.50	6.20	4.50	
31	7.90		2.20		5.55		1.40	1.45		6.90		4.50	
TOTAL	137.40	76.15	68.40	180.60	254.35	72.88	47.80	45.50	42.35	113.64	311.23	139.40	
AVE.	4.43	2.72	2.21	6.02	8.20	2.43	1.54	1.47	1.41	3.66	10.37	4.50	

ANNUAL TOTAL ( ) 1489.70

2-4 River Run-off STATION D.J. RIO MINAS (2-g-1) CATCHMENT AREA 385 sq. km SAN MIGUEL DE CAR. ECUADOR

APAQUI RIVER, IN THE BASIN OF MIRA ELEVATION 2750 m UNIT cu.m/s S ° ' W °

YEAR	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	ANNUAL
'63-'64	3.3	3.0	4.8	4.0	2.7	2.3	2.5	3.2	3.6	10.8	6.2	6.6	4.4
'64-'65	7.0	3.5	3.5	3.8	3.5	2.8	2.8	3.6	6.3	9.8	10.3	6.3	5.3
'65-'66	4.4	4.0	6.5	6.1	4.4	-	-	-	-	-	-	-	-
AVERAGE	4.9	3.5	4.9	4.6	3.5	2.6	2.7	3.4	5.0	10.3	8.3	6.5	4.9

3-1 OUTPUT AND DISCHARGE STATION INTAKE OF LA PLAYA P.S. C.A. = 128 sq.km SAN MIGUEL DE CAR, ECUADOR

BOBO RIVER, IN THE BASIN OF CARCHI ELEVATION 2,896 m UNIT kw, cu.m/s YEAR 1962

DATE	OUTPUT (kw) JUN.	JUL.	AUG.	SEP.		DISCHARGE (cu.m/s) JUN.	JUL.	AUG.	SEP.				DATE
1	560	530	570	520		1.16	1.12	1.18	1.10				
2	560	560	560	495		"	1.16	1.16	1.06	Note:			
3	530	550	540	490		1.12	1.15	1.13	1.05	Discharge are obtained			
4	560	565	560	510		1.16	1.18	1.16	1.08	from Output, using Fig5-5.			
5	540	560	520	520		1.13	1.16	1.13	1.10				
6	560	550	560	515		1.16	1.15	1.16	1.09				
7	560	560	560	500		"	1.16	"	1.06				
8	560	560	560	500		"	"	"	"				
9	560	560	560	470		"	"	"	1.02				
10	520	560	560	460		1.10	"	"	1.00				
11	560	560	560	510		1.16	"	"	1.08				
12	560	560	480	500		"	"	1.03	1.06				
13	560	560	520	-		"	"	1.10	-				
14	560	560	520	470		"	"	"	1.02				
15	560	520	510	485		"	1.10	1.08	1.04				
16	560	560	530	490		"	1.16	1.12	1.05				
17	520	560	580	545		1.10	"	"	1.14				
18	540	560	540	500		1.13	"	1.14	1.06				
19	560	560	520	505		1.16	"	1.10	1.08				
20	560	560	520	515		"	"	"	1.09				
21	560	560	535	515		"	"	1.13	"				
22	560	520	500	510		"	1.10	1.06	1.08				
23	560	540	520	500		"	1.13	1.10	1.06				
24	530	540	520	510		1.12	"	"	1.08				
25	560	560	520	510		1.16	1.16	"	"				
26	560	560	460	490		"	"	1.00	1.05				
27	575	560	480	500		1.19	"	1.03	1.06				
28	540	560	510	490		1.13	"	1.09	1.05				
29	565	500	500	480		1.18	1.06	"	1.03				
30	570	530	500	505		"	1.12	1.06	1.08				
31		550	520				1.15	1.10					
TOTAL	16,630	17,095	16,355	14,510		34.58	35.59	34.47	30.90				
Ave.	554	551	528	500		1.15	1.15	1.11	1.07				

3-2 OUTPUT AND DISCHARGE STATION INTAKE OF LA PLAYA P.S. C.A. = 128 sq.km SAN MIGUEL DE CAR. ECUADOR

BOBO RIVER, IN THE BASIN OF CARCHI ELEVATION 2896 m UNIT kw. cu.m/s YEAR 1963

DATE	OUTPUT (kw) JUN.	JUL.	AUG.	SEP.		DISCHARGE (cu.m/s) JUN.	JUL.	AUG.	SEP.
1	610	620	600	320		1.25	1.27	1.23	0.65
2	584	620	560	350		1.21	"	1.16	0.71
3	610	610	560	360		1.25	1.25	"	0.72
4	610	620	510	340		"	1.27	1.08	0.69
5	600	620	520	360		1.23	"	1.10	0.78
6	615	630	450	260		1.26	1.29	0.99	0.55
7	635	550	500	565		1.29	1.15	1.06	1.18
8	623	583	385	560		1.28	1.21	0.88	1.17
9	595	600	400	580		1.23	1.23	0.90	1.20
10	615	600	405	590		1.26	"	0.91	1.22
11	620	595	400	600		1.27	1.23	0.90	1.23
12	660	595	400	580		1.34	"	"	1.20
13	610	640	400	260		1.25	1.30	"	0.55
14	620	544	420	300		1.27	1.15	0.93	0.62
15	340	600	410	360		1.14	1.23	0.92	0.72
16	578	602	420	300		1.20	"	0.93	0.62
17	620	600	410	340		1.27	1.23	0.92	0.69
18	620	580	420	400		"	1.20	0.93	0.80
19	638	400	400	350		1.29	0.90	0.90	0.70
20	640	590	400	360		1.30	1.22	"	0.72
21	626	530	400	480		1.28	1.12	"	1.03
22	634	540	400	350		1.29	1.14	"	0.71
23	600	540	400	330		1.23	"	"	0.67
24	620	560	400	330		1.27	1.16	"	"
25	620	540	370	330		"	1.14	0.85	"
26	640	540	385	330		1.30	"	0.88	"
27	620	580	370	320		1.27	1.21	0.85	0.65
28	620	530	370	320		"	1.12	"	"
29	640	560	360	320		1.30	1.16	0.84	"
30	600	560	360	320		1.23	"	"	"
31		560	325				"	0.79	
TOTAL	18,471	17,482	13,110	11,565		37.82	37.01	29.10	23.68
Ave.	616	576	424	385		1.26	1.19	0.94	0.79

			DATE

Note:
Discharge are obtained from Output, using Fig 5-5.

3-3 OUTPUT AND DISCHARGE STATION INTAKE OF LA PLAYA P.S. C.A. = 128 sq.km SAN MIGUEL DE CAR. ECUADOR

BOBO RIVER, IN THE BASIN OF CARCHI ELEVATION 2896 UNIT kw, cu.m/s YEAR 1964

DATE	OUTPUT (kw) JUN.	JUL.	AUG.	SEP.	DISCHARGE (cu.m/s) JUN.	JUL.	AUG.	SEP.	DATE
1	570	630	540	595	1.18	1.29	1.14	1.83	
2	620	625	530	600	1.27	1.28	1.12	1.23	
3	610	630	560	600	1.25	1.29	1.17	"	
4	655	640	570	620	1.33	1.30	1.18	1.26	
5	640	600	570	625	1.30	1.23	"	1.28	
6	640	640	560	635	"	1.30	1.17	1.29	
7	600	640	560	570	1.23	"	"	1.18	
8	645	635	560	600	1.31	1.30	"	1.23	
9	640	640	560	600	1.30	"	"	"	
10	635	645	555	620	1.30	1.31	1.16	1.26	
11	640	635	550	600	"	1.30	1.15	1.23	
12	640	600	560	620	"	1.23	1.17	1.26	
13	625	640	550	560	1.28	1.30	1.15	1.16	
14	590	640	560	590	1.22	"	1.17	1.22	
15	610	625	560	605	1.25	1.28	"	1.24	
16	640	620	520	610	1.30	1.27	1.10	1.25	
17	640	640	560	610	"	1.30	1.17	"	
18	640	640	560	605	"	"	"	1.24	
19	635	595	560	610	1.30	1.23	"	1.25	
20	640	600	565	560	"	1.23	1.18	1.16	
21	600	605	560	565	1.24	1.24	1.17	1.18	
22	640	600	580	600	1.30	1.23	1.20	1.23	
23	640	625	560	580	"	1.28	1.17	1.20	
24	640	625	560	620	"	"	"	1.26	
25	635	630	560	600	1.30	1.29	"	1.23	
26	633	590	-	600	"	1.22	-	"	
27	640	600	-	565	"	1.23	-	1.18	
28	595	580	610	615	1.23	1.20	1.25	1.26	
29	600	580	570	560	1.24	"	1.18	1.16	
30	635	540	595	600	1.30	1.13	1.23	1.23	
31		570	560			1.18	1.17		
TOTAL	18,471	17,842	13,110	11,565	38.43	39.12	33.94	36.84	
AVE.	616	576	424	385	1.28	1.26	1.17	1.23	

Note:
Discharge are obtained from Output, using Fig.5-5.

3-4 OUTPUT AND DISCHARGE STATION INTAKE OF LA PLAYA P.S. C.A. = 128 sq.km SAN MIGUEL DE CAR, ECUADOR

BORO RIVER, IN THE BASIN OF CARCHI ELEVATION 2896 UNIT kw, cu.m/s YEAR 1965

DATE	OUTPUT (kw) JUN.	JUL.	AUG.	SEP.		DISCHARGE (cu.m/s) JUN.	JUL.	AUG.	SEP.				DATE
1	650	720	580	530		1.32	1.45	1.20	1.12				
2	640	680	590	500		1.30	1.37	1.22	1.06				
3	680	680	570	500		1.37	"	1.18	"				
4	670	480	580	500		1.35	1.03	1.20	1.10				
5	680	680	600	540		1.37	1.37	1.23	1.13				
6	600	680	580	500		1.23	"	1.20	1.10				
7	690	680	560	535		1.39	"	1.17	1.13				
8	680	660	535	510		1.37	1.34	1.13	1.08				
9	680	700	550	525		"	1.41	1.15	1.11				
10	680	680	550	525		"	1.37	"	1.08				
11	680	625	540	500		"	1.28	1.13	1.06				
12	680	670	560	440		"	1.35	1.17	0.97				
13	640	650	530	460		1.30	1.32	1.12	1.00				
14	660	680	535	445		1.34	1.37	1.13	0.98				
15	675	675	520	440		1.36	1.36	1.10	0.97				
16	715	650	500	440		1.44	1.32	1.06	"				
17	690	670	495	440		1.40	1.35	1.06	"				
18	695	640	480	500		"	1.30	1.03	1.06				
19	700	680	520	480		1.41	1.37	1.10	1.03				
20	640	675	520	525		1.30	1.36	"	1.11				
21	695	600	520	530		1.40	1.23	"	1.12				
22	665	573	560	510		1.34	1.22	1.17	1.08				
23	685	600	580	530		1.38	1.23	1.20	1.12				
24	680	600	585	550		1.37	"	1.20	1.15				
25	665	575	530	555		1.35	1.19	1.12	1.16				
26	675	600	575	460		1.36	1.23	1.19	1.00				
27	640	600	565	500		1.30	"	1.18	1.06				
28	680	600	560	520		1.37	"	1.17	1.10				
29	680	610	530	720		"	1.25	1.12	1.45				
30	720	610	520	705		1.45	"	1.10	1.42				
31		635	520				1.30	"					
TOTAL	20,210	19,878	16,940	15,435		40.82	40.42	35.48	32.75				
AVE.	674	641	546	514		1.36	1.30	1.14	1.09				

Note:
Discharge are obtained from Output, using Fig. 5-5

4. Temperature and Evaporation of Tulcan

Year	Item	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1963	Temperature													
	Max. (°C)	19.9	19.0	18.1	19.4	19.6	18.6	18.5	18.5	21.0	20.8	19.7	19.8	19.4
	Min. (°C)	0.6	0.3	3.2	3.0	0	0.5	0.5	-1.0	-0.6	0.8	2.0	2.0	0.9
	Average (°C)	10.8	10.5	11.2	11.3	10.6	10.1	9.4	9.2	9.6	10.4	10.5	11.2	10.4
	Evaporation(mm)	-	-	-	-	-	-	-	-	-	-	-	-	-
1964	Temperature													
	Max. (°C)	21.8	23.0	20.0	19.4	18.7	17.5	18.7	18.5	18.6	19.6	19.7	19.4	19.6
	Min. (°C)	0.2	0.6	0	3.6	2.1	0.6	0	0.6	0.4	1.0	2.0	1.9	1.1
	Average	10.2	10.8	10.1	11.2	10.6	10.0	9.7	9.3	9.4	9.9	10.3	10.3	10.2
	Evaporation(mm)	143.1	89.1	113.5	101.6	98.0	86.9	116.5	119.9	107.7	106.0	105.5	94.3	1,282.1
1965	Temperature													
	Max. (°C)	20.4	19.5	19.5	20.3	19.7	17.2	16.9	17.8	20.0	21.0	21.0	19.2	19.4
	Min. (°C)	0.6	0.2	0.5	3.1	3.5	2.4	0.4	-0.2	2.5	1.7	0.7	1.4	1.4
	Average	10.3	9.8	10.3	10.6	10.7	9.8	9.7	9.3	10.2	10.8	11.2	10.7	9.5
	Evaporation(mm)	99.4	115.1	111.6	87.8	110.9	98.5	128.5	126.7	41.1	106.7	86.6	86.3	1,179.2