THE REPUBLIC OF ECUADOR

FEASIBILITY STUDY
ON
CHESPI HYDROELECTRIC
DEVELOPMENT PROJECT
FEASIBILITY STUDY REPORT

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AUGUST 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of Ecuador, the Government of Japan has decided to re-examine the master plan of three hydroelectric power development projects at Calderon, Chespi and Palma Real at the midstream of the Guayllabamba River, and to formulate a feasibility study on the Chespi Project, and entrusted the work to the Japan International Cooperation Agency.

JICA dispatched to the Ecuador a 15-man survey team, headed by Mr. Terumi Ushijima, which conducted in a period from January 10 to December 24, 1985 a series of surveys in discussion with the officials concerned of Ecuador.

After the team returned to Japan, further studies were made and the present report has been completed.

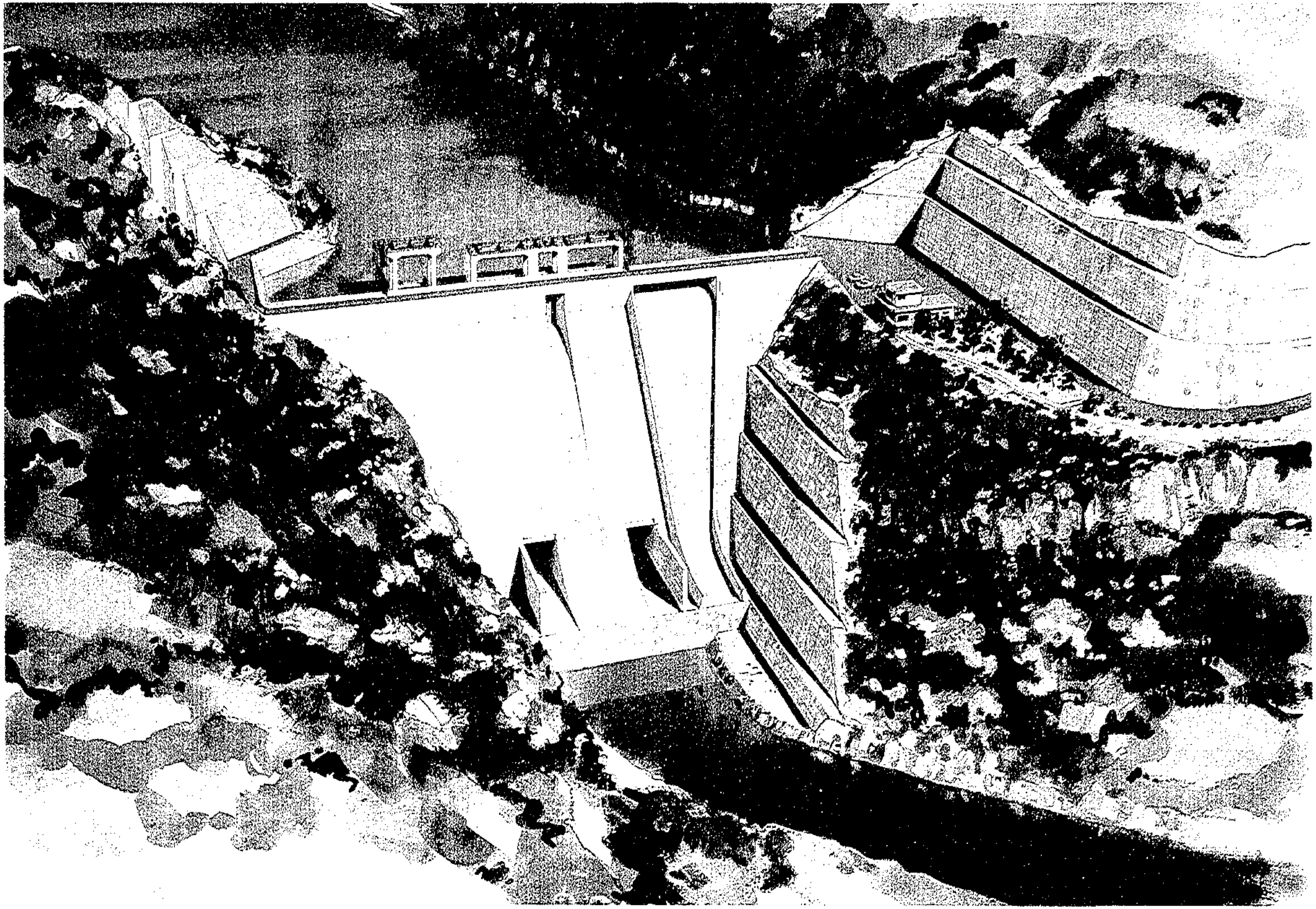
I hope that this report will be useful as a basic reference for the project and contribute to the promotion of friendly relations between our two countries.

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

August, 1986

Keisuke Arita

KEISUKE ARITA
President
Japan International Cooperation Agency



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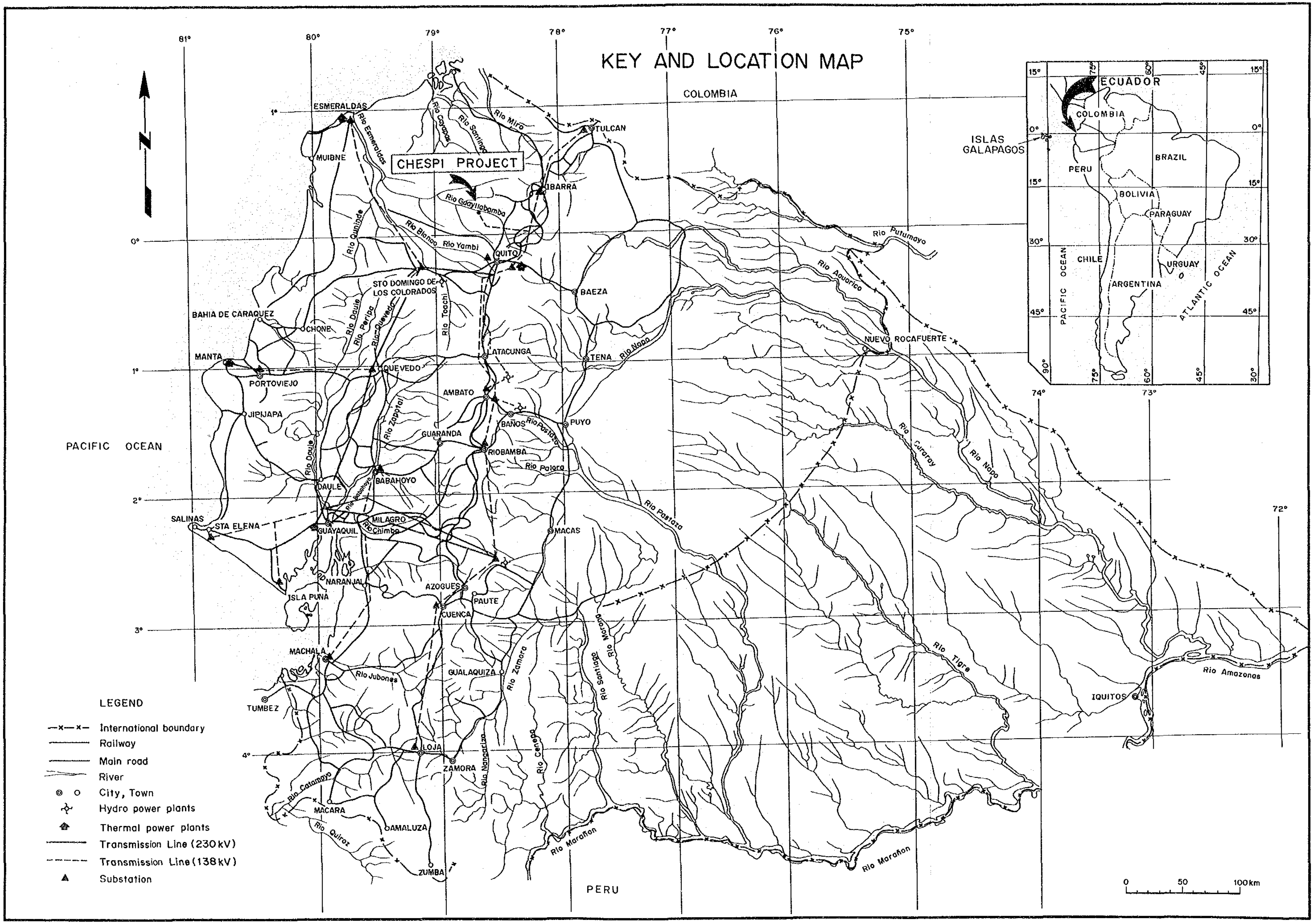

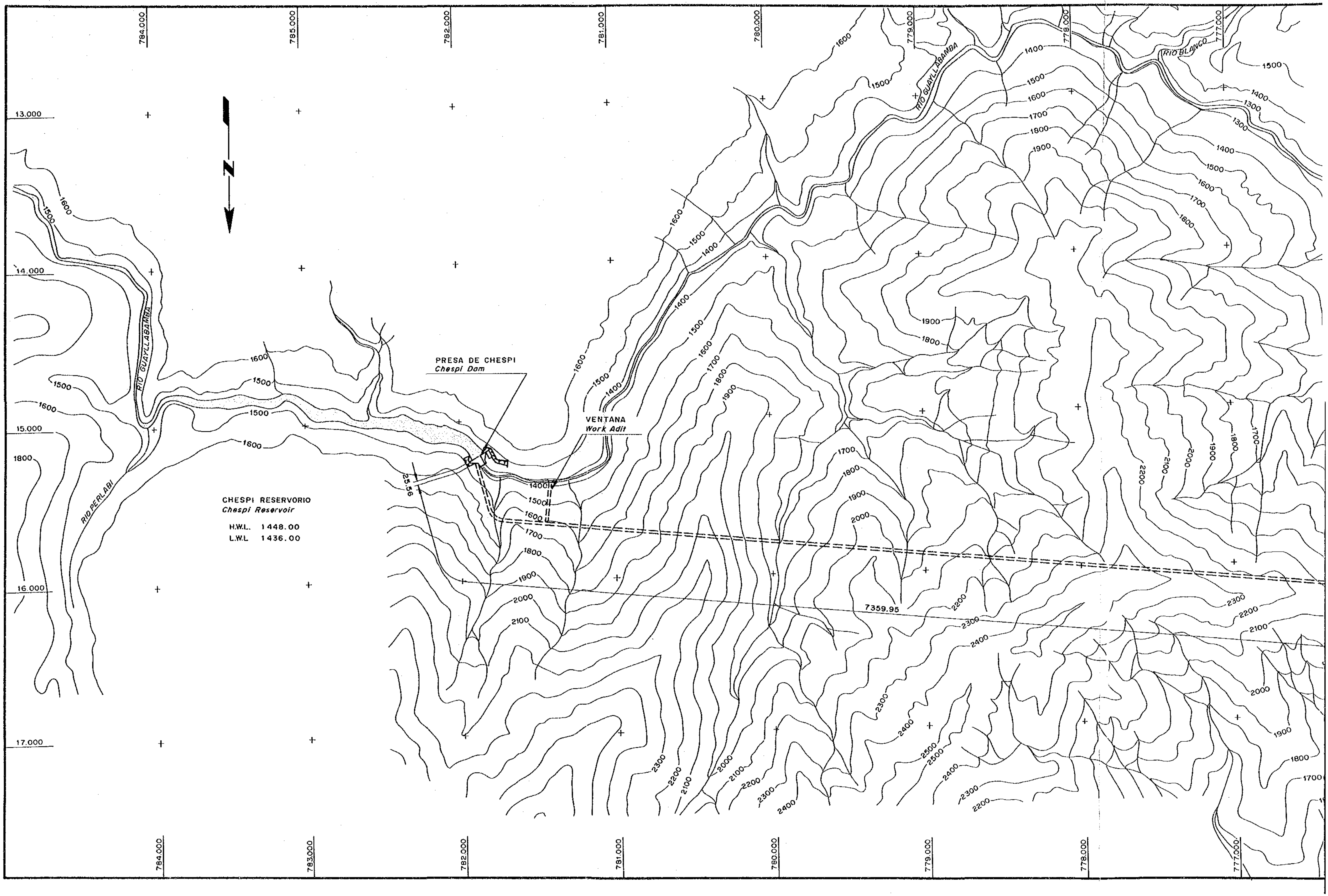784.000
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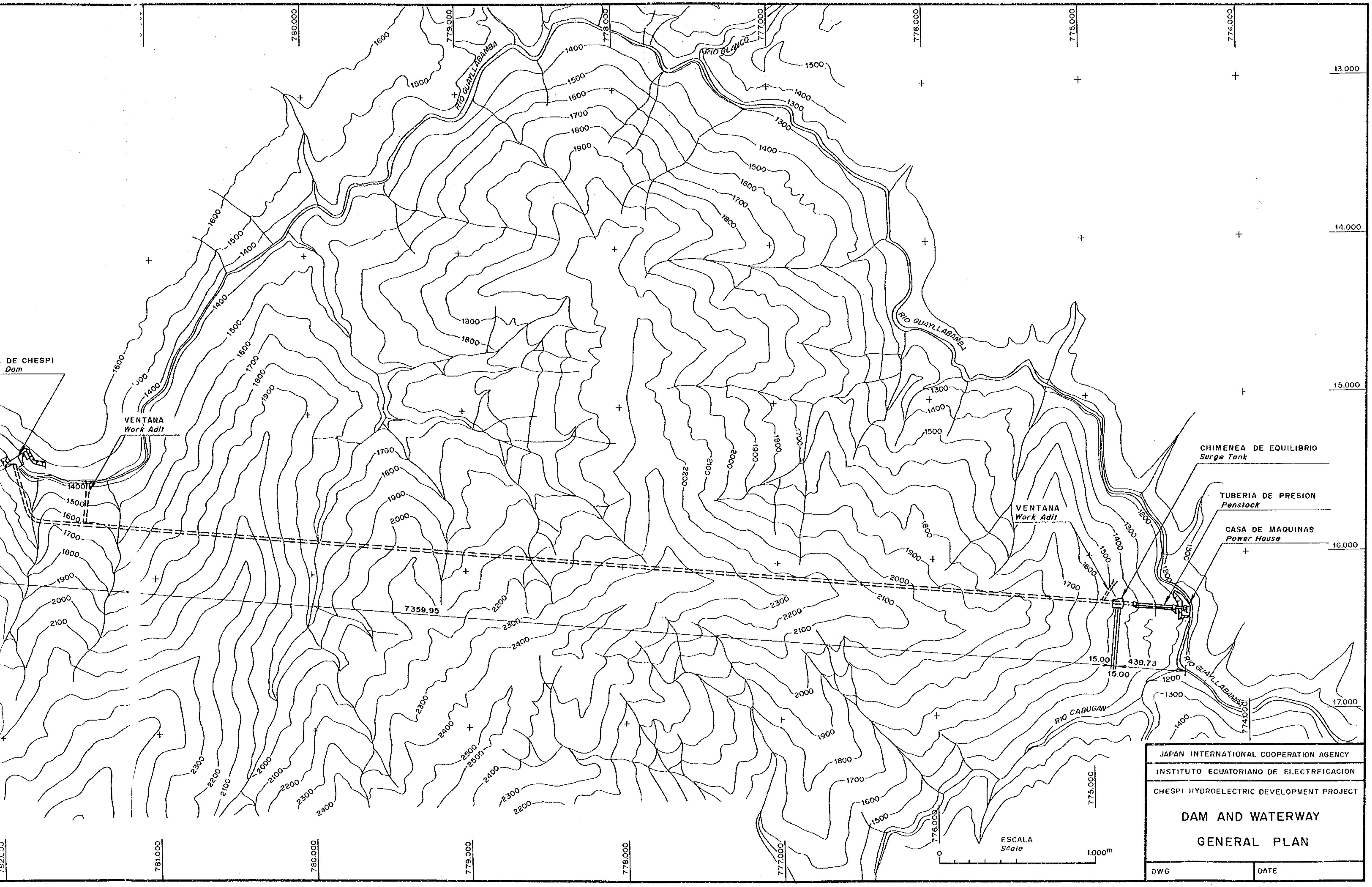

JAPAN INTERNATIONAL COOPERATION AGENCY

INSTITUTO ECUATORIANO DE ELECTRFICACION

CHESPI HYDROELECTRIC DEVELOPMENT PROJECT

DAM AND WATERWAY
GENERAL PLAN

DWG	DATE

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CHAPTER 1 INTRODUCTION

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CHAPTER 1 INTRODUCTION

1.1 Outline of Republic of Ecuador

1.1.1 Geography

The Republic of Ecuador is situated on the equator line at the northwestern part of the South American continent, is bounded on the north by Colombia, on the east and south by Peru, and faces the Pacific Ocean on the west. In addition, the Galapagos Islands in the Pacific Ocean are possessed by Ecuador. The total area of the country is approximately 280,000 km^2. The Andes Mountains continuing down from Colombia run through the middle of the country to Peru in the south, and the mountains are separated into two chains, east and west. Consequently, the basins between the two chains are elevated plains at altitudes from 1,800 to 3,000 m, and this region is highly populated. The two mountain chains have more than 30 volcanoes, headed by the highest peak Chimborazo (6,310 m), and there are three active volcanoes including Cotopaxi (5,897 m) known as the highest active volcano in the world.

Geographically, Ecuador is broadly divided into three parts; the coast region along the Pacific Ocean(Costa), the inter-Andean elevated plains sandwiched between the Andes mountain chains(Sierra) and the eastern tropical forest region (Orient) which drains toward the Amazon river. The basin of the Rio Guayllabamba which is the object of this Project comprises an elevated plain-mountain area, and this river is one of the tributaries of the Rio Esmeraldas which flows out to the Pacific Ocean.

1.1.2 Climate

Ecuador, in spite of being situated directly on the equator, has a variety of climates according to region affected by the varied altitude and by two sea currents the Humboldt Current (cold), and El Nino Current (warm). There are the high temperature, high-humidity climate presented at a part of the northern portion of the Pacific Ocean side and at the western half of the Amazon basin (mean air temperature 25°C, annual precipitation 3,000 to 6,000 mm), the tropical high-temperature, high-humidity climate presented at the sightly inland part of the plain area on the Pacific Ocean side and at the other half of the Amazon basin (mean air temperatures 14 to 24°C, annual precipitation more than 2,000 mm), the tropical high-temperature semi-dry climate at a part of the Pacific Ocean side (mean air temperature 20 to 26°C, little rain but humidity around 80 percent), the equatorial temperate climate at around elevation of 3,000 m (district division between wet and dry seasons, the Chespi project area being included in this region), and the equatorial alpine climate at highlands above 3,000 m (precipitation 1,000 to 2,000 mm, rainfall daily during the rainy season, humidity from 60 to 80 percent).

The Project is located on the previously mentioned Rio Guayllabamba tributary, of the Rio Esmeraldas, the catchment area comprises the regions of varied climate semi-humid climate at highlands of EL. 1,500 m and higher, and equatorial highland climate at highlands above 3,000 m, the annual mean precipitation being from 600 to 1,600 mm depending on the area.

1.1.3 Population

The total population of Ecuador is estimated to have been 9,250,000 as of 1983, with the population growth rate in recent years having been 3.5 percent. The population density is 32.6 per square kilometer, with 49 percent of the total living in the Center Andean rigion, 48 percent in the Pacific Ocean coastal region, and 3 percent in the eastern Amazon region and elsewhere.

1.1.4 Economy and Energy Resources

1) Economy

Ecuador was an agricultural country in the first place and tropical agricultural products such as banana, cacao, and coffee were its main exports. However, production at oil fields discovered in the Amazon region in the late 1960s was taken off, and when export of crude oil was begun from 1972, an oil boom started even though the absolute volume of production was small. Exports of crude oil increased year after year, and a remarkable economic growth was achieved in the 1970s with oil income as the impetus.

The Government launched a 5-year economic development plan from 1973 based on oil income, and made achievements in infrastructure build-up, electric power development, industrialization, etc. However, the economic growth rate dropped with deterioration of the international oil market from 1980, and the outlook was for economic difficulties from the beginning of 1981. The Government took measures such as to successively introduce barter systems and tightening restrictions on imports of nonessential goods, while devaluations were carried out in 1982 and 1983 and the country was burdened with negotiations for rescheduling of official debts. These measures were successful, and after the flood damage of 1983, production of the principal agricultural products recovered smoothly, while production and exports of oil increased, so that in 1984 the balance of foreign trade reached a surplus of approximately 1.1 billion dollars. In 1985, there were significant developments made in negotiations for rescheduling of debts, while oil production was maintained at the upper limit of transportation capacity of 300,000 barrels daily from the oil fields in the northeast Amazon region to the seacoast, and the highest production since the start in 1972 was reached.

2) Energy Resources

[Oil]

Ecuador is an oil exporting country and is a member of OPEC. Production was started in 1972 and reached 300,000 barrels daily in 1985, but practically all of the production is in the Amazon region east of the Andes Mountains and the cost is comparatively high since the oil must be transported by pipeline to Esmeraldas at the Pacific Ocean coast for exportation. The confirmed reserves were 1.5 billion barrels in 1982, and it is estimated there is a total of 3 billion barrels including unconfirmed reserves.

[Natural Gas]

Natural gas has been discovered at the Gulf of Guayaquil and Shushufindi in the Amazon region. The reserves at the Gulf of Guayaquil are estimated to be 377 billion cubic feet.

[Water Power]

Water power resources are abundant with the runoffs and high heads of the rivers from the East and West Andes Mountain chains running down and discharging into the Pacific Ocean in the west and into the Rio Amazonas in the east.

1.2 Background of the Project

The principal water power resources areas in Ecuador are the areas of the East and West Andes Mountains which traverse the country as stated in 1.1.4. The theoretical hydroelectric potential of all Ecuador is said to be 93.4 million kW, with the total capacity of 22.4 million KW that can be (technical and economical feasible) at the 21 major rivers covering 81 percent of the land. The available energy production being 90 billion kWh/yr (380,000 bbl/day in terms of oil).

The commercial power generating facilities of Ecuador as of April 1984 consisted of 728 MW hydro and 954 MW thermal, a total of 1,682 MW. The developed amount of hydroelectric power compared with the technically feasible hydroelectric potential of 22.4 million kW is a mere 3.2 percent.

According to "Catalogo de Proyectos Hidroelectricos, March 1985," prepared by INECEL, it is planned as main for hydroelectric power development to amount of approximately 1966 MW and abolishment plans of existing oil thermal power stations to amount of approximately 580 MW by the 2000 A.D., for a total installed capacity of 3,005 MW as shown below.

Year	Power Demand (MW)	Installed Capacity (MW)
1985	860	1,593
1990	1,181	1,600
1995	1,605	2,224
2000	2,383	3,005
Growth Rate (%)	(7.0)	(4.3)

In carrying out this hydroelectric power development INECEL has classified the present time until 1992 as the short-range, 1992 to 2000 as the middle-range, and further, 2000 to 2010 as the long-range terms, and besides completing Agoyan Hydroelectric (156 MW) and Paute Hydroelectric (phase-C 500 MW), it is planned for a total of 1,966 MW of hydro to be developed up to the year 2000.

The Ecuadorian Government is contemplating export of the oil being consumed at thermal power stations now existing by pushing ahead with development of water power resources as a means of obtaining foreign currency, and the Chespi Project is a part of the abovementioned middle-range plan.

It is with such a background that INECEL carried out investigations from the 1970s for hydroelectric development of the Rio Guayllabamba and a Master Plan for hydroelectric development on three sites of Chespi Project, Palma Real Project, and Calderon Project.

This time, the Government of Ecuador requested the Government of Japan for technical cooperation for investigating and studying the technical, economic, and societal appropriatenesses of the Chespi Project through a reexamination of the Master Plan and clarification of the significance of the Chespi Hydroelectric Power Development Project.

In response to this request, the Japanese Government dispatched a preliminary field investigation team of four men headed by Mr. Michimoto Goto, Deputy Director, Mining and Industrial Investigation Department, Japan International Cooperation Agency (JICA) in July 1984, and in discussions with INECEL (Instituto Ecuatoriano de Electrificacion), the agency responsible for investigations concerning this Project, and "Scope of Work for the Feasibility Study in the Chespi Hydroelectric

Power Development Project in the Republic of Ecuador," (S/W) was agreed upon.

Based on this Scope of Work, JICA dispatched a first Chespi Hydroelectric Power Development Project Survey Team to Ecuador in January 1985.

The survey Team held discussions with INECEL concerning investigations in concrete terms and the implementation program for the study, and the results were summarized in the form of an Inception Report. Based on this report the Survey Team carried out field investigations for reviewing the Master Plan on the Chespi, Palma Real and Calderon projects at the mid-stream area of the Rio Guayllabamba and to investigate and study the technical, economic, and social appropriatenesses of the Chespi Project. In investigations in Ecuador, the Survey Team carried out field reconnaissances and data collection, and cooperated in checking and preparation of topographical maps made by INECEL. Also, based on the results of discussions with INECEL and other agencies concerned, studies in Japan were started and an Interim Report was submitted.

Geological investigation works (boring, seismic exploration) were carried out in the Chespi Project according to the abovementioned Interim Report, and a final study was made taking into account the results of the geological investigations. A Final Report (Draft) was submitted in July 1986, and the Final Report was submitted in August 1986.

1.3 Past Investigations

The investigations carried out up to the present in connection with hydroelectric power development projects on the Rio Guayllabamba are as follows:

	(year)	(Name of Investigation)
1)	1975	Seismic Map of Ecuador
2)	1975	Hydro Power Plans for the Rio Guayllabamba Basin
3)	1975	Preliminary Supplemental Investigations on the Rio Guayllabamba Basin

4) 1977 Geological Maps of the Rio Guayllabamba Basin

5) 1977 Preliminary Investigations of the Rio Guayllabamba Basin

6) 1977 Report on comparison Study of Hydro Power Plans for the Rio Esmeraldas Basin

7) 1978 Seismic Map of Ecuador

8) 1978 Report on Comparison Study of Hydro Power Plants for the Rio Guayllabamba Basin

9) 1979 Report on Feasibility Study Investigations of Hydro Power of the Rio Guayllabamba

10) 1979 Aug. Ecology and Sedimentation in Middle and Upstream Basins of the Rio Guayllabamba

11) 1982 Pisque, Intag, Chespi and Apaqui Hydroelectric Power Projects; Preliminary Studies.

12) 1983 Feb. Report on Preliminary Hydrological Investigations of the Cubi, Perlabi, Pamplona and Quinde Rivers.

13) 1983 Chespi-Guayllabamba Hydroelectric Project

14) 1984 Catalogo de Proyectos Hidroelectricos

1.4 Objectives and Scope of Work

1.4.1 Objectives

The objectives of this investigation are to carry out a review of the existing Master Plan concerning the three projects of Chespi, Palma Real, and Calderon located on the Rio Guayllabamba and to clarify the position of the Chespi Hydroelectric Power Development Project, upon which it was necessary to investigate and study the technical, economic, and social appropriatenesses of the project, then to compile the results in the form of a feasibility study report.

1.4.2 Scope

A review is to be made of the existing Master Plan on the three projects of Chespi, Palma Real, and Calderon to determine the attractiveness of the Chespi Hydroelectric Power Development Project, at the same time carry out geological exploration works (boring, seismic prospecting) on the site, provide guidance in preparation of topographical maps by INECEL and check the maps, conduct studies in Japan, and compile a feasibility report.

Investigations in Ecuador consist of reconnaissances, electric power market survey, data collection, and providing guidance for the previously-mentioned geological investigation works, and guidance in topographical mapping.

Work in Japan consists of hydrological analyses, geological analyses, and design based on the information obtained in field investigations, geological analyses, designing, and estimation of construction costs.

1.5 Field Investigations and Survey Team Members

The works carried out in Ecuador are as follows:

1) Jan. 10, 1985 to March 10, 1985

First Mission (review of Master Plan, reconnaissances, data collection, guidance in preparation of topographical maps)

2) Jun. 16, 1985 to Dec. 24, 1985

Second Mission (explanation of Interim Report, data collection, guidance in preparation of topographical maps, electric power market survey, geological investigation works)

3) Jun. 29, 1986 to Jul. 19, 1986

Third Mission of Final Report draft

The composition of the Survey Team was as follows:

Terumi Ushijima,	Electric Power Development Co., Ltd. (EPDC), Chief, General Supervision.
Tadao Sekizawa,	EPDC International, Ltd., Civil Engineering (Planning)
Jiro Hori,	EPDC, Civil Engineering (Design)
Yoshio Kishida,	EPDC, Civil Engineering (Cost Estimating)
Koji Mishima,	EPDC, Civil Engineering (Hydrology)
Nobuhiro Tsuda,	EPDC, Geology (General)
Kazuo Ohshima,	Ohte Development Co., Ltd., Geology (Boring)
Eijiro Kochi,	Kaihatsu Doboku Consultants, Geology (Seismic Prospecting)
Kazuo Furukata,	Kokusai Kogyo (Surveying)
Hiroshi Katsukawa,	EPDC International, Electrical Engineering (Electric Power)
Akira Tanaka,	EPDC, Electrical Engineering (Power System)
Akihisa Hirota,	Sumitomo Trust and Banking (Economics)
Takeshi Kawashima,	EPDC, Civil Engineering (Design)
Megumi Kitamura,	EPDC, Civil Engineering (Environment)
Morihiro Sato,	EPDC, Electrical Engineering (Design)

CHAPTER 2 CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 2 CONCLUSIONS AND RECOMMENDATIONS

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CHAPTER 2 CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

1) INECEL has defined three scenaries for the power demand forecast, in accordance with the economical development for Ecuador. The first one is optimistic resulting in a yearly 7.4 percent average growth rate in power consumption during a 25 year period; the second one is "moderate optimistic", resulting in 6.2 percent average growth rate; and the third scenaries is pesismistic with 4.9 percent average growth rate.

   The JICA Survey Team has just made a crosscheck of the power demand forecast of INECEL by a macroscopic technique using the growth rate in gross national product, and as a result, it is judged that the load optimistic forecast studied by INECEL is reasonable.

   It's important to point out that the National Development Plan of Ecuador officially implemented since October 1985, established an economical development similar to the second scenary adopted by INECEL. As a result of the above mentioned criterion the power demand forecast used in this study could be in the upper values ranges.

2) If the power demand of Ecuador is to go along at this optimistic growth rate, it is estimated that it will become 1,605 MW and 8,293 MW in 1995, that means 1.86 and 1.90 times compared with the power and energy demands in 1985, respectively.

   INECEL is striving to secure the supply capability in relation to revised demand increase with projects presently under construction or presently planned.

   However, from 1995, there will be a shortage of supply capability according to the present optimistic demand forecast. In order to secure new power supplies to meet this demand increase it will be necessary to plan the construction of new projects.

It is judged that the Chespi hydroelectric power development just investigated is a potencial candidate one for this purpose. Accordingly, it is looked forward to that the other altanative hydroelectric development sites planned by INECEL will be analyzed from the technical, economic, and financial standpoints and will be comprehensively studied in order to establish the development projects.

3) The hydroelectric development sites of Calderon, Chespi, and Palma Real in order from upstream to downstream at the middle stretch of the Rio Guayllabamba, were the objects of the review of the Master Plan and the Chespi hydroelectric development, which ingeniously takes advantage the meandering of the river, is the most economical. The optimum development scale for this project results for a design discharge of 70 m^3/s, an effective head of 278 m, maximum output of 167 MW, and an average net annual energy production of 979 GWh. The total construction cost including a transmission line, will be US$241,970 x 10^3 at constant value in December 1985.

4) According to this study for energy demand and supply balance in the National Interconnected System and considering the hydroelectric energy in the driest year, (100% Hydro guarantee), there is a possibility for a shortage in supply occuring from December 1994. The major reason for this is that the greater part of the water power resources under operation and construction are located in the Rio Amazonas catchment area, and since the hydrological characteristics are the same, the seasonal runoff-trends are similar. Furthermore, thermal power stations are to be gradually abandoned.

5) The Chespi Hydroelectric Project is located in one of the Pacific Ocean side basins and the trend of monthly energy production shows a contrast with that of the Rio Amazonas basin. Consequently, if the Chespi Project were to be interconnected with the national grid, under the condition that the most of the hydro power plants are located on the Amazonas site catchment area, practically all of the energy production of the Chespi Project in the rainy season (October to April) would be utilized, and this will also serve to regulate the monthly electric energy fluctuations of the National Interconnected System.

6) For convenience of operation of the electric power national system, the power demand of the capital city area and of the northern region will be met mainly with supply from the southern power stations. When the electric power from the Chespi Project is added to the interconnected system, the dependence on the abovementioned regions will be lessened to enhance stabilizations of the power system.

7) The purpose of this report is to confirm the feasibility of the Chespi Project. The comparison study on operation commencement year with other projects proposed by INECEL is beyond the limits of this study. According to this energy balance study and taking in consideration the various conditions cited above, the supply capacity is foreseen to be deficient in 1995 so that the operation commencement year is assumed to be the above mentioned year.

8) Special geological and technical problems are not expected with regard to the execution of this project. Sediment inflow to the regulating pond during operation of the power plant is not thought to cause particular troubles in generation, so long as appropriate sand flushing measures are provided.

9) At the time that the Chespi Project is developed, the interconnected national grid will be in a favorable condition for system operation because a 230 kV loop in operation. Interconnection between this system and the Chespi Power Station made at San Antonio Substation by a 2-cct transmission line of high supply reliability is recommendable from the standpoint of economics and system stability.

10) The equalized power generating cost for the service life of the power station will be 38 mill/kWh, considering a shadow exchange for the total local currency, but not to foreing currency, producing a social total cost of the Project of US$208.719 x 10^3.

For the economical and financial analysis, a current price methodology has been used. The financial and economic internal rates of return at the time of commissioning using the economic costs for determining the significance of the project from the national economic viewpoint of Ecuador are 6.19 and 13.50 percent, respectively.

11) As a result of preliminary investigations regarding the effects on the natural and social environment of the Rio Guayllabamba caused by the implementation of the Chespi Project, there will be no problem and it is judged that the construction of the dam, power plant, etc. will contribute to development of the area, and it will be possible to create a social environment that could be better than at present.

2.2 Recommendations

1) Considering that the load forecast is a very important parameter to define the generation planning expansion and knowing that this parameter has an uncertain performance, we recommend to carry out a sensitivity analysis for the other scenaries of load forecasting established by INECEL.

2) From the standpoint of power demand considering an optimistic growth rate and considering a hydro energy supply in the driest year a shortage of supply will occur from around 1995. Therefore, 1995 was set as the year for commissioning of Chespi Project in this Report.

   The final decision on the year of commissioning of this project should be made upon comparisons of engineering aspects, economics, fund procurement procedures, etc. with other projects being considered by INECEL.

   It is recommendable to carry out an individual economical analysis of the Chespi Project in order to find the economics and energetic parameters of the project itself. This analysis will serve to know the quality of the Project and also to compare it with other projects being considered by INECEL.

3) For detailed designs of this Project, it will be necessary to prepare large scale topographical maps and to carry out further geological investigations including Lahar deposits at the vicinity of the regulating pond as well as construction material survey.

4) In order to study the sediment inflow patterns in the regulating pond and to define the flushing out programm of these sediments, it is important to investigate more frequently and in more detailed the relation between run-off discharges and sediments transport load as well as its grain size distribution curve of the river.

Table 2-1 Development Scale of Chespi Project

Item	Unit	Development Scale
Development System	-	Daily Regulation
Catchment Area	Km^2	4,606
Regulating Reservoir		
High-Water level	m	1,448
Total Storage Capacity	10^6m^3	3.3
Effective Storage Capacity	10^6m^3	1.5
Available Depth	m	12
Power Generating		
Effective Head	m	278.5
Maximum Discharge	m^3/s	70
Installed Capacity	MW	167
Annual Energy Production	GWh	979 (Av. 1965 - 1984)
Dam		
Type	-	Concrete Gravity
High x Length	m x m	60 x 120
Volume	10^3m^3	116
Water Way		
Tunnel (D x L x n)	mxmxn	5.2 x 7,360 x 1
Penstock (D x L x n)	mxmxn	(4.5 ~ 2.1) x 552.85 x 1
Spillway		
Design Flood Discharge	m^3/s	2,300
Turbine		
Type	-	Vertical Shaft, Francis
No. of Unit	unit	2
Generator		
Type	-	3-Phase, Alternating Current Sychronous Generator
No. of Unit	unit	2
Transmission Line		
Distance	-	San-Antonio ~ Infernillo
Voltage x Length	KVxKm	138 x 22
Total Construction Cost	106US$	299
Economical Indices		
Benefit-Cost Ratio (B/C)	-	*1.610 (Discount Rate = 12%)
Economic Internal Rate of Return (EIRR)	%	13.50

Note: * Cost comparison with the alternative thermal power plant.

CHAPTER 3 POWER DEMAND AND SUPPLY PLAN

CHAPTER 3 POWER DEMAND AND SUPPLY PLAN

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CHAPTER 3 POWER DEMAND AND SUPPLY PLAN

3.1 Present State of Electric Utility Industry

The electric utility industry of Ecuador is under the jurisdiction of the Ministry of Natural Resources and Energy. Supply of electric power is mainly done by INECEL, seventeen regional electric power companies, EMELEC and a private company with U.S.A. capital, Other than these, there are a few consumers who own private power generating facilities.

The largest load centers in Ecuador are Quito and Guayaquil, and these two cities, in 1984, accounted for approximately 67 percent of the power demand of the entire country. Agricultural crops such as coffee, banana, and tabaco are being produced in the Costa and Oriente regions, while at the abovementioned cities, petroleum-related products, processed agricultural products, tires, textiles, plywood, etc. are being made, and industrialization is on the rise.

3.1.1 Electric Power Demand and Supply Performance Record

The performance record in 1984 excluding private power generating facilities is as follows:

Energy production	4,207 GWh (hydro 76%, thermal 24%)
Maximum power	839 MW (annual load factor 57.2%)
Total population	9,250,000 (1983 estimate)
Generating facilities per capita	182 W/capita
Energy production per capita	455 kWh/capita•yr

The record of energy demand is given in Table 3-1, and the energy demand composition by type of demand in 1983 in Table 3-2.

Table 3–1 Actual Energy Demand

Year	Consumption (GWh)	Generation① (GWh) 1/	Generation② (GWh) 2/	Max. demand (MW) 2/
1965	414.0	492.0	492.0	117.0
1966	438.0	534.0	534.0	127.4
1967	485.0	587.0	587.0	145.8
1968	550.0	668.0	668.0	162.4
1969	626.0	754.0	754.0	177.8
1970	684.0	822.0	822.0	193.4
1971	740.0	905.0	905.0	214.4
1972	824.0	994.0	994.0	229.7
1973	988.0	1,080.0	1,080.0	337.7
1974	1,041.0	1,257.0	1,257.0	281.1
1975	1,200.0	1,458.0	1,458.0	323.7
1976	1,437.0	1,696.0	1,696.0	380.2
1977	1,662.0	2,005.0	2,002.0	444.9
1978	1,988.0	2,370.0	2,363.0	508.1
1979	2,330.0	2,742.0	2,706.0	575.7
1980	2,615.0	3,101.0	3,057.0	647.4
1981	2,838.0	3,410.0	3,344.0	712.1
1982	3,077.0	3,819.0	3,694.0	754.4
1983	3,245.0	4,021.0	3,869.0	773.5
1984	3,376.0	4,207.0	4,025.0	803.3

1」 Generated Energy

2」 Output of Primary Substation

Table 3–2 Power Consumption Ratios by Type of Demand

Type of demand	Ratios (%)
Residential	41.3
Commercial	15.2
Industrial	32.8
Public Lighting, other	10.7
Total	100.0

3.1.2 Power Generating Facilities

The power generating facilities possessed by the electric utility industry in 1984 amount to 1,686.5 MW, composed of 43 percent hydro and 57 percent thermal. In addition, there are 151.4 MW in private generating facilities for a national total of 1,837.9 MW.

INECEL has been aiming for release from oil dependence and is making strong efforts for large-scale hydroelectric power development. Paute A.B. Power Station, 500 MW, (commissioned April 1983) developed as a part of these efforts has contributed to stabilization of supply capability, and also greatly increased the ratio of hydro facilities.

Table 3–3 Installed Capacity at 1984

(unit:MW)

Proprietor / kind of Power Plant	INECEL (SNI)	Regional Eelectric Company	Self-Governing body	Total of Public Service	Private Eelectric Company	Total of Nation
Hydro Power Plant	570.0	158.4	3.3	731.7	14.6	746.3
Thermal Power Plant	382.5	570.7	1.6	954.8	136.8	1,091.6
· Vapor	271.0	63.0	-	334.0	-	334.0
· Diesel	31.2	363.1	1.6	395.9	136.8	532.7
· Gas	80.3	144.6	-	224.9	-	224.9
Total	952.5	724.7	4.9	1,686.5	151.4	1,837.9

3.1.3 Power Transmission and Transformer Facilities

The power transmission and transformation facilities of the National Interconnected System, provincial electric power companies, and local autonomous bodies in 1984 are as follows:

- National Interconnected System

Transmission line	230 kV	510 km
	138 kV	590 km
Total		1,100 km

Substation	230/138, 69 kV	1,200 MVA
	138/69, 46 kV 34.5, 13.8	1,609 MVA
Total		2,809 MVA

- Power Transmission and Distribution Networks of Provincial Electric Power Companies and Local Autonomous Bodies

69 kV	1,393 km
46 kV	112 km
34.5 kV	297 km
Total	1,802 km

3.2 Power Demand Forecast

The power demand forecast constitutes the basis for an electric power company's management plans such as supply plan, power generation and power transmission-transformation plan, and fuel plan. Here, an outline of the load forecasting done by INECEL is described, following a load forecasting done by a macroscopic technique approved and adopted by the International Atomic Energy Agency (IAEA) and the World Bank (IBRD), and crosschecking is performed.

3.2.1 Background of Load Forecast

The total electric energy consumption by the public sector in Ecuador increased approximately 8.2 times in the period from 1965 to 1984 (annual average growth rate 11.7 percent). This growth rate reached a maximum value during the period from 1975 to 1980, with a slowdown indicated from 1980.

A similar trend is seen in maximum power consumption as shown in the table below.

Growth Rates in Energy Consumption and Power Consumption (%)

	1965-1970	1970-1975	1975-1980	1980-1985
Energy consumption	10.5	11.5	11.9	6.6
Power consumption*	10.6	10.9	14.9	5.5

* Value at primary substation take-out point.

These growth rates are roughly due to the reasons below.

- o 1965- 1969: An economic plan aiming for industrialization was initiated and consumption of industrial power began to increase substantially.
- o 1970- 1979: An accelerated economic growth never before seen in the history of Ecuador occurred due to oil extrac-

tion and an export boom began in 1972. The growth rates in gross domestic product during this period were 12 percent for the 5 years from 1970 to 1974 and 6 percent for the 5 years from 1975 to 1979, and the increase in the use of power for electric home appliances further increased energy consumption.

Further, from 1973, supported by establishment of a national electrification fund with oil royalties as the source of income, an electric power development program and a power transmission and transformation expansion plan rapidly took concrete form and it became possible for electric power to be supplied to a wider area.

o 1980- 1984: The growth rate in power consumption was slowed down due to blunting of economic growth because of drops in international oil prices, the meteorological abnormalities (El Nino) over the two-year period of 1982, 1983, and cumulative financial deficits.

The growth rate in GNP during 1980- 1982 was only 3 percent, while in 1983 it was 3.8 percent.

Electric power subscribers

1966	175,000
1983	904,000

Percentage of population receiving power supply

1966	23.8%
1983	59.4%

3.2.2 Load Forecast by INECEL

As mentioned in the preceding section, the trend of the Ecuadorian economy was greatly changed on entering the 1980s. Particularly, in 1983, a serious crisis was faced, and all production activities were affected, mainly in agriculture, construction, manufacturing, and commerce. INECEL has carried out a review of demand giving consideration to the effects of the above.

The method of load forecasting used by INECEL and the forecast values for 1985 are described below.

In forecasting future demand INECEL uses computer models with which basically it is possible to adjust and forecast at the following three levels:

a) Forecast at comprehensive national level
b) Forecast at comprehensive regional level
c) Forecast at regional sector level

A basic and macroscopic load for forecast is made on a national scale, and this is next projected in accordance with the characteristics of the region.

At this stage, a division is made into two differing consumption classes making possible discriminative treatment. (Table 3-4)

Forecasts at the regional sector level are prepared for the benefit of the individual provincial electric power companies based on the comprehensive plans on a national scale.

This has the purpose of classifying total consumption into the four categories of residential, commercial, industrial and others (street lighting, public agencies, etc.). (Table 3-5)

Information used for the abovementioned three models consisting of indices, parameters, etc. is comprised of technical data of the market such as demand, loss factor, load factor and macroscopic economic data such as gross domestic product, export of oil, and further, official documents of the central bank and CONADE.

Furthermore, 26 percent of the total energy consumption in 1984 was at Quito and 41 percent at Guayaquil. This trend of more than 60 percent of total energy consumption being taken up by these two large cities has continued for many years, and this is a major guiding point in load forecasting.

Typical forecasting at the comprehensive national level was done according to the followings:

a) Calculation of energy consumption

To make a load forecast on a national scale INECEL has obtained the following model applying historical data for the period from 1967 to 1983.

$$I_nC_{(t)} = -2.07 + 0.107I_nPIB_{(t-1)} + 0.207I_nPIB_{(t-2)} + 0.805I_nC_{(t-1)}$$

where,

$C_{(t)}$: energy consumption in year t
$C_{(t-1)}$: energy consumption in year t-1
$PIB_{(t-1)}$: GDP in year t-1
$PIB_{(t-2)}$: GDP in year t-2

b) Calculation of energy production and maximum demand

After the energy consumption of the public sector in the forecast model has been established forecasts are made of the losses in secondary power transmission and distribution and load factors, and estimates are made of power generation and maximum demand at the SNI main substation level.

$$PG = \frac{C_{(t)}}{(1 - L_{sf})}$$

$$Pmax = \frac{P_G}{L_f \times 8760}$$

where,

P_G = energy production [MWh]
P_{max} = maximum demand [MW]
L_{sf} = loss factor
L_f = load factor

The forecasts made in 1985 are outlined below.

Year	Consumption	Growth rate (%)	Loss factor (%)	Generation (Gwh)	Load factor (%)	Max demand (MW)
1985	3,567		18.1	4,357	57.2	869
1990	4,942	6.7	16.8	5,940	59.3	1,143
1995	6,964	7.1	16.0	8,293	60.0	1,578
2000	10,427	8.4	15.2	12,295	61.0	2,301
2005	15,471	8.2	14.4	18,074	61.7	3,344
2010	22,668	7.9	13.6	26,241	62.5	4,792

Table 3–4 Characteristic Consumption Special Load

Year	Consumption (Gwh)	Generation (Gwh)	Max. Demand (MW)	Consumpation (Gwh)	Generation (Gwh)	Max. Demand (MW)
1985	3,466	4,249	848	101	108	21
1990	4,588	5,564	1,095	354	376	48
1995	6,542	7,844	1,528	422	449	50
2000	9,821	11,651	2,239	606	644	62
2005	14,760	17,317	3,278	711	757	66
2010	21,907	25,430	4,720	761	811	72

Table 3–5 Division of Actual Consumption

Unit: (%)

Year	Residential	Commercial	Industrial	Others	Total
1975	41	16	32	11	100
1979	40	15	35	10	100
1980	40	15	36	9	100
1981	39	15	37	9	100
1982	39	15	35	11	100
1983	41	15	33	11	100
1984	41	15	34	10	100
1985	40	15	34	11	100
1990	40	15	35	10	100
1995	40	15	36	9	100
2000	40	14	36	10	100
2005	39	13	38	10	100
2010	38	12	41	9	100

3.2.3 Load Forecast by Macroscopic Technique

In order to make a crosscheck of the results of load forecasting by INECEL, a macroscopic load forecast by GNP was made with United Nations statistical data as the basic particulars.

a) Load forecast based on GNP

It has been statistically verified that a correlation exists between power demand in a country and its national economy. Particularly, it is known that a fairly strong correlation exists between per capita GNP and per capita electric energy consumption.

In this present study, the values of GNP and demand per capita were obtained based on the records of approximately 80 countries throughout the world over the 20-year period from 1960 to 1979, and these were statistically handled.

The load forecast (in terms of generating end energy production) for this Report was made as described later using the newest statistically treated data.

In carrying out these calculations it was predicated that the economy of Ecuador hereafter will be in harmonious step internationally and will be able to grow and develop in the same direction as the various countries of the world.

i) Guideline and statistical indices

"Method of Long-term Load Forecasting of Energy and Electric Power of Developing Nations as Seen from Global Viewpoint" (by Hamaaki Aoki, Sept. 1985)

ii) Period forecast:

29 yr (1982- 2010)

iii) Conditions for calculation:

As shown in Table 3-7, the growth in GNP of Ecuador since 1981 has been stagnant in spite of various promotional measures provided by the Government due to overlapping of factors such as falling of international oil prices, meteorological abnormalities because of El Nino current, and cumulative financial deficits.

The increase in power demand has also been suppressed due to this, but judging that the stagnation is a temporary phenomenon the starting point of the forecast was taken to be 1981.

. GNP per capita (1980 basis):	US$1563.8 (1981)
. GNP per capita growth rate :	3% (annual average for 5 years of 1977- 1981: 2.9%)
. Electric energy per capita :	437.2 kWh (1981)
. Population :	7.8 x 10^6 (1981)

. Population growth rate

1982- 1985: 2.8% (annual average for 4 years of 1981- 1985: 2.8%)

1986- 2000: 2.7% (annual average for 10 years of 1975- 1984: 2.7%)

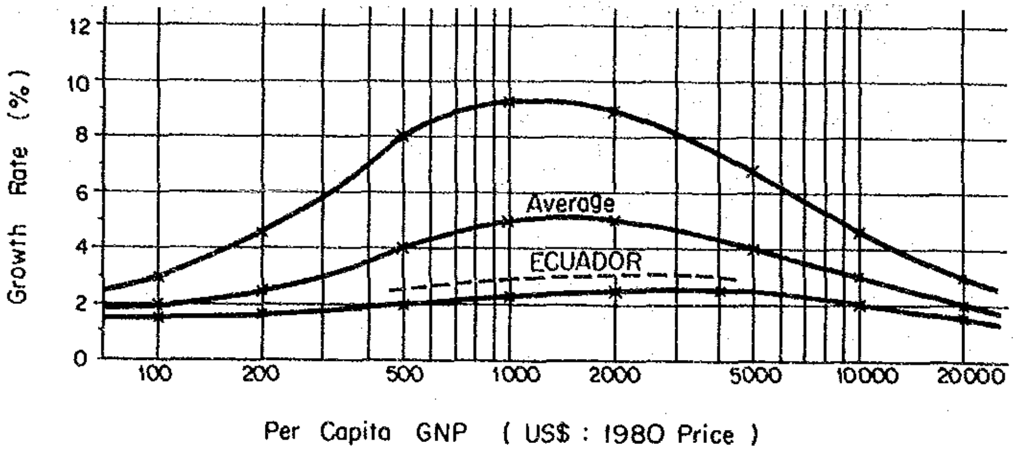
The correlation between per capital GNP and growth rate of GNP was based on Fig. 3-1, while the correlation between GNP per capital and electric energy per capita was based on Fig. 3-2.

b) Results of Forecast

The total energy productions by year obtained based on Table 3-6 and Figs. 3-1 and 3-2 are shown in Table 3-7. The forecast value of maximum demand was calculated from total energy production assuming load factor of 60 percent as estimated by INECEL.

The forecast by INECEL is for the primary substation end demand, and therefore, it was converted to generating-end energy production as shown in Table 3-8 in consideration of past performance.

Fig. 3–1 Correlation Between Per Capita GNP and Growth Rate



GNP/Capita (US $)	Growth Rate (%)	Average Growth Rate (%)
1560	3.00	3.00
1700	3.05	3.05
1900	3.10	3.10
2100	3.10	3.10
2300	3.10	3.05
2500	3.05	3.05
2700	3.05	3.00
2900	3.00	3.00
3100	3.00	2.95
3300	2.95	2.95
3500	2.95	2.90
3700	2.90	2.90
3900	2.90	

Fig. 3-2 Correlation Between Per Capita GNP and Per Capita Energy

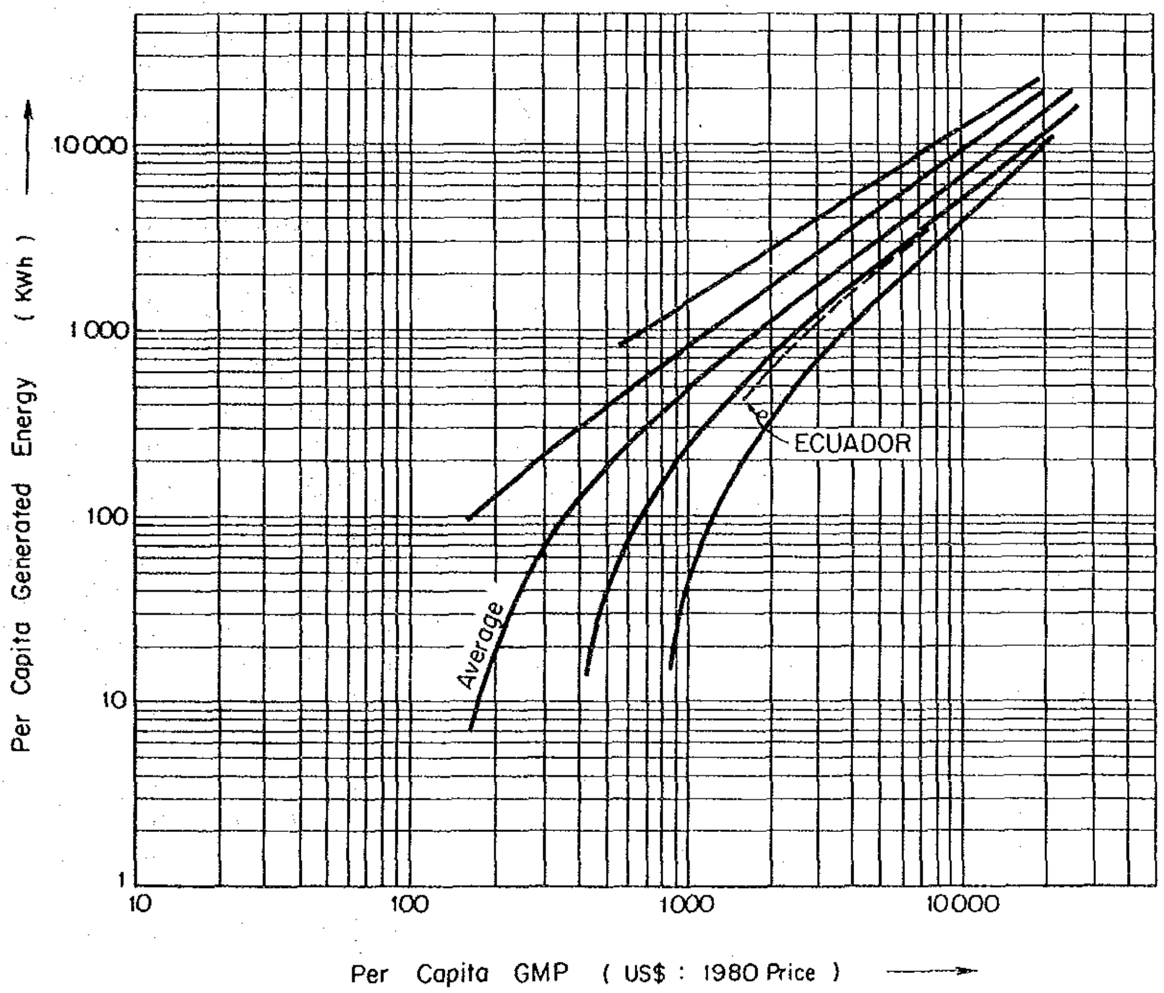


Table 3–6 Demand Forecast by INECEL
(S.N.I.+E.E.+MUNICIPIOS)

Ls.f : Loss factor
L.f : Load factor

Year	Characteristic Consumption					Special Load					Total				
	Consumption (GWh)	Ls.f (%)	Generation (GWh)	L.f (%)	Max. Demand (MW)	Consumption (GWh)	Ls.f (%)	Generation (GWh)	L.f (%)	Max. Demand (MW)	Consumption (GWh)	Ls.f (%)	Generation (GWh)	L.f (%)	Max. Demand (MW)
1985	3466	18.4	4249	57.2	848	101	-	108	-	21	3567	18.1	4357	57.2	869
1986	3637	18.2	4448	57.3	886	106	-	114	-	22	3743	18.0	4562	57.4	908
1987	3827	18.1	4670	57.5	927	157	-	160	-	32	3984	17.7	4830	57.6	959
1988	4044	17.9	4926	57.7	975	160	-	172	-	33	4204	17.5	5098	57.7	1008
1989	4297	17.7	5222	57.9	1030	195	-	209	-	36	4492	17.3	5431	58.2	1066
1990	4588	17.5	5564	58.0	1095	354	-	376	-	48 40	4942	16.8	5940	58.3	1143
1991	4886	17.3	5909	58.2	1159	320	-	340	-	49	5206	16.7	6249	59.1	1208
1992	5236	17.2	6321	57.9	1246	342	-	364	-	49	5578	16.6	6685	58.9	1295
1993	5629	17.0	6779	58.4	1325	369	-	393	-	49	5998	16.4	7172	59.6	1374
1994	6060	16.8	7283	58.3	1426	417	-	444	-	50	6477	16.2	7727	59.8	1476
1995	6542	16.6	7844	58.6	1528	422	-	449	-	50	6964	16.0	8293	60.0	1578
1996	7078	16.5	8475	58.8	1645	634	-	673	-	51	7712	15.7	9148	61.6	1696
1997	7670	16.2	9155	58.9	1774	627	-	665	-	51	8297	15.5	9820	61.4	1825
1998	8317	16.1	9910	59.3	1908	493	-	525	-	52	8810	15.6	10435	60.8	1960
1999	9033	15.9	10742	59.1	2075	532	-	566	-	53	9565	15.4	11308	60.7	2128
2000	9821	15.7	11651	59.4	2239	606	-	644	-	62	10427	15.2	12295	61.0	2301
2001	10690	15.5	12653	59.4	2432	633	-	673	-	63	11323	15.0	13326	61.0	2495
2002	11622	15.4	13730	59.9	2617	658	-	700	-	63	12280	14.9	14430	61.5	2680
2003	12650	15.1	14907	59.7	2850	682	-	725	-	64	13332	14.7	15632	61.2	2914
2004	13660	14.9	16060	60.2	3045	696	-	740	-	65	14356	14.5	16800	61.7	3110
2005	14760	14.8	17317	60.3	3278	711	-	757	-	66	15471	14.4	18074	61.7	3344
2006	15957	14.6	18679	60.7	3513	720	-	767	-	67	16677	14.2	19446	62.0	3580
2007	17262	14.4	20170	60.6	3800	730	-	777	-	68	17992	14.1	20947	61.8	3868
2008	18855	14.2	21974	60.7	4133	740	-	788	-	69	19595	13.9	22762	61.8	4202
2009	20226	14.1	23538	61.7	4355	750	-	799	-	70	20976	13.8	24337	62.8	4425
2010	21907	13.9	25430	61.5	4720	761	-	811	-	72	22668	13.6	26241	62.5	4792

Table 3–7 Basic Data for Demand Forecast

Year	Population	GNP		GNP／Capita		GNP／Capita at price in 1980		Generated Energy		Generated Energy ／Capita	
	(10^6)	(10^6) Dollars	Growth Rate (%)	(U S $)	Growth Rate (%)	(U S $)	Growth Rate (%)	(G W h)	Growth Rate (%)	(k W h)	Growth Rate (%)
1971	5.9	1.601.9		271.5		900.6		905		153.4	
1972	6.1	1.874.4	17.0	307.3	13.2	970.8	7.8	994	9.8	163.0	6.3
1973	6.3	2,489.2	32.8	395.1	28.6	1,209.6	24.6	1,080	8.7	171.4	5.2
1974	6.5	3.710.5	49.6	570.8	44.5	1,247.8	3.2	1,257	16.4	193.4	12.8
1975	6.7	4,309.6	16.1	643.2	12.7	1,278.2	2.4	1,458	16.0	217.6	12.5
1976	6.9	5.316.5	23.4	770.5	19.8	1,355.7	6.1	1.696	16.3	245.8	13.0
	(3.2%)		27.1		23.2		8.5		13.4		9.9
1977	7.0	6.655.0	25.2	950.7	23.4	1,423.7	5.0	2,005	18.2	286.4	16.5
1978	7.2	7,653.8	15.0	1,063.0	11.8	1,475.3	3.6	2,370	18.2	329.2	14.9
1979	7.4	9.358.5	22.3	1.265.7	19.1	1.511.5	2.5	2,742	15.7	370.5	12.5
1980	7.6	11,733.5	25.4	1.543.9	22.0	1,543.9	2.1	3,101	13.1	408.0	10.1
1981	7.8	13,946.5	18.9	1,788.0	15.8	1,563.8	1.3	3,410	10.0	437.2	7.2
	(2.5%)		21.3		18.3		2.9		15.0		12.2
1982	8.1	14,377.9	3.1	1,775.0	▲ 0.7	1,320.9	▲ 15.5	3,819	12.0	471.5	7.8
1983	8.3	12,977.1	▲9.7	1,563.5	▲ 11.9	828.9	▲ 37.2	4,021	5.3	484.5	2.8
1984	8.5	10,061.2	▲ 22.5	1,183.7	▲ 24.3	480.7	▲ 42.9	4,207	4.6	494.9	2.1
	(2.9%)		▲ 10.3		▲ 12.8		▲ 32.5		7.3		4.2

Table 3–8 Results of Demand Forecast by Macro-Method

Year	GNP/Capita		kWh/Capita		Population	Gross Generated Energy		Maxmum Demand
	Growth Rate(%)	US$ (1980Price)	kWh	Growth Rate(%)	(10^6)	GWh	Growth Rate(%)	(MW)
1981	3.0	1563.8	437		7.8	3,329.8		634
'82	3.0	1610	450		8.02	3,609		687
'83	3.0	1658	470		8.24	3,873		737
'84	3.0	1708	490		8.47	4,150		790
'85	3.05	1760	510		8.71	4,442		845
Average	3.0			4.5	(2.8%)		7.5	
1986	3.05	1814	530		8.95	4,744		903
'87	3.05	1869	560		9.19	5,146		979
'88	3.05	1926	590		9.43	5,564		1,059
'89	3.10	1986	620		9.69	6,008		1,143
'90	3.10	2047	650		9.95	6,467		1,230
Average	3.05			5.0	(2.7%)		7.8	
1991	3.10	2111	680		10.22	6,950		1,322
'92	3.10	2176	710		10.50	7,455		1,418
'93	3.10	2244	740		10.78	7,977		1,518
'94	3.10	2313	770		11.07	8,524		1,622
'95	3.05	2384	800		11.37	9,096		1,731
Average	3.10			4.2	(2.7%)		7.1	
1996	3.05	2456	840		11.68	9,811		1,867
'97	3.05	2531	880		11.99	10,551		2,007
'98	3.05	2609	920		12.32	11,334		2,156
'99	3.05	2688	960		12.65	12,144		2,311
2000	3.05	2770	1,000		12.99	12,990		2,471
Average	3.05			4.6	(2.7%)		7.4	
2001	3.0	2853	1,050		13.34	14,007		2,665
'02	3.0	2939	1,100		13.70	15,070		2,867
'03	3.0	3027	1,150		14.07	16,181		3,079
'04	3.0	3118	1,200		14.45	17,340		3,299
'05	2.95	3210	1,250		14.84	18,550		3,529
Average	3.0			4.6	(2.7%)		7.4	
2006	2.95	3305	1,310		15.24	19,965		3,799
'07	2.95	3402	1,370		15.65	21,441		4,079
'08	2.95	3503	1,430		16.07	22,980		4,372
'09	2.90	3504	1,490		16.51	24,600		4,680
2010	2.90	3709	1,550		16.96	26,282		5,002
Average	2.95			4.4	(2.7%)		7.2	

Table 3–9 Results of Demand Forecast by INECEL

Year	Gross Generated Energy (GWh)	Maximum Demand (MW)
1985	4,488	895
'86	4,699	935
'87	4,983	988
'88	5,251	1,038
'89	5,594	1,098
'90	6,118	1,177
'91	6,436	1,244
'92	6,886	1,334
'93	7,387	1,415
'94	7,959	1,520
'95	8,542	1,625
'96	9,422	1,747
'97	10,115	1,880
'98	10,748	2,019
'99	11,647	2,192
2000	12,664	2,370
'01	13,726	2,570
'02	14,863	2,760
'03	16,101	3,001
'04	17,304	3,203
'05	18,616	3,444
'06	20,029	3,687
'07	21,575	3,984
'08	23,445	4,328
'09	25,067	4,558
2010	27,028	4,936

3.2.4 Comparison of Results of Study

The comparisons of the results of load forecast by INECEL and the results of load forecast by the macroscopic technique are as shown in Table 3-10 and Fig. 3-3.

Table 3-10 Comparison of Demand Forecasts

Period (Year)	By INECEL		By Macro-method		Difference	
	GWh a	Growth Rate(%)	GWh b	Growth Rate(%)	c=a-b	$\frac{c}{a}$ (%)
End of 1985	4,488	7.1	4,442	7.5	46	1.0
End of 1990	6,118	6.7	6,467	7.8	-349	-5.7
End of 1995	8,542	7.1	9,096	7.1	-554	-6.5
End of 2000	12,664	8.4	12,990	7.4	-326	-2.6
End of 2005	18,616	8.2	18,550	7.4	66	3.5
End of 2010	27,028	7.9	26,288	7.2	740	2.7
1981-2010	-	7.4	-	7.4	-	-

As shown in Table 3-10, the results according to the two methods are in a range of about ±5 percent, and it was found that there was not much difference.

From 1986 to 2004 the macroscopic method gives a higher value, while from 2005 to 2010, INECEL's method shows the higher value. It is thought this is because the GNP growth rate of the macroscopic method is considered with 3.1 percent as maximum and is saturated, while per capita energy production is within the saturation curve, contrasted to which according to INECEL the growth rate in gross domestic product is low at first as shown in Table 3-11, while from 1990 it is forecast to be constant.

Fig. 3–3 Comparison of Energy Demand Forecasts

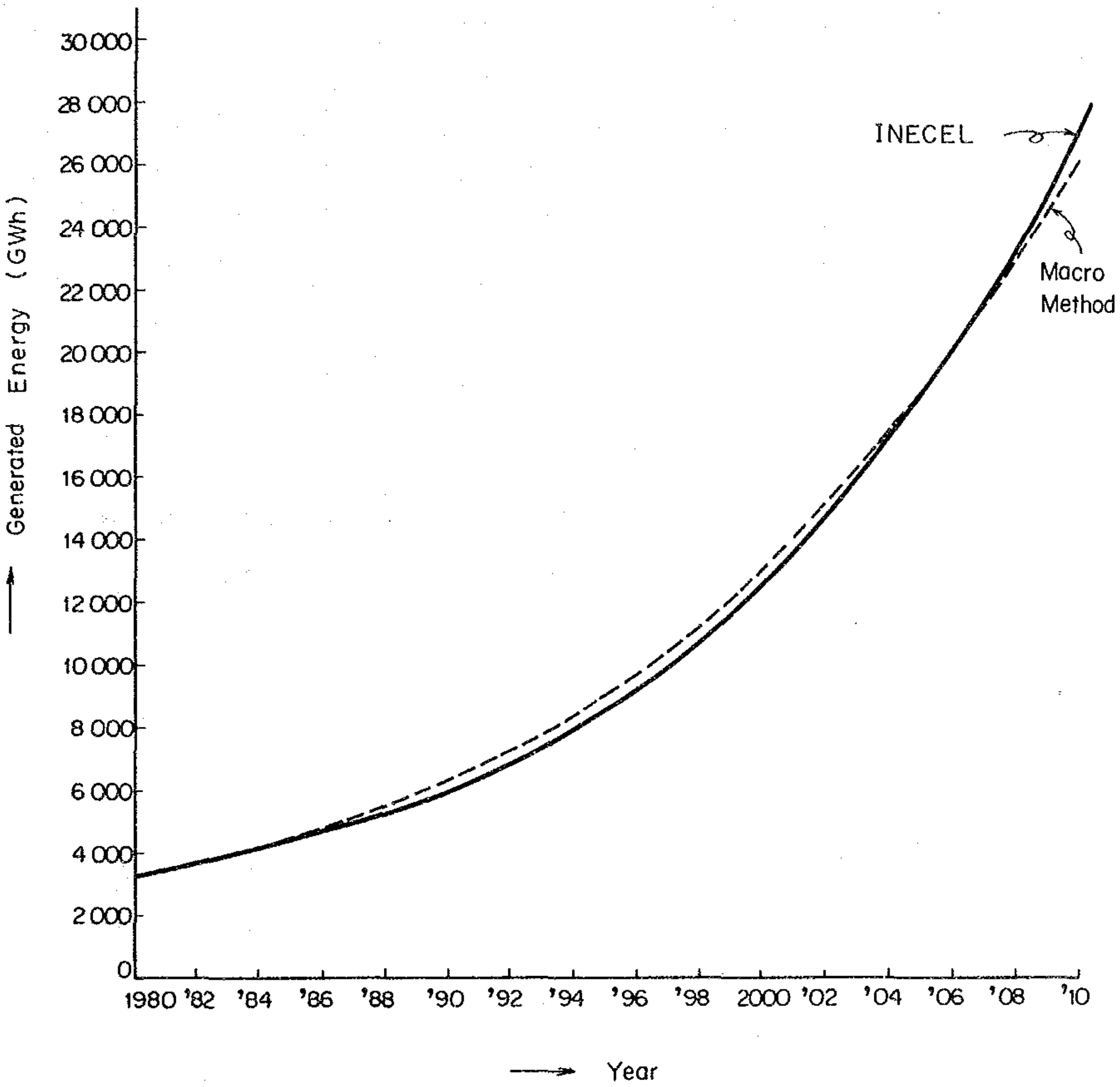


Table 3-11 Growth Rate of GDP

Year	Growth Rate(%)
1985	1.35
1986	2.30
1987	3.18
1988	4.10
1989	4.95
1990	5.50
∫	∫
2010	5.50

As a result of the above studies it was decided to use the load forecast made by INECEL.

3.3 Demand and Supply Balance

The balance of the electric power demand forecast value mentioned in the preceding section and the existing supply capability plus supply capability of which development has already been decided by INECEL was investigated from the two aspects of maximum power and electric energy to examine the timing of commissioning of the Chespi Hydroelectric Power Development Project.

The supply capability (dependable energy production and installed generating capacity) for the maximum power demand was adjusted in order to carry out stable power supply.

The supply capability for electric energy was examined taking into consideration the fact that there is a difference in discharge characteristics between streams belonging to the Amazon side and streams belonging to the Pacific Ocean side according to the season.

There is little seasonal variation in power demand in Ecuador and the power demand record reflects this situation. Consequently, it is difficult to specify the month of maximum power demand in the future, and in this study the performance in 1984 was used as a reference. (Table3-12, Fig. 3-4)

Further, with regard to abolishment plans of existing power stations INECEL's data were used without modification.

3.3.1 Supply Capability

a) Supply capability of existing power generation facilities

The power generating facilities presently possessed by Ecuador amounts to 1681.6 MW (excluding private facilities) and the ratios of hydro: oil-fired thermal: diesel: gas turbine are 43.3: 19.0: 23.4: 13.4.

The ratio between INECEL and provincial electric power companies (including local autonomous bodies) is 56.6: 43.4. (Table 3-13)

INECEL's facilities increased sharply in 1983 with the commissioning of Paute-Molino A, B (500 MW). Ecuador is aiming for relief from dependence on oil such as oil-fired, diesel and gas turbine, and almost all of these have been put on reserve status with the exception of those considered necessary from the standpoint of system operation.

3.3.2 Supply Capability of Power Generating Facilities Planned

The power development plans for 1985 and after comprise only hydroelectric projects in accordance with the policy of nonreliance on oil. The scales of these projects are 130 to 500 MW in consideration of growth in demand and economy, and regulating pond types are selected.

Needless to say, the supply capacity of a hydroelectric power station varies according to the hydrological conditions, and in the case of Ecuador, it is necessary to take into consideration the fact that runoff conditions differ between the Amazon side and the Pacific Ocean Side.

From 1985, it is scheduled for diesel and gas turbine to be abandoned almost every year with even as much as 112 MW to be discarded in a certain year.

As a result of studying the above consideration, the conclusion obtained is that Chespi Hydroelectric Power Station could be recommendable to be commissioned in 1995.

Under Construction and Planning	Out put (MW)	Operating Year	
Agoyan	156	1988	Under Construction
Daule Peripa	130	1991	Under Construction
Paute-Molino C	200	1992	Under Construction
〃	300	1993	〃
Chespi	167	1995	Under Planning
Paute-Mazar	180	1996	Under Planning
San Fransisco	210	1997	Under Planning

Fig. 3–4 Results of Monthly Energy

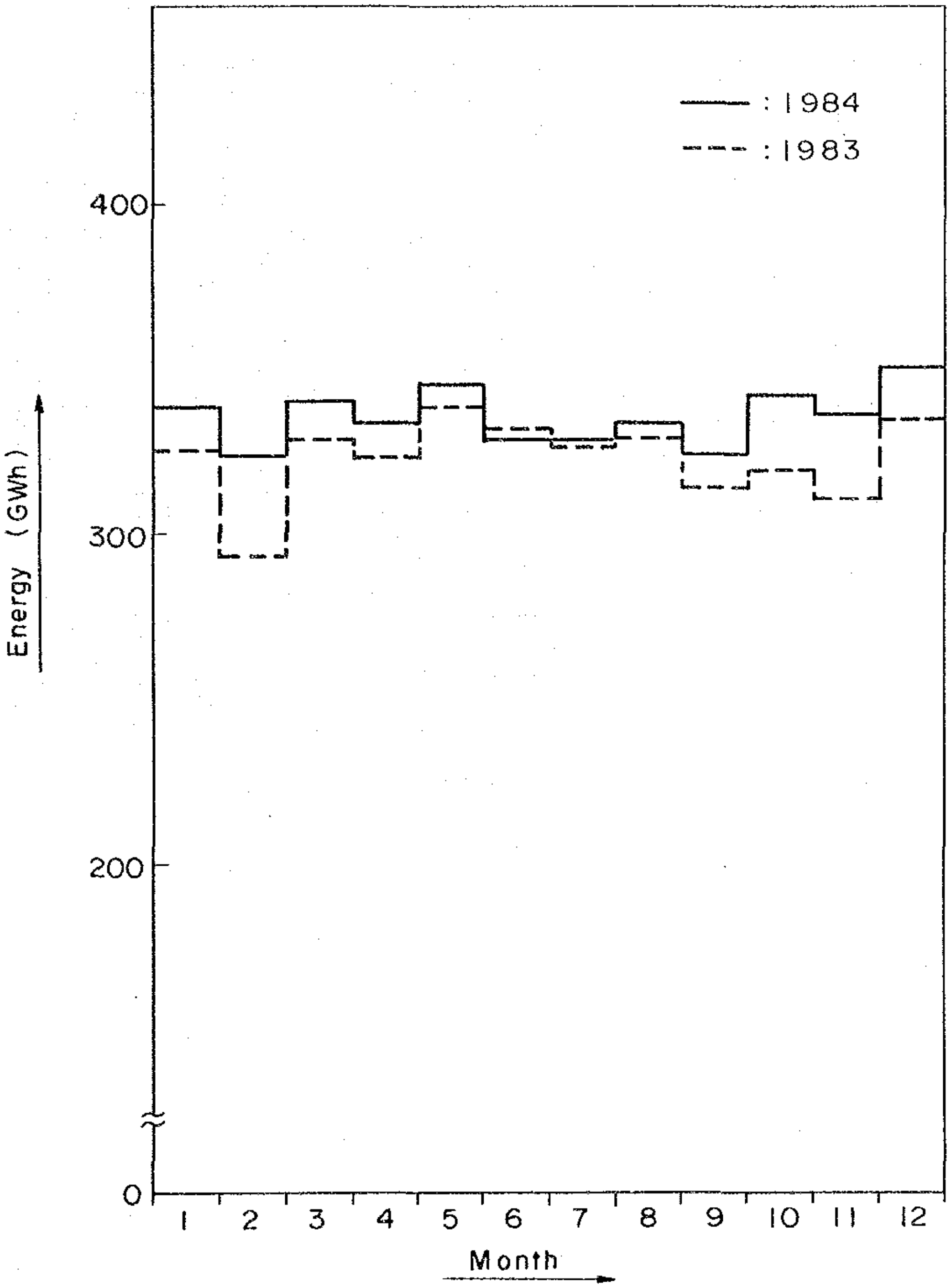


Table 3–12 Monthly Energy Demand of Electric Company

(GWh)

Company / Month	1983				1984			
	E.E.Q	EMELEC	Other Company	Total	E.E.Q	EMELEC	Other Company	Total
1	81.1	144.6	99.8	325.5	85.4	142.8	110.6	338.8
2	74.9	127.3	90.8	293.0	85.2	135.2	103.5	323.9
3	83.5	144.0	101.6	329.1	87.9	141.5	111.0	340.4
4	82.8	139.3	101.0	323.1	85.6	138.3	109.8	333.7
5	84.8	149.3	104.9	339.0	89.8	140.8	114.4	345.0
6	82.2	147.5	102.7	332.4	87.6	129.6	111.4	328.6
7	84.4	137.7	105.1	327.2	87.4	128.1	112.8	328.3
8	84.0	141.0	103.9	328.9	87.8	132.8	114.0	334.6
9	82.2	132.3	99.6	314.1	85.8	128.8	108.7	323.3
10	84.4	130.9	103.7	319.0	91.0	135.4	115.7	342.1
11	81.9	126.9	101.4	310.2	90.9	132.8	112.1	335.8
12	84.9	140.5	109.0	334.4	87.9	144.5	118.2	350.6
Total	991.1	1661.3	1223.5	3875.9	1052.3	1630.6	1342.2	4025.1

Note : Output Energy of Primary Substation

Table 3–13 Existing Generating Facilities in Ecuador

System	Hydro	Steam	Diesel	Gas Turbine	Total
Norte	15.2	0	9.8	0	25.0
Pichincha	85.7	0	77.7	24.1	187.5
Centro-Norte	23.0	0	26.7	0	49.7
Centro-Sur	31.8	0	36.4	0	68.2
Sur	2.4	0	16.4	0	18.8
Esmeraldas	0	0	27.1	0	27.1
Manabi	0	0	52.6	0	52.6
Guayas-Los Rios	0	63.0	73.9	120.5	257.4
El Oro	0	0	31.7	0	31.7
Oriente	0.3	0	10.8	0	11.1
Sub Total	158.4	63.0	363.1	144.6	729.1
(INECEL) S.N.I	570.0	271.0	31.2	80.3	952.5
Total	728.4	334.0	394.3	224.9	1,681.6

3.3.3 KW and KWh Balance

As listed above, it is scheduled for hydroelectric power stations of 130 to 500 MW class to be successively developed beginning with Agoyan Hydroelectric Power Station (156 MW) scheduled for start of operation in 1988. The dependable supply capability planned by INECEL is more than the power demand. Consequently, it is judged that there will be no problem with respect to the electric power balance. (See Table 3-14, Fig. 3-5.)

However, the demand and supply balance of the National Interconnected System was studied by month using hydrological data of the past 20 years. The actual contents of the study will be described in Chapter 6, but it was found that there is possibility of a supply capacity shortage occurring from 1994. Therefore, it was considered that the sites planned would be sequentially commissioned as mentioned previously with Chespi Hydroelectric Power Station starting operation in 1995 to secure supply capability. The above condition is shown in Table 3-15 and Fig. 3-6, and even if the projected sites are successively developed, there will be months in the driest year when shortages of supply capability will occur even though thermal power stations are operated at maximum load. This situation may occur because many of the hydroelectric power station sites have similar hydrological characteristics as watersheds belong to the Amazon side. Further, it should be noted that the degree of dependence on supply capacity of thermal power stations is large in the wintertime(October to April), as shown in Fig. 3-6.

Fig. 3–5 Power Balance of Maximum Demand and Supply

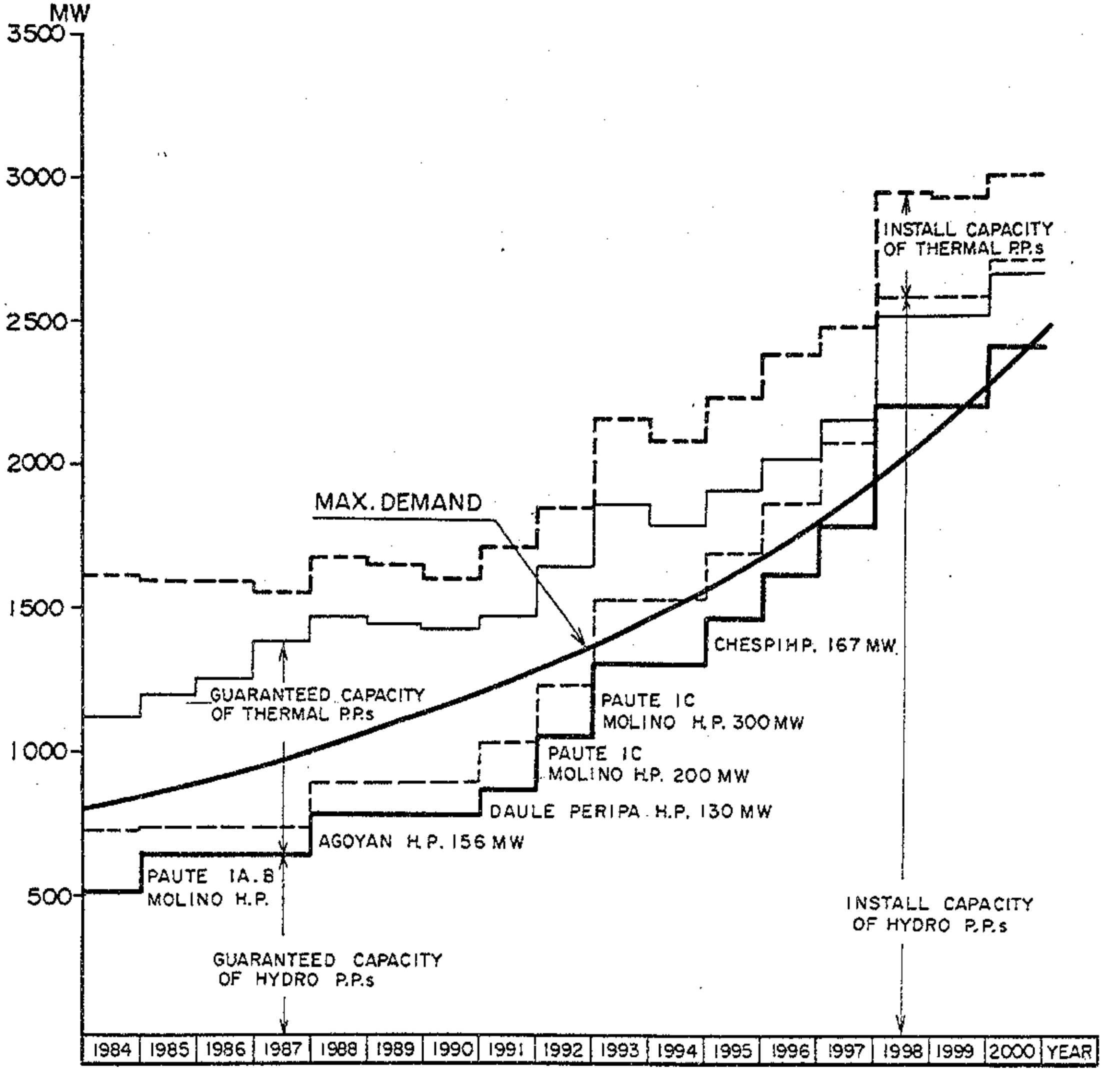


Fig. 3–6 Demand – Supply Balance Curve (with Chespi Project)

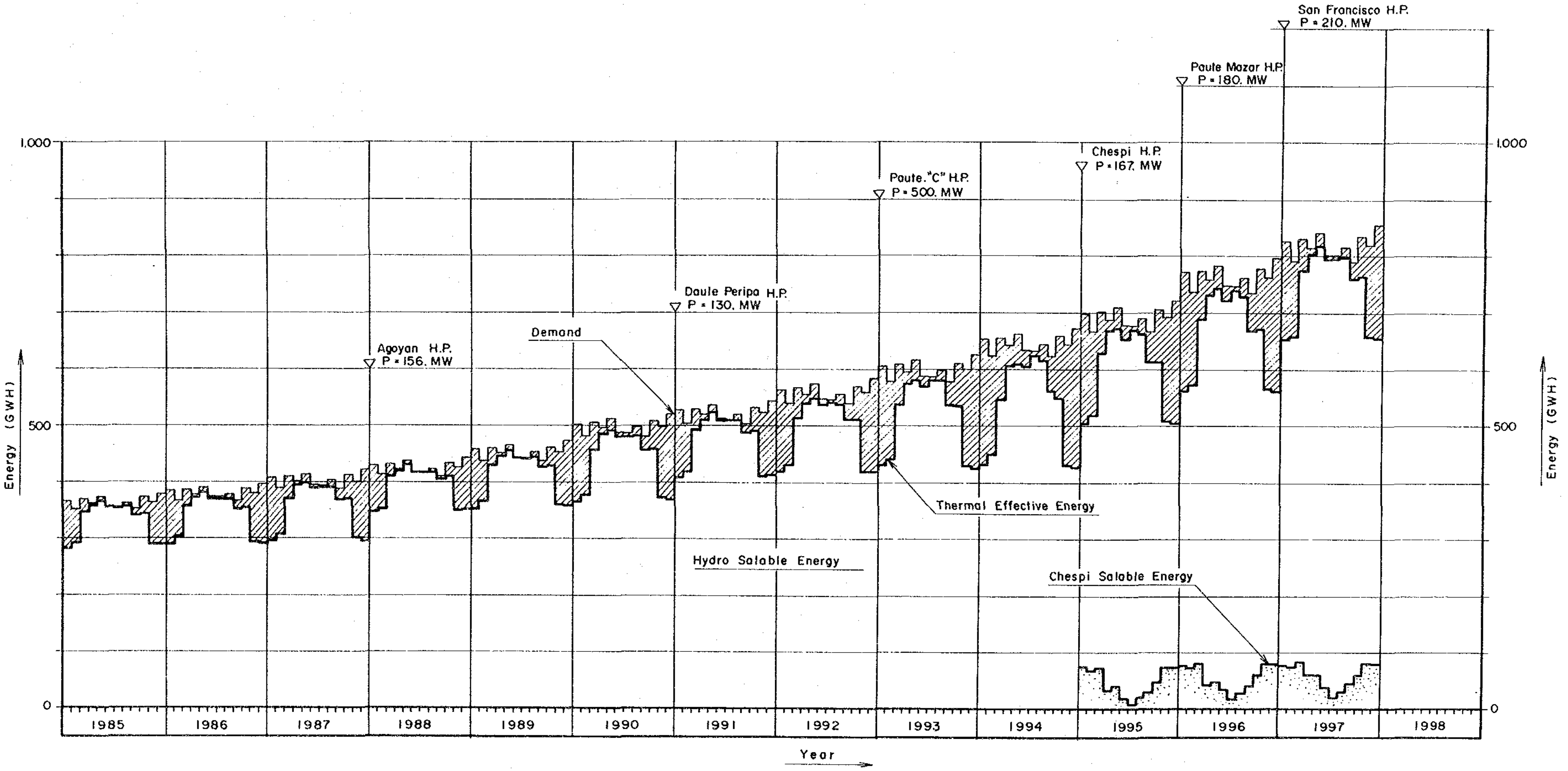


Table 3–14 Power Balance of Demand and Supply

Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	
Maximum Demand (1) (MW)	812	860	912	972	1038	1110	1181	1255	1330	1412	1503	1605	1731	1869	2020	2194	2382	
Hydro Installed Capacity (MW)	722.83	734.43	734.43	734.43	890.43	890.43	890.43	1020.43	1220.43	1520.43	1520.43	1687.43	1861.43	2071.43	2571.43	2571.43	2701.43	
Hydro Guaranteed Capacity (MW)	509.2	641.8	641.8	641.8	780.2	780.2	780.2	872.2	1048.4	1304.9	1304.9	1464.6	1609	1793.7	2216.7	2216.7	2401.6	
Thermal Installed Capacity (MW)	883.3	859.2	859.2	814.2	779.2	756.2	710.2	681.2	681.2	629	549	537	511	399	360	355	304	
Tharmal Guarantead Capacity (MW)	606.8	606.8	714.9	744.7	683.9	661.1	640.8	598.6	598.6	564.1	491.0	459.5	414.2	371.7	312.1	312.1	262.9	
Total Installed Capacity (MW)	1606.13	1593.63	1593.63	1548.63	1669.63	1646.63	1600.63	1701.63	1901.63	2149.43	2069.43	2224.43	2372.43	2470.43	2931.43	2926.43	3005.43	
Total Guaranteed Capacity (2) (MW)	1116	1248.6	1356.7	1386.5	1464.1	1441.3	1421	1470.8	1647	1869	1795.9	1924.1	2023.2	2165.4	2528.8	2528.8	2664.5	
Balance (2)−(1) (MW)	+304	+388.6	+444.7	+414.5	+426.1	+331.3	+240	+215.8	+317	+457	+292.9	+319.1	+292.2	+296.4	+508.8	+334.8	+282.5	
$\frac{(2)-(1)}{(1)} \times 100$ (%)	51.8	45.2	48.8	42.6	41.1	29.8	20.3	17.2	23.8	32.4	19.5	19.9	16.9	15.9	25.2	15.5	11.9	

Table 3–15 kWh Balance of Each Year

KWh Balance in 1985

Item / Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand (GWh)	366.9	350.7	368.6	361.2	373.0	356.0	355.5	362.1	350.3	370.3	363.4	379.1	4,357.0
2 Hydro Effective Energy (GWh)	296.0	308.0	383.2	410.2	410.4	405.2	410.4	397.6	373.4	376.0	299.8	295.6	4,365.7
3 Hydro Salable Energy (GWh)	283.4	293.2	346.5	358.9	366.0	354.3	354.4	356.1	341.7	343.9	289.2	289.8	3,977.5
4 Hydro Effective Ratio 3 / 2 (%)	95.7	95.1	90.4	87.5	89.2	87.4	86.4	89.6	91.5	91.5	96.5	98.0	91.1
5 Other Necessary Energy 1 - 3 (GWh)	83.5	57.5	22.0	2.3	7.0	1.7	1.1	6.0	8.6	26.4	74.2	89.3	379.5
6 Thermal Installed Capacity (MW)	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	-
7 Thermal Plant Factor (%)													
8 Insufficient Frequency in 16 Years	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1986

Month Item	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand (GWh)	384.1	367.2	385.9	378.2	390.5	372.7	372.3	379.1	366.8	387.8	380.5	396.9	4,562.0
2 Hydro Effective Energy (GWh)	296.0	308.0	383.2	410.2	410.4	405.2	410.4	397.1	373.4	376.0	299.8	295.6	4,365.3
3 Hydro Salableve Energy (GWh)	288.8	300.4	357.8	375.0	380.2	369.4	370.4	371.4	354.4	356.1	294.4	292.5	4,110.8
4 Hydro Effective Ratio 3 / 2 (%)	97.6	97.5	93.4	91.4	92.6	91.2	90.3	93.5	94.5	94.7	98.2	99.0	94.2
5 Other Necessary Energy 1 - 3 (GWh)	95.3	66.8	28.1	3.2	10.3	3.3	1.9	7.7	12.4	31.7	86.1	104.4	451.2
6 Thermal Installed Capacity (MW)	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	929.2	-
7 Thermal Plant Factor (%)													
8 Insufficient Frequency in 16 Years	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1987

Month Item	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand (GWh)	407.3	389.5	409.3	401.1	414.1	395.3	394.8	402.0	389.0	411.2	403.5	420.9	4,838.0
2 Hydro Effective Energy (GWh)	296.0	308.0	383.2	410.2	410.4	405.2	410.4	397.1	373.4	376.0	299.8	295.6	4,365.3
3 Hydro Salable Energy (GWh)	294.8	307.5	372.3	396.1	399.1	389.4	391.7	392.0	370.0	371.7	299.8	295.6	4,280.0
4 Hydro Effective Ratio 3 / 2 (%)	99.6	99.8	97.2	96.6	97.2	96.1	95.4	98.7	99.1	98.9	100.0	100.0	98.4
5 Other Necessary Energy 1 - 3 (GWh)	112.5	82.0	37.0	5.0	15.0	5.9	3.1	10.0	19.0	39.5	103.7	125.3	558.0
6 Thermal Installed Capacity (MW)	884.2	884.2	884.2	884.2	884.2	884.2	884.2	884.2	884.2	884.2	884.2	884.2	-
7 Thermal Plant Factor (%)													
8 Insufficient Frequency in 16 Years	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1988

Month Item	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand (GWh)	429.3	410.4	431.3	422.6	436.4	416.5	416.0	423.6	409.9	433.3	425.2	443.5	5.098.0
2 Hydro Effectine Energy (GWh)	367.9	378.0	468.2	499.3	502.3	497.6	506.0	492.0	463.6	460.7	370.1	365.8	5.371.6
3 Hydro Salable Energy (GWh)	347.2	351.8	409.9	420.7	429.8	415.9	414.1	418.3	403.1	408.1	349.2	351.8	4.719.9
4 Hydro Effective Ratio 3 / 2 (%)	94.4	93.1	87.5	84.3	85.6	83.6	81.8	85.2	86.9	88.6	94.4	96.2	87.9
5 Other Necessary Energy 1 - 3 (GWh)	82.1	58.6	21.4	1.9	6.6	0.6	1.9	5.3	6.8	25.2	76.0	91.7	378.1
6 Thermal Installed Capacity (MW)	849.2	849.2	849.2	849.2	849.2	849.2	849.2	849.2	849.2	849.2	849.2	849.2	-
7 Thermal Plant Factor (%)													
8 Insufficient Frequency in 16 Years	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1989

Month Item	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand (GWh)	457.3	437.2	459.5	450.2	464.9	443.7	443.2	451.3	436.7	461.6	452.9	472.5	5.431.0
2 Hydro Effective Energy (GWh)	367.9	378.0	468.2	499.3	502.3	497.6	506.0	492.0	463.6	460.7	370.1	365.8	5,371.5
3 Hydro Salable Energy (GWh)	353.6	364.4	429.1	446.8	454.6	441.1	439.9	443.7	425.9	427.9	360.0	358.5	4.945.4
4 Hydro Effective Ratio 3 / 2 (%)	96.1	96.4	91.6	89.5	980.5	88.6	86.9	90.2	91.9	92.9	97.3	98.0	92.1
5 Other Necessary Energy 1 - 3 (GWh)	103.7	72.8	30.4	3.4	10.2	2.6	3.3	7.6	10.8	33.7	79.9	114.0	485.6
6 Thermal Installed Capacity (MW)	826.2	826.2	826.2	826.2	826.2	826.2	826.2	826.2	826.2	826.2	826.2	826.2	-
7 Thermal Plant Factor (%)													
8 Insufficient Frequency in 16 Years	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1990

Item / Month		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand	(GWh)	500.1	478.2	502.5	492.4	508.5	485.3	484.7	493.6	477.6	504.9	495.4	516.8	5,940.0
2 Hydro Effective Energy	(GWh)	367.9	378.0	468.2	499.3	502.3	497.6	506.0	492.0	463.6	460.7	370.1	365.8	5,371.5
3 Hydro salable Energy	(GWh)	365.3	378.0	456.2	484.8	489.5	478.5	479.4	481.7	456.7	455.8	370.1	365.8	5,261.9
4 Hydro Effective Ratio 3 / 2	(%)	99.3	100.0	97.4	97.1	97.1	96.2	94.7	97.9	98.5	98.9	100.0	100.0	97.6
5 Other Necessary Energy 1 - 3	(GWh)	134.8	100.2	46.3	7.6	19.0	6.7	5.3	11.9	20.9	49.1	125.3	151.0	678.1
6 Thermal Installed Capacity	(MW)	780.2	780.2	780.2	780.2	780.2	780.2	780.2	780.2	780.2	780.2	780.2	780.2	-
7 Thermal Plant Factor	(%)													
8 Insufficient Frequency in 16 Years		0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1991

Item / Month		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand	(GWh)	526.2	503.0	528.7	518.0	534.9	510.5	509.9	519.3	502.4	531.2	521.2	543.7	6,249.0
2 Hydro Effective Energy	(GWh)	420.5	428.8	524.7	553.6	558.1	547.7	557.0	542.3	512.2	510.9	420.8	418.2	5,994.8
3 Hydro Salable Energy	(GWh)	407.8	418.5	492.7	511.9	520.5	507.0	509.9	510.0	486.8	490.1	410.8	413.6	5,679.5
4 Hydro Effective Ratio 3 / 2	(%)	97.0	97.6	93.9	92.5	93.3	92.6	91.5	94.0	95.0	95.9	97.6	98.9	94.7
5 Other Necessary Energy 1 - 3	(GWh)	118.4	84.5	36.0	6.1	14.4	3.5	0	9.3	15.6	41.1	110.4	130.1	569.5
6 Thermal Installed Capacity	(MW)	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	-
7 Thermal Plant Factor	(%)													
8 Insufficient Frequency in 16 Years		0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1992

Item / Month		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand	(GWh)	562.9	538.1	565.6	554.2	572.2	546.2	545.5	555.5	537.5	568.2	557.5	581.6	6,685.0
2 Hydro Effective Energy	(GWh)	420.5	428.8	524.7	553.6	558.1	547.7	557.0	542.3	512.2	510.9	420.8	418.2	5,994.8
3 Hydro Salable Energy	(GWh)	417.8	427.9	513.0	540.2	547.6	536.0	540.6	538.3	509.0	509.5	418.1	417.9	5,916.3
4 Hydro Effective Ratio 3 / 2	(%)	99.4	99.8	97.8	97.6	98.1	97.9	97.1	99.3	99.4	99.7	99.4	99.9	98.7
5 Other Necessary Energy 1 - 3	(GWh)	145.1	110.2	52.6	14.0	24.6	10.2	4.9	17.2	28.5	58.7	139.4	163.7	768.7
6 Thermal Installed Capacity	(MW)	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	751.2	-
7 Thermal Plant Factor	(%)													
8 Insufficient Frequency in 16 Years		0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1993 (Without Chespi P/S)

Item / Month		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand	(GWh)	603.9	577.3	606.8	594.6	613.9	586.0	585.2	596.0	576.6	609.6	598.1	624.0	7,172.0
2 Hydro Effective Energy	(GWh)	429.7	459.3	574.2	707.8	700.8	735.3	810.2	726.8	604.8	574.7	433.9	428.9	7,186.4
3 Hydro Salable Energy	(GWh)	426.6	439.7	534.7	574.9	580.0	568.6	578.7	577.2	535.0	533.4	428.2	424.2	6,201.3
4 Hydro Effective Ratio (3／2)	(%)	99.3	95.7	93.1	81.2	82.8	77.3	71.4	79.4	88.5	92.8	98.7	98.9	86.3
5 Other Necessary Energy (1－3)	(GW)	177.3	137.6	72.1	19.7	33.9	17.4	6.5	18.8	41.6	76.2	169.9	199.8	970.7
6 Thermal Installed Capacity	(MW)	699.0	699.0	699.0	699.0	699.0	699.0	699.0	699.0	699.0	699.0	699.0	699.0	-
7 Thermal Plant Factor	(%)													
3' Hydor Energy in Driest Year	(GWh)	250.3	217.1	290.7	431.7	381.1	468.0	454.7	357.0	379.0	289.3	234.0	223.7	3,976.6
5' Other Necessary Energy (1－3')	(GWh)	353.6	360.2	316.1	162.9	232.8	118.0	130.5	239.0	197.6	320.3	364.1	400.3	3,195.4
7' Thermal Plant Factor	(%)													
8 95% Thermal Effective Energy ⑥×(day)×24×0.95×0.96	(GWH)													
9 Insufficient Energy 9 = 1 - 3' - 8	(GWh)	0	0	0	0	0	0	0	0	0	0	0	0	
10 Insufficient Frequency in 16 Years		0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/240

KWh Balance in 1994 (Without Chespi P/S)

Item / Month		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand	(GWh)	650.6	622.0	653.7	640.6	661.3	631.3	630.5	642.1	621.3	657.0	644.4	672.2	7,727.0
2 Hydro Effective Energy	(GWh)	429.7	459.3	574.2	707.8	700.8	735.3	810.2	726.8	604.8	574.7	433.9	428.9	7,186.4
3 Hydro Salable Energy	(GWh)	429.7	447.8	545.4	605.0	607.5	602.6	621.7	613.6	558.2	548.2	431.2	426.6	6,437.7
4 Hydro Effective Ratio (3/2)	(%)	100.0	97.5	95.0	85.5	86.7	82.0	76.7	84.4	92.3	95.4	99.4	99.5	89.6
5 Other Necessary Energy (1-3)	(GW)	220.9	174.2	108.3	35.6	53.8	28.7	8.8	28.5	63.1	108.8	213.2	245.6	1,289.5
6 Thermal Installed Capacity	(MW)	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0	619.0	-
7 Thermal Plant Factor	(%)													
3' Hydor Energy in Driest Year	(GWh)	250.3	217.1	407.3	431.7	381.1	468.0	454.7	357.0	379.0	289.3	234.0	223.7	4,617.7
5' Other Necessary Energy (1-3')	(GWh)	400.3	404.9	246.4	208.9	280.2	163.3	175.8	285.1	242.3	367.7	410.4	448.5	3,633.8
7' Thermal Plant Factor	(GWh)													
8 95% Thermal Effective Energy ⑥ × (day) × 24 × 0.95 × 0.96	(%)	420.0	379.4	420.0	406.5	420.0	406.5	420.0	420.0	406.5	420.0	406.5	420.0	4,945.3
9 Insufficient Energy 9 = 1 - 3' - 8	(GWh)	0	25.5	0	0	0	0	0	0	0	0	0	28.5	54.0
10 Insufficient Frequency in 16 Years		0/20	1/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	1/20	2/240

KWh Balance in 1995 (With Chespi P/S)

Month Item		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand	(GWh)	698.3	667.6	701.6	687.5	709.9	677.5	676.7	689.1	666.8	704.9	691.6	721.5	8,293.0
2 Hydro Effective Energy	(GWh)	506.2	538.2	680.1	807.1	796.8	814.6	883.2	784.8	657.2	642.8	514.7	508.6	8,124.3
3 Hydro Salable Energy	(GWh)	503.2	518.1	627.0	665.7	672.9	653.2	668.2	660.7	606.3	605.8	507.8	502.7	7,192.6
4 Hydro Effective Ratio (3/2)	(%)	99.4	96.3	93.6	82.6	84.5	80.2	75.7	84.2	92.3	94.2	98.7	98.8	88.5
5 Other Necessary Energy(1 - 3)	(GW)	195.1	149.5	74.6	20.8	37.0	24.3	8.5	28.4	60.5	99.1	183.8	218.8	1,100.4
6 Thermal Installed Capacity	(MW)	607.0	607.0	607.0	607.0	607.0	607.0	607.0	607.0	607.0	607.0	607.0	607.0	-
7 Thermal Plant Factor	(%)													
3' Hydor Energy in Driest Year	(GWh)	302.5	247.7	382.7	500.2	432.9	534.2	517.1	399.9	426.4	330.9	295.3	282.9	4,652.7
5' Other Necessary Energy(1 - 3')	(GWh)	395.8	419.9	318.9	187.3	277.0	143.3	159.6	289.2	240.4	374.0	396.3	438.6	3,640.3
7' Thermal Plant Factor	(GWh)													
8 95% Thermal Effective Energy ⑥ × (day) × 24 × 0.95 × 0.96	(%)	411.9	372.0	411.9	398.6	411.9	398.6	411.9	411.9	398.6	411.9	398.6	411.9	
9 Insufficient Energy 9 = 1 - 3' - 8	(GWh)	0	47.9	0	0	0	0	0	0	0	0	0	26.7	74.6
10 Insufficient Frequency in 20 Years 3' + 8 < 1		0/20	1/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	1/20	2/240

KWh Balance in 1996 (With Chespi P/S)

Item / Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand (GWh)	770.3	736.4	773.9	758.4	783.0	747.4	746.5	760.2	735.5	777.6	762.9	795.9	9.148.0
2 Hydro Effective Energy (GWh)	563.3	592.1	732.7	874.3	871.2	886.4	957.4	857.7	720.9	705.5	570.2	565.5	8.897.2
3 Hydro Salable Energy (GWh)	561.2	572.5	687.4	731.5	743.4	719.3	738.0	728.1	668.1	669.0	564.4	560.4	7.943.3
4 Hydro Effective Ratio (3／2) (%)	99.6	96.7	93.8	83.7	85.3	81.1	77.1	84.9	92.7	94.8	99.0	99.1	89.3
5 Other Necessary Energy(1－3) (GW)	209.1	163.9	86.5	26.9	39.6	28.1	8.5	32.1	67.4	108.6	198.5	235.5	1.204.7
6 Thermal Installed Capacity (MW)	581.0	581.0	581.0	581.0	581.0	581.0	581.0	581.0	581.0	581.0	581.0	581.0	-
7 Thermal Plant Factor (%)													
3' Hydor Energy in Driest Year (GWh)	348.2	289.0	423.9	551.0	484.8	593.9	575.6	441.4	466.3	372.1	335.2	329.2	5.210.6
5' Other Necessary Energy(1－3') (GWh)	422.1	447.4	350.0	207.4	298.2	153.5	170.9	318.8	269.2	405.5	427.7	466.7	3.937.4
7' Thermal Plant Factor (GWh)													
8 95% Thermal Effective Energy (%) ⑥×(day)×24×0.95×0.96	394.2	356.0	394.2	381.5	394.2	381.5	394.2	394.2	381.5	394.2	381.5	394.2	
9 Insufficient Energy (GWh) 9 = 1 - 3' - 8	27.9	91.4	0	0	0	0	0	0	0	11.3	46.2	72.5	
10 Insufficient Frequency in 16 Years	2/20	2/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	1/20	2/20	1/20	6/240

KWh Balance in 1997 (With Chespi P/S)

Item / Month		Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1 Energy Demand	(GWh)	826.8	790.5	830.8	814.1	840.6	802.3	801.3	816.0	789.5	834.7	819.0	854.4	9,820.0
2 Hydro Effective Energy	(GWh)	678.3	696.8	860.2	987.2	1,009.0	1.027.6	1.093.9	1,005.5	864.3	837.8	680.7	667.6	10.408.9
3 Hydro Salable Energy	(GWh)	652.5	658.4	773.6	800.3	816.6	794.9	795.4	798.4	760.1	763.0	656.5	654.9	8,924.6
4 Hydro Effective Ratio (3/2)	(%)	96.2	94.5	89.9	81.1	80.9	77.4	72.7	79.4	87.9	91.1	96.4	98.1	85.7
5 Other Necessary Energy(1-3)	(GW)	174.3	132.1	57.2	13.8	24.0	7.4	5.9	17.6	29.4	71.7	162.5	199.5	895.4
6 Thermal Installed Capacity	(MW)	469.0	469.0	469.0	469.0	469.0	469.0	469.0	469.0	469.0	469.0	469.0	469.0	-
7 Thermal Plant Factor	(%)													
3' Hydor Energy in Driest Year	(GWh)	410.5	334.8	519.4	660.9	572.6	742.0	682.5	682.5	568.8	465.4	412.2	382.5	6,286.0
5' Other Necessary Energy(1-3')	(GWh)	416.3	455.7	311.4	153.2	268.0	60.3	118.8	281.6	220.7	369.3	406.8	471.9	3,534.0
7' Thermal Plant Factor	(GWh)													
8 95% Thermal Effective Energy (6)×(day)×24×0.95×0.96	(%)	318.2	287.4	318.2	308.0	318.2	308.0	318.2	318.2	308.0	318.2	308.0	318.2	
9 Insufficient Energy 9 = 1 - 3' - 8	(GWh)	98.1	168.3	0	0	0	0	0	0	0	51.1	98.8	153.7	
10 Insufficient Frequency in 16 Years		6/20	4/20	0/20	0/20	0/20	0/20	0/20	0/20	0/20	1/20	4/20	5/20	20/240

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CHAPTER 4 METEOROLOGY AND HYDROLOGY

4.1 Fundamental Considerations

The hydrologic data necessary for this Project study are those necessary to calculate benefit, that is, runoff data for computing energy production, and data concerned with costs, that is, flood data related to design of structures such as dams, spillway, river diversion, flushing gates and so on.

The Survey Team, prior to preparation of the abovementioned data, carried out collection of basic data and previously-examined data. These data were well-organized and there was little necessity for further studies to be made, especially in the sector of meteorology.

However, with regard to runoff data directly connected with evaluation of the Project, modifications were made on the calculation method.

In effect, in calculation of inflow at the project site during normal times, the data of Chacapata Gauging Station were newly added to the data of A. J. Cubi Gauging Station and D. J. Alambi Gauging Station.

Regarding flood analyses, the probability analysis was used for calculations considering the fact that this is to be a gravity dam of daily regulating pond type and the effects on the downstream area would not be great. However, there was a substantial difference between the estimate made based on flood records of an approximately 20-year period and that from the rainfall data of Quito Gauging Station during a 92-year period. For this Report, it was decided to adopt the latter which resulted in a higher value from the standpoint of evaluating the Feasibility Study on the conservative side.

The sedimentation analysis is described in Chapter 7, "Preliminary Design."

4.2 Outline of Meteorology in the Project Area

The Rio Guayllabamba is located in Ecuador's northwest part, its fountainhead is in the Andes Mountains and merges at its downstream part as the Rio Esmeraldas which discharge into the Pacific Ocean. The catchment area of the Guayllabamba is 8,662 km^2, and its length is 289 km.

The project area is at the midstream part of the Rio Guayllabamba, the catchment area being approximately 4,600 km^2, with an average gradient of 4.92 percent, and channel length of 125 km.

The features of the climate differ according to the altitude and the mountain topography, and there are many climates from arctic mid-temperate to subtropical.

The annual changes are roughly the rainy season from October to April, the dry period in July and August, and the transitional periods in between, but in the upstream area there are cases when trade winds blow from east to west and heavy rains fall from July to August influenced by the adjacent Amazon River Basin.

As for temperatures, they are roughly constant, monthly and annually, because of the condition that this catchment area is located near the equator.

4.2.1 Temperature

The main temperature in the basin in inversely proportional to elevation and decreases approximately 4°C with every 1,000 m in height. It is 19.4°C at Vina de Chespi Gauging Station at El. 1,490 m in the vicinity of the project site and 13.6°C at Quito at El. 2,800 m. The variations, monthly and annual, are roughly constant at all of the sites and the ranges are narrow at about 2 to 3°C. However, the absolute diurnal maximum-minimum temperature difference is large at around 25°C. (See Table 4-1.)

The relation between temperature and elevation is shown in Fig. 4-1.

Table 4-1 Temperature in the Project Basin

Site / Month	Vina de Chespi '78~'81			Quito Observe. G. S '68~'83		
	minimum	mean	maximum	minimum	mean	maximum
Jan.	12.1	18.9	25.3	2.4	13.6	25.5
Feb.	12.1	19.2	25.2	2.7	13.5	25.4
Mar.	14.1	19.5	27.2	3.0	13.7	25.0
Apr.	13.2	19.7	28.2	3.6	13.6	24.8
May	13.0	19.9	31.0	3.2	13.9	25.0
Jun	9.1	19.6	29.4	3.6	13.6	25.0
Jul.	11.0	19.1	30.4	3.5	13.7	24.8
Aug.	10.1	19.5	33.2	2.2	13.8	26.6
Sep.	11.1	19.2	28.0	3.0	13.8	26.1
Oct.	12.1	19.5	30.1	2.5	13.3	26.2
Nov.	12.0	19.2	28.1	3.2	13.2	25.0
Des.	13.1	19.2	27.0	2.2	13.4	25.5
Total	—	19.4	—	—	13.6	—

Fig. 4-1 Relation Between Temperature and Elevation

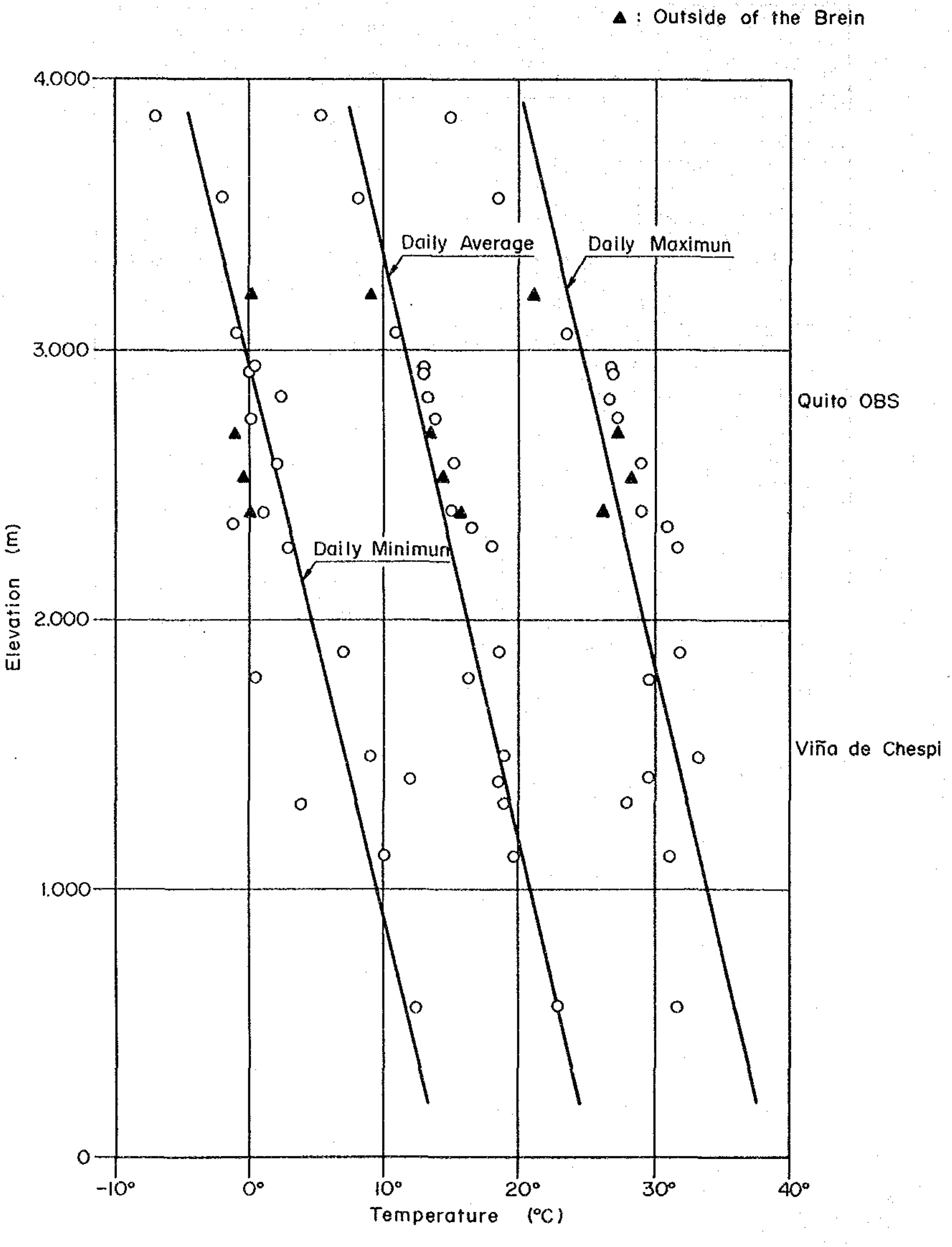
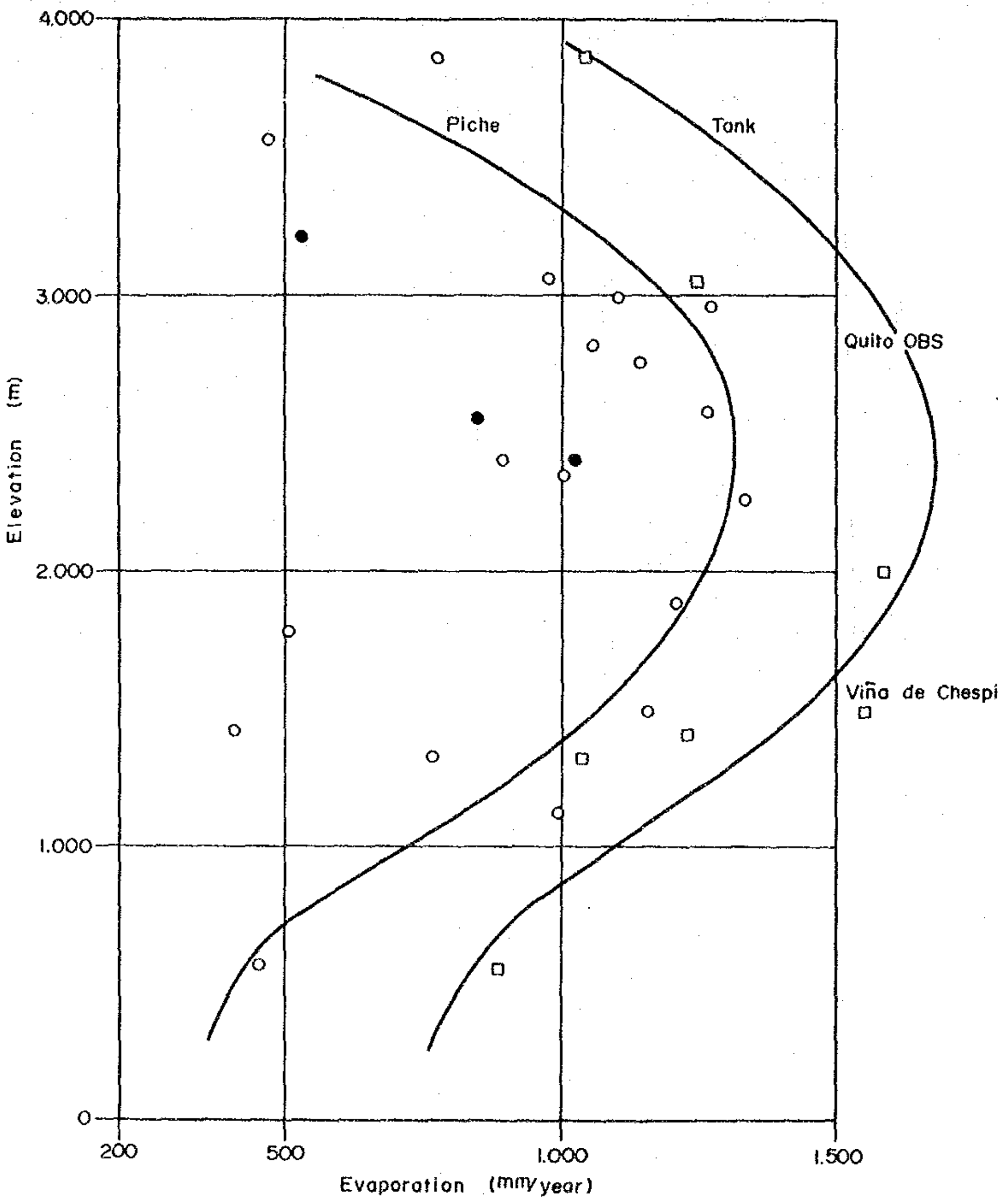


Table 4–2 Evaporation in the Project Basin

Piche Type Unit : mm

Site Month	Viña de Chespi '78～'81	Quito obser, GS '64～'81
Jan.	79.5	86.2
Feb.	72.2	71.6
Mar.	75.3	81.8
Apr.	74.8	66.7
May	90.9	78.9
Jun	100.6	93.7
Jul.	124.8	125.7
Aug.	138.9	124.9
Sep.	120.6	98.1
Oct.	131.0	78.2
Nov.	97.9	65.9
Des.	89.3	80.9
Total	1,195.8	1,052.3

Fig. 4–2 Relation Between Evaporation and Elevation



4.2.2 Evaporation

The relations between evaporation and elevation measured by Piche type and Pan type apparatus are shown in Fig. 4-2. It can be seen from this figure that evaporation is greatest between El. 2,000 and 3,000 m, decreasing above and below this range. The evaporations by month at the Vina de Chespi and Quito gauging stations are given in Table 4-2.

4.2.3 Wind

The mean wind speed is normally 3 m/s with the wind direction differing according to topography. In general, it is in the direction of the river channel and is southwest in the vicinity of the project site.

4.2.4 Rainfall

Rainfall in the Rio Guayllabamba Basin is affected by topography. The rainfall distribution is shown in Fig. 4-3.

It can be seen from this figure that the distribution varies sharply between sites. This is especially prominent in the vicinity of the project site. That is, whereas the mean annual rainfall at the projected dam site is approximately 800 mm, at Chacapata Gauging Station about 23 km downstream it is approximately 1,600 mm, while on the other hand, in the vicinity of Calderon on the upstream side, rainfall is the smallest in the catchment area and approximately 500 mm.

The mean rainfall in this project area is estimated to be about 1,116 mm. The average through the year is divided according to the rainy season from October to April, the dry season in July and August, and the transitional periods in between. The rainfall during the rainy season makes up approximately 73 percent of the annual, while in the dry season it is only 5 percent. The month with the most rainfall during the year differs according to year, but it is generally March or April. The monthly mean rainfalls at Vina de Chespi Gauging Station and Quito Gauging Station are shown in Table 4-3 and Fig. 4-4.

Table 4–3 Monthly Average Rainfall (mm／month)

Month	Viña de Chespi 1978～'83	Quito obs 1891～1982
Jan.	99.8	114.3
Feb.	112.6	130.8
Mar.	104.5	156.5
Apr.	134.2	177.8
May	55.8	125.2
Jun	10.8	49.4
Jul.	13.8	20.3
Aug.	16.5	25.5
Sep.	30.5	80.3
Oct.	47.3	133.2
Nov.	92.4	111.7
Des.	100.9	103.6
Total	877.7	1,228.7

Fig. 4-3 Rainfall Distribution of the Project Basin (1963 ~ 1983)

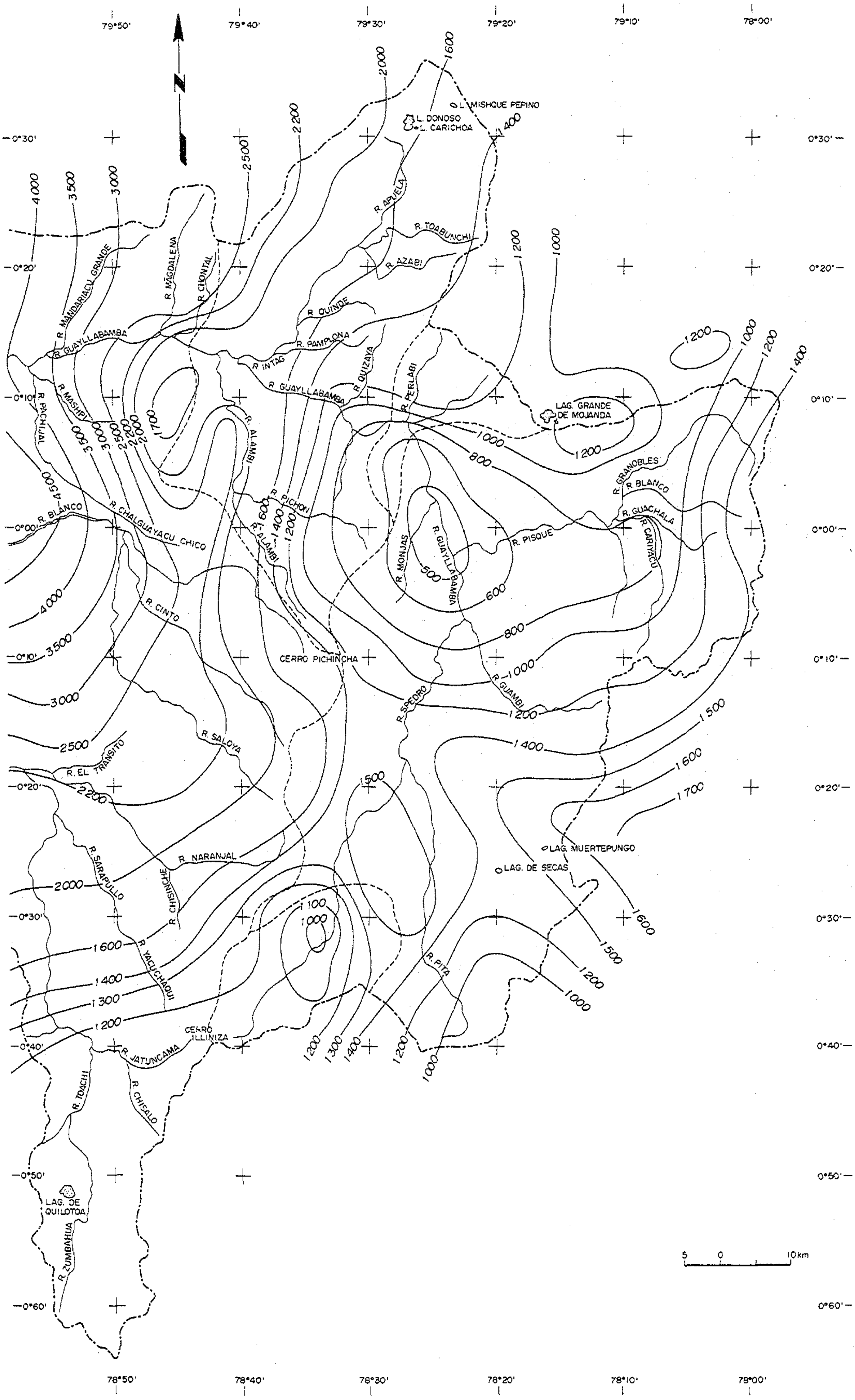


Fig. 4–4 Monthly Precipitation

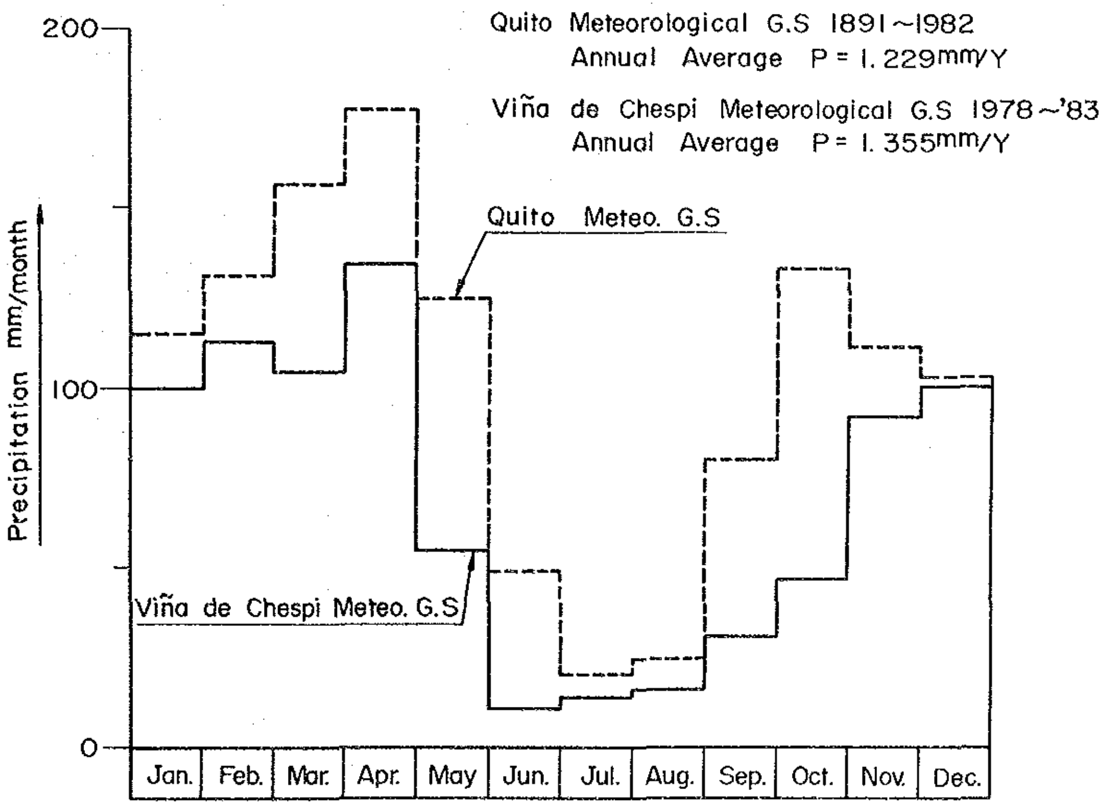


Table 4–4 Existing Rainfall Data

Index No.	Station	Location		Height	Control	Year																					
		La	Lon	(msnm)		1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
13–9	San Antonio de Pichincha	00-00-37S	78-26-13W	2,400	INAMHI	'56– - -	—	—	—	—	—	—	—	—	—	—	—	—	—	- -	—	—	—	—	—	-	
13–10	Malchingui	00-03-24N	78-20-05W	2,850	INAMHI		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
13–19	San José de Minas	00-06-21N	78-24-45W	2,440	INAMHI			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—		
13–20	Perucho	00-06-44N	78-25-19W	1,880	INECEL														—	—	—	—	—	—	—	—	—
13–21	Nanegalito	00-04-05N	78-40-47W	1,610	INECEL			—	—	—	- -	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13–22	Mindo Inecel	00-02-52S	78-46-08W	1,320	INECEL															—	—	—	—	—	—	—	—
13–24	Jerusalen	00-00-11N	78-21-02W	2,360	INAMHI		—	—	—	—	—	—	—	—	—	—											
13–25	Tabacundo	00-03-11N	78-14-06W	2,955	INAMHI		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
13–34	Calderón	00-05-55S	78-25-24W	2,690	INAMHI		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13–35	Cotocolao	00-06-27S	78-24-36W	2,780	INAMHI		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13–36	Quito - Aeropuerto	00-08-00S	78-29-00W	2,812	D.A.C	'50– —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13–43	Quito - Observatorio	00-12-42S	78-30-02W	2,818	Poli. Nac.	1891– —	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
13–67	La Perla	00-11-00N	78-40-00W	1,410	INECEL															—	—	—	—	—	—	—	—
13–75	Nono	00-03-52S	78-34-24W	2,740	INECEL															—	—	—	—	—	—	—	—
13–76	Pacto	00-08-47N	78-45-49W	1,200	INAMHI		- -	—	—		—									—	—	—	—	—	—	—	—
13–92	Viña de Chespi	00-07-00N	78-32-00W	1,490	INECEL																	—	—	—	—	—	—
13–93	Vindobona	00-00-02N	78-25-06W	2,270	INECEL			—	—	—	—	—	—	—	—	—						—	—	—	—	—	—
13–94	Selva Alegre	00-15-00N	78-35-00W	1,800	INAMHI																—	—	—	—	—	—	—
P6–1	Nanegal	00-08-26N	78-40-34W	1,280	INECEL															—	—	—	—	—	—	—	—
P – 8	Toabunchi	00-22-40N	78-26-05W	2,200	INECEL																-	-					
2 – 18	Intag en Apuela	00-21-30N	78-30-40W	1,620	INAMHI			—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
2 – 20	Cambugán	00-16-21N	78-23-30W	3,120	INAMHI				-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2 – 31	San Rafael del Lago	00-12-00N	78-14-24W	2,790	INAMHI				—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 4–5 Existing Runoff Data

Index No.	Station	River	Height (msnm)	Catchment Area (km²)	Year																					
					1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
13–04	A.J Cubi	Guayllabamba	1540	4,364			—	—	—	—	—	—	—	—	—	—	-	—	—	—	—	—	—	—	—	—
F – 2	EN PTE. CHACAPATA	Guayllabamba	650	4,905																	—	—	—	—	—	—
13–05	D.J Alambi	Guayllabamba	625	6,808					—	—	—	—	—	—	—	—	-	-	—	—	—	—	—	—	—	

Note: INAMHI = INSTITUTO NACIONAL DE METEOROLOGIA E HIDROLOGIA
DAC = DIRECCION DE AVIACION CIVIL
U C = UNIVERSIDAD CENTRAL
POLI NAC = POLITECNICA NACIONAL

4.3 Runoff and Meteorological Gauging Stations

There are 72 meteorological gauging stations and 13 runoff gauging stations down to the midstream basin of the Rio Guayllabamba (to El. 500 m) in which the project site is located. However, the meteorological gauging stations are not necessarily spaced evenly. Especially, the densities of installation are low in the Rio guayllabamba Basin including tributaries from A. J. Cubi Gauging Station to Chacapata Gauging Station, the Rio Guachala, a tributary upstream the Rio Pisque, and the Rio Guambi, a tributary of the Rio Guayllabamba.

There are five runoff gauging stations on the main stream and eight on tributaries, the arrangement on the main stream being comparatively apt.

The locations of meteorological and runoff gauging stations are shown in Fig. 4-5.

The hydrological data having a direct relationship with the Project are of the gauging stations on the main stream from the A. J. Cubi site to the D. J. Alambi site.

The rainfall distribution in this basin was used for supplementing these runoff data.

The gauging stations used directly for this Project are shown in Tables 4-4 and 4-5.

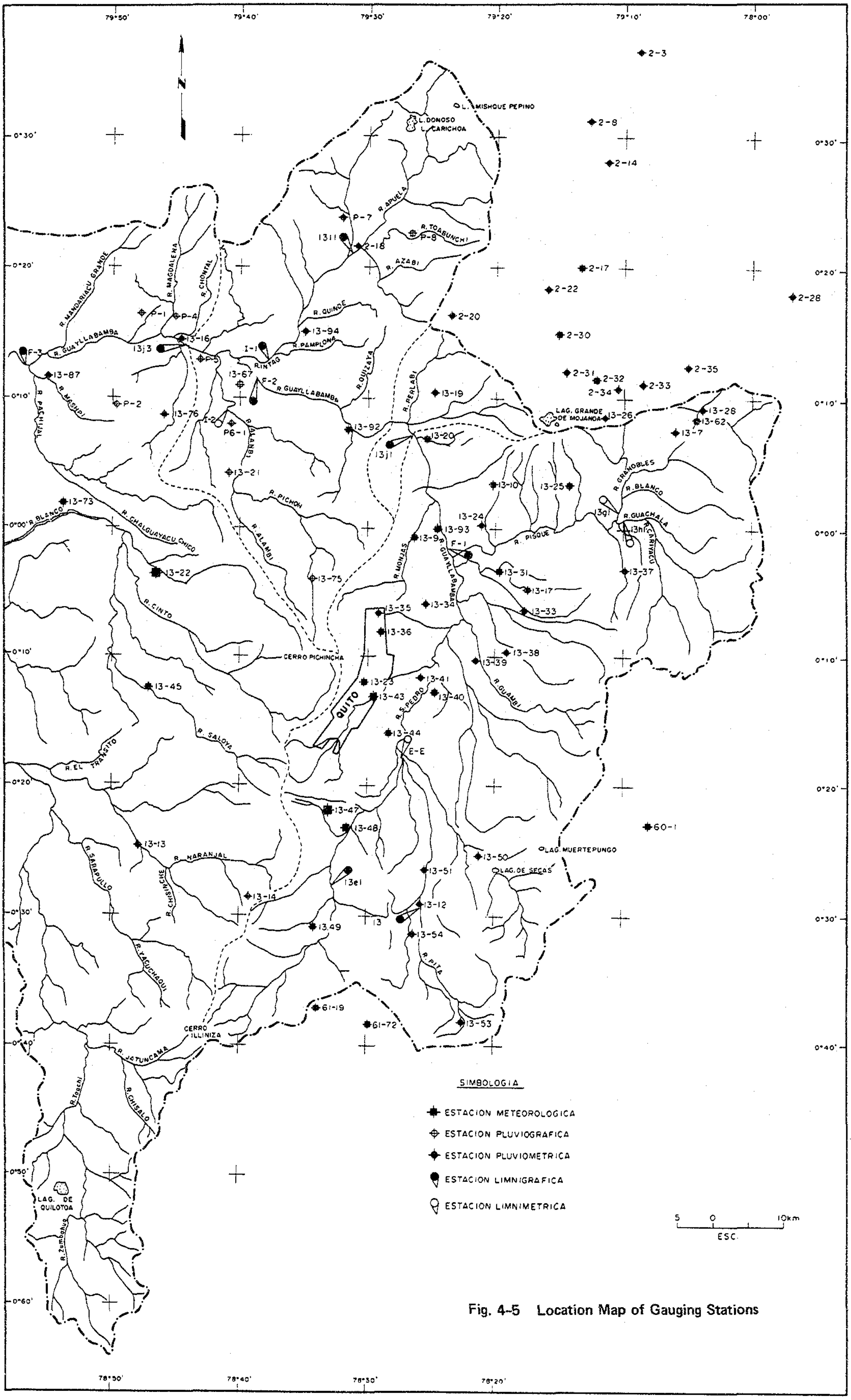


Fig. 4-5 Location Map of Gauging Stations

4.4 Hydrologic Cycle

The period covered by hydrological data used for a project must be a standard one and capable of representing the entire period.

The runoff data obtained by the Survey Team was 18 years at the longest with which it is difficult to estimate long-time cycles.

Generally, the long-term runoff cycle is thought to have the same trend as that of rain. In this case it was decided to use the data of Quito Gauging Station by moving average analyses and power spectral analyses.

The mean annual rainfall at Quito Gauging Station for the 92-year period from 1891 to 1982 is 1,229 mm/yr.

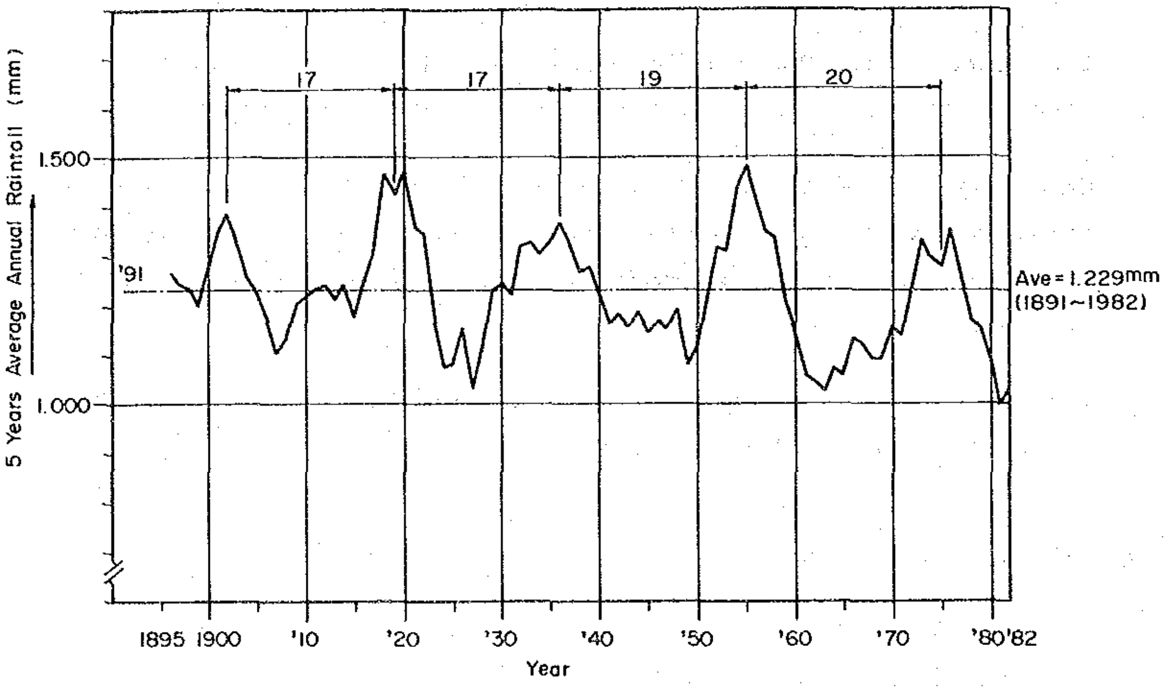
4.4.1 Moving Average Analysis

Fig. 4-6 is a time-series diagram in case the length of time to be averaged is set at 5 years.

The trend of waves for the 92-years period from 1891 to 1982 may be broadly divided into the four parts below.

These are, the 17 years from 1902 to 1919, the 17 years from 1919 to 1936, the 19 years from 1936 to 1955, and the 20 years from 1955 to 1975.

Fig. 4-6 Moving Average Analysis



4.4.2 Power Spectral Analysis

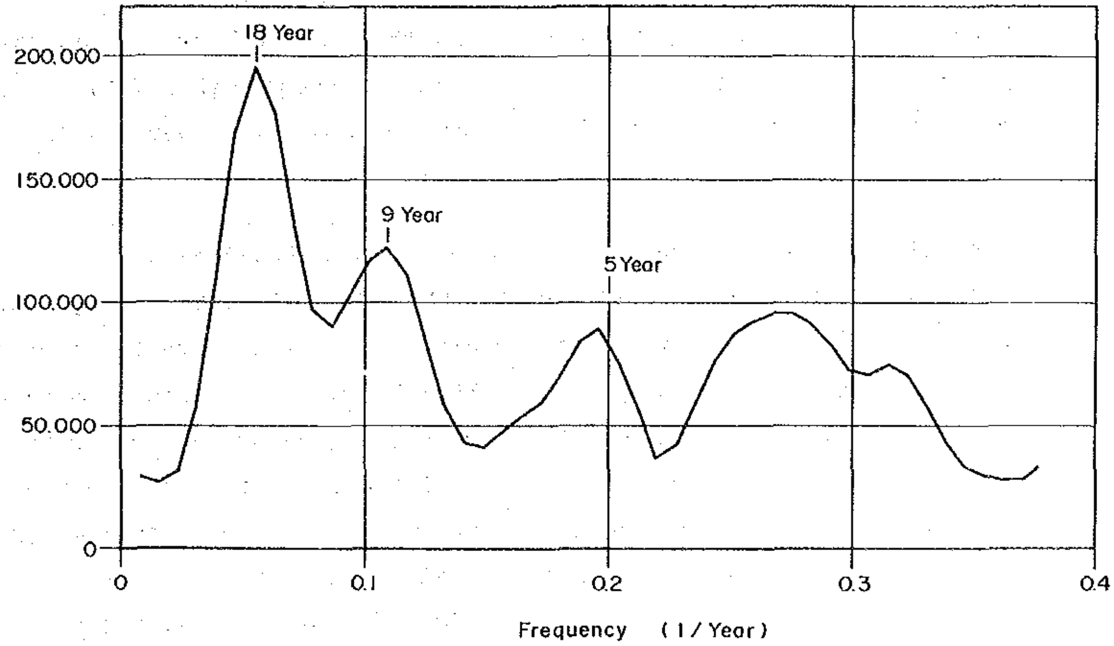
The predominant hydrologic cycle is calculated by power spectral analysis. Firstly, the variation in annual rainfall X (t) [mm] over 92 years is broken up into waves according to each frequency component by the Fourier transform of Eq. 1 , and the power spectrum of frequency (average energy possessed by each frequency) is analyzed by Eq. 2 .

$$X(f) = \int_{-\infty}^{\infty} x\,(t)\ e^{-2\pi ft}\ dx \qquad \text{------------- } 1$$

$$S_x(f) = \lim_{T \to \infty} [1/2\ |x\ (f)|^2] \qquad \text{------------- } 2$$

The results are shown in Fig. 4-7. According to this, the strong cycles are 18, 9, and 5 years in that order.

Fig. 4–7 Smoothed Power Spectrum



In this way, the period 18 years record of measured runoff used in the study of Chespi Project, agrees with the period determined with the methods indicated above.

4.5 Supplementation of Missing Runoff Data

4.5.1 Correlation Between Gauging Stations

It was decided to calculate the inflow at the dam site of this Project from the data of A. J. Cubi Gauging Station and Chacapata Gauging Station in consideration of the rainfall characteristics previously described in 4.2.4. Prior to these calculations, the missing parts of the individual gauging station data were filled in and extended.

According to data studied by INECEL, "Actualizacion del Informe Hidrologico del Proyecto Chespi-Guayllabamba, Diciembre 1984," data that could be used as bases for runoff calculations were those of A. J. Cubi Gauging Station and D. J. Alambi Gauging Station. However, the catchment area between the two gauging stations is large at 2,184 km^2, while further, 70 percent of the remaining catchment area is taken up by the remaining catchment areas of the tributary Rio Alambi and Rio Intag having meteorological characteristics different from those of the main stream, so that the correlation between the two gauging stations is poor.

Becuase of this, it is thought that the runoff at the dam site is of accuracy of monthly level.

In the present study, correlations for three gauging stations were studied adding Chacapata Gauging Station data to the data of the beforementioned two gauging stations. As a result, in simple correlation between A. J. Cubi Gauging Station and Chacapata Gauging Station the coefficient of correlation was 0.96 (monthly), while that between Chacapata and D. J. Alambi Gauging Station was 0.91 (monthly), which were both high. (See Figs. 4-8 to 4-10.)

This signifies that the components of the tributary Rio Alambi and Rio Intag and the components of the main stream were separated by Chacapata Gauging Station. This also signifies the high reliability of Chacapata Gauging Station.

Multiple Correlation Equation

$$Q1 = 2.483 \times Q3 - 0.584 \times Q2 - 20.473$$

$$\gamma = 0.92$$

Fig. 4–8 Relation Between D.J. Alambi G.S and A.J. Cubi G.S (Monthly Data)

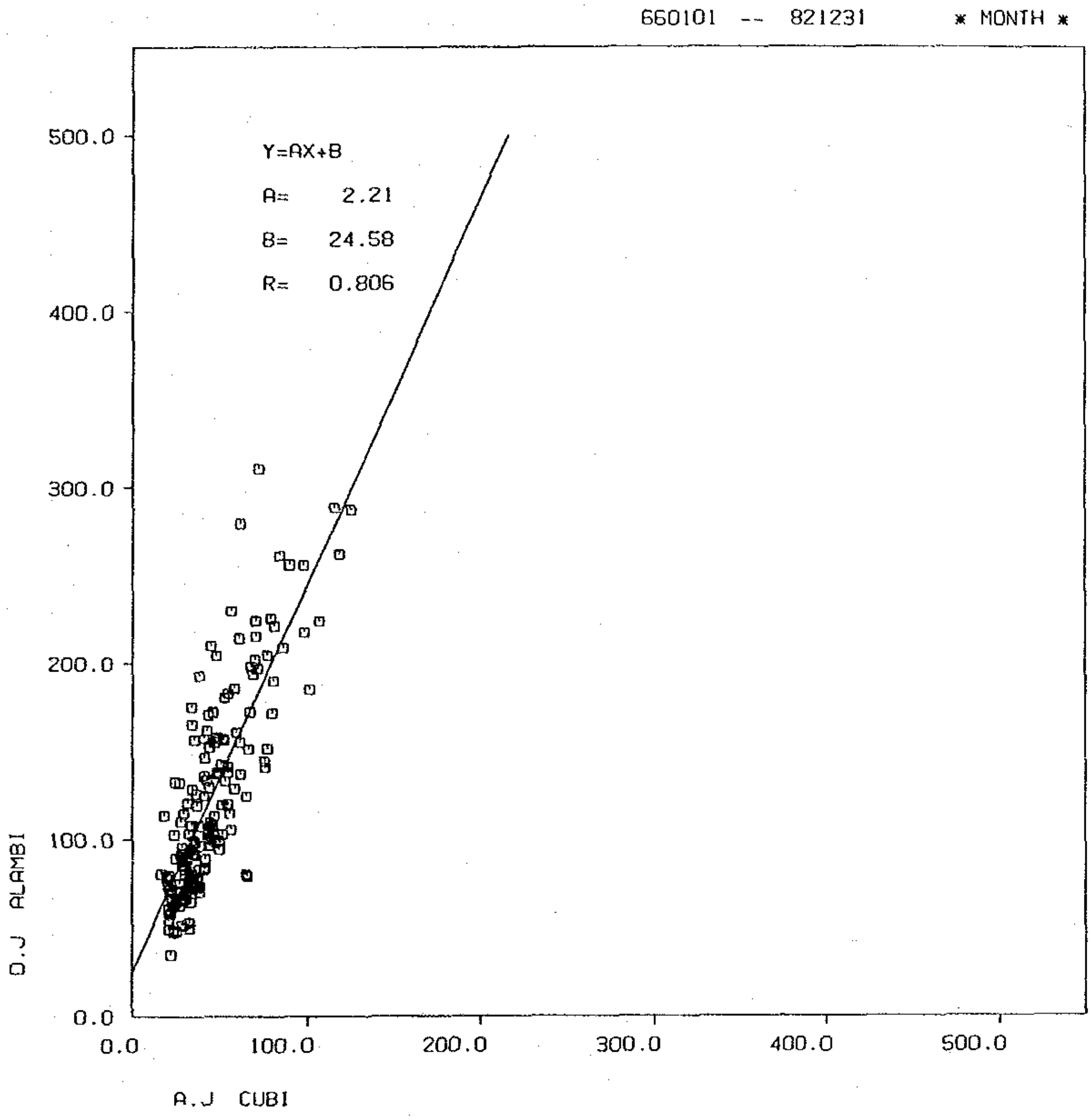


Fig. 4–9 Relation Between Chacapata G.S and D.J. Alambi G.S (Monthly Data)

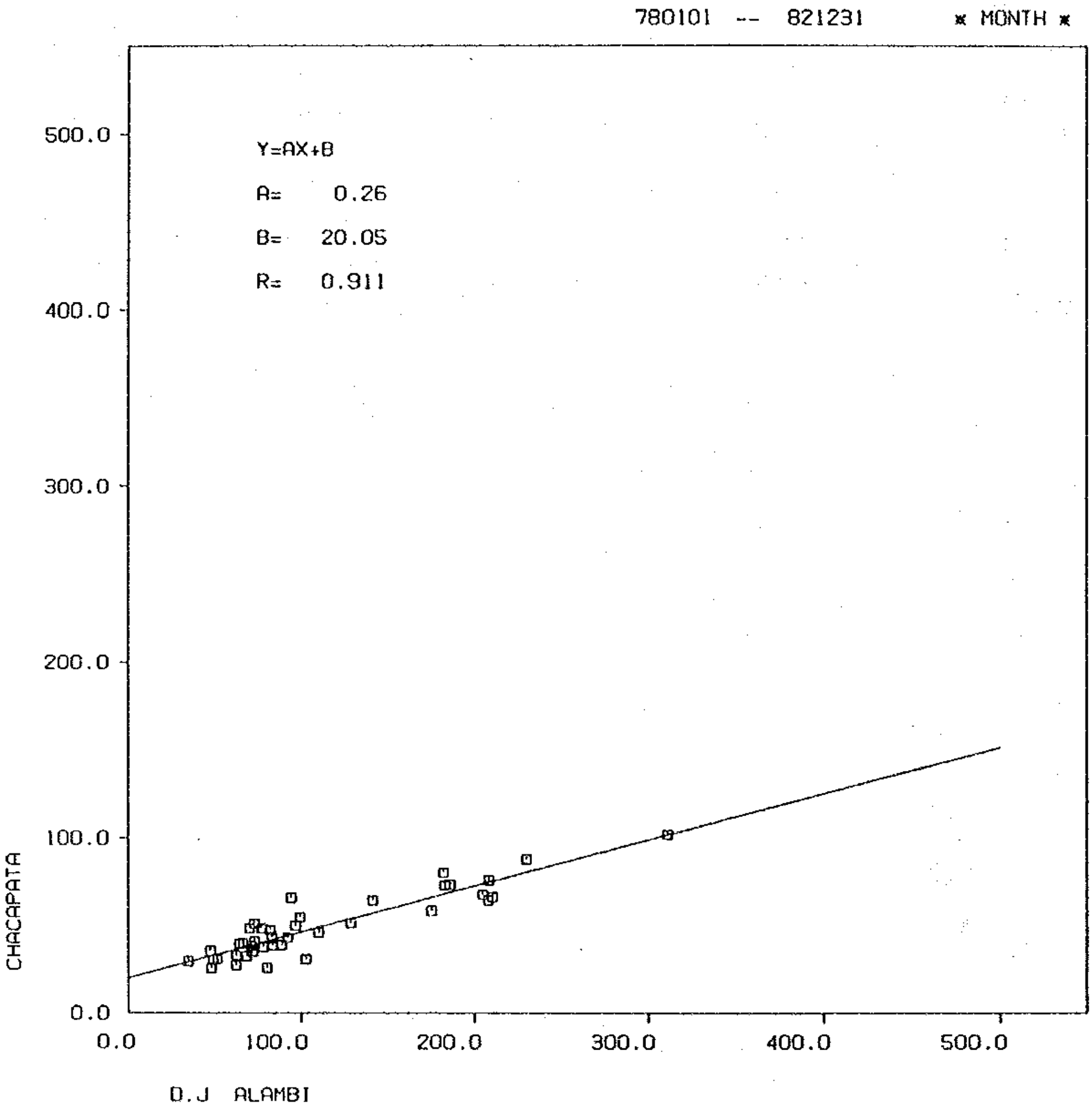
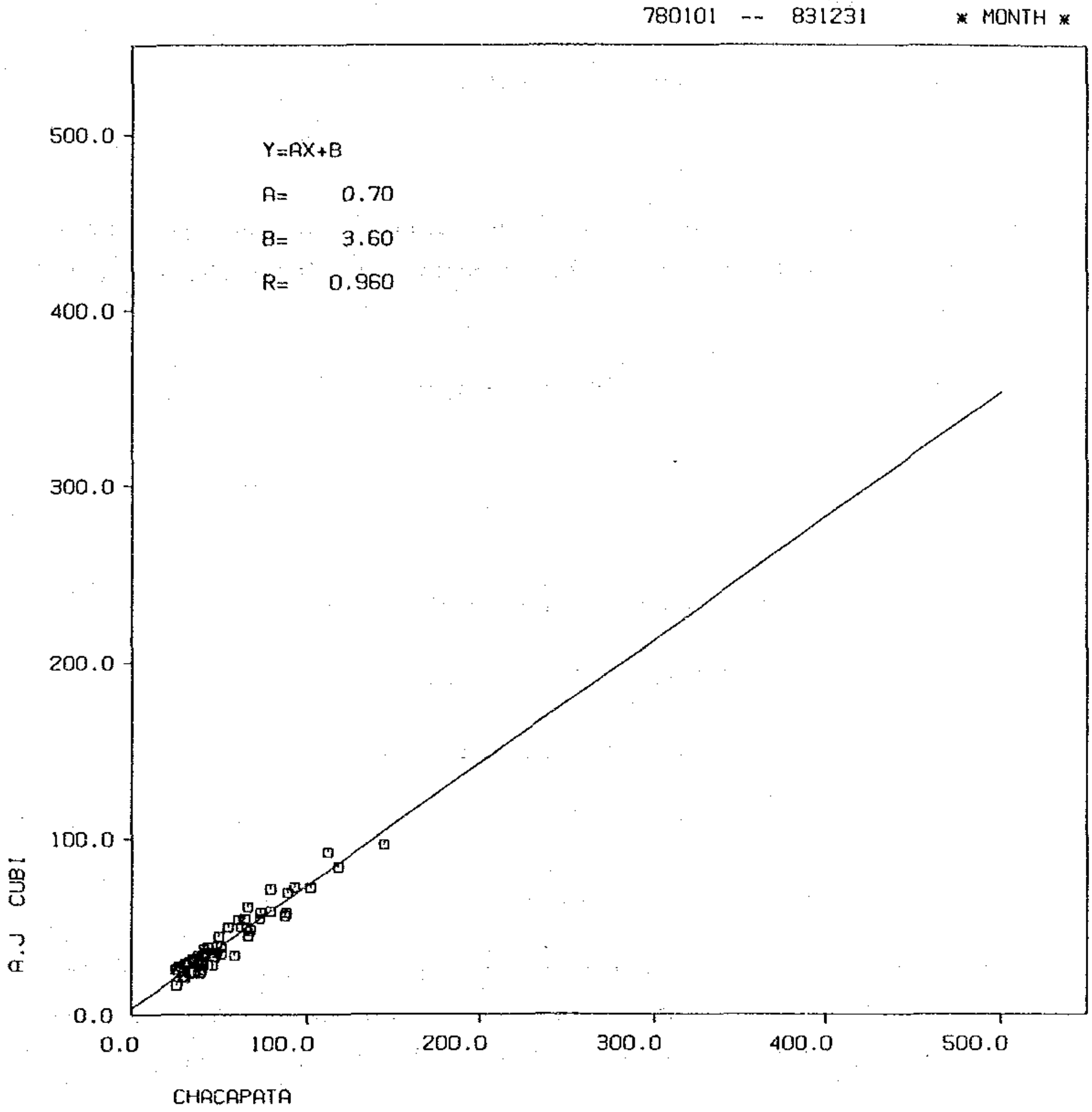


Fig. 4—10 Relation Between A.J. Cubi G.S and Chacapata G.S (Monthly Data)



4.5.2 Supplementation of Missing Data

The supplementation of missing data of A. J. Cubi and Chacapata Gauging Stations and extensions of data were obtained by the correlation formulae given below.

$Q1 = 0.707 \times Q3 + 0.31$ (m^3/s, daily)

$n = 1{,}678 \quad \gamma = 0.93$

$Q3 = 1.414 \times Q1 - 0.44$ (m^3/s, daily)

$n = 1{,}678 \quad \gamma = 0.98$

However, the equations below were applied for the periods of September 1 to October 30, 1973, January 1 to April 30, 1974, and December 18 to 30, 1974.

$Q3 = 0.286 \times Q2 + 0.178$ (m^3/s, daily)

$n = 1{,}285 \quad \gamma = 0.84$

where,

$Q1$: A. J. Cubi Gauging Station runoff (m^3/s)

$Q2$: D. J. Alambi Gauging Station runoff (m^3/s)

$Q3$: Chacapata Gauging Station runoff (m^3/s)

n = number of samples

γ = coefficient of correlation

The average inflows by month of these gauging stations obtained from the daily calculations above are given in Tables 4-6, 4-7, and 4-8, and the daily duration curves in Figs. 4-11, 4-12, and 4-13.

The daily inflows are shown in Appendix. Table A-2-3 to A-2-5.

Table 4–6 Monthly Average Inflow at the A.J. Cubi Gauging Station

			01									<	>
YY	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	CCT.	NOV.	DEC.	AVERAGE
65	30.64	28.11	36.59	71.19	77.65	47.33	36.92	30.20	26.91	37.55	105.17	51.85	48.35
~~66~~	~~40.95~~	~~35.45~~	~~52.61~~	~~48.75~~	~~42.76~~	~~29.48~~	~~35.77~~	~~21.96~~	~~30.59~~	~~35.25~~	~~40.94~~	~~67.12~~	~~40.20~~
67	46.75	61.37	70.20	41.28	34.05	52.76	51.71	36.83	21.35	35.30	33.63	21.16	42.11
~~68~~	~~28.69~~	~~47.20~~	~~70.28~~	~~61.02~~	~~24.96~~	~~32.63~~	~~44.45~~	~~22.91~~	~~27.30~~	~~55.77~~	~~47.65~~	~~30.81~~	~~41.26~~
69	31.65	43.24	38.14	97.45	61.53	50.25	34.40	34.26	31.25	56.58	65.13	75.86	51.61
~~70~~	~~77.38~~	~~123.76~~	~~106.04~~	~~70.63~~	~~97.52~~	~~68.65~~	~~30.29~~	~~37.76~~	~~34.11~~	~~28.72~~	~~66.60~~	~~42.12~~	~~64.83~~
71	57.13	81.71	97.82	90.85	55.70	44.17	37.10	20.13	30.65	50.94	61.74	54.61	56.68
~~72~~	~~80.28~~	~~85.38~~	~~78.93~~	~~81.18~~	~~72.04~~	~~51.88~~	~~46.71~~	~~25.03~~	~~20.67~~	~~21.56~~	~~58.31~~	~~54.57~~	~~56.57~~
73	38.06	43.53	47.84	85.89	45.64	36.60	34.12	32.77	----	----	65.16	65.85	----
~~74~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~	~~----~~
75	100.67	117.50	114.58	83.99	105.26	101.91	102.19	70.78	----	54.01	80.14	72.48	----
~~76~~	~~53.58~~	~~63.50~~	~~70.27~~	~~76.81~~	~~77.20~~	~~79.83~~	~~75.38~~	~~38.46~~	~~23.19~~	~~25.68~~	~~40.97~~	~~43.41~~	~~55.65~~
77	35.55	44.62	49.00	59.60	44.49	45.95	41.59	33.11	32.75	----	----	----	----
~~78~~	~~24.46~~	~~18.45~~	~~40.83~~	~~67.85~~	~~52.36~~	~~43.46~~	~~32.91~~	~~25.45~~	~~23.67~~	~~23.93~~	~~21.24~~	~~33.12~~	~~34.35~~
79	24.39	16.64	----	----	----	54.30	30.13	29.81	38.20	31.42	27.26	25.61	----
~~80~~	~~30.35~~	~~58.71~~	~~61.13~~	~~71.25~~	~~52.92~~	~~49.65~~	~~27.66~~	~~24.10~~	~~22.29~~	~~38.72~~	~~38.70~~	~~35.22~~	~~42.52~~
81	28.04	23.65	56.22	72.08	49.46	28.38	41.45	22.36	23.50	25.68	37.12	28.40	37.19
~~82~~	~~54.42~~	~~44.83~~	~~48.02~~	~~58.00~~	~~68.66~~	~~34.21~~	~~28.16~~	~~29.45~~	~~28.68~~	~~44.21~~	~~58.01~~	~~92.08~~	~~49.14~~
83	70.65	72.40	86.16	56.51	83.91	----	----	----	----	----	35.06	50.00	----
AV	47.42	56.89	66.16	72.61	61.71	50.08	43.00	31.46	27.67	37.69	51.93	49.66	49.63
MA	100.67	123.76	114.58	97.45	105.26	101.91	102.19	70.78	38.20	56.58	105.17	92.08	64.83
MI	24.39	16.64	36.59	41.28	26.96	28.38	27.66	20.13	20.67	21.56	21.24	21.16	34.05

Table 4–7 Monthly Average Inflow at the D.J. Alambi Gauging Station

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YY	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
65	----	----	----	----	----	----	----	----	----	----	----	----	----
66	156.88	156.48	156.53	158.00	161.90	114.75	98.73	71.92	66.93	99.55	124.64	172.30	128.12
67	157.01	279.47	224.18	146.22	165.24	133.17	103.10	78.14	54.40	72.65	65.06	60.63	127.34
68	85.46	155.21	202.23	214.20	132.10	103.40	101.14	66.37	75.36	114.84	98.69	69.43	117.95
69	120.85	170.50	192.79	255.70	155.02	142.81	92.50	78.69	88.98	105.76	124.72	140.85	138.69
70	151.55	287.25	223.90	215.43	217.66	193.90	80.83	78.62	80.73	90.65	151.21	133.67	157.71
71	----	----	----	----	----	152.42	119.56	78.50	85.51	119.77	137.03	120.25	----
72	190.02	255.84	225.70	271.24	197.20	157.17	113.54	89.27	74.39	79.75	128.92	138.26	155.51
73	107.85	129.46	137.56	208.71	172.21	125.94	108.00	94.31	94.88	107.57	80.68	79.54	119.99
74	140.59	286.63	277.09	179.76	----	----	----	----	----	----	----	191.50	----
75	185.07	262.01	288.63	261.02	----	----	----	----	----	----	----	----	----
76	----	----	----	----	204.75	171.62	144.47	96.66	70.43	65.49	83.11	100.49	----
77	91.53	107.80	138.17	160.70	109.53	107.38	83.94	53.51	49.92	----	----	----	----
78	132.67	113.59	175.98	158.02	180.43	104.18	82.05	64.43	----	47.68	49.19	78.16	----
79	102.79	80.48	207.68	208.03	182.12	141.19	83.42	68.83	83.27	72.06	62.63	----	----
80	----	----	----	----	----	95.54	71.31	62.65	34.91	70.53	73.14	77.34	----
81	110.23	175.17	229.59	310.62	94.31	95.82	88.89	58.38	----	48.37	73.41	88.75	----
82	182.88	210.10	204.54	----	----	128.63	92.35	66.48	51.74	96.77	185.76	----	----
83	----	----	----	----	----	----	----	----	----	----	----	----	----
AV	136.81	190.71	203.21	210.59	164.37	131.46	97.58	73.78	70.11	84.75	102.73	111.63	131.01
MA	190.02	287.25	288.63	310.62	217.66	193.90	144.47	96.66	94.88	119.77	185.76	191.50	157.71
MI	85.46	80.48	135.98	146.22	94.31	95.82	71.31	53.51	34.91	47.68	49.19	60.63	117.95

Table 4–8 Monthly Average Inflow at the Chacapata Gauging Station

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YY	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	AVERAGE
65	42.88	39.30	51.30	100.22	108.36	66.48	51.77	42.26	37.62	52.66	148.27	72.88	67.93
66	57.46	49.69	73.94	68.49	60.07	41.25	50.14	30.61	42.82	49.41	57.45	94.47	56.41
67	65.67	86.34	98.96	57.93	47.71	74.17	72.69	51.64	29.74	49.48	47.11	29.48	59.10
68	40.12	66.30	98.94	85.84	37.68	45.70	62.41	31.96	38.16	78.41	66.94	43.12	57.91
69	44.31	60.71	53.49	127.36	86.56	70.61	48.71	48.00	43.74	79.57	91.65	106.83	72.54
70	108.98	174.56	149.50	99.43	137.46	96.63	42.38	52.24	47.79	40.17	93.73	59.11	91.23
71	80.34	115.10	137.88	128.02	78.31	62.01	52.07	28.03	47.90	71.59	86.86	76.78	79.70
72	113.08	125.95	111.17	114.35	101.43	72.92	65.61	34.95	29.79	30.04	82.01	76.72	79.56
73	53.38	61.11	67.71	121.00	64.10	51.31	47.80	45.89	27.31	31.56	91.70	92.67	62.83
74	40.39	82.16	79.43	51.59	----	----	----	----	----	----	----	95.30	----
75	141.90	165.70	161.58	118.32	148.40	143.67	144.06	93.64	----	75.94	112.87	102.05	----
76	75.33	89.35	98.93	108.16	109.73	117.44	106.15	53.94	32.35	35.88	57.49	60.95	78.25
77	49.83	62.66	68.85	63.84	62.46	64.53	55.37	46.37	45.87	----	----	----	----
78	34.15	25.71	57.29	55.50	73.60	61.01	47.37	39.74	38.92	35.59	30.53	38.02	48.21
79	30.92	25.83	64.24	75.81	80.39	64.29	38.59	32.66	43.37	34.94	27.20	26.60	45.49
80	36.00	79.25	65.99	79.12	60.51	54.84	38.61	33.07	29.62	48.46	51.01	48.62	51.93
81	45.97	58.57	87.55	101.71	65.72	39.85	58.16	31.18	32.18	25.45	41.09	38.87	52.12
82	72.94	66.21	67.47	88.17	95.00	51.39	43.13	40.11	30.70	49.77	73.35	111.48	65.86
83	88.85	92.85	121.30	143.98	117.35	64.24	45.71	37.09	36.46	42.35	42.37	62.21	74.44
AV	64.34	80.38	90.26	97.83	85.27	68.74	59.62	43.30	36.96	48.90	70.68	68.68	67.81
MA	141.90	174.56	161.58	143.98	148.40	143.67	144.06	99.64	47.79	79.57	148.27	111.48	91.23
MI	30.92	25.71	51.30	51.59	37.68	39.85	38.59	28.03	27.31	25.45	27.20	26.60	45.49

Fig. 4-11 Daily Duration Curve at the A.J. Cubi G.S.

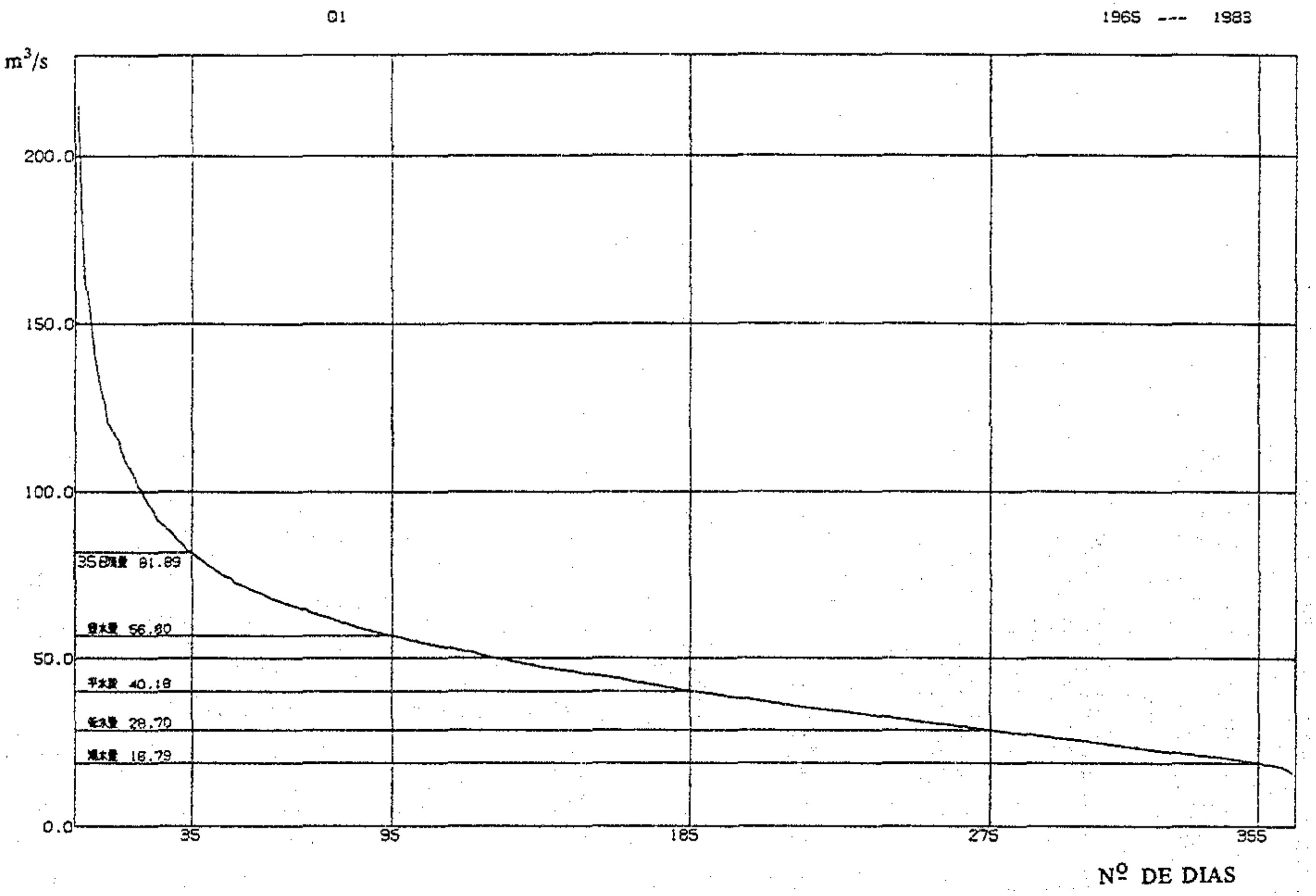


Fig. 4-12 Daily Duration Curve at the D.J. Alambi G.S.

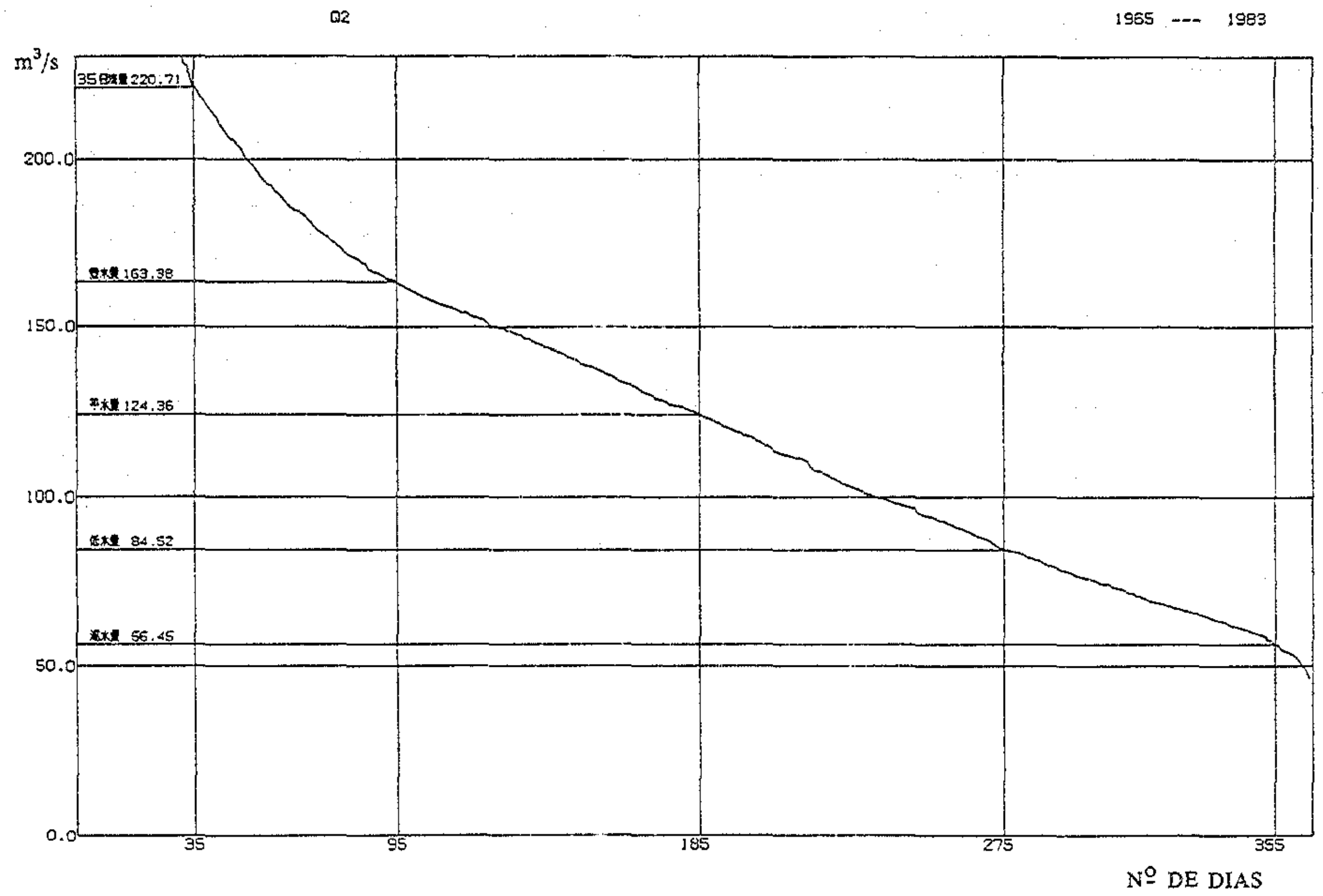
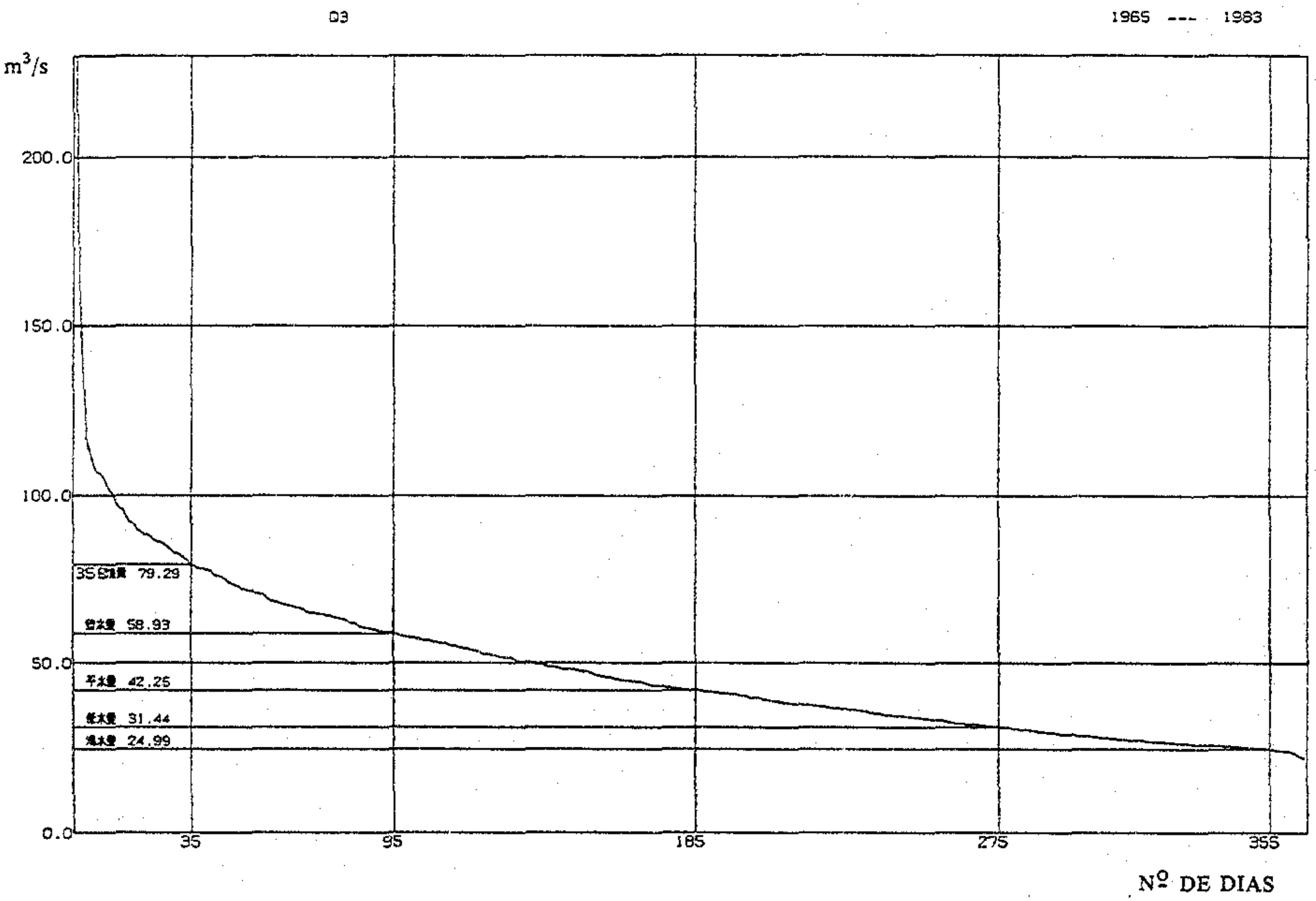


Fig. 4-13 Daily Duration Curve at the Cacapata G.S.



4.6 Site Runoffs

The site runoffs used for evaluation of the Project are not only of the Chespi site, but include the hydroelectric power stations of all of SNI. However, for runoffs of sites other than Chespi, the data furnished by INECEL were used.

4.6.1 Chespi Dam Site Runoff

The catchment area of the dam site in this Project is 4,606 km^2, the site being located between the upstream A. J. Cubi Gauging Station and the downstream Chacapata Gauging Station, and the distances from the respective gauging stations are 9 km and 23 km. The catchment areas between these points are 242 km^2 from the dam site to A. J. Cubi Gauging Station and 299 km^2 from the dam site to Chacapata Gauging Station.

Accordingly, the dam site is at around the midpoint between the above two gauging stations in terms of catchment area.

Rainfall in the vicinity of the dam site differs drastically according to the district. That is, whereas it is an annual mean of approximately 550 mm in the vicinity of the upstream A. J. Cubi Gauging Station, it changes abruptly to approximately 1,700 mm in the vicinity of Chacapata Gauging Station 32 km downstream.

It was decided to calculate the inflow at the dam site of this Project from the data of A. J. Cubi and Chacapata Gauging Stations in consideration of the above-mentioned rainfall characteristics.

The calculation formula is given below.

$$Q4 = Q1 + (Q3 - Q1) \times \frac{P(1 - 4) \times A(1 - 4)}{P(1 - 3) \times A(1 - 3)}$$

where,

Q4: Chespi Dam project site runoff (m^3/s, daily),
CA = 4,606 km^2

Q1: A. J. Cubi Gauging Station runoff (m^3/s, daily),
CA = 4,364 km^2

Q3: Chacapata Gauging Station runoff (m^3/s, daily)
CA = 4,905 km^2

P(1 - 4): mean rainfall at remaining catchment area between project site and A. J. Cubi Gauging Station (1,083 mm/yr)

A(1 - 4): remaining catchment area of above (242 km^2)

P(1 - 3): mean rainfall between A. J. Cubi and Chacapata Gauging Stations (1,070 mm/yr)

A(1 - 3): remaining catchment area of above (541 km^2)

$$Q = Q1 + 0.453\ (Q3 - Q1) \quad (m^3/s)$$

Table 4-9 shows the monthly mean inflow and Fig. 4-14 the average duration curve. The daily inflow is shown in Table of Appendix.

4.6.2 Runoffs at Other Sites

The runoffs of hydroelectric power station project sites scheduled to be incorporated in the SNI by 2000 A.D. are given in Table of Appendix Table 2-7 to 2-11.

These quantities were calculated at "Division de Hidrologia y Sedimentologia" of INECEL.

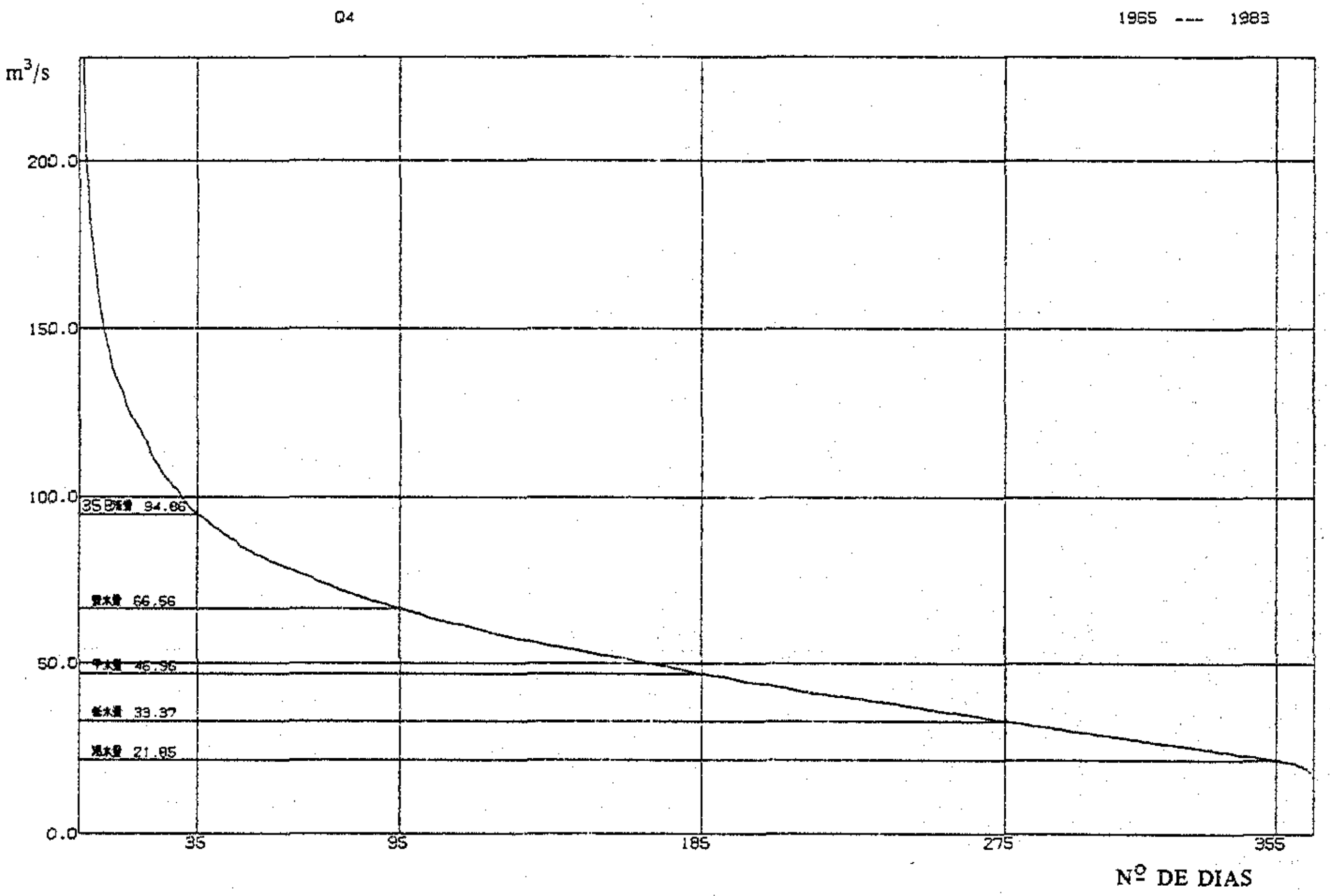
Table 4–9 Monthly Average Inflow at the Project Dam Site

Table 4-9 Monthly Average Inflow at the Project Dam Site

YY	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC. <	> AVERAGE
65	36.19	33.18	43.25	84.34	92.01	56.00	43.65	35.67	31.76	44.39	124.69	61.38	57.22
66	48.43	41.90	62.77	57.69	50.58	34.82	42.28	35.88	36.13	41.66	48.42	79.51	47.54
67	55.32	72.68	83.28	48.82	40.74	67.46	61.21	43.54	25.15	41.72	39.74	24.93	49.80
68	32.87	55.85	82.27	72.26	31.82	39.55	52.59	27.31	32.22	66.03	56.39	36.39	48.80
69	37.38	51.16	45.10	115.53	72.86	59.47	40.66	40.48	36.91	67.00	77.15	89.89	61.09
70	91.70	146.77	125.72	63.68	115.61	81.33	35.77	44.05	40.31	33.91	78.89	49.82	76.79
71	67.64	96.83	115.97	107.69	65.94	52.35	43.86	23.71	36.20	60.29	73.12	64.66	67.10
72	55.14	105.95	93.54	56.20	85.35	61.42	55.27	29.52	24.35	25.40	69.04	64.61	66.98
73	45.00	51.49	56.61	101.79	54.01	43.26	40.32	38.71	23.10	26.66	77.18	78.00	52.93
74	34.07	65.13	66.84	43.47	(79.60)	(65.18)	(59.64)	(44.77)	(39.12)	(66.25)	(75.25)	80.19	75.88
75	119.34	129.33	135.87	99.54	124.80	120.83	121.16	83.86	(50.70)	63.94	94.97	85.88	97.40
76	63.43	75.21	83.25	91.01	91.48	94.60	89.32	45.47	27.34	30.30	48.45	51.36	65.89
77	42.02	52.79	57.99	70.58	52.63	54.36	49.19	39.12	38.69	(43.23)	(37.42)	(32.86)	45.87
78	28.85	21.76	48.29	80.38	61.59	51.41	39.46	31.92	30.58	29.21	25.45	35.34	40.47
79	27.35	20.81	53.08	63.83	69.14	58.83	23.96	31.10	40.54	33.02	27.23	26.06	40.49
80	32.91	63.01	63.33	74.82	56.91	52.00	37.62	28.16	25.61	43.13	44.28	41.29	46.78
81	36.16	44.92	70.41	85.50	56.82	33.58	49.02	26.36	27.43	25.57	38.91	33.14	43.95
82	62.81	54.51	56.83	71.64	80.59	41.99	34.94	34.28	29.60	46.73	64.96	100.87	56.72
83	78.89	81.66	102.08	118.01	99.05	53.47	38.55	31.32	30.79	37.02	38.37	55.53	63.62
(84)	(59.18)	(88.32)	(77.48)	(105.59)	(84.50)	(65.20)	(47 26)	(30.39)	(49.73)	(56.32)	(51.84)	(45.67)	(63.27)
AV	54.78	68.62	76.23	83.62	73.29	59.05	50.53	36.77	33.81	44.09	59.59	56.87	58.10
MA	119.34	146.77	135.87	118.01	124.80	120.83	121.16	83.86	40.54	67.00	124.69	100.87	76.79
MI	27.35	20.91	43.25	43.47	31.82	33.58	32.62	23.71	23.10	25.40	25.45	24.93	40.47

( ): Estimated by INECEL

Fig. 4-14 Daily Duration Curve at the Project Dam Site



4.7 Design Flood Discharge

4.7.1 General

The design flood discharge used for this Project was computed by a probability analysis for the reasons listed below,

i) The regulating pondage is to be of daily regulating type and of small scale.

ii) The dam is to be a gravity-type concrete dam.

iii) There are few houses and irrigation facilities downstream that would be submerged by flood.

Two kinds of design flood discharges were calculated for the purposes of designing the spillway of the dam and for designing care of river during the period of construction.

One is a flood discharge calculated based on the records of floods observed up to the present at A. J. Cubi Gauging Station (Case I), and the other a flood discharge calculated based on rainfall data of Quito Meteorological Gauging Station (Case II).

Each involves a problematic point.

With the former, it is the small number of data (N = 19), while with the latter, it is the large number of uncertainties.

Especially, in case of calculation from rainfall data, the uncertainties below can be pointed out.

i) Relationship between rainfall at Quito and the mean rainfall in the basin

ii) Effective rainfall (runoff coefficient)

iii) Application of standard-type hydrograph

It is necessary to consider data of the entire basin in order to calculate the above items. However, such data are scarce similarly to the case employing flood records. Therefore, even though the rainfall at Quito consists of data for a long period of 89 years, the reliability of the study results is restricted by data for a period which is short.

As discussed above, both cases are accompanied by problems, and design flood discharges were calculated by i) actual flood records for care of river (Case I), and ii) rainfall data for dam spillway (Case II).

The probable flood discharges at the projected dam site are given in Table 4-10 and Fig. 4-15.

Table 4-10 Probable Flood Discharge at the Project Dam Site

C.A = 4.606km^2 Unit : m^3/s

Return Period Case	2	3	20	50	100	200	500	1,000
I	360	450	669	788	882	979	1,100	1,214
II	—	—	1,397	1,553	1,641	1,685	1,935	2,068

Note)

Case－I : Based on the obtained flood discharge records at the A.J.Cubi Gauging Station

Case－II : Based on the Rainfall data

Design flood discharge, as adopted in Chapter 7 "Preliminary Design", is as follows:

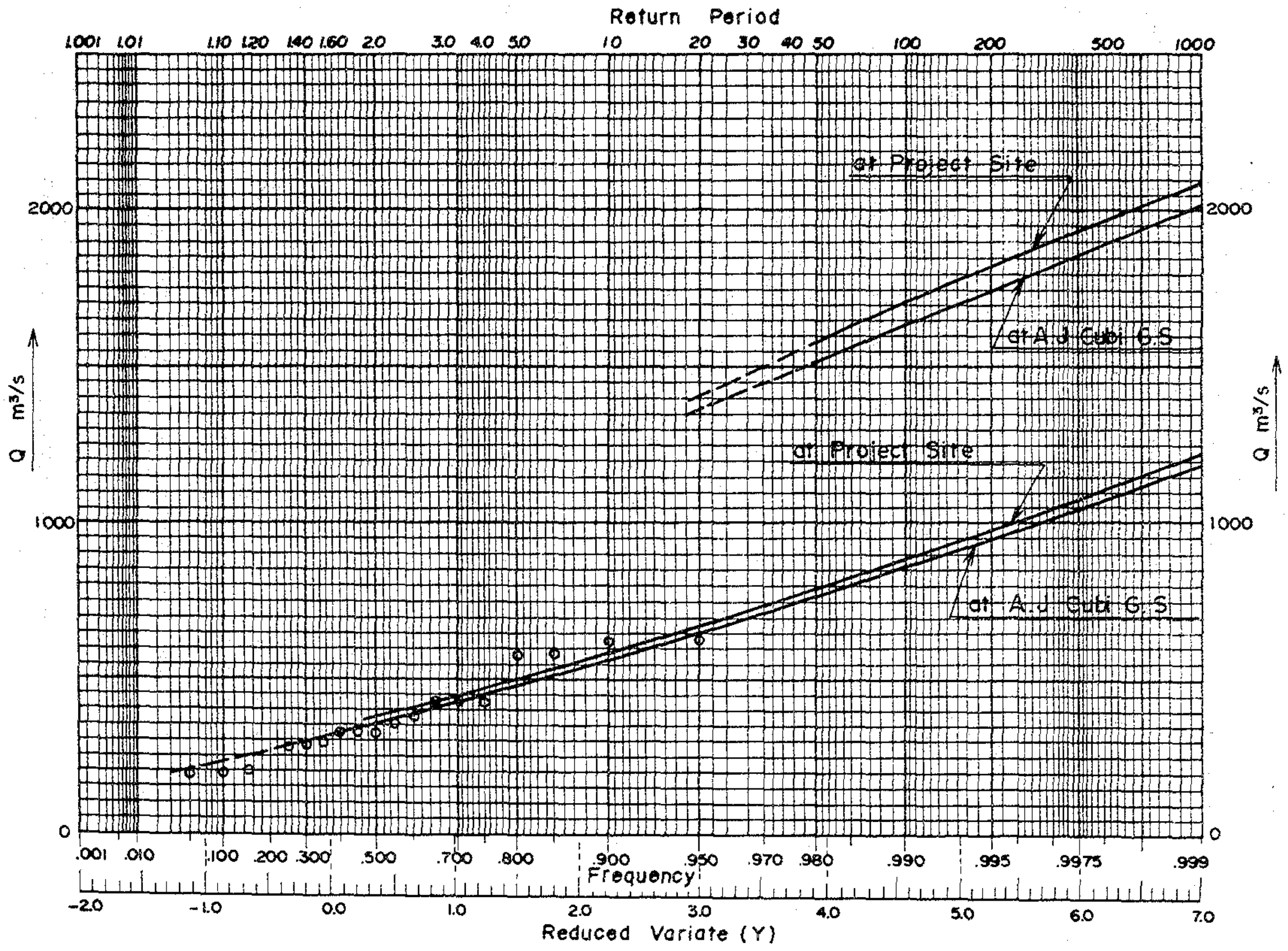
i) Diversion during construction

$Q_F = 450\ m^3/s$: taken from 3-year-flood (Case I)

ii) Spillway

$Q_F = 2,300\ m^3/s$: 110% of 1000-year-flood (Case II)

Fig. 4–15 Probable Flood Discharge



4.7.2 Case I: Flood Discharge Obtained from A. J. Cubi Gauging Station Runoff Data

a) Data

Annual maximum flood discharges observed at A. J. Cubi Gauging Station from 1964 to 1983 (see Table 4-11).

Number of samples: $N = 19$

b) Total calculations

i) Raw data

Average	$\overline{X} = 369.14\ m^3/s$
Dispersion	$S^2 = 20.111$
Standard deviation	$S = 141.81$
Coefficient of variation	$C_v = 0.384$
Unit strain	$C_s = 0.671$
Kurtosis	$C_k = 3.096$

ii) Logarithmic transformation value

Average	$(\overline{X}) = 2.5375$
Dispersion	$(S^2) = 0.0272$
Standard deviation	$(S) = 0.1650$
Coefficient of variation	$(C_v) = 0.0650$
Unit strain	$(C_s)_y = 0.1051$
Kurtosis	$(C_k)_y = 2.8592$

c) Selection of distribution function

The various distribution functions have the following relationships:

i) Normal distribution: $C_s = 0,\ C_k = 3$

ii) Logarithmic normal distribution: $(C_s)_y = 0,\ (C_k)_y = 3$

iii) Pearson III type distribution: $C_k = 1/2\ (3\ C_s^2 + 6)$

Note) Becomes normal distribution when $C_s = 0$.

Table 4–11 Flood Discharge Records at the A.J. Cubi Gauging Station

Year	Hmax	Equation	Qmax	No.
1964	3.030	$Q = 15.9\ (h+0.22)^{2.55}$	321.14	10
65	3.420	"	428.75	5
66	2.835	"	274.27	15
67	2.880	"	284.69	14
68	2.765	$Q = 18.9\ (h+0.30)^{2.51}$	314.34	11
69	2.970	"	369.81	8
70	3.590	"	571.79	4
71	3.140	"	419.98	7
72	3.600	"	575.48	3
73	2.740	"	307.95	12
74	-			
75	3.735	"	626.80	1
76	4.480	$Q = 39.9\ (h-0.10)^{1.86}$	622.46	2
77	2.240	$= 17.1\ (h+0.45)^{2.46}$	195.07	18
78	3.130	$= 30.1\ (h+0.10)^{2.09}$	348.98	9
79	2.990	$= 15.5\ (h+0.40)^{2.39}$	286.75	13
80	2.750	$= 18.5\ (h+0.40)^{2.26}$	247.37	16
81	2.420	"	192.63	19
82	3.615	"	428.06	6
83	2.450	"	197.30	17
84	-			
			$\overline{X}$=369.14	

iv) Logarithmic Pearson III type distribution:

$(C_k)_y = 1.13$, $C_k = 5.4$

v) Gumbel distribution (Extreme Type I):

$Cs = 1.13$, $Ck = 5.4$

Based on the above, normal distribution and Log Pearson Type III are applied.

In general, Log Pearson Type III or Gumbel is adopted in flood analyses. Therefore, it was decided to apply the log Pearson Type III in this study.

d) Probable flood at A. J. Cubi site

The basic equations are as follows:

$$P = 1 - F = 1 \frac{1}{\Gamma(P+1)} \int_0^z e^{-z} \cdot Z^P d_z$$

$$Z = \frac{1}{a} (Y' - m)$$

$$0 \leqq z < \infty$$

where,

P: excess probability of distribution of Y'

F: non-excess probability of distribution of Y'

Y': logarithmically transformed value of hydrological quantity

P, a, m: constants

$\Gamma(P+1)$: gamma function of argument P + 1

The results of calculations are given in Table 4-12.

Table 4–12 Probable Flood Discharge at the *A.J. Cubi Gauging Station*

Tr	P %	QTr m³/s
2	50	350
5	20	474
10	10	563
20	5	651
50	2	768
100	1	859
200	0,5	953
500	0,2	1,081
1,000	0,1	1,182
10,000	0,01	1,547

$X(1 - n),\ N = 19$

$y = \mathrm{Log}\ x$

$$\bar{y} = \frac{1}{N}\sum y = \frac{1}{N}\sum_{i-1}^{N} \log x$$

$= 2.5375$

$S_y = 0.1650$

$y = y\sqrt{y} = 4.0421$

$y = 0.0272$

$C_v = 0.0650$

$C_s = 0.106$

e) Probable flood discharge at project site

The projected dam site is located approximately 9 km downstream of A. J. Cubi Guaging Station. The remaining catchment area in between is 242 km^2 and this corresponds to 5.5 percent of the abovementioned gauging station's catchment area. The probable flood discharge at the project site was calculated here by the equation below.

$$Qdam = Qcubi \times \frac{Adam}{A_{cubi}}$$

$$= 1.027 \times P_{cubi}$$

The calculation results are shown in Table 4-13.

Table 4–13 Probable Flood Discharge at the Project Dam Site

Tr	P %	QTr m^3/s
2	50	360
5	20	487
10	10	578
20	5	669
50	2	789
100	1	882
200	0.5	979
500	0.2	1,110
1,000	0.1	1,214
10,000	0.01	1,589

4.7.3 Case II: Flood Discharge Obtained from Rainfall Data

a) Data

i) Daily maximum rainfall observed at Quito Meteorological Gauging Station during the period from 1891 to 1983. Number of data N = 86 (See Appendix Table)

ii) Mean rainfall in A. J. Cubi Gauging Station catchment area

iii) Flood records at A. J. Cubi Gauging Station

b) Statistical quantities of rainfall data of Quito Meteorological Gauging Station

i) Raw data

Average $\bar{X} = 41.61$ mm
Dispersion $S^2 = 88.98$
Standard deviation $S = 9.43$
Coefficient of variation $C_v = 0.227$
Unit strain $C_s = 0.671$
Kurtosis $C_k = 4.622$

ii) Logarithmic transformation value

Average $(\bar{X}) = 1.609$
Dispersion $(S^2) = 0.00877$
Standard deviation $(S) = 0.09364$
Coefficient of variation $(C_v) = 0.05820$
Unit strain $(S_s)_y = 0.38500$
Kurtosis $(C_k)_y = 3.1914$

c) Selection of distribution function

When the results of b) above are collated with the features of the various distribution functions, it can be seen that these data can be applied to log Pearson Type III and Gumbel.

d) Probable rainfall at Quito

The results of probable rainfall calculations for the Quito Meteorological Gauging Station site are as shown in Table 4-14.

Table 4–14 Probable Daily Rainfall at the Quito Meteorological Gauging Station

Probability		Log Pearson Type Ⅲ	Gumbel	Adopted Vaule
%	Year			
50	2	40.1	40.1	40
20	5	48.5	48.9	49
10	10	54.0	54.8	55
5	20	59.2	60.5	61
2	50	66.1	67.7	68
0.5	200	71.3	73.2	74
0.2	500	83.6	85.8	86
0.1	1,000	89.2	91.3	92

e) Relation between mean rainfall in basin and rainfall at Quito Meteorological Gauging Station site

In general, the relation between the rainfall at a site and the mean rainfall of the basin will differ depending on the meteorological conditions at that time, and it is difficult to show a constant trend. However, it is possible for the distribution range to be determined inductively from recorded values.

According to reports of INECEL, the relation between rainfall at Quito and the critical value of mean rainfall in the basin (expressed by reduction factor) is as shown in Table 4-15.

Table 4–15 Relation between Daily Rainfall and Reduction Factor

P_{QUITO} Item	20 mm	25	30	35	40	45	50
No of event	58	45	27	12	4	3	2
Reduction Factor (%)	72	69	68	62	52	48	48

$$\text{Reduction Factor} \quad Fs = \frac{\Sigma P \cdot A / \Sigma A}{P_{QUITO}} \times 100(\%)$$

According to this, the reduction factor (critical value of mean rainfall) shows a trend of reduction as rainfall at Quito increases.

The above relationship expressed in the form of a regression equation will be as follows:

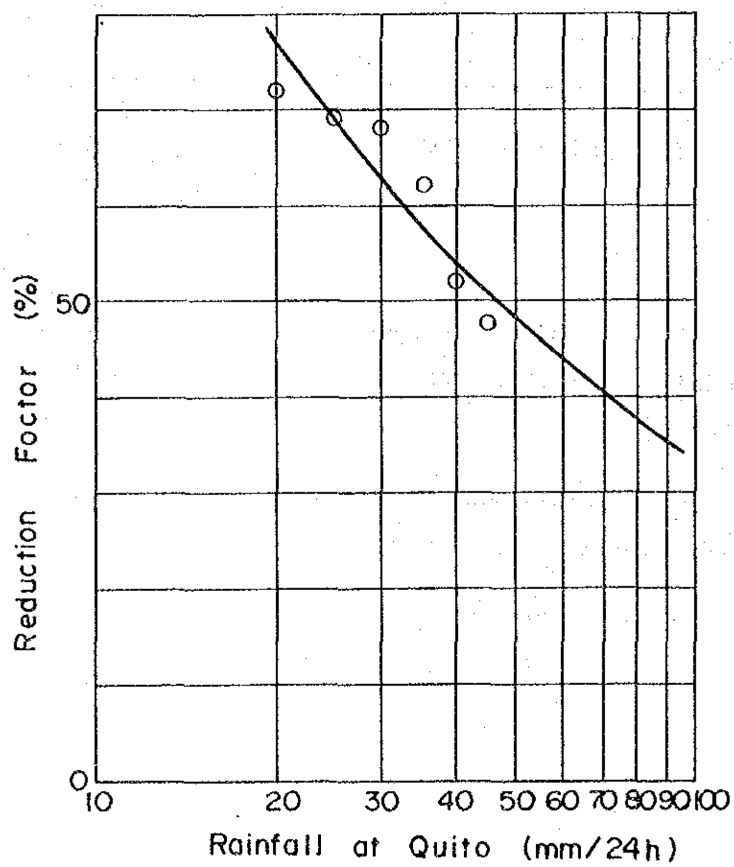
$$F_s = 352.39 \; P_{Quito}$$

$$\gamma = 0.94$$

Assumed Reduction Factor

P_{QUITO} mm)	50	60	70	80	90	100
Fs (%)	48.2	43.9	40.6	37.9	35.7	33.9

Fig. 4–16 Relation between Daily Rainfall and Reduction Factor



However, the data are insufficient for accurately estimating these relationships. In the present study, the reduction factor was taken to be 0.4 to be on the conservative side. The mean rainfall values adopted are given in Table 4-16.

Table 4–16 Probable DailyRainfall of the Project Basin

Probability (year)	P_{Av}mm / 24 hours
50	27.2
100	28.8
200	29.6
500	34.4
1,000	36.8

f) Effective rainfall (Runoff coefficient)

Here, as a handy induction method, it was decided to obtain effective rainfall from runoff coefficient. The runoff constants obtained from flood records of the Rio Guayllabamba are as shown below.

A. J. Cubi G/S Feb. 1970 $c = 0.37$*
May 1982 $c = 0.43$

D. J. Alambi G/S Feb. 1969 $c = 0.34$*

* The INECEL's report, "Proyecto Hidroelectrico Guayllabamba, Estudios de Factibilidad, Aproviemiento Villadora-Contal INFORME FINAL - AGOSTO 1979, TOMO II-A"

These values are for direct runoff and base flows are not included.

However, as has been pointed out in previous reports, these values are somewhat small from a general point of view.

The runoff coefficient will be taken to be 0.6 for the purposes of this study.

g) Unit hydrograph

The duration (time base) of a flood in this basin will be roughly as follows when trial-calculated by a general empirical formula.

$$N = 0.8A^{0.2}$$

$$= 4.28 \text{ day} = 103 \text{ hr}$$

where,

A: catchment area 4,364 km^2

Calculated by the Snyder Method it will be approximately 4.91 days. On the other hand, according to actual records, the value is about 1 to 2 days for a period of short duration. (See Table 4-17.)

The peak duration is estimated at approximately 14 to 16 hours, assuming that the duration of rainfall is 6 hours according to the Snyder Method. The longest of actual peak durations is 14 hours, which is roughly similar.

In view of the above, it is thought that floods recroded at A. J. Cubi Gauging Station mostly were not produced from the entire basin, but from a part of the tributaries. The reasons for this are thought to be the relatively large catchment area of this basin of 4,364 km^2, and the fact that the rainfall pattern is affected by topography.

Consequently, the shapes of the hydrographs for these recorded values show a trend of peak flood discharge being large for the volume of the flood because of the short durations of the floods.

It is recommendable that this trend should be verified by further study.

For the study here, it was decided to adopt the hydrograph for May 27, 1982 which is the most rugged and largest in scale of the records available. (See Fig. 4-17.)

Fig. 4-17 Unit Hydrograph of the A.J. Cobi Basin
(RAINFALL : 1 cm)

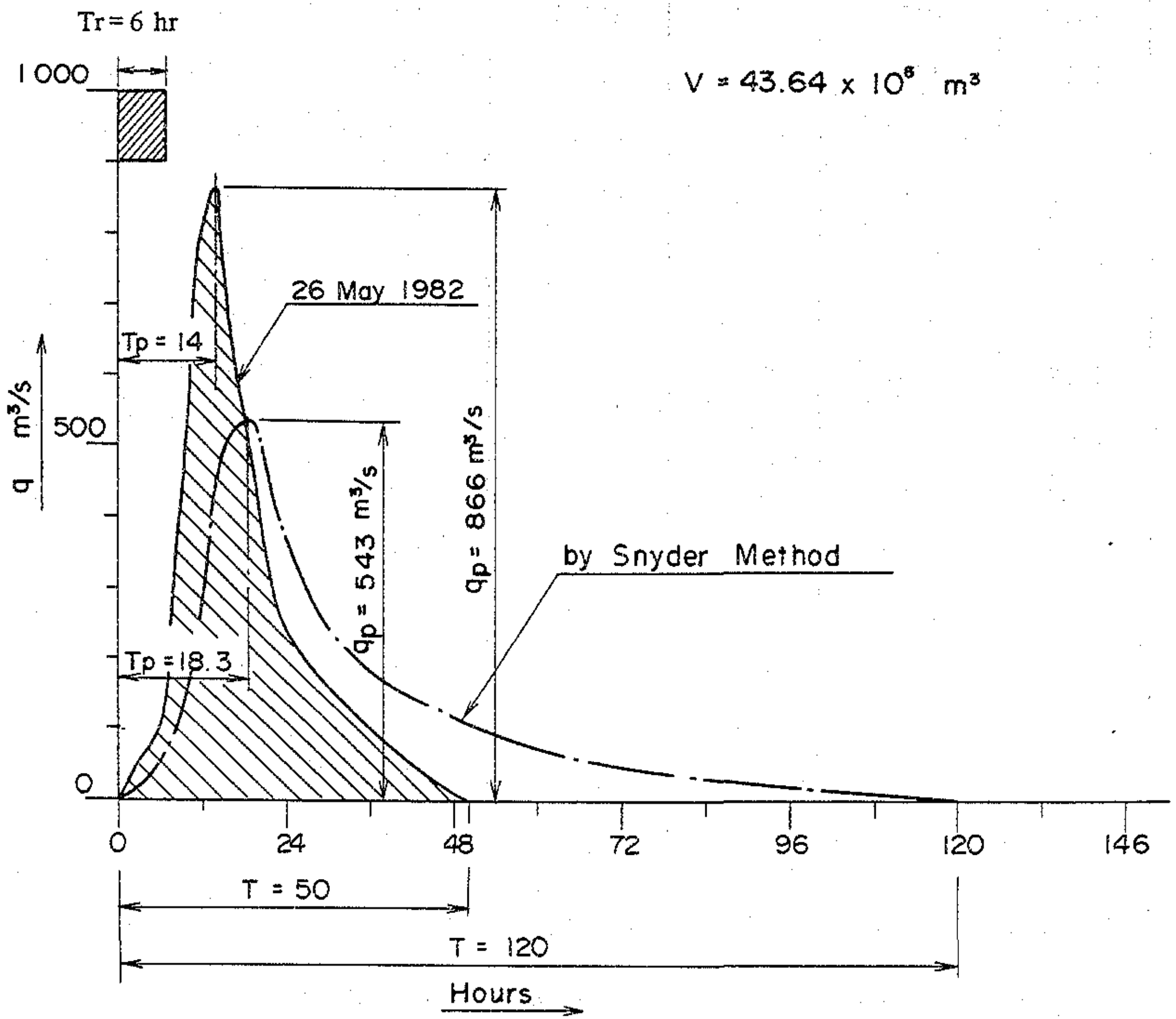


Table 4—18 Principales Caracteristicas de Credidas Estacion Guayllabamba A.J. Cubi

FECHA	Q(pico) m^3/seq	Q(base) m^3/seq	Q(pico) Crecida m^3/seq	Volumen Crecida x 10^6 m^3	Tiempo pico hr	Tiempo base hr	Caudal medio m^3/seq	$\frac{Q(pico)}{Q(med.)}$
19-XI-65	348	152	196	5.85	5.0	16.2	100.3	1.94
20-XI-65	376	178	198	4.49	5.4	14.8	84.3	2.34
21-XI-65	410	152	258	6.26	3.2	22.6	76.9	3.34
25-XI-65	250	120	130	2.94	4.6	14.4	56.7	2.30
6-II-70	425	78	347	12.50	9.0	34.0	102.1	3.40
25-II-75	324	100	224	6.05	4.8	14.0	120.0	1.86
26-II-75	357	110	247	5.08	5.0	14.8	95.0	2.58
18-VII-76	260	72	188	2.99	4.6	15.6	53.2	3.52
19-VII-76	305	104	201	5.76	5.6	17.6	90.9	2.22
24-IV-76	318	92	226	6.83	6.0	18.6	102.0	2.22
27-V-82	428	62	366	18.47	14.0	50.0	102.6	3.57
Med.	345.54	110.91	234.64	7.02	6.11	21.15	89.45	2.66
Min.	250	78	188	2.94	3.2	14.4	53.2	1.86
Max.	428	178	366	18.47	14.0	50.0	102.6	3.57

h) Probable flood discharge of A. J. Cubi site

The probable flood discharges calculated from rainfall data are shown in Table 4-18.

Table 4–17 Probable Flood Discharge at the A.J. Cubi Gauging Station based on the Probable Rainfall

Return Period	P mm	Pef 0.6	Qpeak	Qbase	Qmax m³/s
50	27.2	16.3	1,412	100	1,512
100	28.8	1738	1,498	100	1,598
200	29.6	17.8	1,541	100	1,641
500	34.4	20.6	1,784	100	1,884
1,000	36.8	22.1	1,914	100	2,014

i) Probable flood discharge of project site

Probable flood discharge at the project site were calculated in the same manner as applied to the Case-I.

Table 4–19

Retuen Period	Qmax m³/s
year	
50	1,553
100	1,641
200	1,685
500	1,935
1,000	2,068

The result is shown in Table 4-19. 110% of 1000 year probable flood is applied for the Design flood discharge at spillway.

$$Q_F = 2,068 \times 1.1$$
$$= 2,275$$
$$\fallingdotseq 2,300\ m^3/s$$