INSTITUTO ECUATORIANO DE ELECTRIFICACION

REPUBLIC OF ECUADOR

LA MICA HYDRO-ELECTRIC POWER PROJECT

FEASIBILITY REPORT

MARCH 1969

GOVERNMENT OF JAPAN

FOREWORD

The Government of Japan, at the request of the Government of the Republic of Ecuador, entrusted the feasibility studies of La Mica Hydroelectric Power Project to the Overseas Technical Cooperation Agency. The Agency dispatched a survey team consisting of six experts of the Electric Power Development Company (EPDC) headed by Mr. Akira KUSUMOTO.

The team left Tokyo on the 14th of August, 1968 to Ecuador, where it stayed for about two months. During this period, the survey team carried out the specific studies, discussed the Project to examine its feasibility, conducted field investigations, and collected the available data necessary for planning of the Project.

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

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

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

March 1969

S. Shibusawa

SHIN-ICHI SHIBUSAWA
Director General
Overseas Technical
Cooperation Agency

Mr. Shin-ichi Shibusawa, Director General
Overseas Technical Cooperation Agency
Tokyo

Sir:

As Chief of the Japanese Gonvernment Survey Team for La Mica Hydroelectric Power Project of the Republic of Ecuador, the undersigned has the honor of submitting herewith the report of the studies carried out by the Team.

The Survey Team visited Ecuador for approximately two months from August 14, 1968 to conduct investigations of the topography and geology of the project area, and to collect data and information concerning the electric power situation, hydrological and meteorological conditions and information required to estimate the construction cost of the Project.

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

La Mica Hydroelectric Power Project will consist of the construction of a power station with an installed capacity of 18,300 KW which will produce 127,000 MWh annually, and a 46 KV transmission line approximately 25 km long to satisfy the power demands of Quito City and nearby districts. The Project will also provide satisfactory potable water supply to the City for 18 years after 1984.

In order to meet the ever growing power demands in the above districts, it is essential that the Project be completed and start operation in July, 1974.

A period of approximately two and a half years will be required to construct the power station, and the construction cost including the transmission line will amount to approximately 176,900,000 Sucres which is equivalent to US$9,730,000. However, in comparison with a diesel power plant as an alternative, the benefit-cost ratio of this Project is greater than 2.26, which gives a positive reason to believe that the Project is economically sound and justifiable.

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

March 1969

Respectifully submitted,

A. Kusumoto

AKIRA KUSUMOTO
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Japanese Gonvernment Survey Team
for La Mica Hydroelectric
Power Project

Civil Engineer, Electric Power
Development Co., Ltd.

CONTENTS

Page

CHAPTER 1. INTRODUCTION 1-1

1.1 BACKGROUND 1-1

1.2 PURPOSE AND SCOPE OF REPORT 1-1

1.2.1 Purpose 1-1
1.2.2 Scope 1-1

1.3 SURVEYS AND STUDIES 1-2

1.3.1 Field Surveys 1-2
1.3.2 Studies 1-2

1.4 DATA 1-3

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS 2-1

2.1 CONCLUSIONS 2-1

2.2 RECOMMENDATIONS 2-3

CHAPTER 3. MARKET SURVEY AND LOAD FORECAST 3-1

3.1 BACKGROUND 3-1

3.1.1 Outline 3-1
3.1.2 Pattern of Power Supply 3-1
3.1.3 Present Situation of Supply and Demand 3-10

3.2 DEMAND FORECAST 3-16

3.2.1 Demand Forecast for Each Class 3-19
3.2.2 Energy Losses 3-23
3.2.3 Load Factor 3-24
3.2.4 Total Demand Forecast 3-24
3.2.5 Load Curve 3-26

3.3 TOTAL SUPPLY CAPABILITY 3-29

3.3.1 KW-Supply Capability and Power Demand 3-29
3.3.2 Energy Supply Capability and Energy Demand 3-41

3.4 TIME OF DEVELOPMENT 3-50

CHAPTER 4. DESCRIPTION OF PROJECT 4-1

4.1 GENERAL DESCRIPTION OF PROJECT AREA 4-1

4.2 DESCRIPTION OF PROJECT 4-1

4.2.1 Power Generation 4-1
4.2.2 Water Supply Scheme 4-4
4.2.3 Transmission Line and Substation 4-5

Page

CHAPTER 5. HYDROLOGY 5-1

5.1 RUN-OFF GAGING STATIONS AND METEOROLOGICAL STATIONS 5-1

5.1.1 Run-off Records of La Mica Project 5-1
5.1.2 Run-off Records of Rio San Pedro 5-1
5.1.3 Meteorological Stations 5-1

5.2 PRECIPITATION 5-3

5.3 TEMPERATURE 5-6

5.4 DISCHARGE 5-8

5.4.1 Discharge Data 5-8
5.4.2 Discharge and Mass Curve at Project Site 5-11

5.5 STORAGE CAPACITY OF LA MICA RESERVOIR 5-17

5.6 FLOOD DISCHARGE 5-19

5.6.1 Estimate of Flood Discharge 5-19
5.6.2 Design Flood Discharge 5-24

CHAPTER 6. GEOLOGY 6-1

6.1 GENERAL 6-1

6.2 GEOLOGY AROUND LAKE MICA 6-1

6.3 GEOLOGY OF DAM SITE 6-2

6.4 GEOLOGY OF WATERWAY 6-3

6.5 POWERHOUSE SITE 6-5

6.6 MATERIALS 6-5

6.7 FUTURE INVESTIGATIONS 6-5

CHAPTER 7. POWER PRODUCTION 7-1

7.1 INSTALLED CAPACITY 7-1

7.1.1 Effective Head 7-1
7.1.2 Maximum Discharge 7-1
7.1.3 Available Discharge of La Mica Power Plant 7-3
7.1.4 Maximum Output 7-5
7.1.5 Number of Units 7-6

7.2 AVAILABLE POWER AND ENERGY PRODUCTION 7-7

7.3 EFFECTIVE POWER AND ENERGY OUTPUT 7-13

7.4 BALANCE OF SUPPLY AND DEMAND AFTER COMPLETION 7-20

CHAPTER 8. PRELIMINARY DESIGN 8-1

8.1 DESCRIPTION OF STRUCTURES 8-1

8.1.1 Hydraulic Structures 8-1

8.1.2 Power Generating and Transforming Facilities 8-4
8.1.3 Transmission Line 8-5
8.1.4 Main Dimension 8-7

8.2 CONSTRUCTION SCHEDULE AND METHOD 8-11

8.2.1 Construction Schedule 8-11
8.2.2 Methods of Construction 8-17

CHAPTER 9. COST ESTIMATE OF LA MICA POWER PLANT 9-1

9.1 BASIC ASSUMPTIONS 9-1

9.2 TOTAL CONSTRUCTION COSTS OF LA MICA PROJECT 9-3

9.3 CONSTRUCTION COST OF JOINT FACILITIES 9-10

9.4 COST ALLOCATION TO WATER SUPPLY WORKS 9-13

9.5 ALLOCATION ACCORDING TO AGREEMENT BETWEEN "EEQ" S.A. AND EMPRESA DE AGUA POTABLE 9-17

9.6 BREAKDOWN OF CIVIL WORKS 9-23

CHAPTER 10. ECONOMICAL EVALUATION OF LA MICA POWER PLANT 10-1

10.1 EFFECTIVE SALEABLE POWER AND ENERGY 10-1

10.2 ANNUAL COSTS 10-3

10.2.1 Annual Costs and Energy Cost for Case "A" 10-3
10.2.2 Annual Costs and Energy Cost for Case "B" 10-7
10.2.3 Energy Cost of La Mica Power Plant 10-11

10.3 COMPARISON WITH ALTERNATIVE SOURCE 10-11

10.3.1 Type of Plant Considered 10-11
10.3.2 Energy Cost of Alternative Source 10-15

10.4 ANNUAL BENEFITS OF LA MICA PROJECT 10-21

10.5 BENEFIT-COST RATIO 10-25

CHAPTER 11. FINANCIAL ANALYSIS 11-1

11.1 FUND REQUIREMENTS 11-1

11.2 FINANCING OF FUNDS 11-2

11.2.1 Sources of Funds 11-2
11.2.2 Interest and Term of Repayment 11-2

11.3 OPERATING INCOME 11-3

11.3.1 Income from Sales of Energy 11-3
11.3.2 Operation and Maintenance Costs 11-3
11.3.3 Depreciation Charges 11-4
11.3.4 Net Income 11-4

11.4 AMORTIZATION SCHEDULE 11-4

LIST OF DRAWINGS

DRAWING-1	KEY MAP	
DRAWING-2	LOCATION MAP	
DRAWING-3	GENERAL PLAN	
DRAWING-4	GEOLOGY:	GENERAL MAP
DRAWING-5	GEOLOGY:	DAM SITE
DRAWING-6	GEOLOGY:	POWERHOUSE
DRAWING-7	AUXILIARY DAM & CANAL:	PLAN & SECTIONS
DRAWING-8	RESERVOIR:	PLAN & PROFILE
DRAWING-9	DAM:	PLAN & PROFILE
DRAWING-10	INTAKE:	PLAN & SECTIONS
DRAWING-11	WATERWAY:	PROFILE & SECTIONS
DRAWING-12	REGULATING RESERVOIR:	PLAN & SECTIONS
DRAWING-13	PENSTOCK:	PLAN & PROFILE
DRAWING-14	POWERHOUSE:	PLAN & SECTIONS
DRAWING-15	WATERWAY:	HYDRAULIC CHARACTERISTIC CURVES
DRAWING-16	SCHEME OF EXTENSION OF TRANSMISSION & DISTRIBUTION SYSTEM	
DRAWING-17	SINGLE LINE DIAGRAM IN EEQ'S SYSTEM	
DRAWING-18	MAIN SINGLE LINE DIAGRAM	

APPENDIX

APPENDIX-I — STUDY OF LA MICA DAM SITE

APPENDIX-II — RELATION BETWEEN LA MICA HYDRO POWER PROJECT AND WATER SERVICE PROJECT

APPENDIX-III — CAPACITY OF REGULATING RESERVOIR (HEAD TANK)

APPENDIX-IV — DATA OF METEOROLOGY AND HYDROLOGY

Chapter I

INTRODUCTION

Chapter I

INTRODUCTION

1.1 BACKGROUND

La Mica project was proposed by Empresa Electrica "Quito" S.A. (hereinafter called "EEQ" S.A.) to supply power to Quito city, as well as potable water supply after 1984. There has been shortage in both electricity and potable water supply in Quito, which made a substantial motivation to develop the project. In this regard, feasibility studies of project was neccesiated to analyze the technical feasibility, economic soundness and to frame up financing program of the project before approaching organization concerned.

In April of 1968, "INECEL" and "JUNTA" requested Japanese Government for technical cooperation in the project through Japanese Embassy in Ecuador desiring of the dispatch of a survey team for the feasibility study. On the basis of the request, Japanese government decided to cooperate in propulsion of the economic and technical development of Ecuador.

In August, 1968, a survey team of six engineers of Electric Power Development Co., Ltd. (hereinafter refered to as EPDC) was organized and dispatched to Ecuador through the Overseas Technical Cooperation Agency Association (hereinafter refered to as OTCA). Preliminary survey of the project was carried out by "EEQ" S.A. with regard to hydrology and topographical survey.

1.2 PURPOSE AND SCOPE OF REPORT

1.2.1 Purpose

This report gives the result of the investigations and studies of the technical feasibility and economic soundness of La Mica Project and provides convincing basis for "EEQ" S.A. to supply for a loan from an international financing institution for the required funds to carry out this project.

1.2.2 Scope

In the present study it was basically assumed that electricity of La Mica Project will be supplied only to the city of Quito and its environmental towns and villages which are encompassed in the service territory of "EEQ" S.A. In this connection the scope of analysis made in the present study includes a dam, a power plant, a primary substation and a transmission line from the power plant to the existing step-up substation at Quangopolo, as main components of the project. Construction of a new waterway from the proposed power plant for the purpose of potable water supply was also studied, as well as cost allocation of La Mica Waterway.

1.3 SURVEYS AND STUDIES

1.3.1 Field Surveys

On 14, August, Japanese Government dispatched to Ecuador an investigation mission composed of six members including three civil engineers, a geologist, an electrical engineer and a power market expert, who are all of them engineers with EPDC, with assignments to make field surveys. The field surveys were carried out for a period of two months, details of which are given below.

The members of the mission are:

Akira KUSUMOTO	Civil Engineer (Chief of the mission)
Kokichi YOSHIZAWA	Civil Engineer
Yozo FUKUTAKE	Geologist
Taisuke HASEGAWA	Civil Engineer
Toshimitsu SAKAI	Electrical Engineer
Saburo FUKUMA	Market Expart

(1) August 16 – August 31:

Discussions with "INECEL", "EEQ" S.A. and "Empresa de Agua potable" in regard to La Mica Project; Survey of power service area in Quito, Reconnaissance of the transmission line route from La Mica Site to the Quito South Sub-station; Collection of data and informations about power development in Ecuador.

(2) September 1 – September 20:

Joint field survey and investigation with "EEQ" S.A.'s civil engineers on topography, geology, hydrology, etc. in La Mica project area (the Mica camping facilities builted by "EEQ" S.A. was utilized as the camping quarter.)

(3) September 21 – October 10:

Discussions with "INECEL" and "EEQ" S.A. on basic idea for preparation of feasibility report and designs of structures, and collection of necessary data and informations.

1.3.2 Studies

Upon return to Japan of the investigation mission, engineers and experts of various technical departments of EPDC were mobilized under the direction of their Chief Engineer to carry out further studies of the project in cooperation with the members of the mission. The technical staff mobilized exerted their studies and analysis in power demands, hydrology, framing-up of generating system and development scheme, estimation of quantities of works, construction cost, preliminary design and economic justification of the project.

1.4 DATA

The data and informations, used in the present study were made available by national organization and private institutions concerned, such as INECEL, "EEQ" S.A., Ministerio de Industrias y Comercio and Ministerio de Fomento, República del Ecuador, etc.

Made available by INECEL was the program of electrification in Ecuador and various data on power demand. General informations were also provided by INECEL including the census of population complied by the División Estadística y Censos, Junta de Nacional Planificación y Coordinación Económica.

The data and information from "EEQ" S.A. includes hydrological records, topographical survey maps, data on power demand, descriptions and records of existing generating plants, features of transmission and distribution facilities under operation or planning, as well as some economic indexes to give basis for estimation of construction costs.

Also included in the informations made available by "EEQ" S.A. is that on potable water service in Quito prepared by Empresa de Agua Potable.

"Servicio Nacional de Moteorología e Hidrología" provided general meteorological data including those of temperature and precipitation.

The principal data are as follows;

(1) Hydrological data in general

The annual report (from 1961 to 1966) of S.N.M.H.

The monthly reports (from January to December in 1967) of S.N.M.N.

The records of Micacocha gaging station (from "EEQ" S.A.)

(2) Survey maps

Topographical map (1/50,000) of prepared by I.G.M.

Topographical map of La Mica lake including the survey of water depth (1/10,000 – 1/1,000), prepared by "EEQ" S.A.

Topographical map of waterway (1/10,000) prepared by "EEQ" S.A.

Topographical map and cross-section at the power plant site (1/10,000), prepared by "EEQ" S.A.

Records of water level in La Mica lake

(3) Data of River Run-off

Records of Run-off at ANTIZANA gaging station

Records of Run-off at GUANGOPOLO gaging station

Records of Run-off Rio Pita gaging station prepared by Empresa de Agua potable.

(4) Miscellaneous data and reports

Information of 1968 of INECEL

Reports on the electrification in Ecuador (INECEL)

Feasibility Report on Nayon Project ("EEQ" S.A.)

Plan of Pasochoa Project ("EEQ" S.A.)

Plan of potable water service to Quito (Empresa de Agua potable)

Feasibility Report on Pisayambo project (INECEL)

Outline on Toachi project, etc. (INECEL)

Chapter II

CONCLUSIONS AND RECOMMENDATIONS

Chapter II

CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

As a result of investigation and studies on La Mica Project, the following conclusions have been reached.

(1) The power supply area of Quito served by "EEQ" S.A. is the political center of Ecuador and also the center of economy, industry and culture of the country. Therefore, this area has possibilities to attain a rapid development in the future.

The estimated annual growth rate of population is 4.35%, and for electricity demand 9.0%, respectively.

It is anticipated that around 1974 the demand will exceed the total installed capacity of "EEQ" S.A. if no more development or extension project are established and put into service in the system. Therefore, shortage will soon appear in power supply and development of new power supply capability is of urgent necessity.

Even after the completion of the Nayon Power Plant, which is at present under development for 30,000 kW capacity, the shortage in supply capacity will reach 3,450 kW in the dry season (August to September) of 1972.

(2) As a means to meet this demand increase for power, La Mica project and alternative projects were studied. The results show that since the Quito system is not interconnected to other supply areas, new sources of electricity should be sought and located at the sites which will best guarantee power supply solely in "EEQ" S.A.'s territory, independently of other areas, and that La Mica Project is the most advantageous of the possible sources studied.

La Mica Project area is located at 50 km to the Southeast of Quito.

River flow of the Rio Antizana running through the eastern slope of the East Andes Mountain ranges will be stored in La Mica lake for the seasonal regulation and supplied to Quito basin in the dry season.

The storage can be used not only at La Mica Power Plant, but at a series of existing power plants of Guangopolo, Cumbaya, Nayon which lie on Rio San Pedro. Therefore, La Mica Project will bring about a sizable downstream benefit at the power plants in terms of generating capacity.

(3) La Mica Project consists of dam, intake, tunnel, canal, daily regulating reservoir, penstock, power house and auxiliary diversion facilities. An earthfill type dam, 1.2 m in

height and 55,000 m^2 in volume, will be constructed at the downstream end of La Mica lake. *By the dam the lake will get an additional storage capacity of* 21,000,000 m^3 which corresponds to 4 m increase in the water surface level. Seasonal regulation of river-flow will be possible by the additional storage. Intake structure will be constructed in the south side of La Mica lake and will enable drawdown to the depth of 5.5 m from the present water level of 3,900 m. Intake tunnel will be approximately 5,220 m in length. The inner diameter of the tunnel is 2.2 m in hight and 2.84 m in width. The tunnel will be a non-pressure type with a maximum discharge capacity of 4.5 m^3/sec. The open canal will be constructed along the plateau of the East Andes Mountain ranges and run sinuous according *to the topography through hills of the plateau.*

A regulating reservoir will be constructed at the end of the open canal on Tablón Alto near the power plant. The reservoir will have a regulating capacity of 25,000 m^3 for generating purpose and can compensate time lag of discharge from La Mica lake. A pen-stock line will be provided on the surface of the ground slope to the power plant. The line will bifurcate in the power plant and be connected with two units of turbines directly coupled to generators.

The installed capacity of the power plant will be 18,000 kW, at a maximum discharge of 4.5 m^3/s under an effective head of 496.5 m.

The hydraulic turbines will be of Pelton type. The generated power will be trans-mitted to Quito city. For the transmission, construction of a new transmission line is proposed between La Mica Power Plant *and the step-up substation, at Guangopolo, and from* this substation to the city the existing transmission line will be utilized. The period required for construction of La Mica Power Plant will be approximately 25 months. Preliminary works should be started around September, 1971 and the principal works from July, 1972.

(5) Construction Cost of La Mica Power Plant is estimated to amount to s/.176,900,000, which is equivalent to US$9,730,000. Interest during construction will be s/.13,478,600 at interest rates of 6.5 percent per annum for foreign currency and 10 percent for domestic currency requirements. Foreign currency requirement for imported equipment and materials will amount to s/.72,184,000 (US$3,970,000) including interest during construction, and will be supplied by foreign borrowings. Remaining amount equivalent to s/.104,716,000 will covers substantial part of the costs of civil works and other items, and will be supplied by domestic monetary sources.

(6) The annual energy production which will be available by La Mica Project will be 127,700,000 KWh at the generating end including 82,300,000 KWh at La Mica power plant and downstream benefit of 45,400,000 KWh at the Guangopolo, Cumbaya, Nayon Power plants, etc.

Considering the demand and supply situation and transmission losses, salable effective energy will be 118,540,000 KWh annually during the economic life (50 years) of the project.

On the basis of salable energy, the construction cost previously mentioned, in terms of per unit of output will be s/. 1.49 per KWh and the annual cost factor, which means the ratio of operating expenses against construction cost, was assumed at 10.66 per cent.

Accordingly, cost of electricity at the Quito South Substation will be s/.0.159 per KWh.

The construction cost per KW obtained by dividing the total construction cost (dam, power plant and transmission facilities as far as Quito inclusive) by the maximum output of 18,000 KW is s/.9,830 per KW.

However, if total effective capacity of 20,000 KW, which will be additionally obtainable as downstream benefit at the downstream power plants, is taken into account the construction cost will be s/.5,900 per KW (US$325/KW)

(7) The cost allocation was made of the facilities to be commonly used for power generation and potable water supply, on an assumption that the project is to supply potable water from 1984, ten years after power generation starts. Derived on the assumption were that cost to be shared by the facilities include reservoir, intake, water way, etc. Power generating phase will be s/.143,240,000 equivalent to US$7,880,000. While the salable effective energy will be decreased to 97,580,000 KWh. Therefore, construction cost for electricity will be s/. 1.468 per KWh at end. With the assumed annual cost factor of 10.66 percent taken into account, cost will be s/.0.157 per KWh at Quito South Sub-station.

(8) The average annual benefit of La Mica Power Plant during its serviceable life was estimated on the basis of an alternative diesel power plant.

The estimated annual cost of the alternative diesel power is s/.570 per KW and s/.0.20 per KWh, respectivity. Accordingly, annual benefit of La Mica Power Plant amounts to s/. 34,590,000, on the foregoing assumption that potable water service will start in 1984. On the other hand, the annual cost of La Mica Power Plant will be s/. 15,274,000 including operating expenses estimated on the annual cost factor of 10.66 percent. Consequently, the benefit-cost ratio will be 2.26 and annual surplus benefit (benefit less cost) will be s/. 19,316,000.

(9) The prevailing power rate charged on consumers in "EEQ" S.A. system averages s/. 0.48/KWh. If distribution cost of s/. 0.17/KWh is assumed, the average is s/. 0.309/KWh at distribution substation (s/. 0.48/KWh less s/. 0.17/KWh), while power cost of La Mica Power Plant will be s/. 0.157/KWh at Quito South Sub-station. In this connection, in the study of amortization program it was assumed that power of La Mica Power Plant is salable s/.0.309/KWh at Quito South Sub-station, and the result of the study is that La Mica Project can gain revenue sufficient for amortization.

2.2 RECOMMENDATIONS

Judging from the conclusions stated in the foregoing and the results of investigations described later, intensive attention should be given to the following points in order to promote the execution of La Mica Project.

(1) Of several projects proposed and investigated by "EEQ" S.A. investigations of La Mica Project are the advanced at the present stage. In view of the outstanding supply capability and economic soundness of the project, action should be taken to promote the materialization of the project. La Mica Project should commence its commercial operation in July, 1974, in succession to the Nayon Project for which "EEQ" S.A. is now preparing to start construction work to develop 30 MW capacity. The definite study and preliminary works should be expedited.

(2) The proposed La Mica Project will cause a sizable downstream benefit in respect of power generation at the power plants of "EEQ" S.A. under operation on Rio San Pedro. In the connection, it is preferable that the development of the project be promoted by "EEQ" S.A.

(3) In consideration of the construction period of La Mica Project, which is twenty five months, it is necessary for "EEQ" S.A. to get necessiated preparatory works completed with its own fund by the time the construction starts; the works include construction of the access road, preparation of the power source for construction use, repair of construction equipment, determination of quarry site and acquisition of land or right-of-way, etc.

(4) To secure a foreign loan for La Mica Project, coordination with the Government of Ecuador should be established as soon as practicable so that an appropriate channel may be opened to apply for the loan to an international financing institution.

It is also necessary to exert to raise the level of internal reserved fund, and to approach to city banks or other commercial financing institutions in order that domestic currency requirement may be supplied from reasonable sources.

(5) It is necessary to discuss and negotiate with "Empresa de Agua Potable" to reach an agreement in connection with schedule and manner of potable water supply, methods of cost allocation, etc.

(6) It is recommanded that a special office be established in "EEQ" S.A. to promote La Mica Project. Also recommended is the initiation of a training program of "EEQ" S.A.'s personnel and recruiting of qualified engineers for the operation of the power plant and the system as a whole.

(7) In case potable water supply starts, the downstream benefit of La Mica Project will accordingly be decreased in terms of power generation at the power plants of Guangopolo, Cumbaya, Nayon, etc., while power demand increase will continue at a repid rate of growth. Therefore, development of power supply sources will be necessiated in the very near future to compensate the decrease in downstream benefit and to satisfy the increasing demand. In this respect, studies and investigations should be initiated and expedited for development of projects which are to follow La Mica Project. Toachi or Pisayambo project is best recommendable as such project. Either of the projects can be put into service around 1976 if the said recommendation be accepted.

(8) For the definite study of La Mica Project, desired is the investigation to detail about the items described in Chapter 6., mainly on the geological surveys.

(9) Necessity of an additional installation of 46 KV transmission line between Cuangopolo and Quito.

46 KV transmission line is proposed from La Mica Power Plant to the Guangopolo step-up substation, where the electricity of La Mica Power Plant is to be put into the power system of "EEQ" S.A.

The transmission line from the substation to Quito which is under operation at present in two circuits of 22 KV and 46 KV respectively, will have been improved in the Nayon Project to two circuits of 46 KV by the time of completion of La Mica Project. However, with the commencement of the commercial operation of La Mica Power Plant and the increase in effective energy, the transmission capacity of these two circuits will become short. If one circuit is cut by an accident, the output of the power plant is forced to be limited and the systematic stability may be staggered. Therefore, it is necessary to provide one more circuit of 46 KV transmission line between Guangopolo and Quito as early as possible after the commencement of the commercial operation of La Mica Power Plant.

(10) *Establishment of Central Power Supply Control Station*

La Mica Power Plant with the reservoir and the regulating capacity will give a great influence over the operation of the power system of "EEQ" S.A. which presently consists of a group of run-of-river type power plants and power plants with reservoirs for only daily regulation. In the balance of supply and demand of "EEQ" S.A., the operation of La Mica Reservoir will be very important especially when the downstream benefit in terms of supply capacity at the downstream power plants is considered. Thus, the economical use of the reservoir becomes necessary. After the completion of La Mica Power Plant, "EEQ" S.A. will have a total installed capacity of 103,960 KW in six hydro-electric power plants and 9,800 KW in diesel power plants. Therefore, "EEQ" S.A. should improve the load dispatching mechanism of the organization in order to produce economic power as a whole. It will be necessary for "EEQ" S.A. to establish a load dispatching center which will be capable of instructing the operations, such as, start and stop, output control, voltage control, frequency control, reservoir operation, inter-system supply and receive control, recovery of fault with full knowledge of all the installations and facilities of power generation to distribution.

Chapter III

MARKET SURVEY AND LOAD FORECAST

Chapter III

MARKET SURVEY AND LOAD FORECAST

3.1 BACKGROUND

3.1.1 Outline

The electricity generated at La Mica Project will be supplied to an area including Quito, the Capital, and it's vicinity. The area is a service territory of "Empresa Electrica Quito" S.A. in Quito City.

This area occupies the main part of Pichincha Province. About 10% of the population of Ecuador is concentrated on Quito City. Quito City with 450,000 inhabitants is located in Andes Mountainous area at the altitude of 2,800 meters above sea level and is the political and cultural center of Ecuador, and domestic industries of small scale are very active in the city.

3.1.2 Pattern of Power Supply

(1) Capacity of electric power in Ecuador

As of 1958, Ecuador has a power generating capacity of 221 MW in total, of which 94 MW (43%) is hydro-electric power and the remaining 127 MW (57%) is thermal power. The capacity per capita was 35 W/per person which is slightly lower than the average of South American countries. Distribution of power is mainly concentrated on Quito and Guayaquil. No nation-wide supply network has yet been established, but independent local supply systems are scattered over the country. In small and medium cities, municipal organizations are in charge of power supply. The power transmitting and distributing system of "EEQ" S.A. is one of the largest (now 60 MW), as well as EMELEC (Empresa Electrica Del Equador Inc.), in Ecuador.

The annual energy consumption per capita is 350 KWh in this system, which is the highest in the country. Although Ecuador has a potential hydroelectric power source amounting to several million KW, shortage in actual power supply capacity is a general tendency in the country. Thus INECEL (Institute Ecuadoriano De Electrificacion) was founded in the year of 1961 to carry out power project and administration from a nation-wide viewpoint. INECEL is now energitically proceeding with planning, promotion and enforcement of power generating programs.

(2) History of "EEQ" S.A.

Before 1937, Quito was supplied with electricity by a company named "Empresa de Quito" owned by American capital, and the power plants then owned by Empresa de Quito were "Guapulo" (920 KW, now obsolete) and "Los Chillos" (1,760 KW). However, in 1937, the Quito City Council established "Empresa Electrica Municipal" (EEM) as an organization commercially operated but directly under control of the City Council in order to cope with increasing demands for electricity, and constructed Guangopolo Power Station (9,400 KW).

Later on, it became necessary to form an autonomous organization in order to raise funds to develop new power sources so that EEM was incorporated into a limited liability company in September, 1955 and Empresa Electrica "Quito" S.A. (EEQ) was thus founded.

Immediately thereafter, "EEQ" S.A. started the Cumbaya Project (First Stage Program, 20,000 KW), for which a loan of US$5,000,000 was made from the World Bank in March, 1956 and second agreement for an additional US$5,000,000 was concluded with the World Bank in September, 1957.

Thus in September, 1958, "EEQ" S.A. embarked on the First Stage Program of the Cumbaya Project which was put into operation in August, 1961. The Second Stage Program of the Cumbaya Power Plant (20,000 KW) was completed in January, 1967.

"EEQ" S.A. currently is capitalized at 221 million sucres and has a total generating capacity of 59,925 KW (hydro-electric power 52,080 KW, diesel 7,845 KW) and its annual sales of electricity amounts to 159,573 MWh.

(3) Description of Facilities owned by "EEQ" S.A.

(3)-1 Generating Facilities

As of August, 1968, "EEQ" S.A. has a total generating capacity of 59,925 KW consisting of 4 hydro-electric power plants with a total capacity of 52,080 KW and a thermal power plant comprising 16 diesel generating units totalling 7,845 KW (See Table 3-1).

Table 3-1 Existing Power Plants in "EEQ" S.A.

August, 1968

	Installed Capacity KW	Number of Units	Unit Capacity KW	Year of Installation
Hydraulic Plants				
Guapulo	920	3	200	1905
		1	320	1919
Los Chillos	1,760	2	880	1922
Guangopolo	9,400	2	1,700	1937
		2	2,000	1946
		1	2,000	1953
Cumbaya 1st stage	20,000	2	10,000	1961
Cumbaya 2nd stage	20,000	2	10,000	1967
Sub-total	52,080	15		
Thermal Plant				
Central Diesel	7,845	3	270	1958
		2	500	1958
		2	1,000	1959
		3	325	1960
		2	200	1960
		2	330	1960
		2	1,000	1967
Sub-total	7,845	16		
Total	59,925			

Of these, the Guapulo Power Plant (920 KW) is an obsolete type station built in 1905 and is scheduled to retire from service in 1970 when Nayon Power Plant will be newly built.

The thermal power capacity was 9,035 KW in 1960. Since surplus in supply capability was created with the commencement of the operation of the First Stage of the Cumbaya Project in 1961, small capacity diesel units (2,190 KW) were transferred to INECEL, and the capacity of this plant was cut down to 5,845 KW in 1966. Thereafter as the demand increased, "EEQ" S.A. installed two additional diesel units of 1,000 KW each in 1967 to supplement the need in dry season, and now has the capacity of 7,845 KW. Now being installed are two more 1,000 KW diesel units which will be placed in operation in December, 1968.

In addition, "EEQ" S.A. has a contract with the Municipality of Machachi in 1966 to use 1,000 KW from the Machachi power plant during the rainy season, and 800 KW during the dry season. The capacity of this power plant is 2,000 KW. This contract was supposed to terminate in February, 1968, but has been extended for another 3 years to receive 250 KW. "EEQ" S.A. concluded the same kind of contract with HCTB (Los Voz de Los Andes) broadcasting company in Pifo City. This contract is to receive the electricity of 800 KW from the Papallacta power plant (maximum capacity of 1,500 KW) owned by this broadcasting company for 3 years from September, 1967.

(3)-2 Transmission Facilities

The power generated at the Cumbaya Power Plant (40 MW) which is now major power plant of "EEQ" S.A. is transmitted to the Quito North Substation by a 46 KV, 2 CCT line (6.2 km), and the power from Los Chillos (1.74 MW) and Guangopolo (9.4 MW) is transmitted to the South substation by 22 KV line (27.7 km) and two 46 KW, 1 CCT (6.85 km) lines respectively. The North and South substations are directly connected with a 46 KV subtransmission line (which is a part of the future loop subtransmission line between these two substations) as shown on Drawing 16. 22 KV power from Los Chillos and Machachi is set up to 46 KV at the South substation. Guapulo and diesel power plants are connected directly to the distribution systems at distribution substations by means of 6.3 KV lines. Outline of existing transmission lines are as shown on Table 3-2.

Table 3-2 Existing Transmission Lines in "EEQ" S.A.

August, 1968

Voltage		Length in KM	Number of Circuits	Number of Supports	
46 KV	Cumbaya	6.2	2	35	ACSR 477, MCM
46 KV	Guangopolo #1	6.8	1	47	Copper 1/0 AWG
46 KV	Guangopolo #2	6.8	1	43	ACSR 3/0 AWG
22 KV	Machachi	27.7	1	350	ACSR 3/0 AWG
22 KV	Los Chillos	19.5	1	187	Copper #1 AWG
22 KV	Pifo	11.7	1	100	Aluminum 1/0 AWG
6.3 KV	Guapolo	5.1	2	172	Copper #4 AWG

Note:

Guangopolo #1 and #2 lines are still operating at 22 KV, but they were constructed for 46 KV, the transmission voltage in near future.

(3)-3 Distribution System

In the city of Quito, there is 46 KV loop subtransmission line, and branch subtransmission lines of 46 KV and 22 KV extending to the south and north of the city of supply power in the suburban area of the city where sizable demand increase is anticipated due to expansion of residential areas and industrial establishments. Thus the power is planned to be transmitted to every substation. This plan has now been partially completed as shown on Drawing 16.

To the village around Quito, there are 6.3 KV distribution lines extending from the distribution substations within the city. However, low-voltage distribution networks have not been established as yet. "EEQ" S.A. has a plan to extend or newly build distribution systems in the near future in order to supply power to villages which are now served with small diesel generator sets or not yet electrified. These distribution system will be included in Quito power distribution system.

At present, Quito City is divided into 18 distribution areas and each area has a distribution substation (46 KV/6.3 KV), which is designed to permit future extension corresponding to demand increase. In order to avoid power supply stoppage, emergency tie lines interconnected with other substations are constructed. For information about the existing distribution substations, subtransmission lines, distribution transformers and distribution lines, see Tables 3-3, 3-4, 3-5 and 3-6.

Table 3-3 Existing Distribution Substation

August, 1968

Name or Number of Substation	Voltage KV	Installed Capacity KVA	Number of Distribution Circuit in Service
Hospitalillo	22/6.3	1,000	1
Argelia	22/6.3	1,000	1
La Tola (Old No. 3)	22/4.16/2.3	2,500	2
El Recreo	22/4.16/2.3	3,000	-
No. 2	22/4.16/2.3	4,000	3
No. 3	22/6.3	4,000	2
No. 6	46/6.3	6,250	6
No. 8	46/6.3	6,250	6
No. 9	46/6.3	6,250	5
No. 10	46/6.3	6,250	2
No. 12	46/6.3	6,250 x 2	5
No. 14	46/6.3	6,250	4
No. 16	46/6.3	6,250	3
No. 17	46/22/6.3	4,000	4
Total		68,500	

Substation "El Recreo" belongs to a local industry.

Table 3-4 Existing Subtransmission Lines

August, 1968

Name	Voltage	Length in km
East bus No. 2	46 KV	8.20
Taps to distribution substations	46 KV	3.63
West bus No. 1	46 KV	11.0
Taps to distribution substations	22 KV	5.30
Total		28.13

Table 3-5 Existing Distribution Transformers

August, 1968

Primary voltage (V)	Number of transformers							Installed capacity (KVA)		
	Single phase			Three phase						
	Property of particulars	Property of EEQ	Total 1ϕ	Property of particulars	Property of EEQ	Total 3ϕ	Total 1ϕ & 3ϕ	Single phase	Three phase	Total
6,300	71	293	364	331	1,005	1,336	1,700	8,169.5	98,652	106,821.5
2,300	61	231	292	27	17	44	336	5,082.6	2,494	7,576.6
Total	132	524	656	358	1,022	1,380	2,036	13,252.1	101,146	114,398.1

Table 3-6 Existing Distribution Lines

Length in km

August, 1968

	Primary System						Secondary System			
	6.3 KV		4.16/2.3 KV				210/121 V			
	Single phase	Three phase	Single phase	Two phase	Three phase	Total	Single phase	Two phase	Three phase	Total
Underground	-	58.1	-	-	-	58.1	-	-	113.8	113.8
Aerial	50.5	209.8	7.9	0.4	76.0	344.6	25.6	68.2	244.4	338.2
Total	50.5	267.9	7.9	0.4	76.0	402.7	25.6	68.2	358.2	452.0

(4) Description of Facilities to be constructed by "EEQ" S.A. prior to the development of La Mica Project.

(4)-1 Generating Facilities

(4)-1-1 Pasochoa Power Plant

This power plant was proposed by "EEQ" S.A. in relation to Pita Water Supply Project of "Empresa de Agua Potable" and is now being partially constructed for the commencement of service scheduled for July, 1970. The power plant will have a maximum installed capacity of 4,500 KW at a maximum discharge of 3 m^3/sec. under an effective head of 194 m, which is available on the waterway to carry potable water to Quito. The power produced at the plant will be transmitted to the existing distribution system through Guangopolo substation by 46 KV transmission line, 19 km in total length.

(4)-1-2 Nayon Power Station

"EEQ" S.A. has proposed to construct this power station immediately in the downstream of the existing Cumbaya Power Station, which will be placed in operation in July, 1972. The preparation works has been completed and construction works are about to start. For this power station, the discharge of 36 m^3/s from the Cumbaya Power Station will be conducted through tunnel of 2.6 km long to the power plant site along the main stream of Rio San Pedro. Nayon power plant utilizes a head of 98 m and will have a maximum capacity of 30,000 KW and annual energy production of 107,400,000 KWh. The generated power will be boosted to 46 KV, and transmitted to the Quito North Substation, on existing transmission lines by way of Cumbaya Substation.

Table 3-7 Project under Construction and Planning

August, 1968

Name of Project	Installed Capacity KW	Number of Unit	Unit Capacity KW	Year of Completion
Hydraulic Plants				
Pasochoa	4,500	2	2,250	1970
Nayon	30,000	2	15,000	1972
Thermal Plant				
Central Diesel	2,000	2	1,000	1968
Total	36,500			

(4)-1-3 Expansion of Central Diesel Power Station

In order to secure the peak energy supply, which will be in shortage before the completion of Nayon and Pasochoa Power Plant, "EEQ" S.A. is now considering the expansion of diesel power plant. The existing capacity is 7,845 KW. Two sets of 1,000 KW units are being installed to expand the capacity of the power plant which will be placed in operation in December, 1968. The total installed capacity will be 9,845 KW.

(4)-1-4 Transmission Facility

To connect the existing Quito power system with Pasochoa Power Station which will start operation in 1970, 46 KV transmission line will be built in 1 circuit between Pasochoa and Guangopolo, 19 km in length. The power will be transmitted through existing Guanpolo–Quito line (46 KV, 2 CCT, 6.8 km) to the Quito South Substation.
Los Chillos–Guangopolo line (46 KV, 1 CCT) will be newly built, and the existing Los Chillos–Quito line (22 KV, 1 CCT) will be used for the distribution to San Rafael district. Along the construction of Nayon Power Station, Cumbaya–Quito No. 1 line (46 KV, 1 CCT, 6 km) and Nayon–Cumbaya line (46 KV, 1 CCT, 3 km) will be constructed and go into operation in 1972.

(4)-1-5 Substation Facility

In order to unify the transmission voltage and reduce the transmission loss in "EEQ" S.A. power system, a step-up substation (22/46 KV) will be constructed near Guangopolo Power Station in the Nayon stage. As the results power generated at Guangopolo (9.4 MW) and Los Chillos (1.74 MW) power stations will be stepped up to 46 kV and transmitted to Quito.

(4)-1-6 Sub-transmission Line

The South and North substations, the major substations in Quito at present, are connected each other by East-Bus No. 2 (46 KV, 1 CCT). In the future, West-Bus No. 2 (46 KV, 1 CCT) will be constructed between the two substations to form a loop sub-transmission line. Further constructed will be East-Bus No. 1 (46 KV, 1 CCT) and No. 16 and No. 18 Distributing Substations which are to be connected with the former. West-Bus No. 1 (46KV, 1 CCT) and No. 15 and No. 17 Distributing Substations will also be provided.

Also scheduled are West-Bus No. 3 (46 KV, 1 CCT) to be connected to No. 2 and No. 3 Distributing Sbustations and East-Bus No. 3 connecting to Argelia, Hospitalillo and El Recreo substations.

The branch sub-transmission lines connecting to the existing distributing substations of No. 6, No. 7, No. 9, No. 11 and No. 13 (or No. 15) will be constructed until 1967.

(4)-1-7 Expansion Program of Distributing Networks to Surrounding Areas of Quito City

In preparation for the expansion of the distribution area around Quito City, "EEQ"

S.A. is proceeding with the construction of 6.3 KV distributing networks and distributing substations. Also, "EEQ" S.A. is planning on new 138 kV distribution network to supply power to the villages around Quito where power supply is not served at all or power is supplied with electricity from compact type diesel generators.

3.1.3 Present Situation of Supply and Demand

Shown in Table 3-8 are the trends in the increase of number of consumers, system maximum power demand (KW) and its rate of growth, energy demand and its rate of growth, as well as load factor on "EEQ" S.A. system from 1945 through 1967.

From 1945 to 1961, namely before 20 MW of the First Stage of the Cumbaya Power Plant was added to the system, the balance between supply and demand had been unstable, so that "EEQ" S.A. had made up the deficit in supply capability by increasing the capacity of Guangopolo Power Plant, and by purchasing electricity from the Machachi Power Plant. In 1962 and thereafter, the hydro-electric supply capability was stabilized due to the completion of the First Stage of the Cumbaya Power Plant, and the diesel power plant was held in reserve only to be operated in the dry season of August and September or for peak supply in the month of maximum demand (December). Then "EEQ" S.A. completed the Second Stage of Cumbaya Power Plant in 20 MW in January, 1967. In the end of 1967, the maximum demand recorded in EEQ's system was 45,200 KW, and energy demand was 196,420 MWh. In the "EEQ" S.A. system a maximum power output of 60,975 KW was made available in the same year including thermal and hydro-electric power and the purchased power.

On the other hand, in order to meet the rapid increase in power demand at an annual rate of about 9 percent, "EEQ" S.A. has since 1966 proceeded with the studies of Nayon Power Plant (30 MW) which is scheduled to be placed in operation in July, 1972.

The composition of power demand of "EEQ" S.A. is residential use which is the largest and accounts for 42 percent of the entire demand, followed by 27 percent for industrial use, 14 percent for commercial use, and the balance being public lighting, pumping stations, etc.

The records of yearly consumption according to demand classification are shown in Table 3-9 and Fig. 3-1.

The charges for electricity supplied by "EEQ" S.A. were revised in 1964 and the revised rates have since been in effect. The rates are roughly based on the 5 classifications of: residential use, business use, industrial use, public agencies, and public lighting. Also, the rates differ according to the capacity of the consumer's installation, and the tariff consists of minimum charge plus energy charge.

EEQ's operating revenues and energy sales in 1964 and thereafter are shown in Table 3-10. It will be seen in the table that the average unit price per KWh in 1967 was about s/.0.48/KWh or US$0.026/KWh. This is fairy close to the average price of electricity in South American countries.

For Period 1945 to 1946

Year	Number of Consumer		Installed Capacity				Maximum Demand		Energy Demand at Generating End					Load Factor
	Number of Consumers	Increase %	Hydro MW	Thermal MW	Purchase MW	Total MW	MW	Increase %	Hydro MWh	Thermal MWh*	Purchase MWh	Total KWh	Increase %	
1945	5,127	5.5	6.08	-	-	6.08	6.44	21.8	33.74	-	-	30,639,000	6.39	54.49
46	15,790	207.98	10.08	-	-	10.08	7.84	21.8	33.74	-	-	33,840,640	10.45	49.41
47	18,202	15.28	10.08	-	-	10.08	8.70	10.7	39.01	-	-	39,132,560	15.64	51.47
48	20,370	11.91	10.08	-	-	10.08	9.60	10.35	42.02	-	-	42,102,200	7.64	50.88
49	22,483	10.37	10.08	-	-	10.08	10.30	7.95	44.05	-	-	44,443,430	5.51	49.04
1950	24,652	9.65	10.08	-	-	10.08	10.50	1.94	50.10	-	-	50,884,530	12.86	53.20
51	26,910	9.16	10.08	-	-	10.08	10.90	3.32	55.65	-	-	55,884,530	11.39	58.47
52	28,738	6.79	10.08	-	-	10.08	10.90	10	59.08	-	-	59,036,760	5.66	61.77
53	30,779	-7.10	12.08	-	-	12.08	12.90	1.83	64.71	-	-	64,815,720	9.79	57.36
54	33,121	7.61	12.08	-	-	12.08	13.10	1.86	71.33	-	-	70,401,020	8.62	61.15
1955	32,579	-0.16	12.08	-	-	12.08	13.30	1.22	75.23	-	-	75,346,540	7.02	64.67
56	34,314	5.32	12.08	-	-	12.08	13.40	2.56	78.08	-	-	78,072,510	3.62	65.34
57	35,541	3.57	12.08	-	-	12.08	15.11	10.78	74.00	2.63	-	76,842,660	1.58	58.05
58	39,077	9.94	12.08	3.40	2.00	17.48	17.89	18.07	73.82	6.23	7.24	87,271,230	13.57	55.84
59	41,697	6.70	12.08	5.40	2.00	19.48	20.26	13.57	75.27	12.18	8.54	96,119,856	10.14	54.15
1960	45,109	8.18	12.08	8.035	2.00	22.115	22.85	12.78	75.77	19.52	9.20	105,345,466	9.60	52.49
61	48,605	7.75	32.08	7.915	2.00	41.995	27.36	19.74	99.25	14.34	5.65	117,311,200	11.36	48.94
62	50,908	4.74	32.08	7.915	2.00	41.995	29.80	8.92	128.56	0.136	3.68	132,386,760	12.85	50.71
63			32.08	7.525	2.00	41.605	32.32	8.46	138.44	0.334	3.85	142,631,880	7.74	50.38
64	54,533		32.08	6.175	1.20	40.255	34.50	6.75	150.07	1.794	3.84	155,692,386	9.16	51.37
1965	57,009	4.53	32.08	5.845	1.20	39.125	37.00	7.24	160.65	2.192	3.85	166,672,580	7.05	51.42
66	60,194	5.58	32.08	5.845	1.20	39.125	40.05	8.24	169.83	4.85	3.85	178,538,910	7.11	50.89
1967	63,962	6.25	52.08	7.845	1.20	61.125	45.20	12.85	183.33	8.233	3.68	196,419,798	10.01	49.61

Note: Computed from MW meter reading.

Table 3-9 Consumption according to Consumer Classifications

Year	Residential KWh	Commercial KWh	Street Lighting KWh	Industrial KWh	Water pumping KWh	Municipal Lighting KWh	Government Lighting KWh	Total KWh	Increase %
1947	8,981,536	3,756,962	2,080,500	6,733,821	4,002,360	171,092	1,818,996	27,545,267	54.00
1948	10,424,653	4,170,575	2,086,200	7,413,330	3,522,680	175,121	1,859,093	29,751,652	8.01
1949	11,711,499	4,538,670	2,080,500	6,422,721	3,795,840	181,946	2,190,479	30,921,655	3.93
1950	13,421,444	4,741,550	2,249,592	6,762,452	4,077,588	199,051	2,138,773	33,590,450	8.63
1951	14,350,408	4,883,529	3,394,500	7,990,050	5,526,963	220,494	2,408,351	38,774,295	15.43
1952	15,804,646	5,242,624	3,394,500	8,328,025	5,688,192	370,427	2,912,767	41,741,181	7.65
1953	17,434,142	5,779,686	3,394,500	9,011,648	7,108,358	406,551	3,106,052	46,240,937	10.78
1954	19,105,271	6,430,843	3,808,596	10,234,794	7,910,797	271,371	3,103,841	50,865,513	10.00
1955	20,989,238	7,334,926	3,899,552	12,465,647	11,276,113	2,144,695	3,373,639	61,483,810	20.87
1956	22,939,261	8,256,417	3,954,747	12,504,374	10,134,774	2,432,638	3,589,753	63,805,964	3.78
1957	25,459,205	8,591,268	3,252,055	12,368,206	7,975,108	1,040,421	3,484,650	62,170.913	-2.56
1958	29,574,656	9,897,156	3,317,525	12,311,807	8,361,637	913,749	3,889,412	68,265,942	9.80
1959	33,628,673	10,597,163	3,527,677	12,084,293	8,222,578	838,597	3,129,612	72,608,593	6.36
1960	35,086,488	11,205,381	3,900,961	14,385,916	7,897,913	918,572	4,288,578	77,683,809	6.99
1961	37,930,218	13,455,704	5,010,693	16,762,779	8,036,537	1,243,638	5,668,752	88,108,326	13.42
1962	42,175,836	13,718,958	6,052,227	23,548,557	7,000,610	1,637,719	6,328,140	100,462,047	14.02
1963	47,230,232	16,098,126	6,825,050	24,709,510	8,038,144	1,000,981	6,235,861	110,137,904	9.63
1964	49,853,047	16,836,851	5,896,728	28,471,919	9,134,054	922,338	6,263,832	117,428,769	6.62
1965	54,866,099	18,007,946	6,326,228	30,951,364	10,107,647	775,647	7,474,508	128,509,505	9.44
1966	60,621,135	19,377,862	6,830,685	35,466,254	11,087,197	961,552	8,063,032	142,407,717	10.81
1967	67,209,665	21,582,621	7,455,080	43,280,345	10,121,267	986,408	8,901,875	159,537,261	12.02

Fig. 3-1 Actual Load in Quito Electric Power System
(from 1945 to 1967)

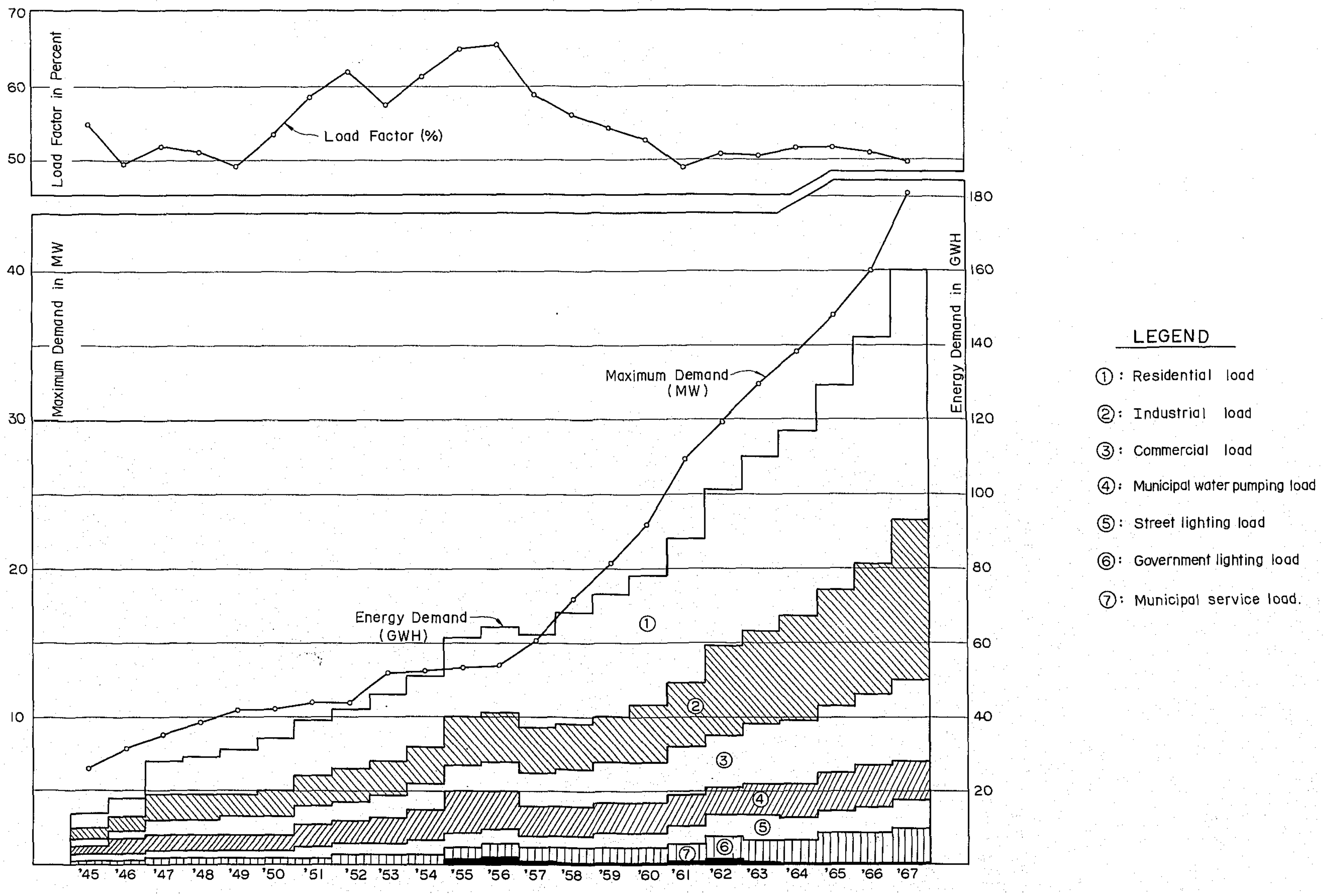


Table 3-10 Revenues from Sales of Electricity-Empresa Electrica "Quito" S.A.

Unit: sucres

Year	Residential		Commercial		Street Lighting		Industrial		Water Pumping		Municipal Lighting		Government Lighting		Total	
	Amount	per KWh	Amount	per KWh	Amount	per KWh	Amount	per KWh	Amount	per KWh	Amount	per KWh	Amount	per KWh	Amount	per KWh
1947	2,783,651	0.3099	1,368,642	0.3643	392,798	0.1888	1,085,492	0.1612	280,165	0.070	29,428	0.1720	316,691	0.1741	6,283,075	0.2281
1948	3,163,466	0.3035	1,541,099	0.3815	442,065	0.2119	1,208,373	0.1630	266,267	0.0735	30,243	0.1727	326,427	0.1756	6,976,762	0.2345
1949	3,461,251	0.2955	1,637,287	0.3607	443,180	0.2159	1,150,952	0.1792	275,198	0.025	29,239	0.1607	309,850	0.1415	7,312,971	0.2365
1950	3,893,774	0.2901	2,242,465	0.4729	449,244	0.1997	2,176,157	0.3218	299,295	0.0734	34,854	0.1751	507,269	0.2362	9,603,510	0.2859
1951	4,164,380	0.2902	2,357,479	0.4827	449,092	0.1223	2,485,025	0.3190	440,499	0.0797	42,533	0.1929	576,951	0.2395	10,600,892	0.2734
1952	4,560,319	0.2885	2,548,794	0.4861	449,092	0.1323	2,534,218	0.3043	449,367	0.0790	69,232	0.1869	726,283	0.2493	11,336,905	0.2716
1953	5,023,565	0.2881	2,792,344	0.4831	449,092	0.1323	2,819,680	0.3127	526,729	0.0741	75,009	0.1845	285,055	0.2849	12,443,436	0.2719
1954	5,494,108	0.2876	3,121,190	0.4853	449,033	0.1179	3,209,631	0.3136	557,711	0.0705	50,909	0.1876	915,837	0.2950	13,820,160	0.2717
1955																
1956	6,575,159	0.2867	3,905,834	0.4731	449,208	0.1136	3,994,758	0.3195	1,337,764	0.1320	82,783	0.0340	986,584	0.2748	17,332,091	0.3716
1957	7,312,044	0.2872	4,134,762	0.4813	449,208	0.1381	4,156,888	0.3361	1,586,932	0.1990	135,647	0.1304	1,099,033	0.3154	18,874,514	0.3036
1958	9,932,477	0.3358	5,537,252	0.5595	449,208	0.1354	4,726,982	0.3839	2,098,373	0.2510	178,808	0.1957	1,424,237	0.3662	24,347,447	0.3567
1959	11,035,551	0.3282	5,972,025	0.5635	449,208	0.1273	4,747,863	0.3935	2,161,699	0.2629	176,370	0.2103	1,486,034	0.3984	26,028,750	0.3585
1960	12,363,807	0.3524	6,881,587	0.6141	449,208	0.1152	5,635,842	0.3918	1,990,260	0.2520	188,932	0.2057	1,649,064	0.3845	29,158,702	0.3754
1961	13,634,080	0.3595	8,152,967	0.6059	449,208	0.0896	6,371,690	0.3801	2,192,585	0.2728	266,841	0.1824	2,208,054	0.3895	33,235,424	0.3772
1962	15,707,532	0.3724	9,043,078	0.6592	632,906	0.1045	8,467,764	0.3596	2,059,796	0.2942	226,286	0.1382	2,873,221	0.4540	39,010,582	0.3883
1963	17,592,564	0.3725	9,295,863	0.5775	525,108	0.0769	9,157,901	0.3706	1,377,485	0.2399	237,176	0.2369	2,735,365	0.4387	41,472,612	0.377
1964	23,803,324	0.4775	12,219,353	0.7236	2,027,583	0.3438	12,018,815	0.4221	2,377,485	0.2603	460,012	0.4987	2,760,429	0.4407	55,667,001	0.474
1965	27,302,447	0.4976	13,512,179	0.7503	2,323,220	0.3672	13,371,637	0.4220	2,658,786	0.2630	420,177	0.5185	2,009,904	0.2689	61,580,350	0.4792
1966	30,474,925	0.5027	14,800,357	0.7638	2,667,920	0.3906	14,916,210	0.4206	2,752,556	0.2480	461,505	0.4800	2,198,764	0.2727	68,272,237	0.4794
1967	33,417,620	0.4972	16,392,249	0.7595	2,848,853	0.3821	17,415,447	0.4203	3,134,656	0.3097	466,882	0.4733	2,377,036	0.267	76,052,743	0.4767

3.2 DEMAND FORECAST

Studies of future demand were made as below on the basis of the data compiled in 1967 by "EEQ" S.A.

The demand in "EEQ" S.A. power system were classified into the following 4 classes and a forecast was made of each class for a 10 year period from 1968 to 1977.

Class A : residential use, commercial use, and lighting in government or municipal facilities

Class B : industrial use

Class C : water pumping use

Class D : street lighting use

For the future power demand forecast, the past records were reviewed. Up to 1961, that is, before the First Stage of the Cumbaya project was added to EEQ's supply capability, power supply capacity had fallen short of demand and in some years during this period restrictive supply was forced. Thus it was considered not appropriate to use the growth trend of the period as a basis for forecasting future demands.

Accordingly, data of the past six years from 1962 through 1967 were employed as the basis for the forecast of the future power demand, because the balance between supply and demand was stable during this period.

The past records of each classification of demand in the above 6 years are shown in Table 3-11.

Table 3-11 Records of Each Classification of Demand

Category of Demand		1962	1963	1964	1965	1966	1967	Annual increase rate %
CLASS"A"	Demand at consuming end in MWh	63,860	70,565	73,926	81,133	89,024	98,681	9.1
	Number of subscriber	48,970	51,784	53,700	55,281	58,154	61,607	4.7
	MWh per subscriber	1.30	1.36	1.38	1.47	1.53	1.60	4.2
CLASS"B"	Demand at consuming end in MWh	23,549	24,710	28,472	31,034	35,466	43,280	13.1
	Number of subscriber	804	861	849	869	890	921	2.9
	MWh per subscriber	239	287	335	357	398	446	10.0
CLASS"C"	Demand at consuming end in MWh	7,001	8,038	9,134	10,016	11,087	10,121	8.2
	Number of subscriber	27	29	22	21	23	24	- 3.3
	MWh per subscriber	259	277	414	477	482	421	12.0
CLASS"D"	Demand at consuming end in MWh	6,052	6,825	5,897	6,326	6,831	7,455	4.7
TOTAL	Demand at consuming end in MWh	100,462	110,138	117,429	128,509	142,408	159,537	9.7
	Number of subscriber	49,801	52,674	54,571	56,171	59,092	62,559	4.7

Note: The number of subscribers represents the average of each year

Table 3-12 Forecast of Class "A" Demand

Year	Population	Number of subscribers	MWh per subscriber	Energy Demand MWh
1968	483,850	64,690	1.67	107,300
1969	505,580	67,920	1.74	118,200
1970	528,090	71,320	1.81	129,100
1971	551,160	74,880	1.89	141,500
1972	575,120	78,630	1.96	154,100
1973	599,900	82,560	2.05	169,200
1974	625,590	86,690	2.13	184,600
1975	652,290	91,020	2.22	202,100
1976	680,130	95,570	2.32	221,700
1977	709,160	100,350	2.41	241,800
Annual rate of increase	4.35%	5.0%	4.2%	9.45%

Note: (1) Population forecast was obtained from publications of "División de Estadísticas y Censos" of Junta Nacional de Planificación.

(2) The number of subscribers and population are estimated figures for December of each year.

3.2.1 Demand Forecast for Each Class

(1) Forecast of Class "A" Demand (Residential use, commercial use, and lighting in government or municipal facilities)

Growth of Class"A"demand was forecasted on the basis of the rates of growth of population, number of subscribers and power consumption per family. The annual population growth in Quito and its environmental cities was estimated at a rate of 4.35 percent on the basis of the data prepared by "Junta Nacional de Planificación Económica, División de Estadística y Censos". The ratio of subscribers against total number of households was 89 percent in 1962. However, taking into consideration that "EEQ" S.A. has planned and already proceeded with the expansion program of distribution network, it was assumed that this ratio would reach and stand at 97 percent by and after 1974. This means annual rate of growth of 7 percent up to 1974.

Demand forecast of Class "A" was calculated based on the power consumption per subscriber or 1.60 MWh/year/person which is actual record in 1967 and the annual growth rate of 4.2% averaged for the six years. The result is, as shown in Table 3-2, that growth rate of Class "A" will be 9.45 per cent annually.

(2) Forecast of Class "B" Demand (Industrial use)

The growth rate of industrial demand in the six years from 1962 to 1967 was 13.1 per cent annually. However, in the areas surrounding Quito, new factories were established and existing plants were expanded between 1966 and 1968 on the basis of a government policy to encourage industrial development.

Reflecting the situation, the growth rate for this demand bracket reached 14.3 per cent at the end of 1966 and 22.1 per cent in 1967 over preceeding year, respectively. A rapid growth of the same level as that in 1967 is expected for 1969.

However, this sharp increase is considered to be temporary nature and after 1969 the rate of growth will presumably calm down to around 11 per cent which is the growth rate registered in the past five-year period of a steady growth from 1962 to 1966.

This figure (11 per cent) is a little higher than the growth rate of the gross industrial production in the past several years, which averages 10.4%, and will be appropriate for power demand. The result of estimation is shown in Table 3-13.

Table 3-13 Forecast of Class "B" Demand

Year	Energy Demand (MWh)	Annual average rate of increase (%)	Remarks
1968	51,900	20.0[1)]	1) 20% of 1967 record of 43,280 MWh.
1969	57,600	11.0[2)]	2) Values in and after 1969 are estimates.
1970	64,000	11.0	
1971	71,000	11.0	
1972	78,800	11.0	
1973	87,400	11.0	
1974	97,000	11.0	
1975	107,700	11.0	
1976	123,800	11.0	
1977	132,600	11.0	

(3) Forecast of Class "C" Demand (Water pumping use)

The water supply of Quito currently relies upon a pumping system within the city. The annual energy consumption for this purpose was 11,386 MWh with the facilities of about 3,000 HP until 1968.

However, as Quito City cannot meet the demand for water by pumping only, "Empresa de Agua Potable" planned Pita project to draw water from the Rio Pita, which is scheduled to be completed in 1972, to make it possible to conduct the potable water of average 1.6 m^3/sec.

When this program is completed the existing pumping facilities will become unnecessary and will be retired from service except for some of the installations which would be reserved for emergency use. On the other hand, there is another plan to build new pumping stations to serve some areas around Quito which cannot be served by gravity flow.

Therefore, a little increase over the current level is anticipated in Class "C" demand until 1971 and a sharp decline is expected after the Pita project is started, as shown in Table 3-14.

Table 3-14 Forecast of Class "C" Demand

Year	Existing Wells MWh	New Wells			Pumping Stations		New Water Treatment Plant MWh	Total Energy Demand MWh
		No. 6 MWh	El Rosario MWh	La Delicia MWh	"A" MWh	"B" MWh		
1968	6,170	-	164	-	4,767	285	-	11,386
1969	7,741	780	225	164	4,767	285	-	13,972
1970	9,311	780	800	225	4,767	285	-	16,168
1971	9,311	780	800	225	4,767	285	-	16,168
1972	1,570	13	13	13	-	285	1,221	3,115
1973	90	13	13	13	-	285	1,360	1,774
1974	90	13	13	13	-	285	1,460	1,874
1975	90	13	13	13	-	285	1,560	1,974
1976	90	13	13	13	-	285	1,670	2,084
1977	90	13	13	13	-	285	1,790	2,204

Note: Pumping station "A" includes the following stations: No. 1, El Sena, Ichimbia Alto and Guapolo.
Pumping station "B" includes the existing water treatment plant of El Placer.

(4) Forececast of Class "D" Demand (Street lighting use)

"EEQ" S.A. has plans to increase street lighting facilities during the period between 1966 and 1972 and this was included in the forecast. The outline of the plan includes as follows:

1) Installation of mercury lamps and incandescent lamps at 4,000 locations in the city amounting to 520 KW.

2) Installation of lightings at 1,000 locations in the suburban villages of Quito, 100 KW in total.

3) Improvement of distribution system for lighting in the city, which will cause load increase of about 100 KW.

4) Installation of lighting facilities on the basis of a town development program, which will result in an increase of load of about 150 KW.

The annual average increase will be 7.6 per cent for the six years from 1968 to 1974 taking the plan into consideration. For after 1974, there is no particular plan at the present which would cause an increase of demand. Therefore, natural increase of 2.5 per cent was assumed for the period after 1974. The results are shown in Table 3-15.

Table 3-15 Forecast of Class "D" Demand

Year	Energy Demand (MWh)	Rate of increase (%)
1968	8,136	9.1
69	8,822	8.4
70	9,508	7.8
71	10,194	7.2
72	10,880	6.7
73	11,566	6.3
74	11,856	2.5
75	12,152	2.5
76	12,455	2.5
77	12,768	2.5

3.2.2 Energy Losses

The past records of loss factors in EEQ's power system are as shown in Table 3-16. The records indicate a declining, or improving trend. In 1961, "EEQ" S.A. started a reorganization of its transmission and distribution networks which is scheduled to be completed in 1968. As a result of this reorganization program, loss factor has been declining after 1962. In addition, "EEQ" S.A. has a plan to install capacitor banks at every distribution substations to further reduce losses in its system. As against these background it is expected that loss factor will be improved to 18.5 per cent in 1968 and that the level will be maintained for quite sometime after the year.

Table 3-16 Record of Loss Factor of "EEQ" S.A.

Year	Energy at generating end (KWh)	Energy at consuming end (KWh)	Losses (KWh)	Loss factor %
1947	39,132,560	27,545,267	11,587,293	29.6
1948	42,102,200	29,751,652	12,370,548	29.2
1949	44,443,430	30,921,655	13,521,755	30.4
1950	50,160,780	33,590,450	16,570,330	33.0
1951	55,884,530	38,774,295	17,100,235	30.6
1952	59,036,760	41,741,181	17,295,579	29.3
1953	64,815,720	46,240,937	18,574,783	28.7
1954	70,401,020	50,865,513	19,535,507	27.7
1955	75,346,540	61,483,810	13,862,730	18.4
1956	78,072,510	63,805,964	14,266,546	18.3
1957	76,842,660	62,170,913	14,671,747	19.1
1958	87,271,230	68,265,942	19,005,288	21.8
1959	96,119,856	72,608,593	23,511,263	24.5
1960	105,345,466	77,683,809	27,661,657	26.3
1961	117,311,200	88,108,326	29,202,874	24.9
1962	132,386,700	100,462,047	31,924,653	24.1
1963	142,631,880	110,137,904	32,493,976	22.8
1964	155,692,386	117,428,769	38,263,617	24.6
1965	166,672,580	128,509,505	38,163,075	23.0
1966	178,538,910	142,407,717	36,131,193	20.2
1967	196,419,798	159,537,261	36,882,537	18.8

3.2.3 Load Factor

Annual load factors of EEQ's power system are shown in Table 3-8 for the period after 1945. According to the table, for the period up to 1961 load factor recorded unstable fluctuation from 50 per cent to 65 per cent, but after completion of Cumbaya Power Plant in 1962, it has been stable at 51 to 52 per cent because of the adequate supply capacity made available.

In view of the above situations, the load factor after 1968 was estimated by the following method.

Of the demand classification, Class"A"demand for residential, commercial and government facilities lighting uses with predominantly affect the load factor of the power system.

In the estimation, the ratio of Class"A"demand to the total demand was first computed for each year from 1962 to 1967. Then, correlation was sought and established between the said ratio and total system load factor. The annual load factors were estimated on the basis of the correlation. The results are given in Table 3-17.

3.2.4 Total Demand Forecast

In the estimation of total demand, estimated amounts for each demand bracket, which are given in the preceding paragraph 3.2.1, were first summed up. Then gross energy demand was calculated at generating end on the basis of the sum and energy losses estimated.

From this gross energy demand and the estimated load factor, the maximum KW demand was estimated, the result of which is shown in Table 3-17.

The annual rate of growth will average about 9.0 per cent until 1977 for energy demand and capacity demand as well. This rate of growth is considered reasonable in the light of the actual trend after 1945, and anticipated rise and progress in the living standard of the people and in industrizlization of the region.

Table 3-17 Total Load Forecast

Year	Class "A" MWh	Class "B" MWh	Class "C" MWh	Class "D" MWh	Total demand at consuming end MWh	Loss factor %	Total demand at generating end MWh	Annual load factor %	Maximum demand KW
1968	107,300	51,900	11,400	8,100	178,700	18.5	219,300	49.5	50,600
1969	118,200	57,600	14,000	8,200	198,000	18.5	242,900	49.5	56,000
1970	129,100	64,000	16,200	9,500	218,800	18.5	268,500	50.5	60,700
1971	141,500	71,000	16,200	10,200	238,900	18.5	293,100	50.5	66,200
1972	154,100	78,800	3,100	10,900	246,900	18.5	302,900	50.5	68,500
1973	169,200	87,400	1,800	11,600	270,000	18.5	331,300	50.0	74,900
1974	184,600	97,000	1,900	11,900	295,400	18.5	362,500	50.0	82,800
1975	202,100	107,700	2,000	12,200	324,000	18.5	397,500	50.0	90,800
1976	221,700	123,800	2,100	12,500	360,100	18.5	441,800	50.0	100,900
1977	241,800	132,600	2,200	12,800	389,400	18.5	477,800	49.5	110,200
Average growth rate	9.45%	11.0%.	-16.7%	5.1%	9.0%		9.0%		9.0%

Note:
Class "A" – Residential, commercial, government and municipal lighting
Class "B" – Industrial
Class "C" – Water pumping
Class "D" – Street lighting

3.2.5 Load Curve

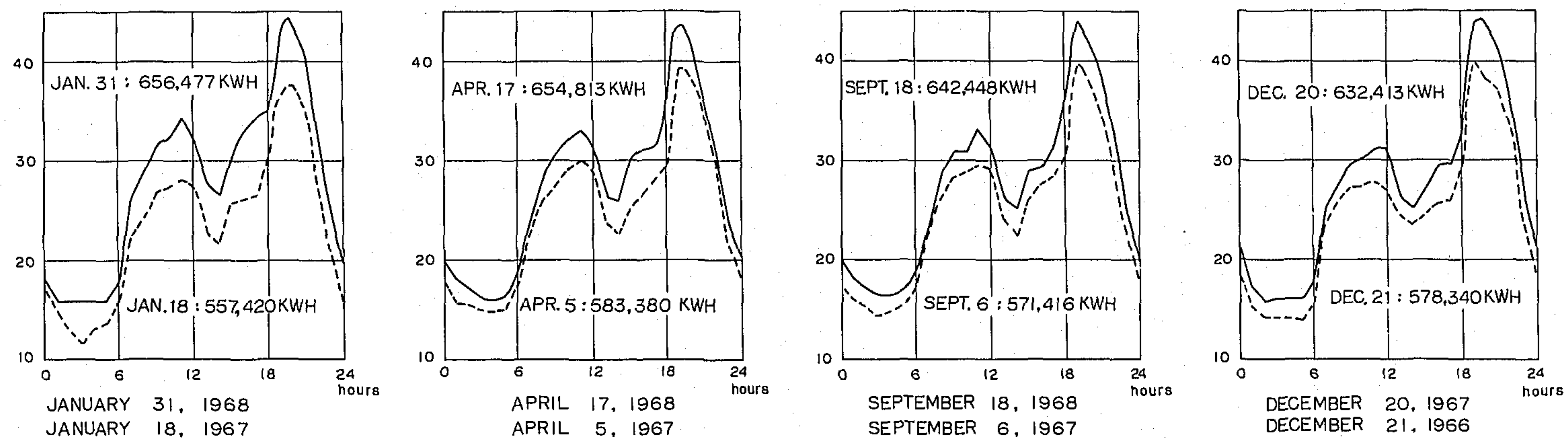
In estimating the load curve of future power demand, it was assumed that the pattern of the actual daily load curve in 1967 and 1968 would be maintained without change in the future for the following reasons.

Annual load factor will remain to stand at 51 to 52 per cent, in the future, as described in 3.2.3 and there would be little variation in the proportional composition of power demands as classified. Especially, the ratio of residential use, which comprises the substantial portion of the demand, can be assumed to be almost constant against the total demand.

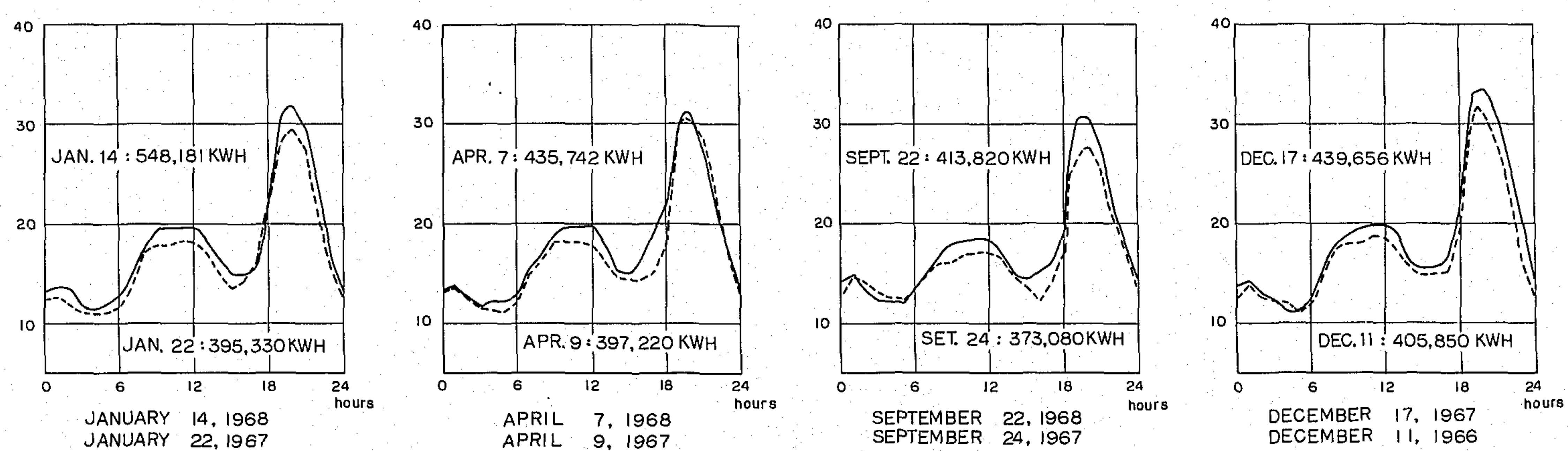
According to the result of analysis of weekday load curve and holiday load curve recorded in 1967, the load of Wednesdays can be considered to be a normal weekday load representing the five days from Monday through Friday. The demand decreases on Saturdays and Sundays and the load curve differs from that of weekday accordingly. Therefore, the load curve of Sundays were taken as a representative holiday load curve.

As the load condition varies somewhat according to the month, January, April, September and December were selected to represent seasons of mean run-off, rich run-off, drought, and the maximum demand, respectively, according to generating schedule of power plants of San Pedro system. Thus, typical load curves were obtained for holidays and weekdays as shown in Fig. 3-2.

Fig. 3-2 Typical Load Curve



TYPICAL LOAD CURVE IN WEDNESDAY



TYPICAL LOAD CURVE IN SUNDAY

Note; These load curves are quoted from the records of EEQ in 1968.

3.3 TOTAL SUPPLY CAPABILITY

3.3.1 KW-Supply Capability and Power Demand

Although December is the month of maximum demand, no critical shortage will be encountered in the month in supply capability since the run-off of this month is nearly equal to the annual average run-off utilized in the power plants of Rio San Pedro. Shortage of supply capability is the most critical in September which has the least run-off.

Therefore, no deficiency will be presented in supply capability throughout the year, if careful analysis of supply capability in KW is made for September in determining the supply capability. The KW-demand in September is 93 per cent of the estimated demand of December. The maximum demand in September will be as shown in Table 3-18.

Table 3-18 Assumed Maximum KW-demand in EEQ's System

Year	Max. Demand in Sept. (KW)	Max. Demand in Dec. (KW)	Year	Max. Demand in Sept. (KW)	Max. Demand in Dec. (KW)
1968	47,000	50,600	1973	69,600	74,900
69	52,000	56,000	74	77,000	82,800
70	56,400	60,700	75	84,400	90,800
71	61,500	66,200	76	93,800	100,900
72	63,700	68,500	77	102,400	110,200

In order to determine the supply capability of hydro power, the potential output was first obtained of every power stations. The potential output was calculated based on the run-off available for 25 days in the dry month (September), which hereinafter will be referred to as firm run-off. The potential output was divided into two portions, that is, output by natural flow and output by regulated flow for each of the existing power plants. The results of the study are shown in Table 3-19 and Table 3-20.

Table 3-19 Average Power Output (KW) and Energy Output of Existing Power Plants Based on Firm Run-off in September

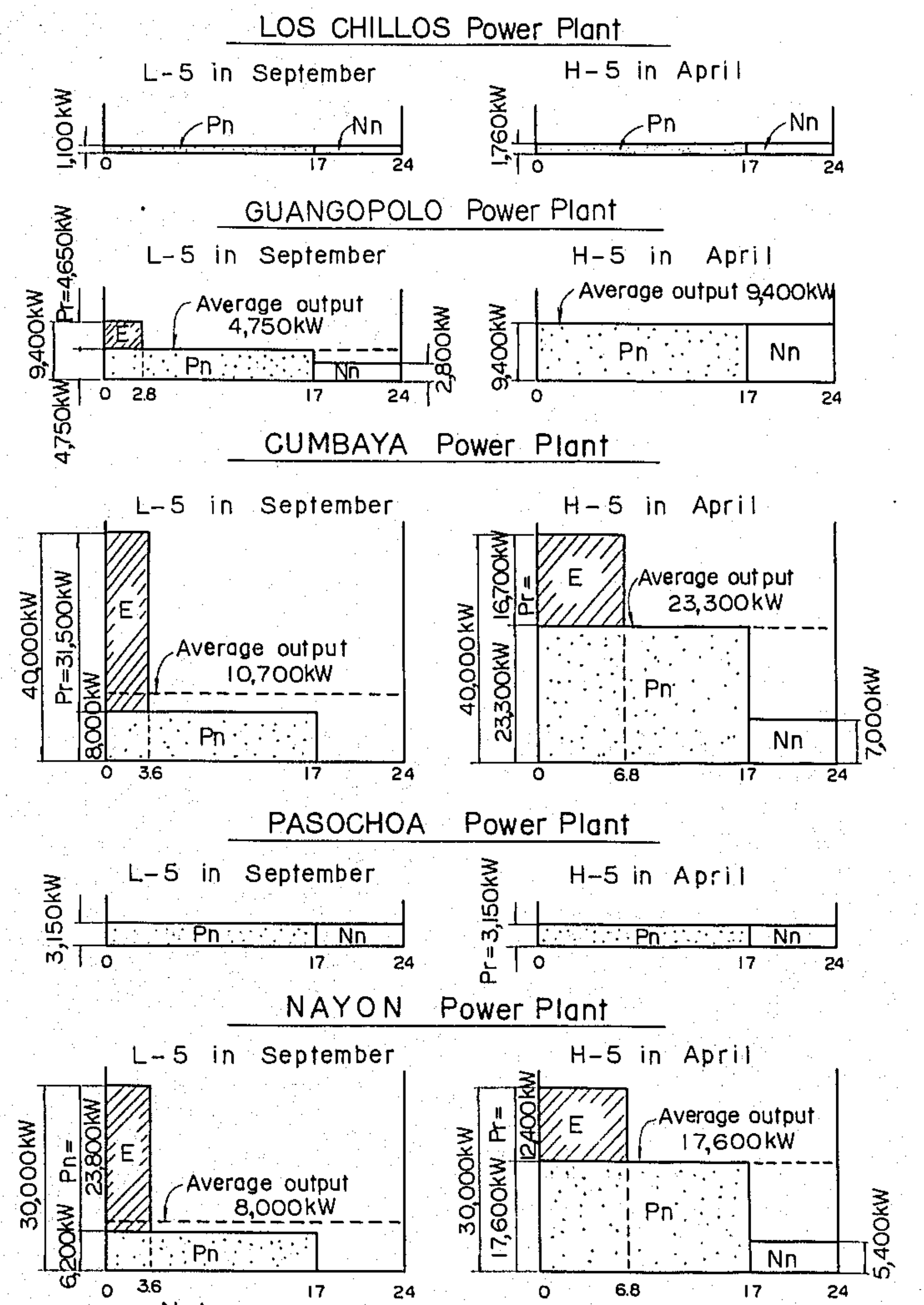
Power Plant	Capacity (KW)	Firm-Run-off (m^3/s)	Average output (KW)	Daily energy output (KWh)	Remarks
Los Chillos	1,760	-	1,100	26,400	River-run type
Guangopolo	1,400	9.1	4,750	114,000	Regulated flow type
Cumbaya	40,000	9.6	10,700	257,000	Regulated flow type
Pasochoa	4,500	-	3,100	74,500	River-run-off type
Nayon	30,000	9.6	8,000	192,700	Regulated flow type
Total	85,600		27,700	664,600	

Table 3-20 Firm Power of EEQ's Existing Power Plant in Sept.

Power Plant	Installed capacity (KW)	Regulated flow Output		Natural flow output	
		Daily regulated Energy: E (KWh/day)	Output Pr. (KW)	Output in peak hour Pn. (KW)	Output in off peak hour: Nn (KW)
Los Chillos	1,760	0	0	1,100	1,100
Guangopolo	9,400	13,200	4,650	4,750	2,800
Cumbaya	40,000	113,900	31,580	8,420	0
Posochoa	4,500	0	0	3,150	3,150
Nayon	30,000	85,600	23,740	6,260	0
Total	85,660	212,700	59,970	23,680	7,050

As shown on Table 3-20, run-off-river type power plants have only output by natural flow, while power plants with regulating ponds can store, surplus run-off in the regulating pond during off-peak hours and use the retained run-off in peak-hours. The power which will be available by the retained run-off is referred to as regulated flow output in this report.

Fig. 3-3 Capability of EEQ's Existing Power Plant



Note

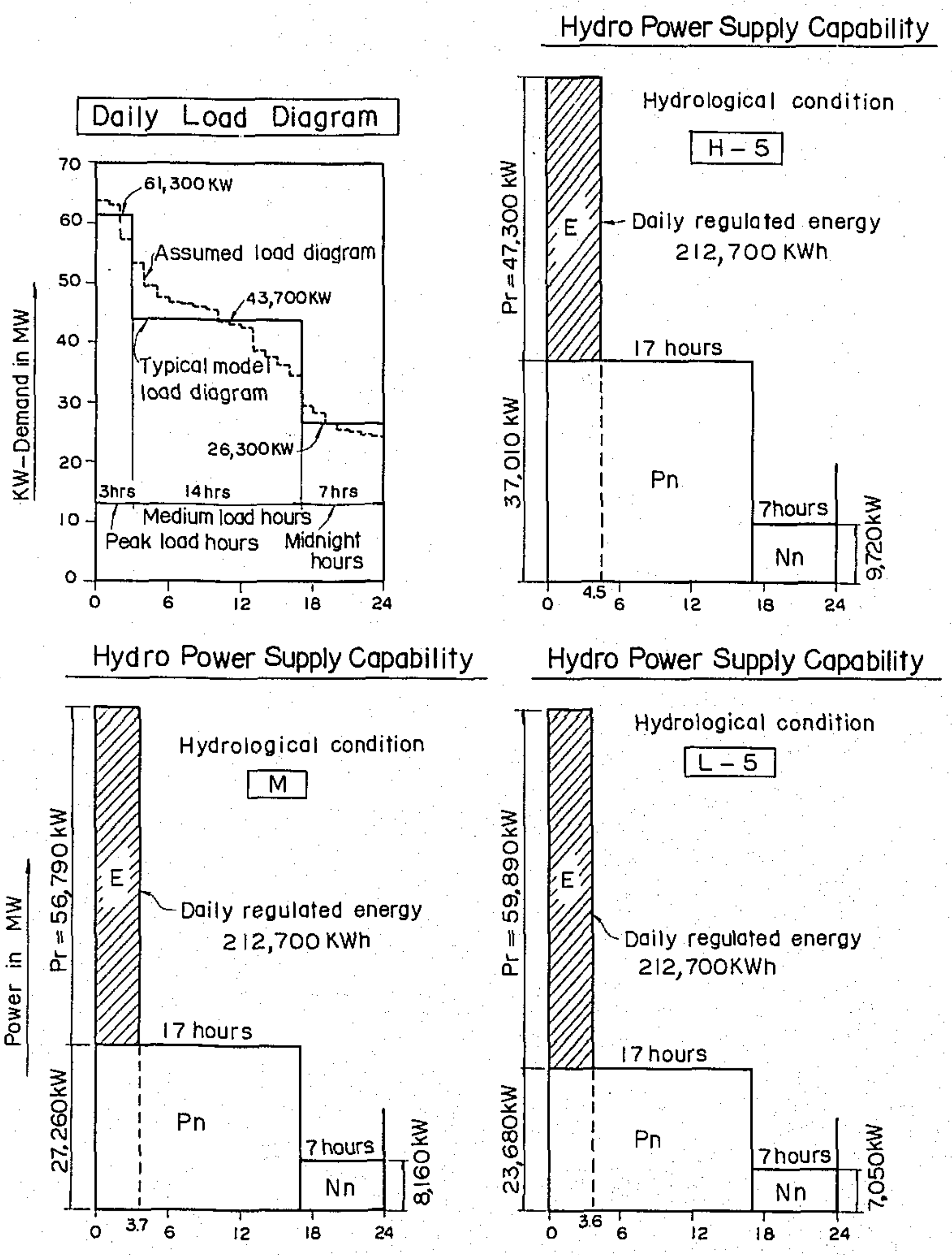
Pr : Daily regulated power (KW)

E : Daily regulated energy (KWh)

Pn : Natural flow power in peak hours (KW)

Nn : Natural flow power in off-peak hours (KW)

Fig. 3-4 Daily Load Diagram and Hydro Power Capability in Sept. 1972



Note

Pn : Natural flow output in peak hours

Nn : Natural flow output in off-peak hours

E : Daily regulated energy

Pr : Regulated flow output.

The capability of the existing power plants with regulating ponds is shown in Fig. 3-3. In the figure Pn is the part which can be generated without regulation during peak hours, and Pr shows the capacity which can generate power at required hours by the help of regulating pond, while Nn is the capacity obtainable during off-peak hours by natural flow. The daily regulated energy (KWh/day) represents the quantity of water converted into electric energy which is available when the capacity of the regulating pond is used to a full extent. The firm-power capability during firm-run-off is as shown in Fig. 3-4 for the hydro power plants owned by "EEQ" S.A. The available output of the power plants was compared with the daily load curve of the dry month (September) in each year from 1968 to 1977 to check the balance of demand and supply. In the comparison, a graphic method was employed, in which the base part of daily load curve was first filled by the natural flow energy, (Pn x 17 hours) + (Nn x 7 hours), and then the energy (E) by the regulated flow was added on top of the natural flow energy part. For shortages which appeared on the diagram, load factor was made large to allowable extent in order that investment to cover the deficiency may be most economical for the system as a whole.

As for the thermal power, it was assumed that the capacity of 9.8 MW, which was available in 1968, should be maintained as stand-by facility to operate in case of shortage.

The KW-balance between supply and demand thus obtained for each year is as shown in Table 3-21 and Fig. 3-5.

Table 3-21 KW-Balance between Demand and EEQ's Existing Power Plants in Dry Month (September)

Year		1970	1972	1974	1976
Max. demand in Sept.: (1) (KW)		56,400	63,700	77,000	93,800
Capability of hydro power plant.	Natural flow (KW)	18,720	23,680	23,680	23,680
	Regulated flow.	21,780	26,770	30,760	36,420
	Total: (2)	40,500	50,450	54,440	60,100
(3) = (1) - (2)		- 15,900	-13,250	-22,560	-33,700
Diesel Power: (4)		9,800	9,800	9,800	9,800
Shortage in Capability (KW) (5) = (3) - (4)		- 6,100	- 3,450	-12,760	-23,900
Marginal max. hydro power capability (KW): (6)		*54,950	**83,650	83,650	83,650
Non-utilized output (KW) (6) - (2)		14,450	32,650	29,210	23,550

Note: *54,950KW = 1,100 + 9,400 + 40,000 + 3,150 + 1,300
Los Chillos Cumbaya Guangopolo
Guangopolo Pasochoa Machachil
Pito

**83,650 KW = 1,100 + 9,400 + 40,000 + 3,150 + 30,000
Los Chillos Cumbaya Nayon
Guangopolo Pasochoa

In the table, marginal maximum hydro-power capability means the average KW output by daily natural flow for run-off-river type power plants (Ex Los Chillos), and the maximum installed capacity for power plants with regulating ponds. The figures in the table 3-21 are for hydro-capacity of EEQ system as a whole, representing maximum available output during the firm-run-off.

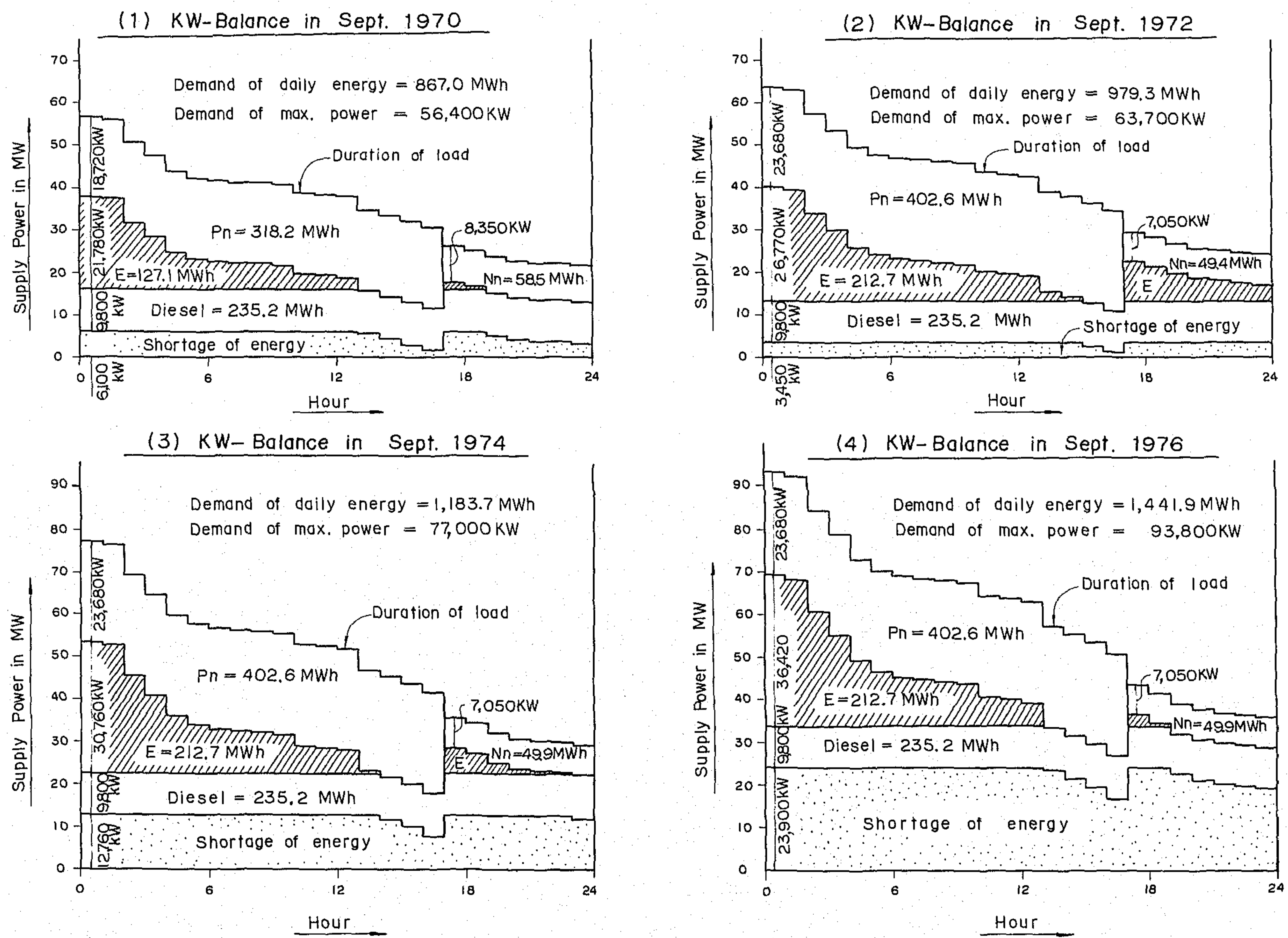
Fig. 3-6 illustrates load share to be supplied by regulated flow output, natural flow output and existing diesel output, respectively, for several typical years from 1968 to 1976. As can be seen in Fig. 3-6, a part of regulated flow power is to supply in off-peak hours. This means that regulating capacity of power plants is not necessarily utilized to the full extent at peak hours depending upon the condition of run-off or pattern of load.

As can be seen in Table 3-21 and Fig. 3-5, the KW-supply capability falls short of demand in the droughty month (September) of 1968. The deficit will be temporarily mitigated to 3,450 KW in 1972 after the 30 MW of Nayon Project is placed in operation. However, it will tend to increase year by year.

Fig. 3-7 shows the relation between the maximum demand and the installed capacity of power plant. In 1974, this maximum demand will surpass the installed capacity of hydro-power plants owned by "EEQ" S.A.

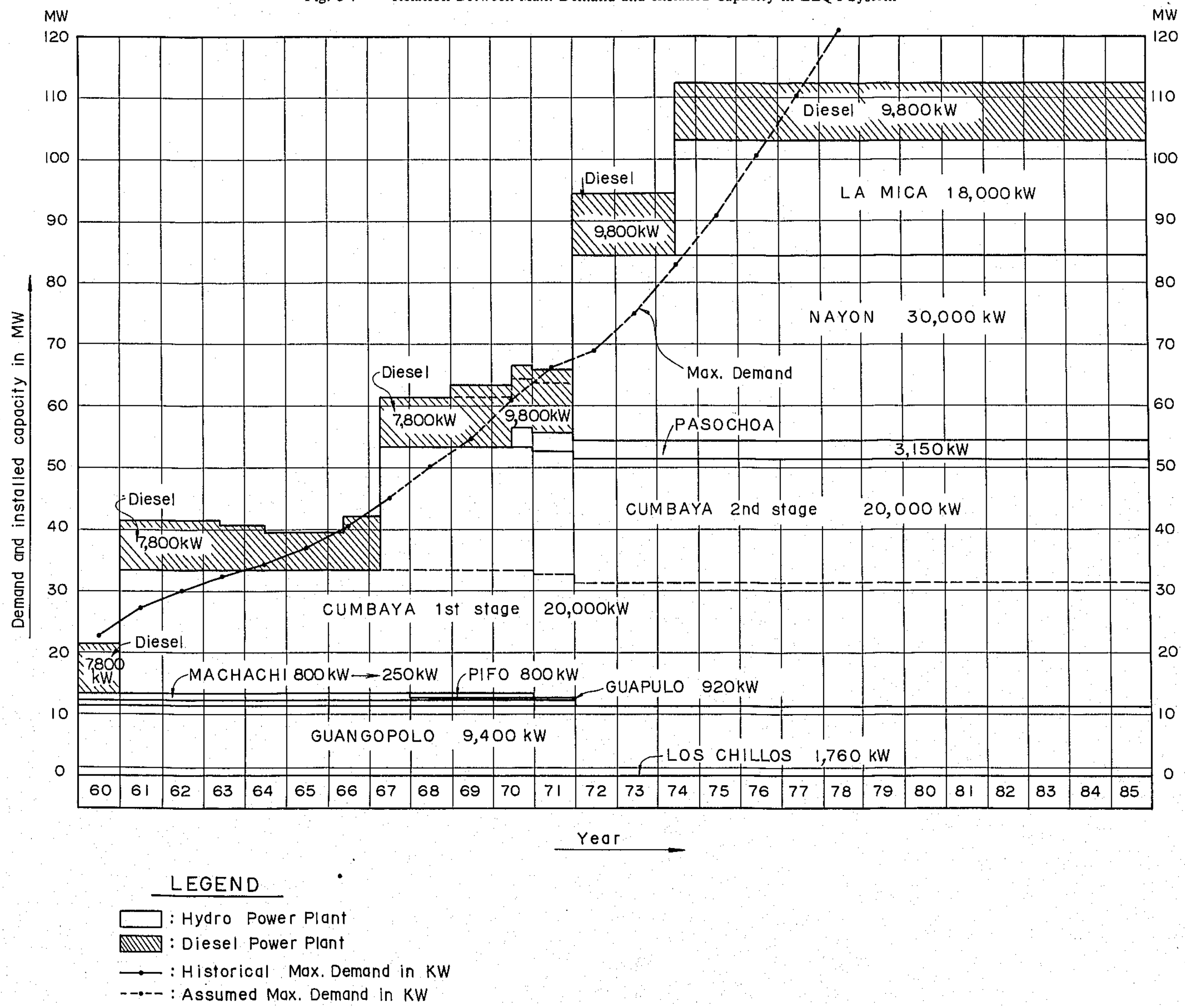
Detailed above is the critical situation between demand and supply in the dry month (September). As for the other months, the shortage will also occur in and after 1974.

Fig. 3-6 Diagram of KW-Balance of Existing EEQ's System in Sept.



Note
E : Regulated energy
Pn: Natural flow energy in peak hour
Nn: Natural flow energy in off-peak hour

Fig. 3-7 Relation Between Max. Demand and Installed Capacity in EEQ's System



3.3.2 Energy Supply Capability and Energy Demand

In order to simplify the study of the balance between energy demand and supply capability, the following method was employed in the calculation.

(1) The following four months were taken as representing seasons of various run-off.

January	:	representing average run-off months from January to March.
April	:	representing wet months from April to June.
September	:	representing dry months from July to October.
December	:	representing maximum demand months of November and December.

(2) The typical daily load curve was divided into three parts, that is, peak hours (3 hours), intermediate hours (14 hours) and midnight hours (7 hours) as shown on Fig. 3-4, and was employed as a standardized base for the study.

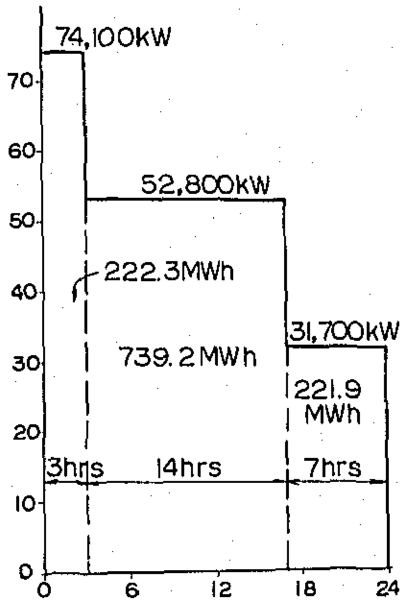
(3) In order to estimate available energy output under various run-off, monthly run-off was divided into three component categories, that is, maximum run-off (5 days), average run-off (20–21 days) and minimum run-off (5 days). Then, the supply capability was computed for these three run-off conditions as shown on Fig. 3-4.

Based on the typical daily load curve as afore-mentioned and supply capability estimated, the share of natural flow energy and regulated flow energy was determined. Diesel supply requirement, energy deficit and surplus energy were also calculated. Fig. 3-8 and Fig. 3-9 show an example of load share.

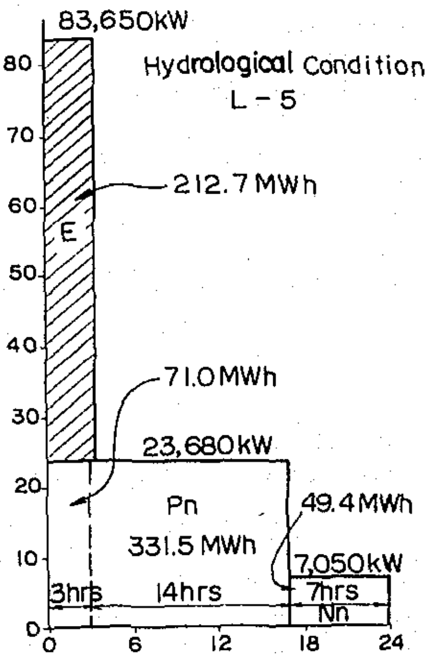
The daily KWh-balances calculated as above were totalled for each month. On the basis of the records in 1967 a supplementary calculation was made for the holiday (Saturdays, Sundays, national holidays, etc.) demand. Thus the KWh balance of supply and demand was obtained.

Table 3-22 shows available energy output of EEQ's hydro-electric power plants which are under operation or construction. Table 3-23 shows the result of the calculation of KWh balance of each year. The results are graphically presented in Fig. 3-10. According to the Figure, the energy shortage which has been encountered in the dry season since 1968 will partially be relaxed for a while after the commencement of operation of Nayon Power Plant. However, the energy shortage will tend to be aggravated after the year and, in 1976, energy supply capability will be in short of demand throughout the year, not only in the dry season. In 1974, despite a total surplus energy of 49,450 MWh throughout the year, there will be a shortage of 14,890 MWh during the dry season and in the maximum demand month. This means that the energy supply capability of hydro-electric power plants is not effectively utilized. Table 3-24 shows the effective available energy and the surplus energy in each month of the year at the hydro-electric power plants owned by "EEQ" S.A.

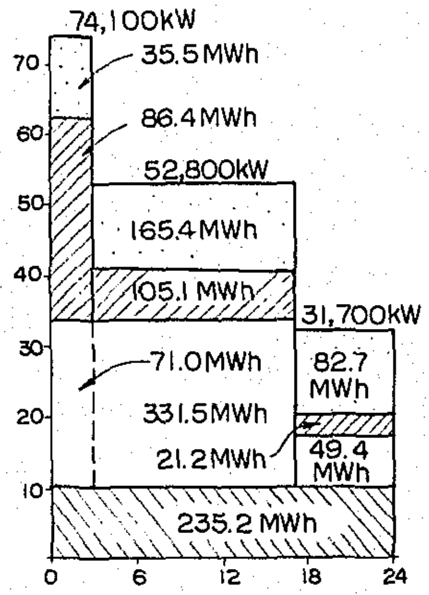
Fig. 3-8   Calculation Method of Energy Balance



Daily Load Diagram



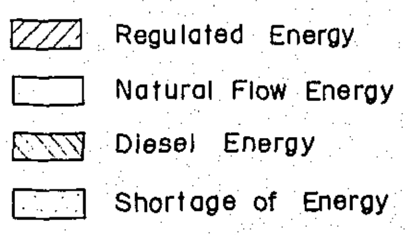
Hydro Power Capalility



Energy Balance

Results

Hydro Natural Flow Energy	: 451.9 MWh
Hydro Regulated Energy	: 212.7 MWh
Total Hydro Energy	: 664.6 MWh
Diesel Energy	: 235.2 MWh
Shortage of Energy	: 283.6 MWh



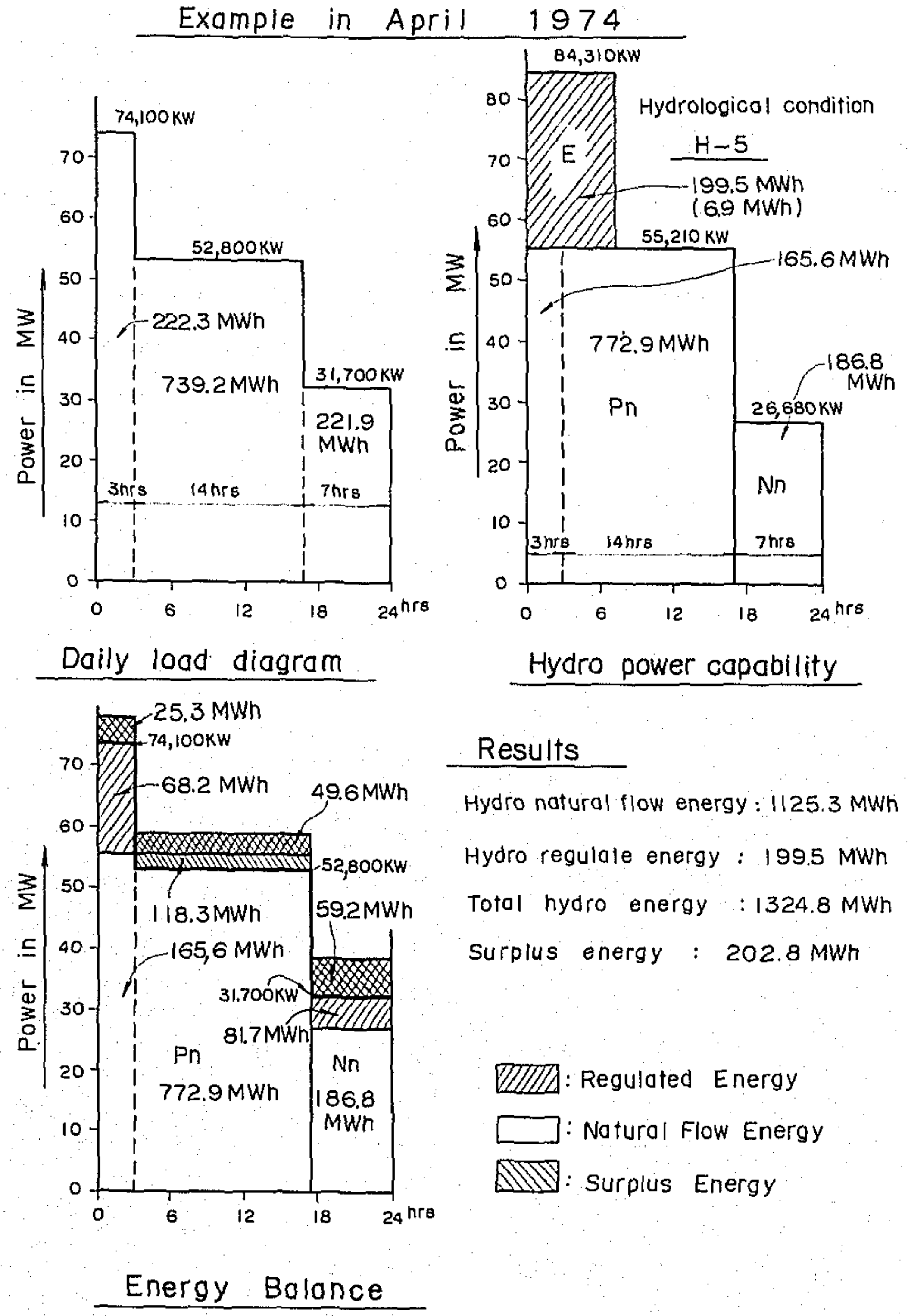
Note

Pn : Natural Flow Energy in Peak Hours

Nn : Natural Flow Energy in Off-peak Hours

E : Regulated Energy

Fig. 3-9 Calculation Method of Energy Balance



Note

Pn : Natural flow energy in peak hours

Nn : Natural flow energy in off-peak hours

E : Regulated energy

Table 3-22 Available Hydro Energy of Existing Power Plants in EEQ's System

Unit: MWh

	Los Chillos	Guangopolo	Cumbaya	Pasochoa	Nayon	Total
Installed Capacity(KW)	1,760	9,400	40,000	4,500	30,000	85,660
Jan.	818	5,825	13,105	2,344	9,804	31,896
Feb.	739	5,366	12,129	2,117	9,074	29,425
Mar.	818	6,174	14,157	2,344	10,590	34,083
Sub-total	(2,375)	(17,365)	(39,391)	(6,805)	(29,468)	(95,404)
Apr.	792	6,276	14,483	2,268	10,834	34,653
May	818	6,369	14,480	2,344	10,833	34,844
June	792	5,412	11,978	2,268	8,960	29,410
Sub-total	(2,402)	(18,057)	(40,941)	(6,880)	(30,627)	(98,907)
July	818	4,815	10,597	2,344	7,928	26,502
Aug.	818	4,155	9,141	2,344	6,838	23,296
Sept.	792	3,946	8,690	2,268	6,501	22,197
Oct.	818	5,009	11,083	2,344	8,291	27,545
Sub-total	(3,246)	(17,925)	(39,511)	(9,300)	(29,558)	(99,540)
Nov.	792	5,186	11,508	2,268	8,609	28,363
Dec.	818	5,475	12,215	2,344	9,138	29,990
Sub-total	(1,610)	(10,661)	(23,723)	(4,612)	(17,747)	(58,353)
Annual	9,633	64,008	143,566	27,597	107,400	352,204

Fig. 3-5 Diagram of KW-Balance of EEQ's System in Sept.

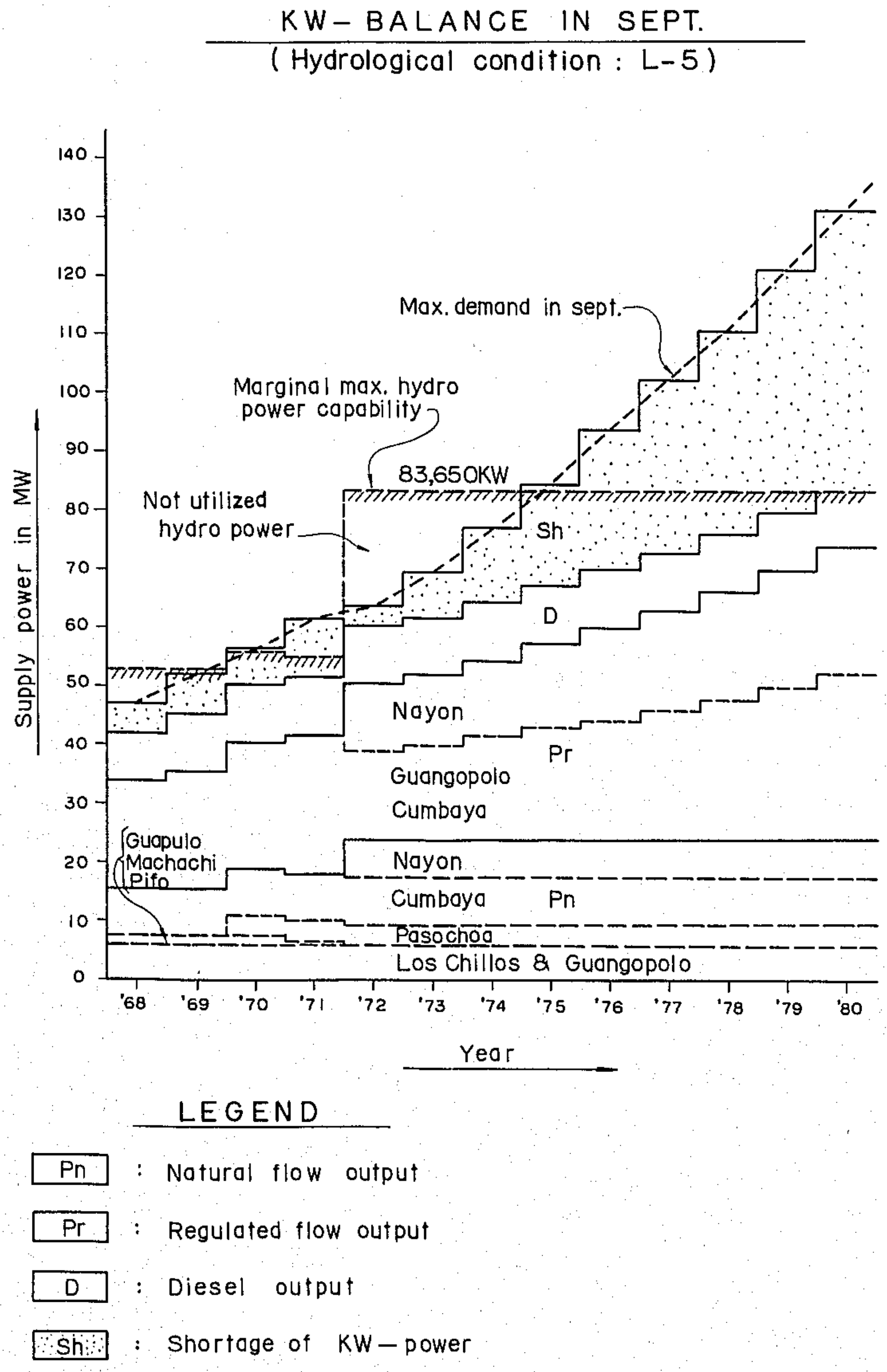


Table 3-23 Balance of Energy Demand in EEQ's Existing System

Unit: MWh

Year	1968				1970				1972				1974				1976			
Month	Demand	Supply of Effective Hydro Energy	Supply of Diesel Energy	Shortage of Energy	Demand	Supply of Effective Hydro Energy	Supply of Diesel Energy	Shortage of Energy	Demand	Supply of Effective Hydro Energy	Supply of Diesel Energy	Shortage of Energy	Demand	Supply of Effective Hydro Energy	Supply of Diesel Energy	Shortage of Energy	Demand	Supply of Effective Hydro Energy	Supply of Diesel Energy	Shortage of Energy
Jan.	18,200	17,600	600	0	21,800	19,090	2,710	0	24,600	24,260	340	0	29,700	27,340	2,230	130	36,200	28,340	5,390	2,470
Feb.	16,800	16,260	540	0	20,200	17,560	2,640	0	22,800	22,490	310	0	27,600	25,480	2,120	0	33,600	26,530	4,870	2,200
Mar.	18,700	18,100	600	0	22,500	20,330	2,170	0	25,300	24,960	340	0	30,600	28,240	2,230	130	37,300	29,440	5,390	2,470
Apr.	18,600	18,180	420	0	22,300	21,670	630	0	25,200	25,200	0	0	30,500	29,680	820	0	37,100	32,730	3,520	850
May	18,600	18,160	440	0	22,300	21,700	600	0	25,200	25,200	0	0	30,500	29,650	850	0	37,100	32,590	3,630	880
June	18,400	16,460	1,940	0	22,100	19,370	2,730	0	24,900	24,900	0	0	30,100	27,710	2,390	0	36,700	29,410	3,520	3,770
July	18,600	13,710	4,570	320	22,300	15,600	5,210	1,490	25,200	22,370	2,830	0	30,500	22,310	6,150	2,040	37,100	26,500	6,590	4,010
Aug.	18,000	11,900	4,570	1,530	21,600	14,800	5,210	1,590	24,300	19,660	4,640	0	29,400	19,600	6,150	3,650	35,800	23,300	6,590	5,910
Sept.	18,300	11,500	4,430	2,370	21,900	14,350	5,040	2,510	24,800	18,730	5,250	820	29,900	18,990	5,960	4,960	36,500	22,200	6,160	8,140
Oct.	18,700	14,290	4,410	0	22,500	16,200	5,210	1,090	25,300	23,250	2,050	0	30,600	23,000	6,150	1,450	37,300	26,550	6,590	4,160
Nov.	19,300	16,380	2,920	0	23,100	19,520	3,580	0	26,100	24,390	1,710	0	31,600	25,450	3,920	1,230	38,500	26,000	5,630	6,870
Dec.	19,400	16,380	3,020	0	23,300	20,620	2,680	0	26,300	24,530	1,770	0	31,700	25,330	5,080	1,290	38,700	25,780	5,820	7,100
Annual	221,600	188,920	28,460	4,220	265,900	220,810	38,410	6,680	300,000	279,940	19,240	820	362,700	302,780	45,040	14,880	441,900	329,370	63,700	48,830

Fig. 3-10 Balance of Energy Demand in EEQ's Existing System

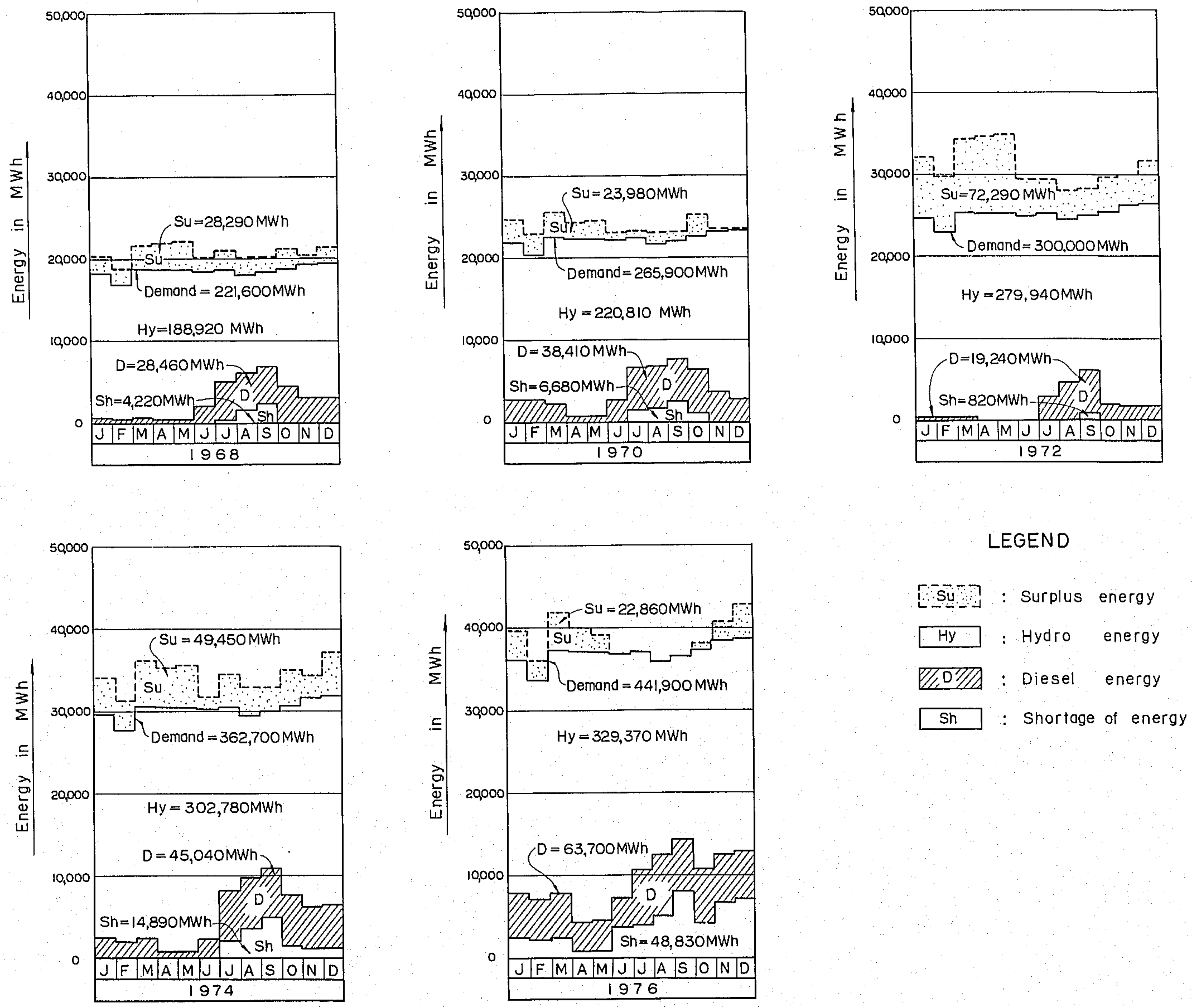


Table 3-24 Monthly Effective Energy of Hydro Power Plants in EEQ's System

Unit: MWh

Year	1968			1970			1972			1974			1976		
Month	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So
Jan.	19,750	17,600	2,150	22,090	19,090	3,000	31,900	24,260	7,640	31,900	27,340	4,560	31,900	28,340	3,560
Feb.	18,230	16,260	1,970	20,350	17,560	2,790	29,450	22,490	6,960	29,480	25,480	3,970	29,450	26,530	2,920
Mar.	21,150	18,100	3,050	23,490	20,330	3,160	34,080	24,960	9,120	34,080	28,240	5,840	34,080	29,440	4,640
Apr.	21,550	18,180	3,370	23,820	21,670	2,150	34,650	25,200	9,450	34,650	29,680	4,970	34,650	32,730	1,920
May	21,670	18,160	3,510	24,010	21,700	2,310	34,840	25,200	9,640	34,840	29,650	5,190	34,840	32,590	2,250
June	18,180	16,460	1,720	20,450	19,370	1,080	29,410	24,900	4,510	29,410	27,710	1,700	29,410	29,410	0
July	16,230	13,710	2,520	18,570	15,600	2,970	26,500	22,370	4,130	26,500	22,310	4,190	26,500	26,500	0
Aug.	14,110	11,900	2,210	16,460	14,800	1,660	23,300	19,660	3,640	23,300	19,600	3,700	23,300	23,300	0
Sept.	13,430	11,500	1,930	15,700	14,350	1,350	22,200	18,730	3,470	22,200	18,990	3,210	22,200	22,200	0
Oct.	16,910	14,290	2,620	19,250	16,200	3,050	27,550	23,250	4,300	27,550	23,000	4,550	27,550	26,550	1,000
Nov.	17,490	16,380	1,110	19,750	19,520	230	28,360	24,390	3,970	28,360	25,450	2,910	28,360	26,000	2,360
Dec.	18,510	16,380	2,130	20,850	20,620	230	29,990	24,530	5,460	29,990	25,330	4,660	29,990	25,780	4,210
Annual	217,210	188,920	28,290	244,790	220,810	23,980	352,230	279,940	72,290	352,230	302,780	49,450	352,230	329,370	22,860

3.4 TIME OF DEVELOPMENT

Judging from the studies made of the balance of supply and demand based on available output in KWand KWh of the power system of "EEQ" S.A., as described in the previous chapters, the supply capability of the power plants, existing or under planning or construction inclusive, cannot cover the shortage in KW and KWh which has been chronically encountered in the dry seasons since 1968. Moreover, the shortage will be more stringent year by year, and be presented not only in the dry season, but in the rainy season, as well.

In 1975, even the installed capacity will be in shortage throughout the year against the maximum demand. Particularly, supply capability will be obliged to fluctuate sizably between the rainy season and the dry season. Therefore, the development of reservoir type project is indespensable to increase supply capability in the dry season.

Accordingly, La Mica Project should be developed as early as possible. However, the date of commencement of operation of the project would be in April, 1974, at the earliest if the schedule and amount of works of Nayon project to be undertaken by "EEQ" S.A., and the period required for the definite study, tenders for works and preparatory works are taken into consideration in addition to the proposed period of about 25 months for construction works.

Chapter IV

DESCRIPTION OF PROJECT

Chapter IV

DESCRIPTION OF PROJECT

4.1 GENERAL DESCRIPTION OF PROJECT AREA

The objective of La Mica Project is to supply power generated to the city of Quito and, from 1984, to provide water supply to the city. Therefore, the project covers the areas of Quito City, the load center, La Mica lake located 50 km southeast of Quito City, the waterway route which will extend for a distance of 27 km, and the power plant site on the slope of Tablón Alto plateau. This project is closely related to the existing power stations of Rio San Petro system owned by "EEQ" S.A. which are expected to produce downstream benefits, and the Rio Pita Project to provide water supply to Quito City.

Quito City is located in the Quito Basin, 2,000 m to 2,800 m above sea level, surrounded by the Andes mountain range running the central part of Ecuador from south to north.

Quito city is the center of politics, and culture of Ecuador, and has a large concentration of population. Although the city is directly under the equator, the climate is mild without much fluctuation in temperature throughout the year. However, rainy season and dry season are in a great contrast. Much rainfall is concentrated in March – June while the months of August – October are dry. During the rainy season, water is sufficient to meet the requirements for power generation and water supply, but it become short in the dry season.

In order to cope with this situation, water of Lake La Mica which is in the Amazon basin where rainy and dry seasons are the revirse should be diverted to the Rio San Pedro Basin so that the existing power plants in the basin may firm up their output during the dry season, and to utilize water, which is of good quality, for city water supply after 1984.

Such diversion will be made by excavating a tunnel of only 2.95 km through the Andes Mountain Range and 20.9 km of canals with two additional tunnels of 1.77 km and 0.5 km in length. Water thus diverted will released into the Rio San Pedro which drains into the Pacific Ocean.

The geological and topographical conditions along the route of waterway are favorable. Hydrological and topographical survey has been conducted by "EEQ" S.A. for 8 years since 1960. Since the structures to be constructed are to be located within the premises of a hasienda, all the construction sites are accessible by jeep through existing roads. Therefore, temporary works of the project can be started immediately.

4.2 DESCRIPTION OF PROJECT

4.2.1 Power Generation

The water level of Lake La Mica which drains into the River Amazon will be raised by

4m to create a reservoir with an effective storage capacity of 21,000,000 m^3 for power generation and city water supply. The annual flow will be regulated and an average of 2.3 m^3/s will be released into the Rio San Pedro which drains into the Pacific Ocean. For this diversion scheme a waterway of 27.4 km will be necessary. Water in the reservoir will be conducted by this waterway to Tablón Alto from where a penstock will be installed on the Western slope of the East Andes mountain range to the powerhouse. The difference of elevation between Tablòn Alto and the powerhouse will produce a total head of 530.3 m and an effective head of 496.5 m. If the capacity of the waterway is 4.5 m^3/s in consideration of release of water in the dry season, it is possible to provide 18,000 KW of installed capacity in the powerhouse.

The tail water level of the powerhouse was designed so as to permit connection in the future with Rio Pita waterworks project (to be described later) for city water supply. La Mica Power Plant will generate 82,300,000 KWh of energy annually with an annual average discharge of 2.3 m^3/s, before water is diverted for city water service which is estimated after 1984. And before this time the Rio San Pedro will benefit from the increased flow at the existing power stations of Guangopolo (Q_{max}=18m^3/s P=9,500 KW), Cumbaya (Q_{max}=36m^3/s P=40,000 KW) and Nayon (Scheduled operation 1972, Q_{max}=36m^3/s P=30,000KW). The annual benefits at the downstream plants will be 45,400,000 KWh

This power benefit will gradually decrease when water is diverted for city water service. Calculations based on a serviceable life of 50 years show that the annual average benefit will be 18,760 KWh after the commencement of city water service in 1984, and above all most of this energy will be generated during the dry season which will greatly firm up the supply capability of "EEQ" S.A. power system.

The main features and economic of La Mica Project are as follows.

Maximum output:	18,300 KW
Maximum discharge:	4.5 m^3/sec.
Effective head:	496.5 m
Reservoir	
Normal high water level:	3,904 m
Low water level:	3,894.5 m
Drawdown:	9.5 m
Effective storage capacity	21,000,000 m^3
Dam	
Type of dam:	Earthfill
Height:	12 m (average height: 6.3 m)
Crest length:	415 m
Volume:	55,000 m^3
Waterway (tunnels and canals)	
Total length:	27,410 m (tunnel : 5,223 m, open canal : 20,907 m)

Maximum capacity: 4.5 m^3/sec.

Tributory diversion waterway (open canals)

Total length: 1,070 m

Regulating pond (head tank)

Normal high water level: 3,870.90 m

Effective storage capacity: 25,000 m^3

Penstock

Length: 2,596 m

Number of line: 1

Inner diameter: 1.60 – 1.00 m

Powerhouse

Type: Above ground, indoor type

Number of units: 2 units

Output per unit: 9,500 KW

Annual average energy production (including downstream benefit):

101,010,000 KWh/year (generating end) 97,580,000 KWh/year (sending end)

48,000,000 KWh/dry season months (July – October)

Construction cost:

Total construction cost: s/. 176,900,000 (domestic currency s/. 104,716,000, foreign currency s/. 72,184,000)

Construction cost after allocation water supply s/. 143,240,000 (domestic currency s/. 80,400,000, foreign currency s/. 62,840,000)

Benefit (before allocation)

Construction cost per KW: s/. 9,830 KW

Construction cost per KWh: s/. 1.49 KWh (Guangopolo substation end)

Generating costs: s/. 0.159 KWh (Guangopolo substation end)

Benefit (after allocation)

Construction cost per KW: s/. 7,960 KW

Construction cost per KWh: s/. 1.468 KWh (Guangopolo substation end)

Generating cost: s/. 0.157 KWh

Benefit/cost: B/C = 2.26

4.2.2 Water Supply Scheme

The water stored and regulated in La Mica Reservoir will be supplied to the waterworks of Quito City after 1984. The water supply will be a maximum of 3 m^3/sec. and an annual average 2.3 m^3/sec. This means that the total natural inflow to Lake La Mica will be released for water supply. In view of the growth of demand for city water, it will not be until after 18 years that the total inflow is consumed for city water. Until that time, the water flowing into Lake La Mica can also be used for power generation. The water used for power generation at La Mica Power Station will be led to Pita intake dam of Rio Pita (First Stage to be completed in 1972) through a connecting waterway (maximum flow: 3 m^3/sec., length 21.5 km) which will be constructed after 1984. This water will be led to the water purification plant in the suburbs of Quito City through a big siphon and a waterway constructed at the foot of Pasochoa. This water from La Mica will meet the demand for city water in Quito City for 18 years.

Investigation on La Mica Connecting Waterway will have to be made in the future, but according to present approximate estimates, the main features and the preliminary estimated construction costs are as follows.

Maximum intake: 3 m^3/sec.

Average intake: 2.3 m^3/sec.

(1) Re-regulating Pond

Purpose: The maximum discharge for power of 4.5 m^3/sec. is regulated to 3 m^3/sec. which is the capacity of the connecting waterway.

Normal high water level: 3,339.00 m

Effective storage capacity: 42,000 m^3

(2) Bypass Waterway for City Water Supply during Stoppage of Power Station.

Purpose: When the powerhouse is stopped for maintenance or by accident water will be release from the head tank to Qda.de Secas through the spillway and taken to the tailrace of the power station.

Type: Canal, trapezoidal cross section

Capacity: 3 m^3/sec.

Length: 5,000 m

(3) Waterway between Power Station Tailrace and Re-regulating Pond

Purpose: The water discharged from the powerhouse will be taken through this waterway to the re-regulating pond.

Type: Canal, trapezoidal cross-section

Capacity: 4.5 m^3/sec.

Length: 1,200 m.

(4) Waterway between Rio Pita Intake Dam and Re-regulating Pond

Purpose: The water will be taken from the re-regulating pond through this waterway to Rio Pita Intake Dam (to be completed in 1972).

Type: Canal and tunnel

Capacity: 3 m^3/sec.

Total length: 21,500 m (Canal: 20,000 m, tunnel: 1,500 m)

The estimated construction cost of La Mica connecting waterway is s/. 82,360,000. With the amount to be borne by La Mica Power Station (1984 fiscal year) s/. 79,681,000 added, the total cost is s/. 162,041,000
If an annual cost of s/.162,200,000,which is 10%, is devided by the annual average volume of city water supply of 38,340,000 m^3 in the remaining life 40 years, the cost will be s/. 0.42 per m^3 of water.

4.2.3 Transmission Line and Substation

The 18 MW of power to be generated at La Mica Power Station will be stepped-up to 46 kV at the substation which will be constructed on the north side of the power station. The power will be transmitted from this substation to Guangopolo Substation via Alangasi on a new 46 kV, 1 circuit transmission line 25 km long. Between Guangopolo and Quito South Substation. There is an existing 46 KV and 22 KV line, 6.8 km long, strung on a common tower. The 22 KV line will have to be stepped-up to 46 kV in 1972. With these two circuits, upon commencement of operation of La Mica in 1974, the increment in output at Guangopolo, Cumbaya and Nayon power stations can transmitted to Quito on the existing transmission lines which have sufficient capacity.

The main features and estimated construction costs of the substation and transmission line are as follows.

(1) La Mica Substation

Type: Outdoor, three-phase, oil-immersed self-cooling.

Number of unit: 2

Capacity: 10,000 kVA

Voltage: 6.9/46 kV

(2) New Transmission line

Route: La Mica to Guangopolo Substation

Length: 25 km

Voltage: 46 KV

Number of circuit: 1

Construction cost: s/. 5,000,000

domestic currency
s/. 2,476,500
foreign currency
s/. 2,523,500

Chapter V

HYDROLOGY

Chapter V

HYDROLOGY

5.1 RUN-OFF GAGING STATION AND METROLOGICAL STATIONS

5.1.1 Run-off Records of La Mica Project

Run-off data for the catchment area (125 km^2) of La Mica Project are available at Antizana run-off gaging station (owned by EEQ) which measures the discharge of Rio Antizana at a site approximately 2 km downstream of Laguna Mica. Run-off measurement has been continued for seven years from 1960 to November of 1966 and is suspended at present, but measurement can be resumed if required. There is also a staff gage installed at Desaguadero to measure the outflow from Laguna Mica. Water level records at the outlet of Laguna Mica are available from September of 1960 to May of 1966. Another staff gage is installed on the western edge of the lake to measure the surface level of the lake. Records are available from 1960 to November, 1966 and readings are not taken at present. Measurement of water level by staff gage has been carried out on the Rio Segundo from September, 1960 to November, 1965.

The run-off data of Antizana gaging station should be most reliable in consideration of its good location, and measurement has been continued for a long period. Therefore, it is most appropriate to use the run-off data this gaging station for La Mica Project.

5.1.2 Run-off Records of Rio San Pedro

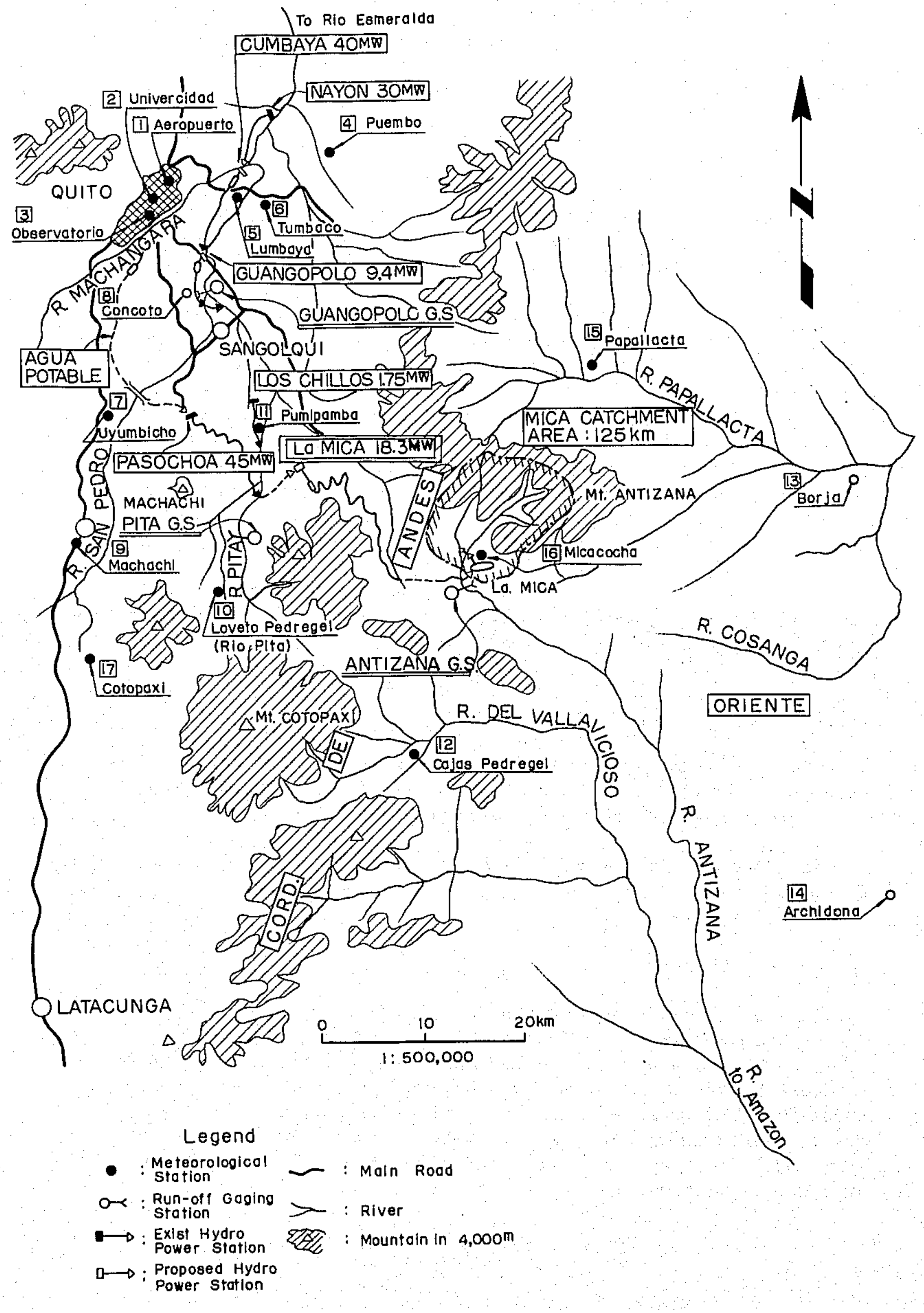
Guangopolo Gaging Station (owned by EEQ) on the Rio San Pedro, which is indirectly related to La Mica Project, has continued the measurement from 1956 until the present. This is an important installation to judge the run-off of the Rio San Pedro.

The records available indicate the average run-off per day at a certain time, and the peak flood run-off has not been measured.

5.1.3 Meteorological Stations

There are 17 meteorological stations directly or indirectly related to La Mica Project. There is Micacocha observatory (3,900 m in height) established on the lake side of La Mica by EEQ. This observatory was opened in April, 1959 for the study of La Mica Project and has continued the observation for 8 years until October, 1966 when the observation was discontinued. There is also Rumipamba Observatory which is the nearest to La Mica Project. However, this observatory has been in operation for less than several years. As the project site is within a short distance from Quito City, it is proper to refer to the records of Quito Observatory which has been in operation since 1936.

Fig. 5-1 Location of Meteorological Sta. & Run-off Gaging Sta.



To study the meteorology of the project area on the eastern slope of the East Andes Mountain, which is called Oriente District, reference must be made to the data of the observatories at Papallacta, Cajas Pedregal, Borja, etc.

5.2 PRECIPITATION

La Mica Project catchment area is located on the equator in the eastern slope of the Andes Mountain (4,000 – 5,000 m) and its climate is affected by the climate of Andes Mountains and heavily influenced by the rainy zone along River Amazon. This area is also under the influence of Niño and Humbolt Currents of the Pacific Ocean, as this area is located in the area where the topography of Andes Mountain is a narrow strip. Therefore, precipitation is evenly distributed throughout a year. Generally speaking, July, August, September and October are the wet season, while January, February and March are the dry season. The amount of precipitation in the wet season is about two and a half time more than in the dry season. Fig. 5-2 shows the general distribution of rainfall through a year in this district. According to the figure, it will be noted the project area is located in the district with an annual precipitation of 1,500 mm – 2,000 mm and is strongly influenced by the rainy district of the Amazon.

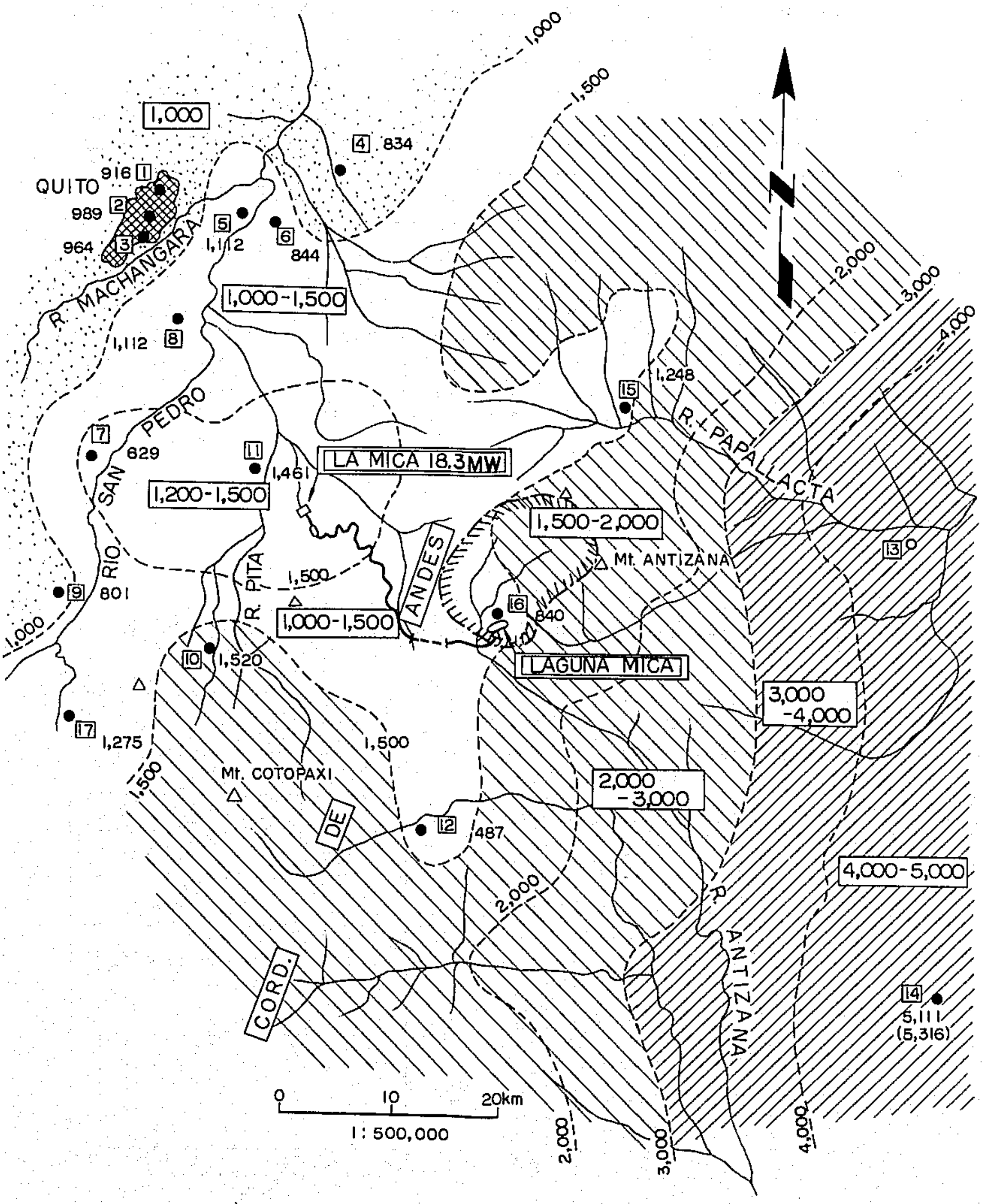
Generally, the peak of the rainy season in the Amazon basin is in August and September, when the annual maximum precipitation is recorded. Even in the dry season, there is abundant precipitation in this area. The reason is that this area is influenced by convection and orographic precipitation. Therefore, when both phenomenon occur simultaneously, it causes heavy rainfall. Rainfall is experienced during the highest temperature hours, namely from noon to 4 p.m.

Generally, rain falls in the afternoon in many cases. Therefore, the sky is clear in the morning throughout the year. The data of Micacocha Observatory is available to analyze this meteorological phenomenon. It is judged that these data show the meteorological phenomenon of approximately the average in La Mica catchment area. According to the records of Micacocha Observatory, the maximum annual precipitation is 856.0 mm, the minimum 576.9 mm and the average 794.9 mm. These show that the precipitation is averaged throughout a year. The monthly maximum precipitation is 188.0 mm and the daily maximum is 51.0 mm. (See Table 5-1).

Table 5-1 Monthly Precipitation at Micacocha Observatory
(For period 1959 to 1966)

Month	Maximum	Average	Minimum
January	48.7	29.3	8.6
February	67.8	42.6	13.6
March	139.2	68.2	35.7
April	133.7	71.1	42.2
May	141.2	85.7	25.8
June	156.5	91.7	37.7
July	188.0	88.9	56.7
August	95.7	63.4	43.6
September	124.1	65.5	23.3
October	91.7	70.0	49.0
November	139.6	70.8	24.5
December	57.3	47.7	25.3
Annual Total	-	794.90	-

Fig. 5-2 Rainfall Chart in La Mica Project Area



Legend

● : Location of Meteorological Station

2 : Marks of Meterological Station (See Fig.5-1)

⊏⟶ : Proposed Hydro Power Station

Note

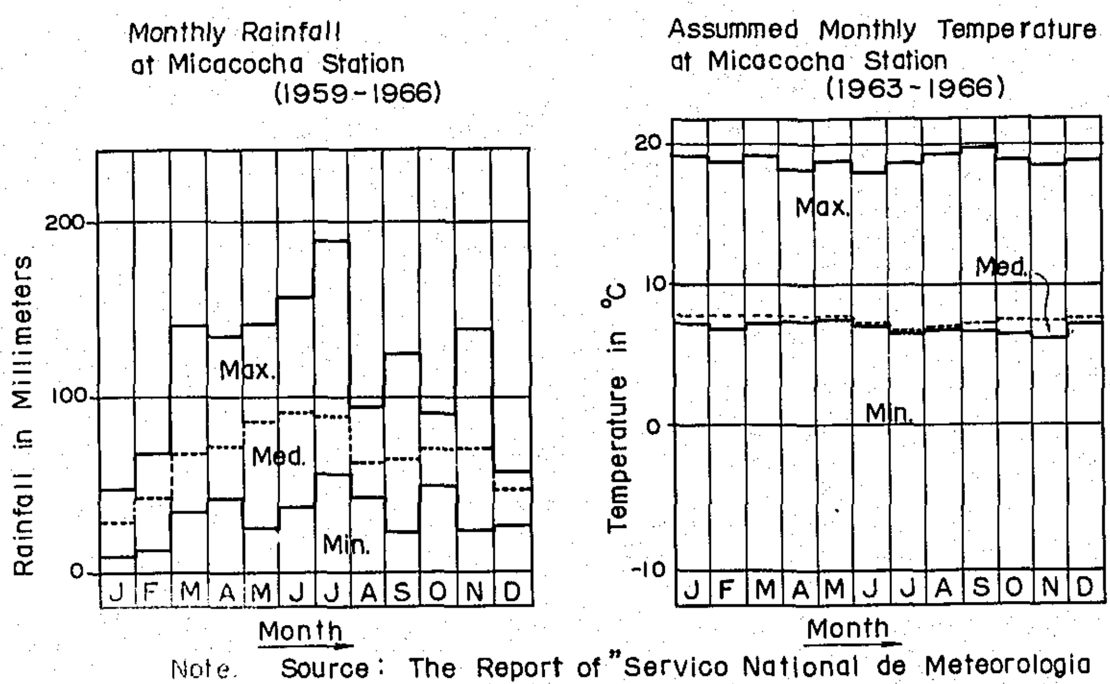
Source : The Report of "Servico National de Meteorologia e Hidrologia"

5.3 TEMPERATURE

The climate in La Mica Project area depends on the altitude. Climatic condition in the project area is uniform throghout the year, and the variation of temperature is only 1 to 2°C. However, the climate largely changes in a day as the project area is located at high altitude.

The temperature goes down in the dawn and night, while it goes up to the highest from the noon to 1 p.m. The difference of temperature may be 20° and more. The reservoir area of La Mica Project is located in the mountainous region of elevation 4,000 m and it is estimated to have nearly the same characteristics as those in Papallacta (3,160 m in height), Cotopaxi (3,560 m in height), etc. Estimating from the observation values of these observations, the annual average temperature is 7.7°C to 9.5°C. The lowest temperature is 0°C to 1.5°C around September. However, the lowest temperature changes within the range of 4.8°C through a year. On the other hand, the highest temperature is around noon ranging from 14.0°C to 19.0°C. This temperature condition is assumed to be the same in the reservoir area and along the waterway course which are located at an altitude of 4,000 m. However, the temperature at the site of La Mica Power Plant is estimated to be the middle value between Quito and Cotapaxi. It is estimated under such conditions that the average temperature is 10.6°C, the lowest temperature is 4.4°C and the highest temperature is 19.0°C

Fig. 5-3 Monthly Rainfall and Assumed Temperature in Micacocha Station



Note. Source: The Report of "Servico National de Meteorologia e. Hidrologia"
Micacocha Station is 3,800m above mean sea level

Table 5-2 Table of Monthly Temperature

Location and Altitude	Papallacta			Cotopaxi			Quito		
	3,160 m			3,560 m			2,818 m		
Month	Max.	Min.	Med.	Max.	Min.	Med.	Max.	Min.	Med.
January	17.5	2.9	10.0	16.5	1.1	8.1	22.0	8.1	13.8
February	18.4	3.0	10.0	16.1	0.8	7.9	21.6	8.1	13.6
March	17.4	2.7	9.5	17.2	1.4	8.0	21.7	8.4	13.7
April	16.6	3.7	9.8	15.6	1.8	7.7	21.1	8.5	13.5
May	17.0	4.8	10.2	16.0	2.1	8.0	21.9	8.2	13.9
June	16.0	2.5	8.9	15.0	1.0	7.3	21.4	7.6	13.5
July	15.1	2.0	8.6	15.7	0.1	7.0	22.1	7.2	13.6
August	15.5	2.9	8.6	15.9	0.4	7.4	22.9	7.0	13.7
September	16.4	2.6	9.1	16.6	0	7.7	23.1	7.2	13.9
October	18.1	2.1	9.7	16.2	0.4	7.8	22.0	7.7	13.3
November	18.4	2.8	10.2	16.1	0	7.8	21.2	7.7	13.1
December	18.1	2.9	9.9	16.3	1.5	7.8	21.5	8.1	13.5
Annual Average: Maximum	19.6	4.0	10.6	17.8	3.5	8.7	24.2	9.1	14.4
Annual Average	17.0	2.9	9.5	16.1	0.9	7.7	21.9	7.8	13.6
Annual Average: Minimum	16.2	0	8.3	14.0	-1.5	6.5	19.3	6.5	12.3

Note: For Papallacta: the average value from Aug. 1963 to Dec. 1966.
For Cotapaxi: the average value from Jan. 1963 to Dec. 1966.
For Quito: the average value from Jan. 1959 to Dec. 1966.

5.4 DISCHARGE

5.4.1 Discharge Data

The inflow to La Mica Reservoir consists of two sources. The one is from the two large streams of Qda. Banio Urria Pungo (CA = 55 km^2) and Rio Chico (CA = 35 km^2) which originate in Mt. Antizana and the other is the run-off from the catchment (CA = 35 km^2) of Mica Lake itself. The discharge of these two streams combined with the water of La Mica Lake flows into Antizana River which joints the main stream of the Amazon River. Antizana Gaging Station is located immediately downstream of the confluence of the two streams. The catchment area of Antizana Gaging Station and the catchment area of the lake have nearly the same areas. Therefore, it is judged reasonable to adopt the recorded data at Antizana Gaging Station as the inflow of La Mica Reservoir.

Water stored in La Mica Reservoir will be diverted through the East Andes Mountain, to the Rio San Pedro which flows into the Pacific Ocean. Thus the increment of flow in the Rio San Pedro will firm up the output of the existing power plant along on the river. Accordingly, the discharge records of Guangopolo Gaging Station should be used for the study of the flowing conditions of Rio San Pedro after the diversion of water from La Mica Reservoir. The monthly discharge at Antizana Gaging Station was measured in the rainy and dry years. The results are shown in Table 5-3 and Table 5-4.

Table 5-3 Monthly Average Inflow of La Mica Reservoir
Discharge at Antizana

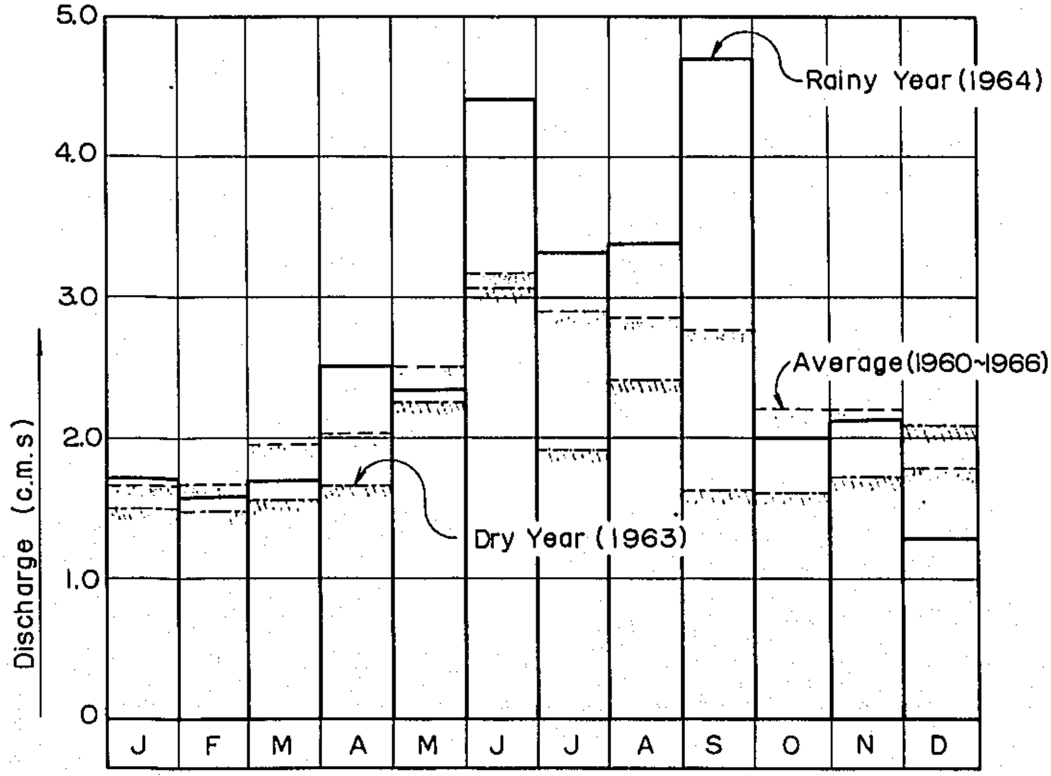
Month	Average Year	Rainy Year	Dry Year
January	1.66	1.73	1.50
February	1.67	1.59	1.49
March	1.95	1.70	1.57
April	2.03	2.52	1.69
May	2.52	2.35	2.27
June	3.18	4.41	3.07
July	2.92	3.33	1.92
August	* 2.87	3.38	2.43
September	* 2.78	4.71	1.64
October	* 2.21	2.00	1.62
November	2.21	1.73	2.13
December	1.79	1.29	2.09
Annual Average	2.32	2.56	1.95
Maximum	3.18	4.71	3.07
Minimum	1.66	1.29	1.49

Note: * The dry months of the Rio San Pedro are August, September and October.

Average year is the monthly average values for the seven years from 1960 to 1966.

The rainy year is 1964 and the dry year is 1963.

Fig. 5-4 Monthly Average Discharge in La Mica Reservoir



5.4.2 Discharge and Mass Curve at Project Site

As stated in 5.4.1, the source of inflow to La Mica Reservoir is the two large branch streams, Qda. Bañio Urria Pungo and River Chico, and La Mica Lake. These waters are stored in the reservoir. Therefore, to study the necessary reservoir capacity for seasonal regulation in wet and dry years, it is necessary to draw a mass curve of daily river run-off from 1959 to 1966. The discharge from Qda. Bañio Urria Pungo and Rio Chico was a maximum of 8.0 m^3/s in the past. The maximum capacity of the connecting waterway is 4.5 m^3/s, so almost 100% of the annual discharge can be conducted to La Mica reservoir. Therefore, the inflow to La Mica Reservoir can be obtained by preparing the mass curves of the measured discharge at Antizana Gaging Station. The mass curves are shown in Fig. 5-5 and 5-6.

(1) Fig. 5-5 is the mass curve when La Mica Reservoir is operated for power generation only. It is assumed that the power plants on the Rio San Pedro will use an average discharge of 4.0 m^3/s in the four months of July, August, September and October, and an average discharge of 1.436 m^3/s in the other months.

(2) Fig. 5-6 is the mass curve when La Mica Reservoir is used for the two purposes of power generation and potable water supply. The operating discharge is estimated as follows:

Average 1.8 m^3/s from January to June.

Average 3.0 m^3/s from July to September.

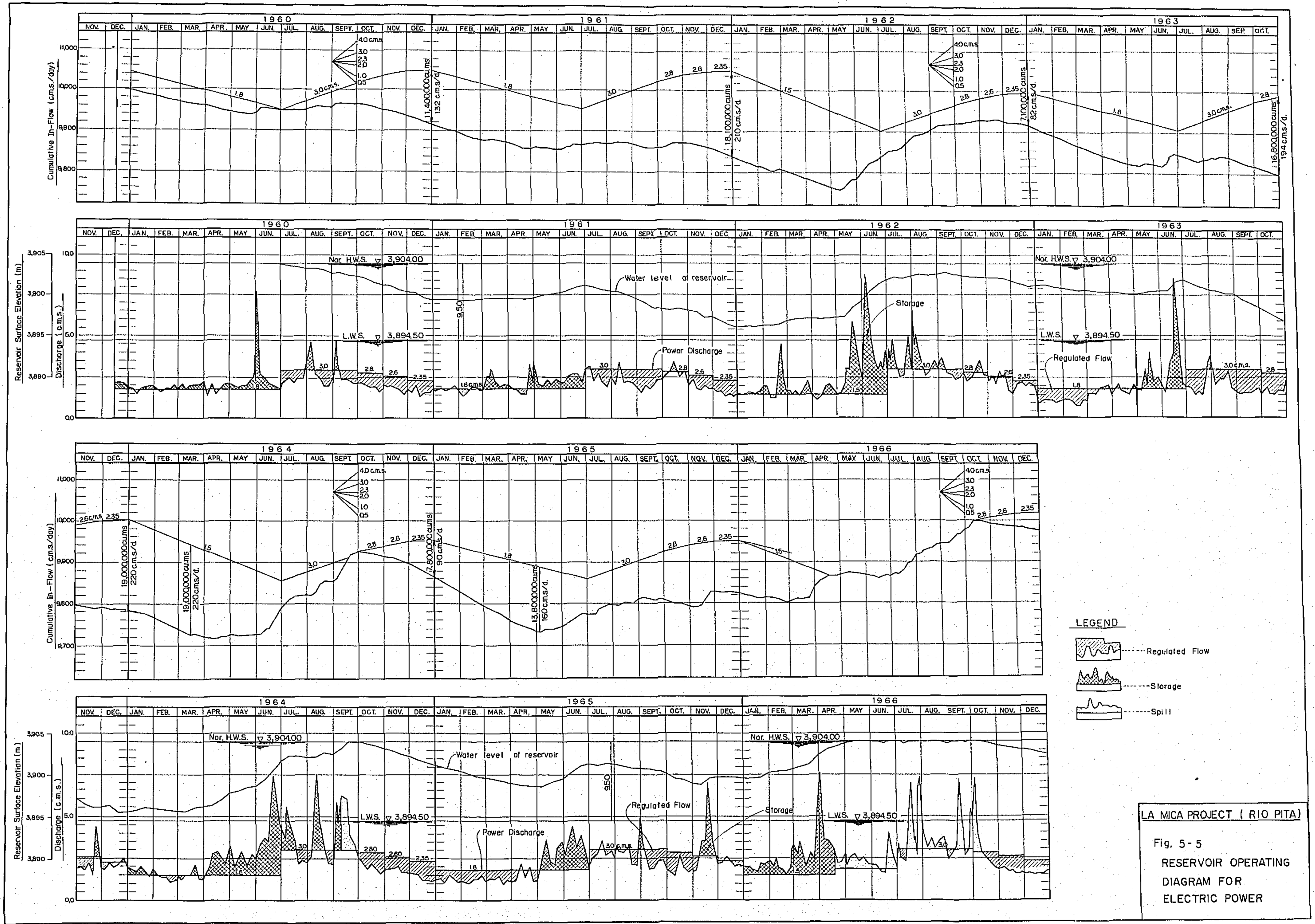
Average 2.8 m^3/s in October.

Average 2.6 m^3/s in November.

Average 2.35 m^3/s in December.

According to the two figures, the years, 1960, 1961, 1963 and 1965, from a hydrologic viewpoint, correspond to dry years or normal years. With an effective storage capacity of 21,000,000 m^3, it is possible to carry over the storaged water in the preceeding year and discharge an average of 2.3 m^3/s.

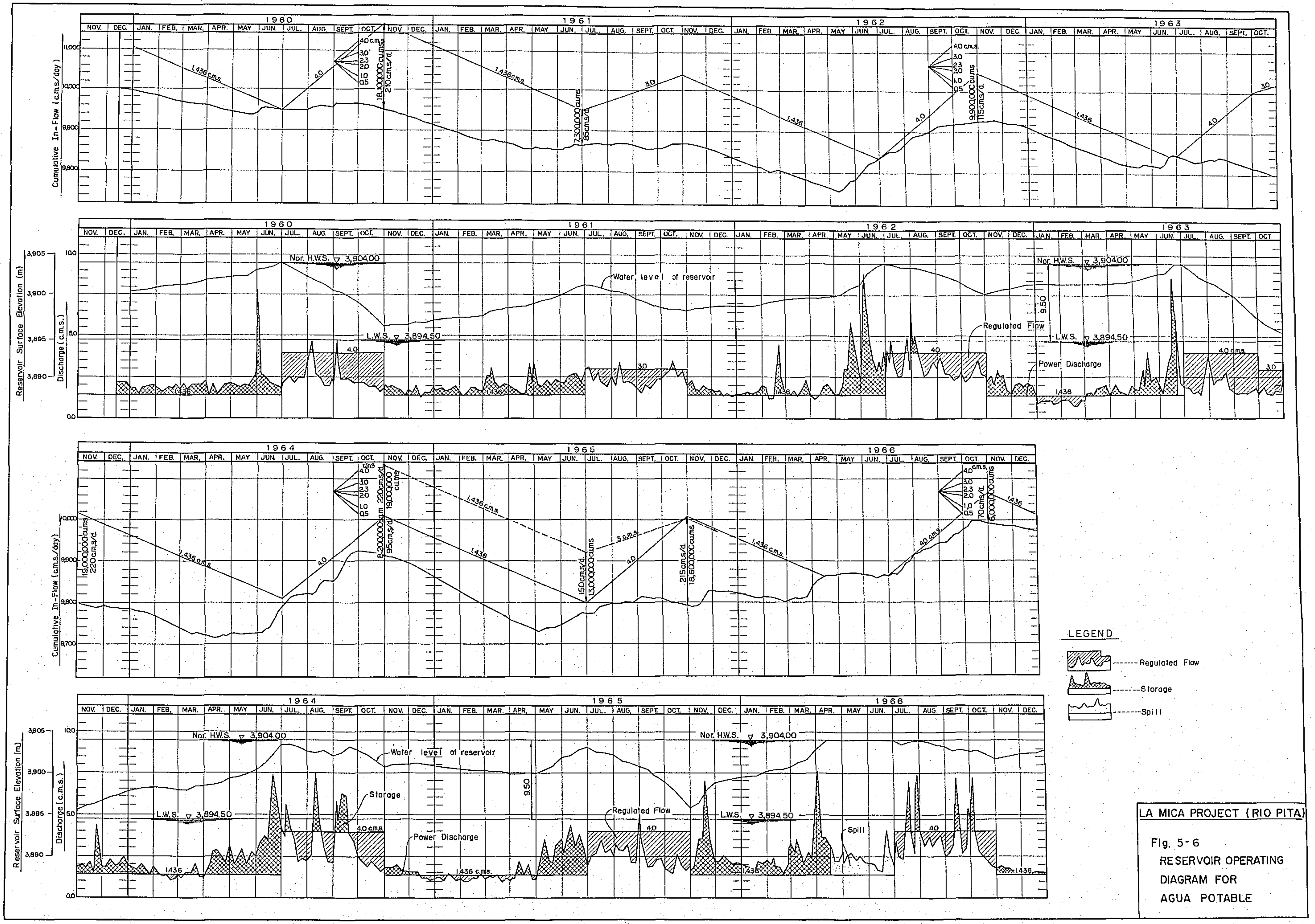
Note: The discharge (m^3/sec. days) plotted on the ordinate of the abovementioned mass curves is the cummulative value of daily discharge less the average of 2.3 m^3/s for 8 years.



LA MICA PROJECT (RIO PITA)

Fig. 5-5

RESERVOIR OPERATING DIAGRAM FOR ELECTRIC POWER



LA MICA PROJECT (RIO PITA)

Fig. 5-6
RESERVOIR OPERATING
DIAGRAM FOR
AGUA POTABLE

5.5 STORAGE CAPACITY OF LA MICA RESERVOIR

In determining the storage capacity of La Mica Reservoir, the cases of operation for power generation only and operation primarily for potable water were taken into consideration. The operating rule of the reservoir in the two cases is as follows:

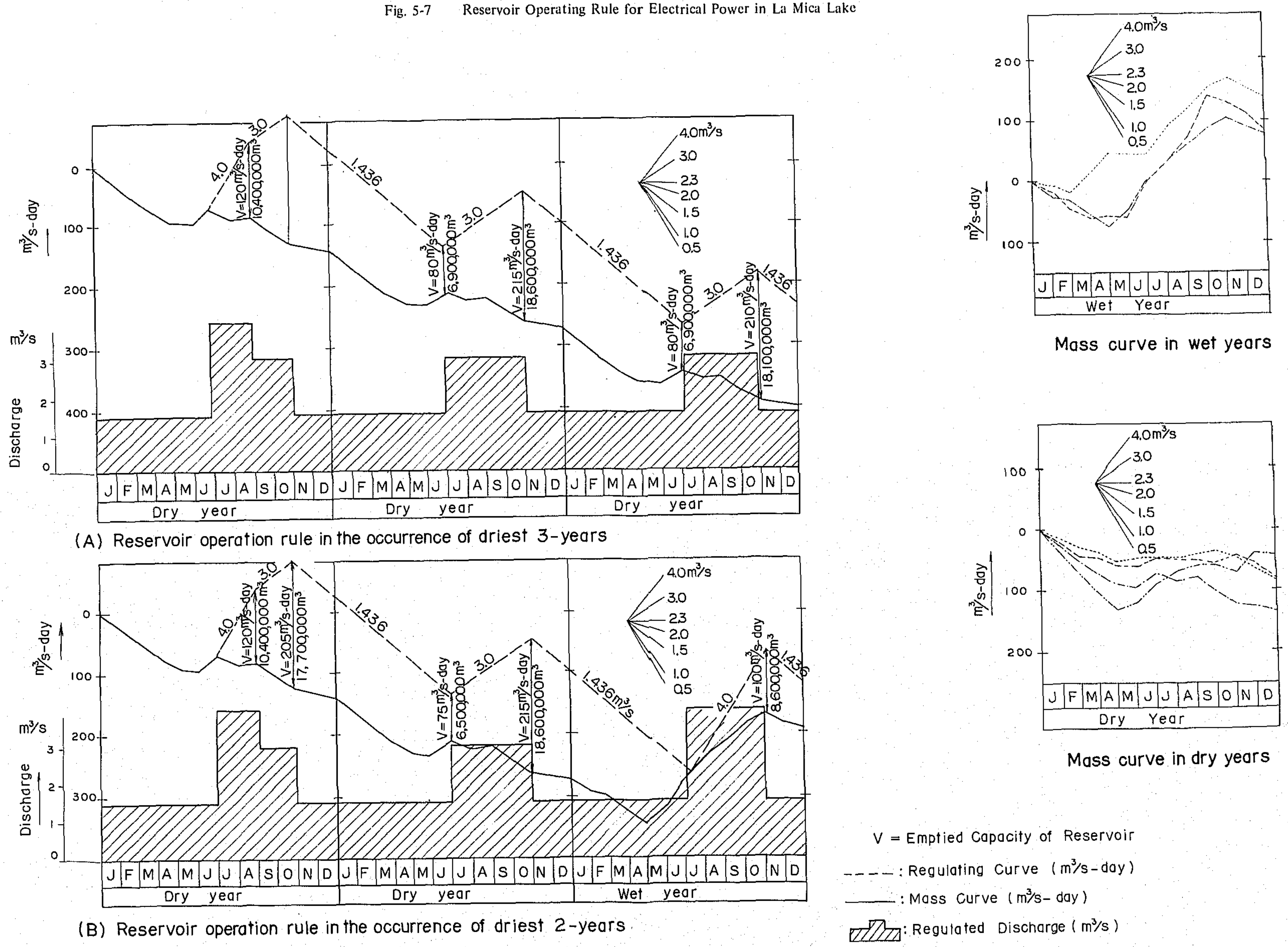
(1) Reservoir operation rule for power generation only

According to the records for 7 years of 1960 to 1966, the above years can be divided into wet and dry years as shown in Fig. 5-7.

When the reservoir operation for power generation only is considered, it is appropriate to study it under the conditions of three consecutive dry years. Two cases were studied. One was three consecutive dry years and the other is two consecutive dry years followed by a wet year, and the operating rule as shown in Fig. 5-7 was applied. The results show that the necessary storage capacity of the reservoir is 18,600,000 m^3/s. Including an allowance of 13%, the effective capacity of the reservoir becomes 21,000,000 m^3/s. It is in the end of October, when the reservoir is fully drawn down. Monthly average discharge for power generation is to be 1.436 m^3/sec. from November to June, 4.0 m^3/sec. for the four months from July to October which is the dry season.

In case of two consecutive dry years, the average discharge in the third year, is limited to 3.0 m^3/sec. for the period from July to October.

Fig. 5-7 Reservoir Operating Rule for Electrical Power in La Mica Lake



(A) Reservoir operation rule in the occurrence of driest 3-years

(B) Reservoir operation rule in the occurrence of driest 2-years

Mass curve in wet years

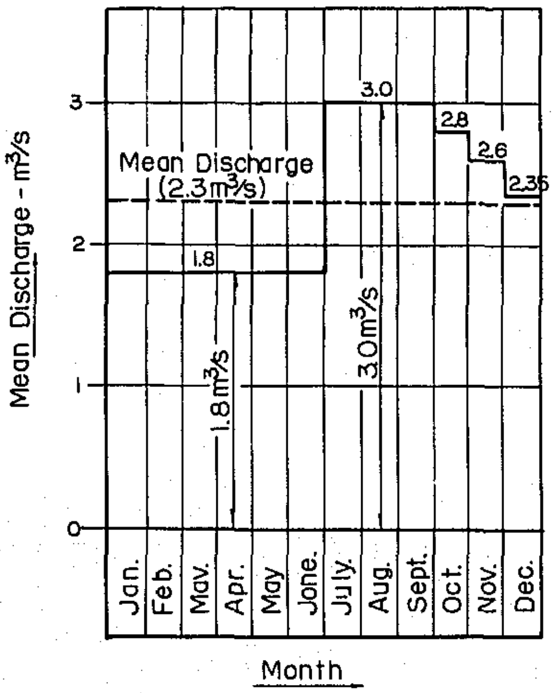
Mass curve in dry years

(2) Reservoir operation for primarily potable water supply

The monthly discharge in relation to demand of potable water is given in the table which follows.

Month	Monthly average discharge	
	m^3/s	m^3
Jan.	1.8	4,821,120
Feb.	1.8	4,354,560
Mar.	1.8	4,821,120
Apr.	1.8	4,665,600
May	1.8	4,821,120
Jun.	1.8	4,665,600
Jul.	3.0	8,035,200
Aug.	3.0	8,035,200
Sept.	3.0	7,776,000
Oct.	2.8	7,499,520
Nov.	2.6	6,739,200
Dec.	2.35	6,294,240
Annual average	2.30	72,528,480

Fig. 5-8 Reservoir Operating Rule for Potable Water Supply



In the study of the storage capacity, the necessary capacity in case of three consecutive dry years was calculated by the mass curve. The result shows that the supply water must be limited to 1.5 m^3/sec. from the normal discharge of 1.8 m^3/sec. in the second dry year.

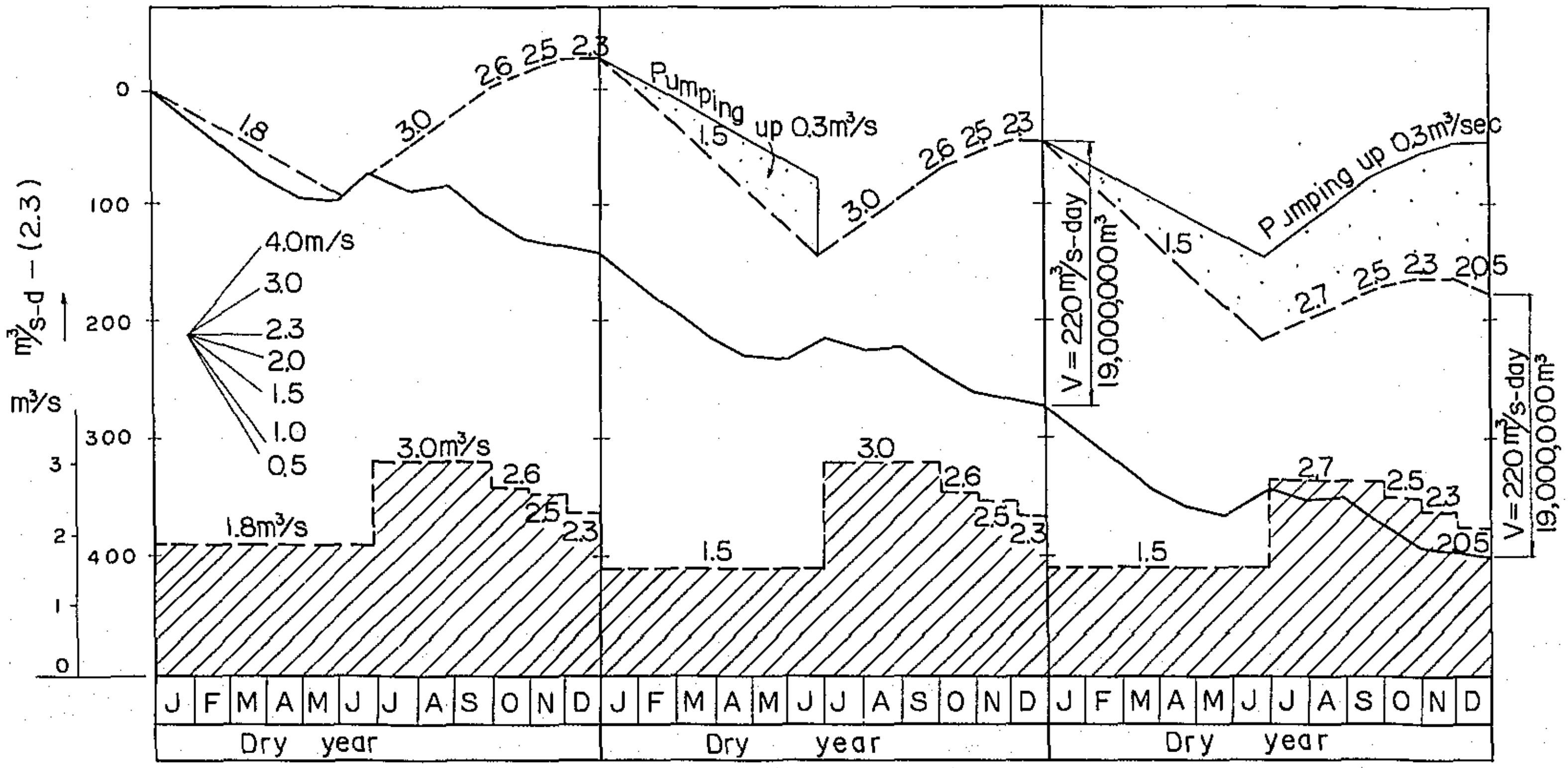
In this period from January to June, the discharge of 0.3 m^3/sec. should be supplied by full operation of the pump plants in Quito, as those pump plants are reserved for such cases. Moreover, in the third year of the three consecutive dry years, the release from the reservoir is limited to 2.7 m^3/sec. from July to September, 2.5 m^3/sec. in October, 2.3 m^3/sec. in November and 2.05 m^3/sec. in December.

The necessary reservoir capacity for this pattern of operation is 19,000,000 m^3, as shown in Fig. 5-9.

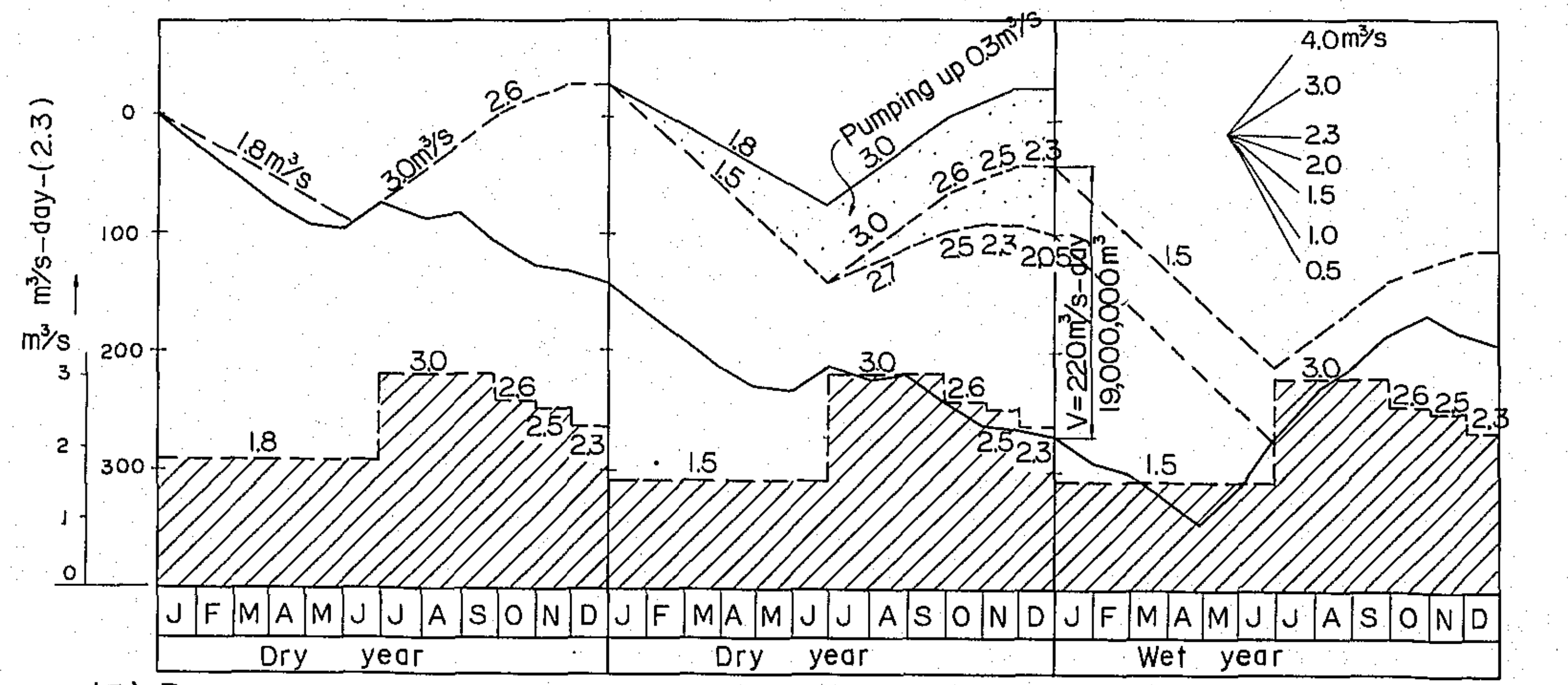
If an allowance of 10% is added, the necessary reservoir capacity of La Mica is 21,000,000 m^3 which is the same as that for power generation only. The above reservoir operating rule for a reservoir capacity of 21,000,000 m^3 was applied to the recorded inflow for the seven years from 1960 to 1966, and the results are shown in Fig. 5-5 and Fig. 5-6. It will be noted that 1960 and 1961 were the consecutive dry years, while in the other years wet and dry years occurred alternately. Therefore, in the operation for power generation only, almost all of the stored water or 19,000,000 m^3 will be consumed in 1963. On the other hand, the critical year for water supply was 1964 in which year 19,000,000 m^3 of the stored water was consumed. Therefore, Lake La Mica fully serve its purpose if it is designed to have an effective capacity of 21,000,000 m^3.

To order to create an effective reservoir capacity of 21,000,000 m^3 as shown in Drawing-4, the present normal high water surface level of 3,900 m of Lake Mica must be raised by 4 m and the total storage capacity will be 34,200,000 m^3. The required storage capacity will be obtained by a drawdown of 9.5 m.

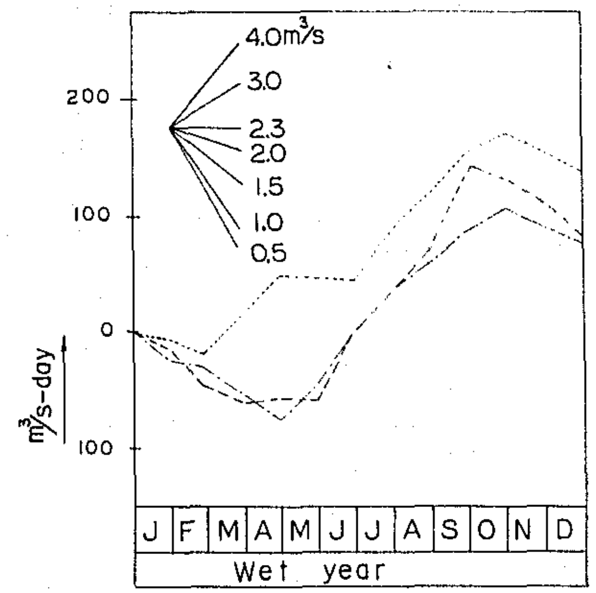
Fig. 5-9 Reservoir Operating Rule for Potable Water in La Mica Lake



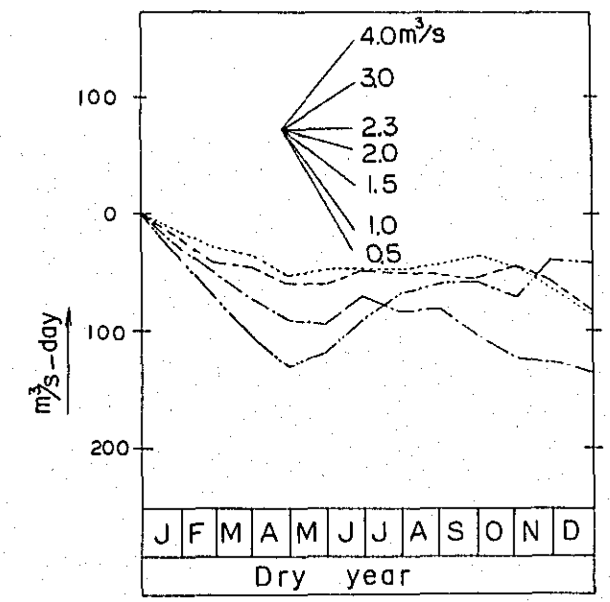
(A) Reservoir operation rule in the occurrence of driest 3-years



(B) Reservoir operation rule in the occurrence of driest 2-years.



Mass curve in wet years



Mass curve in dry years

Reserved Capacity of Pumping Station (0.3 m³/sec)

V : Emptied Capacity of Reservoir

– – – – :Regulating Curve (m³/s - day)

——— :Mass Curve (m³/s-day)

▨ :Regulated Discharge (m³/s)

5.6 FLOOD DISCHARGE

5.6.1 Estimate of Flood Discharge

The run-off gaging station having relation to La Mica Project is Antizana (CA = 125 km^2) which is located approximately 2 km downstream of the lake. Discharge data are available for the seven years from 1959 to November, 1966. According to the records, the maximum flood discharge of 8.79 m^3/sec. (0.032 m^3/sec. per km^2) was recorded in June, 1962. This flood record was measured by staff gage at a fixed time, and has been taken as the daily average discharge, as the peak flood discharge has not been measured. Accordingly, it is dangerous to calculate the probability directly from the recorded maximum discharge of each year and to estimate the design flood discharge. For this purpose, the design flood discharge at La Mica site was estimated from precipitation record.

For estimating the maximum daily precipitation, it is thought that the records of Micacocha Observatory represent the typical meteorology in the catchment area of La Mica. Therefore, the data of this observatory was adopted for the calculations. The records of the maximum daily precipitation of each year at Micacocha Observatory are shown in Table 5-6.

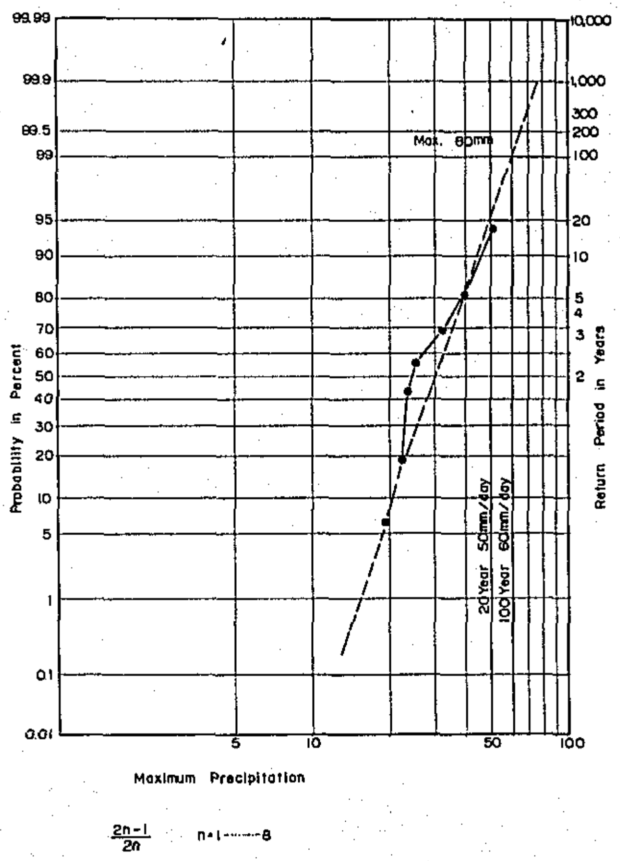
Table 5-6 Maximum daily precipitation recorded at Micacocha Station

Order of year	Maximum daily precipitation (mm/day)	Month and year of occurrence
1	51.0	May, 1959
2	32.0 1)	November, 1965
3	30.0	June, 1962
4	25.3	August, 1964
5	24.5	April, 1961
6	23.0	May, 1960
7	22.6	March, 1966
8	21.6	November, 1963

Note: 1) The recorded value of Order-2 is considered to be the total precipitation in four days. Therefore, the daily maximum precipitation of 32 mm/day was estimated.

The probability was calculated by Hazen method on the basis of the data given in Table 5-6. The results are as follows. (See Fig. 5-10).

Fig. 5-10   Probability of Maximum Daily Precipitation at Micacocha Observatory



Maximum daily precipitation in 20 years: 50 mm/day

Maximum daily precipitation in 50 years: 52 mm/day

Maximum daily precipitation in 100 years: 60 mm/day

This daily precipitation is assumed to fall within the whole catchment area, and the Rational formula is used to estimate the maximum probable flood discharge.

$$Qp = \frac{1}{3.6} \times f \times r \times A \quad \cdots\cdots (1)$$

where: f = coefficient of run-off

r = hourly precipitation intensity within the arrival time of flood (mm/hour)

A = catchment area (km^2)

r is obtained by the following formula.

$$r = \frac{R24}{24} \left(\frac{24}{T}\right)^{t} \quad \cdots\cdots (2)$$

where: $R24$ = daily precipitation (mm/day). T = arrival time of flood (hour),

$t = 1/2$

Arrival time of flood (T) is calculated from the following formula.

$$T = \frac{L}{72\,(H/L)^{0.6}} \quad \cdots\cdots \quad (3)$$

where: L = the length of river channel to estimated flood site (km).

H = head of outflow.

H/L = gradient.

Table 5-7 shows the calculated arrival time of flood at the selected sites.

Table 5-7 Result of Calculation of Arrival Time of Flood

Name of intake dam	Interval	Length of Channel (km)	Gradient (H/L)	Velocity of flood discharge (V)	Arrival time of flood (T)
Rio Chico	1-2	5.0	0.016	6.02	0.831
	2-3	3.0	0.013	6.32	0.564
	3-4	2.5	0.016	6.02	0.415
	4-A	1.5	0.213	7.15	0.210
	Total				2.020
Qda. Bañio Urria Pung	1-2	5.5	0.015	5.78	0.952
	2-3	4.5	0.036	9.80	0.459
	3-4	2.3	0.122	20.38	0.113
	4-B	1.1	0.109	19.05	0.058
	Total				1.582
Rio Desaguadero (La Mica Dam)	1-2	3.7	0.005	3.14	1.179
	2-3	2.0	0.050	11.93	0.168
	3-4	1.7	0.047	11.51	0.148
	4-C	0.3	0.067	14.18	0.021
	Total				1.516

Note: $V = 72\,(H/L)^{0.6}$ (km/hour)

$T = L/V$ (hours)

The daily precipitation for 100 years, R24 = 60 mm/day, is calculated at each diversion dam site and the hourly precipitation intensity is obtained as follows:

Name of Intake Dam	R24 (mm/day)	T (hour)	r (mm/hour)
Rio Chico	60	2.020	8.617
Qda. Bañio Urria Pungo	60	1.582	9.738
Rio Desaguadero	60	1.516	9.948

Therefore, in this study, the coefficient of run-off (:f) was estimated from the records of Micacocha Observatory and Antizana Run-off Gaging Station. As a result, f = 0.2 was roughly estimated taking into consideration the water holding condition of the catchment area.

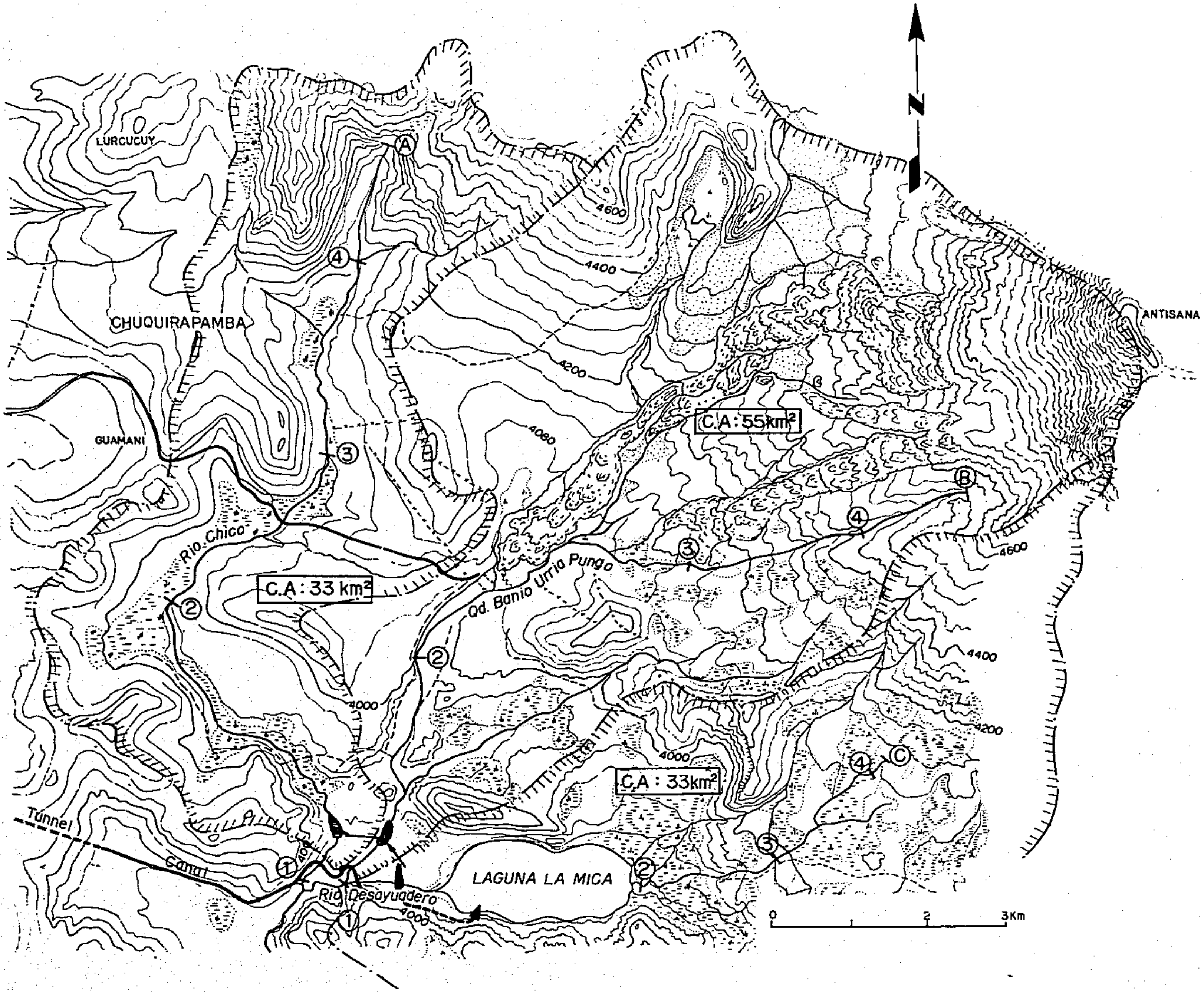
The probable flood discharge in 100 years was calculated for each diversion site. The results are as shown in Table 5-8.

Table 5-8 Probable Flood Discharge in 100 years

Name of Intake Dam	Catchment area :A (km^2)	Coefficient of River Run-off :f	r (mm/hour)	Flood discharge :Qp (m^3/sec.)
Rio Chico	35	0.2	8.6	17
Qda. Bañio Urria Pungo	55	0.2	9.7	30
Rio Desaguadero	35	0.2	9.9	20

As shown in Table 5-8, the probable flood discharge in 100 years is 17 m^3/sec. at Rio Chico diversion dam site, 30 m^3/sec. at Qda. Bañio Urria Pungo diversion site and 20 m^3/sec. at La Mica Dam (Rio Desaguadero site).

Fig. 5-11 Topographical Condition of La Mica Basin



5.6.2 Design Flood Discharge

The probable flood discharge in 100 years at the three diversion dam sites of La Mica Project are described in 5.6.1. In consideration of the fact that La Mica Dam (Rio Desaguadero site) is to be an embankment structure, a marginal capacity of 25% was added, and also the discharge of 4.5 m^3/sec. from Rio Chico and Qda. Bañio Urria Pungo were included to determine the design flood discharge which was estimated to be 30 m^3/sec.

Rio Chico and Qda. Bañio Urria Pungo intake dams are concrete structure and therefore they will be safe and stable against a 100 years flood probability estimated to be 17 m^3/sec. and 30 m^3/sec. respectively.

The surcharge capacity of 3,260,000 m^3 which is 1 m in structural height, will have sufficient capacity to cut peak flood discharged and release water safely from the dam.

Chapter VI

GEOLOGY

Chapter VI

GEOLOGY

6.1 GENERAL

Ecuador situated in the northwest part of the South American continent, is bounded on the north by Columbia, on the south by Peru and faces the Pacific Ocean to the west. The general geographical position can be divided into 3 sections, namely the coastal zone (Costa) facing the Pacific Ocean, the mountainous zone (Sierra) in the center part and the eastern zone (Oriente) facing Rio Amazon.

Costa which extends south to north along the Pacific Ocean is the flat area with elevations of 200 to 300 m. The area is covered with tropical trees and there are many marshlands.

Sierra consists of the East and West Andes Mountain ranges in two parallel rows which extend to the south and north and the Intercordilleran Depression between the mountain ranges. In the Intercordilleran Depression, Quito, the metropolis, and the major cities (Ibarra, Ambato, Cuenca, etc.) and villages have developed, forming the centers of agriculture and stock farming. The greater part of this area is the mountain zone with elevations of 2,000 to 4,000 m or higher. Sierra is formed as the result of the geologically complicated epeirogenetic movement during the period from the Tertiary to the Quaternary period, and therefore, the tectonic line is conspicuous in this zone. As many tectonic lines made the passage to lead the Magma to the surface of the earth, many vlocanos, (Cotapaxi, Antizana, Chimborazo, Cayambe, etc.) which were active in the Quaternary period, are located along the mountain range from north to south. The eastern zone (Oriente) is called the great forest zone of the upper stream of Rio Amazon, the most part of which is unexplored and undeveloped area. As described above, Ecuadorian topography is divided into 3 zones. As for the outline of the geology, the coastal and eastern zones generally consiste of sedimentary rocks, while the mountainous zone is composed of sedimentary rocks, metamorphic rocks with sedimentary rocks as original rocks and various volcanic products and glacial deposits.

La Mica project area located about 50 km southeast of Quito Cityand on the foot of the southwest slope of Mt. Antizana (domant volcano 5,705 m above MSL), one of the main peaks of the East Andes Mountain Range. The whole area around Mt. Antizana is a typical volcanic zone with lakes formed as a result of volcanic action and swampy fields around the lakes. The largest of the lakes is Lake Mica which is 15 m in depth with a water surface area of 2 km^2. The lake is ellisptical shaped.

6.2 GEOLOGY AROUND LAKE MICA

The geology around Lake Mica which is to be utilized for La Mica project is closely related to the volcanos as already described. The volcano of the largest scale in the vicinity is Mt.

Antizana covered with a glacier. This volcano was active in the early period of Quaternary period, as in the case of other volcanos in the Intercordilleran Depression, and lies dormant at present.

When the active history of Mt. Antizana is traced, this volcano seams to have ejected various volcanic products repeatedly during a long period of time. The volcanic products which can be observed around Lake Mica are andesite, agglomerate, volcanic ashes and lava flow ejected in the latest time. Andesite mainly forms the foundation of this area. Agglomerate was ejected in the same period as andesite or immediately after andesite. Volcanic ash is widely and deeply deposited in the whole area on top of the andesite and agglomerate and forms a gentle-sloping hill except for the steep cliff of andesite. Though the latest lava flow is on a comparatively small scale, it has filled the valleys in Qda. Bañio Urria Pungo and Derrame Lavico around Lake Mica. There is a narrow part with steep cliffs formed by andesite, composing the foundation of this area, on the right and left banks about 1,000 m downstream from the outlet of Lake Mica. It appears that the mad-flow from the upper stream temporarily dammed up the narrow part and formed a lake. This mad-flow mainly came from the Rio Chico. It is probable that the extreme point of the mad-flow was near the western edge of the present Lake La Mica. The Lake made by this dam perhaps was larger than the present lake. However, the dammed part has gradually widened by erosion, and the present lake was probably formed as the water level retarted. As to the geology around Lake Mica which was created in this manner, the mountains surrounding the lake are composed of andesite, and the flat part around the lake is composed of sand and gravel layer and volcanic ash with natured soil covering the upper part of the gravel layer. The bottom of Lake Mica is in the shape of the bottom of a ship which forms a gentle slope from the bank of the lake to the center.

6.3 GELOGY OF DAM SITE

As for the proposed location of the dam, the upstream site (A site) is now being compared with the downstream site (B site). A site is located about 600 m downstream along the mouth of Rio Desaguadero and B site is located about 1,300 m downstream of the lake near the confluence of the three rivers of Rio Desaguadero, Rio Chico and a quebrada.

(1) A Site

The left bank which lies on the foot of the mountain mainly composed of andesite with a little steep slope, and the right bank where most part of the dam foundation will be located consists of deposits which created lake La Mica, and the topography is a hill with a gentle slope.

The axis of the dam was selected on the top of this hill. Rio Desaguadero flows around the foot of the mountain on the left bank as seen from the lake side. The width of the river is about 5 meters. The stream flow is slow with a gentle slope.

The geology of the foundation of the dam consists of black volcanic-ash corrosive soil, lacustrine deposits and volcanic products. Black volcanic-ash corrosive soil is loamy and covers the entire area to a depth of about 1.5 m. Lacustrine deposit lies beneath the black corrosive soil and is composed of sand layers (fine to coarse sand) and gravel layer. Sand and gravel are originally products of the volcano. Concentration of gravel is comparatively poor with much breccia. It is judged that the upper part of the lacustrine deposit (2 to 3 m) is not cemented and might have high permeability, while the lower part is well cemented and in parts as hard as conglomerate.

The dam to be constructed at A site will have an average height of 6 m and 12 m at the highest part. It is estimated that water in the reservoir will have very little influence to the present foundation. Moreover, the topographic conditions downstream of the dam is a very gentle slope and the geology is composed of well compacted deposits. It is judged that even if seepage of water increases to some extent, the water will not affect the stability of the foundation around the dam, because the line of seepage length is long. Accordingly, the imperviouse core zone should rest on cemented layer by excavating surface black corrosive soil (about 1.5 m) and uncemented sand and gravel layer which is 2 to 3 m thick. The lacustrine deposit is estimated to be more than 10 m in depth. However, it is judged not economical and necessary to excavate to this deposit and rest the dam on this deposit. The foundation of the left abutment of the dam is composed of andesite. On this rock is deposited volcanic products which are estimated to be several meters in depth. As the concrete structure is to be built in this area, the deposits should be excavated and the foundation for the structure should rest on andesite.

(2) B Site

B Site is located near the end of the dammed part by the volcanic products which caused the formation of Lake Mica. The geology of the both banks are composed of andesite and form steep slope. The right bank has a slope of 30° and the left bank forms a steep cliff of exposed andesite eroded by the flow of Rio Antizana. The plain between both banks is 400 m in width with a hill about 25 m high near the center.

The geology of B Site consists of black corrosive soil, lacustrine depost and volcanic products. The flat part which takes the largest part of the dam foundation is composed of black corrosive soil and lacustrine deposit. The geology is almost the same as that of A Site. As to the abutments at the dam site, andesite is exposed on the left bank, while on the right bank talus deposit is estimated to lie several meters on the andesite. The small hill at the center of the dam axis is covered with black soil of about 1.5 m. Though the geology of the inner part has not yet been investigated, it is estimated that it is a volcanic dome of andesite or glacial deposit.

The maximum height of the dam at B Site will be about 25 m as the ground elevation at B Site is lower than at A Site. Accordingly, water load acting on the foundation will become high. The topography downstream of the dam site is deeply eroded by the river flow. Therefore, countermeasures should be taken against seepage of water. Further, as the deposit is anticipated to be considerably deep at the dam site, it is not economical to remove this deposit to prepare the foundation of the dam.

6.4 GEOLOGY OF WATERWAY

As shown in Drawing 4, the waterway consists of three tunnels and connecting open canals. The length of No. 1 tunnel which will connect to the intake is about 1.77 km, No. 2 tunnel excavated through the East Andes Mountain range is about 2.95 km and No. 3 tunnel is about 0.5 km. The total length of these tunnels is 5.22 km.

(1) Geology of Tunnels

No. 1 tunnel.

The general geology along the route of No. 1 tunnel mainly consists of lacustrine deposit and volcanic products (volcanic ash, andesite lava, etc.). Accordingly, if the route of the tunnel is selected near the bank of the lake, there is the danger of encountering difficulties in the excavation of the tunnel due to seepage of water from the lake. The route should pass through hard andesite which forms the deep part of the mountain.

No. 2 Tunnel

The route where No. 2 tunnel will pass through consists of andesite and agglomerate. Black volcanic ash covers only the surface of the mountain, while the deep part of the mountain is andesite and agglomerate. Black volcanic ash is 1 to 3 m in depth, and is compact, but it is not cemented. As andesite and agglomerate are well cemented, it seems that no trouble will be encountered in the excavation of the tunnel. The volcanic ash forms a part of the slope of the mountain side, where the tunnel passes through and landslides can be seen on the surface. Therefore, before determining the location of the inlet and the outlet of the tunnel, the condition of the mountain should be thoroughly investigated and the sites where there is no danger of landslide should be selected.

No. 3 Tunnel

The whole of the tunnel route is thick black volcanic ash. Though the lower part of this volcanic ash is probably agglomerate or tuff, outcrop could not be seen. However, unfovoragle geologic condition such as seepage of water should not be encountered in the excavating of the tunnel, because the tunnel will pass through a ridge.

(2) Geology of Canal Route

No. 1 canal is 3.75 km long. The upper half passes along a mountain side with the slope of 10^{o} to 15^{o} and the lower half passes through almost flat grassy plain. Swampy fields are found in this grassy plain, through which the canal must be constructed. In order to construct the canal in the swamp, the unstable material must be excavated and replaced with good soil to prepare the foundation.

Canal - II and III

Canal - II and III have a total length of 20.4 km. The topography of most part of the canal route is a gentle sloping hill. This zone is heavily covered with black volcanic ash, and the lower part of this zone consists of well compacted yellowish-grey colored volcanic ash. Along this route, the mountain has a gentle slope which is apparently stable judging from the existing canal that is constructed at a lower elevation than the proposed new canal. As the topography and geology is stable as a shole, there is no problem in constructing the canals.

(3) Geology of Head Tank and Penstock Sites

The head tank is to be located on the terrace of Tablon Alto on the west end of the East Andes mountain range. The terrace is covered with black volcanic ash of 3 to 5 m in thickness. It is estimated that the deep part is andesite or tuff. For the foundation of the head tank, the surface black volcanic ash layer should be excavated and to prepare a sound foundation for the structure.

The penstock will be installed on the slops of Tablon Alto. It will be about 2,600 km long. The penstock will be installed on an average gradient of 12 degrees. The geology of this route is a thick deposit of black volcanic ash similar to the head tank site. The topography and geology are both stable. It appears that about 2 m will have to be excavated from the ground surface to construct the anchor blocks for the penstock.

6.5 POWERHOUSE SITE

The location of powerhouse is proposed on the right bank of Qda. Carmen. At the vicinity of the proposed site, the area which is lower than 3,420 m in elevation is rugged hills. The geology of this area is black volcanic ash (loamy soil) and conglomerate. Volcanic ash distributed on the ground surface is about 2 m deep under which is hard cemented conglomerate. The foundation of powerhouse should be built on ths conglomerate.

6.6 MATERIALS

Soil material required for the enpervious core of the dam is about 16,300 m^3. The material is planned to be obtained in the vicinity of the dam site. The underlying rock at the proposed borrow area is andesite. The around surface is widely covered with volcanic ash. This material is white grey colored, fine granular volcanic ash which is widely distributed in this area. According to field survey, it is judged that this material can be used for the inpervious zone. However, the final decision should be made on the basis of the quality and available quantity, after thorough field investigations and laboratory tests. For fill materials of the upstream and downstream zones, it would be economical to use the sand and gravel deposits distributed around the dam site and the excavated materials of No. 1 tunnel than to quarry andesite.

Aggregate for concrete in the intake, spillway, No. 1 tunnel, No. 2 tunnel and other structures, seems to be economical to make use of sand and gravel deposits on the downstream of the dam site and the excavated material of tunnels. Aggregate tests of this deposit should be carried out. In respect of aggregate for concrete structure from No. 3 tunnel to powerhouse, as sand and gravel deposit cannot be found in this area, material excavated from No. 2 tunnel, and sand and gravel deposit distributed on the Pita Riva can be considered. However, efforts should be made to obtain aggregates economically by investigating the area around the powerhouse site which is much closer than the Pita River.

6.7 FUTURE INVESTIGATIONS

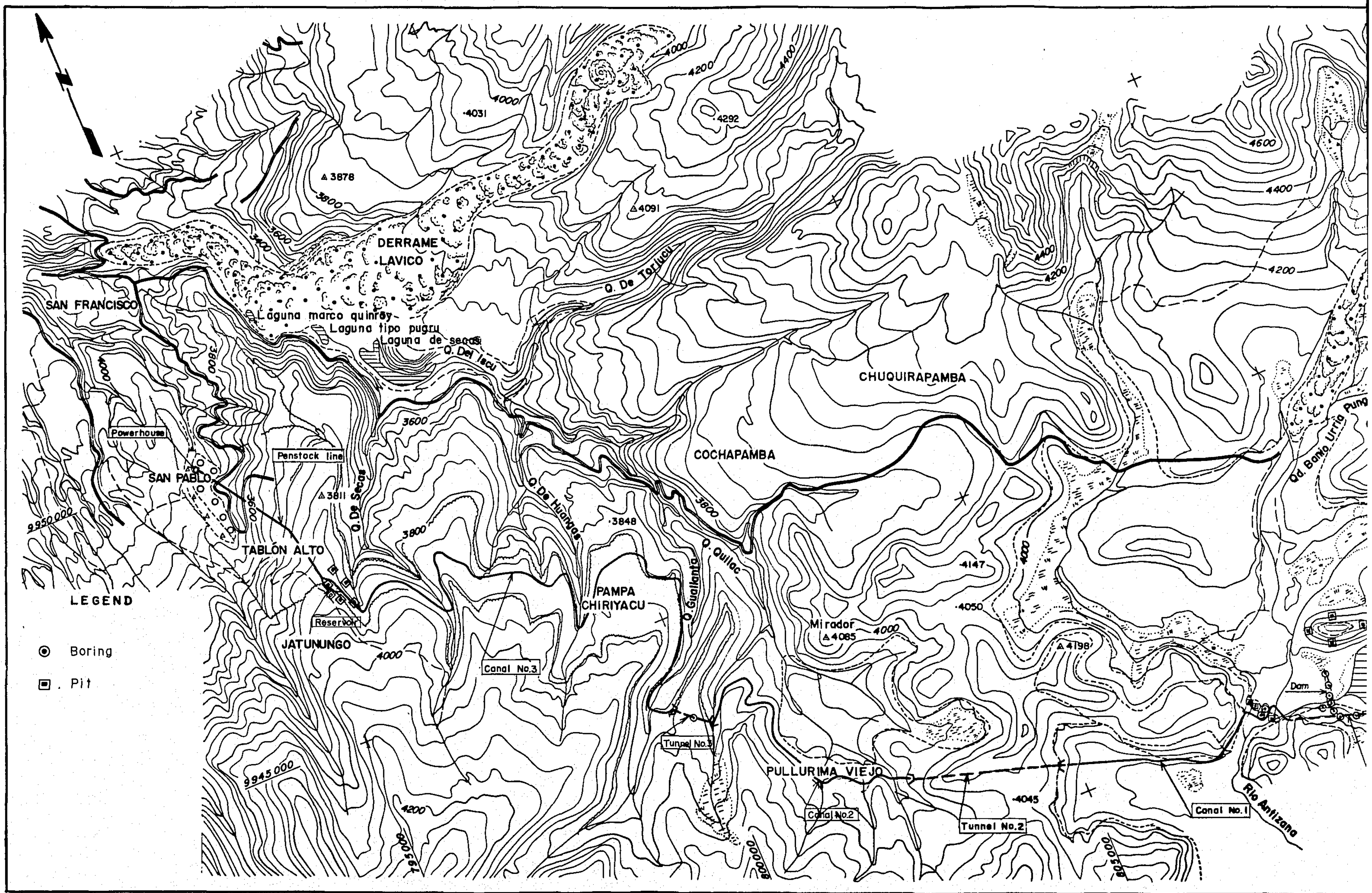
According to the results of surface geologic investigations, the geology of the area consists of lacustrine deposit and volcanic products. Except for andesite, all layer are almost horizontal and the geologic structure is comparatively simple. However, as these layers belong to the recent age (Quanternary period) geologically, cementation is not highly developed. Accordingly, thorough investigations are required to obtain knowledge of the permearability of each layer.

The following is the geological investigations which are thought to be necessary for the definite study of the project.

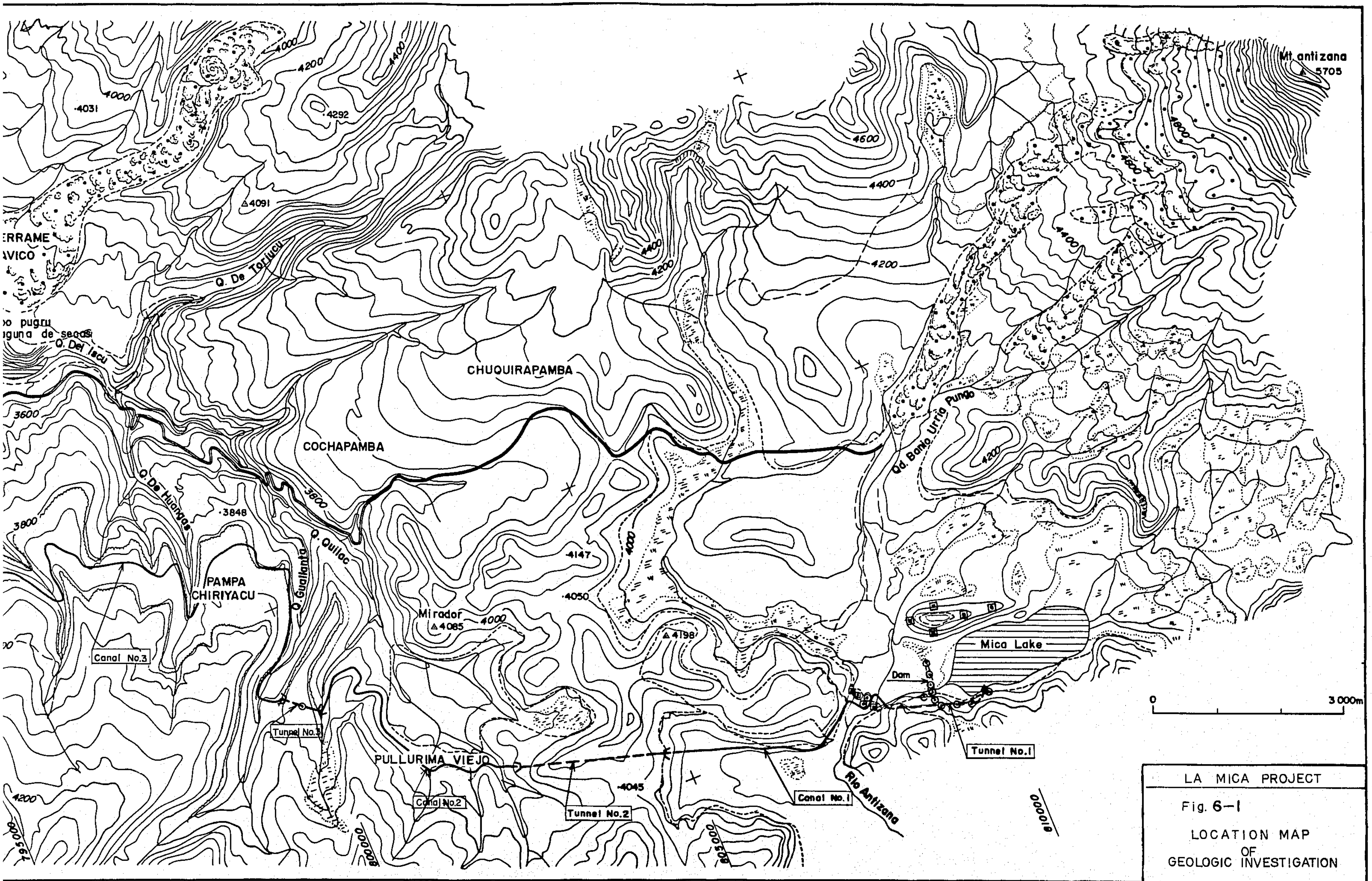
(1) Dam site

A site dam axis	Boring: 4 holes, each hole 15 m long, total 60 m.			
	Permeability test executed in each hole			
	pit:	5 pits	5 m each,	Total 25 m
Spillway site	Boring: 2 holes, each hole 20 m long,			Total 40 m
	adit:	1 adit	20 m	Total 20 m
B site dam axis	Boring: 2 holes, each hole 15 m long,			Total 30 m
	Permeability test executed in each hole			
	pit:	2 pits	5 m each,	Total 10 m
(2) Intake	Boring: 3 holes each hole 25 m long,			Total 75 m
	Permeability test executed in each hole			
	pit:	1 pit	5 m,	Total 5 m
(3) No. 1 tunnel	Boring: 3 holes, each hole 35 m long,			Total 105 m
	along the route near the bank of the lake.			
(4) Head tank site	pit:	5 pits, each pit 10 m deep,		Total 50 m
(5) Powerhouse site	pit:	2 pits	each pit 10 m deep,	Total 20 m
(6) Borrow area	pit:	5 pits	each pit 5 m deep,	Total 25 m
Total	Boring:	14 holes	310 m	
	Pit:	20 pits	135 m	
	Adit:	1 adit	20 m	

For the location of these sites see Fig. 6-1.



DERRAME
LAVICO
SAN FRANCISCO
Laguna marco quinray
Laguna tipo pugru
Laguna de secas
Q. Del Iscu
Q. De Torucu
CHUQUIRAPAMBA
COCHAPAMBA
Powerhouse
Penstock line
SAN PABLO
TABLÓN ALTO
Q. De Secas
Q. De Huangas
PAMPA
CHIRIYACU
Q. Guallanta
Q. Quilac
Reservoir
JATUNUNGO
Canal No.3
Tunnel No.3
PULLURIMA VIEJO
Canal No.2
Tunnel No.2
Canal No.1
Rio Antizana
Dam
Qd. Banjo Urria Pung
Mirador
LEGEND
Boring
Pit



LA MICA PROJECT

Fig. 6-1

LOCATION MAP OF GEOLOGIC INVESTIGATION

Chapter VII

POWER PRODUCTION

Chapter VII

POWER PRODUCTION

7.1 INSTALLED CAPACITY

7.1.1 Effective Head

The water level of La Mica reservoir is 3,904 m at normal high water level and 3,894.5 m at low water level, but the intake level will be at 3,892.4 m as water can be drawn by controlling the water pressure with a valve. Moreover, when the gradient of tunnel and canal, etc. are taken into consideration with respect to the said water level, the water level of the regulating resorvoir at the Tablón Alto site will be 3,870.9 m at normal high water level and 3,868.4 m at low water level. On the other hand, the tailrace water level of La Mica Power Plant was determined at 3,340.0 m from the water level of Rio Pita divertion dam (to be constructed by "Empresa de Agua Potable") for future potable water service, and taking into consideration necessary height for a 1/1,000 gradient water-way, including some margin of 1.9 m necessary for discharge of Pelton turbine. The effective head of 496.5 m was determined by deducting a loss head of 33.8 m (Q max = 4.5 m^3/s) in the penstock from the total head obtained in the manner mentioned above.

7.1.2 Maximum Discharge

In order to determine the scale of development most effective throughout the year for EEQ's power system, including Guangopolo, Cumbaya, Nayon power plants situated on the downstream of La Mica, the operation pattern of La Mica reservoir was assumed, and the benefit-cost ratio was studied in respect of discharges of 5 m^3/s, 4.5 m^3/s, 4.0 m^3/s, 3.5 m^3/s, 3.0 m^3/s in the dry season. As shown in Table 7-1-1, the results of the study shows that firm power from the aforesaid four power plants can be made maximum by discharging an average of 4.0 m^3/s in the dry season, and an average of 1.44 m^3/s in the wet season from La Mica reservoir to the Rio San Pedro.

Then, the benefit-cost ratio was obtained on the basis of the said reservoir operation with respect to powerhouse maximum discharge of 5 m^3/s, 4.5 m^3/s and 4.0 m^3/s. The results showed that a maximum discharge of 4.5 m^3/s gives the greatest surplus benefit as shown in Table 7-1-2. That is, it is most effective to the power system to operate La Mica power plant at a load factor of 90% in the dry season and at 32% in the wet season. Therefore, the maximum discharge will be 4.5 m^3/s and maximum output will be 18,300 kW.

Table 7-1-1 Maximum Discharge of La Mica Project

Max. discharge (Q m^3/sec.) Max. output KW	Q = 5 m^3/sec. Pm = 20,400 KW	Q = 4.5 m^3/sec. Pm = 18,300 KW	Q = 4.0 m^3/sec. Pm = 16,300 KW	Q = 3.5 m^3/sec. Pm = 14,200 KW	Q = 3.0 m^3/sec. Pm = 12,200 KW
(I) Construction costs Grand total	s/. 181,712,200	s/. 171,908,700	s/. 163,805,400	s/. 155,719,400	s/. 148,035,200
(II) Annual energy and power output including downstream benefits	E: 125,140,000 P: 37,200	E: 124,400,000 P: 37,330	E: 123,320,000 P: 35,520	E: 122,260,000 P: 31,000	E: 121,200,000 P: 26,640
Unit construction cost (KWh)	s/. 1.45	s/. 1.38	s/. 1.33	s/. 1.27	s/. 1.22
(III) Annual cost: (C) = Construction costs x annual cost ratio (10.66)	s/. 19,371,000	s/. 18,325,000	s/. 17,462,000	s/. 16,600,000	s/. 15,781,000
(IV) Annual benefit: (B)					
P x s/. 570	21,200,000	21,278,000	20,246,000	17,670,000	15,185,000
E x s/. 0.20	25,028,000	24,880,000	24,668,000	24,452,000	24,240,000
Total	s/. 46,228,000	s/. 46,158,000	s/. 44,910,000	s/. 42,122,000	s/. 39,425,000
(B) - (C)	s/. 26,857,000	s/. 27,833,000	s/. 27,448,000	s/. 25,522,000	s/. 23,644,000
(B) / (C)	2.39	2.52	2.57	2.54	2.50
(V) Annual unit cost (C) / (E)	s/. 0.155	s/. 0.147	s/. 0.142	s/. 0.136	s/. 0.130

Table 7-1-2 Comparison of Maximum Discharge of La Mica Power Plant

Max. discharge Max. output	Q = 5 m^3/s P = 20,000 kW	Q = 4.5 m^3/s P = 18,300 kW	Q = 4.0 m^3/s P = 16,000 kW
Construction costs	s/. 181,320,000	s/. 171,908,700	s/. 163,805,400
Annual energy production	E = 123,320 MWh	E = 123,320MWh	E = 123,320MWh
Effective output (including downstream benefit)	P = 39,520 kW	P = 37,520 kW	P = 35,520 kW
Annual cost	C = s/. 19,371,000	C = s/. 18,325,000	C = s/. 17,462,000
Annual benefit	B = s/. 47,190,000	B = s/. 46,050,000	B = s/. 44,910,000
(B) - (C)	s/. 27,819,000	s/. 27,725,000	s/. 27,448,000
(B) / (C)	2.44	2.52	2.57

7.1.3 Available Discharge of La Mica Power Plant

(1) Reservoir operation for power generation only

By seasonal regulation of inflow at La Mica reservoir with an effective storage capacity of 21,000,000 m^3, it will be possible to release 2.3 m^3/s throughout the year, and the powerhouse maximum discharge can be released, whenever necessary, corresponding to system demand. However, by reason of operation in relation to the existing downstream power plants on the Rio San Pedro, the available discharge shall be an average of 4.0 m^3/s in the dry season (July to October) and an average of 1,436 m^3/s in the other months including wet seasons. Operation studies were made for seven years, from 1960 to 1966, with a mass curve prepared from recorded run-off data and the monthly discharge of La Mica Power Plant are given in Table 7-2.

Table 7-2 Monthly available discharge of La Mica Power Plant (reservoir operation for power generation only)

Unit: m^3/s

	1960	1961	1962	1963	1964	1965	1966	Average
Jan.	1,436	1,436	1,436	1,436	1,436	1,436	1,436	1,436
Feb.	"	"	"	"	"	"	"	"
Mar.	"	"	"	"	"	"	"	"
Apr.	"	"	"	"	"	"	"	"
May	"	"	"	"	"	"	"	"
June	"	"	"	"	"	"	"	"
July	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Aug.	"	"	"	"	"	"	"	"
Sept.	"	"	"	"	"	"	"	"
Oct.	"	"	"	"	"	"	"	"
Nov.	1,436	1,436	1,436	1,436	1,436	1,436	1,436	1,436
Dec.	"	"	"	"	"	"	"	"
Annual average	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30

(2) Reservoir operation for potable water supply

Water released from La Mica Power Plant will be delivered to "Empresa de Agua Potable" in the future for potable water service. At present a study is being made by "Empresa de Agua Potable" on the following two alternatives with respect to the use of water released from La Mica.

Case "A": A plan to draw water from 1984, that is, 10 years after operation of La Mica Power Plant.

Case "B": A plan to draw water from the Rio Tanbó first and then from La Mica in or about 1999, that is, about 25 years after operation of La Mica Power Plant.

If water service is commenced, La Mica reservoir must be operated to meet the demand for water service. To service the demand for water supply an average of 1.8 m^3/s from January to June, 3 m^3/s from July to September, 2.8 m^3/s in October, 2.6 m^3/s in November and 2.35 m^3/s in December must be released from the reservoir.

The reservoir operation to meet the demand for water service was studied for the 7 years, from 1960 to 1966, with a mass curve prepared from recorded run-off data, and the monthly available discharge at La Mica Power Plant was obtained as shown in Table 7-3.

Table 7-3 Monthly available discharge of La Mica Power Plant
(reservoir operation for potable water service)

Unit: m^3/s

	1960	1961	1962	1963	1964	1965	1966	Average
Jan.	1.8	1.8	1.5	1.8	1.5	1.8	1.5	1.67
Feb.	"	"	"	"	"	"	"	1.67
Mar.	"	"	"	"	"	"	"	1.67
Apr.	"	"	"	"	"	"	"	1.67
May	"	"	"	"	"	"	1.8	1.71
June	"	"	"	"	"	"	"	1.71
July	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Aug.	"	"	"	"	"	"	"	3.0
Sept.	"	"	"	"	"	"	"	3.0
Oct.	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
Nov.	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Dec.	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35
Annual average	2.30	2.30	2.15	2.30	2.15	2.30	2.20	2.24

Since a dry month for power and water service coincides as shown in Table 7-2 and Table 7-3, the requirement to meet the demand of water service will not influence the operation of La Mica Power Plant. Moreover, in either alternative, case "A" or case "B", release of water for water service will be a future problem, and for several years from start of operation La Mica Reservoir can be operated for the exclusive use of power generation.

7.1.4 Maximum Output

From the foregoing studies, the installed capacity of La Mica Power Plant will be 18,300 kW. The basic data for the power production are as follows:

1.	Intake water level		3,892.4 m
2.	Tailrace water level		3,340.6 m
3.	Effective head	He	496.5 m
4.	Maximum discharge:	Qmax	4.5 m^3/s
5.	Turbine (Pelton) efficiency:	ηt	87 %
6.	Generator efficiency:	ηg	96 %
7.	Maximum output		

$$P\ max = 9.8 \times Q\ max \times He \times \eta t \times \eta g = 18{,}300\ kW$$

7.1.5 Number of Units

Generally speaking, the following should be taken into consideration to determine the number of units.

(1) Loss and inconvenience at the time of outage

(2) Economic comparision between construction cost and benefit

(3) Transportation limit

(4) Percentage of unit capacity to total power demand

(5) Charging capacity required for transmission line

La Mica Power Plant, will occupy about 18 percent of the total installed capacity of EEQ's system in 1974, the scheduled year of its operation.

The impact of outage of plant due to transmission line fault or repair and maintenance will be small if small size units are adopted. In this case, the existing standby diesel plant will sufficiently cover the said unit capacity.

Comparison of construction costs for one, two and three unit development was made as shown in Table 7-4. The more the number of units will improve the power system stability, but as seen in Table 7-4, it will cause a rise in the project construction costs. Therefore, the number of generating units, that is either one or two units, to be installed should be determined in relation to system stability and construction costs. An one unit development will reduce the construction costs by approximately 4,000,000 Sucres in comparison with a two unit development. However, in an one unit development, a standby thermal plant will be required in case of plant outage due to accident or repair and maintenance, and investment will be required to build the standby plant. Whereas, in a two unit development, the existing 9,800 kW diesel generating plant will be of adequate capacity to augment the system capacity in case of outage of one unit, and therefore, the difference in costs between the one and two unit development can be justified.

From the standpoint of transmission line charging capacity, since the line is only 25 km long, this will not be an important factor in making the decision between an one unit and two unit development.

La Mica Project will be the only power plant in EEQ's system that will have seasonal regulating capability. Therefore, when the project is put into operation it will firm up the output of the three existing power plants on the downstream. In this respect, La Mica Project will be an important installation demanding stabilized and reliable operation. Consequently, with emphasis placed on the improvement of power system reliability, a two unit development (unit capacity 9,150 KW each) has been adopted.

Table 7-4 Number of Units and Construction Costs

Unit: sucres

Installed capacity	One unit 18,300 KW	2 units of 9,150 KW each	3 units of 6,100 KW each
Cost of equipment 1/	19,960,000	20,333,000	24,380,000
Civil works	75,580,200	78,530,200	84,580,200
Other costs	72,458,900	73,045,500	74,828,500
Total	167,999,100	171,908,700	183,788,700

Note: 1/ Includes turbine, generator, transformer, switchyard, crane, etc.

7.2 AVAILABLE POWER AND ENERGY PRODUCTION

The water discharged from La Mica Power Plant will be utilized at the existing power plant on the Rio San Pedro. Therefore, until the time the demand of potable water reaches the maximum on the La Mica source, the existing power plants (Guangopolo, Cumbaya and Nayon) on the downstream will benefit by the increased power and energy production.

Table 7-5 shows the result of calculation on the increment of power and energy output of the downstream plants by the operation of La Mica power plant.

Table 7-6 shows the firm supply capability of all power plants in the dry month of September and in the maximum demand month of December before and after completion of La Mica Project and this trend is graphically depicted in Figs. 7-1 and 7-2. The figures show that with the completion of La Mica Power Plant, the supply capability of power plants on the Rio San Pedro is greatly firmed up, and that an extremely large benefit is produced especially in the dry months of August and September. The monthly power production of La Mica Power Plant and the increment in output of the existing three power plants on the downstream are shown in Table 7-7. As indicated in Table 7-7, the annual energy production of La Mica Power Plant proper is 82,300 MWh and the annual increment of energy production at the three existing power plants on the Rio San Pedro is 45,400 MWh, giving a total production of 127,700 MWh.

Table 7-5 Available Power and Energy by the Firm Run-off at EEQ's Power Plants

(after completion of La Mica Project)

In September

	Installed Capacity	Firm Run-off (m^3/sec.)			Average output (KW)			Daily energy product (KWh)		
	(KW)	Natural flow	Increase	Total	Natural flow	Increment	Total	Natural flow	Increment	Total
Los Chillos	1,760	-	0	-	1,100	0	1,100	26,400	0	26,400
Guangopolo	9,400	9.1	4.0	13.1	4,750	2,090	6,840	114,000	50,200	164,200
Gumbaya	40,000	9.6	4.0	13.6	10,700	4,400	15,100	257,000	105,800	362,800
Pasoshoa	4,500	-	-	-	3,150	0	3,150	74,500	0	74,500
Nayon	30,000	9.6	4.0	13.6	8,000	3,340	11,340	192,700	80,200	272,900
La Mica	18,300	4.0	-	-	16,000	0	16,000	384,000	0	384,000
Total	103,960	-	-	-	43,700	9,830	53,530	1,048,600	236,200	1,284,800

In December

	Installed Capacity	Firm Run-off (m^3/sec.)			Average output (KW)			Daily energy product (KWh)		
	(KW)	Natural flow	Increase	Total	Natural flow	Increment	Total	Natural flow	Increment	Total
Los Chillos	1,760	-	0	-	1,100	0	1,100	26,400	0	26,400
Guangopolo	9,400	11.7	1.9	13.6	6,100	990	7,090	146,400	23,800	170,200
Cumbaya	40,000	12.3	1.9	14.2	13,700	2,090	15,790	328,800	50,200	379,000
Pasochoa	4,500	-	-	-	3,150	0	3,150	74,500	0	74,500
Nayon	30,000	12.3	1.9	14.2	10,270	1,590	11,860	246,500	38,200	284,700
La Mica	18,300	1.9	0	1.9	7,600	0	7,600	180,000	0	180,000
Total	103,960	-	-	-	41,920	4,670	46,590	1,002,600	112,200	1,114,800

Table 7-6 Firm Power Supply Capability
(After completion of La Mica Project)

In September

Power Plant	Installed Capacity (KW)	Regulated flow output: Daily Energy output E (KWh/day)	Regulated flow output: Power (KW)	Natural flow output: Output in peak hours Pn (KW)	Natural flow output: Output in off-peak hours Nn (KW)
Los Chillos	1,760	0	0	1,100	1,100
Guangopolo	9,400	13,200	3,100	6,300	4,500
Cumbaya	40,000	113,900	25,550	14,450	0
Pasochoa	4,500	0	0	3,150	3,150
Nayon	30,000	85,600	19,050	10,950	0
Sub-total	85,660	212,700	47,700	35,950	8,750
La Mica	18,300	384,000	18,300	0	0
Total	103,960	596,700	66,000	35,950	8,750

In December

Power Plant	Installed Capacity (KW)	Regulated flow output: Daily Energy output E (KWh/day)	Regulated flow output: Power (KW)	Natural flow output: Output in peak hours Pn (KW)	Natural flow output: Output in off-peak hours Nn (KW)
Los Chillos	1,760	0	0	1,100	1,100
Guangopolo	9,400	13,200	2,300	7,100	5,200
Cumbaya	40,000	113,900	24,650	15,350	0
Pasochoa	4,500	0	0	3,150	3,150
Nayon	30,000	85,600	18,350	11,650	0
Sub-total	85,660	212,700	45,300	38,350	9,450
La Mica	18,300	180,000	18,300	0	0
Total	103,960	392,700	63,600	38,350	9,450

Fig. 7-1 Hydro Power Capability in Sept. 1974

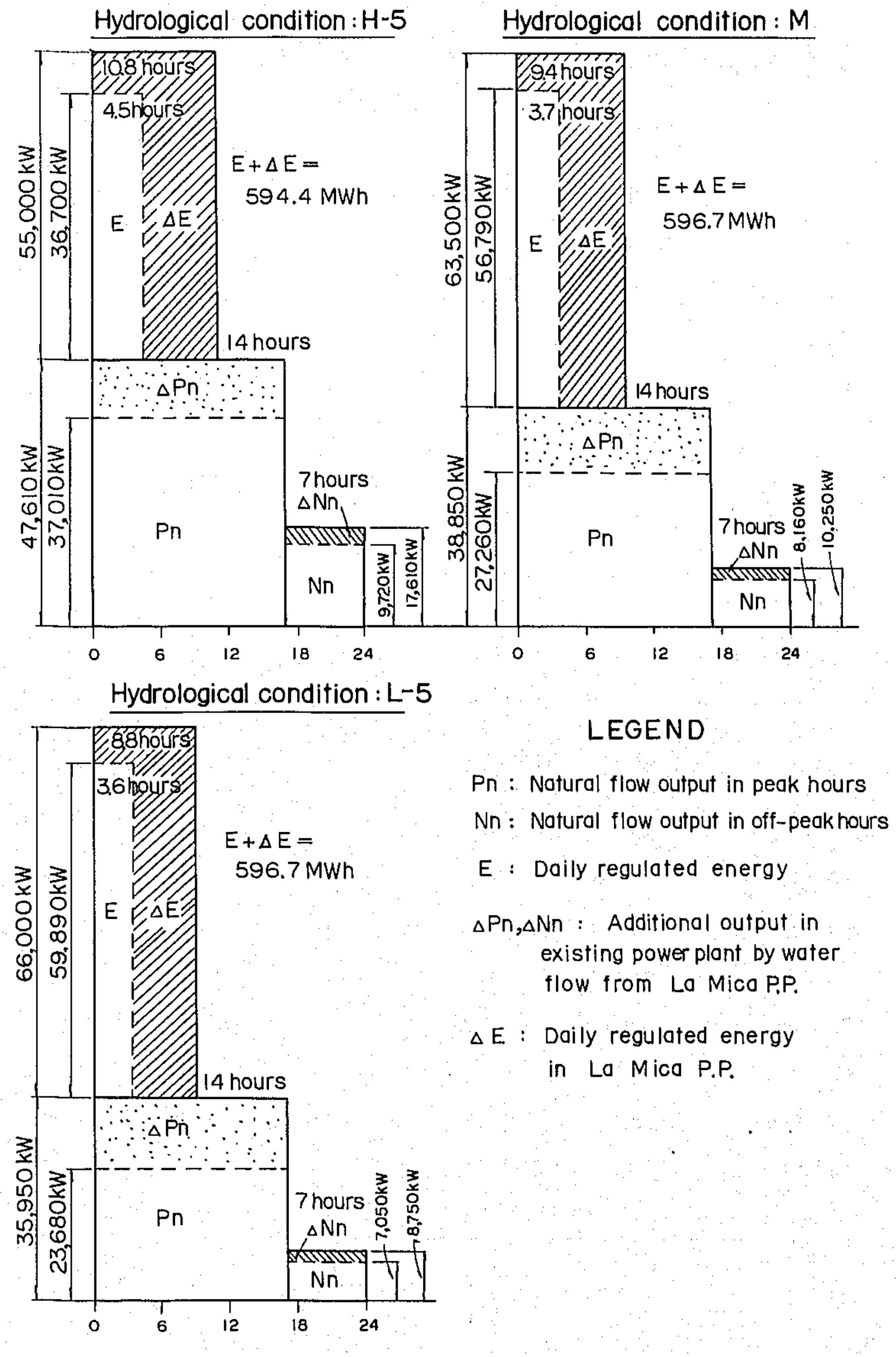


Fig. 7-2 Hydro Power Capability in Dec. 1974

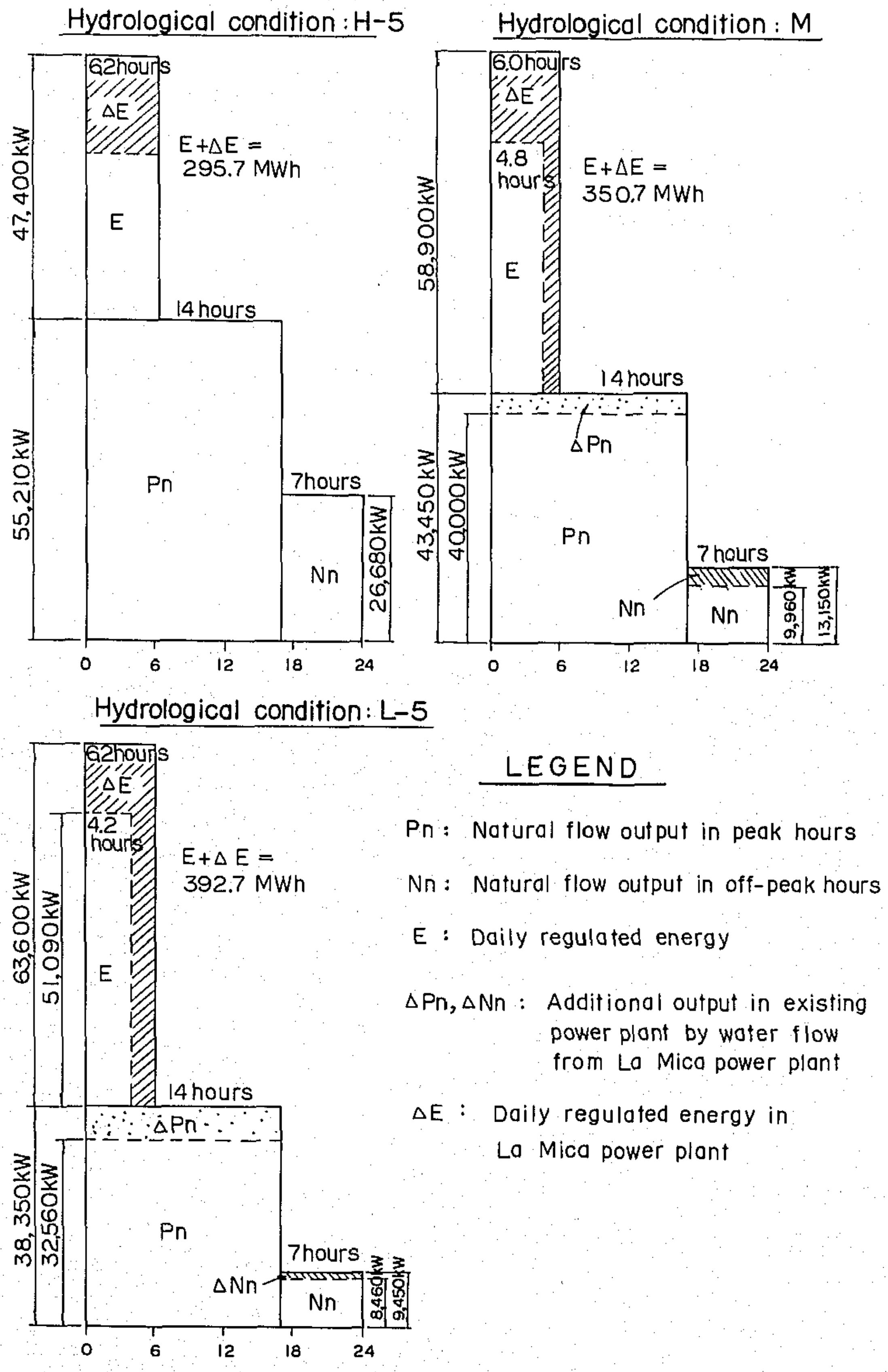


Table 7-7 Energy Production of La Mica Power Plant and Downstream Benefits of Existing Power Plants on the Rio San Pedro

Power Plant / Month	La Mica		Guangopolo		Cumbaya & Nayon		Total	
	Average Capacity (KW)	Energy (MWh)	Average Capacity (KW)	Energy (MWh)	Average Capacity (KW)	Energy (MWh)	Average Capacity (KW)	Energy (MWh)
Jan.	5,750	4,450	650	490	2,380	1,770	8,780	6,710
Feb.	5,750	3,900	650	430	2,380	1,570	8,780	5,900
Mar.	5,750	4,450	650	490	2,380	1,770	8,780	6,710
Apr.	5,750	4,200	170	120	2,380	1,700	8,300	6,020
May	5,750	4,450	170	120	2,380	1,770	8,300	6,340
Jun.	5,750	4,200	170	120	2,380	1,700	8,300	6,020
Jul.	16,000	12,100	2,090	1,550	7,710	5,740	25,800	19,390
Aug.	16,000	12,100	2,090	1,550	7,710	5,740	25,800	19,390
Sept.	16,000	11,700	2,090	1,500	7,710	5,550	25,800	18,750
Oct.	16,000	12,100	2,090	1,550	7,710	5,740	25,800	19,390
Nov.	5,750	4,200	650	470	2,380	1,700	8,780	6,370
Dec.	5,750	4,450	650	490	2,380	1,770	8,780	6,710
Annual Total		82,300		8,880		36,520		127,700

7.3 EFFECTIVE POWER AND ENERGY OUTPUT

In general, the generated power at a power plant will not all become effective immediately upon commencement of operation, but the output will be absorbed year after year with the growth in demand of power. Therefore, in the case of La Mica Project, it will be necessary to calculate the effective power (KW) and effective energy (MWh) for each year upon commencement of operation. For this purpose, the balance of supply and demand in the power system of "EEQ" S.A. for each year and month has been examined and a study was made of the manner in which the output of La Mica Power Plant would become effective.

Table 7-8 shows the effective power in September in the 50 years life time of the power plant which graphically shown on Fig. 7-3. According to the table, it shows that the power output in September at La Mica Power Plant will all become effective in 1981, 7 years after commencement of operation. It also shows that the power output at the downstream power plants on the Rio San Pedro will be promoted to become effective by the water discharged from La Mica Power Plant in the dry season, and the incremented power output in September will all become effective in 1976, but will be gradually decrease with the growth of water demand after diversion for water service.

As can be seen in the figure, the annual average effective power in September at La Mica Power Plant will properly be 17,740KW, and the incremented power at the downstream power plants will be 6,260 KW in Case "A" and 8,910 KW in Case "B".

Table 7-9 shows the annual effective energy in the 50 years life time of the power plant which graphically shown on Fig. 7-4. According to the table it shows a trend to become effective (KWh) with the growth of demand in the system and a trend of the incremented output of the power plants on the downstream of La Mica Power Plant to decrease after water is drawn for water service. As can be seen in the figure, La Mica Power Plant will have surplus energy of 45,420 MWh in the first year (1974), and by the 6th year (1980) all of the energy output will become effective. In case "A" water supply scheme, the annual effective energy will be 101,010 MWh including the increment of energy output at the downstream power plants and in case "B" water supply scheme the energy output will be 110,120 MWh.

Table 7-8 Effective Power in September

Case "A"				Case "B"			
Year	La Mica proper (KW)	Downstream benefit (KW)	Total (KW)	Year	La Mica proper (KW)	Downstream benefit (KW)	Total (KW)
1974	11,700	10,860	22,560	1974	11,700	10,860	22,560
1975	12,470	11,530	24,000	1975	12,470	11,530	24,000
1976	13,270	12,270	25,540	1976	13,270	12,270	25,540
1977	14,230	"	26,500	1977	14,230	"	26,500
1978	15,230	"	27,500	1978	15,230	"	27,500
1979	16,330	"	28,600	1979	16,330	"	28,600
1980	16,980	"	29,250	1980	16,980	"	29,250
1981	18,300	"	30,570	1981	18,300	12,270	30,570
1982	"	"	"	:	‖	‖	‖
1983	"	"	"	1990	18,300	12,270	30,570
1984	18,300	10,500	28,800	:	‖	‖	‖
:	‖	‖	‖	1995	18,300	12,270	30,570
1990	18,300	9,400	27,700	:	‖	‖	‖
:	‖	‖	‖	1999	18,300	11,200	29,500
1995	18,300	8,200	26,500	:	‖	∨	∨
:	‖	‖	‖	2005	18,300	8,400	26,700
2000	18,300	6,900	25,300	:	‖	∨	∨
:	‖	∨	∨	2010	18,300	6,100	24,400
2005	18,300	5,300	23,600	:	‖	∨	∨
:	‖	∨	∨	2015	18,300	3,600	21,900
2010	18,300	2,400	20,800	:	‖	∨	∨
:	‖	∨	∨	2020	18,300	1,300	19,600
2012	18,300	0	18,300	:	‖	∨	∨
:	‖	∨	∨	2022	18,300	0	18,300
2023	18,300	0	18,300	2023	18,300	0	18,300
Annual average	17,740	6,260	24,000	Annual average	17,740	8,910	26,650

Note:

Case "A" : Diversion for water supply to begin in 1984

Case "B" : Diversion for water supply to begin in 1999.

Annual average effective power is made the average value for a life time of 50 years.

Fig. 7-3 Assumed Annual Effective Power of La Mica Project

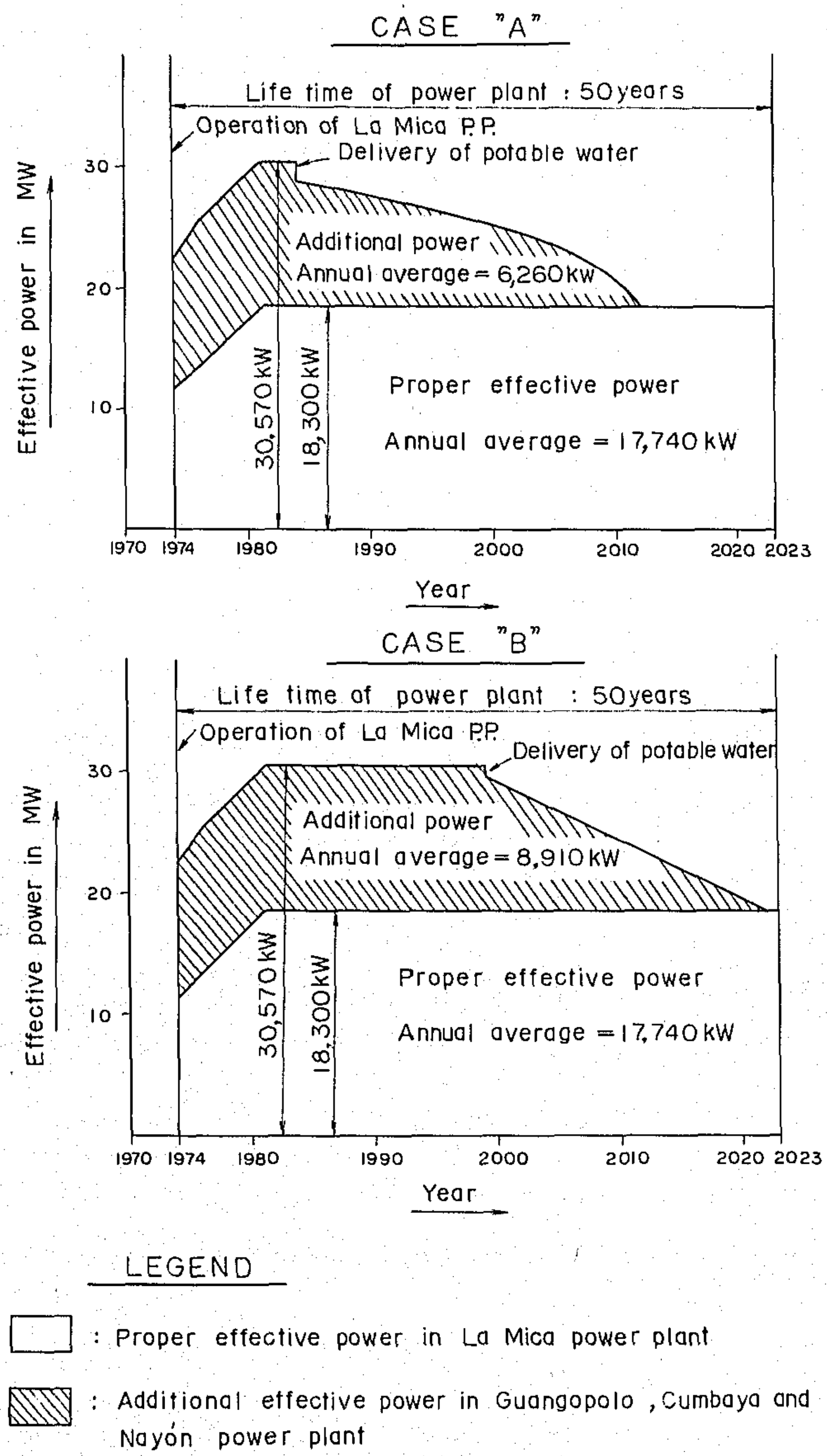


Table 7-9 Annual Effective Energy of La Mica Project

Case "A"				Case "B"			
Year	La Mica proper (KWh)	Down-stream benefit (KWh)	Total (MWh)	Year	La Mica proper (KWh)	Down-stream benefit (KWh)	Total (MWh)
1974	36,880	20,350	57,230	1974	36,880	20,350	57,230
1975	46,080	25,420	71,500	1975	46,080	25,420	71,500
1976	51,560	28,450	80,010	1971	51,560	28,450	80,010
1977	56,070	30,930	87,000	1977	56,070	30,930	87,000
1978	59,610	32,880	92,490	1978	59,610	32,880	92,400
1979	70,760	39,040	109,800	1979	70,760	39,040	109,800
1980	82,300	45,400	127,700	1980	82,300	45,400	127,700
1981	"	"	"	:	‖	‖	‖
1982	"	"	"	1985	82,300	45,400	127,700
1983	82,300	45,400	127,700	:	‖	‖	‖
1984	82,300	39,700	122,000	1990	82,300	45,400	127,700
:	‖	V	V	:	‖	‖	‖
1990	82,300	35,600	117,900	1995	82,300	45,400	127,700
:	‖	V	V	:	‖	‖	‖
1995	82,300	30,800	113,100	1999	82,300	43,510	125,810
:	‖	V	V	:	‖	V	V
2000	82,300	25,100	107,400	2005	82,300	32,210	114,510
:	‖	V	V	:	‖	V	V
2005	82,300	18,900	101,200	2010	82,300	22,790	105,090
:	‖	V	V	:	‖	V	V
2010	82,300	10,200	92,500	2015	82,300	13,370	95,670
:	‖	V	V	:	‖	V	V
2012	82,300	0	82,300	2022	82,300	0	82,300
:	‖	‖	‖	:	‖	‖	‖
2023	82,300	0	82,300	2023	82,300	0	82,300
Annual average	78,840	22,170	101,010	Annual average	78,840	31,280	110,120

Note:

Case "A" : Diversion for water supply to begin in 1984.

Case "B" : Diversion for water supply to begin in 1999.

Annual average effective energy is made the average value for a life time of 50 years.

Fig. 7-4 Assumed Annual Effective Energy of La Mica Project

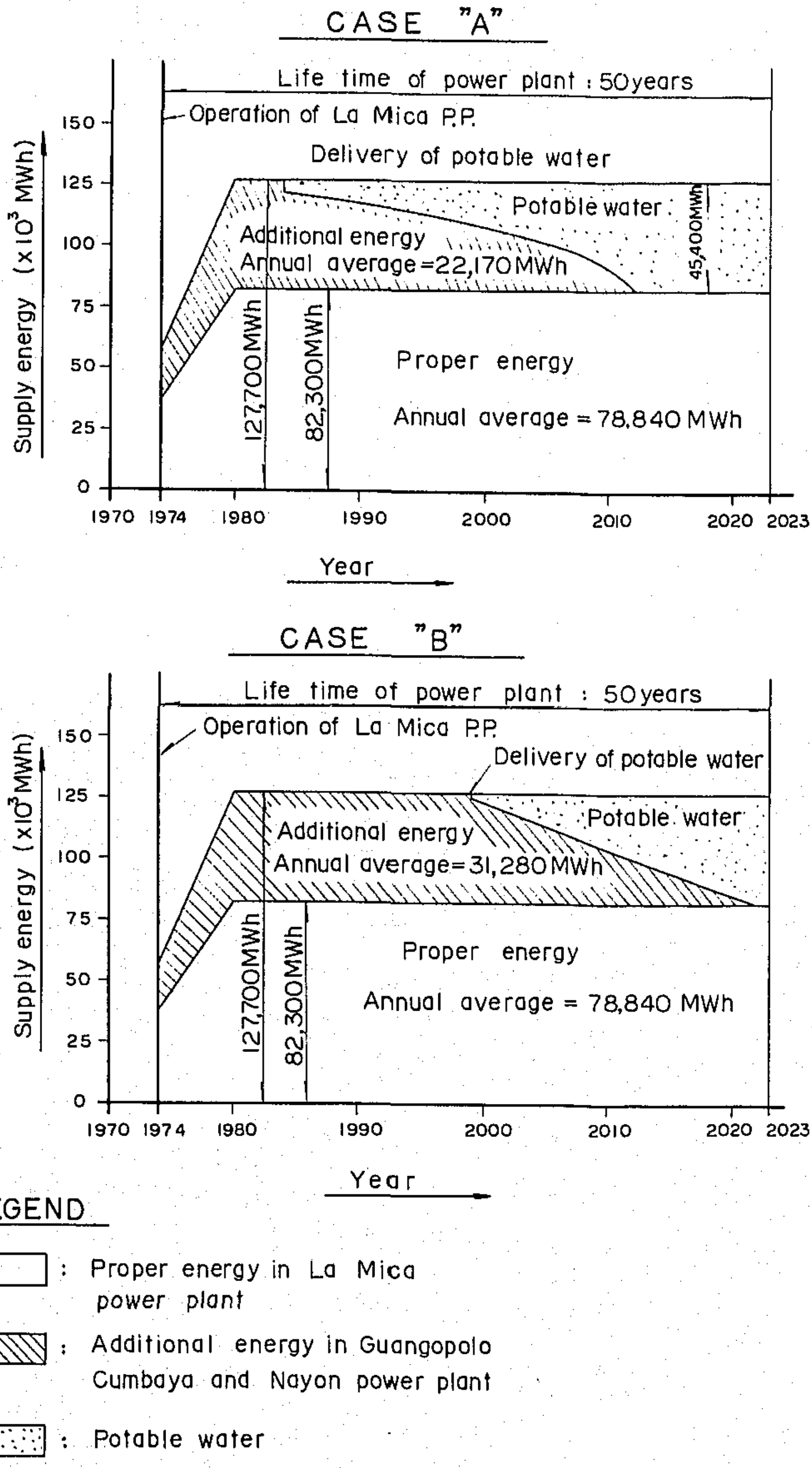
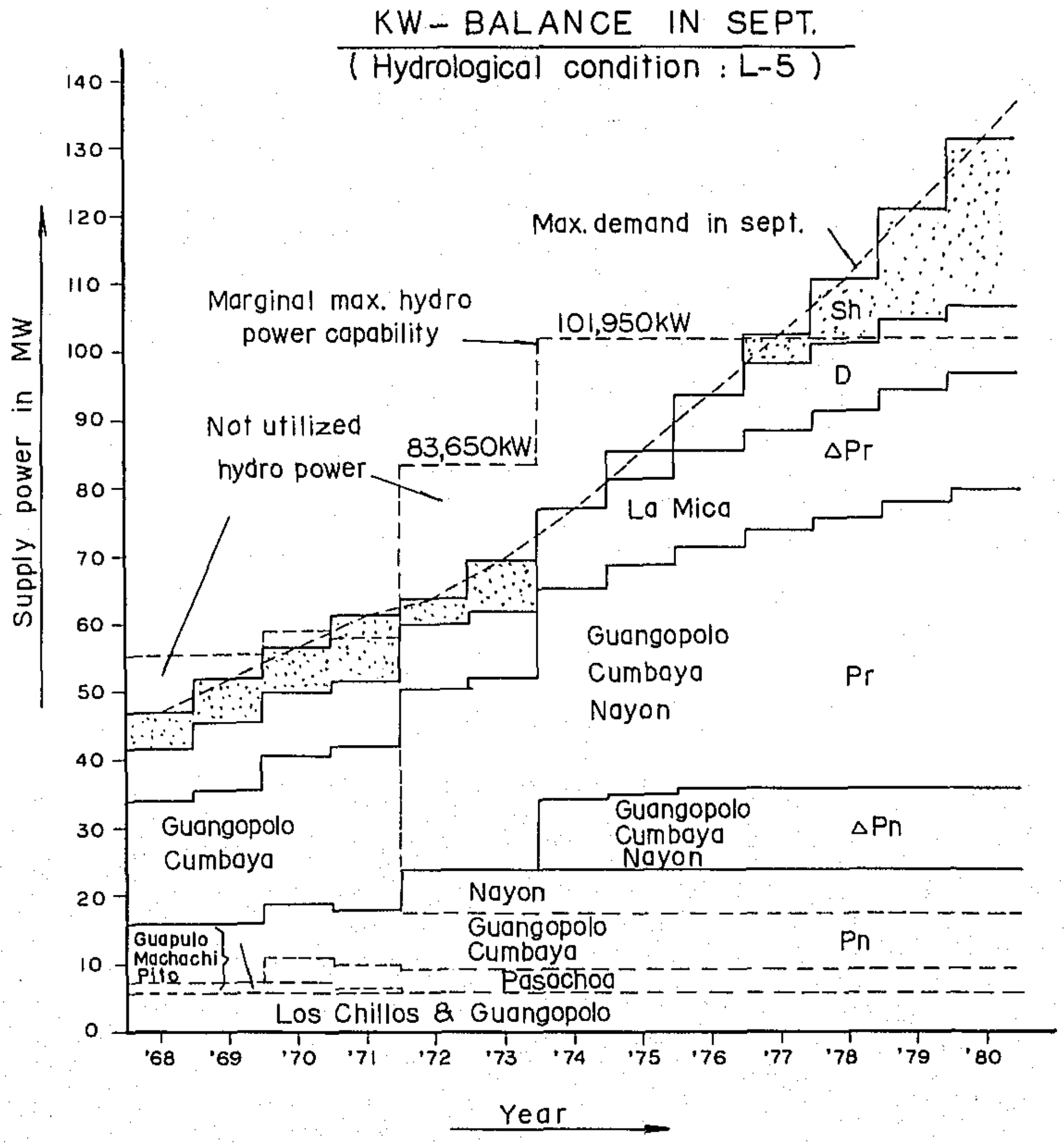


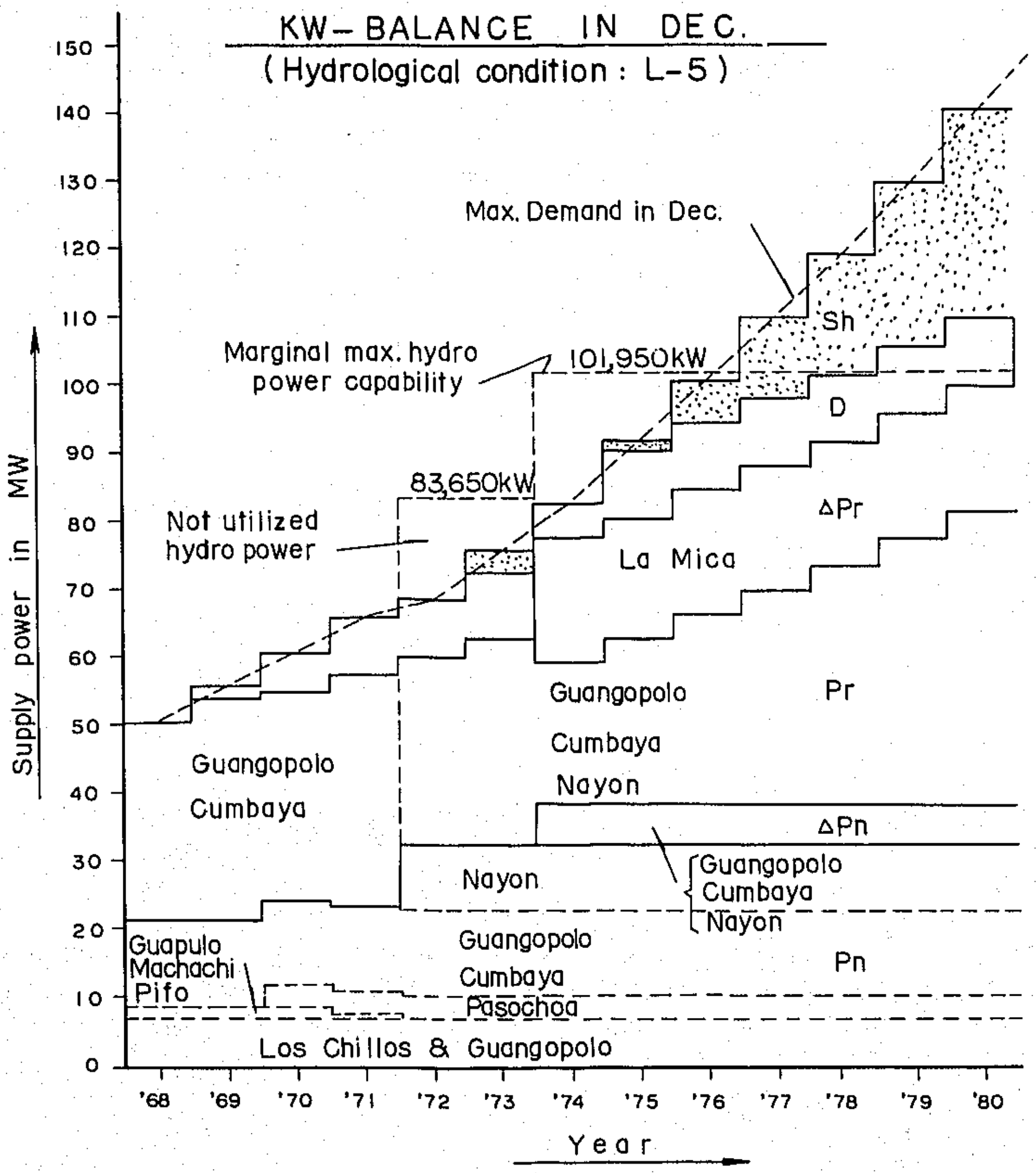
Fig. 7-5 Diagram of KW-Balance of EEQ's System in Sept.



LEGEND

Pn	:	Natural flow output in existing power plant
ΔPn	:	Additional output in existing power plant by La Mica project
Pr	:	Regulated output in existing power plant
ΔPr	:	Proper output of La Mica project
D	:	Diesel output
Sh	:	Shortage of KW– power

Fig. 7-6 Diagram of EEQ's System in Dec.



LEGEND

- Pn : Natural flow output in existing power plant
- ΔPn : Additional output in existing power plant by La Mica project
- Pr : Regulated output in existing power plant
- ΔPr : Proper output of La Mica project
- D : Diesel output
- Sh : Shortage of KW-power

7.4 BALANCE OF SUPPLY AND DEMAND AFTER COMPLETION OF LA MICA PROJECT

The kW-balance of the power system of "EEQ" S.A. after completion of La Mica Project is obtained by the method mentioned in 3-3 for the dry month of September, and for the maximum demand month of December. The result is shown in Table 7-10, Figs. 7-5 and 7-6. As shown in the figure, the shortage of kW supply capability in the dry month, which has occurred every year since 1968 will be eliminated immediately upon completion of La Mica Project, and the diesel plant will be used as stand-by entirely, bringing about a stabilized state of balance of supply and demand. However, it is anticipated that the said state will not be maintained very long and in 1977 kW-supply will run short again. Figs. 7-7 and 7-8 show the assumed daily load curve of dry month and of the month of maximum load with the supply capability of EEQ's hydropower plants after completion of La Mica Project. The said figures show that La Mica Power Plant will supply the base load in the dry month of the Rio San Pedro and will supply the peak load in the other months, mainly in December. The increment of flow by the regulated discharge from La Mica Power Plant will firm up the output of the three power plants of Guangopolo, Cumbaya and Nayon.

Table 7-11 and Table 7-12 show the KWh-balance and effective energy of EEQ's hydro-power plants after completion of La Mica Project.

These tables are graphically depicted in Fig. 7-9. As evident in the figure, in the first year (1974) La Mica Power Plant goes into operation, the major part of KWh-load is supplied with hydro-power and the operation of diesel plant is limited to the months of November and December, which are the months of maximum load.

Therefore, KWh supply capability in the dry season will increase with the completion of La Mica Project, and the most critical period from the standpoint of balance of supply and demand will change from the dry month of September to the month of maximum load which is December.

In view of the fact that La Mica Power Plant will have seasonal regulating capability, it will be a very effective plant from the standpoint of supply and demand and will fully display its merits with the growth of demand in the system and will become a major power plant in the power system of "EEQ" S.A.

Table 7-10 Demand and Supply Capability

Hydrological condition : L - 5

	September					December				
	1972	1974	1976	1978	1980	1972	1974	1976	1978	1980
Max Demand (KW) (1)	63,700	77,000	93,800	110,900	131,400	68,500	82,800	100,900	119,300	140,900
Hydro Capability										
Natural flow (KW)	23,680	34,400	35,950	35,950	35,950	32,560	38,350	38,350	38,350	38,350
Regulated flow (KW)	26,770	42,600	50,710	56,810	63,120	27,790	39,460	46,360	53,370	61,580
Total(KW) (2)	50,450	77,000	86,660	82,760	99,070	60,350	77,810	84,710	91,720	99,930
(3) = (1) - (2)	-13,250	0	-7,140	-18,140	-32,330	-8,150	-4,990	-16,190	-27,580	-40,970
Diesel Power(KW) (4)	9,800	0	7,140	9,800	7,800	8,150	4,990	9,800	9,800	9,800
Shortage of capability (KW) (5) = (3) - (4)	-3,450	0	0	-8,340	-22,530	0	0	-6,390	-17,780	-31,170
Marginal max. hydro capability (KW) (6)	83,650	101,950	101,950	101,950	101,950	83,650	101,950	101,950	101,950	101,950
Idle output(KW) (7) = (6) - (2)	33,200	24,950	16,310	9,190	2,250	23,300	24,140	17,240	10,230	2,020

Fig. 7-7 Diagram of KW-Balance of EEQ's System in Sept.

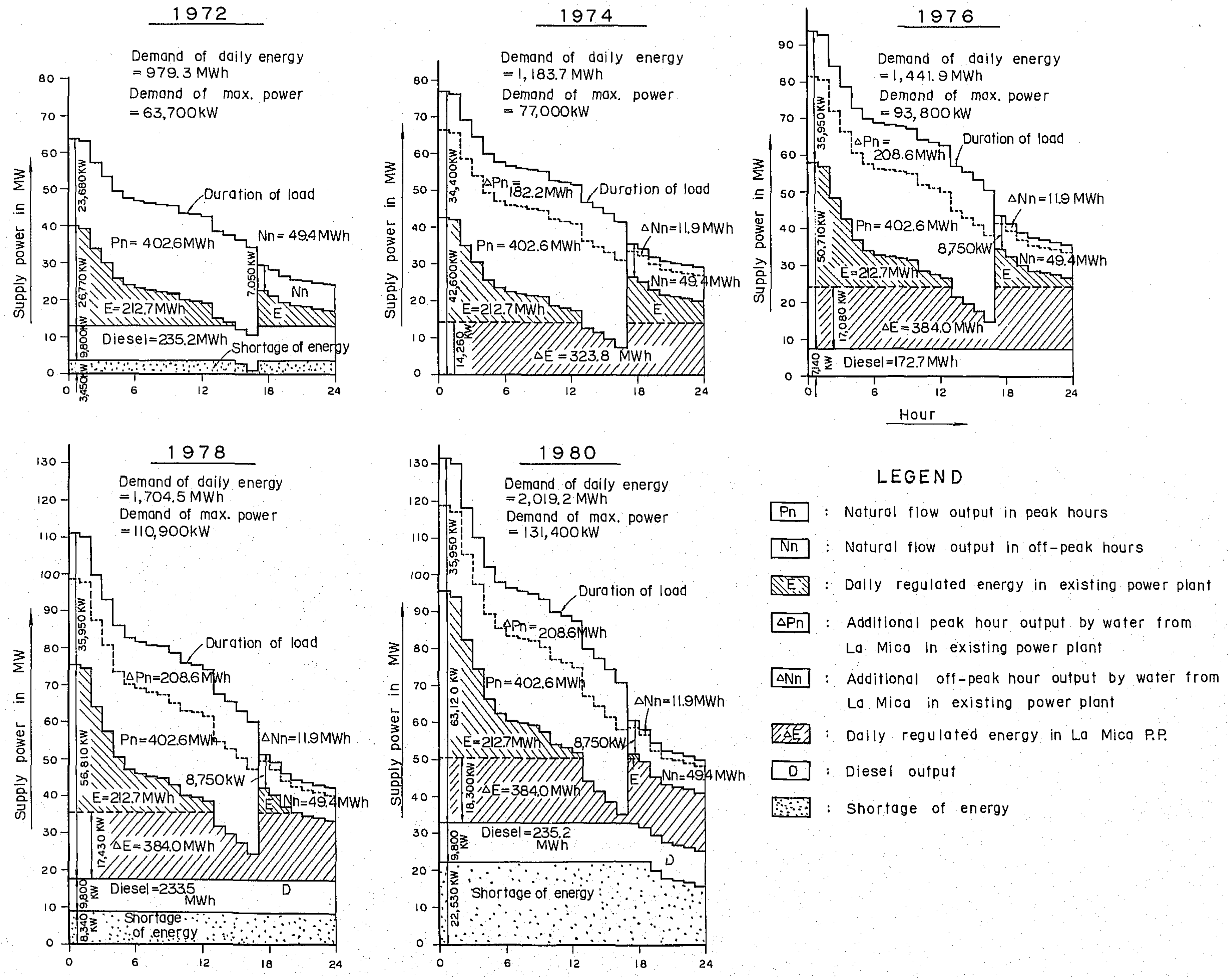


Fig. 7-8 Diagram of KW-Balance of EEQ's System in Dec.

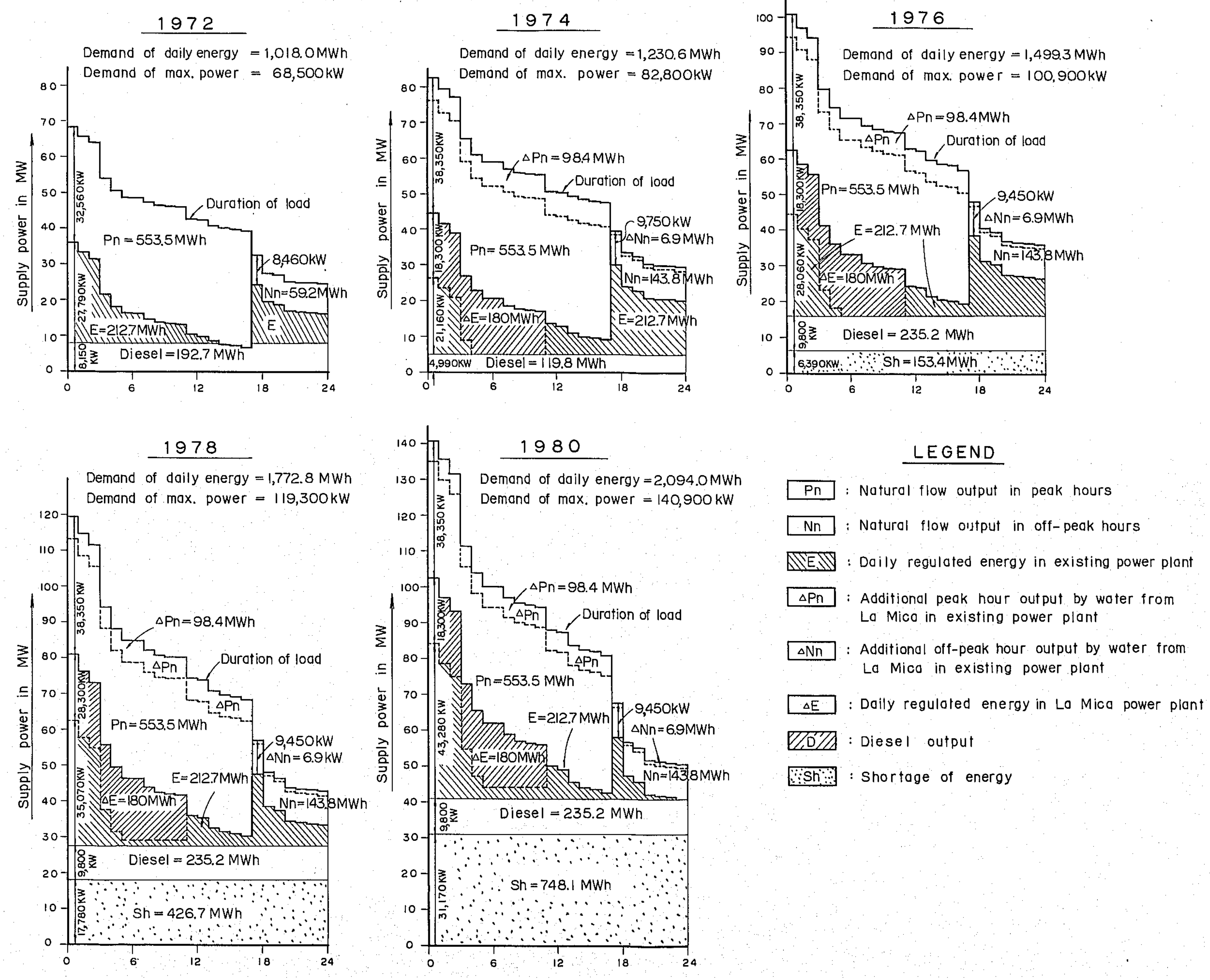


Table 7-11 Balance of Energy Demand in EEQ's System (After Completion of La Mica Project)

Unit: MWh

Year	1972				1974				1976				1978				1980			
Month	Demand	Effective Hydro Energy	Diesel Energy	Shortage	Demand	Effective Hydro Energy	Diesel Energy	Shortage	Demand	Effective Hydro Energy	Diesel Energy	Shortage	Demand	Effective Hydro Energy	Diesel Energy	Shortage	Demand	Effective Hydro Energy	Diesel Energy	Shortage
Jan.	24,600	24,260	340	0	29,700	29,700	0	0	36,200	33,630	2,570	0	43,100	36,030	6,110	960	51,300	38,420	6,420	6,460
Feb.	22,800	22,490	310	0	27,600	27,600	0	0	33,600	31,280	2,320	0	40,000	33,290	5,500	1,210	47,500	35,300	5,780	6,420
Mar.	25,300	24,960	340	0	30,600	30,600	0	0	37,300	34,730	2,570	0	44,500	38,050	6,110	340	52,800	40,610	6,420	5,770
Apr.	25,200	25,200	0	0	30,500	30,500	0	0	37,100	36,470	630	0	44,200	38,560	5,340	300	52,500	40,620	6,390	5,490
May	25,200	25,200	0	0	30,500	30,500	0	0	37,100	36,450	650	0	44,200	38,730	5,470	0	52,500	41,000	6,580	4,920
June	24,900	24,900	0	0	30,100	30,100	0	0	36,700	34,500	2,200	0	43,700	34,940	5,340	3,420	51,900	35,370	6,390	10,140
July	25,200	22,370	2,830	0	30,500	30,500	0	0	37,100	35,410	1,690	0	44,200	40,710	3,490	0	52,500	45,700	6,360	440
Aug.	24,300	19,660	4,640	0	29,400	29,400	0	0	35,800	34,110	1,690	0	42,600	38,460	4,140	0	50,600	42,490	6,360	1,750
Sept.	24,800	18,730	5,250	820	29,900	29,900	0	0	36,500	34,860	1,640	0	43,400	37,820	5,580	0	51,600	40,770	6,170	4,660
Oct.	25,300	23,250	2,050	0	30,600	30,600	0	0	37,300	35,610	1,690	0	44,500	41,330	3,170	0	52,800	46,740	5,750	310
Nov.	26,100	24,390	1,710	0	31,600	30,270	1,330	0	38,500	31,180	5,270	2,050	45,800	32,930	5,880	6,990	54,400	34,680	6,340	13,380
Dec.	26,300	24,530	1,770	0	31,700	30,330	1,370	0	38,700	31,150	5,440	2,110	46,000	33,840	6,060	6,100	54,700	36,520	6,540	11,640
Annual	300,000	279,940	19,240	820	362,700	360,000	2,700	0	441,900	409,380	28,360	4,160	526,200	444,690	62,190	19,320	625,100	478,220	75,500	71,380

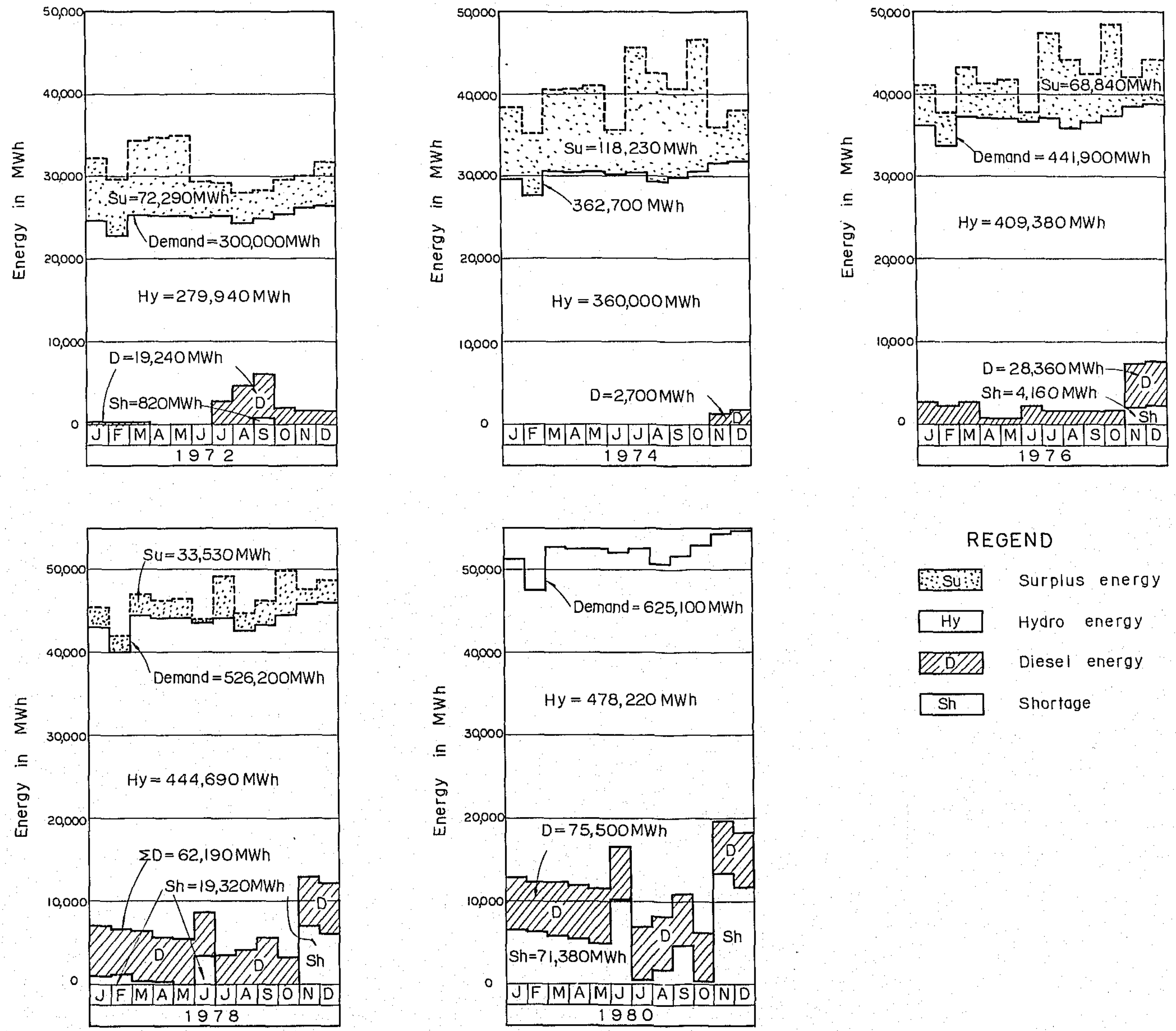
Table 7-12 Monthly Effective Energy of Hydro Power Plant in EEQ's System

(After Completion of La Mica Project)

Unit: MWh

Year	1972			1974			1976			1978			1980		
Month	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So	Available Hydro Energy Hd	Effective Hydro Energy Hl	Surplus Energy So
Jan.	31,900	24,260	7,640	38,420	29,700	8,720	38,420	33,630	4,790	38,420	36,030	2,390	38,420	38,420	0
Feb.	29,450	22,490	6,960	35,300	27,600	7,700	35,300	31,280	4,020	35,300	33,290	2,010	35,300	35,300	0
Mar.	34,080	24,960	9,120	40,610	30,600	10,010	40,610	34,730	5,880	40,610	38,050	2,560	40,610	40,610	0
April	34,650	25,200	9,450	40,620	30,500	10,120	40,620	36,470	4,150	40,620	38,560	2,060	40,620	40,620	0
May	34,840	25,200	9,640	41,000	30,500	10,500	41,000	36,450	4,550	41,000	38,730	2,270	41,000	41,000	0
June	29,410	24,900	4,510	35,370	30,100	5,270	35,370	34,500	.870	35,370	34,940	430	35,370	35,370	0
July	26,500	22,370	4,130	45,700	30,500	15,200	45,700	35,410	10,290	45,700	40,710	4,990	45,700	45,700	0
Aug.	23,300	19,660	3,640	42,500	29,400	13,100	42,490	34,110	8,380	42,490	38,460	4,030	42,490	42,490	0
Sept.	22,200	18,730	3,470	40,770	29,900	10,870	40,770	34,860	5,910	40,770	37,820	2,950	40,770	40,770	0
Oct.	27,550	23,250	4,300	46,740	30,600	16,140	46,740	35,610	11,130	46,740	41,330	5,410	46,740	46,740	0
Nov.	28,360	24,390	3,970	34,680	30,270	4,410	34,680	31,180	3,500	34,680	32,930	1,750	34,680	34,680	0
Dec.	29,990	24,530	5,460	36,520	30,330	6,190	36,520	31,150	5,370	36,520	33,840	2,680	36,520	36,520	0
Annual	352,230	279,940	72,290	478,230	360,000	118,230	478,220	409,380	68,840	478,220	444,690	33,530	478,220	478,220	0

Fig. 7-9 Balance of Energy Demand in EEQ's System



Chapter VIII

PRELIMINARY DESIGN

Chapter VIII

PRELIMINARY DESIGN

8.1 DESCRIPTION OF STRUCTURES

8.1.1 Hydraulic Structures

Main structures of La Mica Project are dam, intake, headrace tunnel, and canal, regulating pond (head tank), penstock, powerhouse, and auxiliary intake.

(1) Dam (La Mica Reservoir)

La Mica Reservoir will be the natural lake called Mica Cocha (high water level: 3,900 m, water surface area: 2.09 km^2, maximum depth: about 15 m, dammed lake due to volcanic action). At Desaguadero which is the outlet of the lake, a dam will be constructed to raise the water level of Laguna Mica by 4 m. Thus the effective reservoir capacity of 21,000,000 m^3 will be obtained for annual regulation. As a result of technical and economic studies, the location of the dam has been selected at A point in Desaguadero around the dammed terrace which is closest to Lake Mica. (Refer to Appendix II). The dam will be a homogeneous earthfill structure, constructed with materials easily obtainable around the dam site. On the downstream side of the dam, a drain will be constructed to reduce the line of seepage. The upstream surface will be protected with riprap. The cross-section of the dam has been designed to have a slope of upstream 1 : 3.0 on the upstream and 1 : 2.5 – 3.0 and to be divided into zones so that excavated materials of tunnel and spillway can be used as embankment materials. In the detail design of the project it will be necessary to study in more detail the nature and characteristics of embankment materials and the foundation.

The crest of the dam which is 6.00 m on wide will be utilized as a road. The general feature of the dam are: height 12.00 m, volume 55,000 m^3, length of crest 415 m and average height 6.30 m. The average height of the dam is 6.30 m and the maximum height of 12.00 m is only 10 m long.

The spillway to be constructed on the left bank of the dam will be a side channel spillway. The design flood discharge of 30 m^3/s can be released over the concrete crest by a 1 m surcharge.

(2) Intake

The intake will be constructed on the left bank of the dam in consideration of its connection to the headrace. The structure has been designed as illustrated in Drawing 10, for a draw down of 9.5 m, which is lower than the maximum water level of the natural lake by 5.5 m, and therefore a part of the structure must be executed in water. A trash-rack will be installed on the upstream face of the intake. A valve will be installed in the headrace tunnel to kill energy and to control the flow. At the inlet portal of the tunnel, a gate will be provided for inspection and repair of the valve. A vertical shaft will be constructed for access to the valve chamber.

(3) Principal Waterway

The waterway consisting of tunnel, open canal and culvert will be constructed to conduct a maximum of 4.5 m^3/s of water from the intake to the regulating pond (to be commonly used as head tank) to be located around Tablón Alto. The total length of this waterway will be 27,410 m including about 5,220 m of tunnels, about 21,860 m of canals and 330 m of culverts.

(3)-1 Tunnel

The tunnel will be of non-pressure type. From hydraulic and construction points of view, the study was made on the gradient within the scope of 1/1500 – 1/600 (0.067 – 0.17%). As a result, the gradient has been decided to be 1/800 (0.125%). The cross-section of the tunnel is rectangular with the arch section of semi-circular design. Some sections of the tunnel will be completely lined with concrete and in the other sections only the invert will be concrete lined. Main specifications are: height 2.00 m and width 1.80 m for completely lined cross-section, and height 2.20 m and width 2.84 m for invert lined section. In consideration of the geologic conditions, it is estimated that 30% of the total length of the tunnel will require full lining and the remaining 70% will require concrete in the invert. No. 2 tunnel which is to be excavated through the East Andes Mountain Range is the longest and its length is 2,950 m.

(3)-2 Canal and Culvert

The major part (about 84%) of the waterway is the canal. The cross-section adopted is trapedoizal, which is easy to construct as the route of the waterway will pass through hilly regions and the construction cost is cheap (about 31% of the cost of tunnel per meter). The waterway will have a bottom width of 1.20 m, side slope of 1 : 1 and gradient of 1/1,500 (0.067%). The facing of the canal is to be Rubble masonry for the protection of the slope and drains will to be constructed in the bottom of the canal. Some sections of the canal will pass through marshland.

Therefore, the foundation of the canal in the marshland must be constructed by partially replacing the existing soil with the soil of the good quality and drainage works must be executed.

On the other hand, the waterway must cross over ravines at eleven points. The culverts, shown in Drawing 11 are to be adopted at these crossing points.

Moreover, it is necessary to construct concrete or wooden bridges across the canal in the pasture land, where necessary, to permit crossing. Also, fences must be constructed on both sides of the waterway for safety.

(4) Regulating Pond (to be commonly used as head tank)

The head tank is to be constructed at Tablón Alto which is the end of the waterway and the starting point of the penstock for the following reasons.

i) It will take about eight hours before the required quantity of water reaches the head tank from La Mica reservoir through the 27.4 km long waterway. Accordingly, there is fear of occurrence of time lag between the release from La Mica reservoir and the operation of the powerhouse according to system load.

ii) It is necessary to adjust the difference between inflow and discharge for power generation which may occur for a very short time.

iii) Measures are necessary to cope with misappropriation of the power plant in relation to available quantity of water. To meet the above requirements, the pattern of operation in relation to the assumed load pattern (refer to Fig. 3-2) of the power system and the monthly average discharge for power were studied. As a result, the necessary capacity of the regulating pond has been determined to be 25,000 m^3. Considering the structural stability, it was determined to construct a reservoir 40 m wide and about 250 m long with a draw down of 25 m. (Refer to Drawing 12)
Tablón Alto, the starting point of the penstock is a flat plateau apparently presenting excellent topographic and geologic conditions, and therefore, this site was selected for the reservoir. Since the water in Lake Mica Cocha is clear, flushing of sand will not be required so often. On this judgement, the head tank is designed to be a simple single-chamber structure for easy construction and economical maintenance. As auxiliary facilities, an overflow type spillway (capacity of 4.5 m^3/s.) is to be constructed to discharge surplus water into Qda de Secas. Gates will be installed at the inlet and outlet of the regulating pond. Since La Mica Power Plant will be the most important station in the power system, a by-pass waterway will be constructed on the mountain side to avoid complete shut down of the power station during sand flushing operations. The slope of the regulating pond will be protected by soil cement and partially by masonry. The sand flushing structure will be a submerged weir with an sloping bottom to facilitate removal of sand. Sand will be washed out through the spillway. The geology around the regulating pond, as described in Chapter 6, the surface has been affected by weathering and covered with 3 to 4 m layer of black volcanic ash. Before constructing structures, this layer has to be removed to provide a stable foundation.
Excellent quality of soil should be selected for the fill material which must be thoroughly compacted to prepare a firm the foundation. Also drainage facilities must be provided.

(5) Penstock

The penstock will connect the regulating pond (to be commonly used as head tank) with the powerhouse by the shortest possible distance. The arrangement of this line has been made simple for easy construction work. A single line plan has been adopted for economic reason. Repainting of the inside of the pipe will not be frequent as the water from La Mica is clean, and damage due to abrasion will be small. In consideration of economy, the inner diameter of the pipe at the upper part was decided to be 1.60 m, the average 1.30 m and the diameter at the lower part 1.00 m. The total length is about 2,600 m.

In consideration of the topography, the penstock will be of exposed type installed aboveground with a gentle inclination of 12°, the steepest being 40°. Anchor blocks will be constructed at maximum spacing of 150 m and the penstock will be firmly supported by ring girders. The section of pipes will be electrically welded. Although a comparative study was made of the dresser joint, electrical welding has been selected in consideration of maximum water pressure, durability and reliability. The inner diameters of the pipes (1.60 – 1.00 m) have been determined so that one can be inserted into another for convenience of transportation.

Although the internal pressure will be high, carbon steel (SM41) can be used as the material for pipes. The thickness of the material which is carbon steel will be a maximum of 25 mm because of small inner diameter and highly effective electrical welding is possible. The lower part of the penstock line will bifurcate to serve two Pelton water wheels. T-shaped branch pipe will be installed and embedded in the powerhouse concrete foundation. At the inlet of the penstock, an intake gate will be installed to facilitate repair and closure of water in case of accident.

(6) Powerhouse

In consideration of topographical and geological conditions, the powerhouse will be of indoor structure constructed on the ground. The location of the powerhouse as shown on Drawing-14 is most suitable in consideration of the topographical and geological conditions, the location of Rio Pita intake dam (for city water), the tailrace elevation, etc. In case of operation for power generation only, this location enables the discharge of water into the Rio Pita through Qd. El Carmen for use at the downstream power stations. Also with favorable road conditions access to the powerhouse will be easy. This road can be utilized during construction with a minor improvement works. The powerhouse will have two units each of Pelton water wheels directly coupled to horizontal-shaft generators and other auxiliary equipment. The floor space of the powerhouse building is about 540 m^2 (19.0 m x 28.5 m). The foundation of the powerhouse will be constructed on tuff as described in Chapter 6 "Geology of Power Station". As the design load is small, it is judged that the foundation will adequately support the structure and equipment to be installed.

The powerhouse building will be of structural steel. It will have necessary space for hydraulic turbines, generators, switchboards, offices, and so forth. The main transformers will be installed just behind the building. The switchyard will be located adjacent to the powerhouse. The layout as a whole has been designed to be compact. Slope excavation at the mountain side will be 15 to 20 m at the highest place. These sections will be protected by Rubble masonry depending on the geology, with drainage provided. Around the powerhouse, the catchment area of Qd. El Carmen is small and there is no fear of a big flood. Thus it is not necessary to construct protective facility against flood. However, there will be a by-pass waterway in front of the powerhouse parallel with the tailrace to release the run-off and flood water from the ravine. At the tailrace of the powerhouse, gates will be installed in the intake structure of water supply and for the control of discharge.

8.1.2 Power Generating and Transforming Facilities

As described in Chapter 7, La Mica Power Station is to be equipped with two units each of 9,500 KW hydraulic turbines and 10,000 KVA generators. The maximum discharge of one unit of hydraulic turbine is 2.25 m^3/s and the effective head is 496.5 m. For such design condition, the Pelton turbine is most suitable, and from an engineering point of view, it is difficult to employ other types of hydraulic turbines than the Pelton-type. Thus the Pelton type turbine will be installed in the La Mica Power Station. The turbine will have two nozzles to increase the revolving speed and to reduce the cost of generators. The horizontal-shaft has been adopted for convenience of maintenance and inspection, taking into considerations the small capacity and high speed of the machine. Equipment in the powerhouse should be so arranged as to be convenient for inspection and maintenance. Two sets of main transformers will be installed to improve power system reliability since La Mica will be an important plant in "EEQ" S.A. power system. As emergency power, one set of compact type diesel engine generator will be installed in the powerhouse. At outdoor substation to be constructed adjacent to the powerhouse, 46 KV circuit breakers will be installed to cope with accidents on the transmission line between La Mica and Guangopolo. On the top of the steel structure an overhead ground wire will be strung to protect the transformers and switchyard equipment from lightning strike.

The single-line diagram of La Mica Power Station is shown on Drawing-18.

8.1.3 Transmission Line

The 18 MW of power generated at La Mica Power Station will be transmitted to South Substation in Quito City by way of Guangopolo step-up Substation. One circuit of 46 KV transmission line over a distance of 25 km between La Mica and Guangopolo step-up Substation was selected to run along the existing road by the shortest possible distance, in consideration of the convenience of construction works and maintenance and the density of population along the route. The planned route of the transmission line is in the district of elevation of about 3,000 m. Therefore, in the design of the line, attention was paid to increase the dielectric strength due to the thin air density. The size of the conductor has been determined to be 200 mm^2 ACSR, as the result of economic comparison (shown on Table 8-1) between construction cost and annual transmission loss.

Table 8-1 Comparison between Reduction of Annual income caused by Annual Expenses

Unit: sucres

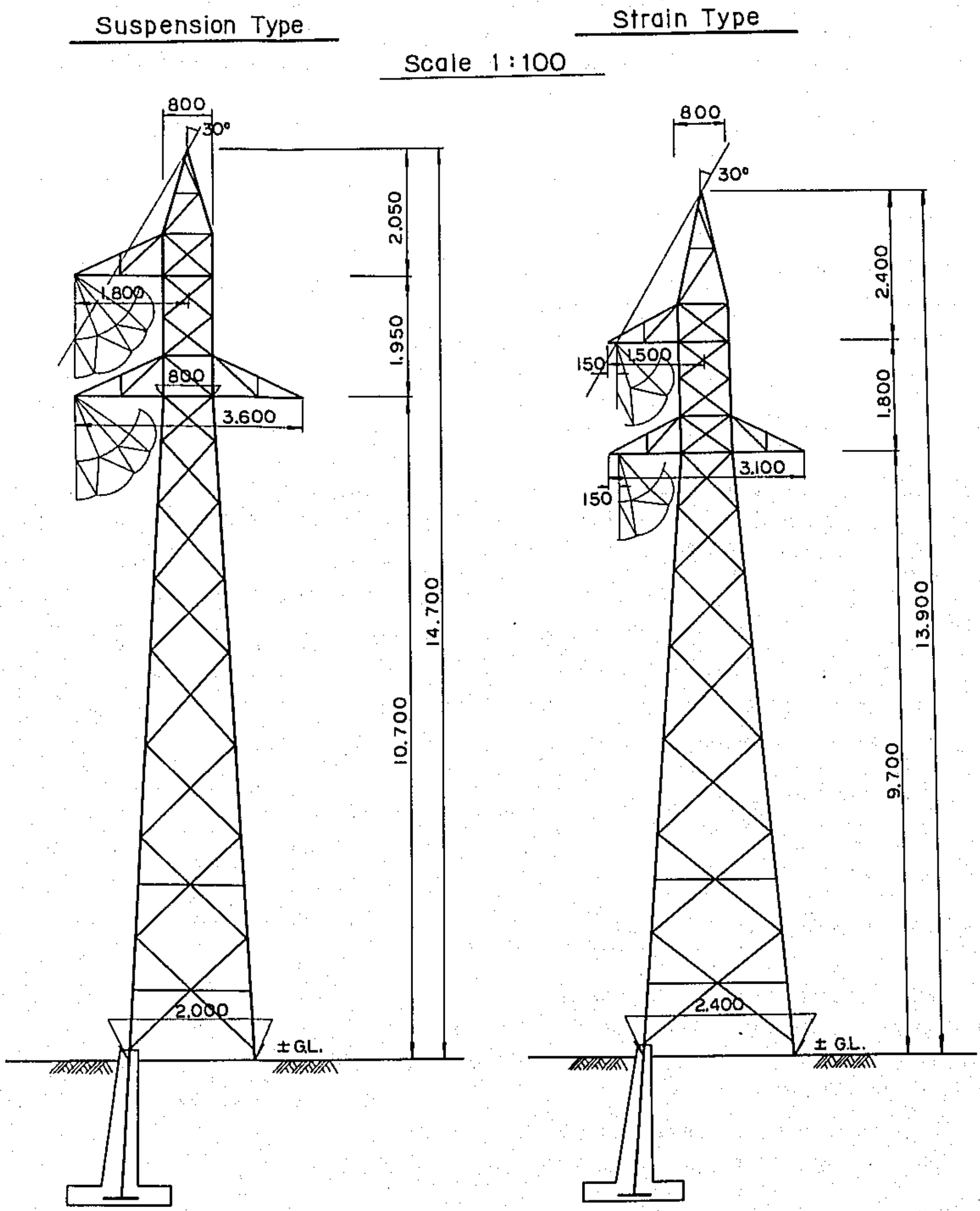
Size of Conductor	120 mm^2 ACSR	160 mm^2 ACSR	200 mm^2 ACSR	240 mm^2 ACSR
Reduction of Annual income caused by Transmission Loss	660,000	510,000	410,000	340,000
Annual Expenses	510,000	560,000	640,000	740,000
Total	1,170,000	1,070,000	1,050,000	1,080,000

The supports will be of triangular arrangement self-standing one-circuit steel towers, erected at standard spacing of 200 m. On the top of the steel towers, a 38 mm^2 zinc-coated steel stranded cable will be strung to avoid lightning strike. The shielding angle of the overhead ground wire is designed to be 30^o.

In order to prevent counter flashover from the steel tower to the line, counter poise will be provided and the grounding resistance of the steel towers will be made small.

A typical one-circuit line steel tower is shown on Fig. 8-1.

Fig. 8-1 Typical Steel Tower



8.1.4 Main Dimension

The main specifications of La Mica Power Station and transmission lines are as follows:

A. Hydraulic Structures

(1) Reservoir

Effective storage capacity	21,000,000 m^3
Normal high water level	3,904 m
Low water level	3,894.50 m
Draw down	9.50 m

(2) No. 1 Intake Structure

No. 1 Intake dam (concrete dam)

Height	6.20 m
Crest length	19.00 m
Volume	450 m^3

Waterway (open canal)

Discharge	1.8 m^3/s
Cross section: trapezoidal	
Bottom width	1.20 m
Side slope	1 : 1
Gradient	0.14%

(3) No. 2 Intake structure

No. 2 intake dam (concrete dam)

Height	7.20 m
Crest length	19.0 m
Volume	620 m^3
Discharge	2.7 m^3/s
Cross section: trapezoidal	
Bottom width	1.20 m
Side slope	1 : 1
Gradient	0.14%

(4) Main Dam

Type: Earthfill

Height	12.00 m
Crest length	415.00 m
Crest width	6.00 m
Volume	55,000 m^3
Upstream slope	1 : 3.0
Downstream slope	1 : 2.5 – 3.0

Spillway: Overflow type

Capacity	30 m^3/s
Surcharge water level	3,906.00 m

(5) Main Intake

Type and structure: Reinforced concrete

Maximum intake 4.5 m^3/s

Regulating type: Howell-Bunger valve

(6) Waterway

Total waterway length	27,416 m
Maximum discharge	4.5 m^3/s

(6)-1 Tunnel

Total length: 5,223 m

Cross section -I: Completely concrete lined

Upper part semi-circular	radius	0.90 m
Lower part rectangular		1.10 x 1.80 m
Height		2.00 m
Width		1.80 m

Cross section -II: Invert only concrete lined

Upper part semi-circular	radius	1.45 m
Lower part rectangular		0.78 x 2.84 m
Height		2.20 m
Width		2.84 m

Gradient for I and II	1/800 (0.125%)

(6)-2 Canal

Total length: 20,907 m

Cross section: trapezoidal

Bottom width	1.20 m
Side slope	1 : 1
Height	1.80 m
Gradient	1 : 1500 (0.067%)
Slope protection	Rubble masonry

(6)-3 Culvert

Total length: 330 m

Cross section: Completely concrete lined

Upper part semi-circular radius	0.90 m
Lower part rectangular	1.10 x 1.80 m
Height	2.00 m
Width	1.80 m
Gradient	1/800 (0.125%)

(7) Auxiliary intake facilities

Total length: 1,050 m

(7)-1 No. 1 auxiliary canal

Length	700 m
Maximum discharge	1.8 m^3/s

Cross section: trapezoidal

Bottom width	1.20 m
Side slope	1 : 1
Height	1.05 m
Gradient	1/700 (0.143%)
Slope protection	Rubble masonry

(7)-2 No. 2 Auxiliary Canal

Length	350 m
Maximum discharge	4.5 m^3/s

Cross section: trapezoidal	
Bottom width	1.20 m
Side slope	1 : 1
Height	1.55 m
Gradient	1/700 (0.143%)
Slope protection	Rubble masonry

(8) Regulating Reservoir (to be commonly used as head tank)

Maximum water level	3,870.90 m
Low water level	3,868.40 m
Effective storage capacity	25,000 m^3
Draw down	2.5 m

(9) Penstock

Total length	2,596 m
Number of line	1
Inner diameter: Upper part	1.60 m
Average	1.30 m
Lower part (before branching)	1.00 m

Type of support: Ring girder

Type of joints: Electrical welding

(10) Powerhouse

Type: Indoor type on the ground

Structure of building: Steel structure

Floor space of building	540 m^2 (19.0 m x 28.5 m)

B. Generating Facilities

(1) Hydraulic turbine

Type: Horizontal-shaft single-runner, 2 nozzles, Pelton type

Number of unit	2
Output	9,500 kW
Maximum discharge	2.25 m^3/s
Effective head	496.5 m

(2) Generator

Type: Horizontal-shaft, enclosed hood, internal cooling type, 3-phase synchronous generator

Number of set	2
Generating capacity	10,000 KVA
Frequency	60 cycles
Rotating speed	600 rpm

(3) Main transformer

Type: Outdoor, 3-phase, oil-immersed, self-cooled type

Number of set	2
Capacity	10,000 KVA
Voltage	6.9/46 KV

(4) Transmission line

Voltage	46 KV
Number of circuit	1 cct
Length	25 km

Support: Triangular arrangement, 1 circuit, steel tower

Impedance	4.0 + j 10.5 ohm

8.2 CONSTRUCTION SCHEDULE AND METHODS

8.2.1 Construction Schedule

In consideration of the magnitude of the project, location of structures, capabilities of contractors and the various site conditions, a period of 25 months as shown in Fig. 8-2 seems to be reasonable for construction of the project. Power generation should desirably start from July 1974 as described in Chapter 3, 3-4, and to meet this target date the field works must start by July 1, 1972 at the latest.

Prior to starting the principal works, about 8 months are estimated to be necessary for preliminary works, such as construction of the access roads and power facilities for constructing so that the detail design and project financing must be all finished by around December, 1971.

Described in the following are the details of the major works.

(1) First year (1972)

The construction works will be carried out for 6 months from July 1, 1972. At La Mica dam site, the river diversion works will be started. Eighty (80) percent of the dam excavation should be completed so that the dam can be constructed in the dry season of the following year. The open cut excavation works at the intake should be completed simultaneously so that Coffer dam works of intake can be started from December, 1972 to proceed with the excavation work below the water level of the lake. The Coffer dam is to be constructed of excavated much from the intake and the dam foundation for economic purpose. Therefore, an overall construction schedule has been prepared. Construction of No. 1 canal will be started from the outlet portal of No. 1 tunnel.

Completion of the project within the scheduled time will depend on the construction of No. 2 tunnel. So, work on the tunnel should start from the upstream and downstream ends from August or September and 25% of the work must be completed within that year.

As for No. 2 canal, the part to be connected to the inlet portal of No. 1 tunnel can be constructed in early stage of construction and 40% of this work could be completed within the year. Excavation of No. 3 canal should be begun from the section near the access road, and 20% of this work should be completed within the year. Excavation of the penstock line should be started from August with emphasis on the vicinity of the powerhouse to enable the early start of the construction of powerhouse building. Progress of this work should be 30% within the year, and should be executed in such a manner not to interfere with the excavation of the powerhouse foundation. From August, manufacture of penstock has to be started. To follow this schedule, final contract should be concluded with the manufacturer in July. The excavation of the powerhouse will be completed during the period of 2.5 months from August to the middle of October. Placing of concrete in the foundation of the powerhouse has to be completed during the period of 2.5 months from the middle of October to the end of December so that construction of the building can be started from the beginning of the following year. Prior to the start of this construction works, orders should be placed for the water turbines and generators by the end of March so that the works can proceed wihtout delay.

(2) Second Year (1973)

In 1973, 50% of the construction works of La Mica Project have to be completed. The works should proceed with emphasis on hydraulic works in the first half of the year and on the installation works of equipment in the second half. Work on No. 1 intake dam and No. 2 intake dam will continue from the previous year, and 90% of the works including the canal construction will be completed within the year. Foundation excavation of La Mica dam started in the previous year will be completed, and embankment of the dam will be completed in the period of 4 months from February to May. The spillway and other concrete works should be finished by the end of July before the rainy season so that no problem will be encountered in the rainy season. Excavation of No. 1 tunnel will begin from the start of the year and 80% of the work will be completed by the end of the year. No. 1 canal will be constructed from the last half of the year to avoid concentration of work in certain months, and excavation and embankment works of this canal will be completed within the year. For No. 2 tunnel, excavation work will continue from the previous year and completed by the end of the year. The excavation of No. II and No. III canals will be completed and slope protection works of No. I canal will be started, completing

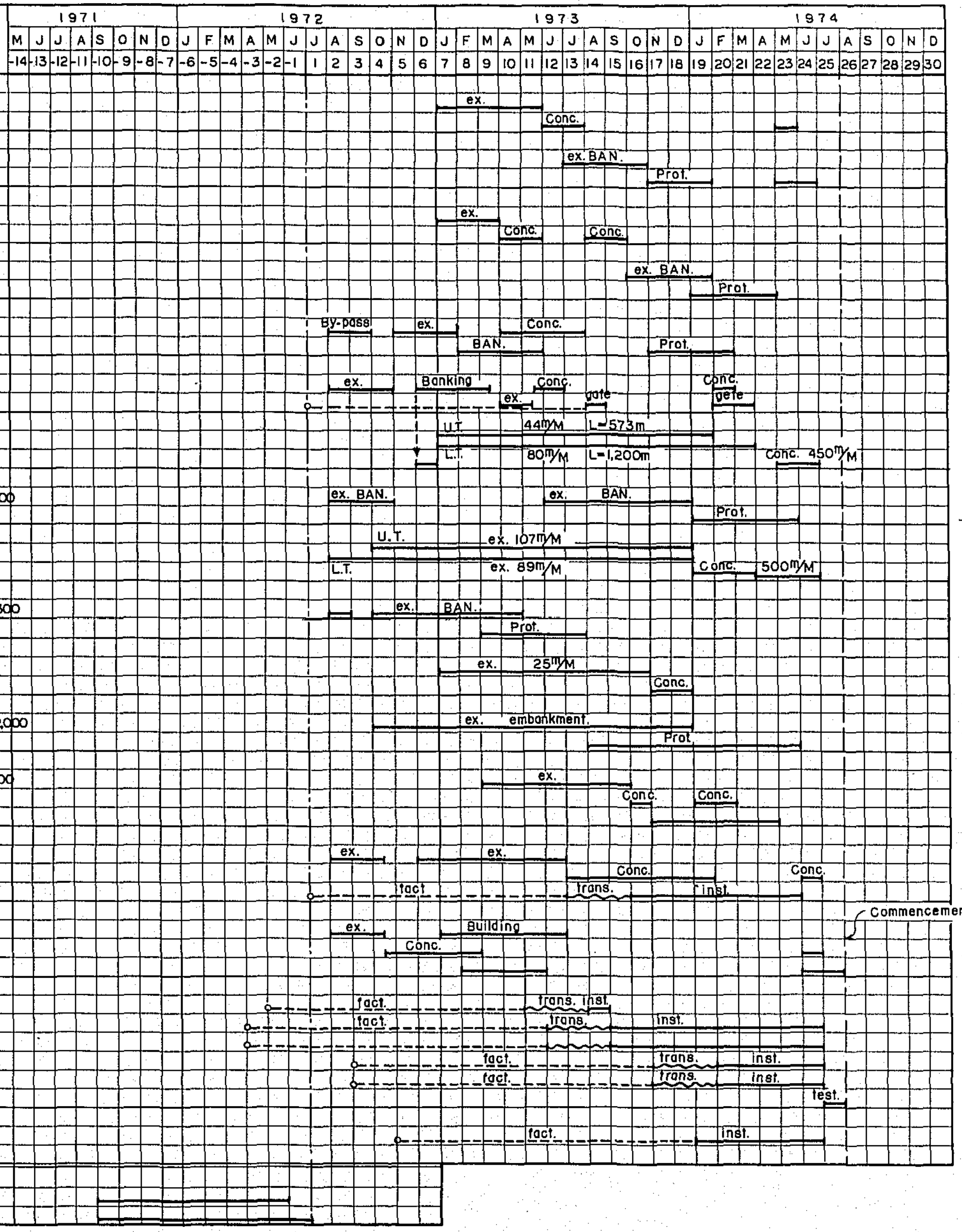
70% of the work within the year. No. 3 tunnel which is not long can wait until the works on the upstream and downstream canals make some progress and road conditions improve. In this year, all excavation and concrete lining works should be completed. Excavation of the head tank can wait until the works with priority are finished, and the excavating machines employed on the dam, powerhouse, etc. become free which will probably be March 1973. Excavation as well as embankment of the head tank will be finished in 7 months from March to September. Concrete structures will be constructed in October. The slope protection work will be started from November immediately after the rainy season. Excavation of the penstock foundation will be completed in the early half of the year, and the installation of steel pipes will start from October. Eight months will be necessary for the installation of the penstock. The construction of powerhouse building will start from the beginning of the year with the foundation works completed by June. The overhead travelling crane will be installed in July, and the installation of main powerhouse equipment will start from September.

The construction schedule has been prepared on the assumption that the main equipment will arrive at the construction site 3 months after they are shipped from the factories.

(3) Third Year (1974)

The third year is the period of 7 months until the start of operation of the powerhouse. For hydraulic works, emphasis will be placed on concrete works and final finishing works. The installation of main equipment will be carried out and the month of July is scheduled for test operation. Accordingly, the works should be completed by the end of June. The slope protection works of canals and the concrete lining of tunnels will be all completed by June.

No.	Division of works	Unit	Quantities
1	No. 1 Diversion Dam		
	excavation	m^3	900
	concrete	m^3	450
2	No. 1 Canal		
	excavation	m^3	5,800
	embankment	m^3	5,900
3	No. 2 Diversion Dam L=350m		
	excavation	m^3	700
	concrete	m^3	620
4	No. 2 Canal L=700m		
	excavation	m^3	11,700
	embankment	m^3	11,900
5	Main Dam		
	excavation	m^3	45,300
	embankment	m^3	50,800
6	Main Intake		
	excavation	m^3	9,500
	embankment	m^3	2,400
7	No. 1 Tunnel L=1,773m		
	excavation	m^3	9,800
	concrete	m^3	1,360
8	No. 1 Canal L=3,662m		
	ex. & embankment	m^3	ex.62,800 BAN.63,100
	slope protection	m^2	23,700
9	No. 2 Tunnel L=2,950m		
	excavation	m^3	16,300
	concrete	m^3	2,260
10	No. 2 Canal L=4,660m		
	ex. & embankment	m^3	ex.80,000 BAN.80,300
	protection	m^2	30,290
11	No. 3 Tunnel L=500m		
	excavation	m^3	2,800
	concrete	m^3	380
12	No. 3 Canal L=13,650m		
	ex. & embankment	m^3	ex.228,100 BAN 232,000
	slope protection	m^2	86,230
13	Reserveir		
	ex. & embankment	m^3	ex.55,300 BAN.4,900
	concrete	m^3	950
	slope protection	m^2	1,400
14	Penstock Line		
	excavation	m^3	26,100
	concrete	m^3	2,700
	steel penstock	m	
15	Powerhouse		
	excavation	m^3	56,400
	concrete	m^3	4,810
	other works	L.S	—
	Machine & Equipment		
	crane	t	
	turbine	t	160
	generator	t	145
	transformer	t	60
	switchyard	t	31
	test operation		
	Transmission line 46kV (Guangopolo ~ La Mica)	km	25
	Preliminary works		
	access road		
	transmission line for construction		



LEGEND

ex.	;	Excavation
Conc.	;	Concrete
BAN.	;	Enbankment
Prot.	;	Rock facing
trans.	;	Transportation
fact.	;	Factory
inst.	;	Installation
U.T.	;	Upper tunnel
L.T.	;	Lower tunnel
m/M.	;	Progress m/Month
L.	;	Length

LA MICA PROJECT

Fig. 8-2

Construction Schedule

8.2.2 Methods of Construction

(1) Road for Transportation, Construction Base Camp, Power for Construction, and Water for Construction

Either road or railroad can be used for the transportation of materials and equipment for the Project from Guayaquil via Quito to Cumbaya where "EEQ" S.A. warehouse is located. At Cumbaya base, there are sufficient unloading and storage facilities. This base was used for the construction of Cumbaya and Nayon Projects. Since the location of this base is only 40 km by road to La Mica Project site, the base will be utilized for this project.

The road from Cumbaya to La Mica via Quito will run along the route shown on Drawing -2. Prior to the full-scale construction works, this road will be improved to accommodate traffic for construction purposes. Branch access roads will be constructed as required.

The survey camp at Antizana will be enlarged and used as the construction base for "EEQ" S.A. and the consulting engineer. The camp for contractors will be provided separately at two places of the vicinity of dam and the powerhouse.

A power distribution system for a maximum of 300 to 400 KW will be necessary for the construction works. As described in Clause 8.1.3, the transmission line connecting Guangopolo and La Mica powerhouse and dam sites will be first constructed and used for construction works. For the construction of tunnels, and canals, portable diesel engines will be used for mobility.

Water for construction will be taken from Rio Antizana near the dam site or from the ravine (Qda.) along the canal route by gravity or pumping.

During the non-irrigation period, the water of the existing irrigation system can be utilized. In this region, there is adequate water throughout the year, and there will be no shortage of water for construction purposes.

(2) Procurement of Materials and Aggregate

The materials required for the construction of La Mica Project are as follows.

Cement:	5,500 t = 12,940 sacks (42.5 kg/sacks)
Reinforcement bars:	310 t
Steel material:	10 t
Aggregates:	40,000 t

As mentioned above, the total required quantity of cement is about 5,500 t. Both quantitatively and qualitatively, domestic products can be used. Most of the reinforcement bars, steel materials, tools, etc. will have to be imported from foreign countries. It is possible to obtain the total required quantity of aggregates from natural deposite, but an aggregate plant will be installed to produce the necessary materials by crashing massive rock for emergency purpose should there be a shortage of natural aggregates. The suitable capacity of the aggregate plant would be a maximum of 30 T/H judging from the maximum volume of concrete placing of 40 m^3/day. The location of the aggregate plant should be determined in consideration of the location of the quarry, and the layout of construction roads.

(3) Construction of Main Structures

In order to construct a dam at the outlet of Lake Mica, the flow must be temporarily diverted during construction by coffering. In consideration of the geology, run-off, weather conditions, and type of dam proposed, care and diversion of flow will be executed by constructing a culvert in the lower part of the dam foundation on the left bank of the dam site. The maximum discharge capacity of this culvert is 3.5 m^3/s, which is sufficient to discharge the largest recorded flood in the past. Where the culvert passes through the dam body, a cut-off collor will be constructed to assure watertightness.

After the river flow is diverted, the foundation of the dam will be excavated. The excavation will be to the extent of removing surface soil, except in the center impervious core zone where the foundation will be excavated to relatively impermeable layer. The weak zone in the foundation will be treated by removing rejectable soil and backfilling with suitable soil.

Embankment material will be obtained from the hill near the dam site, transported and embanked in place and then thoroughly compacted. Embankment and compaction of material must be executed carefully, conducting soil tests, to determine the optimum water content in consideration of the weather condition in the project area. Excavated material from the spillway can be used for embankment in an appropriate zone of the dam to economize construction costs. The riprap on the upstream will be placed by dumping and the material for the riprap will excavated material from the tunnel. There may not be any problem about the construction road, in view of the scale of the construction.

The intake structure will be constructed in the dry by building a coffer dam around the site above the present maximum water level of Lake Mica (3,900 m). After the completion of the intake structure and No. 1 tunnel, the coffer dam will be removed. The lake bottom in the forebay of the intake will have to be excavated in water which is 9 m depth at the maximum. Therefore, this work should be carried out when the water level recedes after the project in put into operation. The manner in which to perform this work will require further detailed investigations and study. The access road to the intake site will be constructed on the left bank of the river and will be connected to the access road to the dam for inspection and maintenance purposes after the project is completed. After the dam and intake are completed, stoplog will be inserted in the upstream portal of the culvert used temporary diversion channel to start storage of water. While the flow is closed with the stoplog, the inside of the culvert will be plugged with concrete.

The waterway is about 27.4 km long and consists of tunnels, culverts and canals. There may not be any special problem encountered in their construction in view of geological and topographical conditions. The work schedule largely depends upon the construction of No. 1 (1,773 m) and No. 2 (2,950 m) tunnels. Since the geology is assumed to be good, neither special construction method nor adit will be required. The works can be completed within the proposed work schedule. No. 3 tunnel being short presents no problem, but special care should be taken for protection of the portal section. The culvert structure will be constructed in places where the waterway crosses ravines. In view of the present condition, it is believed that no difficulty will be encountered in the construction of culverts. In case the foundation of canal is prepared by banking soil, the foundation should be compacted well to avoid problems caused by settlement.

The construction works should be started simultaneously dividing the work into several sections in order to allow time for the embanked material to settle and stabilize.

In view of the geology and topography, there will be no problem in the construction of the intake dams at Rio Chico and Qda Banio Urria Pungo and the construction could be executed by conventional method.

The head tank will be constructed on a wide tableland of Tablón Alto, and construction machines can be efficiently utilized. Soil cement will be used for impervious facing. The method for stabilizing and preparing the foundation of the structive and the composition of soil cement should be decided by material test and other methods.

The foundation work of the penstock should be executed by dividing the work into several sections to expedite construction and to allow time for concrete placed in the foundation to cure.

Because of the topography of the powerhouse site, a relatively large volume of excavation will be required. Therefore, the excavation of the powerhouse foundation should be started at an early stage, so that the powerhouse substructive can be constructed with allowance of time for the foundation to stabilize.

For the concrete placing works for the above structures, a concrete plant will be erected near the outlet portal of No. 1 tunnel to supply concrete to the dam, the intake, and the inlet portal of No. 1 and No. 2 tunnels. An auxiliary plant will be set up around the outlet portal of No. 2 tunnel to supply concrete to the outlet portal of No. 2 tunnel and No. 2 culvert. A portable plant will be adequate to supply concrete to the other culverts. The concrete will transported by agitator car.

The main concrete plant will be erected at the powerhouse site to supply concrete for the penstock foundation and the powerhouse. Concrete in the powerhouse will be placed by chute and concrete for the penstock foundation will be transported by agitator car.

The transmission line between La Mica and Guangopolo will be constructed along the road extending from Mica to Pintag and Guangopolo. The line will pass through comparatively flat land and, therefore, there should be no problem in the execution of the work.

Chapter IX

COST ESTIMATE OF LA MICA POWER PLANT

Chapter IX

COST ESTIMATE OF LA MICA POWER PLANT

9.1 BASIC ASSUMPTIONS

The costs of La Mica Project were estimated according to the following basic assumptions.

(1) Scope of Works

The cost estimates of the project includes the dam, intake structure, headrace and all other appurtenant structures, powerhouse, switchyard, transmission line between the powerhouse and Guangopolo Substation and extension of Guangopolo Switchyard.

(2) Quantities of Works

The attached Drawings 1 to 12 were used in estimating the quantities of each work and where necessary, supplementary drawings were prepared to assure accuracy. The topographical maps supplied by EEQ were used for preparation of the drawings.

(3) Interest during Construction

Interest was calculated at 6.5% per annum for foreign currency and 10% for domestic currency for only the parts to be financed with loans.

(4) Customs and Import Duties

As for customs and import duties, EEQ is completely exempted from payment of such charges by special decree of the Government.

(5) Basic Unit Prices

For materials to be procured domestically, the market prices in 1968 were used, while for materials to be imported, the 1968 prices at Port of Guayaquil, i.e., C.I.F. prices were used. Wages for labor were based on 1968 figures.

(6) Domestic Currency and Foreign Currency

Ecuadorian currency will be required for disbursements of civil works, installation of machinery and equipment, procurement of domestic materials, transportation within the country, etc., while foreign currency will be required for items directly requiring foreign currency such as purchase of imported machinery and equipment, engineering and supervisory costs, etc.

(7) Scope of Contract Work

It was assumed that civil works, such as dam, intake structure, tunnel, canal, regulating reservoir and powerhouse will be let to foreign contractors, while installation of penstock and generating equipment will be carried out by foreign contractor with erectors provided by each manufacturer of equipment, and under the supervision of a consultant.

(8) Preliminary Works

The road between Quito and Pifo will be utilized as the construction road. Within the Hacienda, the existing road will be used by executing partial improvement work. The cost for roads include the new roads from EEQ's camp to the dam site and further to the portal of tunnel, and for the construction of waterways (open canal). Camps for construction are to be set up at the dam site and at the powerhouse site. Power for construction will be supplied by the permanent transmission line between Guangopolo and La Mica which will be constructed prior to the commencement of construction works. The cost for this has been estimated as preliminary work. Warehouses and temporary storage places for materials and equipments will be provided at Cumbaya camp. Supplementary camp will be provided at the powerhouse site.

(9) *Cost of Land*

Almost all structures of La Mica Project will be built on land now privately owned so that it will be necessary to acquire by purchase the required land. This cost is included in the estimate.

(10) EEQ Administration Costs

The administration costs of EEQ will include the wages and salaries of its staff in the field and head office as well as other related expenses during the construction period.

(11) Engineering and Supervisory Costs

Engineering and supervision for the main structure will be undertaken by foreign consultants and domestic consulting company.

(12) Contingencies

For contingencies, the following percentages are included:

5% for all foreign currency expenditures

10% for local currency expenditures for the dam, tunnel, canal, powerhouse, etc.

10% for all other local currency expenditures

9.2 TOTAL CONSTRUCTION COSTS OF LA MICA PROJECT

Under the conditions described in 9.2, the construction costs of La Mica Project were estimated. The results are as follows, including interest during construction and the transmission line.

Local currency	s/. 104,716,000	
Foreign currency	s/. 72,184,000	(US$3,970,000)
Total construction cost	s/. 176,900,000	(US$9,730,000)

As shown above, the amount of foreign currency is about 40% of the total construction costs. The cost for each component of the project is shown in Table 9-1 (3-1, 3-2 and 3-3). Shown in the following table are the annual fund required for the construction works to achieve the commencement of operation in the end of July, 1974, as described in 8.2 of Chapter 8.

Unit: sucres

Year	July–Dec., 1972	Jan.–Dec., 1973	Jan.–Dec., 1974	Total
Local currency	22,844,200	49,328,450	32,543,350	104,716,000
Foreign currency	8,135,000	34,451,050	29,597,950	72,184,000
Total construction cost	30,979,200	83,779,500	62,141,300	176,900,000

The breakdown of the construction costs is shown in Table 9-2 (3-1, 3-2 and 3-3).

Table 9-1 Construction Cost of La Mica Project (3-1)

Unit: sucres

No.	Works	Foreign Currency	Local Currency	Total Costs	Remarks
A	Civil Works				
A-1	No. 1 Diversion dam	211,250	314,950	526,200	
A-2	No. 1 Diversion canal	96,800	359,200	456,000	
A-3	No. 2 Diversion dam	289,400	423,600	713,000	
A-4	No. 2 Diversion canal	190,900	712,100	903,000	
A-5	Main dam	1,801,900	3,210,100	5,012,000	
A-6	Intake $Q = 4.5\ m^3/s$	882,800	1,217,200	2,100,000	
A-7	No. 1 tunnel $Q = 4.5\ m^3/s$, L = 1,773 m	2,697,500	4,652,500	7,350,000	
A-8	No. 1 canal $Q = 4.5\ m^3/s$, L = 3,752 m	1,081,600	3,918,400	5,000,000	
A-9	No. 2 tunnel L = 9,950 m	4,483,700	7,716,300	12,200,000	
A-10	No. 2 canal	1,373,500	4,926,500	6,300,000	
A-11	No. 3 tunnel	768,800	1,331,200	2,100,000	
A-12	No. 3 canal	3,718,500	13,621,500	17,340,000	
A-13	Reservoir	932,100	2,247,900	3,180,000	
A-14	Penstock foundation	1,485,900	3,714,100	5,200,000	
A-15	Powerhouse	3,852,600	6,297,400	10,150,000	
Sub-total		23,867,250	54,662,950	78,530,200	

Table 9-1 Construction Cost of La Mica Project (3-2)

Unit: sucres

No.	Works		Foreign Currency	Local Currency	Total Costs	Remarks
B	Mechanical Equipment					
B-1-1	Trashrack & stop logs		280,000	50,000	330,000	
B-1-2	Gates		597,000	358,000	955,000	
B-1-3	Penstocks	1,700 tor	13,819,000	10,986,000	24,805,000	
B-1-4	Turbines	160 ton	5,596,000	1,123,000	7,079,000	
Sub-total			20,652,000	12,517,000	33,169,000	
	Electrical Equipment					
B-1-5	Generator	145 ton	5,579,000	1,022,000	6,601,000	
B-1-6	Main Transformer	60 ton	1,348,000	266,000	1,614,000	
B-1-7	Control board and cubicles	22 ton	2,362,000	168,000	2,530,000	
B-1-8	Switchyard equipment	31 ton	883,000	216,000	1,099,000	
B-1-9	Miscellaneous equipment	32 ton	819,000	190,000	1,009,000	
Sub-total			10,991,000	1,862,000	12,853,000	
	Mechanical Equipment					
B-1-10'	Crane		311,000	90,000	401,000	
	Sub-total (B)		31,954,000	14,469,000	46,423,000	

Table 9-1 Construction Cost of La Mica Project (3-3)

Unit: sucres

No.	Works	Foreign Currency	Local Currency	Total Costs	Remarks
C	Preliminary Works				
C-1-1	Access road – (1) Width = 5.5 m L = 3.0 km	240,000	1,440,000	1,680,000	Unit cost: s/. 560/m
C-1-2	Access road – (2) Width = 4.5 m L = 18.5 km	1,350,000	7,900,000	9,250,000	Unit cost: s/. 500/m
C-1-3	Base camp	1,350,000	150,000	1,500,000	
C-1-4	Distribution line for 6.3 kV the construction L = 20 km	350,000	150,000	500,000	s/. 25,000/km
Sub-total		3,290,000	9,640,000	12,930,000	
D	Studies & Investigation	-	1,500,000	1,500,000	
E	Right-of-way and Land Acquisition Area = 800,000 m^2 s/. 2/m^2	-	1,600,000	1,600,000	
F	EEQ's Administration Cost	-	2,400,000	2,400,000	Personal expense = $400 x 25 month x 6 persons = $60,000 Expense of office = s/. 1,300,000
G	Engineering & Supervisory Cost	1,900,000	827,000	2,727,000	Definite design = US$70,000 Supervisory = US$80,000 Total $150,000
H	Contingency	4,494,850	7,816,350	12,311,200	
I	Interest during Construction	4,153,900	9,324,700	13,478,600	
	GRAND TOTAL	69,660,000	102,240,000	171,900,000	

Table 9-2 Annual Fund Requirement (3-1)

Unit: sucres

No.	Works	Construction Costs			1972			1973			1974		
		Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
A-1	No. 1 Diversion dam	211,250	314,950	526,200				203,950	302,700	506,650	7,300	12,250	19,550
A-2	No. 1 Diversion canal	96,800	359,200	456,000				90,000	271,250	361,250	6,800	87,950	94,750
A-3	No. 2 Diversion dam	289,400	423,600	713,000				289,400	423,600	713,000	0	0	0
A-4	No. 2 Diversion canal	190,900	712,100	903,000				71,100	159,500	230,600	119,800	552,600	672,400
A-5	Main dam	801,900	3,210,100	5,012,000	256,200	406,800	663,000	1,300,700	2,048,300	3,349,000	245,000	755,000	1,000,000
A-6	Intake	882,800	1,217,200	2,100,000	463,000	422,000	885,000	353,500	487,200	840,700	66,300	308,000	374,300
A-7	No. 1 Tunnel	2,697,500	4,652,500	7,350,000				2,247,500	3,880,500	6,128,000	450,000	772,000	1,222,000
A-8	Canal-I	1,081,600	3,918,400	5,000,000	151,000	340,000	491,000	353,200	793,400	1,146,600	577,400	2,785,000	3,362,400
A-9	No. 2 Tunnel	4,483,700	7,716,300	12,200,000	750,000	1,200,000	1,950,000	2,999,000	4,831,000	7,830,000	734,700	1,685,300	2,420,000
A-10	Canal-II	1,373,500	4,926,500	6,300,000	320,900	721,500	1,042,400	1,052,600	4,205,000	5,257,600	0	0	0
A-11	Tunnel	768,800	1,331,200	2,100,000				768,800	1,331,200	2,100,000	0	0	0
A-12	Canal-III	3,718,500	13,621,500	17,340,000	347,000	777,000	1,124,000	2,363,500	7,679,300	10,042,800	1,008,000	5,165,200	6,173,200
A-13	Reservoir	932,100	2,247,900	3,180,000				604,100	1,448,000	2,052,100	328,000	799,900	1,127,900
A-14	Penstock line	1,485,900	3,714,100	5,200,000	16,000	78,300	94,300	1,068,100	2,477,700	3,545,800	401,800	1,158,100	1,559,900
A-15	Powerhouse	3,852,600	6,297,400	10,150,000	872,100	1,706,900	2,579,000	2,924,100	4,082,900	7,007,000	56,400	507,600	564,000
	Sub-total (A)	23,867,250	54,662,950	78,530,200	3,176,200	5,652,500	8,828,700	16,689,550	34,421,550	51,111,100	4,001,500	14,588,900	18,590,400

Table 9-2 Annual Fund Requirement (3-2)

Unit: sucres

No.	Works	Construction Costs			1972			1973			1974		
		Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
B-1-1	Trashrack & stop log	280,000	50,000	330,000				84,000	10,000	94,000	196,000	40,000	236,000
B-1-2	Gates	597,000	358,000	955,000				328,400	179,000	507,400	268,600	179,000	447,600
B-1-3	Penstocks	13,819,000	10,986,000	24,805,000				6,054,100	4,119,800	10,173,900	7,764,900	6,866,200	14,631,100
B-1-4	Turbines	5,956,000	1,123,000	7,079,000				2,739,800	449,200	3,189,000	3,216,200	673,800	3,890,000
	Sub-total	20,652,000	12,517,000	33,169,000				9,206,300	4,758,000	13,964,300	11,445,700	7,759,000	19,204,700
B-1-5	Generator	5,579,000	1,022,000	6,601,000				2,566,300	408,800	2,975,100	3,012,700	613,200	3,625,900
B-1-6	Main transformer	1,348,000	266,000	1,614,000				134,800	0	134,800	1,213,200	266,000	1,479,200
B-1-7	Control board & cubicles	2,362,000	168,000	2,530,000				236,200	0	236,200	2,125,800	168,000	2,293,800
B-1-8	Switchyard equipment	883,000	216,000	1,099,000				88,300	0	88,300	794,700	216,000	1,010,700
B-1-9	Miscellaneous equipment	819,000	190,000	1,009,000				81,900	0	81,900	737,100	190,000	927,100
	Sub-total	10,991,000	1,862,000	12,853,000				3,107,500	408,800	3,516,300	7,883,500	1,453,200	9,336,700
B-1-10	Crane	311,000	90,000	401,000				311,000	90,000	401,000	0	0	0
	Total	31,954,000	14,469,000	46,423,000	0	0	0	12,624,800	5,256,800	17,881,600	19,329,200	9,212,200	28,541,400
	Grand Total (A–B)	55,821,250	69,131,950	124,953,200	3,176,200	5,652,500	8,828,700	29,314,350	39,678,350	68,992,700	23,330,700	23,801,100	47,131,800

Table 9-2 Annual Fund Requirement (3-3)

Unit: sucres

No.	Works	Construction Costs			1972			1973			1974		
		Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total	Foreign	Local	Total
C-1	Preliminary works												
C-1-1	Access road – (1)	240,000	1,440,000	1,680,000	240,000	1,440,000	1,680,000						
C-1-2	Access road – (2)	1,350,000	7,900,000	9,250,000	1,350,000	7,900,000	9,250,000						
C-1-3	Base camp	1,350,000	150,000	1,500,000	1,350,000	150,000	1,500,000						
C-1-4	Distribution line for construction	350,000	150,000	500,000	350,000	150,000	500,000						
	Sub-total	3,290,000	9,640,000	12,930,000	3,290,000	9,640,000	12,930,000						
D	Studies & Investigation	0	1,500,000	1,500,000	0	1,500,000	1,500,000						
E	Indemnities	0	1,600,000	1,600,000	0	1,600,000	1,600,000						
F	EEQ's Administration	0	2,400,000	2,400,000	0	576,000	576,000	0	1,152,000	1,152,000	0	672,000	672,000
G	Engineering & Supervisory	1,900,000	827,000	2,727,000	456,000	198,500	654,500	912,000	396,900	1,308,900	532,000	231,600	763,600
	Total (A–G)	61,011,250	85,098,950	146,110,200	6,922,200	19,167,000	26,089,200	30,226,350	41,227,250	71,453,600	23,862,700	24,704,700	48,567,400
H	Contingency	4,494,850	7,816,350	12,311,200	510,900	1,760,500	2,271,400	2,230,700	3,786,800	6,017,500	1,753,250	2,269,050	4,022,300
	Total (A- H)	65,514,650	92,915,450	158,430,100	7,433,100	20,927,500	28,360,600	32,457,050	45,014,050	77,471,100	25,615,950	26,973,750	52,589,700
I	Interest during construction	4,153,900	9,324,700	13,478,600	449,900	1,916,700	2,366,600	1,994,000	4,314,400	6,308,400	1,710,000	3,093,600	4,803,600
	Total	69,660,000	102,240,000	171,900,000	7,883,000	22,844,200	30,727,200	34,451,050	49,328,450	83,779,500	27,325,950	30,067,350	57,393,300
	Transmission line	2,524,000	2,476,000	5,000,000	252,000	0	252,000	0	0	0	2,272,000	2,476,000	4,748,000
	Grand total	72,184,000	104,716,000	176,900,000	8,135,000	22,844,200	30,979,200	34,451,050	49,328,450	83,779,500	29,597,950	32,543,350	62,141,300

9.3 CONSTRUCTION COST OF JOINT FACILITIES

Cost allocation of La Mica Project will be made to city water service and the joint facilities include structures to conduct water from Rio Chico, Qda. Bañio Urria Pungo to La Mica Reservoir, La Mica Dam, the intake, waterways (tunnels and open canals) and other related equipment. The costs for the above were extracted from Table 9-1 totalling as follows.

Local currency:	s/. 65,805,000	
Foreign currency:	s/. 27,165,000	(US$1,494,000)
Total cost of joint facilities:	s/. 92,970,000	(US$5,114,000)

The above amount is 69% of the total construction cost of s/. 176,900,000.

The breakdown of each item and expenses is shown in Table 9-3. The required maximum flow for water supply is 3 m^3/sec. and a peak discharge of 4.5 m^3/sec. is designed for power generation. Therefore, the construction cost for the waterway has increased to accommodate the additional 1.5 m^3/sec. of water, which is the difference between water supply and power generation. Alternative construction cost for water supply was calculated in consideration of the following situation.

For alternative construction costs, the costs for No. 1 canal, No. 2 canal and No. 3 canal are substracted from the previously mentioned costs for joint facilities. As described in Chapter 5, La Mica Dam requires a reservoir with a storage capacity of 21,000,000 m^3 either for power generation or for water supply. So, the alternative costs will be the same. As for the construction of tunnels, a tunnel of 4.5 m^3/sec. will have a dimension of 2.00 m high and 1.80 m wide which is the minimum cross section than can be constructed. Therefore, there will be no difference in the construction cost for the flow of 3 m^3/sec. The alternative costs were estimated as follows taking the above into consideration.

Domestic currency:	s/. 63,301,000	
Foreign currency:	s/. 26,129,000	(US$1,437,000)
Construction cost of alternative works for water supply:	s/. 89,430,000	(US$4,919,000)

Table 9-3 Construction Costs of Joint Facilities

Unit: sucres

No.		Construction Cost	Foreign Currency	Local Currency
A-1	No. 1 divertion dam	526,200	211,250	314,950
A-2	No. 2 divertion canal	456,000	96,800	359,200
A-3	No. 2 divertion dam	713,000	289,400	423,600
A-4	No. 2 divertion canal	903,000	190,900	712,100
A-5	Main dam	5,012,000	1,801,900	3,210,100
A-6	Intake	2,100,000	882,800	1,217,200
A-7	No. 1 Tunnel	7,350,000	2,697,500	4,652,500
A-8	No. 1 Canal	5,000,000	1,081,600	3,918,400
A-9	No. 2 Tunnel	12,200,000	4,493,700	7,716,300
A-10	No. 2 Canal	6,300,000	1,373,500	4,926,500
A-11	No. 3 Tunnel	2,100,000	768,800	1,331,200
A-12	No. 3 Canal	17,340,000	3,718,500	13,621,500
	Sub-total	60,000,200	17,596,650	42,403,550
B-1	Hydraulic equipment	330,000	280,000	50,000
C-1	Pleriminary works	12,455,000	3,169,000	9,286,000
D	Studies & investigation	1,140,000	0	1,140,000
E	Land adquisition	1,220,000	0	1,220,000
F	EEQ's Administration	1,820,000	0	1,820,000
G	Engineer & supervisory	2,073,000	1,440,000	629,000
	Sub-total	19,038,000	4,893,000	14,145,000
H	Contingency	6,653,800	2,432,350	4,221,450
I	Interest during construction	7,278,000	2,243,000	5,035,000
	Sub-total	13,931,800	4,675,350	9,256,450
	Grand total	92,970,000	27,165,000	65,805,000

Table 9-4 Construction Cost of Alternative Facilities for Water Supply

Unit: sucres

No.	Item	Construction Cost	Remarks
A-1	No. 1 divertion dam	526,200	
A-2	No. 1 divertion canal	456,000	
A-3	No. 2 divertion dam	713,000	
A-4	No. 2 divertion canal	903,000	
A-5	Main dam	5,012,000	
A-6	Intake	2,100,000	
A-7	No. 1 Tunnel	7,350,000	
A-8	No. 1 Canal	4,489,000	5,000,000 x 904/1.007 Q = 3 m^3/sec.
A-9	No. 2 Tunnel	12,200,000	
A-10	No. 2 Canal	5,656,000	6,300,000 x 904/1.007 Q = 3 m^3/sec.
A-11	No. 3 Tunnel	2,100,000	
A-12	No. 3 Canal	15,567,000	17,340,000 x 904/1.007 Q = 3 m^3/sec.
A-13	Cascade	500,000	
	Sub-total	57,572,200	
B-1	Hydraulic equipment	330,000	
C-1	Preliminary works	11,951,000	12,455,000 x 60,000,200/57,572,200
D	Studies & investigation	1,094,000	1,140,000 "
E	Land acquisition	1,171,000	1,220,000 "
F	Administration	1,746,000	1,820,000 "
G	Engineer & supervisory	1,996,000	2,080,000 "
	Sub-total	18,288,000	
H	Contingency	6,403,800	6,640,000 x 75,860/78,748
I	Interest during const.	7,166,000	7,439,000 "
	Grand Total	89,430,000	

9.4 COST ALLOCATION TO WATER SUPPLY WORKS

A. In case water is diverted for city water supply 10 years after completion of La Mica Project (1984):

A-1 Optimum investment

(Power generation)

Current price per KWh in 1984:	1,123,850 MWh
Energy cost at generating end:	s/. 0.18/KWh
Optimum investment:	1,123,850 MWh x s/. 0.18 = s/. 202,293,000

(Water supply)

The alternate cost for 3 m^3/sec. intake should be the optimum investment.

Alternate construction cost: s/. 89,430,000 (breakdown in Table 9-4)

A-2 Separable costs

(Power generation)

Joint cost – alternate cost = s/. 91,236,300 – s/. 87,755,400
= s/. 4,480,900 (Residual value in 1984)

(Water supply) None

A-3 Cost of specific facilities

Total construction cost – joint cost = s/. 171,900,000 – s/. 92,970,000
= s/. 78,930,000

Residual value in 1984: s/. 77,467,900

A-4 Allocation of cost to joint facilities

This cost should be the remaining price of the joint facilities in 1984.

s/. 91,236,300

A-5 Cost allocation

	Item	Power generation	Water supply	Total
a.	Alternative	s/. 90,000,000	s/.89,430,000	
b.	Optimum investment	s/.202,293,000	–	
c.	Smaller one of a & b	s/. 90,000,000	s/.89,430,000	
d.	Specific cost	s/. 77,467,900	–	
e.	(c) – (d)	s/. 12,532,100	s/.89,430,000	s/.101,962,100
f.	Separable cost	s/. 3,480,900	s/. 0	s/. 3,480,900
g.	Remaining benefits (e–f)	s/. 9,151,200	s/.89,430,000	s/. 98,481,000
h.	Percentage of above item	9.2%	90.8%	100%
i.	Balance allocated to joint facilities	s/. 8,074,000	s/ 79,681,000	s/. 87,755,000 (= s/.91,236,300 - 3,480,900)
j.	Allocated cost	s/. 11,555,300	s/.79,681,000	s/. 91,236,300
k.	Percentage of allocated cost	12.7%	87.3%	100%

The allocation of s/. 79,681,900 for water supply is in the 1984 and this cost converted into present worth as of 1974 is as follows.

$$\text{s/. } 79{,}681{,}000 \times 1/(1 + 0.09)^{10}$$
$$= \text{s/. } 79{,}681{,}000 \times 0.4224$$
$$= \text{s/. } 33{,}660{,}000$$

The above amount should be borne by water supply. Therefore, the cost for power generation will be as follows.

(total construction cost) - (allocation to water supply)

$$= \text{s/.}176{,}900{,}000 - \text{s/. } 33{,}660{,}000$$
$$= \text{s/.}143{,}240{,}000$$

The annual average energy output during the serviciable life for case of A is 97,580,000 MWh. The construction cost per KWh is:

s/. 143,240,000/97,580,000 KWh = s/. 1.468/KWh

B. In case water is diverted for city water 25 years after completion of La Mica Project (1999).

B-1 Optimum investment and alternate cost

(Power generation)

Current price per KWh in 1999: 1,011,240 MWh

Energy cost at generating end: s/. 0.18/KWh

Optimum investment: 1,011,240 MWh x s/. 0.18 = s/. 182,023,200

Alternate construction cost: 18,000 KW x s/. 5,000/KW = s/. 90,000,000

(Water supply)

The alternate cost for 3 m^3/sec. intake should be the optimum investment.

Alternate construction cost: s/. 89,430,000

B-2 Separable cost

(Power generation)

Residual value of joint facilities - Residual value of alternate for water supply

= s/. 83,307,800 - s/. 80,129,900

= s/. 3,177,900

Note: Residual value in 1999.

(Water supply) None

B-3 Cost of specific facilities

Total construction cost - joint costs

= s/.171,900,000 - s/. 92,970,000

= s/. 78,930,000

Residual value in 1999 according to Table 9-6: s/. 70,735,400

B-4 Allocation of cost to joint facilities

Residual value of joint facilities in 1999: s/. 83,307,800

B-5 Cost allocation

	Item	Power generation	Water supply	Total
a.	Alternative	s/. 90,000,000	s/. 89,430,000	
b.	Optimum investment	s/.182,023,200	–	
c.	Smaller one of a & b	s/. 90,000,000	s/. 89,430,000	
d.	Specific cost	s/. 70,735,400	–	
e.	(c) - (d)	s/. 19,264,600	s/. 89,430,000	s/.108,694,600
f.	Separable cost	s/. 3,177,900	–	s/. 3,177,900
g.	Remaining benefits (e–f)	s/. 16,086,700	s/. 89,430,000	s/.105,516,700
h.	Percentage of above item	15.2%	84.8%	100%
i.	Balance allocated to joint facilities	s/. 12,179,700	s/. 67,950,200	s/. 80,129,900 (= s/.83,307,800 - 3,178,900)
j.	Allocated cost	s/. 15,357,600	s/. 67,950,200	s/. 83,307,800
k.	Percentage of allocated cost	18.4%	81.6%	100%

The allocation to water supply of s/. 67,950,200 is in the year 1999 and this value converted into present worth as at 1974 is as follows.

$$= \text{s/. } 67{,}950{,}200 \times 1/(1 + 0.09)^{25}$$

$$= \text{s/. } 67{,}950{,}200 \times 0.11597$$

$$= \text{s/. } 7{,}900{,}000$$

In 1984, the cost to be shared by water supply will be only s/. 7,880,200. Thus the construction cost for power generation will be as follows.

(total construction cost) - (allocation to water supply)

$$= \text{s/.}176{,}900{,}000 - \text{s/. } 7{,}900{,}000$$

$$= \text{s/.}169{,}000{,}000$$

In B case, the annual average energy output during the serviceable life is 106,560,000 MWh. The construction cost per KWh is:

s/.169,000,000/106,560,000 KWh = s/. 1.586/KWh

9.5 ALLOCATION ACCORDING TO AGREEMENT BETWEEN "EEQ" S.A. AND EMPRESA DE AGUA POTABLE

Shown below is the allocation of joints costs according to the documents exchanged between "EEQ" S.A. and Empresa de Agua Potable in January, 1968.

Ie = Initial investment of joint cost for 4.5 m^3/sec. waterway = s/. 92,970,000

Ia = Initial investment of alternate cost for water supply for 3.0 m^3/sec. waterway = s/. 89,422,200

The serviceable life is taken as 45 years.

Annual depreciation charge = $\frac{Ia}{45}$ = s/.1,987,200/year.

(1) In case water supply is started in 1984:

Allocation to water supply in 1984 is:

$\frac{35}{45}$ x s/. 89,422,200 = s/. 69,552,000

Present worth in 1974 = s/. 69,552,000 x 0.4224
= s/. 29,378,800

(2) In case water supply is started in 1999:

Allocation to water supply in 1999 is:

$\frac{20}{45}$ x s/. 89,422,200 = s/. 39,744,000

Present worth in 1974 = s/. 39,744,000 x 0.11597
= s/. 4,609,000

Table 9-5 Present Worth in 1983 (40 years from 1983 to 2023)

	Year	Energy MWh	Present worth factor	Present worth MWh		Year	Energy MWh	Present worth factor	Present worth MWh
1	1984	113,090	0.9174	103,750	22	2005	93,810	0.1502	14,090
2	1985	112,540	0.8417	94,720	23	2006	92,700	0.1378	12,770
3	1986	112,070	0.7722	86,540	24	2007	91,490	0.1264	11,560
4	1987	111,430	0.7084	78,940	25	2008	90,100	0.1160	10,450
5	1988	110,780	0.6499	72,000	26	2009	88,250	0.1064	9,390
6	1989	110,030	0.5963	65,610	27	2010	85,750	0.09761	8,370
7	1990	109,290	0.5470	59,780	28	2011	81,110	0.08955	7,260
8	1991	108,460	0.5019	54,440	29	2012	74,720	0.08215	6,140
9	1992	107,620	0.4604	49,550	30	2013	74,720	0.07537	5,630
10	1993	106,700	0.4224	45,070	31	2014	74,720	0.06915	5,170
11	1994	105,770	0.3875	40,990	32	2015	74,720	0.06344	4,740
12	1995	104,840	0.3555	37,270	33	2016	74,720	0.05820	4,350
13	1996	103,820	0.3262	33,870	34	2017	74,720	0.05339	3,990
14	1997	102,800	0.2992	30,760	35	2018	74,720	0.04899	3,660
15	1998	101,780	0.2745	27,940	36	2019	74,720	0.04494	3,360
16	1999	100,670	0.2519	25,360	37	2020	74,720	0.04123	3,080
17	2000	99,560	0.2311	23,000	38	2021	74,720	0.03783	2,830
18	2001	98,350	0.2120	20,850	39	2022	74,720	0.03470	2,590
19	2002	97,240	0.1945	18,910	40	2023	74,720	0.03184	2,380
20	2003	96,130	0.1784	17,150					
21	2004	94,920	0.1637	15,540	Total				1,123,850

Table 9-6 Present Worth in 1999 (25 years from 1999 to 2023)

	Year	Energy (MWh)	Present Worth Factor	Present Worth (MWh)
1	1999	116,630	0.9174	107,000
2	2000	114,880	0.8417	96,690
3	2001	113,140	0.7722	87,370
4	2002	111,390	0.7084	78,910
5	2003	109,650	0.6499	71,260
6	2004	107,900	0.5963	64,340
7	2005	106,150	0.5470	58,060
8	2006	104,410	0.5019	52,400
9	2007	102,660	0.4604	47,260
10	2008	100,910	0.4224	42,620
11	2009	99,170	0.3875	38,430
12	2010	97,420	0.3555	34,630
13	2011	95,670	0.3262	31,210
14	2012	93,930	0.2992	28,100
15	2013	92,180	0.2745	25,300
16	2014	90,430	0.2519	22,780
17	2015	88,690	0.2311	20,500
18	2016	86,940	0.2120	18,430
19	2017	85,200	0.1945	16,570
20	2018	83,450	0.1784	14,890
21	2019	81,700	0.1637	13,370
22	2020	79,960	0.1502	12,010
23	2021	78,210	0.1378	10,780
24	2022	76,460	0.1264	9,660
25	2023	74,720	0.1160	8,670
	Total			1,011,240

Table 9-7 Residual Value of Joint Facilities

Joint facilities: s/. 92,969,200

Unit: Mil sucres

	Year	Redemption of Principal Rate = 0.091227	Interest Rate = 0.09	Redemption Principal	Outstanding Principal
1	1974	8,480	8,367.2	114.1	92,855.1
2	1975	"	8,357.0	124.3	92,730.8
3	1976	"	8,345.8	135.5	92,595.3
4	1977	"	8,333.6	147.7	92,447.6
5	1978	"	8,320.3	161.0	92,286.6
6	1979	"	8,305.8	175.5	92,111.1
7	1980	"	8,290.0	191.3	91,919.8
8	1981	"	8,272.8	208.5	91,711.3
9	1982	"	8,254.0	227.3	91,484.0
10	1983	"	8,233.5	247.7	91,236.3
11	1984	"	8,211.3	270.0	90,966.3
12	1985	"	8,187.0	294.3	90,672.0
13	1986	"	8,160.5	320.8	90,351.2
14	1987	"	8,131.6	349.7	90,001.5
15	1988	"	8,100.1	381.2	89,620.3
16	1989	"	8,065.8	415.5	89,204.8
17	1990	"	8,028.4	452.9	88,751.9
18	1991	"	7,987.7	493.6	88,258.3
19	1992	"	7,943.2	538.1	87,720.2
20	1993	"	7,894.8	586.5	87,133.7
21	1994	"	7,842.0	639.3	86,494.4
22	1995	"	7,784.5	696.8	85,797.6
23	1996	"	7,721.8	759.5	85,038.1
24	1997	"	7,653.4	827.9	84,210.2
25	1998	"	7,578.9	902.4	83,307.8

Table 9-8 Residual Value of Power Facilities

Total construction cost – cost of joint facilities = s/. 78,939,500

Unit: Mil sucres

	Year	Redemption of Principal Rate = 0.091227	Interest Rate = 0.09	Redeemed Principal	Outstanding Princiapl
1	1974	7,201.4	7,095.8	105.6	78,842.6
2	1975	"	7,086.3	115.1	78,737.1
3	1976	"	7,076.0	125.4	78,622.0
4	1977	"	7,064.7	136.7	78,496.5
5	1978	"	7,052.4	149.0	78,360.0
6	1979	"	7,039.0	162.4	78,210.8
7	1980	"	7,024.4	177.1	78,048.3
8	1981	"	7,008.4	193.0	77,871.3
9	1982	"	6,991.0	210.4	77,678.3
10	1983	"	6,972.1	229.3	77,467.9
11	1984	"	6,951.5	249.9	77,238.6
12	1985	"	6,929.0	272.4	76,988.7
13	1986	"	6,904.5	297.0	76,716.2
14	1987	"	6,877.7	323.7	76,419.3
15	1988	"	6,848.6	352.8	76,095.6
16	1989	"	6,816.9	384.6	75,742.8
17	1990	"	6,782.2	419.2	75,358.2
18	1991	"	6,744.5	456.9	74,939.1
19	1992	"	6,703.4	498.0	74,482.2
20	1993	"	6,658.6	542.8	73,984.2
21	1994	"	6,609.7	591.7	73,441.3
22	1995	"	6,556.5	644.9	72,849.6
23	1996	"	6,498.4	703.0	72,204.7
24	1997	"	6,435.2	766.3	71,501.7
25	1998	"	6,366.2	835.2	70,735.4

Table 9-9 Residual Value of Alternative Structure for Water Supply

Construction costs: s/. 89,422,200

Unit: Mil sucres

	Year	Redemption of Principal Rate = 0.091227	Interest Rate = 0.09	Redeemed Principal	Outstanding Principal
1	1974	8,157.7	8,048.0	109.7	89,312.5
2	1975	"	8,038.1	119.6	89,192.9
3	1976	"	8,027.4	130.3	89,062.6
4	1977	"	8,015.6	142.1	88,920.5
5	1978	"	8,002.8	154.9	88,765.6
6	1979	"	7,988.9	168.8	88,596.8
7	1980	"	7,973.7	184.0	88,412.8
8	1981	"	7,957.2	200.5	88,212.3
9	1982	"	7,939.1	218.6	87,993.7
10	1983	"	7,919.4	238.3	87,755.4
11	1984	"	7,898.0	259.7	87,495.7
12	1985	"	7,874.6	283.1	87,212.6
13	1986	"	7,849.1	308.6	86,904.0
14	1987	"	7,821.4	336.3	86,567.7
15	1988	"	7,791.1	366.6	86,201.1
16	1989	"	7,758.1	399.6	85,801.5
17	1990	"	7,722.1	435.6	85,365.9
18	1991	"	7,682.9	474.8	84,891.1
19	1992	"	7,640.2	517.5	84,373.6
20	1993	"	7,593.6	564.1	83,809.5
21	1994	"	7,542.9	614.8	83,194.7
22	1995	"	7,487.5	670.2	82,524.5
23	1996	"	7,427.2	730.5	81,794.0
24	1997	"	7,361.5	796.2	80,997.8
25	1998	"	7,289.8	867.9	80,129.9

9.6 BREAKDOWN OF CIVIL WORKS

On the basis of the conditions described in 9.1, the quantity of work was estimated from Drawings 1–18. The unit cost for each item of works was assumed and the construction cost was estimated as shown in [A-1]– [A-17].

[A-1] No. 1 Divertion dam

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
	Open-cut excavation (common)	900	m^3	8	26	34	7,200	396.0	23,400	30,600
	Back-fill	30	m^3	5	10	15	150	8.3	300	450
	Rubble masonry in river bed t = 0.5 m	80	m^2	20	100	120	1,600	88.0	8,000	9,600
	Concrete in structure	450	m^3	300	500	800	135,000	7,425.7	225,000	360,000
	Reinforcing steel bar	20	ton	2,200	1,800	4,000	44,000	2,420.2	36,000	80,000
	Metal works	2	ton	8,000	5,000	13,000	16,000	880.1	10,000	26,000
	Illumination system	3	post	2,100	1,000	3,100	6,300	346.5	3,000	9,300
	Other works	-	lump-sum				1,000	55.0	9,250	10,250
Total							211,250	11,619.8	314,950	526,200

[A-2] No. 1 Diversion canal

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation (common)	5,800	m^3	2	8	10	11,600	638.1	46,400	58,000
2	Embankment & backfill	5,900	m^3	6	10	16	35,400	1,947.2	59,000	94,400
3	Rock facing	2,250	m^2	20	100	120	45,000	2,475.2	225,000	270,000
4	Rubble masonry	200	m^2	20	80	100	4,000	220.0	16,000	20,000
5	Drain system	350	m	0	15	15	0	0	5,250	5,250
6	Other works	-	lump-sum				800	44.0	7,550	8,350
Total							96,800	5,324.5	359,200	456,000

[A-3] No. 2 Diversion dam

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation (common)	700	m^3	8	26	34	5,600	308.0	18,200	23,800
2	Back-fill	40	m^3	5	10	15	200	11.0	400	600
3	Rubble masonry in river bed t=0.5m	140	m^2	20	100	120	2,800	154.0	14,000	16,800
4	Concrete in structure	620	m^3	300	500	800	186,000	10,231.0	310,000	496,000
5	Reinforcing steel bar	25	ton	2,200	1,800	4,000	55,000	3,025.3	45,000	100,000
6	Metal works	4	ton	8,000	5,000	13,000	32,000	1,760.2	20,000	52,000
7	Illumination system	3	post	2,100	1,000	3,100	6,300	346.5	3,000	9,300
8	Other works	-	lump-sum				1,500	82.5	13,000	14,500
Total							289,400	15,918.5	423,600	713,000

[A-4] No. 2 Diversion canal

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation (common)	11,700	m^3	2	8	10	23,400	1,287.1	93,600	117,000
2	Embankment & backfill	11,900	m^3	6	10	16	71,400	3,927.4	119,000	190,400
3	Rock facing	4,410	m^2	20	100	120	88,200	4,851.5	441,000	529,200
4	Rubble masonry	300	m^2	20	80	100	6,000	330.0	24,000	30,000
5	Drain system	700	m	0	25	25	0	0	17,500	17,500
6	Other works	-	lump-sum				1,900	104.5	17,000	18,900
Total							190,900	10,500.5	712,100	903,000

[A-5] Main dam

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation (common)	39,000	m^3	5	7	12	195,000	10,726.1	273,000	468,000
2	Open-cut excavation (rock)	6,300	m^3	15	25	40	94,500	5,198.0	157,500	252,000
3	Embankment (imperrious zone)	16,300	m^3	10	15	25	163,000	8,965.9	244,500	407,500
4	Embankment (earth zone) including drain zone	34,500	m^3	15	25	40	517,500	28,465.3	862,500	1,380,000
5	Rock facing (thickness: 50 cm)	3,900	m^3	30	70	100	117,000	6,435.6	273,000	390,000
6	Concrete of structure in spillway	1,400	m^3	300	500	800	420,000	23,102.3	700,000	1,120,000
7	Concrete of diversion canal including plug	300	m^3	300	500	800	90,000	4,950.5	150,000	240,000
8	Excavation of coffer dam	1,800	m^3	4	16	20	7,200	396.0	28,800	36,000
9	Embankment of coffer dam	1,300	m^3	10	15	25	13,000	715.1	19,500	32,500
10	Reinforcement steel bar	26	ton	2,200	1,800	4,000	57,200	3,146.3	46,800	104,000
11	Handrail of steel pipe	15	ton	8,000	5,000	13,000	40,000	2,200.2	25,000	65,000
12	Illumination system	20	post	2,100	1,000	3,100	42,000	2,310.2	20,000	62,000
13	Other works	-	lump-sum				45,500	2,502.8	409,500	455,000
Total							1,801,900	99,114.3	3,210,100	5,012,000

[A-6] Intake

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Excavation (common)	6,500	m^3	6	14	20	39,000	2,145.2	91,000	130,000
2	Excavation (rock)	3,000	m^3	15	25	40	45,000	2,475.2	75,000	120,000
3	Excavation in vertical shaft	100	m^3	250	400	650	25,000	1,375.1	40,000	65,000
4	Excavation in tunnel	200	m^3	250	370	600	46,000	2,530.3	74,000	120,000
5	Concrete of structure	700	m^3	300	500	800	210,000	11,551.2	350,000	560,000
6	Concrete of lining in vertical shaft Concrete of lining in tunnel	180	m^3	300	480	780	54,000	2,970.3	86,400	140,400
7	Reinforcement steel bar	35	ton	2,200	1,800	4,000	77,000	4,235.4	63,000	140,000
8	Illumination system	6	post	2,100	1,000	3,100	12,600	693.1	6,000	18,600
9	Metal works	4	ton	8,000	5,000	13,000	32,000	1,760.2	20,000	52,000
10	Embankment of coffer dam	2,400	m^3	10	20	30	24,000	1,320.1	48,000	72,000
11	Sheet pile		ton	4,500	3,000	7,500	300,000	16,501.7	200,000	500,000
12	Other works		lump-sum				18,200	1,001.1	163,800	182,000
Total							882,800	48,558.9	1,217,200	2,100,000

[A-7] No. 1 Tunnel

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Excavation	9,800	m^3	230	370	600	2,254,000	123,982.4	3,626,000	5,880,000
2	Concrete lining	1,360	m^3	300	520	820	408,000	22,442.2	707,200	1,115,200
3	Other works	-	lump-sum				35,500	1,952.7	319,300	354,800
Total							2,697,500	148,377.3	4,652,500	7,350,000

[A-8] No. 1 Canal

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation (common)	62,800	m^3	2	8	10	125,600	6,908.7	502,400	628,000
2	Embankment & backfill	63,100	m^3	6	10	16	378,600	20,825.1	631,000	1,009,600
3	Rock facing	23,770	m^2	20	100	120	475,400	26,149.6	2,377,000	2,852,400
4	Concrete in culvert	280	m^3	300	550	850	84,000	4,620.5	154,000	238,000
5	Drain system	3,662	m	0	25	25	0	0	92,000	92,000
6	Other works	-	lump-sum				18,000	990.1	162,000	180,000
Total							1,081,600	59,494.0	3,918,400	5,000,000

[A-9] No. 2 Tunnel

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Excavation	16,300	m^3	230	370	600	3,749,000	206,215.6	6,031,000	9,780,000
2	Concrete lining	2,260	m^3	300	520	820	678,000	37,293.7	1,175,000	1,853,000
3	Other works	-	lump-sum				56,700	3,118.8	510,300	567,000
Total							4,483,700	246,628.1	7,716,300	12,200,000

[A-10] No. 2 Canal

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation (common)	80,000	m^3	2	8	10	160,000	8,800.9	640,000	800,000
2	Embankment & backfill	80,300	m^3	6	10	16	481,800	26,501.7	803,000	1,284,800
3	Rock facing	30,290	m^2	20	100	120	605,800	33,322.3	3,029,000	3,634,800
4	Concrete in culvert	370	m^3	300	550	850	111,000	6,105.6	203,500	314,500
5	Drain system	4,660	m	0	25	25	0	0	116,500	116,500
6	Other works	-	lump-sum				14,900	819.6	134,500	149,400
Total							1,373,500	75,550.1	4,926,500	6,300,000

[A-11] No. 3 Tunnel

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Excavation	2,800	m^3	230	370	600	644,000	35,423.5	1,036,000	1,680,000
2	Concrete lining	380	m^3	300	520	820	114,000	6,270.6	197,600	311,600
3	Other works	-	lump-sum				10,800	594.1	97,600	108,400
Total							768,800	42,288.2	1,331,200	2,100,000

[A-12] No. 3 Canal

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation (common)	228,100	m^3	2	8	10	456,200	25,093.5	1,824,800	2,281,000
2	Embankment & backfill	232,000	m^3	6	10	16	1,392,000	76,567.7	2,320,000	3,712,000
3	Rock facing	86,230	m^2	20	100	120	1,724,600	94,862.5	8,623,000	10,347,600
4	Concrete in culvert	370	m^3	300	550	850	111,000	6,105.6	203,500	314,500
5	Drain system	13,535	m	0	25	25	0	0	338,400	338,400
6	Other works	-	lump-sum				34,700	1,908.7	311,800	346,500
Total							3,718,500	204,538.0	13,621,500	17,340,000

[A-13] Reservoir

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation	55,300	m^3	5	10	15	276,500	15,209.0	553,000	829,500
2	Embankment	4,900	m^3	10	15	25	49,000	2,695.3	73,500	122,500
3	Soil cement facing including cement	14,000	m^2	10	40	50	140,000	7,700.8	560,000	700,000
4	Concrete in structure	950	m^3	300	500	800	285,000	15,676.6	475,000	760,000
5	Subgrade	300	m^3	15	60	75	4,500	247.5	18,000	22,500
6	Rubble masonry	2,250	m^3	20	100	120	45,000	2,475.2	225,000	270,000
7	Reinforcement steel bar	37	ton	2,200	1,800	4,000	81,400	4,477.4	66,600	148,000
8	Illumination system	10	post	2,100	1,000	3,100	21,000	1,155.1	10,000	31,000
9	Other works	-	lump-sum				29,700	1,633.7	266,800	296,500
Total							932,100	51,270.6	2,247,900	3,180,000

[A-14] Penstock

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation	26,100	m^3	2	10	12	52,200	2,871.3	261,000	313,200
2	Concrete in structure	2,700	m^3	300	550	850	810,000	44,554.5	1,485,000	2,295,000
3	Rubble masonry	14,200	m^2	20	100	120	284,000	15,621.6	1,420,000	1,704,000
4	Reinforcement steel bar	30	ton	2,200	1,800	4,000	66,000	3,630.4	54,000	120,000
5	Illumination system	110	post	2,100	1,000	3,100	231,000	12,706.3	110,000	341,000
6	Other works	-	lump-sum				42,700	2,348.7	384,100	426,800
Total							1,485,900	81,732.8	3,714,100	5,200,000

[A-15] Powerhouse

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation	56,400	m^3	6	14	20	338,400	18,613.9	789,600	1,128,000
2	Back-fill	200	m^3	5	10	15	1,000	55.0	2,000	3,000
3	Concrete in super structure	2,600	m^3	360	600	960	936,000	51,485.1	1,560,000	2,496,000
4	Concrete in sub-structure	2,210	m^3	300	500	800	663,000	36,468.6	1,105,000	1,768,000
5	Rubble masonry	1,900	m^2	20	100	120	39,000	2,145.2	190,000	229,000
6	Stone paving	1,260	m^2	10	40	50	12,600	693.1	50,400	63,000
7	Reinforcement steel bar	136	ton	2,200	1,800	4,000	299,200	16,457.6	244,800	544,000
8	Architectural fecture	lot					750,000	41,254.1	1,150,000	1,900,000
9	Sanitary system	lot					50,000	2,750.3	20,000	70,000
10	Ventilation system	lot					175,000	9,626.0	75,000	250,000
11	Indoor lighting system	lot					215,000	11,826.2	95,000	310,000
12	Outdoor equipment	lot					85,000	4,675.5	340,000	425,000
13	Steel roof structure	lot					232,000	12,761.3	168,000	400,000
14	Other works	-	lump-sum				56,400	3,102.3	507,600	564,000
Total							3,852,600	211,914.2	6,297,400	10,150,000

2nd Stage Works

[A-16] No. 4 Canal

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation	83,000	m^3	2	8	10	166,000	9,130.9	664,000	830,000
2	Embankment & backfill	99,000	m^3	6	10	16	594,000	32,673.3	990,000	1,584,000
3	Rock facing	40,500	m^2	20	100	120	810,000	44,554.5	4,050,000	4,860,000
4	Concrete in structure	340	m^3	300	550	850	102,000	5,610.6	187,000	289,000
5	Drain system	1,200	m	10	30	40	12,000	660.1	36,000	48,000
6	Reinforcement steel bar	14	ton	2,200	1,800	4,000	30,800	1,694.2	25,200	56,000
7	Other works		lump-sum				43,500	2,392.7	391,500	435,000
Total							1,758,300	96,716.3	6,343,700	8,102,000

[A-17] Regulating reservoir for Agua potable

Unit: sucres

Item No.	Item of Works	Q'ty	Unit	Unit Price			Construction Cost			
				Foreign	Local	Total	Foreign		Local	Total
1	Open-cut excavation	167,000	m^3	5	10	15	835,000	45,929.6	1,670,000	2,505,000
2	Embankment & backfill	151,000	m^3	10	15	25	1,510,000	83,058.3	2,265,000	3,775,000
3	Rubble masonry	2,500	m^3	20	100	120	50,000	2,750.3	250,000	300,000
4	Soil cement facing	38,000	m^2	10	40	50	380,000	20,902.1	1,520,000	1,900,000
5	Concrete in structure	180	m^3	300	500	800	54,000	2,970.3	90,000	144,000
6	Reinforcement steel bar	7	ton	2,200	1,800	4,000	15,400	847.1	12,600	28,000
7	Drain system	-	lot				96,000	5,280.5	224,000	320,000
8	Illumination system	10	post	2,100	1,000	3,100	21,000	1,155.1	10,000	31,000
9	Metal works	4	ton	8,000	5,000	13,000	32,000	1,760.2	20,000	52,000
10	Other works	-	lump-sum				44,500	2,447.7	400,500	445,000
Total							3,037,900	167,101.2	6,462,100	9,500,000

[H] Contingency

Unit: sucres

Item No.	Percent	Total Cost	Foreign Currency	Local Currency
A	10	7,844,300	2,378,150	5,466,150
B	5	2,321,200	1,597,700	723,500
C	10	1,293,000	329,000	964,000
D	20	300,000	0	300,000
E	10	160,000	0	160,000
F	5	120,000	0	120,000
G	10	272,700	190,000	82,700
Total	8.4	12,311,200	4,494,850	7,816,350

Chapter X

ECONOMICAL EVALUATION OF LA MICA POWER PLANT

Chapter X

ECONOMICAL EVALUATION OF LA MICA POWER PLANT

10.1 EFFECTIVE SALEABLE POWER AND ENERGY

The effective power and effective energy output of La Mica Project have been described in Chapter 7 "POWER PRODUCTION". .

Assuming average transmission losses to Quito South Substation to be a maximum of 5.8 percent for power and a maximum of 3.7 percent for energy, the effective saleable power (KW) and effective energy (KWh) for case "A" and case "B" will be as shown in Table 10-1 and Table 10-2.

Table 10-1 Effective Saleable Energy for Case "A" at Sub-Station end

Year	Effective Saleable Power (KW)	Effective Saleable Energy (MWh)	Year	Effective Saleable Power (KW)	Effective Saleable Energy (MWh)
1974	23,100	55,460	2000	21,200	103,750
1976	28,500	77,530	2002	20,300	101,330
1978	28,500	89,620	2004	19,400	98,920
1980	28,500	123,740	2006	18,600	96,600
1982	28,500	123,740	2008	17,700	93,900
1984	28,100	117,850	2010	17,400	89,360
1986	27,200	116,790	2012	17,200	79,250
1988	26,400	115,440	⋮	⋮	⋮
1990	25,500	113,890			
1992	24,600	112,150			
1994	23,800	110,220	2023	17,200	79,250
1996	22,900	108,190	Annual average	22,170	97,580
1998	22,000	106,070			

Table 10-2 Effective Saleable Energy for Case "B" at Sub-Station end

Year	Effective Saleable Power (KW)	Effective Saleable Energy (MWh)	Year	Effective Saleable Power (KW)	Effective Saleable Energy (MWh)
1974	23,100	55,460	2006	24,500	108,800
1976	28,500	77,530	2008	23,500	105,160
1978	28,500	89,620	2010	22,500	101,520
1980	28,500	123,740	2012	21,500	97,880
⋮	⋮	⋮	2014	20,500	94,240
			2016	19,500	90,600
			2018	18,000	86,960
			2020	17,400	83,320
1998	28,500	123,740	2022	17,200	79,680
2000	27,500	119,720	2023	17,200	79,500
2002	26,500	116,070	Annual average	25,120	106,560
2004	25,500	112,440			

Note:
1. Case "A" – Diversion of water for water supply to begin from 1984.
2. Case "B" – Diversion of water for water supply to begin from 1999.
3. Annual average is the arithmetic mean of a 50 years life time.
4. Effective saleable power is the value in September.

10.2 ANNUAL COST

10.2.1 Annual Costs and Energy Cost for Case "A"

The total costs of construction after cost allocation to water supply are s/. 143,251,000 as described in Chapter 9 and the construction costs classified according to "EEQ" S.A.'s accounting system by the useful life of respective facilities are shown in Table 10-3-1. The total costs includes the main structures of La Mica Power Plant and the transmission line.

Table 10-3-1 Total Construction Costs of La Mica Project for Case "A"

Unit: sucres

Item	Life in years	Local currency	Foreign currency	Total costs
Lands and right of way	-	2,035,300	0	2,035,300
Access roads	50	12,072,100	2,286,500	14,358,600
Powerhouse	50	8,010,800	4,540,700	12,551,500
Camp & buildings	30	190,800	1,591,100	1,781,900
Civil works	50	32,484,400	12,485,400	44,969,800
Penstocks	32	4,724,700	1,751,300	6,476,000
Turbines and generators	35	2,728,600	13,595,200	16,323,800
Electrical equipment	33	908,300	5,704,400	6,612,700
Other equipment	29	14,494,200	17,320,700	31,814,900
Step-up substation	28	274,800	1,040,700	1,315,500
Total cost of power plant		77,924,000	60,316,000	138,240,000
Transmission line	35	2,476,000	2,524,000	5,000,000
Grand total		80,400,000	62,840,000	143,240,000

Note: Overhead costs are allocated proportionately to all items.

Applying the interest rates described in Chapter 9, that is, 6.5 percent for foreign currency and 10 percent for domestic currency, to obtain the capital recovery factor at 50 years, the result is as shown in Tables 10-3-2 to 10-3-4.

In this case the following conditions will be applied.

Replacement cost:

The present worth of replacement cost after the life of the facilities averaged for 50 years.

The residual value of the facilities is not considered.

Table 10-3-2 Replacement Cost

Unit: sucres

	Investment (1)	fs.p (%) (2)	fc.r (%) (3)	Annual cost (1)x(2)x(3)
At 28 years				
Local currency	274,800	0.0693	0.1009	1,920
Foreign currency	1,040,700	0.1715	0.0679	12,120
At 29 years				
Local currency	14,494,200	0.0630	0.1009	92,140
Foreign currency	17,320,700	0.1610	0.0679	189,350
At 30 years				
Local currency	190,800	0.0573	0.1009	1,100
Foreign currency	1,591,100	0.1512	0.0679	16,330
At 32 years				
Local currency	4,724,700	0.0473	0.1009	22,600
Foreign currency	1,751,300	0.1333	0.0679	15,850
At 33 years				
Local currency	908,300	0.0430	0.1009	3,950
Foreign currency	5,704,400	0.1252	0.0679	48,490
At 35 years				
Local currency	5,205,100	0.0356	0.1009	18,700
Foreign currency	16,118,700	0.1103	0.0679	120,720
Annual cost				544,000

Amortization of initial investment:

The total cost averaged for 50 years.

Table 10-3-3 Amortization of Initial Investment

Unit: sucres

	Investment (1)	fc.r (2)	Annual cost (1) x (2)
Local currency (i = 10%)	80,400,000	0.1009	8,113,000
Foreign currency (i = 6.5%)	62,840,000	0.0679	4,267,000
Annual cost			12,380,000

Note: fc.r = Capital recovery factor (%)
i = Annual interest

Table 10-3-4 Maintenance, Operation and Administrative Costs

Unit: sucres

Item			Annual costs
(1)	Personnel expense		
	Plant personnel	(12 persons x s/.48,000)	576,000
	Camp personnel	(10 persons x s/.32,000)	320,000
(2)	Other expenses		135,000
(3)	Maintenance of machinery and equipment		573,000
(4)	Maintenance of structures		296,000
	Sub-total		1,900,000
(5)	Administrative expenses		450,000
	Annual costs		2,350,000

Note:

(3) Estimated at 0.7% of the construction cost of the related items, that is, s/. 573,300. (See Table 10-3-1)

Access roads:	s/. 14,358,600
Penstock:	s/. 6,476,000
Turbine & generator:	s/. 16,323,800
Electrical equipment:	s/. 6,612,700
Other equipment:	s/. 31,814,900
Step-up substation:	s/. 1,315,500
Transmission line:	s/. 5,000,000
Total cost:	s/. 81,901,500
	x 0.007 = s/. 573,000

(4) Estimated at 0.5% of the construction cost of the related items, that is, s/. 296,600. (See Table 10-3-1)

Powerhouse:	s/. 12,551,500
Camp & buildings:	s/. 1,781,900
Civil works:	s/. 44,980,800
Total cost:	s/. 59,314,200
	x 0.005 = s/. 296,000

Other annual costs were estimated from actual costs in 1968 of existing power plants of "EEQ" S.A.

Therefore the total annual costs were estimated from Table 9-(4), 9-(5) and 9-(6).

Replacement costs:	s/. 544,000
Amortization of initial investment:	s/. 12,380,000
Maintenance and operation costs:	s/. 2,350,000
Total annual costs:	s/. 15,274,000

10.2.2 Annual Costs and Energy Cost for Case "B"

The total costs of construction after cost-allocation to water supply are s/.169,028,500 as described in Chapter 9 and the construction costs classified according to "EEQ" S.A.'s accounting system by useful life of respective facilities are shown in Table 10-3-5.

Table 10-3-5 Total Construction Costs of La Mica Project for Case "B"

Unit: sucres

Item	Life in years	Local currency	Foreign currency	Total costs
Land and right of way	-	2,035,300	0	2,035,300
Access road	50	12,072,100	2,286,500	14,358,600
Powerhouse	50	8,010,800	4,540,700	12,551,500
Camp & buildings	30	190,800	1,591,100	1,781,900
Civil works	50	51,084,400	19,645,400	70,729,800
Penstocks	32	4,724,700	1,751,300	6,476,000
Turbine and generator	35	2,728,600	13,595,200	16,323,800
Electrical equipment	33	908,300	5,704,400	6,612,700
Other equipment	29	14,494,200	17,320,700	31,814,900
Step-up substation	28	274,800	1,040,700	1,315,500
Total cost of power plant		96,524,000	67,476,000	164,000,000
Transmission line	35	2,476,000	2,524,000	5,000,000
Grand total		99,000,000	70,000,000	169,000,000

Applying the interest rates described in Chapter 9, that is, 6.5 percent for foreign currency and 10 percent for the domestic currency, the capital recovery factor at 50 years, was obtained as shown in Tables 10-3-6 to 10-3-8.

In this case the following conditions were applied.

Replacement cost:

The present worth of replacement cost after the life of the facilities is averaged out for 50 years. The residual value of the facilities is not considered in this case.

Table 10-3-6 Replacement Cost

Unit: sucres

	Investment (1)	fs.p (%) (2)	fc.r (%) (3)	Annual cost (1)x(2)x(3)
At 28 years				
Local currency	274,800	0.0693	0.1009	1,920
Foreign currency	1,040,700	0.1715	0.0679	12,120
At 29 years				
Local currency	14,494,200	0.0630	0.1009	92,140
Foreign currency	17,320,700	0.1610	0.0679	189,350
At 30 years				
Local currency	190,800	0.0573	0.1009	1,100
Foreign currency	1,591,100	0.1512	0.0679	16,330
At 32 years				
Local currency	4,724,700	0.0473	0.1009	22,600
Foreign currency	1,751,300	0.1333	0.0679	15,850
At 33 years				
Local currency	908,300	0.0430	0.1009	3,950
Foreign currency	5,704,400	0.1252	0.0679	48,490
At 35 years				
Local currency	5,205,100	0.0356	0.1009	18,700
Foreign currency	16,118,700	0.1103	0.0679	120,720
Annual cost				544,000

Amortization of initial investments:

The total cost averaged for 50 years.

Table 10-3-7 Amortization of Initial Investment

Unit: sucres

	Investment (1)	fc.r (2)	Annual cost (1) x (2)
Local currency (i = 10%)	99,000,000	0.1009	9,990,000
Foreign currency (i = 6.5%)	70,000,000	0.0679	4,760,000
Annual costs			14,750,000

Note: fc.r = Capital recovery factor (%)

i = Annual interest

Table 10-3-8 Maintenance, Operation and Administrative Costs

Unit: sucres

Item		Annual cost
(1)	Personnel expense	
	Plant personnel (12 persons x s/.48,000)	576,000
	Camp personnel (10 persons x s/.32,000)	320,000
(2)	Other expenses	135,000
(3)	Maintenance of machinery and equipment	573,000
(4)	Maintenance of structures	426,000
	Sub-total	2,030,000
(5)	Administrative expenses	450,000
	Annual costs	2,480,000

Note:

(3) Estimated at 0.7% of the construction cost of the related items, that is, s/. 573,300 (See Table 10-3-5).

Access road:	s/. 14,358,600
Penstock:	s/. 6,476,000
Turbine & generator:	s/. 16,323,800
Electrical equipment:	s/. 6,612,700
Other equipment:	s/. 31,814,900
Step-up substation:	s/. 1,315,500
Transmission line:	s/. 5,000,000
Total cost:	81,901,500 x 0.007 = s/. 573,000

(4) Estimated at 0.5% of the construction cost of the related items, that is, s/. 425,500 (See Table 10-3-5).

Powerhouse:	s/. 12,551,500
Camp & building:	s/. 1,781,900
Civil works:	s/. 70,758,300
Total cost:	85,091,700 x 0.005 = s/. 426,000

Other annual costs were estimated from actual costs in 1968 of existing power plants of "EEQ" S.A.

The total annual costs were estimated from Table 3-6, Table 3-7 and Table3-8.

Replacement cost:	s/. 544,000
Amortization of initia investment:	s/. 14,750,000
Maintenance and Operation costs:	s/. 2,480,000
Total annual costs:	s/. 17,774,000

10.2.3 Energy Cost of La Mica Power Plant

(1) Case - "A"

Dividing the total annual cost s/. 15,274,000 of La Mica Project obtained in 10.2.1 by the effective saleable energy of 97,580,000 KWh, the cost per KWh delivered at Quito South Substation is s/. 0.157 per KWh.
Dividing the total annual cost by the total construction cost, the annual cost ratio is 10.66 percent.

(2) Case - "B"

Dividing the total annual cost s/. 17,774,000 of La Mica Project obtained in 10.2.2 by the effective saleable energy of 106,560,000 KWh, the cost per KWh delivered at Quito South Substation is s/. 0.167 per KWh.
Dividing the total annual cost by the total construction cost, the annual cost ratio is 10.51 percent.

10.3 COMPARISON WITH ALTERNATIVE SOURCE

10.3.1 Type of Plant Considered

As an alternative plan to La Mica Project, the following types of 30,000 KWthermal power plants were assumed for construction in the vicinity of Quito, and the most advantageous alternative was selected for comparison purposes.

Note: The 30,000KW capacity of the alternative is to accommodate the 18,000 KW of La Mica power plant and increment in output of 22,000 KW due to downstream benefits at the Guangopolo, Cumbaya and Nayon in September.

Table 10-4 Comparison of Types of Thermal Power

Type	Installed capacity MW x unit	Construction cost sucres	Efficiency (BTU/KWh)	Years of depreciation	Unit cost of energy sucres/KWh
Diesel power	5 MW x 6 =30,000KW	s/. 102,000,000	11,500	15	0.373
Steam power	15 MW x 2 =30,000KW	s/. 120,000,000	14,000	20	0.412
Gas turbine	15 MW x 2 =30,000KW	s/. 93,000,000	17,000	10	0.513

Note:

1) BTU/Gallon of fuel = 148,000

2) Efficiency includes influence of high elevation at Quito (El. 2,800 m)

3) Annual energy production = 97,580,000 KWh/year

4) Utilization factor = (Average output) 11,140 kW/30,000 KW = 37.1%

5) Construction cost per KW:

Diesel power : s/. 3,400/KW

Steam power : s/. 4,000/KW(includes cooling plant)

Gas turbine : s/. 3,100/KW

Table 10-5 Construction Costs of Alternative Thermal Plants (1)

	Diesel power 5 MW x 6 units	Steam power 15 MW x 2 units	Gas turbine 15 MW x 2 units
Initial Investment Foreign currency Local currency	S/. 102,000.000 C_1 = 86,700,000 C_2 = 15,300,000	S/. 120,000,000 102,000,000 18,000,000	S/. 93,000,000 79,000,000 14,000,000
(1) Amortization Cost	T = 15	T = 20	T = 10
Foreign i = 6.5%	C_1 x 0.068 = S/. 5,896,000	C_1 x 0.068 = S/. 6,936,000	C_1 x 0.068 = S/. 5,372,000
Local i = 10%	C_2 x 0.101 = 1,545,000	C_2 x 0.101 = 1,818,000	C_2 x0.101= 1,414,000
Total	7,441,000	8,754,000	6,786,000
(2) Replacement Cost			
	At 15	At 20	At 10
	C_1 x 0.389 x 0.106 = 3,575,000 C_2 x 0.239 x 0.131 = 479,000	C_1 x 0.284 x 0.091 = 2,636,000 C_2 x 0.149 x 0.117 = 314,000	C_1 x 0.533 x 0.139 = 5,853,000 C_2 x 0.385 x 0.163 = 879,000
	At 30	At 40	At 20
	C_1 x 0.151 x 0.076 = 995,000 C_2 x 0.057 x 0.106 = 92,000	C_1 x 0.080 x 0.071 = 579,000 C_2 x 0.022 x 0.102 = 40,000	C_1 x 0.284 x 0.091 = 2,042,000 C_2 x 0.149 x 0.117 = 244,000
	At 45		At 30
	C_1 x 0.059 x 0.069 = 353,000 C_2 x 0.014 x 0.101 = 22,000		C_1 x 151 x 0.076 = 907,000 C_2 x 0.057 x 0.106) = 85,000
			At 40
			C_1 x 0.080 x 0.070 = 442,000 C_2 x 0.022 x 0.102 = 31,000
Total	5,516,000	3,569,000	10,483,000

continued on next page

Table 10-5 Construction Costs of Alternative Thermal Plants (2)

	Diesel power 5 MW x 6 units	Steam power 15 MW x 2 units	Gas turbine 15 MW x 2 units
(3) Operating cost			
Energy production in KWh	97,580,000	97,580,000	97,580,000
Fuel consumption in gallon	KWh x $\frac{11,500}{148,000}$ = 7,582,000	KWh x $\frac{14,000}{148,000}$ = 9,230,000	KWh x $\frac{17,000}{148,000}$ = 11,208,000
Cost of fuel	s/. 2.25/gal.	s/. 2.25/gal.	s/. 2.25/gal.
Fuel expenses	s/. 17,060,000	s/. 20,768,000	s/. 25,218,000
Personnel expenses	35 p x s/. 4,500 = s/. 1,575,000	s/. 1,575,000	s/. 1,575,000
Other expenses	s/. 250,000	s/. 250,000	s/. 250,000
Maintenance expenses Cost x 0.076	s/. 1,632,000	s/. 1,920,000	s/. 1,860,000 Cost x 0.02
Oil and lubricant costs Fuel Ex. x 0.0115	s/. 1,962,000	s/. 2,388,000	s/. 2,900,000
Administration expenses	s/. 1,000,000	s/. 1,000,000	s/. 1,000,000
Total	23,479,000	27,901,000	32,803,000
Grand total (1) – (3)	s/. 36,395,000	s/. 40,224,000	s/. 50,072,000
Cost/KWh	s/. 0.373	s/. 0.412	s/. 0.513

The steam power plant of the alternative sources considered in Table 10-5 produces the least expensive energy, but the plant will require approximately 6,000 m^3/hours (1.67 m^3/sec) of cooling water, and it will be impossible to secure this amount of clean water at Quito. If a cooling tower is added, the cost will be higher than the other alternative.

Gas turbine power plants are being operated in some parts of South America, and in the future it is assumed this type will be generally used for peak power plant, but in areas of high altitude such as Quito which is 2,800 m above mean sea level, even jet gas turbines which are considered to have the least loss in output will lose 25 percent of its output, and it's estimated energy cost of s/. 0.513 per KWh, is the most expensive of the 3 alternatives considered. Overhauling of the plant will be difficult at Quito.

In order to operate a steam power plant or a gas turbine plant according to the pattern of the demand for energy, it will be more appropriate to install several small capacity units, and this will result in an increase in the unit cost of energy. Therefore, the most advantageous alternative plan would be to construct a diesel power plant in the vicinity of Quito.

10.3.2 Energy Cost of Alternative Source

As described above, construction of a diesel power plant in the vicinity of Quito is selected as the best alternative source. The features of the diesel plant and the estimated energy cost are shown below.

(A) The construction cost of a 30,000 KW diesel plant is for an installation of the following characteristics.

Number of units:	6
Capacity of units:	5,000 KW
Total capacity:	30,000 KW
Revolving speed:	500 r.p.m.
Cooling method:	Water cooling
Generating voltage:	6,600 volts

<u>Step-up transformer</u>

Number:	3-phase, 1 unit
Capacity:	30,000 KVA, OA/FA
Voltage:	6.6 KV/46 KV

<u>Transmission line</u>

Assumed length of transmission line:	1 km

<u>Land</u>	120 m x 120 m
Land required for the power plant	
<u>Fuel tanks</u>	
Number :	2
Capacity of each tank :	500,000 gallon
Approximate dimension of power house :	65 m x 35 m
Approximate dimension of other building :	20 m x 10 m

Table 10-6 Construction Costs of 30 MW Diesel Power Plant at Quito

Unit: sucres

	Life in year	Local Currency	Foreign Currency	Total cost
(1) Cost of land	-	150,000		150,000
(2) Powerhouse, cooling pond & shops	30	1,700,000	2,500,000	4,200,000
(3) Waterhouse & other buildings	30	125,000	125,000	250,000
(4) Fuel tanks, Fuel handling equipment	29	1,000,000	11,000,000	12,000,000
(5) Motor-generator sets	15	6,500,000	57,000,000	63,500,000
(6) Electrical equipment (Control board, switchgear, etc.)	22	120,000	1,100,000	1,220,000
(7) Other equipment	22	200,000	1,000,000	1,200,000
(8) Step-up substation	28	300,000	2,100,000	2,400,000
(9) Transmission line	35	140,000	200,000	340,000
Sub-total		10,235,000	75,025,000	85,260,000
(10) Engineering and supervision	-	-	3,000,000	3,000,000
(11) Administration costs		1,600,000	-	1,600,000
(1) - (11)		11,835,000	78,025,000	89,860,000
(12) Contingency		1,775,000	5,461,000	7,236,000
(1) - (12)		13,610,000	83,486,000	97,096,000
(13) Interest during construction		1,690,000	3,214,000	4,904,000
Grand total		15,300,000	86,700,000	102,000,000

Note:

Period of construction: 1.5 years

Applicable rates of interest are the same as for La Mica Project, i.e. 6.5% for foreign currency and 10% for local currency.

Interest during construction calculated on amounts to be financed with loans only.

Contingency estimated as follow:

Local currency: 15%

Foreign currency: 7%

Life in year is given as reference.

(B) Annual Costs of the Diesel Power Plant

Annual costs of the diesel power plant are calculated in the same manner as for La Mica Project, over a 50 years period, and are the sum of amortization of investment costs, replacement costs, maintenance and operation costs and administrative expenses, as shown in Table 10-7 to 10-10.

Table 10-7 Construction Costs of 30 MW Diesel Power Plant at Quito

Unit: sucres

	Item	Life in year	Local currency	Foreign currency	Total cost
(1)	Cost of land	-	224,000	-	224,000
(2)	Powerhouse, cooling pond & shops	30	2,541,000	2,888,000	5,429,000
(3)	Warehouse & other buildings	30	187,000	145,000	332,000
(4)	Fuel tanks & fuel handling equipment	29	1,495,000	12,711,000	14,206,000
(5)	Motor-generator sets	15	9,716,000	65,872,000	75,588,000
(6)	Electrical equipment (Control board, switchyard, etc.)	22	179,000	1,271,000	1,450,000
(7)	Other equipment	22	299,000	1,155,000	1,454,000
(8)	Step-up substation	28	449,000	2,427,000	2,876,000
(9)	Transmission line	35	210,000	231,000	441,000
	Grand total		15,300,000	86,700,000	102,000,000

Table 10-8 Replacement Cost of Diesel Power Plant

Unit: sucres

	Investment (1)	fs.p (2)	fc.r (3)	Annual costs (1)x(2)x(3)
At 22 years				
Local currency	478,000	0.1228	0.1140	6,690
Foreign currency	2,426,000	0.2502	0.0867	52,630
At 28 years				
Local currency	449,000	0.0693	0.1075	3,340
Foreign currency	2,427,000	0.1715	0.0785	32,670
At 29 years				
Local currency	1,495,000	0.0630	0.1067	10,050
Foreign currency	12,711,000	0.1610	0.0775	158,600
At 30 years				
Local currency	12,444,000	0.0573	0.1061	75,650
Foreign currency	68,905,000	0.1512	0.0766	798,050
At 35 years				
Local currency	210,000	0.0356	0.1037	780
Foreign currency	231,000	0.1103	0.0731	1,860
At 15 years				
Local currency	9,716,000	0.2394	0.1310	304,710
Foreign currency	65,872,000	0.3888	0.1064	2,725,000
At 44 years				
Local currency	478,000	0.0151	0.1015	6,690
Foreign currency	2,426,000	0.0626	0.0693	52,630
At 45 years				
Local currency	22,160,000	0.0137	0.1014	30,780
Foreign currency	134,777,000	0.0588	0.0691	547,610
Annual costs				4,807,740

Note: fs.p = Single payment present worth factor (%)
fc.r = Capital recovery factor (%)

Table 10-9 Amortization of Initial Investment of Diesel Plant

Unit: sucres

	Investment	fc.r	Annual cost
Local currency (i = 10%)	15,300,000	0.10086	1,543,000
Foreign currency (i = 6.5%)	86,700,000	0.0679	5,896,000
Annual cost			7,439,000

Note: fc.r = Capital recovery factor (%)
i = Annual interest

Table 10-10 Maintenance, Operation and Administrative Costs

Unit: sucres

		Annual cost
(1)	Fuel expenses (s/. 0.175/KWh) 97,580,000 KWh x s/. 0.175	17,060,000
(2)	Personnel expense (35 persons) 35 p x s/. 4,500	1,575,000
(3)	Other expenses	250,000
(4)	Maintenance expenses	1,632,000
(5)	Oil and lubricant expenses	1,962,000
(6)	Administrative expenses	1,000,000
Annual cost		23,479,000

Note: For cost of fuel, the present cost of diesel fuel at Quito of s/. 2.25/gallon, has been taken.

(C) Energy Cost of the Diesel Power Plant

The annual costs of the diesel power plant obtained in Table 10-8 to Table 10-10 are s/. 35,697,740.

Replacement cost	s/. 4,807,740
Amortization	s/. 7,411,000
Maintenance, operation & administrative expenses	s/. 23,479,000
Total annual costs	s/. 35,697,740

Dividing this amount, s/. 35,697,740, by the effective saleable energy of 97,580,000 KWh, the energy cost per KWh of the diesel power plant would be s/. 0.366 per KWh in case "A".

10.4 ANNUAL BENEFIT OF LA MICA PROJECT

The annual benefit of La Mica Project should be evaluated for kW and KWh respectively.

For this purpose, as shown in Table 10-11, the annual costs of the diesel power plant were apportioned between fixed cost and variable cost, and the unit costs of KW and KWh respectively were obtained and these were used as the unit costs for calculating benefits of La Mica Project.

The results are:

Unit power benefit: s/. 17,138,740/30,000 KW = s/. 570/KW

Unit energy benefit: s/. 19,559,000/97,580,000 KWh = s/. 0.20/KWh

Table 10-11 Annual benefit for KW and KWh

Unit: sucres

		Total annual costs	Fixed cost	Variable cost
(1)	Replacement	4,807,740	4,807,740	-
(2)	Amortization	7,411,000	7,411,000	-
(3)	Maintenance, operation & administration costs			
	Fuel expenses	17,060,000	-	17,060,000
	Personnel expenses	1,575,000	1,575,000	-
	Other expenses	250,000	150,000	100,000
	Maintenance expenses	1,632,000	1,300,000	332,000
	Oil & lubricants	1,962,000	1,295,000	1,667,000
(4)	Administrative expenses	1,000,000	600,000	400,000
	Total	35,697,740	17,138,740	19,559,000

The above unit power and energy benefits were applied to the effective saleable power and energy given in 10.1 to obtain the annual benefits, and the sum of the benefits were converted to present worth to arrive at the benefit of La Mica Project. The benefits thus calculated for Case "A" and Case "B" are given in Tables 10-12 and 10-13.

Table 10-12 Annual benefit of La Mica Project for Case "A"

No.	Year	Effective Saleable power & Energy		Annual benefit		1974 present worth	
		Power (KW)	Energy (KWh)	Power (mil sucres)	Energy (mil sucres)	KW annual benefit (mil sucres)	KW annual benefit (mil sucres)
1	1974	23,100	55,460	13,167	11,092	12,080	10,180
3	76	28,500	77,530	16,245	15,506	12,540	11,970
5	78	28,500	89,620	16,245	17,924	10,560	11,650
7	80	28,500	123,740	16,245	24,748	8,890	13,540
9	82	28,500	123,740	16,245	24,748	7,480	11,390
11	84	28,100	117,850	16,017	23,570	6,210	9,130
13	86	27,200	116,790	15,504	23,358	5,060	7,620
15	88	26,400	115,440	15,048	23,088	4,130	6,340
17	90	25,500	113,890	14,535	22,778	3,360	5,260
19	92	24,600	112,150	14,022	22,430	2,730	4,360
21	94	23,800	110,220	13,566	22,044	2,220	3,610
23	96	22,900	108,190	13,053	21,638	1,800	2,980
25	98	22,000	106,070	12,540	21,214	1,450	2,460
27	2000	21,200	103,750	12,084	20,750	1,190	2,040
29	2002	20,300	101,330	11,571	20,266	950	1,670
31	4	19,400	98,920	11,058	19,784	760	1,370
33	6	18,600	96,600	10,602	19,320	620	1,120
35	8	17,700	93,900	10,089	18,780	490	920
37	2010	17,400	89,360	9,918	17,872	410	740
39	2012	17,200	79,250	9,804	15,850	340	550
	:	:	:	:	:	sub-total	sub-total
	:	ditto	ditto	ditto	ditto	from 2012	from 2012
	:	:	:	:	:	to 2023	to 2023
	:	:	:	:	:	2,320	3,740
50	2023	17,200	79,250	9,804	15,850		
Total						168,860	221,540
Capital recovery factor at 50 years = 9.0 %						KW Benefit = s/.15,200	KWh Benefit = s/.19,940
						Total Benefit = s/.35,140	

Note: The interest rate is 9.0% which is the same weighted average interest rate for La Mica Project.

Table 10-13 Annual Benefit of La Mica Project for Case "B"

No.	Year	Effective Saleable power & energy		Annual benefit		1974 present worth	
		Power (KW)	Energy (KWh)	Power (mil sucres)	Energy (mil sucres)	KW annual benefit (mil sucres)	KWh annual benefit (mil sucres)
1	1974	23,100	55,460	13,167	11,090	12,080	10,180
3	1976	28,500	77,530	16,245	15,506	12,540	11,970
5	1978	28,500	89,620	16,245	15,506	10,560	10,080
7	1980	28,500	123,740	16,245	24,748	8,890	13,540
:	:	:	:	:	:	sub total from 1980 to 1998	sub total from 1980 to 1998
:	:	ditto	ditto	ditto	ditto	77,800	118,530
:	:	:	:	:	:		
25	1998	28,500	123,740	16,245	24,748	1,880	2,870
27	2000	27,500	119,720	15,675	23,944	1,530	2,340
29	2002	26,500	116,070	15,105	23,214	1,240	1,910
31	2004	25,500	112,440	14,535	22,488	1,000	1,550
33	2006	24,500	108,800	13,965	21,760	810	1,270
35	2008	23,500	105,160	13,395	21,032	660	1,030
37	2010	22,500	101,520	12,825	20,304	530	840
39	2012	21,500	97,880	12,255	19,576	430	680
41	2014	20,500	94,240	11,685	18,848	340	550
43	2016	19,500	90,600	11,115	18,120	270	450
45	2018	18,000	86,960	10,260	17,392	210	360
47	2020	17,400	83,320	9,918	16,664	170	290
49	2022	17,200	79,680	9,804	15,936	140	230
50	2023	17,200	79,500	9,805	15,900	130	210
	Total					184,620	239,230
	Capital recovery factor at 50 year = 9.0%					KW Benefit = 16,620	KWh Benefit = 21,530
						Total Benefit = 38,150	

Note: The interest rate is 9.0% which is the same weighted average interest rate for La Mica Project.

10.5 BENEFIT-COST RATIO

The annual benefit and annual costs of La Mica Project for Case "A" and "B" are described in 10.2.1, 10.2.2 and 9.4.

The annual surplus benefit and benefit-cost ratio are as shown below.

Case "A"

Annual benefit (B):	s/. 34,590,000
Annual costs (C):	s/. 15,274,000
Annual surplus benefit (B) - (C):	s/. 19,316,000
Benefit-cost ratio (B)/(C):	2.26

Case "B"

Annual benefit (B):	s/. 37,430,000
Annual costs (C):	s/. 17,774,000
Annual surplus benefit (B) - (C):	s/. 19,656,000
Benefit-cost ratio (B)/(C):	2.11

Chapter XI

FINANCIAL ANALYSIS

Chapter XI

FINANCIAL ANALYSIS

"EEQ" S.A., the owner of La Mica Project, has a paid-up capital of s/. 221,000,000, an installed capacity of 60 MW and annual energy sales of 160,000 MWh.

It is a privately owned electric utility company which is operating on revenues from sale of electricity. Therefore, in preparing the financial program of this project, it is desirable to prepare a financial program of "EEQ" S.A. as whole including other committed projects which are in the course of construction. The Electric Power Development Company (EPDC), which is the parent organization of the six engineers who carried out the fuild investigations of this Project, submitted to "EEQ" S.A. in 1967 the feasibility report of Nayon Project in accordance with the Contract for engineering services of the Nayon Project. The financial program considered in the feasibility report of Nayon Project was made on the basis of the financial situation of "EEQ" S.A. as of 1966 and included the funds required for Nayon Project and the operating income upon completion of the Project. Construction of the Nayon Power Plant is expected to start about July of 1969 and "EEQ" S.A. is now examining its entire financial program.

Therefore, many uncertain elements are assumed in the financial program for La Mica Project on the basis of the financial situation of "EEQ" S.A. as a whole in the same manner as that of the Nayon Project. Therefore, the income statement was prepared independently for this Project as follows.

11.1 FUND REQUIREMENTS

As stated in Chapter 9, the estimated total construction cost of this project is s/.176,910,000 consisting of s/.72,193,000 in foreign currency and s/.104,717,000 in local currency.

The breakdown by years of fund requirements is as follows.

Unit: Mil sucres

	1972	1973	1974	Total
Foreign currency	(450) 8,135	(1,994) 34,451	(1,710) 29,598	(4,154) 72,184
Local currency	(1,917) 22,844	(4,314) 49,328	(3,094) 32,544	(9,325) 104,716
Total	(2,367) 30,979	(6,308) 83,779	(4,804) 62,142	(13,479) 176,900

Note) Figures in parentheses indicate interest during construction which is included in the annual fund requirements.

11.2 FINANCING OF FUNDS

11.2.1 Sources of Funds

There are possible sources of funds, such as foreign loans, loans from local financial institutions, equity financing and investment of "EEQ" S.A.'s own funds. For this Project, it was assumed that a loan from an international financial institution is expected for the foreign currency fund requirements. As sources of local currency fund requirements, the surplus and other available funds of "EEQ" S.A. were considered. However, as stated in the beginning of this Chapter, the amount of financing available from these sources cannot be precisely estimated under the present condition, and therefore, the revenues from sales of electricity were not considered. As for equity financing, as present there are no prospect of local institutions or persons interested in buying "EEQ" S.A.'s stock in the required amount. Such being the case, equity financing was also not considered. Therefore, the total amount of local currency fund requirements was assumed to be borrowed from local financial institutions.

11.2.2 Interest and Term of Repayment

(1) Foreign Currency

As to the loans from international financial institution, "EEQ" S.A. raised a loan from the World Bank for the construction of the first stage of Cumbaya Project. Moreover, "EEQ" S.A. is now negotiating with the World Bank for another loan to finance a part of the construction costs of the Nayon Project. Information available indicates that the World Bank is favorably considering a second loan at an interest rate of 6.5% per year and term of repayment of 17 years after start of operation. For La Mica Project, the following conditions were applied.

Interest rate:	6.5% per annum
Term of redemption:	20 years after beginning of operation in uniform annual installments of principal plus interest.

(2) Local Currency

At present, prevailing interest rate by the city banks or financial institutions in Ecuador is 9 to 10% per annum and the period of redemption is 7 to 10 years in general. Therefore, the conditions of local currency borrowings for this Project were estimated on the conservative side as follows.

Interest rate:	10% per annum
Term of redemption:	10-years from beginning of operation in uniform annual installments of principal plus interest.

11.3 OPERATING INCOME

11.3.1 Income from Sales of Energy

(1) Unit Sales Price at Substation

Electricity generated by La Mica Project is assumed to be delivered at Quito South Substation. The unit sales price of electricity at this substation is estimated as follows.

In "EEQ" S.A.'s power system, the average unit sales price of energy at the consumer's end was s/. 0.479 in 1966 and s/. 0.477 in 1967. In case the average unit sales price of energy is applied to La Mica Project, it is necessary to consider the future trend in the composition of demand which will influence the average unit revenue. For this project, an average unit revenue of s/. 0.483 at the consumer's end was taken, which is the same value adopted for the Nayon Project. However, this unit sales price of energy includes the transformation and distribution cost for facilities "EEQ" S.A. invested in the past.

The ratio of these costs to the unit sales price computed from the investiments for said facilities is 25%. On the other hand, if the average rate of loss of "EEQ" S.A.'s power system is estimated to be 18.5%, the loss rate at the Quito South Substation in this Project is 3.7%. Therefore, if s/. 0.483, the average unit sales price of energy at the consumer's end, is computed at the bus bar of Quito South Substation, it becomes s/. 0.412. In consideration of this situation, the unit sales price of energy of this project was taken to be s/. 0.309 which is 75% of the cost at the bus bar of Quito South Substation.

(2) Salable Energy at Quito South Substation

The Salable Energy at Quito South Substation was estimated assuming that the transmission loss rate is 3.7%, stated in Chapter 7.

(3) Income

The income from electric energy sales at Quito South Substation calculated from (1) and (2) becomes the same as described in Table 11-1 "Income Statement".

11.3.2 Operation and Maintenance Costs

(1) Wages and Salaries

The personnel required for operation and maintenance of La Mica Power Plant is estimated to be 22 persons, and the wages and salaries are calculated by including an annual increase of 5%.

(2) Miscellaneous expenses

The expenses are calculated on the basis of the expenses of the whole system of "EEQ" S.A. as of 1968.

(3) Repair Costs

The repair costs are calculated to be 0.7% of the costs of equipment and 0.5% of the construction costs of structures.

(4) Administrative Cost

This is calculated on the basis of the administrative cost of the whole system of "EEQ" S.A. as of 1968 with an annual increase of 3%.

11.3.3 Depreciation Charges

Depreciation was calculated for the serviceable years described in Table 10-3-1 of Chapter 10 by the straight line method with a 10% salvage value.

11.3.4 Net Income

Deducing operation and maintenance costs, depreciation charges and interest payments on foreign and local currency loans from the annual income of this Project which is calculated on the various abovementioned conditions, the net income is as indicated in Table 11-1 "Income Statement".

11.4 AMORTIZATION SCHEDULE

The source of funds for repayment of loans will be the net income from operations and depreciation reserve. Repayment of foreign and local borrowing according to the terms and conditions aforementioned is given in Table 11-2, "Amortization Schedule". Table 11-3 "Cash Flow Statement" gives net resources for debt financing. It will be seen in the table that there will be a shortage of funds amounting to s/. 6,595,000 for 3 years after 1975 for debt service. Therefore, "EEQ" S.A. must consider the appropriation of the internal reserve and other funds to make up this shortage in preparing the financial program for its whole operation. However, after 1978, the foreign and local loan can be redeemed under the assumed terms and conditions from operating income. Accordingly, La Mica Project is economically feasible.

Table 11-1 Income Statement

Unit: Mil Sucres

Order of Years	1	2	3	4	5	6	7	8	9	10	11
Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(A) Gross Revenue from Sales	7,140	21,408	23,957	26,049	27,693	32,878	38,236	38,236	38,236	38,236	36,416
Annual Sales of Energy (MWh)	23,108	69,280	77,530	84,300	89,620	106,400	123,740	123,740	123,740	123,740	117,850
Unit Sales Price (Sucre/KWh)	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309
(B) Total Operating Costs	3,451	8,281	8,339	8,400	8,463	8,530	8,599	8,672	8,748	8,828	8,911
Operating and Wages	980	2,351	2,409	2,470	2,533	2,600	2,669	2,742	2,818	2,898	2,981
Salaries and Wages	373	896	896	896	896	896	896	896	896	896	896
Other Expenses	56	135	135	135	135	135	135	135	135	135	135
Operation and Maintenance Costs	363	870	870	870	870	870	870	870	870	870	870
Administration Expense	188	450	450	450	450	450	450	450	450	450	450
Increase in Salaries	-	-	45	92	141	193	247	304	364	427	493
Increase in Administration Expense	-	-	13	27	41	56	71	87	103	120	137
Depreciation	2,471	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930
(C) Operating Income: (A) - (B)	3,689	13,127	15,618	17,649	19,230	24,348	29,637	29,564	29,488	29,408	27,505
(D) Final Expenditure (Interest)		15,164	14,385	13,534	12,602	11,581	10,464	9,240	7,900	6,432	4,823
Local Loan (10 years)	-	10,472	9,814	9,092	8,297	7,422	6,460	5,402	4,238	2,958	1,549
Foreign Loan (20 years)	-	4,692	4,571	4,442	4,305	4,159	4,004	3,838	3,662	3,474	3,274
(E) Net Income: (C) - (D)	3,689	- 2,037	1,233	4,115	6,628	12,767	19,173	20,324	21,588	22,976	22,682

Table 11-2 (1) Amortization Schedule - Foreign Currency

Unit: Mil Sucres

Year	Borrowing			Redemption			Outstanding Balance	Remarks
	Generating Facilities	Trans-mission Line	Total	Principal	Interest	Total		
1972	7,883	252	8,135					Interest Rate: 6.5%
1973	34,451	-	34,451					
1974	27,326	2,272	29,598				72,184	Redeemble in equal annual installments in 20 years after beginning of commercial operation.
1975				1,859	4,692	6,551	70,325	
1976				1,980	4,571	6,551	68,345	
1977				2,109	4,442	6,551	66,236	
1978				2,246	4,305	6,551	63,990	
1979				2,392	4,159	6,551	61,598	
1980				2,547	4,004	6,551	59,051	
1981				2,713	3,838	6,551	56,338	
1982				2,889	3,662	6,551	53,449	Amortization Rate: 0.09075640
1983				3,077	3,474	6,551	50,372	
1984				3,277	3,274	6,551	47,095	
1985				3,490	3,061	6,551	43,605	
1986				3,717	2,834	6,551	39,888	
1987				3,958	2,593	6,551	35,930	
1988				4,216	2,335	6,551	31,714	
1989				4,490	2,061	6,551	27,224	
1990				4,781	1,770	6,551	22,443	
1991				5,092	1,459	6,551	17,351	
1992				5,423	1,128	6,551	11,928	
1993				5,776	775	6,551	6,152	
1994				6,152	399	6,551	0	
Total	69,660	2,524	72,184	72,184	58,836	131,020		

Table 11-2 (2) Amortization Schedule - Local Currency

Unit: Mil Sucres

Year	Borrowing			Redemption			Outstanding Balance	Remarks
	Generating Facilities	Trans-mission Line	Total	Principal	Interest	Total		
1972	22,844	-	22,844					Interest Rate: 10%
1973	49,328	-	49,328					
1974	30,068	2,476	32,544				104,716	Redeemble in equal annual installments in 10 years after beginning of commercial operation.
1975				6,570	10,472	17,042	98,146	
1976				7,228	9,814	17,042	90,918	
1977				7,950	9,092	17,042	82,968	
1978				8,745	8,297	17,042	74,223	
1979				9,620	7,422	17,042	64,603	
1980				10,582	6,460	17,042	54,021	Amortizations Rate: 0.16274539
1981				11,640	5,402	17,042	42,381	
1982				12,804	4,238	17,042	29,577	
1983				14,084	2,958	17,042	15,493	
1984				15,493	1,549	17,042	0	
Total	102,240	2,476	104,716	104,716	65,704	170,420		

Unit: Mil Sucres

Year	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
(A) Cash Receipt	30,979	83,779	68,302	3,893	7,163	10,045	12,558	18,697	25,103	26,254	27,518	28,906	28,612
(1) Net Income			3,689	-2,037	1,233	4,115	6,628	12,767	19,173	20,324	21,588	22,976	22,682
(2) Depreciation			2,471	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930	5,930
(3) Borrowings													
Local Loan	22,844	49,328	32,544										
Foreign Loan	8,135	34,451	29,598										
(B) Cash Disbursement	30,979	83,779	62,142	8,429	9,208	10,059	10,991	12,012	13,129	14,353	15,693	17,161	18,770
(1) Construction Expenditure													
Local Currency	23,844	49,328	32,544										
Foreign Currency	8,135	34,451	29,598										
(2) Amortization of Debit (Principal)													
Local Currency				6,570	7,228	7,950	8,745	9,620	10,582	11,640	12,804	14,084	15,493
Foreign Currency				1,859	1,980	2,109	2,246	2,392	2,547	2,713	2,889	3,077	3,277
(C) Balance Carried Forward: (A) - (B)	0	0	6,160	-4,536	-2,045	-14	1,567	6,685	11,974	11,901	11,825	11,745	9,842