CAUCA RIVER REGULATION PROJECT

REPUBLIC OF COLOMBIA

FEASIBILITY REPORT

VOLUME I

GENERAL REPORT

MARCH 1970

prepared for

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

by

ELECTRIC POWER DEVELOPMENT CO., LTD.

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PREFACE

The Government of Japan, at the request of the Government of the Republic of Colombia, entrusted the feasibility studies for the Cauca River Regulation Project to the Overseas Technical Cooperation Agency.

In view of the importance of developing water resources in Colombia, the Agency organized a survey team consisting of five experts, including one stationed in Colombia, of the Electric Power Development Co., Ltd.

The team, headed by Mr. Narao Takemura, a senior irrigation and drainage engineer, engaged in field surveys in Colombia for a period of about fifty days from the end of June 1969. The surveys involved a number of discussions with the Government officials of the Republic of Colombia, field investigations and collection of data necessary for planning the project and outcome of which is hereby presented as "Feasibility Report on Cauca River Regulation Project".

Nothing would be more gratifying to the Agency if this report could contribute to the promotion of this project and to the furtherance of the friendly relations and economic cooperation between the Republic of Colombia and Japan.

I take this opportunity to express my hearty thanks to the officials of the Government of the Republic of Colombia for their valuable assistance and support extended to the team.

March 1970

Keiichi Tatsuke
Director General
Overseas Technical Cooperation Agency
Japan

LETTER OF TRANSMITTAL

Mr. Keiichi Tatsuke, Director General
Overseas Technical Cooperation Agency

Dear Sir:

Transmitted herewith is the report on the feasibility study of the Cauca River Regulation Project in the Republic of Colombia. This report has been prepared by the Electric Power Development Co., Ltd. (hereinafter referred to as "EPDC") for the Overseas Technical Cooperation Agency, the agency for overseas technical cooperation of the Government of Japan, at the request of Corporacion Autonoma Regional del Cauca (hereinafter referred to as "CVC"), government agency of the Republic of Colombia, to the Government of Japan.

In order to carry out the study, EPDC dispatched to Colombia four engineers, headed by H. Watanabe, civil engineer, for a period of 18 months from March 1968 to September 1969 and a team of five engineers, headed by N. Takemura, irrigation and drainage engineer, from June 1969 to August 1969. These engineers, with the cooperation of CVC and various government agencies of Colombia, carried out field investigations of topography, geology, materials, hydrology and also collected relevant data for the purpose of preparing a project report.

Upon return of the team to Japan, analyses of hydrologic data, detailed studies of flood control, load forecasts, preliminary design, estimation of construction costs and economic evaluations, etc. were performed based on the results of field investigations and on the data and informations which were obtained. The studies were carried out by the engineering staff of EPDC under the direction of the Chief Engineer of the company.

The Cauca River Regulation Project is designed to control floods occurring almost every year along the Cauca River by constructing a dam at the Salvajina site and levees along the main stream and its tributaries in the areas flooded. At the same time, it is designed to increase agricultural production by the improvement of farmland through drainage works in lowland and also to meet the power demand of the CVC System, which in recent years has been growing at a remarkable rate, by hydroelectric generation. Recently, sewerage and industrial wastes discharged from Cali and the Yumbo industrial districts have caused serious contamination of the Cauca River from the vicinity of Cali for a distance of about 50 km downstream so that fishing resources are presently on the verge of extinction, while water supply to municipalities along the downstream area and also agricultural water are beginning to be adversely affected creating a new social problem together with yearly flood damage. By discharging water stored at Salvajina Dam during the low water period of the Cauca River to provide storage space for flood discharge in November and December through power generation releases, the runoff of the river during the dry period of August, September and October can be roughly doubled and the projected investment plans of Empresas Municipales de Cali for purification of the contaminated water can be greatly reduced. Furthermore, at a stage after flood control and drainage works have been realized, it will become possible to gradually expand irrigation areas in the Cauca Plain, including the present flooded lowland, corresponding to the growth of demand for agricultural products.

For the execution of this project capital expenditure of 91.3 million dollars will be required. The construction period for the dam, spillway and power plant is 4 years for the first stage including 2 units of turbines and generators. A construction period of 7 years each for levees and drainage works will be required. The benefit-cost ratio of the project is 1.53 and through its implementation an annual surplus benefit of 4.14 million dollars is anticipated. Also, from the aspect of amortization of construction expenditures, it will be possible to repay borrowings within a reasonable period of time. The project is feasible both technically and economically. This is a multi-purpose river development project which is extremely important and beneficial.

As for the time of start of operation of the project, since a major portion of the source of fund for repayments will come from the wholesale of electricity, there will be a close relationship with the power balances of the Bogota, Medellin and CVC Systems which are to be interconnected by transmission line being constructed by Interconexion Electrica S.A., but on the standpoint that the power demand in the CVC System is to be met by supply capacity within its system, and also taking into account power balances of interconnected system, it is considered appropriate to commission the plant around the end of 1976.

I take this opportunity to record my sincere gratitude and appreciation to the officials of CVC, the various organizations of the Republic of Colombia and the Japanese Embassy in Bogota for the assistance and cooperation extended to the team during their stay in Colombia.

March 1970

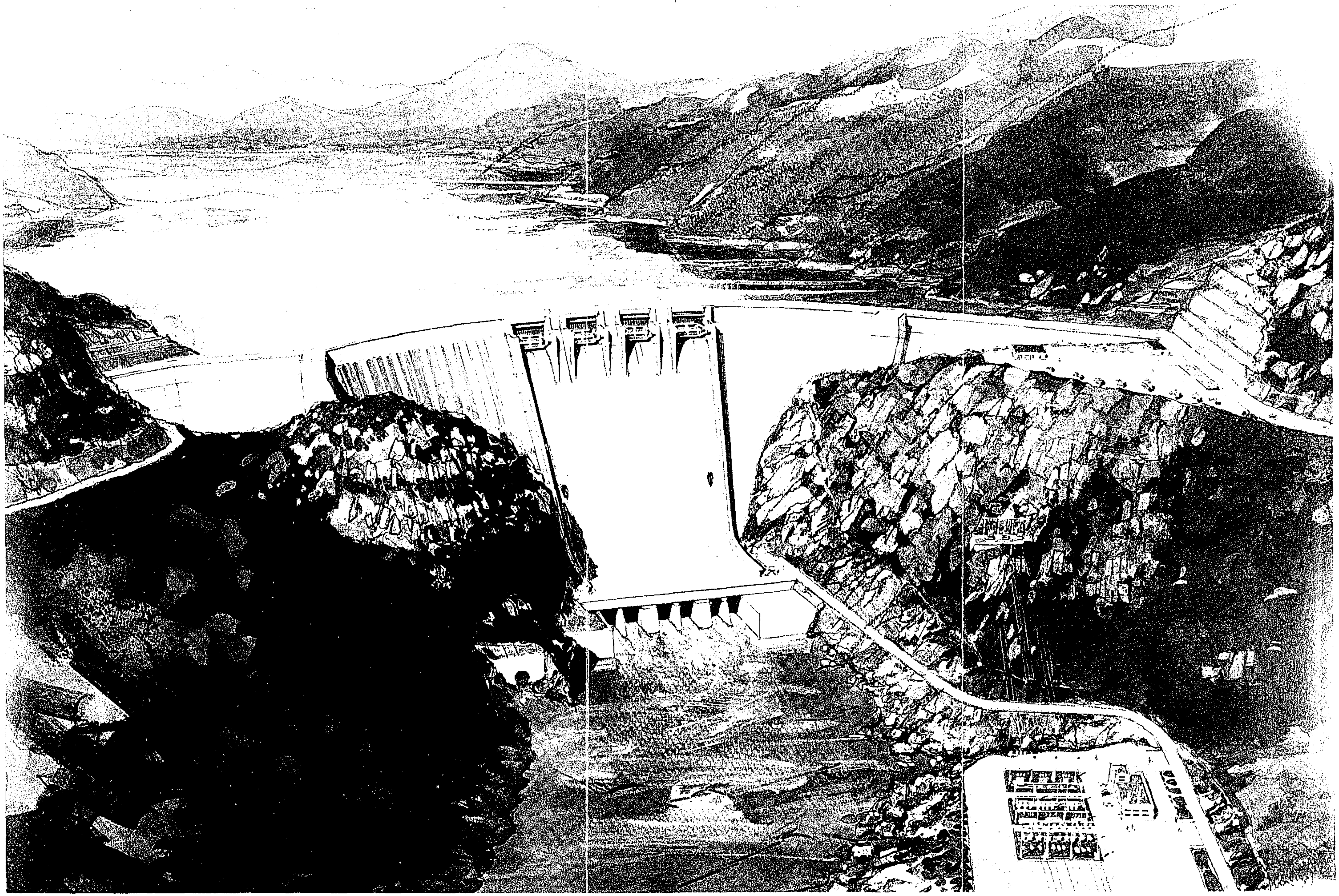
Takeji Yasuda

Takeji Yasuda, Director
Foreign Activities Department
Electric Power Development Co., Ltd.

ACKNOWLEDGEMENT

Profound gratitude is due to those persons for their untiring assistance and cooperation during the investigations in Colombia in the project study. The great volume of data and information needed for preparing this report was collected through the great efforts of these persons. It would have been impossible to complete this report without their assistance and cooperation. The number of individuals whose efforts and contributions have made this report possible is too great to properly express our appreciations to each of them. It is with the intention of fully acknowledging their great help and cooperation that we list the organizations with which we contacted.

Departamento Nacional de Planeación
Embajada del Japón
Corporación Autónoma Regional del Cauca
Instituto Colombiano de la Reforma Agraria
Instituto Colombiano de Energía Eléctrica
Universidad del Valle
Interconexión Eléctrica S.A.
Empresa de Energía Eléctrica de Bogota
Empresas Publicas de Medellín
Central Hidroeléctrica de Caldas
Empresas Municipales de Cali
Hazen & Sawyer Co.

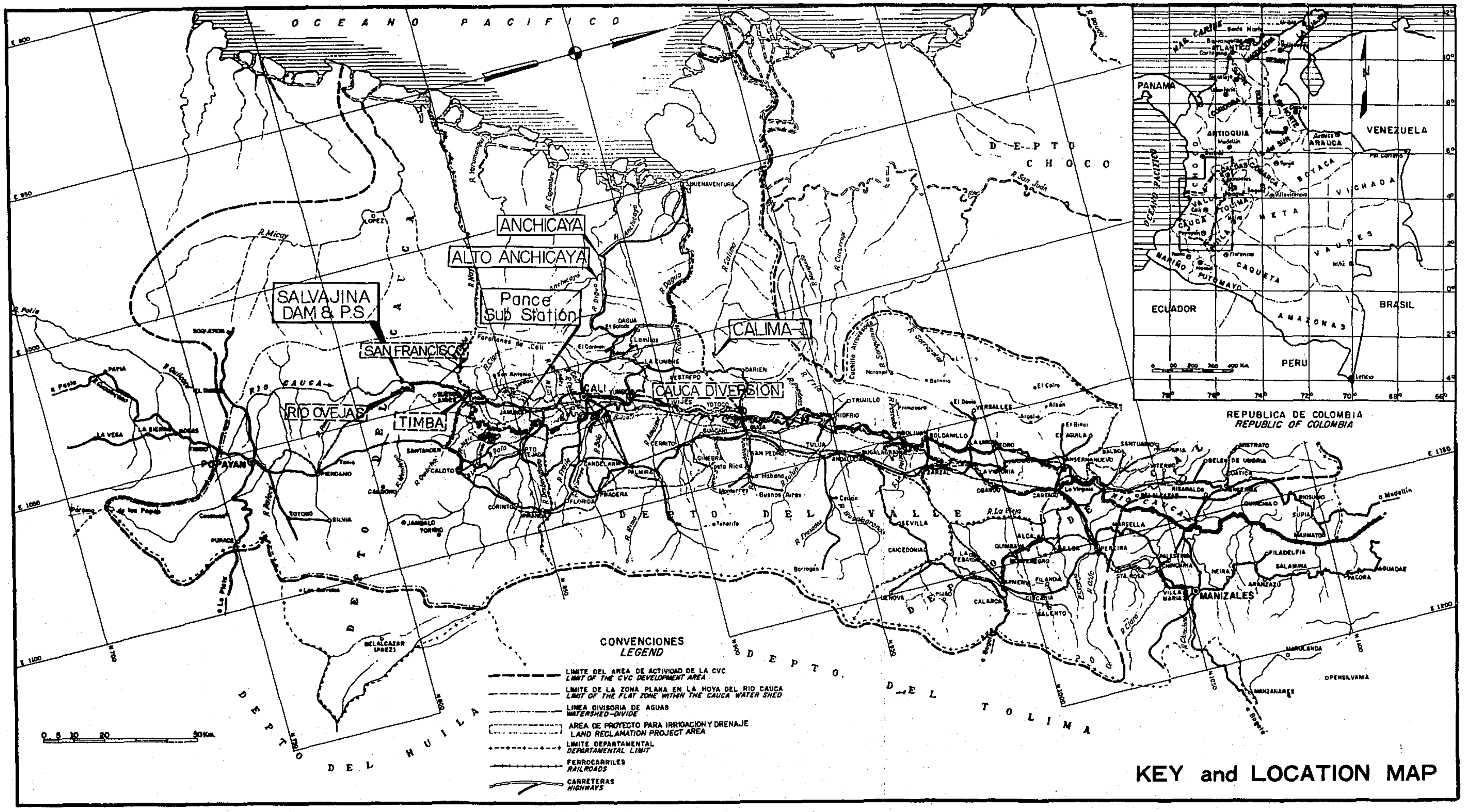


CONTENTS

UNITS AND CONVERSIONS

mm	millimeter	kg/sq.cm	kilogram per square centimeter
cm	centimeter	ton	metric ton
m	meter	m/sec	meter per second
km	kilometer	kW	kilowatt
sq.mm	square millimeter	MW	megawatt
sq.cm	square centimeter	kV	kilovolt
sq.m	square meter	kVA	kilovolt-ampere
sq.km	square kilometer	kWh	kilowatt-hour
ha	hectare	mill	U.S. mill
cu.m	cubic meter	U.S.$	U.S. dollar
cu.m/s	cubic meter per second	PS	Colombian Peso
cu.m/s.day	cubic meter per second per day	p.p.m.	parts per million
gr	gram	EL	the height above mean sea level
%	percent	°C	centigrade
rpm	revolutions per minute	Max.	maximum
kg	kilogram	Min.	minimum

1 m	39.37 inches	3.2808 feet
1 km	0.6214 miles	3,2808.8 feet
1 n.m.	(1 nautical mile)	1,852 m
1 sq.m	1.196 sq.yards	10.764 sq.feet
1 sq.km	100 hectares	247.1 acres
1 ha	10,000 sq.m	2,471 acres
1 plaza	6,400 sq.m	
1 cu.m	1,000 liters	35.31 cu.feet
1 kg	2.2046 pounds	
1 ton	1,000 kilograms	2,204.6 pounds
1 cu.ms	35.31 cu.ft/sec	
°C	5/9 (°F-32°)	
1 US$	17.35 Colombian Pesos	
1 PSI	0.07031 kg/sq.cm.	



KEY and LOCATION MAP

CHAPTER 1

INTRODUCTION

CONTENTS

CHAPTER 1 INTRODUCTION

1.1 Authorization

In December 1967, Corporacion Autonoma Regional del Cauca, (hereinafter referred to as "CVC"), a government agency of the Republic of Colombia having as one of its purposes the conservation and development of the water resources of Departamento del Valle del Cauca, requested the Government of Japan to conduct a technical and economic feasibility study of the "Timba Project". In response this request, the Government of Japan directed Overseas Technical Cooperation Agency (hereinafter referred to as "OTCA"), its agency for the execution of overseas technical cooperation operations, to carry out the study and OTCA in turn entrusted the work to Electric Power Development Co. Ltd. (hereinafter referred to as "EPDC").

This project was originally called "Timba Project", but in view of the multi-purpose nature of the project which includes flood control, drainage, alleviation of river contamination and power generation, the name was changed to Cauca River Regulation Project by CVC.

1.2 Purpose of Project

The Cauca River, flowing from south to north through the Cauca Plain (approximately 4,000 sq.km) which is one of the most fertile areas in the South American Continent, is the second biggest river in Colombia with a drainage area of approximately 9,000 sq.km at the point near the city of Cali. In the rainy season from November to December of almost every year, an area of 10,000 ha to 30,000 ha. of farmland on both banks of the river, and in some years as much as 60,000 ha, is inundated over a distance of approximately 300 km long from Timba to Cartago causing considerable damage to farm crops. Also, in recent year, because of sewerage disposal from Cali (population, 1,000,000) and industrial wastes from the Yumbo industrial district discharged into the Cauca River, contamination of the river during the dry months has become a critical problem and fish resources are now on the verge of extinction while adverse effects are beginning to appear in city water and agriculture water supply in the downstream areas.

The purpose of the Cauca River Regulation Project is principally to alleviate the beforementioned flood damage by the construction of a dam on the upstream of the river and of levees on both banks of the main river and tributaries in the flood-afflicted areas. At the same time, it is proposed to construct drainage systems in the flooded areas which are mainly the lowland to improve the farmland and thereby increase agricultural production. Furthermore, the project purposes include abatement of river contamination by approximately doubling the river discharge in the dry months during which period river contamination has been worsened yearly and power generation to meet rapidly growing demand in the Cauca Plain.

At the present time, there are some irrigation facilities in the Cauca Plain constructed by landowners utilizing subterranean water and water from tributaries, but it would be possible to gradually expand irrigation facilities in the entire Cauca Plain to increase agricultural production corresponding to demand after the flood control and drainage works have been essentially completed.

1.3 Purpose and Scope of Report

1.3.1 Purpose of Report

In order to achieve the purposes described in 1.2 at the earliest practicable date through execution of the project, CVC is now preparing to apply to the Government of Colombia for approval of execution of the project and for appropriation of the necessary budget. This report is concerned with investigations and studies of the technical and economic feasibility of the project and has been prepared with the purpose of providing necessary and sufficient information for CVC to apply to the Government for approval to execute the project and in financing of construction funds.

1.3.2 Scope of Report

This report concerns the multi-purpose development of the Cauca River including flood control, drainage, alleviation of river pollution and power generation.

Concerning the irrigation program for the Cauca Plain including flood-afflicted areas, it could be a later stage works left to private interests. Therefore, only the basic conception for the irrigation program was referred to in the Appendix. A diversion project to the Pacific Ocean and intake from the Rio Ovejas both for the purpose of power generation were also commented in the Appendix.

Concerning the project area for flood control and drainage, it was taken to be from La Balsa at the upstream to the confluence with the Rio Bugalagrande on the downstream on the right bank and to Roldanillo-Union-Torro Project (hereinafter referred to as "R-U-T") on the left bank, thus excluding the existing R-U-T Project and Aguablanca Project carried out by CVC, the Rio Paila Project carried out by Ingenio Rio Paila and the Victoria-Cartago Project which is proposed by CVC.

1.3.3 Composition of Report

The report consists of two volumes, the first being a general report comprised of the following chapters.

GENERAL REPORT

CHAPTER 1.	INTRODUCTION
CHAPTER 2.	CONCLUSIONS AND RECOMMENDATIONS
CHAPTER 3.	DESCRIPTION OF PROJECT
CHAPTER 4.	DESCRIPTION OF PROJECT AREA
CHAPTER 5.	PROBLEMS AND NEEDS OF THE REGION
CHAPTER 6.	PLAN OF DEVELOPMENT
CHAPTER 7.	PRELIMINARY DESIGN
CHAPTER 8.	CONSTRUCTION SCHEDULE
CHAPTER 9.	CONSTRUCTION COST
CHAPTER 10.	ECONOMIC EVALUATION
CHAPTER 11.	REPAYMENT OF INVESTMENT
CHAPTER 12.	BIBLIOGRAPHY

The second volume contains, as appendices, basic data on meteorology, hydrology and earthquakes as well as studies concerned with geology, agriculture, hydrology, preliminary design, etc. which were utilized in the preparation of the general report. The second volume consists of the following.

APPENDIX

APPENDIX 1.	HYDROLOGICAL AND METEOROLOGICAL DATA
APPENDIX 2.	GEOLOGY AND EARTHQUAKE
APPENDIX 3.	PRESENT STATUS OF AGRICULTURE IN CAUCA PLAIN
APPENDIX 4.	PROBABLE MAXIMUM FLOOD, SEDIMENT TRANSPORTATION AND DEPOSITION IN RESERVOIR, EVAPORATION FROM RESERVOIR SURFACE
APPENDIX 5.	DAM TYPE
APPENDIX 6.	SCHEME OF LAND RECLAMATION IN CAUCA PLAIN
APPENDIX 7.	RIO OVEJAS INTAKE PROJECT
APPENDIX 8.	DIVERSION SCHEME TO PACIFIC OCEAN
APPENDIX 9.	SURVEYS AND INVESTIGATION HEREAFTER REQUIRED

1.4 Existing Reports

Since its establishment in 1954, the interest of CVC to implement this project has been evident by the big amount of research and study, of which the major works are listed below. These reports are all of the stage of feasibility studies which are comprehensive and have been of immense help and value in the preparation of this report.

"The Unified Development of Power and Water Resources in the Cauca Valley", January 1956, Olarte, Ospina, Arias & Payan Ltda; Gibbs & Hill Inc.; Knappen-Tippettes-Abbett-McCarthy

"The Timba Project", April 1958, Olarte, Ospina, Arias & Payan Ltda; Gibbs & Hill Inc.,; Tippetts-Abbett-McCarthy-Stratton

"The Salvajina Project", February 1965, Design: CVC Hydroelectric Department, Consultants: Acres International Limited

1.5 Investigation and Study

1.5.1 Investigations in Colombia

Investigations in Colombia were conducted mainly by two teams of engineers of EPDC during a period of 18 months from March 1968 to September 1969. The first team consisted of 4: Hiroshi Watanabe, civil engineer; Kazuo Shindo, civil engineer; Yozo Fukutake, geologist; and Akiyoshi Noda, irrigation and drainage engineer. These four engineers stayed in Colombia from 6 to 18 months and carried out preliminary studies of the project, including topographical survey and geological investigation works by boring and pits for the San Francisco damsite, transverse and profile survey of the Cauca River and tributaries in the flooded areas, analyses of existing data, etc.

The second team consisted of five engineers: Narao Takemura, irrigation and drainage engineer; Kokichi Yoshizawa, civil engineer; Hisanori Morita, design engineer; Kazuo Shindo, civil engineer; and Tsutomu Kidahashi, electrical engineer. These five engineers stayed in Colombia from June 1969 to August 1969 and made supplementary field investigations. They also checked all the studies which had been done by the first team and collected all necessary data which were available.

1.5.2 Work in Japan

After the return of the teams to Japan, this report was prepared at the head office of EPDC from August 1969 to January 1970 based on the data and information obtained in the field by mobilizing the technical staff of the company under the direction of the Chief Engineer. The project studies cover analyses of hydrologic data, preliminary designs, estimation of construction cost, economic evaluation, etc.

1.6 Basic Data

All data regarding meteorology, hydrology, flood damage, agricultural production, power demand and other relevant data were furnished by CVC. Recent data in connection with the Cauca River contamination were obtained from Hazen & Sawyer Co. through Empresas Municipales de Cali, while information on power demand and supply balances of other organizations than CVC System were made available by Empresa de Energia Electricas de Bogota (hereinafter referred to as "EEEB"), Empresas Publicas de Medellin (hereinafter referred to as "EPM"), Interconexion Electrica S.A. (hereinafter referred to as "ISA"), Instituto Colombiano de Energia Electrica (hereinafter referred to as "ICEL") and Departamento Nacional de Planeación, etc. Information on the effect of contamination of the Cauca River on fishlife was obtained from Division de Ciencias, Universidad del Valle.

There are sufficient information on the topography and geology of Salvajina and Timba damsites in the existing reports mentioned in 1.4, therefore new surveys, borings, and other field investigation works were not performed. But for the San Francisco damsite, preparation of map from aerial photographs, exploratory tunnels, borings, soil materials tests were carried out under the direction of EPDC engineers by either force account of CVC team or contractors. Transverse and profile survey of both banks of the Cauca River and tributaries downstream from Timba to R-U-T and the Rio Bugalagrande were mainly carried out by CVC team and a surveying firm under contract.

Besides, questionnaire type investigations in the flood affected area and aerial surveys at the time of flooding, etc. were conducted jointly by CVC and EPDC engineers. Soil materials tests for levees on both banks of the Cauca River were performed at the laboratory of CVC.

CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

CONTENTS

LIST OF DRAWINGS

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

The following conclusions have been reached from the studies and investigations of the Cauca River Regulation Project.

(1).(i) It is evident that there is a urgent need of establishing stability and to increase agricultural income in the area along the Cauca River which is one of the most fertile and vast farmlands in the Republic of Colombia, by controlling seasonal floods which occur almost every year and by carrying out drainage works.

(1).(ii) Although electric power demand and supply balance of the CVC System will be greatly improved by the 340 MW capacity of Alto Anchicaya Power Plant scheduled to be in service in 1974, it is anticipated that power shortage will come again around 1976 on account of the rapid growth of power demand due to the steady rise of living standards and industrial development in Departamento del Valle del Cauca.

This power shortage could be met to some extent with surplus power of the Bogota and Medellin systems through the 230-kV transmission line which is scheduled to be completed in 1971. However, from the standpoint of the principle that the power demand in one supply system should be mainly provided with its own supply capacity and also from the power balance of interconnected system, there is a need for CVC to construct a new stable source of power within its system in 1976.

(1).(iii) Some measures to alleviate the present trend of extreme contamination of the Cauca River between Juanchito and Paso de la Torre is urgently needed.

(2) From the investigations and studies of the feasibility of the project, it is concluded that this project is the most effective and economical with no other comparable alternative to achieve the purposes abovementioned. This project consists of the construction of a concrete arch-gravity dam 133 m high at Salvajina site which has excellent topographical and geological features, a hydroelectric power plant with an installed capacity of 210 MW, 115 kV double circuits transmission line to Pance situated 15 km south of Cali, levees on both banks of the Cauca River and major tributaries from La Bolsa to R-U-T and the Rio Bugalagrande, two regulating ponds, and drainage works in approximately 81,600 ha of flood-afflicted land. There are no unusual or difficult problems in the design and execution of the project.

(3) The construction cost of the project is estimated at 91.3 million dollars, of which 37.0 million dollars are for the dam and spillway, 19.5 million dollars are for the power generation and transmission facilities, 12.8 million dollars are for the levees and appurtenant structures, and 22.0 million dollars are for the drainage works. Of the total construction cost, 44.3 million dollars will be required in foreign currency and an equivalent of 47.0 million dollars in domestic currency.

(4) On the basis of discharge records for the driest period from 1956 to 1960, the Salvajina Power Plant can generate 74 MW of firm power in joint operation with Calima No. 1 and Alto Anchicaya Power Plants. Deducting transmission loss between the power plant and Pance Substation, the annual salable energy will be 632 million kWh. The energy cost at the substation obtained from the annual generating cost described in Sub-paragraph (5) below will be 5.4 mill per kWh.

(5) The cost of the dam was allocated to flood control, power generation and alleviation of river contamination. The benefit-cost ratios for each purpose were calculated on the basis of annual costs and annual benefits estimated from the flood damages and alternative source for power generation and alleviation of river contamination, applying discount rates of 7.0% and 10.0% for foreign and local currencies respectively. The ratio is 1.53 for all the purposes which indicate that the project is economically justified.

(6) The project will generate adequate income to redeem both foreign and local currency borrowings.

(7) Upon repayment of the borrowings for the dam and power plant in 25 years from start of operation, this project will become a major source of income for CVC.

(8) When floods control and drainage works for the lowlands along the Cauca River are realized through the execution of this project, it will be possible to expand irrigation facilities for this area, with the purpose of further stabilizing and increasing agricultural production of the lowlands as well as the Cauca Plain which holds an extremely promising potential for the future economic development of Colombia.

2.2 Recommendations

Based on the foregoing conclusions the following recommendations are made:

(1) In consideration of demand and supply balances of the CVC, Bogota and Medellin power systems, preparations should be initiated at the earliest possible date for the project implementation with a target of starting operation at the end of 1976. It is estimated that 4 years will be required for the construction of the dam, spillway, powerhouse with two of the three turbine-and-generator units installed, and transmission and substation facilities, including temporary works. Therefore, construction should be commenced in 1973.

(2) It is considered that the levees along the mainstream and tributaries, regulating ponds should be completed in 7 years from 1975 and also the drainage works in flood-afflicted areas be completed in 7 years from 1977.

(3) In view of the balance of demand and supply of the abovementioned power systems, it will be necessary for the third turbine-and-generator unit to be installed by the end of 1978.

(4) A general schedule including the definite studies required for preparation of specifications is given in Table 8.1, and necessary field works for the studies are described in Appendix 9.

(5) The investigations listed in above Appendix will be required to be undertaken in order to carry out the definite studies of the project and construction works.

(6) It will be necessary to recheck the construction costs of levees and drainage works when topographical maps of the flood-afflicted areas covering the sites of levees and of drainage facilities are completed. It is probable that some modifications might arise in the costs of these structures when the maps become available.

(7) The construction schedules for the mainstream and tributary levees, regulating ponds, and drainage works were contemplated based on several considerations such as expansive area involved and negotiations with landowners, etc. However, it is important that further studies be made not only from the engineering standpoint, but also from the socio-economic standpoints.

(8) In order to secure best operation of the proposed reservoir, it is recommended that gauging facilities with interconnected communication system should be provided in the basin which may observe and record meteorological and hydrological conditions including precipitations and run-off in the basin and could furnish reliable data for flood forecast. Construction of such facilities should preferably be proceeded along with the construction of the proposed project components. It is also recommended that studies should be continued of the rivers in the basin with respect to their hydrological characteristics including precipitation run-off relationship, etc.

CHAPTER 3

DESCRIPTION OF PROJECT

CONTENTS

LIST OF TABLES

CHAPTER 3. DESCRIPTION OF PROJECT

3.1 Major Structures

3.1.1 Dam

A concrete arch-gravity dam with a height of 133 m above lowest foundation is to be constructed at the Salvajina site on the mainstream of the Cauca River, 60 km south of Cali. The drainage area at the damsite is 3,830 sq.km. The reservoir created by the dam will have a total storage capacity of 500 x 10^6 cu.m and an effective storage capacity of 350 x 10^6 cu.m at a drawdown of 34 m, which will be utilized for multi-purposes including flood control, power generation and abatement of contamination of the river.

3.1.2 Levees

Levees, 1.5 to 2.5 m high, are to be constructed on both banks of the mainstream from the vicinity of Paso de la Bolsa, 30 km south of Cali, downstream to R-U-T on the left bank and to the confluence with the Rio Bugalagrande on the right bank. Levees are also to be constructed along major tributaries near the confluence with the mainstream.

3.1.3 Regulating Ponds

Regulating ponds are to be provided by constructing levees around Laguna Sonso and Cienago Burriga for the purposes of storing peak flood discharge and also for protection of natural resources such as fishlife. Check gates are to be installed in the channels linking the Cauca River and these ponds for control flood discharge.

3.1.4 Power Plant

Salvajina Power Plant is to be constructed at the immediate downstream of the dam. In consideration of the joint operation with Calima No. 1 and Alto Anchicaya Power Plants and also demand and supply balances in the CVC, Bogota and Medellin power systems, the optimum capacity of the plant is to be 210,000 kW in three units of 70,000 kW each. Two units are to be installed in the first stage and the third unit 2 years later.

A double circuit transmission line, 115 kV and 50 km long is to be constructed from the power plant to Pance, south of Cali.

3.1.5 Drainage Works

Drainage works consisting of main canals, interceptional canals and gravity and pumping outlet are to be constructed in 81,600 ha of farmland (mainly the area inundated by the flood of December 1966.) on both banks of the river from La Balsa to R-U-T and the Rio Bugalagrande.

3.2 Flood Control Effect

According to the runoff data at the Suarez, La Balsa, Juanchito and La Victoria gauging stations for the past 23 years from 1946 to 1968, floods have occurred almost every years as indicated in Table 3.2. The records indicate that 18 large and small floods occurred at Juanchito and 21 at La Victoria during this period. Although the losses incurred in the several thousand hectares at the beginning of flood may be small, it is estimated that approximately 70 million pesos of flood damage has been caused annually from the study of the abovementioned flood discharge records.

Through the execution of the project, flood flows of a probability of once in ten years and also peak flood discharges of the same occurrence probability can be completely controlled while damage by floods of larger discharge can also be alleviated.

1. Salvajina Reservoir

Catchment Area	3,830 sq.km
Annual Inflow	4,400 x 10^6 cu.m
Normal Water Level	1,139 m
Total Storage Capacity	500 x 10^6 cu.m
Drawdown	34 m
Effective Storage Capacity	350 x 10^6 cu.m
Dam	
Type	Concrete Arch Gravity
Height	133 m
Crest Length	403 m
Volume	700 x 10^3 cu.m
Capacity of Spillway	3,500 cu.m/s

2. River Scheme (Levees)

Design High Water Discharge	
Juanchito	720 cu.m/s
La Victoria	1,000 cu.m/s
Length and Volume of Levees	
Levees of Main River	
Length	355 km
Volume	8,750 x 10^3 cu.m
Tributaries	11 Tributaries
Length of Levees	46 km
Capacities of Regulating Ponds	
Lag. Sonso	35 x 10^6 cu.m
Cga. Burriga	15 x 10^6 cu.m
Reduction of Flood Discharge	
Lag. Sonso	80 cu.m/s
Cga. Burriga	40 cu.m/s
Improvement of Bridges	6 Bridges

3. Power Generation

Installed Capacity	1st Stage 140 MW
	2nd Stage 70 MW
	(Total 210 MW)
Unit Capacity and Number of Unit	1st Stage 70 MW x 2
	(2nd Stage 70 MW x 1)
Max. Discharge	90 cu.m/s per Unit
Effective Head	68 - 102 m
Rated Head	90 m
Firm Power Energy	
Salvajina Proper	54,000 kW
Combined Operation with Calima I and Alto Anchicaya	74,000 kW
Dependable Peak Capacity	129,000 kW
Annual Energy Production	
Salvajina Proper	
Average Energy	813.0 x 10^6 kWh
Firm Energy	477.6 x 10^6 kWh
Combined Operation	
Firm Energy	648.3 x 10^6 kWh

4. Transmission Line

Length	50 km
Voltage	115 kV
Number of Circuit	2 Circuits

5. Drainage Works

Drainage Area	81,600 ha
Design Drainage Discharge	
Mountain Area	2.2 ~ 3.6 cu.m/s/sq.km
Flat Basin	0.23 ~ 0.56 cu.m/s/sq.km
Length of Principal Drainage Canals	155 km
Length of Intercepting Canals	121 km
Drainage Pumping Stations	
Number of Stations	14 places
Total Capacity	7,330 kW

6. Alleviation of River Contamination

River Discharge Increase at Juanchito	
Before Project	70 cu.m/s
After Project	130 cu.m/s

7. Construction Cost (10^3\$)

	Total	Foreign Currency	Domestic Currency
Dam and Spillway	31,281	19,266	12,015
Levees	11,600	2,250	9,350
Power Plant (Including Transmission Line, Sub-Station and Tele-communication System)	17,049	13,867	3,182
Drainage Works	19,198	3,335	15,863
Interest during Construction	12,175	5,631	6,544
Total	91,303	44,349	46,954

8. Economic Evaluation (10^3\$)

	Annual Benefits (B)	Annual Costs (C)	Benefit-Cost Ratio (B/C)
Flood Control and Drainage	5,020	3,740	1.34
Power	5,550	3,440	1.61
River Contamination	1,350	600	2.26
Total	11,920	7,780	1.53

Table 3.2 Max. Daily Average Discharge of Cauca River

Date	Salvajina (cu.m/s)	La Balsa (cu.m/s)	Juanchito (cu.m/s)	La Victoria (cu.m/s)
Dec. 1945	338	512	697 (674)	1,021
Nov. 1946	275	328	558	736
Apr. 1948	432	713	870 (670)	1,070
May 1949	377	591	590	746
Feb. 1950	633	1,189	1,600 (965)	1,961
Dec. 1950	638	775	1,078	1,381
Nov. 1951	308	603	607	930
Dec. 1952	449	627	830 (660)	1,069
Dec. 1953	465	739	1,330 (870)	1,706
Dec. 1954	461	888	1,090 (819)	1,400
Jan. 1956	835	1,175	1,325 (845)	1,551
Jun. 1957	369	734	1,110 (735)	1,440
Dec. 1957	505	673	840 (678)	1,058
Dec. 1958	304	321	590	797 (644)
Jan. 1960	660	637	1,280 (836)	1,613
Dec. 1960	457	923	1,010 (820)	1,566
May 1962	305	416	610	820
Dec. 1962	500	764	833 (681)	1,230 (767)
Nov. 1963	425	550	718 (681)	1,127 (730)
Dec. 1964	387	643	707 (668)	831 (693)
Nov. 1965	334	698	797 (732)	996 (805)
Dec. 1966	903	1,254	1,270 (1,057)	1,460 (1,048)
Nov. 1967	598	830	960 (805)	1,180 (758)

Note: The maximum daily average runoff indicated in parentheses for Juanchito and La Victoria are according to actual measurements.
These values are deformed daily average runoffs influenced by upstream inundation.

3.3 Effect of Alleviation of Contamination

The water level of the reservoir has to be drawn down to low water level prior to November and December when occurrence of floods are most frequent. For this purpose, all the effective storage volume of the reservoir has to be discharged through the powerhouse from August through to October. Therefore, the runoff of the Cauca River in September can be roughly doubled, and the alleviation of river contamination can be achieved.

In the power generation to draw down the reservoir to low water level during the dry period, it is possible to operate the plant to supply base loads to keep a constant discharge to the downstream area and daily peak demand can be supplied by Calima No. 1 and Alto Anchicaya Power Plants.

CHAPTER 4

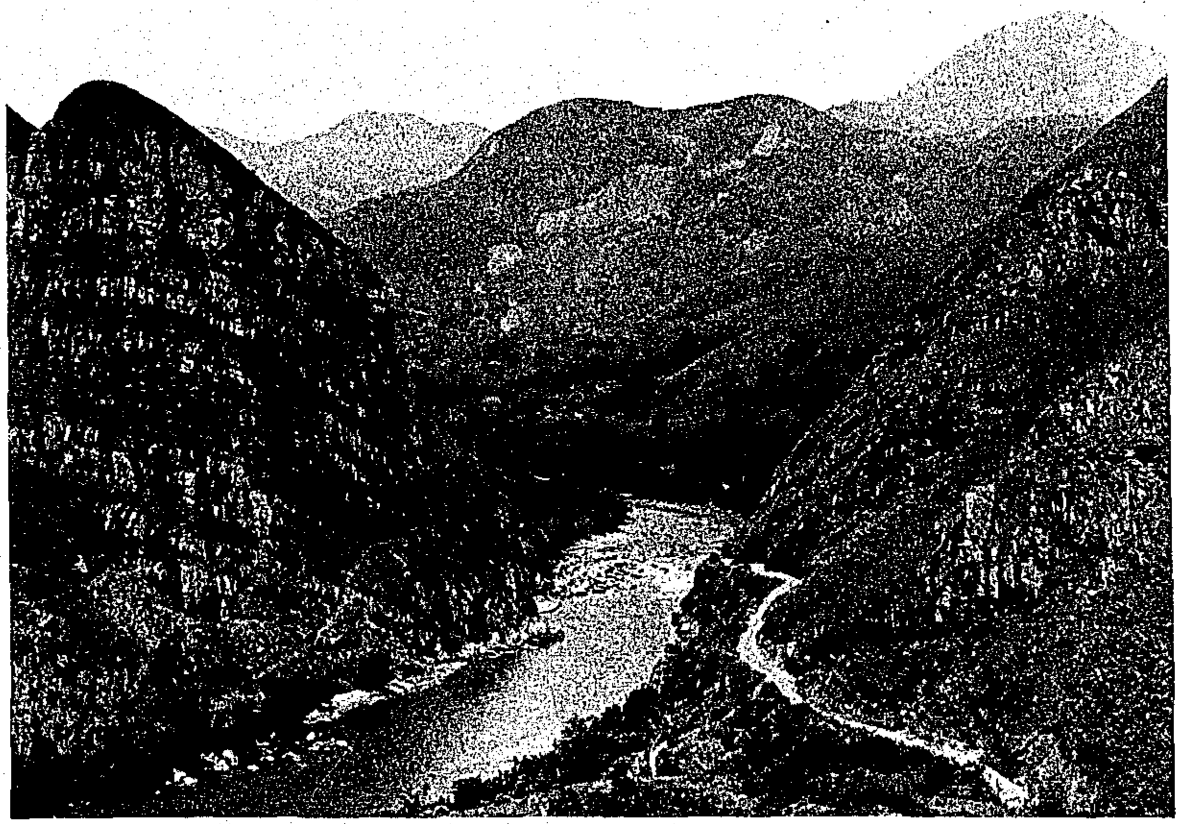
DESCRIPTION OF PROJECT AREA

CONTENTS

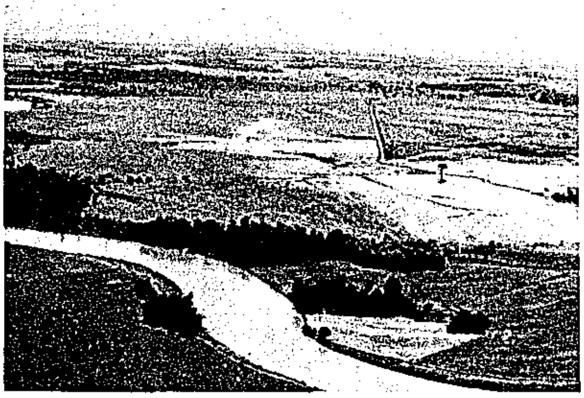
LIST OF TABLES

LIST OF FIGURES

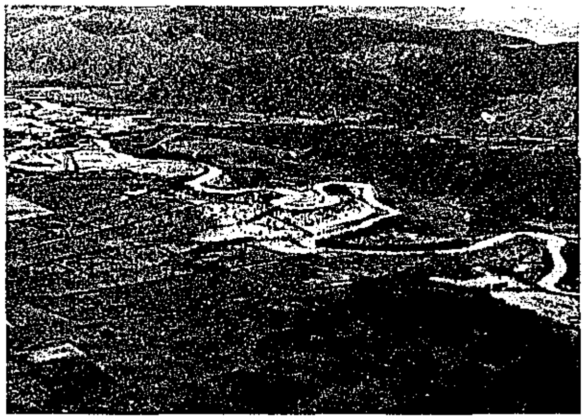
Salvajina Dam Site



Beginning of Inundation in the Riparian Area of Cauca River

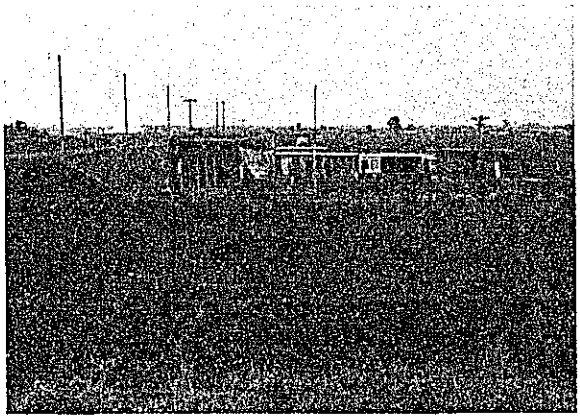
Oct. 1968 (Juanchito : 630 cu.m/s)

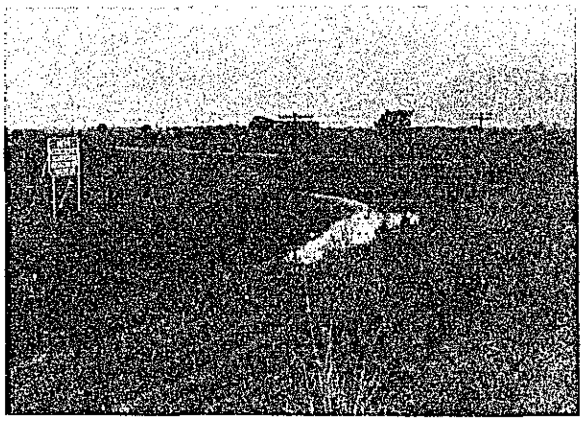



Nov. 1968 (Juanchito : 560 cu.m/s
La Victoria : 750 cu.m/s)

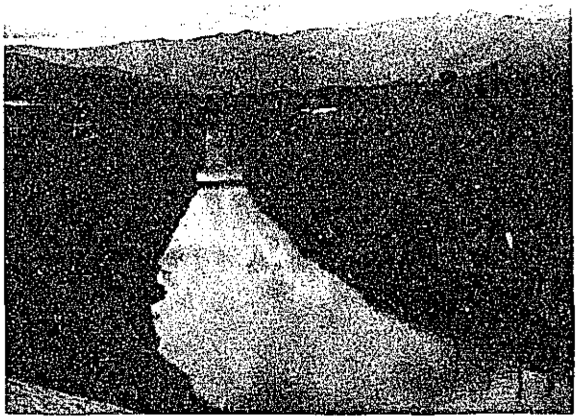

May, 1968 (Juanchito : 760 cu.m/s
La Victoria : 840 cu.m/s)

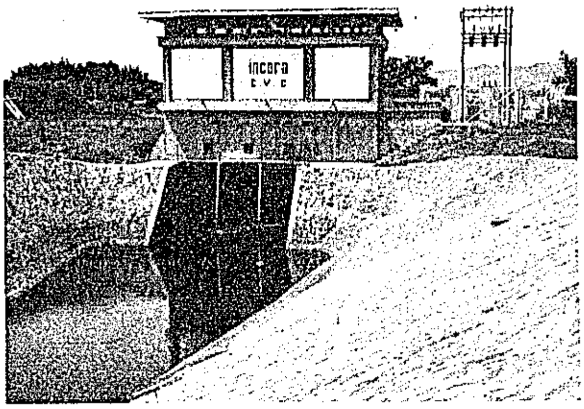
Drainage Facilities



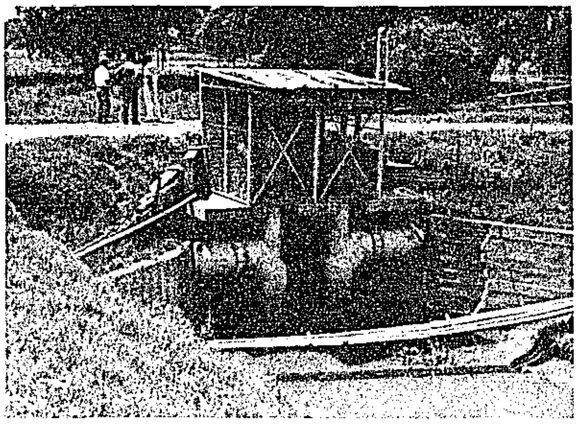


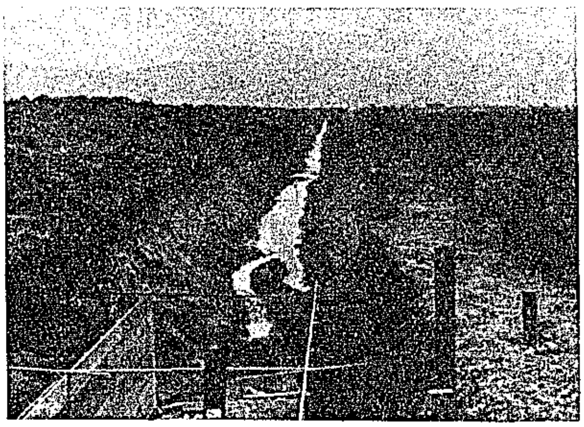
Aguablanca Project





R-U-T Project





Ing. Rio Paila

CHAPTER 4. DESCRIPTION OF PROJECT AREA

4.1 Physical Features and Hydrologic Conditions

4.1.1 Location of Project Area

The Cauca River originates at Paramo de las Papas, Departamento del Cauca of Colombia, flows to the north through several Departamentos and joins with the Magdalena River at Brazo de Loba in Departamento del Bolivar. The project area is the district along the Cauca River in Departamento del Cauca and Departamento del Valle del Cauca from 3° to 5° north latitude and 76.5° west longitude.

4.1.2 Topography and Geology

(1) Topography

Topographically, Colombia can be divided roughly into three parts. These are namely, the coastal region on the Pacific Ocean side, the mountainous region in the central area and the Amazon region in the east side. The mountainous region can further be divided into Cordillera Occidental, Cordillera Central and Cordillera Oriental. These three cordilleras are mountain ranges which form the backbone of the country running roughly parallel from south to north.

In the valleys between Cordillera Occidental and Cordillera Central and between Cordillera Central and Cordillera Oriental, there are two major rivers of Colombia, the Cauca River and the Magdalena River. The Magdalena River, after joining the Cauca River at the northern area where Cordillera Occidental and Cordillera Central terminate, flows into the Caribbean Sea.

The project area is situated in the middle of the upper stretches of the Cauca River at elevation of approximately 900 m to 1,000 m. The topography of the project area can roughly be divided into three sections.

The first section is the area upstream of the Salvajina site. The topography of this district is represented by the volcanic plateau seen in the vicinity of Popayan and the steep mountain features seen in the valley where Cordillera Occidental and Cordillera Central come close together. The river width is narrow and the topographical features are of the young to mature stage.

The next section is from Salvajina to Timba passing San Francisco. In this district the distance between Cordillera Occidental and Cordillera Central is wider than in the first section and the slopes on both sides of the river become more gentle. The width of the river, which is approximately 30 m at the Salvajina site, expands to approximately 80 m at the San Francisco site with river terraces of 50 m to 300 m wide on both banks. However, meandering of the river channel is not remarkably developed in this section.

The last section is from the Timba site passing Cali down to the lowest part of the project area. In this section the distance between the two mountain ranges is more than 40 km and the river shows completely aged topographical features. The width of the river is from several tens of meters to 100 m with flood plains of several kilometers wide formed on both banks. The river meanders forming oxbow lakes in places.

The average river gradients of these three sections are 1/100 to 1/200 upstream of Salvajina, approximately 1/600 between Salvajina and Timba and 1/1,000 to 1/7,000 between Timba and Cartago.

(2) Outline of Geology

The geological features of the project area have a close relationship with the topographical characteristics. The geology of Popayan volcanic plateau in the upstream area is comprised of volcanic products from the volcanoes around Popayan, while the geology presenting steep mountain feature in the vicinity of Salvajina consists of hard sedimentary rock such as siliceous shale and sandstone and igneous rock such as diorite. The geology of the section between Salvajina and Timba is comprised of shale and sandstone which have been extremely weathered. The last section between Timba and Cartago which presents a hilly topography consists mainly of fan deposit and river terrace deposit.

The various formations distributed in the project area are described below.

Cauca Formation

The formation of the Eocene and Oligocene epochs of the Tertiary Period are widely distributed on both banks of the Cauca River. As examples, the Salvajina dam site and a most part of the reservoir area, the San Francisco dam site and its reservoir area are composed of this formation.

This formation is further divided into the Lower Cauca, Middle Cauca and Upper Cauca Formations, The base of the Lower Cauca Formation consists of conglomerate and coarse sandstone. The Middle Cauca Formation mainly consists of black to dark blue shale and sandstone. This Middle Cauca Formation is known as a coal bearing formation. The lower part of the Upper Cauca Formation consists of conglomerate containing a large quantity of quartz pebbles while the upper part are shale interbedded with coal.

The geology of the Salvajina and San Francisco dam site belongs to this Upper Cauca Formation, but at the San Francisco site it is extremely weathered and comprises of residual soil.

Popayan Formation

The formation comprising the Popayan Plateau consists of volcanic products of the Pleiocene to Pleistocene epochs. The distribution of this formation is remarkable from Popayan to the skirts of the Cordillera Central around the project area.

These volcanic products are comprised generally of andesite and agglomerate at the lower parts and volcanic ash interbedded with andesite lava at the upper parts. The thickness of the formation is estimated to be 700 m at the thickest parts.

Valle Formation

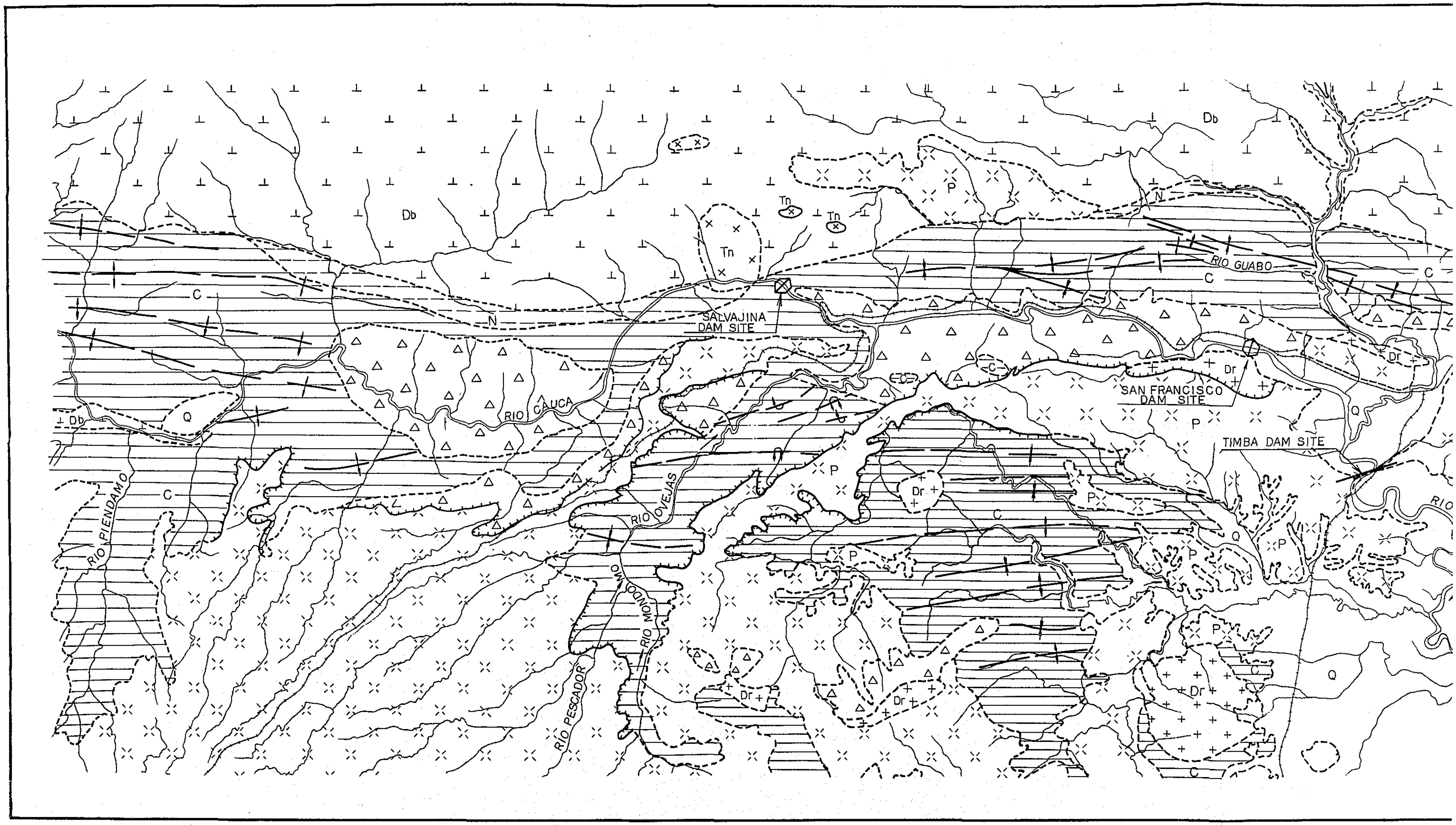
This formation of Holocene epoch is a general name for the river deposit, terrace deposit and alluvial fan deposit brought down by the Cauca River and its tributaries. The distribution of this formation can be roughly divided into two areas. One is from the Timba site to the upstream of Suarez and the other is from Timba downstream to the vicinity of Cartago.

The first is comprised of river terrace deposits accumulated along both banks of the river and small-scale fan deposits developed at the mouths of major valleys. The river terrace deposit were dredged in the past for gold mining and presently remains in the form of dredger tailings. The fan deposit are of small scale and it can be seen around the village of San Francisco typically.

The Valle Formation between the Timba site and Cartago comprises the Cauca Plain and consists of river deposit and fan deposit. The flood plains formed on both banks of the Cauca River are very wide with a total area of approximately 4,000 sq.km, while the depth of deposit is estimated to be greater than 100 m. The deposited material is generally gravelly towards the mountains and sandy to silty towards the river.

Intrusive Rock

As intrusive rocks, there are diorite distributed on the left bank approximately 2 km upstream of the Salvajina dam site and rhyolite distributed roughly parallel with the river approximately 200 m high on the mountain on the right abutment of San Francisco dam site. The diorite is estimated to be of Paleocene epoch while the rhyolite is thought to be of Miocene-Pliocene epochs.


SALVAJINA
DAM SITE
RIO GUABO
SAN FRANCISCO
DAM SITE
TIMBA DAM SITE
RIO CAUCA
RIO PIENDAMO
RIO OVEJAS
RIO MONDOMO
RIO PESCADOR
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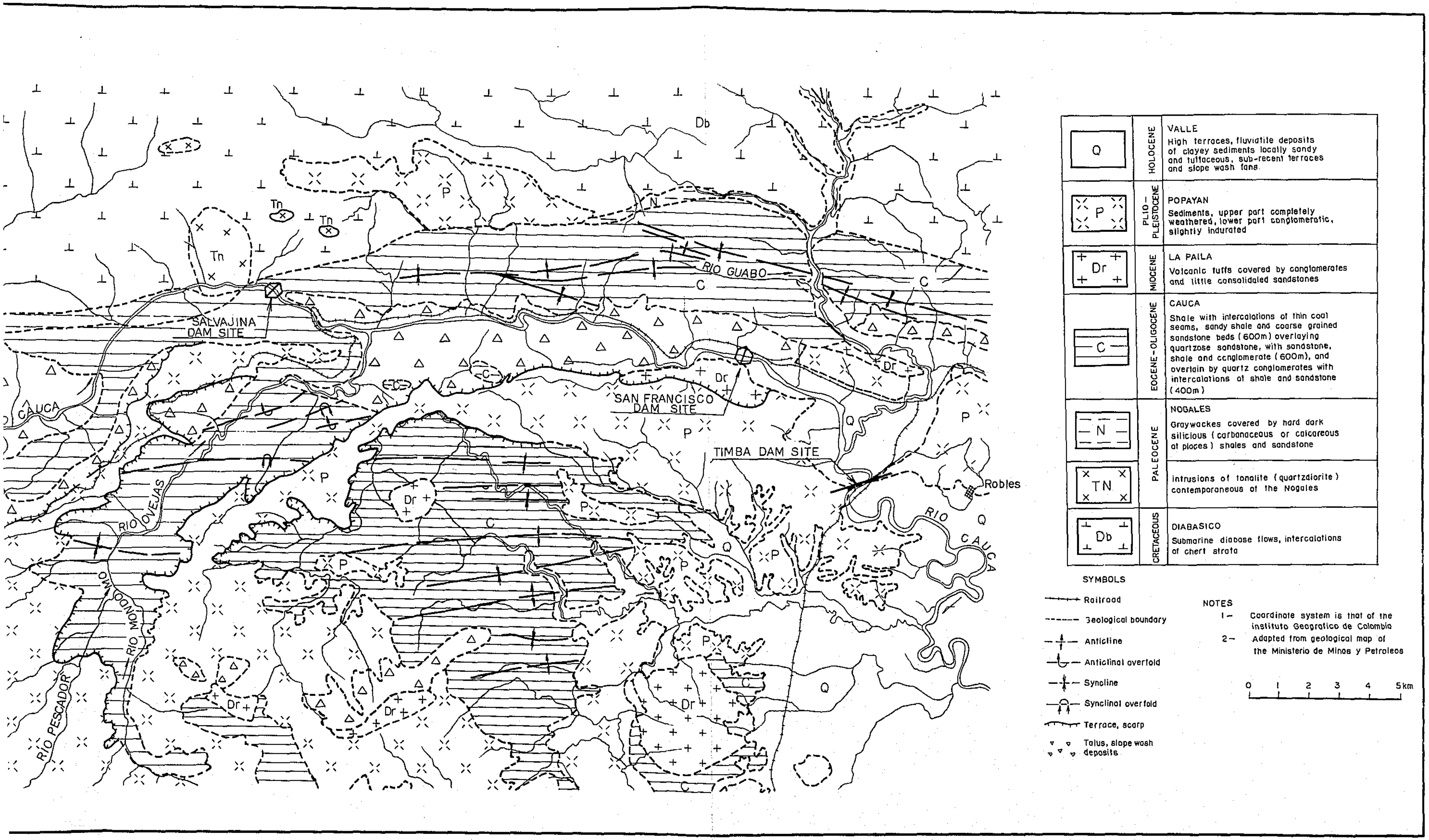


Fig. 4.1 General Geologic Plan of Project Area

4.1.3 Soil and Subterranean Water of Cauca Plain

The soil of the Cauca Plain is mainly composed of volcanic ash and water-transported sediment of weathered shale, sandstone and diabase and covered with topsoil of more than 120 cm deep. The texture composition of the soil is from sandy loam to clay. Topographically, the soils can be classified into three categories, terrace soils, alluvial plain soils and levees soils.

The PH values of the soils range generally between 5 and 8.5 (weak acid to weak alkali). The soils cannot be said to be particularly fertile from the view point of their components, but water retentivity and permeability are good and can be considered generally suitable for agricultural cultivation.

Subterranean water is abundant and many wells for irrigation, drinking, industrial and miscellaneous uses can be seen in the plain area. Investigation work is being made by CVC to obtain data of the present status of subterranean water.

Along the Cauca River, especially in flooded areas, the subsurface water table is rather high at all times, and being influenced by topographic and soil properties, there are some districts covered with water even in the dry season.

4.1.4 Meteorology

(1) Precipitation

The Cauca River basin is called "Doldrums" and is situated in a temperate weather zone uninfluenced by cold fronts and tropical depressions. The precipitation records of the basin is shown in Appendix 1, the most upstream part of the Cauca River has an annual precipitation of 2,000 mm, while in the middle reaches down to La Balsa and at the lower slopes of Cordillera Occidental and Cordillera Central, the annual precipitation is between 1,500 mm and 2,000 mm.

In general, annual precipitation of 1,000 mm to 1,500 mm is observed in the Cauca Plain area. But at Buga, Tulua and La Victoria districts along the Cauca River, the precipitation is slightly less than in the surrounding areas. (See Fig. 4.2) The period from April to May and from October to December are called rainy seasons and from July to September the dry season. The monthly precipitation distribution at Popayan and Cali are shown in Fig. 4.3 (1) and Fig. 4.3 (2). A characteristic of rainfall in this area is that it is extremely localized and that shower-type rainfall are seen.

(2) Temperature

The project area is located near the equator, but because of the relatively high elevation (higher than 900 m) the temperature is mild. Table 4.1 gives the changes in monthly average temperatures at Cali (EL. 1,080 m), La Manuelita (EL. 1,030 m) and La Union (EL. 913 m) showing that there is very little variation, being about 24°C throughout the year. The monthly averages of daily temperature changes are given in Fig. 4.4, which indicate that at Ortigal (30°17' N, 76°19'23"W, EL. 1,002 m) it is 14°C to 20°C with the maximum being 37°C and the minimum 15°C.

Table 4.1 Monthly Average Temperature (Unit: °C)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Cali 1/	23.6	23.5	23.7	24.0	24.3	24.4	23.9	23.6	23.8	24.3	24.3	24.5
La Manuelita 2/	23.3	23.3	23.2	23.5	23.7	23.8	23.6	23.4	23.4	23.6	23.6	23.7
La Union 3/	23.0	22.7	23.0	23.6	23.9	23.7	23.6	23.3	23.2	23.5	23.8	23.7

1/ Jan. 1933 - Dec. 1968
2/ Jan. 1929 - Sept. 1968
3/ Oct. 1965 - Sept. 1968

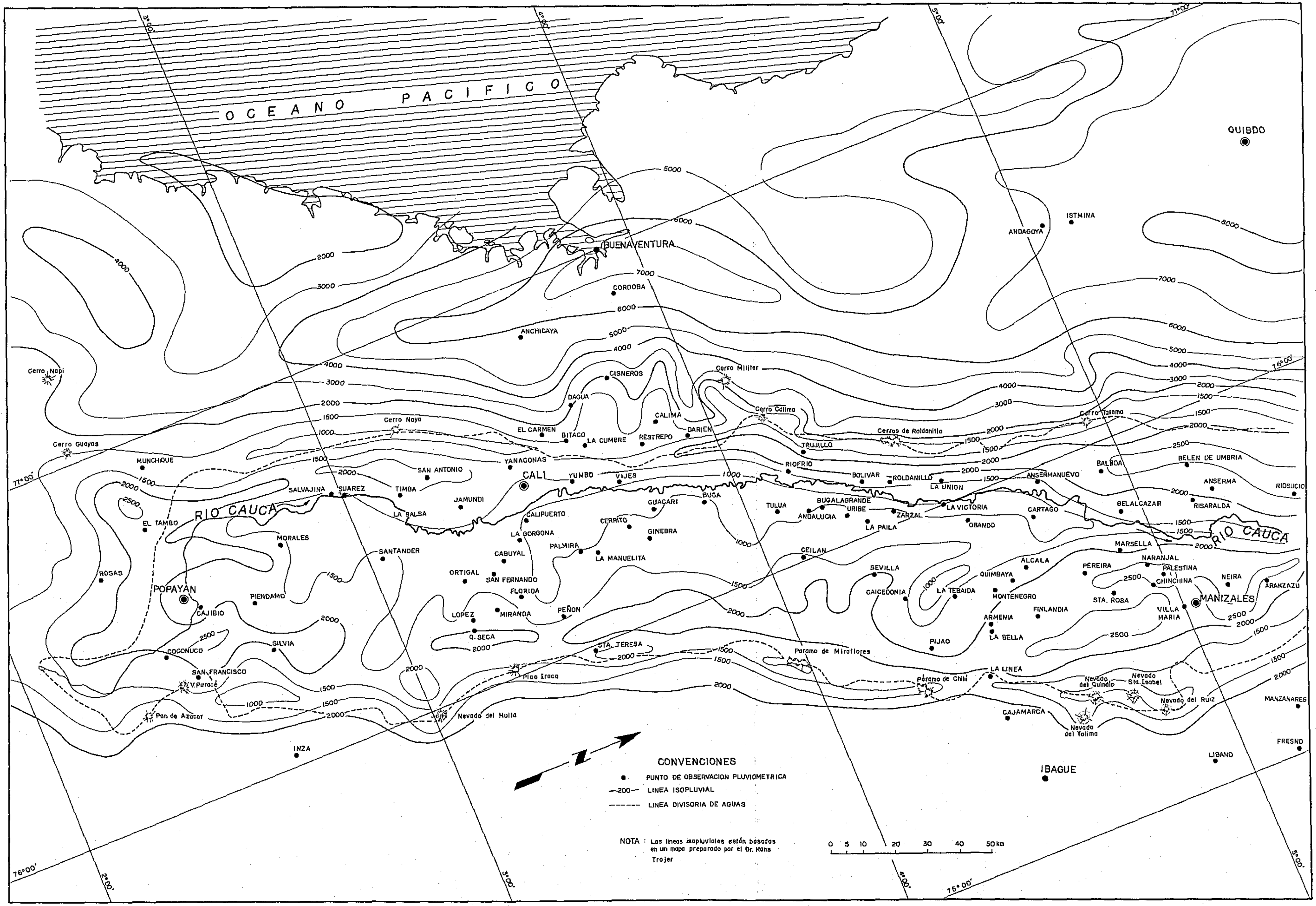


Fig. 4.2 Isohyetal Map of Cauca Valley

Fig. 4.3(1) Monthly Precipitation at Cali

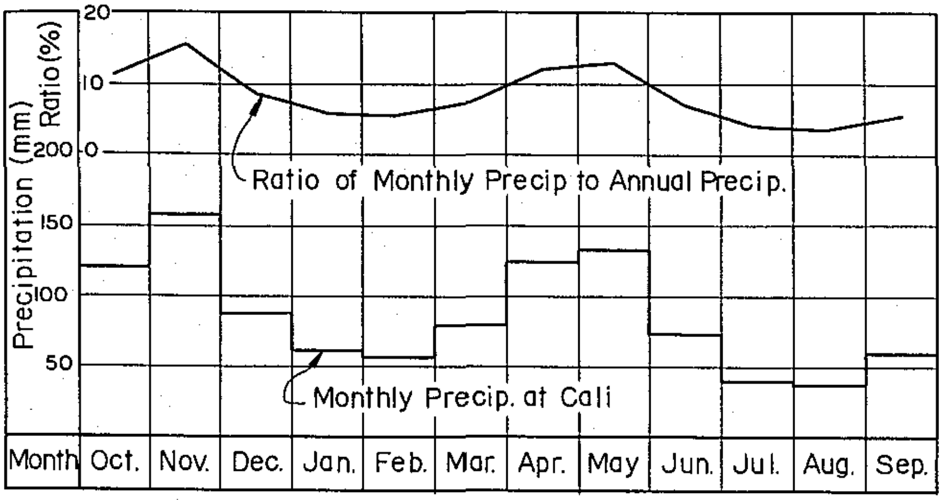


Fig. 4.3(2) Monthly Precipitation at Popayan

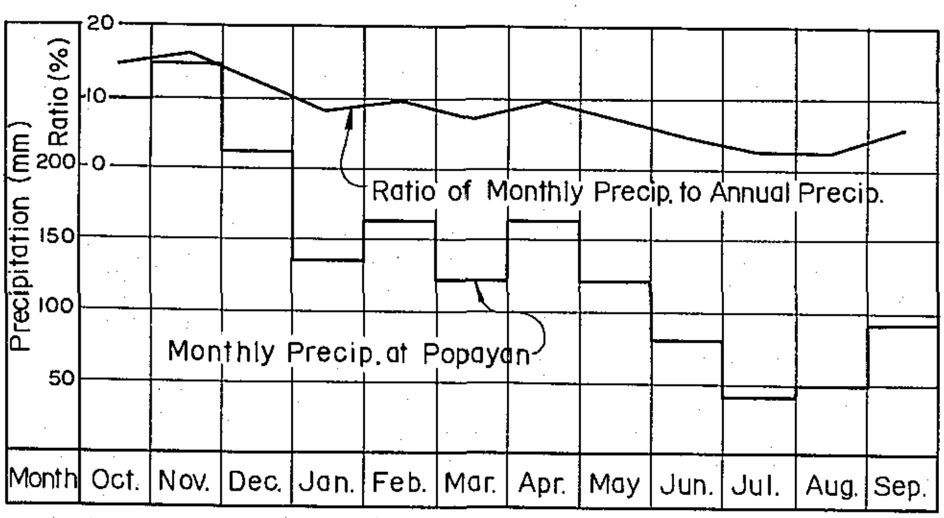
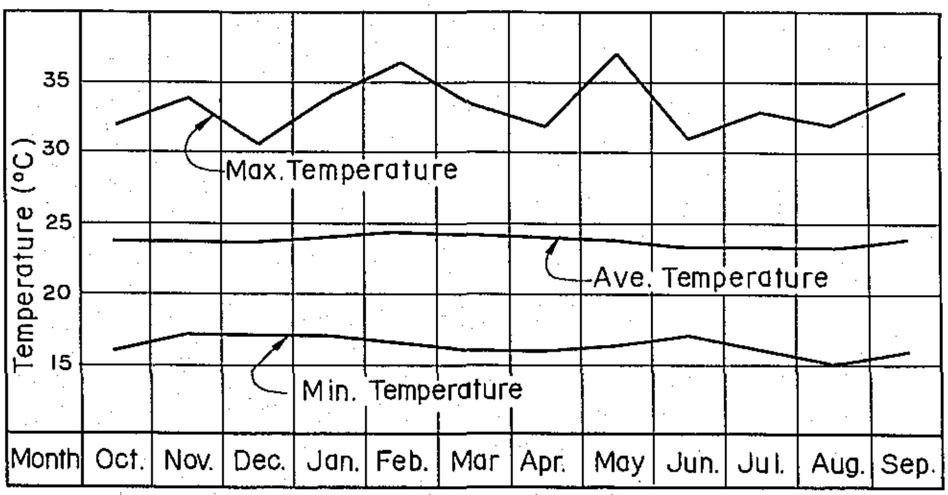


Fig. 4.4 Monthly Temperature



(3) Relative Humidity

The relative humidity as shown in Table 4.2 is around 70% 80% in the rainy seasons and 60% - 75% in the dry season indicating a dry condition throughout the year.

Table 4.2 Monthly Average Relative Humidity (Unit: %)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
La Manuelita 1/	80.6	82.6	80.6	79.6	78.6	78.1	80.1	80.4	75.5	77.8	74.7	76.4
Cali 2/	67.0	68.0	65.0	64.0	62.0	64.0	65.0	67.0	65.0	57.0	59.0	60.0

1/ Aug. 1959 - Apr. 1968
2/ 1933 - 1947

(4) Evaporation

The monthly average evaporation as observed by a class A pan is given in Table 4.3 showing that at La Manuelita it is 1,650 mm annually and 2,240 mm at La Union. Both values exceed the respective annual precipitations.

Table 4.3 Monthly Evaporation (Unit: mm)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
La Manuelita 1/	150.6	127.7	136.5	141.0	139.1	150.6	141.7	133.8	122.6	142.4	134.3	134.3
La Union 2/	177.7	147.6	158.1	195.0	192.2	205.5	218.5	143.4	152.3	202.0	233.4	217.5

1/ Aug. 1959 - Apr. 1968, Annual Total 1,654.6 mm
2/ Apr. 1967 - Mar. 1968, Annual Total 2,243.2 mm

4.1.5 River Characteristics and Flow Conditions of the Cauca River

The Cauca River between La Balsa and La Victoria presents a typical meandering feature with progressive meandering in accordance with flow velocity, discharge and soil character at the river banks. As a result, there are many oxbow lakes along both banks of the river such as Cienaga Cauca Muerto and Madre Vieja. Some of these oxbow lakes have become swamps and bogs, losing the nature of lakes through sedimentation caused by periodical inundations in the long years since their formation. Also, there are many low basins which have already lost the character of swamps and bogs, and although slightly low in elevation, are suitable for farming and are being used as pastures and farmland which are widely distributed on both banks of the Cauca River.

On the other hand, deposition of silt and sand transported from the upstream and soil eroded by the action of flowing water have slowly raised the river bed and reduced the flow capacity of the river channel. Consequently, the flow capacity of the river is approximately 650 cu.m/s and approximately 750 cu.m/s at Juanchito and La Victoria respectively, which capacity compared to the drainage area is extremely unbalanced.

Because of the above situation, taking Juanchito and La Victoria as examples, when the river discharge approaches the beforementioned capacity, inundation of the lowlands along both banks of the river begins due to back flow of the mainstream or retardation of tributary flow. This phenomena can be seen on the aerial photographs which are attached in this chapter. These low basin lands are in itself areas with poor drainage and are easily inundated by heavy local rainfall irrespective of the water level of the Cauca River. The initial stages of floods along the Cauca River which are occurring periodically are thought to be provoked by the above causes. It is clearly seen that the inequilibrium and lack of river channel capacity and the low basin areas along both banks are the causes of floods of the Cauca River.

The annual runoffs at Salvajina (drainage area 3,830 sq.km), Juanchito (drainage area 9,060 sq.km) and La Victoria (drainage area 17,650 sq.km) gauging stations on the Cauca River from 1946 to 1968 (from 1959 for La Victoria) are shown in Table 4.4 and Fig. 4.5. The annual average runoffs are 140 cu.m/s, 270 cu.m/s and 330 cu.m/s respectively. Floods occur in the period from November to January and from April to May while the dry season is from August to September.

Table 4.4 Monthly Average Discharge (Unit: cu.m/s)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.
Salvajina	106.1	202.5	236.6	162.0	143.9	132.9	145.6	151.3	134.8	105.1	79.2	58.0
Juanchito	205.8	389.5	417.0	308.9	281.1	254.9	319.5	341.6	278.6	192.0	138.4	105.8
La Victoria	221.3	507.8	511.2	367.2	334.3	282.2	408.4	475.9	401.2	267.9	185.0	141.8

Average Discharge:

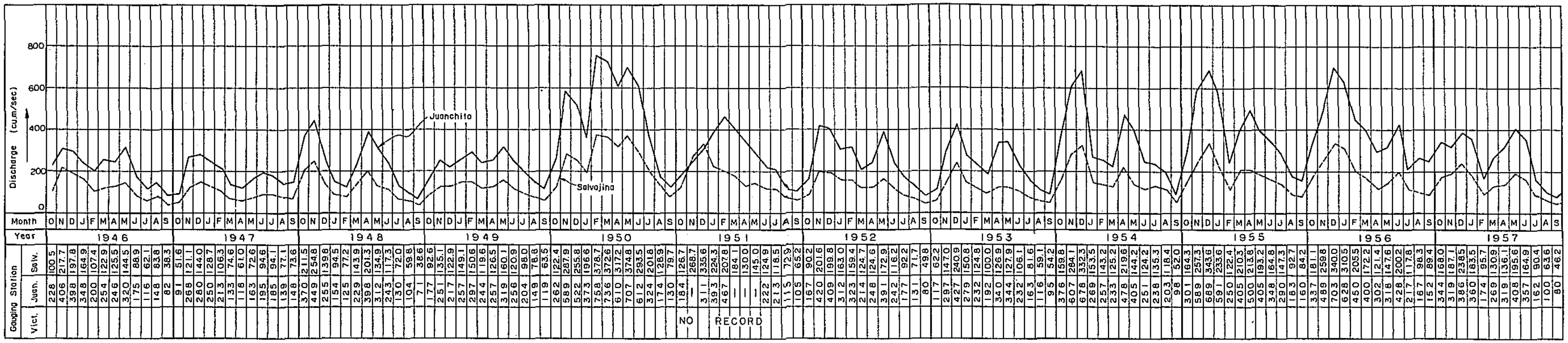
Salvajina	130.2 cu.m/s
Juanchito	281.2 cu.m/s
La Victoria	326.0 cu.m/s

The average monthly maximum and minimum and the average daily maximum and minimum discharges of the abovementioned three stations are given in Table 4.5.

Table 4.5 Flow Condition of Cauca River

	Salvajina		Juanchito		La Victoria	
	cu.m/s	Date	cu.m/s	Date	cu.m/s	Date
Max. Monthly Average	606	Dec. 1967	836	Dec. 1967	913	Dec. 1967
Min. Monthly Average	38	Sep. 1946	71	Sep. 1948	100	Sep. 1961
Max. Daily Average	903	19 Dec. 1966	1057	20 Dec. 1967	1048	23 Dec. 1967
Min. Daily Average	29	4 Oct. 1961	53	30 Sep. 1961	64	8 Oct. 1962

Because of the present river channel capacity, which are about 650 cu.m/s at Juanchito and 750 cu.m/s at La Victoria, discharge records of more than 650 cu.m/s at Juanchito and 750 cu.m/s at La Victoria present deformed values due to inundation in the lowland area.



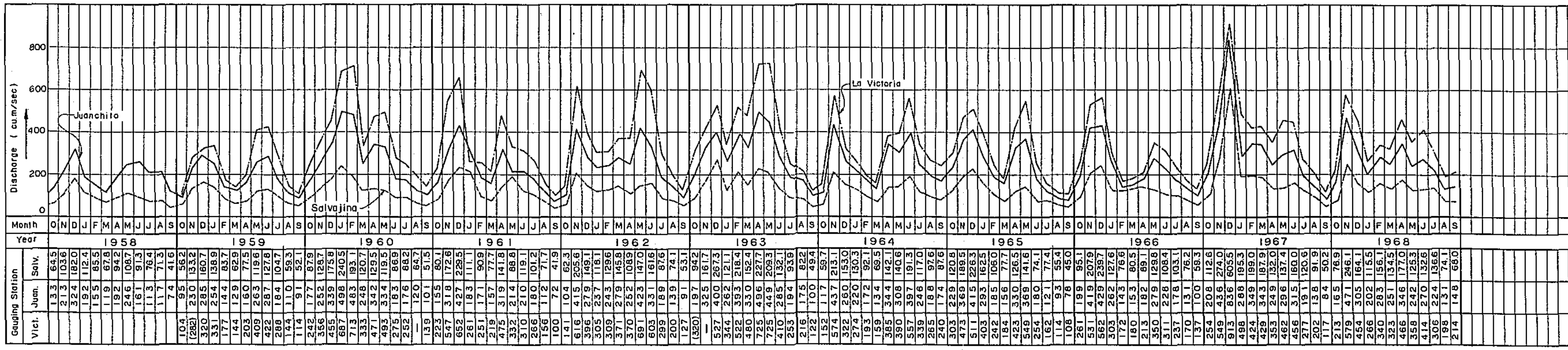


Fig. 4.5 Natural Discharge of Cauca River

4.2 Social and Industrial Situation

4.2.1 Population

The estimated population in 1969 of Departamento del Cauca and Departamento del Valle del Cauca in which the project area is located is 2,725,000, corresponding to 13.3% of the entire nation, while the population density is 52.8 per sq.km which is one of the heaviest in the country.

The recent population growth rate has been 3.2% per annum for the entire country, but in Departamento del Valle del Cauca to which most of the Cauca Plain belongs, the annual growth rate has been 3.4%. Particularly in the city of Cali, the center of government and economy of this region, there has been a rapid development from 1950 recording an annual population growth rate of more than 6%.

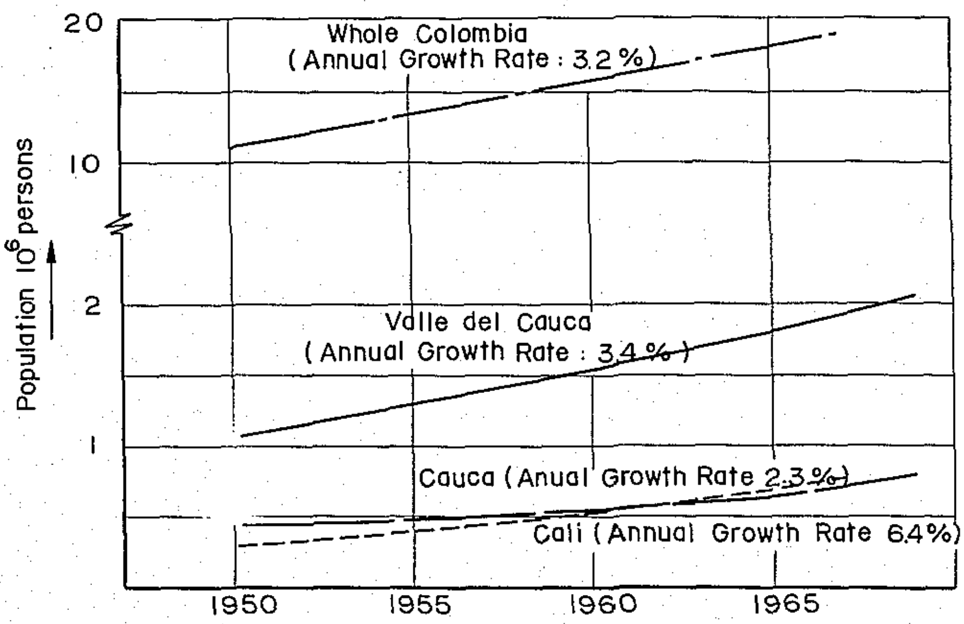
According to the population census conducted in 1964, the industrial workers in Departamento del Valle del Cauca and Departamento del Cauca numbered 717,000 out of which 43% were engaged in agriculture, forestry and fishing, 17% in services, 15% in manufacturing and 10% in commerce. (See Table 4 in Appendix 3.)

Table 4.6 Area and Population in 1969

Departamento	Area		Population		
	10^3 sq.km	Percent	10^3 persons	Percent	per sq.km
Cauca	30.5	2.7	680	3.3	22.3
Valle del Cauca	21.2	1.9	2,045	10.0	96.5
Total	51.7	4.6	2,725	13.3	52.8
Whole Colombia	1,138.9		20,463		18.0

Colombia Estadisticas Basicas, Banco de la Republica, 1969.

Fig. 4.6 Trend of Population



4.2.2 Agriculture

It is said that the agricultural land in the Cauca Plain is approximately 400,000 ha. One half of the area is pasture land for livestock grazing, 25% is, in contrast to pasture land, comprised of sugar cane plantations which are centered around sugar mills. Where the agriculture is organized, irrigation and drainage facilities are fully equipped. The remaining 25% is ordinary fields in which maize, sorghum, cotton and soybean are cultivated 1/2/; Most of the agriculture is of large scale with mechanized operations.

The average area managed by one farm household is 23 ha 1/, but farm households with more than 100 ha are numbered only 4% of the total farmholding and constitute 60% of the total farm area. (See Table 5 in Appendix 3.)

Ownership of the land is mostly private. The ratio between privately owned land and tenant land is 7:3 for farmholdings of 3 - 10 ha, while for larger farmholds, the ratio is about 8.5 : 1.5 3/

With the exception of sugar cane and cotton, two-crop farming is practiced, the first crop from February to July and the second crop from August to January. Cotton, on account of weather, is grown only in the first season, while sugar cane requires over ten months for one crop.

The cropping ratios 4/ of these crops and the yields per ha 5/ are generally as indicated in Table 4.7. Of these crops, the cultivated area for maize and soybean are recently showing a trend of rapid increase, while rice, beans and sugar cane are in a state of balance and cotton is lightly on a downward trend. Cattles raised in pastures number 1 to 2 head per ha.

Table 4.7 Average Yield and Cropping Ratio in Cauca Plain

Crop	Average Yield per Ha (Ton)	Cropping Ratio 1/ 1st Season (%)	Cropping Ratio 1/ 2nd Season (%)
Cotton	2.0	14	–
Rice	3.0	6	7
Maize	2.5	37	39
Sorghum	2.5	13	9
Soybean	2.0	26	39
Bean	1.5	4	5
Others	–	–	1
Total		100	100
Sugar cane	80.0		

1/ Cropping Ratio in "Departamento Valle del Cauca" only.

1/ Encuesta Agricola Nacional 1966
(Departamento Administrativo Nacional de Estadistica)

2/ Informe Sobre Evaluacion de Perdidas Causadas por las Inundaciones en las Departamentos del Valle y Norte del Cauca - en Diciembre 1966 - CVC

3/ Censo Agropecuario del Valle del Cauca 1959

4/ Desarrollo Agricola del Valle del Cauca, Censo de Seis Cultivos (IFA, 1967)

5/ Rentabilidad de Diversos Cultivos Agricolas y Explotaciones Ganaderas en el Valle del Cauca
(Universidad del Valle, Facultad de Ciencias Economicas, Cali Marzo de 1966)

4.2.3 Present Irrigation and Drainage Facilities

Some of the farmers have privately constructed levees surrounding their property and drainage canals to prevent inundations and to dispose waste water. But, for the greater part of farmland in the Cauca Plain, tributaries and creeks serve as drainage channels.

Except for a small number of concrete intake dams, most irrigation water is obtained by means of primitive weirs built with brushwood and stone or by simple intakes. Some farmers who have no title to conduct water from tributaries are taking abundant subterranean water of the Cauca Plain for irrigation purpose.

Generally speaking, private irrigation facilities and levees have all been planned and constructed privately so that there are some facilities which are technically inadequate. From the standpoint of overall development program for the Cauca Plain, they are considered to be inefficient with regards to utilization of water resources and planning of irrigation and drainage system.

4.2.4 Mining and Manufacturing

The major mineral resources found in the Cauca Plain and surrounding areas are coal (deposits 400 x 10^6 tons), gold and limestone in Cordillera Occidental and gold and gypsum in Cordillera Central.

The main manufacturing industries in the Cauca Plain are agricultural products processing industries such as sugar mill, flour mill, oil extraction and cotton mill and related industries including confectionery, paper manufacturing and textile weaving, and ceramic industries such as cement and porcelain using mineral resources. Besides, there are manufacturing industries of rubber products, chemicals, machinery parts and electrical appliances. Most factories are in Cali and its suburbs, although there are some distributed in the country such as sugar mills.

4.2.5 Electric Power Situation

(1) Background

The power systems of Colombia have been developed centering around the three large cities of Bogotá, Medellin and Cali. Each of these systems have been operated independently, but interconnection by 230 kV transmission lines is being carried out by ISA with completion scheduled in 1971. Thereafter, a central interconnected system including the abovementioned three large cities will have been completed, and it will then be possible to interchange power through the interconnection transmission line.

The gross national product of Colombia in 1967 was 5,700 million dollars in real terms or 300 dollars per capita[1/], which is roughly the same level as in Brazil and Peru, belonging to the middle group of Central and South American countries. An economic growth rate of 4.6% was achieved in that year. In the 10-Year Economic and Social Development Plan initiated in 1961, the target annual growth rate in real gross national product in the first half of the plan is 5.6% while in the latter half a higher rate is anticipated.

Reflecting the above economic activity, there has been a marked increase in power demand in Colombia in recent years and during the 10 years from 1957 to 1967 energy production has increased from 2.1 x 10^9 kWh in 1957 to approximately 2.8 times or 6.0 x 10^9 kWh. This corresponds to an annual average growth rate of 11%. Taking into account the fact that this growth rate has not changed in the recent 5-year period, it may be judged that the growth rate is very steady. The per capita energy production in 1968 was 380 kWh, and as in the case of GNP per capita, this is near the average value for Central and South American countries including Brazil and Peru.

1/ Progreso Anexo Estadistica

The Andes Mountain Range which passes through Colombia hinders economic development of an expansive area, but creates a great number of favorable hydroelectric sites. Therefore, hydroelectric power generation is of great importance in this country. Taking the energy production of 1967 as an example, three-fourths of the entire energy production was supplied by hydro while only one-fourth was thermal. Thermal power generation is mostly situated in the northern coastal areas where natural conditions for hydroelectric power generation are not favorable.

The installed power capacity in 1967 was 1,680 MW, of which 980 MW was hydro, 59%, and 700 MW was thermal, 41%. In view of the fact that new power plants under construction (770 MW) is mostly hydro, the composition of hydro is expected to become even greater.

(2) Organization of Electric Utilities

Power supply in Colombia is carried out by publicly-owned utilities and government agencies, described below, which are centered around large cities. These organizations supply more than 90% of the energy consumed in Colombia.

(i) Empresa de Energia Electrica de Bogotá (EEEB)

This is a municipally operated power company supplying electricity to Bogotá, the capital of Colombia, and the surrounding area. As of 1968 the installed capacity was 437.5 MW (353.5 MW hydro, 84.0 MW thermal). At present the second stage of El Colegio Project (50 MW x 3) and the Canoas Project (50 MW) are under construction.

(ii) Empresas Publicas de Medellin (EPM)

This is a municipally operated public utility serving Medellin, the second largest city in Colombia. Besides electric power, it also provides telephone service and city water and sewage facilities.

When the first stage of Guatape Project, 280 MW, now under construction is completed, the installed capacity is scheduled to reach 695 MW. Since the vicinity of Medillin is favored with promising hydroelectric sites with high heads, the facilities of the company are comprised entirely of hydro and there are still many large projects which can be developed in the future.

(iii) CVC

CVC is a public utility established by law in 1954 with one of its purposes being the comprehensive development of water resources in Departamento del Valle del Cauca. In addition to power, it is engaged in a broad field of activities including flood control, irrigation and drainage, and farmland improvement, etc.

(iv) Instituto Colombiano de Energia Electrica (ICEL)

This is a government agency which was called before 1968 "Instituto de Aprovechamiento de Aguas y Fomento Electrico". The objective of this agency is to promote electrification of Colombia through capital participation in departamento-operated power companies in areas other than those served by the beforementioned big-three power companies. It provides financial and technical assistance. The installed capacity administered by the agency in 1968 was 466 MW with 292 MW under construction.

(v) ISA

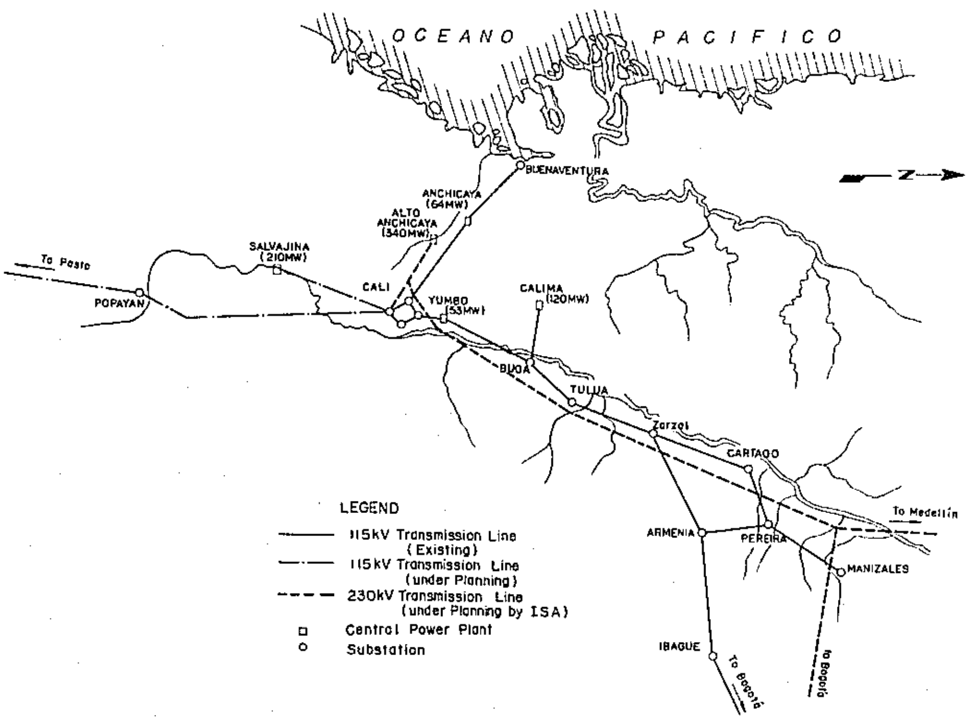
ISA, unlike the 4 power supply organizations mentioned above, is a unique existence which does not have direct consumers. It was established in 1967 with the purpose of interconnecting the 4 power systems of Bogota, Medellin, CVC and Central Hidroelectrica de Caldas (hereinafter referred to as "CHEC") by constructing transmission lines to improve system reliability and to make savings in reserve capacity, and also to produce scale merit through development of large-scale hydroelectric projects. EEEB, EMP, CVC and ICEL have respectively contributed 25% to the capital. The 230 kV interconnection transmission lines are presently under construction and are scheduled to be completed in 1971.

(3) Present Status of CVC Power Facilities

CVC has, up to the present, constructed Calima No. 1 Power Plant (120 MW, hydro) and Yumbo Power Plant (coal-burning thermal, 53 MW). Operation of the power plants is left to Anchicaya Power Co. (CHIDRAL), a subsidiary, and CVC is not concerned directly with operation and maintenance. Also, CVC is not engaged in the distribution of power, except for a limited area. At Cali, distribution is carried out by Empresas Municipales de Cali (hereinafter referred to as "EMCALI"), a municipal enterprise. The CVC System is now interconnected with the CHEC System to the north by a 115 kV transmission line, and with Bogotá System by 115 kV transmission line between Ibague and Zarzal.

As capacity addition corresponding to growth of load was not implemented in the past, a severe load restriction was imposed in the CVC System for two months of August and September of 1969. This critical situation was relieved by the energy received through the abovementioned transmission line and by the natural increase of runoff, but a fundamental solution will not be achieved until completion of the interconnecting transmission line scheduled in 1971.

Fig. 4.7 CVC Transmission Line System



The power generation facilities of CVC and its subsidiary, CHIDRAL at the end of 1969 are given in Table 4.8. The installed capacity consists of 194.4 MW of hydro (73%) and 71.6 MW of thermal (27%). Compared with the Bogota and Medellin Systems, the proportion of thermal is relatively high. In Departamento del Cauca, there are also 4 MW of small-scale hydro so that the installed capacity which can be utilized in the CVC System is 270 MW with continuously available energy being 120 MW. When Alto Anchicaya Power Station (340 MW) is completed, the installed capacity will be 610 MW with a dependable output of 282 MW. The installed capacity and continuously available energy of the CVC-CHEC System are 344 MW and 181 MW respectively as shown in Table 4.9.

Table 4.8 Generating Facilities of CVC System

Generating Plant	Type of Plant	Dependable Peak Capacity (MW)	Continuously Available Energy (Firm Power Energy) (MW)
Calima I	Hydro	120.0	22.1
Anchicaya	Hydro	64.0	21.5
Cali	Diesel	9.7	3.5
Yumbo I, II, III	Thermal	53.0	42.4
Nima I, II	Hydro	7.3	5.3
El Morro	Diesel	6.0	2.3
Buenaventura	Diesel	2.9	1.8
Small Hydro	Hydro	3.1	2.2
Increase of Prime Energy for Combined Operation of Calima I and Anchicaya Power Plant	–	–	16.4
Sub-total		266.0	117.5
Small Hydro of Other Company	Hydro	4.0	2.5
Grand Total		270.0	120.0

Table 4.9 Dependable Peak Capacity and Continuously Available Capacity of CVC–CHEC System

	Dependable Peak Capacity (MW)	Continuously Available Energy (Firm Power Energy) (MW)
CVC	270	120
CHEC	70	57
CEDELCA	4	4
Total	344	181

4.2.6 Transportation

Transportation in the Cauca Plain has developed rapidly in recent years and is conveniently accessible both by land and air. In the Cauca Plain, besides Cali, there are local municipalities such as Santander, Palmira, Buga, Tulua, Zarzal and Cartago, etc. which are located from south to north at distances of several tens of kilometers from one to another and highways and railroads have been constructed connecting these cities.

To the south, only the highway extends to Popayan and leads to Ecuador passing Pasto, while to the north, the roads leads to Medellin and Bogota. The only port on the Pacific Ocean coast, Buenaventura, is connected with Cali by highway and railroad. Cali Airport located between Cali and Palmira is serving not only a domestic airline connecting the major cities of Colombia, but also international airlines serving North America and Andean countries.

CHAPTER 5

PROBLEMS AND NEEDS OF THE REGION

CONTENTS

LIST OF TABLES

LIST OF FIGURES

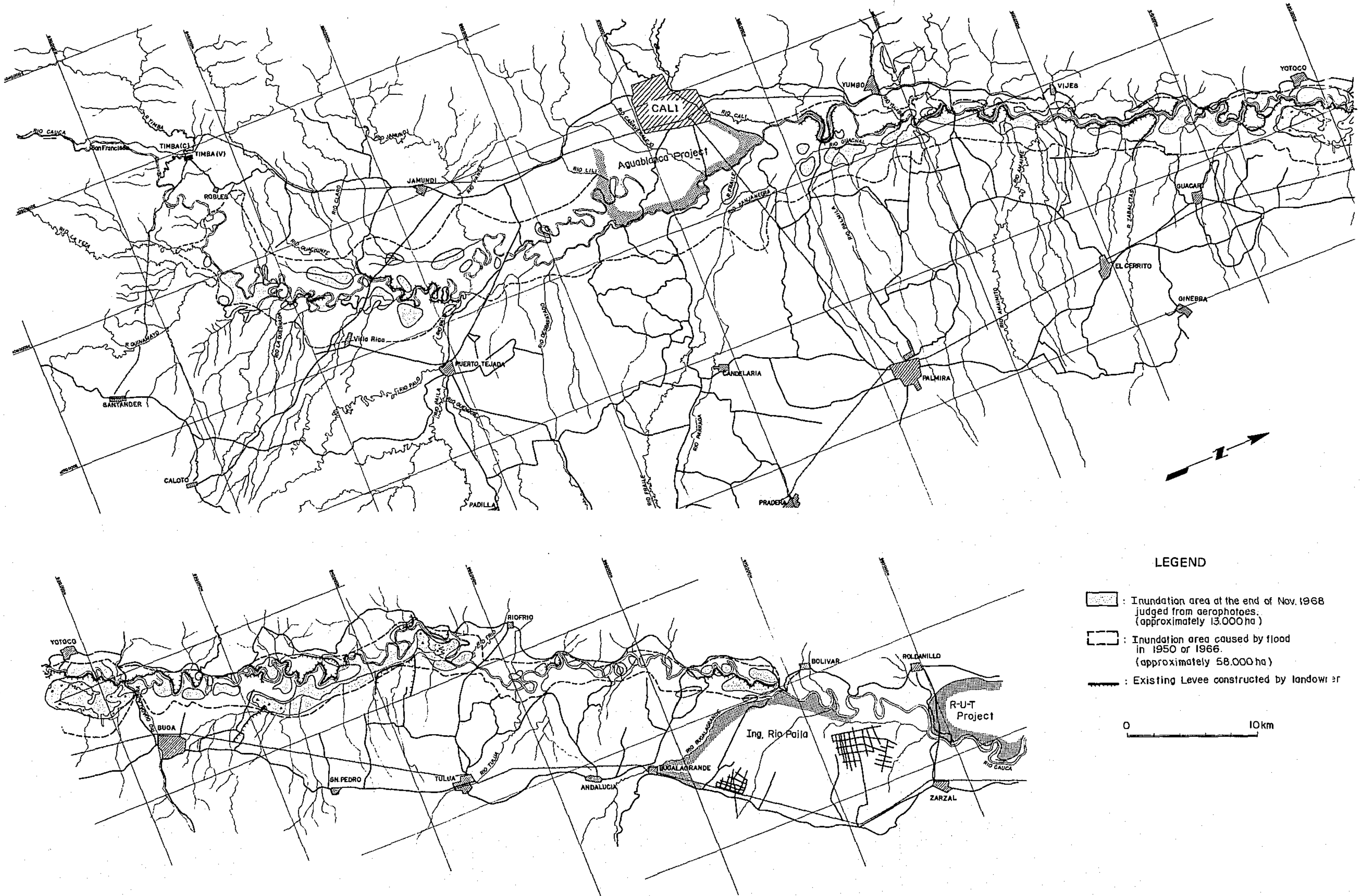


Fig. 5.1 Inundation Area in Cauca Plain

CHAPTER 5. PROBLEMS AND NEEDS OF THE REGION

5.1 Population Growth and Improvement of Living Standards

In consideration of the recent rapid increase of population and the increase of food consumption 1/ 2/ per capita due to improvement of living standard as a result of economic development and the necessity of improving trade balance through exports of agricultural products and its processed goods, it is considered a pressing need to improve and increase agricultural products economically and sufficiently through effective agricultural development.

Considerable weight has been put on this sector by the government in the 10-Year Social and Economic Development Plan which started in 1961. And also in the agricultural development plan established in 1967, the goal has been set to increase production of staple food and broadening exports of other agricultural products than the traditional export item of coffee.

Table 5.1 Consumption of Agricultural Products

Agricultural Products	Consumption per Capita		Annual Increasing Ratio
	1965 (kg)	1970 (kg)	(%)
Cotton	3.5	4.0	2.5
Maize	56.4	60.0	1.2
Soybean	2.8	3.1	2.3
Rice	21.6	24.5	2.5
Sorghum	3.9	6.9	12.0
Bean	2.9	2.9	–

5.2 Periodical Flood of the Cauca River and Poor Drainage

The Cauca River, due to insufficiency and inequilibrium in river channel capacity and the low basin areas along both banks, has caused inundation periodically almost every year from November to January. The areas inundated have ranged from several thousand hectares in small floods to 50,000 to 60,000 ha in big floods. (See Fig. 5.1) Also, because of the vast catchment area, the duration of flood peak is long, and aggravated by poor drainage of the low basin areas on both banks. Farmland once covered with flood water is inundated or kept in an overwet condition for a long period. As a result, there is hindrance to crop growth and damage to facilities as well as presenting obstacles to tilling of land.

Concerning damage caused by floods, the losses in the several thousand hecters in small floods are rather small as the inundated land is mostly pastures. But for the flood of December 1966, which has a return period of approximately 10 years at La Victoria, the investigations by CVC 3/ of the inundated area of 57,600 ha disclosed total damages amounting to 82.6 million pesos to crops, livestock, facilities, houses and factories. Based on this amount of damage and corresponding excess flood volume which exceeds river channel capacity of the 1966 flood, and considering the excess flood volume for each of the past 23 years, annual loss from flood damage is estimated at approximately 70 million pesos at the present rate of 17.35 pesos per US dollar.

1/ Controle del Inundacion en el Valle del Cauca, Banco Interamericano de Desarrollo, 1968.

2/ According to "The State of Food and Agriculture, 1968, FAO", the average per capita consumption of nutrition in Colombia was 2,220 calories, 55.3 grams of protein (including 25.6 grams of animal protein) and 47.2 grams of fat, with possibility of further increase in the future.

3/ Perdidas Causadas por las Inundaciones en Los Departamento del Valle del Cauca y Norte del Cauca

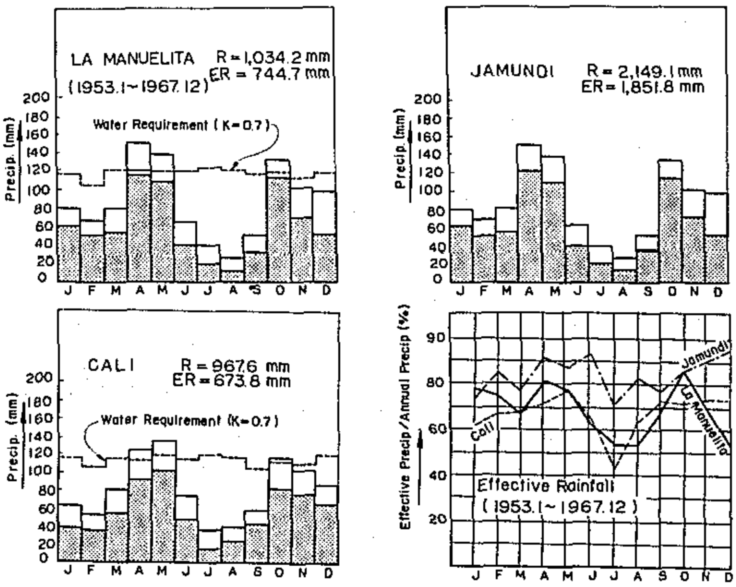
There are some levees constructed by CVC and private enterprises along the mainstream and major tributaries, but except for those of Aguablanca, R-U-T and Rio Paila[1/] they are of small scale and not continuous and not reliable for large flood. Regarding drainage facilities, there are a few gravity and pumped drainage facilities in parts of the farmland besides in the abovementioned three areas. And it is indispensable to apply drainage works for the low basin areas for promotion of agriculture industry.

5.3 Shortage of Irrigation Water

Sunshine and temperature in the Cauca Plain are suited for cultivation of crops throughout the year. Rainfall in the plain is 1,500 mm annually. However, the distribution of rain is not favorable for growth of crops. In other words, while the amount of water necessary for favorable growth of crops is about 110 mm to 130 mm monthly, the effective rainfall as shown in Fig. 5.2 is 40 mm to 120 mm satisfying only 40% to 80% of the needs. There are several times annually of 10 to 15 days of continuous drought during growth period of crops.

The shortage of water hinders not only the growth of crops, but also causes disruptions in rotation of crops resulting in, while also indirect losses due to holding back of fertilizer application for fear of drought also cannot be neglected.

Fig. 5.2 Water Requirement and Effective Rainfall



5.4 Contamination of the Cauca River

5.4.1 Present Status of Contamination

Cali, the foremost city along the Cauca River, is said to have a population of one million. The economic development of the area centered around Cali has been remarkably aided by timely policies of the government and favorable circumstances, but in proportioning to the development, the increasing sewage from Cali and the industrial wastes from the Yumbo industrial district discharged directly into the Cauca River have steadily raised the degree of contamination of the river to aggravate the situation to extremes. There are areas where fishlife has disappeared while domestic and agricultural water uses on the downstream are beginning to be adversely affected.

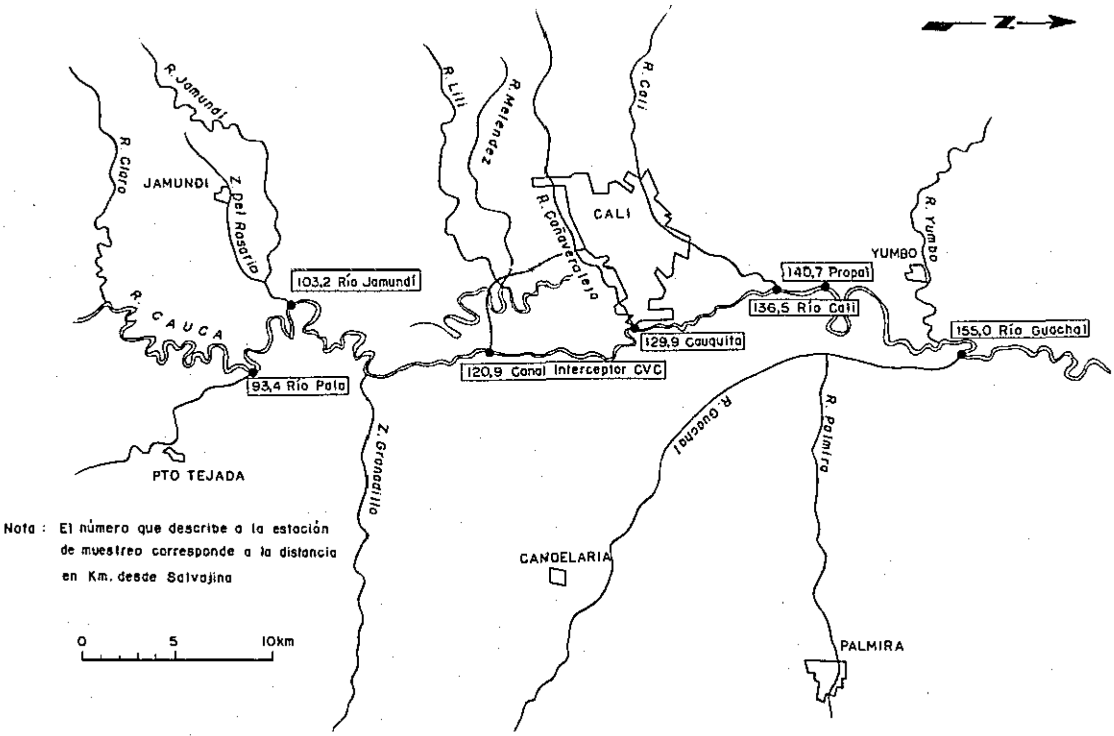
1/ Length of Levees

Aguablanca	:	15 km
R-U-T	:	44 km
Rio Paila	:	6.5 km

Regarding this situation of the Cauca River, there are reports of the investigations carried out by Mr. Jacques Edward Donaldson of Tulane University and four other specialists, indicating the status of contamination of the river in 1963[1/] Figures 5.3 to 5.5 give the indices of water contamination, i.e., dissolved oxygen coliform count and biochemical oxygen demand for the stretch between the Rio Claro and Mediacanoa which show that the degree of contamination had already become considerable between Paso de Navarro and Mediacanoa. CVC recently has started another investigation of the Cauca River contamination and report is soon to be published.

On the other hand, according to the preliminary report prepared by a consultant under Empresas Municipales de Cali in September 1969, it is reported that a capital investment of approximately 1,458 million pesos[2/] will be necessary for primary, intermediate and secondary sewage disposal facilities during the period from 1975 to 2000. This amount is based on the premise that the Cauca River will be left in its present stage. On the other hand, it is anticipated that city water demand of Cali in 2000 A.D. will reach 20 cu.m/s and in consideration of the dry month discharge of 70 cu.m/s at Juanchito, it can be said that increase in discharge in the dry season is an effective mean for this purpose. (See Fig. 5.6)

Fig. 5.3 Location of Sampling Site for Contamination



1/ An Investigation of Water-Borne Wastes Contributing to the Pollution of the Rio Cauca, by Jacques Edward Donaldson

2/ Refer to Memorandum (6) in Chapter 12.

Fig. 5.4 Water Quality of Cauca River in 1963

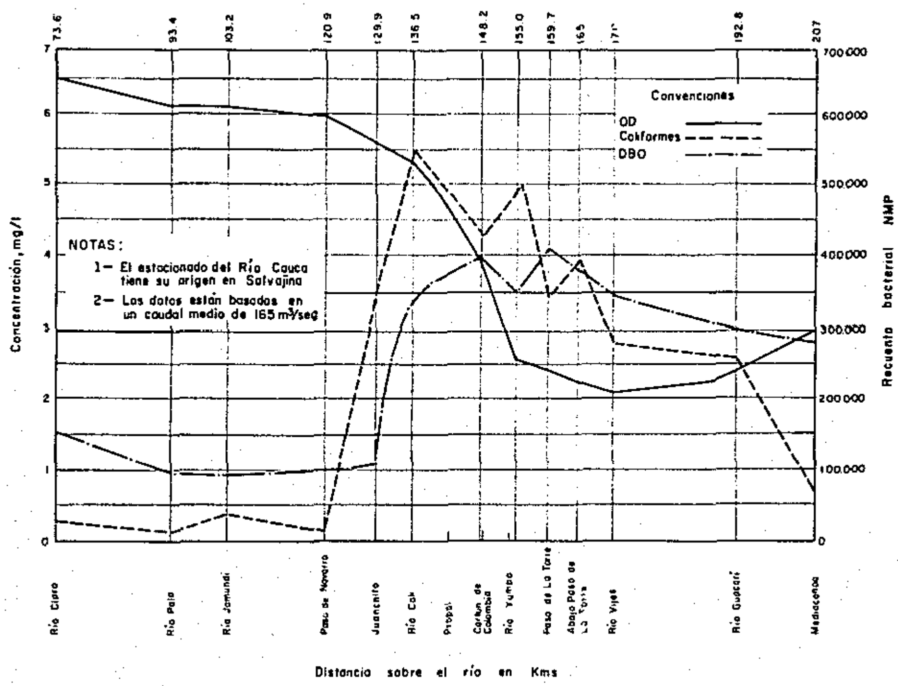


Fig. 5.5 Duration Curve at Juanchito in September

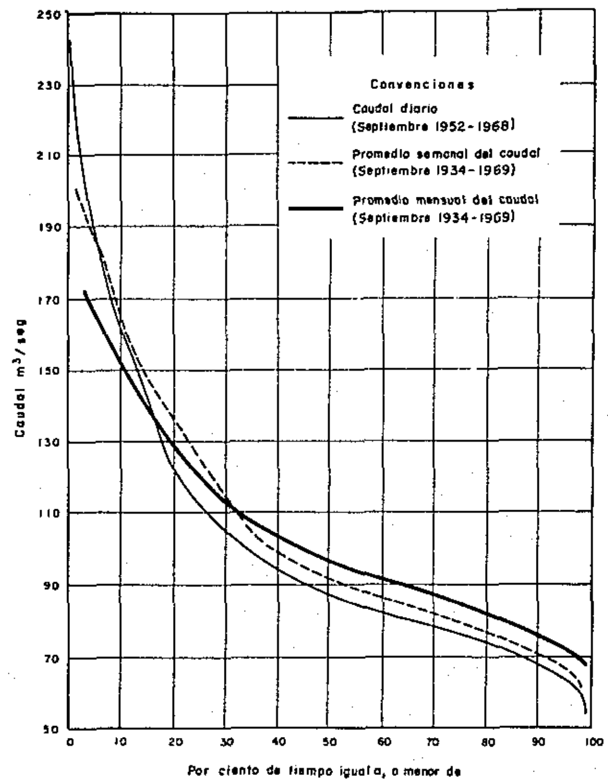
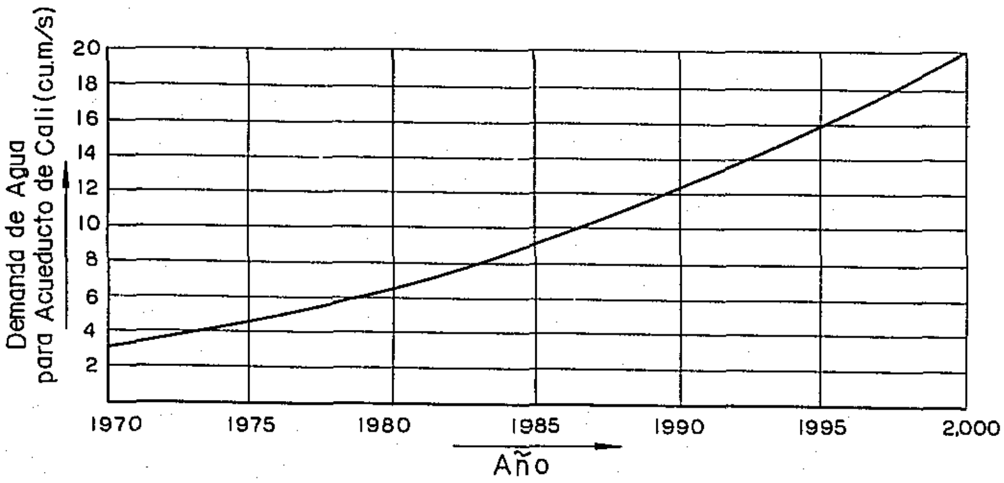


Fig. 5.6 Trend of Water Demand at Cali



5.4.2 Aspects in Fishing Industry

Although there is no definite information on the effect of the Cauca River contamination on fishlife along the river, the considerations by Dr. Anibal Patiño R., Biologist of Universidad del Valle are worth to be cited [1/] These considerations are preliminary, but it can be seen that there is a trend for a marked drop in fish catches in recent years. Although decrease in the catch of river fish may not be so serious in this country where livestock resources and sea fish are abundant, the decrease in fishlife in the Cauca River must be prevented as much as possible through execution of river contamination abatement.

1/ Refer to Memorandum (5) in Chapter 12.

5.5 Power Demand

5.5.1 Load Forecast

(1) Service Area

With the growth of each of the power systems, interconnection transmission line is highly effective from the standpoint of system reliability and efficiency, especially in case of emergency in each system. But needless to say, the most desirable pattern is to have adequate supply capability to satisfy demand within CVC's own system. Therefore, in the load projection study, the balance of demand and supply and time of commissioning the Salvajina Plant for an isolated CVC System was first studied, followed by a review of the demand and supply balance of the interconnected system.

(2) Period and Method of Load Forecast

The load projection was made for 15 years from 1970 up to 1984. This expanse of time is considered adequate to study the scale of development and timing of operation of the Salvajina Power Plant which is tentatively scheduled to be in 1977. There are various methods of forecasting power demand, but as the period of forecast is fairly long, it is extremely difficult to estimate demand with a fair degree of reliability due to lack of necessary data. Therefore, only a broad outlook was estimated macroscopically, and the trend method was followed to forecast future demand by type of power demand.

(3) Past Recorded Demand and Forecast of Power Demand in CVC System

Table 5.2 indicates the actual power demand in the CVC System. The total energy production and peak demand in 1968 were 1,034 x 10^6 kWh and 211 MW respectively corresponding to 2.4 times and 2.5 times increase in 8 years from 1960, which are annual average growth rates of 11.8% and 12%.

The growth rate in the recent past 5 years is 8% in the statistics, which indicates a slow down in demand, but this is considered to have been caused chiefly by load restrictions because of shortage in supply capability and it is judged that the potential growth in demand would be greater than indicated by the above percentage. For example, the growth rate from 1964 to 1965 was only 4%, but on the other hand, with the start of operation of Calima No. 1 in 1966, the growth rate from 1965 to 1966 was 10.8%. Such an increase was also recorded at the time Yumbo Thermal Power Plant came into operation in 1962.

Table 5.2 Maximum Demand and Total Generation of CVC System (1959~1968)

Year	Maximum Demand (MW)	Increase (%)	Total Generation (10^6 kWh)	Increase (%)	Annual Load Factor (%)	Remarks
1959	81.0	–	–	–	–	
1960	86.8	7.2	417.7	–	54.9	
1961	103.3	19.0	475.4	13.8	52.5	
1962	135.1	30.9	591.6	24.7	50.0	Yumbo I
1963	152.5	12.8	703.7	18.8	52.5	
1964	160.7	5.3	796.0	13.0	56.6	
1965	169.8	5.8	827.6	4.0	55.6	
1966	194.2	14.3	918.5	10.8	54.0	Calima
1967	195.4	0.8	962.8	4.8	56.4	Yumbo II
1968	211.0	8.0	1,033.9	7.8	56.0	
68/60	2.43 (times)	11.8	2.48 (times)	12.0		

In order to understand the unrestricted load growth, it is important to grasp the trend of demand for long period as possible. From the above considerations, although the growth rate of power demand in the CVC System has been low in the past several years, if there is sufficient supply capability, it is judged that a fairly high level of growth can be maintained for several years. Therefore, it was estimated that the growth rate will be 12% for the 2 years up to 1972, after which it will fall down to 10% by 1976, and thereafter grow 9% annually. The peak demand can be obtained from the total energy production by applying the annual load factor. In view of the past annual load factor of the CVC System shown in Table 5.2, a value of 55% was adopted which was considered to be constant for the entire period of the forecast.

(4) Past Recorded Demand and Forecast of Power Demand in Bogota, Medellin and CHEC System

In the manner described above, forecasts were also made for the Bogota, Medellin and CHEC Systems. The growth rates in demand of these power systems and load factors are indicated in Table 5.3 (1), 5.3 (2), 5.3 (3).

(5) Result of Load Forecast

As for the CVC System, it will be noted that the peak demand in 1975 will be 425 MW or approximately double the value in 1968, while in 1980 it will grow three fold to 660 MW. If the required reserve capacity is taken to be the largest unit of the system, this will correspond to the 85 MW unit of Alto Anchicaya in 1975, the necessary supply capacity of the CVC System will be 510 MW in 1975 and 745 MW in 1980 respectively. As the CVC supply capacity will be 610 MW after 1974 including Alto Anchicaya, it is estimated that there will arise a shortage in supply capability in 1978.

Table 5.3 (1) Maximum Demand and Total Generation of Bogota System (1959～1968)

Year	Maximum Demand (MW)	Increase (%)	Total Generation (10^6kWh)	Increase (%)	Annual Load Factor (%)
1959	129.0	–	593.1	–	52.5
1960	129.2	–	689.5	16.2	60.9
1961	147.6	13.9	706.5	2.5	54.5
1962	152.7	3.5	761.7	7.8	57.0
1963	199.2	30.4	873.1	14.5	50.0
1964	224.9	12.9	982.1	12.5	49.8
1965	243.4	8.2	1,085.2	10.5	51.0
1966	267.7	10.0	1,218.6	12.2	51.9
1967	315.1	17.7	1,383.6	13.5	50.1
1968	350.1	11.1	1,629.7	17.7	53.1
	(times)		(times)		
68/59	2.71	11.8	2.75	11.9	
68/63	1.76	12.0	1.87	13.3	

Table 5.3 (2) Maximum Demand and Total Generation of Medellin System (1959~1968)

Year	Maximum Demand (MW)	Increase (%)	Total Generation (10^6kWh)	Increase (%)	Annual Load Factor (%)
1959	147.5	–	724.3	–	56.1
1960	149.9	1.5	824.1	11.4	62.6
1961	148.3	–	851.2	3.2	65.5
1962	199.6	34.6	936.5	10.0	53.6
1963	215.8	8.1	1,100.4	17.5	58.2
1964	231.5	7.5	1,236.0	12.2	60.8
1965	267.0	15.3	1,373.3	11.2	58.7
1966	289.0	8.2	1,478.4	7.6	58.4
1967	309.8	7.0	1,579.0	7.0	58.3
1968	327.0	5.5	1,698.4	7.5	59.4
	(times)		(times)		
68/59	2.22	9.3	2.35	10.0	
68/63	1.52	8.7	1.54	9.0	

Table 5.3 (3) Maximum Demand and Total Generation of CHEC System (1964~1968)

Year	Maximum Demand (MW)	Increase (%)	Total Generation (10^6kWh)	Increase (%)	Annual Load Factor (%)
1964	58.9	–	279.1	–	54.0
1965	63.6	8.0	295.9	6.0	53.0
1966	66.9	5.0	319.7	7.0	55.0
1967	69.2	3.5	339.9	6.2	56.0
1968	75.5	9.0	373.4	9.7	56.2
	(times)		(times)		
68/64	1.28	6.4	1.34	7.6	

Table 5.4 Load Forecast of Interconnection System

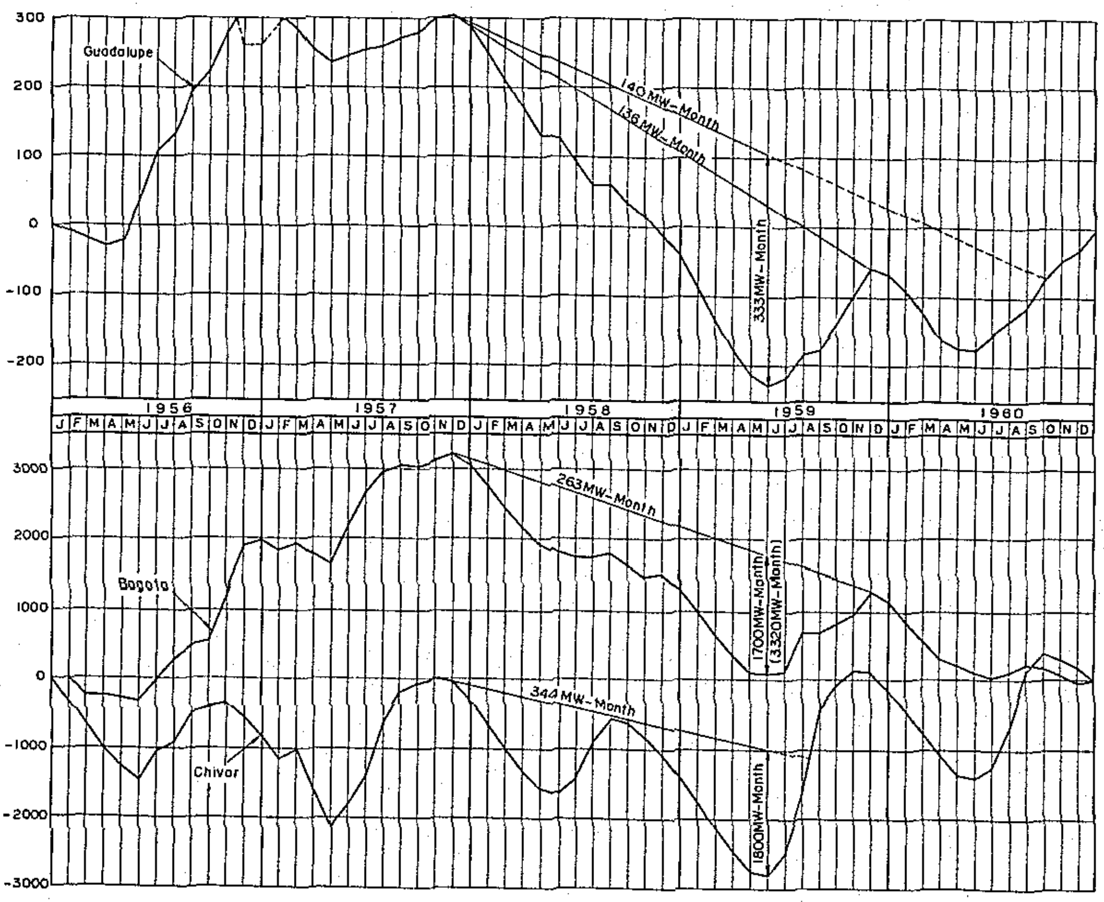
Year	Bogota		Medellin		CVC		CHEC		Total System	
	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)	Power (MW)	Energy (GWh)
1967	315.1	1,383.6	309.8	1,579.0	196	–	69.2	339.9	850	–
1968	350.1	1,629.7	327.0	1,698.4	211	1,033.9	75.5	373.4	920	4,735.4
1969	393.0	1,825.3	352.0	1,851.3	236	1,140.0	84.0	410.7	1,010	5,227.3
1970	440.0	2,044.3	384.0	2,017.9	264	1,270.0	92.0	451.8	1,120	5,784.0
1971	492.0	2,289.6	418.0	2,199.5	290	1,400.0	101.0	497.0	1,240	6,386.1
1972	552.0	2,564.4	456.0	2,397.4	320	1,540.0	111.0	546.7	1,370	7,048.5
1973	607.0	2,820.8	497.0	2,613.2	351	1,690.0	122.0	601.4	1,500	7,725.4
1974	668.0	3,102.9	542.0	2,848.4	386	1,860.0	135.0	661.5	1,640	8,472.8
1975	733.0	3,413.2	590.0	3,104.7	425	2,050.0	148	727.7	1,800	9,295.6
1976	807.0	3,754.4	643.0	3,384.2	468	2,260.0	163.0	800.4	1,980	10,199.0
1977	890.0	4,092.4	695.0	3,654.9	510	2,450.0	178.0	872.5	2,160	11,069.8
1978	960.0	4,460.7	751.0	3,947.3	556	2,680.0	194.0	951.0	2,340	12,039.0
1979	1,046	4,862.2	809.0	4,263.1	606	2,930.0	211.0	1,036.6	2,540	13,091.9
1980	1,140.0	5,299.8	875.0	4,604.1	660	3,180.0	230.0	1,129.9	2,760	14,213.8
1981	1,242.0	5,776.8	946.0	4,972.5	720	3,470.0	251.0	1,231.5	3,000	15,450.8
1982	1,355.0	6,296.7	1,020.0	5,370.2	785	3,780.0	274.0	1,342.4	3,260	16,789.3
1983	1,489.0	6,863.4	1,102.0	5,799.9	856	4,130.0	298.0	1,463.2	3,560	18,256.5

Note: (1) Figures in 1967 and 1968 are actual records.
(2) Growth rate of energy in each system are as follows:
Bogota 1968 ~ 1972: 12%, up to 1976: 10%, up to 83: 9%
Medellin 1968 ~ 1976: 9%, up to 1983: 8%
CVC 1968 ~ 1970: 12%, up to 1976: 10%, up to 83: 9%
CHEC 1968 ~ 1976: 10%, up to 1983: 9%
(3) Maximum demand of the interconnection system is obtained by applying 95% diversity factor to total sum of maximum demand in each system.

5.5.2 kW and kWh Balance

The power demands of the CVC, Bogota, Medellin and CHEC systems are given in Table 5.4. The supply capabilities of the power systems were estimated by adopting the values for the historically driest year and the firm energy output in 1958 was calculated from the mass curves (Fig. 5.7) from 1956 through 1960 for reservoir controlled power plants. The output of run-of-river plants and the energy output of reservoir controlled plants in 1958 are given in Tables 5.5 and 5.6 for each power system.

Fig. 5.7 Energy Mass Curve in MW-Month of Medellin and Bogota System



In examining the kW and kWh balance, each year was divided into quarters and the average supply capability for every 3-month period noted in Table 5.6 was adopted. This method was followed by the reason that the installed capacity of run-of-river type power plants in 1975 will be only 24% of the entire interconnected system capacity while the energy supply capability is only 23% on the system capability. Therefore, evaluation by quarter instead of monthly is adequate because of the small weight of run-of-river type power plants in the entire system.

Table 5.5 Available Supply Energy in Each Power System in 1958
(Without Consideration of Reservoir Capacity)
(Unit: MW-month)

System	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
BOGOTA-System												
Bogota 1/ 4/	53	22	81	107	237	232	382	406	182	195	393	133
Chivor 4/	53	33	71	164	355	569	919	754	330	190	157	64
MEDELLIN-System												
Guadalupe 2/ 4/	80	68	75	72	145	94	87	155	94	119	92	93
Guatape	119	105	151	166	282	158	122	256	159	237	212	192
Rio Grande	56	33	48	48	88	55	37	67	38	70	63	66
Piedras Blancas	5	6	4	6	8	8	8	8	8	9	7	6
CVC-System												
A. Anchicaya 4/	151	93	84	184	253	133	103	141	89	206	277	226
Calima No.1 4/	12	10	10	14	23	19	11	12	7	12	19	19
Anchicaya	33	19	18	40	55	29	22	30	19	45	60	49
Salvajina 4/	63	66	65	65	68	67	66	65	61	54	71	62
Small Hydro	10	8	6	9	10	8	7	6	4	5	10	10
CHEC-System												
CHEC 3/	73	67	69	77	78	78	73	67	67	75	78	78

1/ Represents Canoas, Salto I, Salto II, Laguneta and Colegio Power Plants.
2/ Guadalupe I, II, III and Troneras Power Plants.
3/ La Esmeralda, San Francisco, Insula and other small power plants.
4/ Indicate reservoir type power plant.

Table 5.6 Available Supply Energy in Each Power System in 1958
(With Consideration of Reservoir Capacity)
(Unit: MW-month)

System	Jan.	Feb.	Mar.	(Ave.)	Apr.	May	Jun.	(Ave.)	Jul.	Aug.	Sep.	(Ave.)	Oct.	Nov.	Dec.	(Ave)
BOGOTA-System																
Bogota 1/	263	263	263	(263)	263	263	263	(263)	263	263	263	(263)	263	263	263	(263)
Chivor 2/	250	250	250	(250)	250	250	250	(250)	250	250	250	(250)	250	250	250	(250)
MEDELLIN-System																
Guadalupe 3/	140	140	140	(140)	140	140	140	(140)	140	140	140	(140)	140	140	140	(140)
Guatape	119	105	151	(125)	166	282	158	(202)	122	256	159	(179)	237	212	192	(214)
Rio Grande	56	33	48	(46)	48	88	55	(64)	37	67	38	(47)	70	63	66	(66)
Piedras Blancas	5	6	4	(5)	6	8	8	(7)	8	8	8	(8)	9	7	6	(7)
CVC-System																
A. Anchicaya	138	138	115	(130)	149	159	145	(151)	132	139	106	(126)	159	147	140	(148)
Calima No.1	12	32	42	(29)	10	16	15	(14)	21	29	25	(25)	10	14	15	(13)
Anchicaya	33	19	18	(23)	40	55	29	(41)	22	30	19	(24)	45	60	49	(51)
Salvajina	87	66	79	(77)	77	60	77	(71)	82	68	105	(85)	66	76	81	(74)
Small Hydro	10	8	6	(8)	9	10	8	(9)	7	6	4	(6)	5	10	10	(8)
CHEC-System																
CHEC 4/	73	67	69	(70)	77	78	78	(78)	73	67	67	(69)	75	78	78	(77)

1/ Represents Canoas, Salto I, Salto II, Laguneta and Colegio Power Plants.
2/ Available continuous energy of Chivor Power Plant is 344 MW, but in the first stage development it is limited to 250 MW.
3/ Represents Guadalupe I, II, III and Troneras Power Plants.
4/ Represents La Esmeralda, San Francisco, Insula and other small power plants.

For simplification of estimating load curves triangular expression was adopted.

(1) Demand and Supply Balance of CVC Power System

The demand and supply balance in each year from 1973 through 1978 is given in Fig. 5.8 (1). As clearly seen in this figure, after completion of Alto Anchicaya, there will be no power shortage up to 1975, if the supply capacity of Yumbo Thermal is included. However, in 1976, there will be a shortage of 11 MW, even if the 53 MW of Yumbo Thermal and 18 MW of other thermal power plants are operated. However, it will be possible to augment this shortage by receiving power from other systems. From 1977, when Salvajina Power Plant is in operation, the balance of demand and supply can be maintained for two years. The power output of Alto Anchicaya of 340 MW will not be fully effective in the CVC System alone for the time being.

(2) Demand and Supply Balance of Bogota Power System

When the No. 1 and No. 2 units (250 MW) of Chivor Power Station are in service, there will be no power shortage until 1976. However, in 1977, as indicated in Fig. 5.8 (2), there will be kW shortage during peak demand hours, while in the midnight hours water will be spilled from Chivor Reservoir. But in the interconnected system as a whole, it is possible to interchange power between each system when necessary and to make up power shortages and to make effective this spilled water in the midnight saling energy to other system. (See Fig. 5.8 (5).) When Bogota System is considered independently, there will be a kW shortage of 236 MW in 1979, if thermal plants such as Zipaquira are not brought in.

(3) Demand and Supply Balance of Medellin Power System

In the Medellin Power System, the energy production capability of run-of-river power plants such as Guatape Power Plant and Rio Grande Power Plant is small in the first quarter of the year, so that there will be a power shortage of 70 MW in the first quarter of 1976 as shown in Fig. 5.8 (3). However, it will be possible to cover this shortage by receiving power from the Bogota or CVC Systems and Medellin will be the power system benefiting most from the merits of the interconnection transmission line. In the case of an independent Medellin System, the power shortage in 1979 will be 170 MW.

(4) Demand and Supply Balance of CHEC Power System

Even if San Francisco Power Plant now under construction is put in service, a power shortage will occur in 1976 and a shortage of 67 MW is anticipated in 1979. There are no reservoir controlled power plants in this system and it will enjoy the merits of the transmission interconnection together with the Medellin Power System. (See Fig. 5.8 (4).)

(5) Demand and Supply Balance of Interconnection System

The overall balance of demand and supply of the four systems is indicated in Fig. 5.8 (5). The maximum load of the four power systems was taken to be the value of the total maximum peaks of these systems multiplied by a diversity factor of 0.95. The annual load factor of the interconnected system will be 59%. When the four power systems are combined it will be possible to maintain a balance of demand and supply until 1974 by utilizing existing thermal power plants. However, in 1975, a power shortage will occur and it will be necessary to put in service the No. 1 and No. 2 units of Chivor Power Plant in 1975 as presently planned.

Salvajina Power Plant will be required to be in service in 1977 and the almost all the energy output can be consumed. At the same time, the No. 3 and No. 4 units of Chivor will be required to be in service. If the existing thermal power plants continue to be in service, it will be possible to postpone the start-up of the No. 3 and No. 4 units of Chivor to 1978. It will be possible to maintain the power demand and supply balance up to 1978, but as the reservoir-controlled power plants will have to be in operation at full capacity in 1978, the No. 3 unit of the Salvajina or other new power sources must be available.

Table 5.7 Installed Capacity and Firm Energy of Four Power Systems

Power Plant	Max. Output (MW)	Max. Discharge (cu.m/s)	Head (m)	Annual Firm Energy (GWh)	In Service Date
(1) Bogota System					
Hydro					
Canoas	46	44	140	214	1970
Salto I & II	125	43	394	600	Salto I 1937 Salto II 1964
Laguneta	80	35	300	430	1962
Colegio	300	40	940	1,420	1,2,3 unit 1967 3,4,5 unit 1971
Chivor (1st stage)	250	40	765	3,200	1975
Chivor (2nd stage)	250	40	765		1977
Thermal					
Zipaquira	70	–	–	275	
Charquito	14	–	–	61	1974 (retirement)
Paipa	33	–	–	145	
Sub-total	1,168	–	–	6,345	
(2) Medellin System					
Hydro					
Guadalupe I & III	316	74	530	1,453	Guadalupe I 1932 Guadalupe III 1962
Guadalupe II	10	10	143	79	
Troneras	36	50	73.3	245	
Guatape 1/	280	41.6	804	1,500	1969
Rio Grande 1/	78	34	292.8	440	1952
Piedras Blancas 1/	11	2.6	–	35	1958
Sub-total	731	–	3,752	–	
(3) CVC System					
Hydro					
Alto Anchicaya	340	94.5	450	1,250	1973
Calima I	120	76.5	212	360	1968
Anchicaya	64	112	72	340	1955
Salvajina	210	270	90	648	1977
Small Hydro 1/	10			70	
Thermal					
Yumbo	53			300	
Sub-total	797			2,968	
(4) CHEC System					
Hydro					
La Esmeralda 1/	30			155	
San Francisco 1/	135			170	1969
Insula 1/	16			98	
Small Hydro 1/	22			130	
Sub-total	203			553	
Total	2,899			13,618	

1/ Indicate run-of-river type power plant

Fig. 5.8(1)   kW & kWh Balance in CVC System

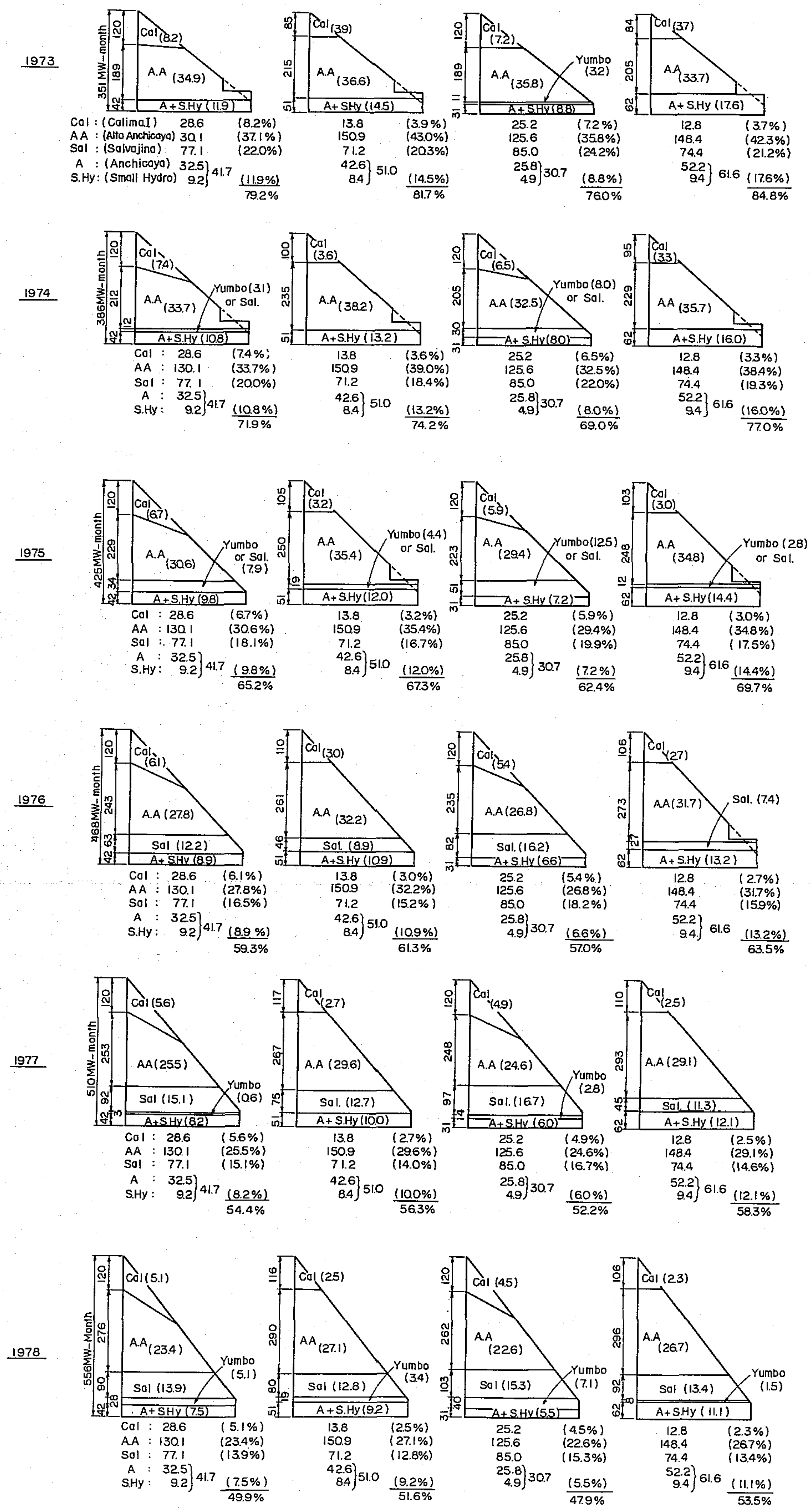


Fig. 5.8(2) kW & kWh Balance in Bogota System

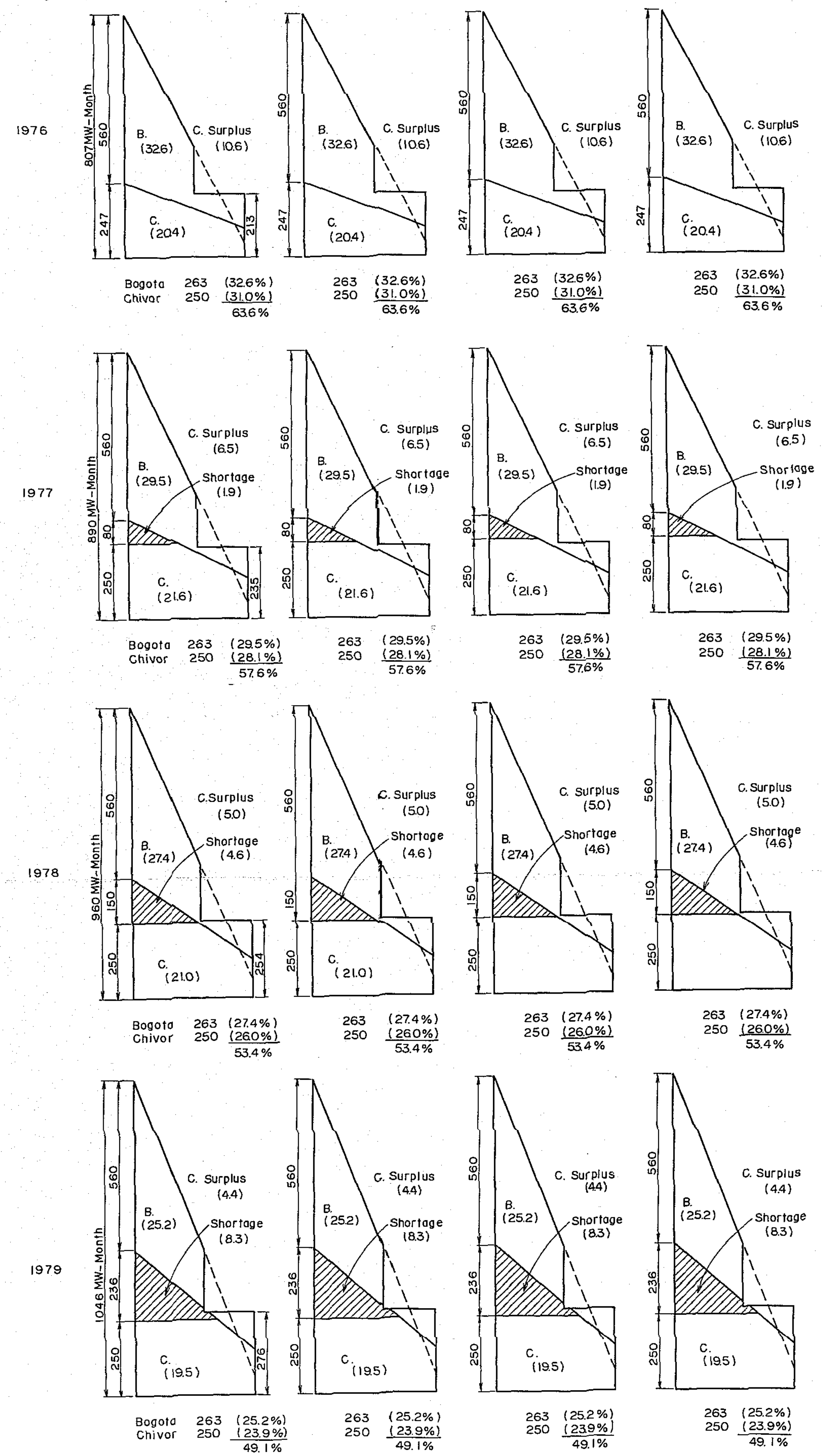


Fig. 5.8(3) kW & kWh Balance in Medellin System

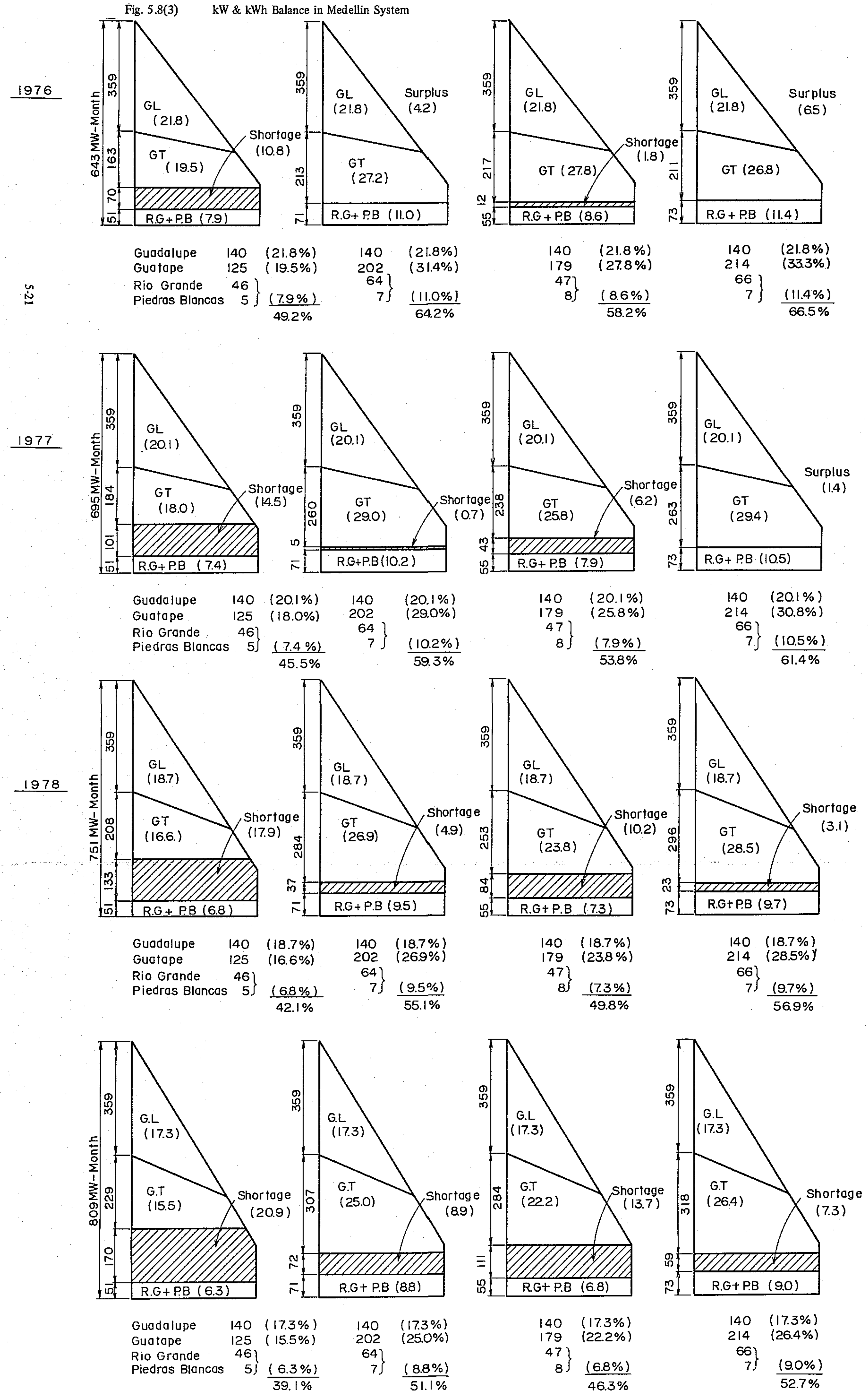


Fig. 5.8(4) kW & kWh Balance in CHEC System

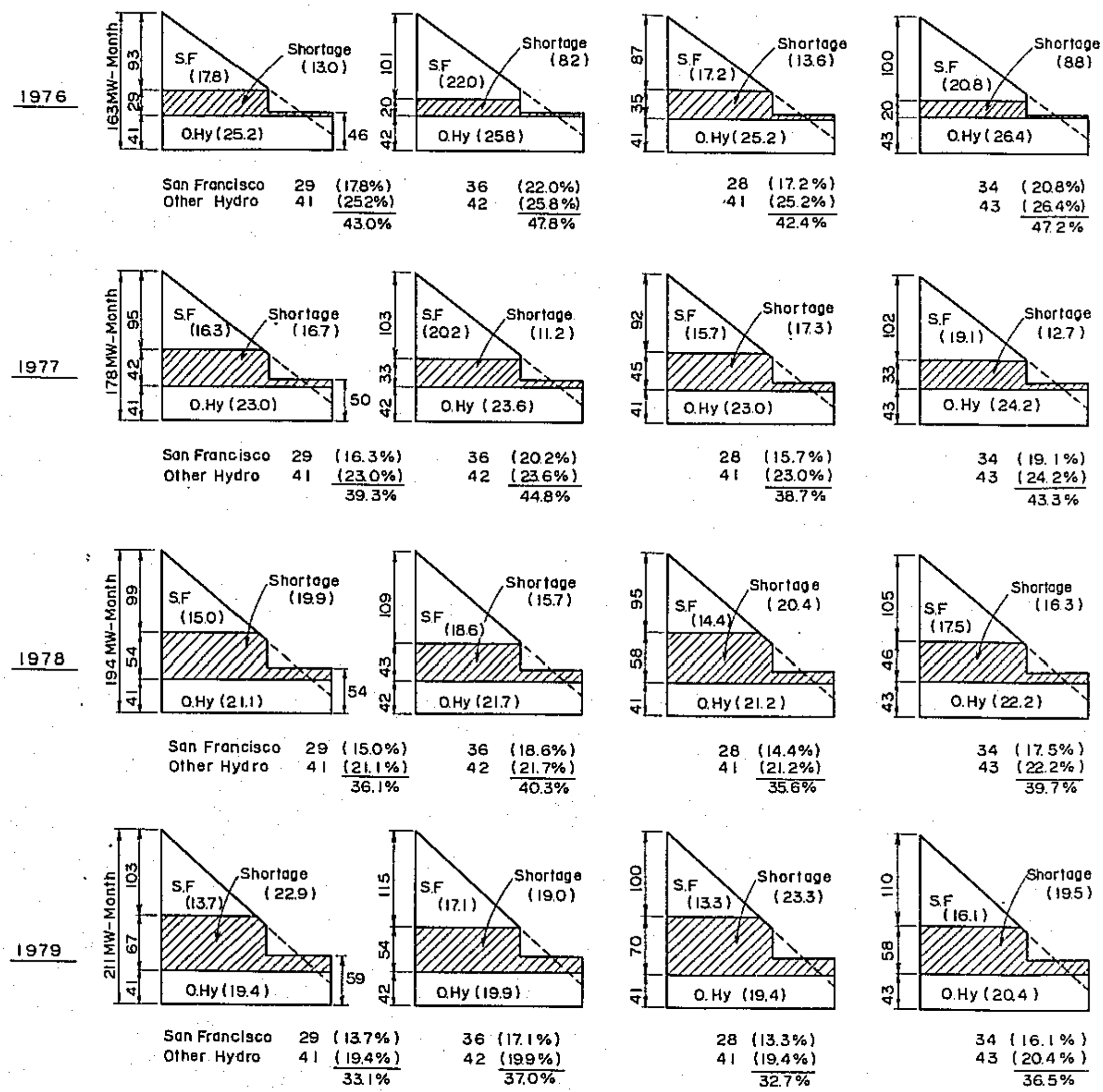


Fig. 5.8(5) kW & kWh Balance in Interconnection System

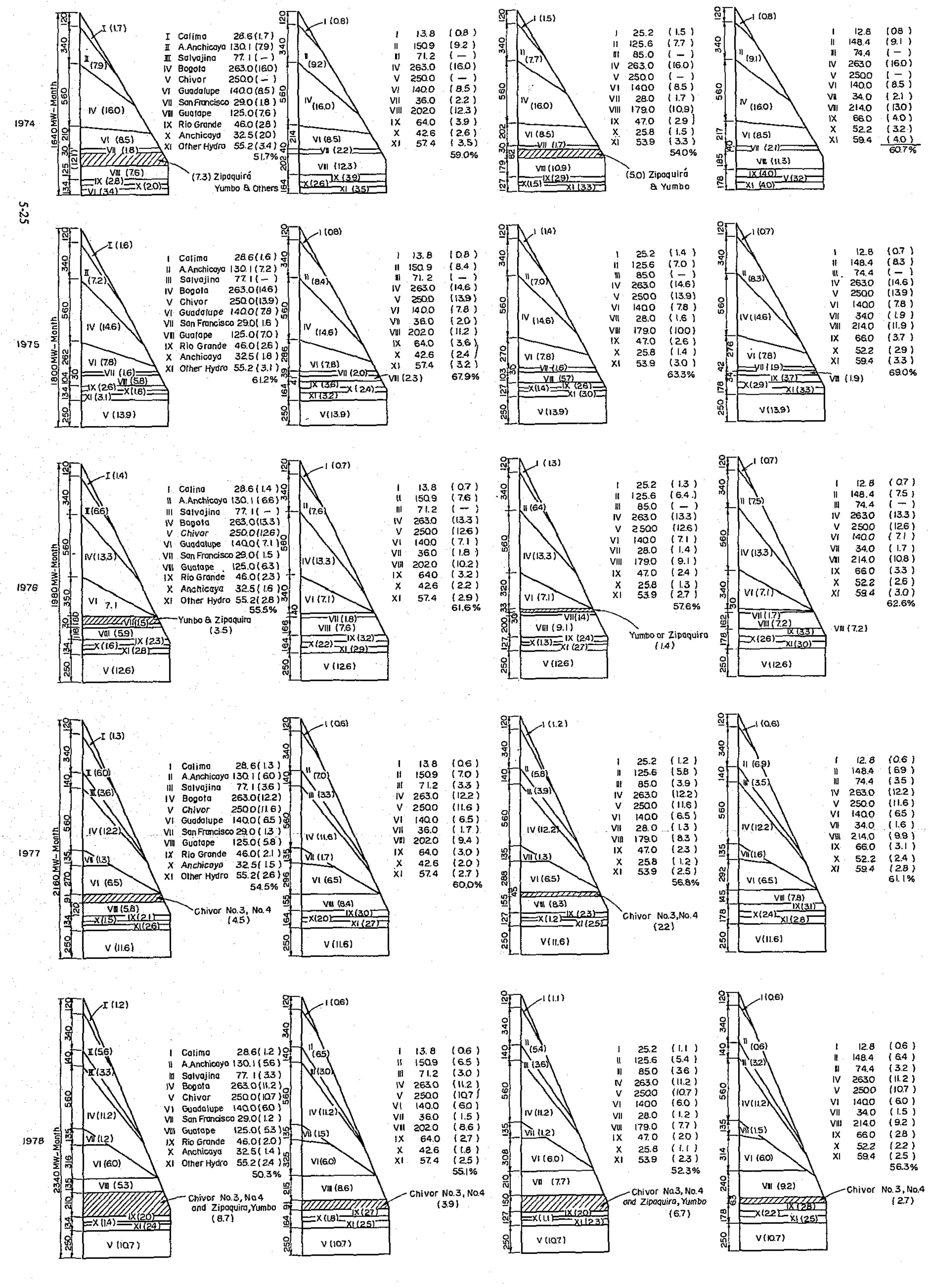


Fig. 5.9(1) kW & kWh Balance by Year in CVC System

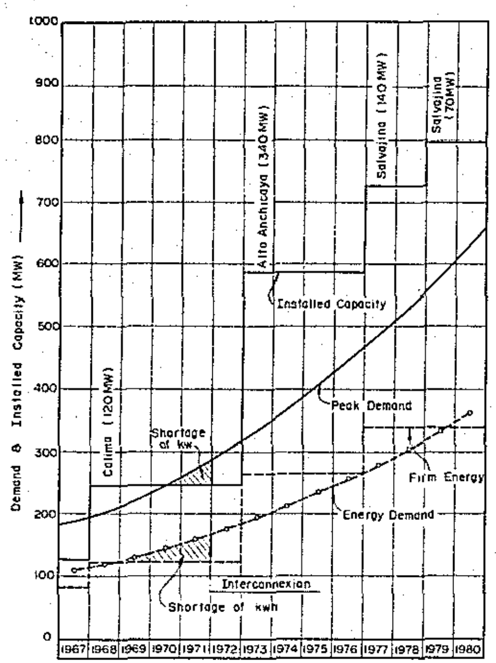
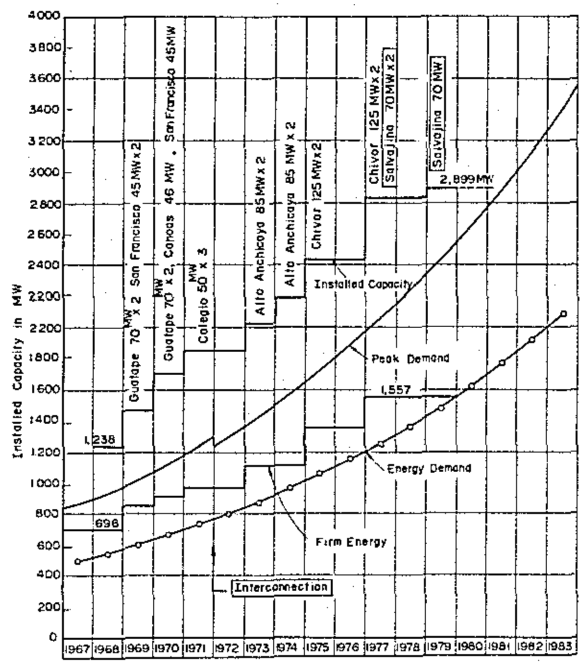


Fig. 5.9(2) kW & kWh Balance by Year in Interconnection System



CHAPTER 6

PLAN OF DEVELOPMENT

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 6 PLAN OF DEVELOPMENT

There are many alternatives for achieving the multi-purpose development of the Cauca River Regulation Project with flood control as the chief purpose. But the selected development program must be the best one that will be the most economical for the region from a long-term view, because it is impossible to change the program once the project is constructed.

In other words, the scale of structures must be such to achieve the highest economic benefit for their economic lives, while it can be said the smaller the amount of investment, the more suitable is the project in the present state of developing countries for structures with a little difference of economic benefit.

On the other hand, besides economic benefit, there must be assurance of amortization of capital invested. Generally speaking, development programs involving agricultural development are of extreme importance in developing countries and should be promoted as much as possible from the standpoint of policy, while the amortization of invested capital should be planned with emphasis in terms of public investment by the Government. Power generation included in a multi-purpose program including agricultural development is to play an important role in the amortization of funds invested.

6.1 Alternative Sites

There are three alternative dam sites, i.e., Salvajina, San Francisco and Timba in the order of from upstream to downstream. The construction costs for dam and downstream levees to control six cases of flood discharges were compared for flood probabilities ranging from 1:5 to 1:50 for the three alternative sites. The Timba site, because of more than 1,000 buildings and houses which will be submerged by the reservoir and require relocation, and because of low bearing strength of the foundation rock at the damsite; and the San Francisco site, because of the deep deposit of sand and gravel of approximately 50 m to the foundation rock in the river bed, the construction costs for these two alternatives resulted to be more costly in every case than that of the Salvajina site as shown in Table 6.1 and Fig. 6.1. Therefore, these two sites were abandoned.

The geological features of the San Francisco and Timba sites are described in Appendix 2.

Fig. 6.1 Comparison of Three Dam Sites

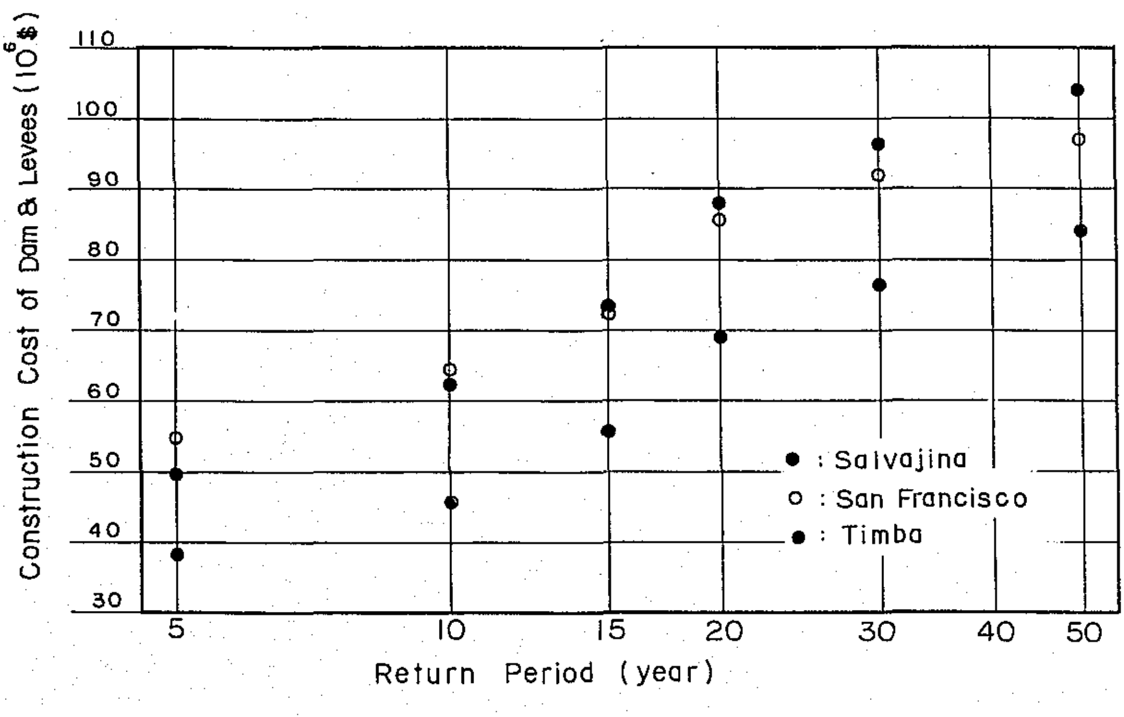


Table 6.1 Comparison of Three Dam Sites

Return Period (year)	5	10	15	20	30	50
Effective Storage Capacity of Reservoir (10^6 cu.m)	270	350	403	445	502	586
Capacity of River Channel (cu.m/s)						
Juanchito	620	720	770	830	880	950
La Victoria	860	1,000	1,100	1,170	1,250	1,350
Construction Cost 1/ (10^6 $)						
Salvajina						
Dam 2/	29.8	31.3	34.5	35.8	38.0	41.3
Levee 3/	9.0	14.7	21.0	33.3	38.5	43.0
Total	38.8	46.0	55.5	69.1	76.5	84.3
San Francisco						
Dam 2/	46.0	49.5	51.5	52.5	53.5	54.3
Levee 3/	9.0	14.7	21.0	33.3	38.5	43.0
Total	55.0	64.2	72.5	85.8	92.0	97.3
Timba						
Dam 2/	40.7	48.0	51.8	54.5	57.7	61.6
Levee 3/	9.0	14.7	21.0	33.3	38.5	43.0
Total	49.7	62.7	72.8	87.8	96.2	104.6

1/ Construction cost excluding interest during construction.

2/ Dam Type;
- Salvajina: Arch-gravity for return period of 5 and 10 years. Fill-type for other cases.
- San Francisco: Fill-type
- Timba: Fill-type

3/ The extent of levees was assumed to be variable corresponding to the magnitude of design high water discharge. The construction costs of levees from La Balsa to Cartago was regarded as that of levees which protect the flood corresponding to probability of once in ten years. The existing levees of Aguablanca, Rio Paila and R-U-T Projects were not considered in this study.

6.2 Scale of Development

In order to determine the optimum scale of Salvajina Reservoir, the effects of flood control, drainage, power generation and alleviation of river contamination were estimated for nine alternative cases to achieve the highest benefit-cost ratio in relation to their investment costs. Three different high water levels of the reservoir were selected in combination with three different low water levels to obtain nine alternatives. In these nine alternatives, the construction costs of dam and spillway are divided into three groups in accordance with dam height. The flood control benefits vary with effective storage capacities which in turn vary with the three different low water levels and thus the scale of the downstream levees were changed accordingly. Also, the power installation capacity was changed corresponding to the effective storage capacity of the reservoir.

The basic assumptions for benefit calculations for flood control, drainage, power generation and alleviation of river contamination in the nine alternatives are described in the following chapters, but the results of comparison indicate that greatest economy can be realized in the case C-b with the height of dam of 133 m, reservoir high water level of EL. 1,139 m, reservoir low water level of EL. 1,105 m, downstream levees from La Bolsa to R-U-T and Rio Bugalagrande, and with generating capacity of 210,000 kW as shown in Table 6.2 and Fig. 6.2.

Table 6.2 Benefits and Costs Relation for Alternatives

	A-a	A-b	A-c	B-a	B-b	B-c	C-a	C-b	C-c	Remarks
Effective Reservoir Capacity (10^6 cu.m)	450	535	590	360	445	500	270	350	410	
High Water Level (m)	1,150	1,150	1,150	1,145	1,145	1,145	1,139	1,139	1,139	
Low Water Level (m)	1,115	1,105	1,095	1,115	1,105	1,095	1,115	1,105	1,095	
Gross Head (m)	120	120	120	115	115	115	109	109	109	Tail water level 1,030 m
Draw Down (m)	35	45	55	30	40	50	24	34	44	
Rated Head (m)	101	98	95	98	95	90	94	90	87	
Firm Power 1/ (MW)	81	80	78	77	76	74	72	72	70	
Installed Capacity(MW)	239	235	229	226	224	217	212	210	206	
Annual Firm Energy (10^6 kWh)	710	701	683	675	666	648	631	631	613	
Construction Cost 2/ (10^3 $)	93,300	100,200	105,300	71,500	87,400	92,000	58,200	63,100	74,300	
Annual Cost [C] (10^3 $)	9,150	9,833	10,340	6,988	8,569	9,024	5,675	6,163	7,276	
Amortization (10^3 $)	8,067	8,663	9,104	6,182	7,557	7,954	5,032	5,456	6,424	Discount rate:8.5% Economic life:50 yrs.
O&M Expense (10^3 $)	1,083	1,170	1,236	806	1,012	1,070	643	707	852	
Annual Benefit [B] (10^3 $)	9,755	10,280	10,514	8,789	9,443	9,737	7,608	8,416	8,840	
Flood Control (10^3 $)	3,760	4,010	4,140	3,350	3,730	3,920	2,780	3,280	3,580	
Power Generation (10^3 $)	4,260	4,206	4,098	4,050	3,996	3,888	3,786	3,786	3,678	6 mills/kWh See Table 10.3(2),(3) 3/
Alleviation of River Contamination (10^3 $)	1,735	2,064	2,276	1,389	1,717	1,929	1,042	1,350	1,582	
Benefit-Cost Ratio [B/C]	1.07	1.05	1.02	1.26	1.10	1.08	1.34	1.37	1.21	

1/ Firm power applied in this table was calculated on the basis of provisional conversion factor between discharge and power, consequently being differed from the final firm power of Salvajina Power Plant.

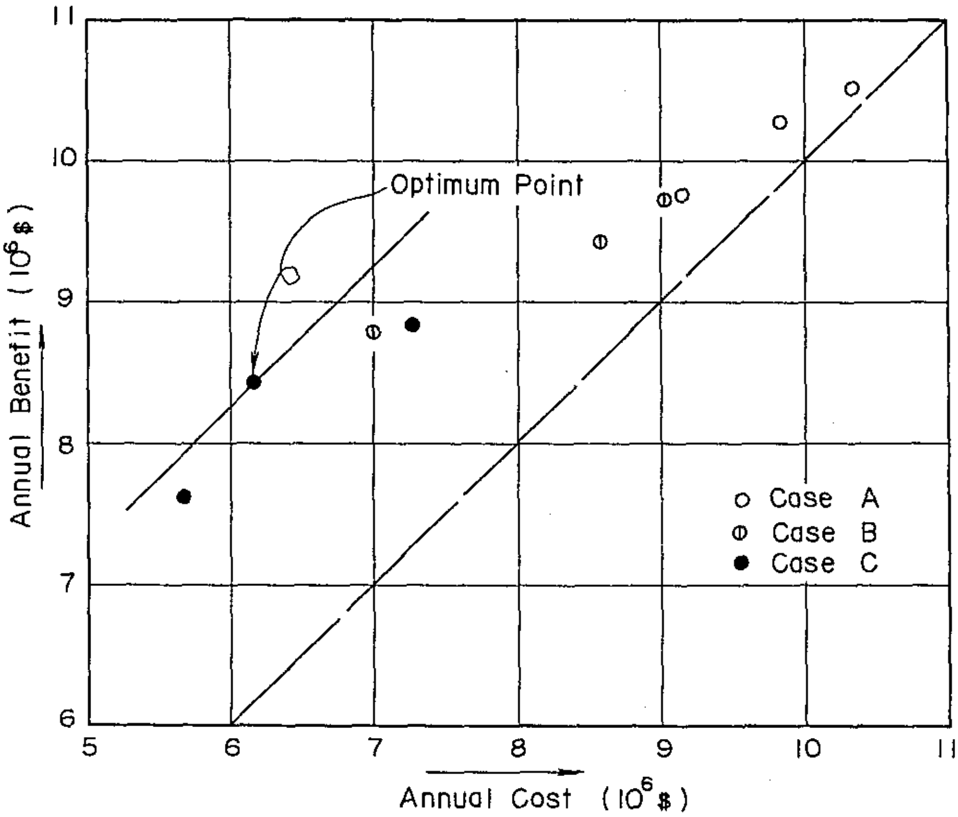
2/ Construction costs of dam, power plant, transmission line and levee were included in these figures but not included interest during construction.

3/ Total annual cost of standard thermal power plant and transmission lines : $7,321 \times 10^3$ $

Energy production : $1,242(1-0.02) \times 10^6$ kWh $= 1,217 \times 10^6$ kWh

Energy cost per kWh : 6 mills/kWh

Fig. 6.2 Relation between Benefdits and Costs for Varying Scales of Developments



6.3 Flood Control

For the purpose of controlling floods which are occurring in the area between La Balsa and La Victoria, the Salvajina Reservoir and downstream levees are both necessitated. According to Fig. 6.8, except for the flood in December 1966 which had exceptionally small discharge from the drainage area between Juanchito and La Victoria, there is a pretty good relationship between the flood discharge at Salvajina and that at Juanchito and also between the flood discharge at Salvajina and that at La Victoria.

Therefore, the basic assumption for planning the scale of Salvajina Reservoir and downstream levees is that the levees have to protect floods from the drainage area downstream of Salvajina with the equivalent probability magnitude which correspond to those to be controlled by the storage capacity of Salvajina Reservoir.

6.3.1 Hydrologic Analyses of Floods at Juanchito and La Victoria

There are daily records of water level and runoff from January 1934 to the present at Juanchito and from October 1958 to the present at La Victoria, which are major gauging stations in the flood-afflicted areas of the Cauca River. But the data at the time of flooding do not necessarily represent the true river discharge and deformed since inundation of low basin areas on both banks of the river have already occurred through tributaries when flood discharges exceeded abovementioned river channel capacity.

Therefore, it is necessary in the study of flood control program to have undeformed hydrograph not including regulating effect in the upstream low land areas. In view of the fact that inundation does not occur upstream of La Balsa, the starting point of the Cauca Plain, the discharge data at La Balsa and discharges of major tributaries joining at the downstream of La Balsa were used to obtain the undeformed flood hydrograph at Juanchito and La Victoria.

In other words, the undeformed flood hydrographs at Juanchito and La Victoria were calculated by the equations which follow taking into account the specific runoff of flood, represented by that of the major tributaries such as the Rio Palo and Rio Fraile, and the same flood discharge volume which is obtained from the deformed flood hydrograph based on actual measurements. The results are shown in Fig. 6.3 and these flood hydrographs are the original flood hydrographs undeformed, not including up-stream inundation effect.

Note: Estimation of undeformed flood discharge

Discharge at Juanchito (Q_{Juan})

$(Q_{Juan})_{N+1} = \gamma [\beta \{ \alpha_I (Q_{Jam})_N + \alpha_{II} (Q_{Pal})_N \} + (Q_{Bal})_N]$ .... Eq. (1)

Block	Tributary Applied for Estimation	Discharge	Value of α	Alternative Tributary	Discharge	Value of α
I	Rio Jamundi	Q_{Jam}	10.0	Rio Timba	Q_{Tim}	2.5
II	Rio Palo	Q_{Pal}	2.7	Rio Fraile	Q_{Fra}	11.0

Discharge at La Victoria (Q_{Vic})

$(Q_{Vic})_{N+2} = \gamma [\beta \{ \alpha_{III} (Q_{Pal})_N + \alpha_{IV} (Q_{Vie})_{N+1} + \alpha_V (Q_{Jam})_N + \alpha_{VI} (Q_{Pes})_{N+1} \} + (Q_{Juan})_N]$ .... Eq. (2)

Block	Tributary Applied for Estimation	Discharge	Value of α	Alternative Tributary	Discharge	Value of α
III	Rio Palo	Q_{Pal}	3.6	Rio Fraile	Q_{Fra}	23.8
IV	Rio La Vieja	Q_{Vie}	1.2	Rio Tulua	Q_{Tul}	4.7
V	Rio Jamundi	Q_{Jam}	6.0	Rio Claro	Q_{Cla}	7.0
VI	Rio Pescador	Q_{Bes}	8.4	Rio Frio	Q_{Fri}	10.0

where,

Q_{Bal} : Cauca River runoff at La Balsa

Q_{Juan} : Cauca River runoff at Juanchito

Q_{Vic} : Cauca River runoff at La Victoria

α : Ratio between catchment area of tributary of which runoff data was used and the catchment area of each block represented by that tirbutary.

β : Hydrograph adjustment factor
Ratio between discharge (actual measurement) within the river capacity and corresponding composite discharge estimated from tributaries flow using the above equation
$\beta = 0.9$ for Eq. (1) for Juanchito
$\beta = 0.6$ for Eq. (2) for La Victoria

γ : Flood discharge volume correction factor,
$\gamma = 0.8 \sim 1.2$

N : Date of occurrence of flood at each site

6.3.2 Present River Channel Capacity of Cauca River

In considering the flood damage caused by the Cauca River, the flow capacity of the river channel for the 300 km section from La Balsa to La Victoria must first be studied. As mentioned previously, flooding of low land areas on both sides of the river begins due to back flow of the main stream or retardation of tributaries flow before inundation by overflowing of the banks occurs.

This flooding of low areas begins at the discharge of approximately 650 cu.m/s at Juanchito and approximately 750 cu.m/s at La Victoria. At this time, the banks on both sides of the river still have some freeboard. On the other hand, present river channel high water capacities of which water level are close to the top of banks at Juanchito and La Victoria which are defined as probable flow capacities with full water level of the river are 720 cu.m/s and 770 cu.m/s respectively. The capacities of the river channel high water between La Balsa and La Victoria are shown in Table 6.3.

Table 6.3 Present River Channel High Water Capacity

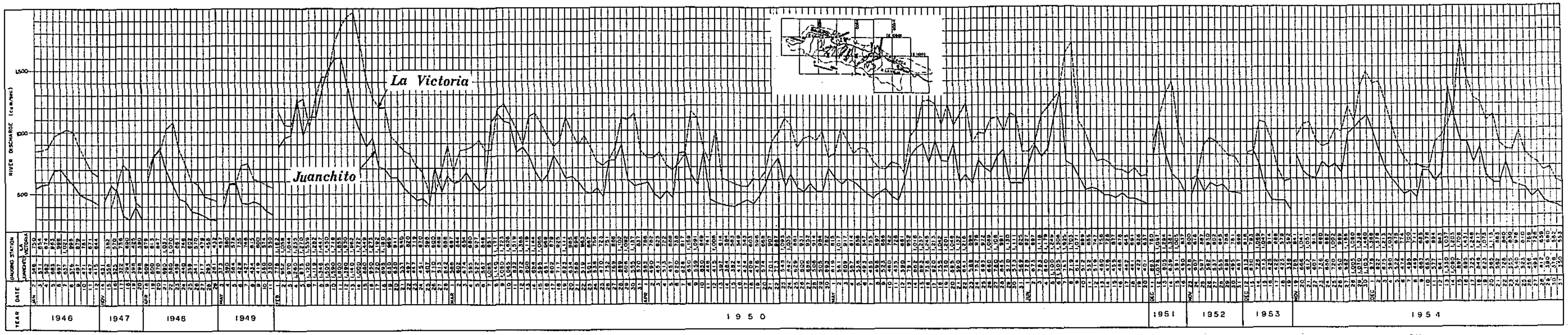
(Unit: cu.m/s)

Gauging Station	Discharge	Gauging Station	Discharge
La Balsa	580	Mediacanoa	680
La Bolsa	600	Rio Frio	540
Hormiguero	690	Guayabal	760
Juanchito	720	La Victoria	770
Pto. Isaccs	870	Anacaro	1,060
Paso de la Torre	840		

6.3.3 Excess Flood Volume at Time of Flood Discharge

Under the assumption that large and small floods of the Cauca River occur corresponding to the excess flood volumes of flood discharges which exceed the river channel capacity, and using the hydrographs obtained in 6.3.1 for the period from 1946 through 1968, the probability of excess flood volume exceeding three cases of river channel capacity at Juanchito and La Victoria were calculated as shown in Table 6.4 and in Fig. 6.4. Using this figure, it is possible to estimate the excess flood volume of flood discharge which can be controlled by combination of reservoir and levees.

And also, the correlation between the excess flood volumes for the present channel capacities of 650 cu.m/s at Juanchito and 750 cu.m/s at La Victoria is exhibited in Fig. 6.5. It can be seen on this figure that there is a fairly good correlation between the values at Juanchito and La Victoria, except for the flood of December 1966. It is widely said and proved that the discharges from tributaries between Juanchito and La Victoria were exceptionally small at this time.



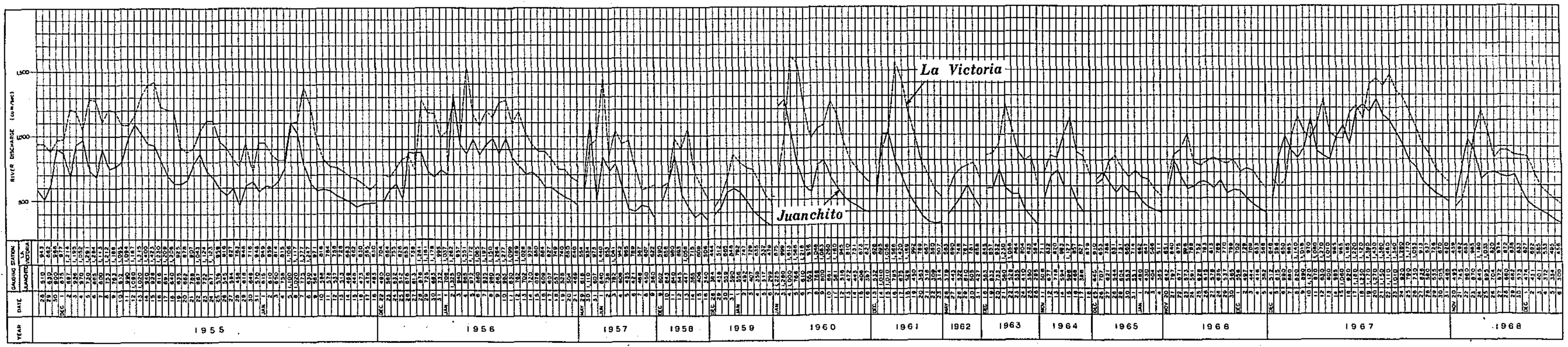


Fig. 6.3 Estimated Undeformed Flood at Juanchito and La Victoria

Table 6.4 Relation between River Channel Capacity and Excess Flood Volume

(Unit: 10^6 cu.m)

Return Period	Capacity of River Channel at Juanchito in cu.m/s			Capacity of River Channel at La Victoria in cu.m/s		
	650	800	950	750	1,000	1,200
10	350	170	80	1,050	300	110
20	650	330	160	2,100	610	190
30	900	460	220	3,080	900	250
40	1,080	580	260	4,000	1,100	300
50	1,250	690	330	4,600	1,340	340

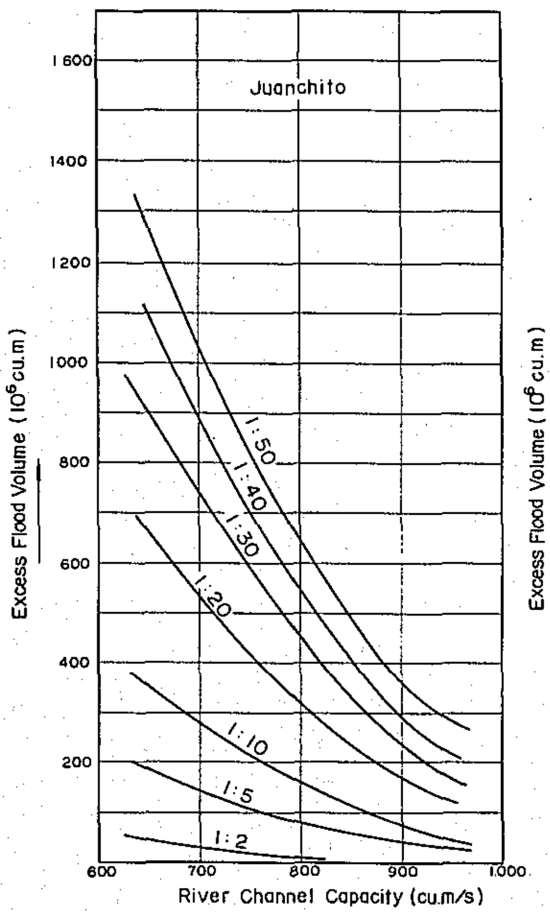


Fig. 6.4 (1) Probability of Excess Flood Volume Exceeding River Channel Capacity at Juanchito

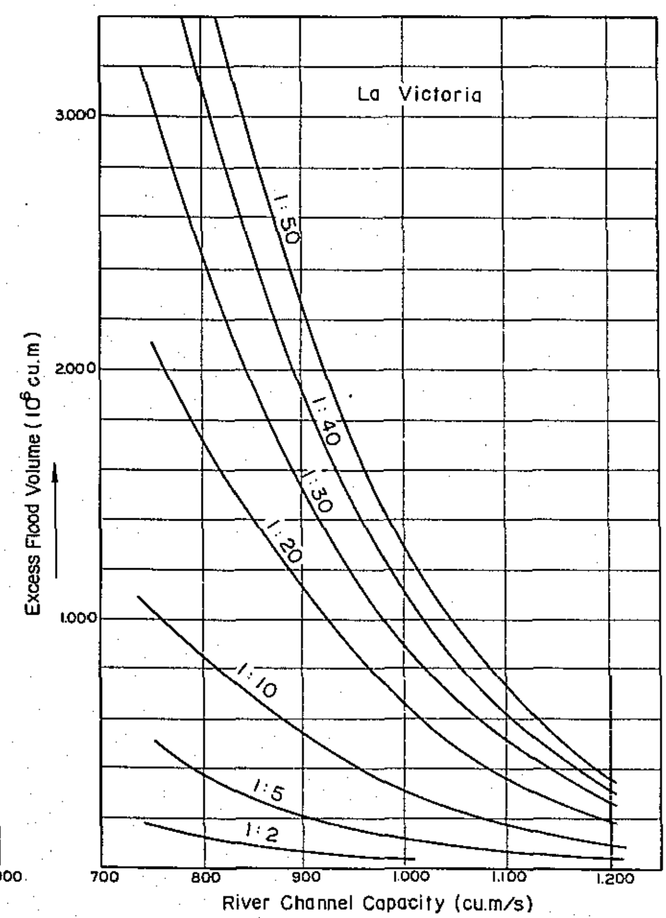
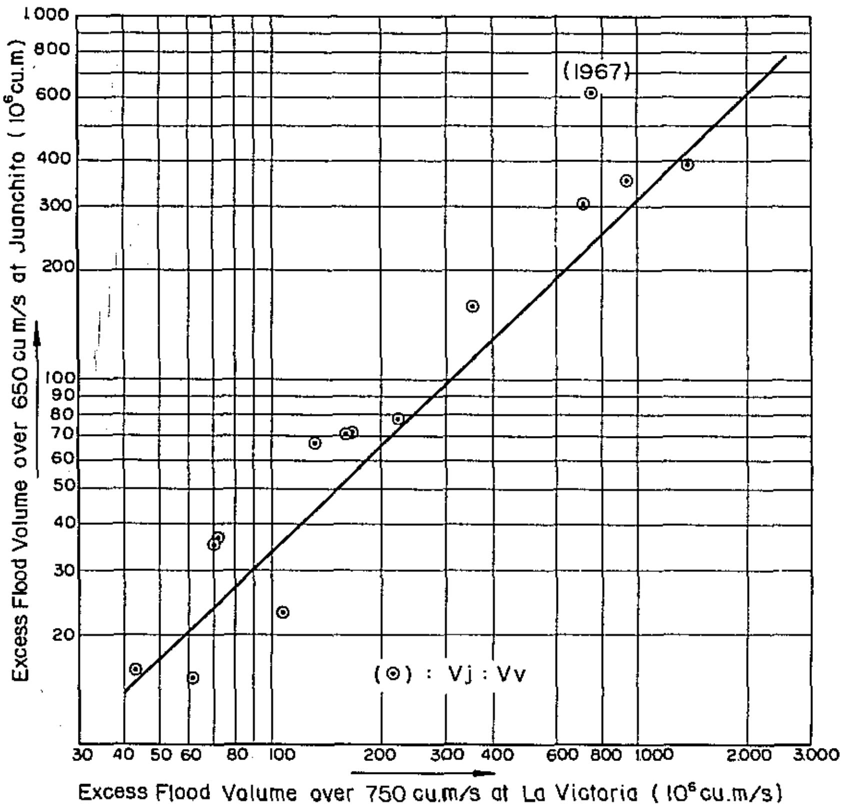


Fig. 6.4 (2) Probability of Excess Flood Volume Exceeding River Channel Capacity at La Victoria

Fig. 6.5   Relation between Excess Flood Volume at Juanchito and La Victoria



6.3.4   Relation between Excess Flood Volume and Flood Damages

There are only a few data regarding damages caused by inundation and it is rather difficult to obtain an accurate knowledge of the relation between magnitude of flood and inundated area or amount of damage. Therefore, the relationship between magnitude of flood and amount of damage was estimated on the basis of past floods. From the investigations of oral questionnaire and aerial photograph for the flooded area in the flood of November 1967 corresponding to frequency of once in two or three years, it is estimated that inundated area have been approximately 13,000 ha as shown in Fig. 5.1.

For inundated area and amount of damages by a relatively large flood, there is a precise investigation data carried out by CVC of the flood of December 1966 which is of a probability of once in ten years at La Victoria. (estimated flood discharge; 1,450 cu.m/s, inundated area; 57,600 ha)

Table 6.5 gives a summary of inundated area and amount of damages caused by this flood. The total amount of damages for the inundated area of 57,600 ha is estimated at 82.6 million pesos. This total amount includes damages of sugar mills, agricultural facilities and livestock as well as losses in crops. It is considered that approximately 8,000 ha of inundated area at the beginning of flooding is river channels, marshes and unutilized waste land which do not involve monetary losses.

Besides the inundation of farmland, there are losses to transportation, communication facilities and commerce and industry, but in this report only the flood damages mentioned in the CVC Report were considered. The unit loss per ha convereted into 1969 values are estimated to be 2,000 pesos per ha using the present rate of exchange to the dollar (13.5 pesos to one dollar in 1966, 17.35 pesos to one dollar at present). The relation of "excess flood volume–inundated area–amount of damage" graphically expressed based on the past floods record is given in Fig. 6.6.

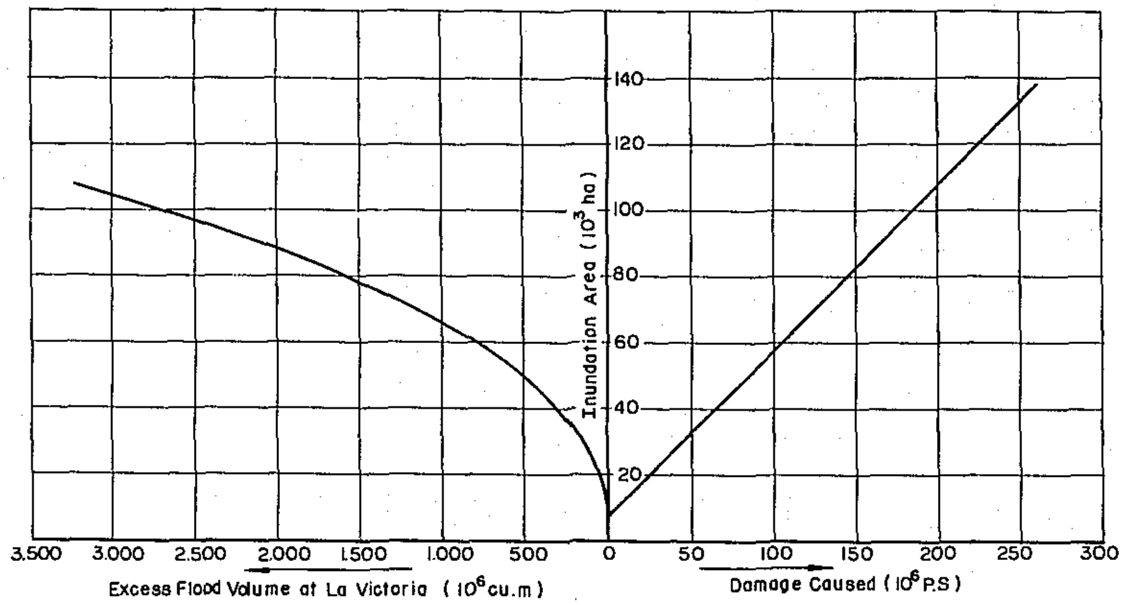
Table 6.5 Damage Caused by Flood in December 1966

		Dept. Valle	Dept. Cauca
I.	Damage Area (plaza)	Dept. Valle	Dept. Cauca
1.	Crops and Pasture Area Directly Affected	42,834	5,435
2.	Sugar Cane Field in Mills	3,456	150
3.	Tributaries Overflow Area	5,000	
4.	Water Retired without Making Damage	33,125	
	Total Area	90,000 (57,600 ha)1/	

		Dept. Valle	Dept. Cauca
II.	Costs of Losses (10^3 pesos)	Dept. Valle	Dept. Cauca
1.	Damages of Civil Engineering Works in Mills	1,494.5	–
2.	Direct Investments in Sugar Cane Plantations	13,180.0	600.0
3.	Net Income Received in Mills	4,910.0	298.9
4.	Direct Investments made by the Cultivators	23,237.8	2,525.2
	Temporales	18,525.4	1,714.0
	Permanentes	2,636.8	298.0
	Intercaldas	1,516.6	350.7
	Pastos	508.5	84.0
	Otros	50.5	51.5
5.	Net Income not Received by Cultivators	25,104.3	2,909.7
6.	Livestocks	1,883.5	25.7
7.	Installations and Agriculture Machineries	4,188.4	277.7
8.	Houses and Household Goods	1,882.2	91.0
	Total	75,883.9	6,728.2
	Grand Total	82,612.1	
	Damage per ha	1,440.0 pesos per ha.	

1/ Including 3,000 ha of river bed

Fig. 6.6 Relation between Damage Caused and Excess Flood Volume



6.3.5 Flood Hydrograph at Salvajina and Reservoir Operation

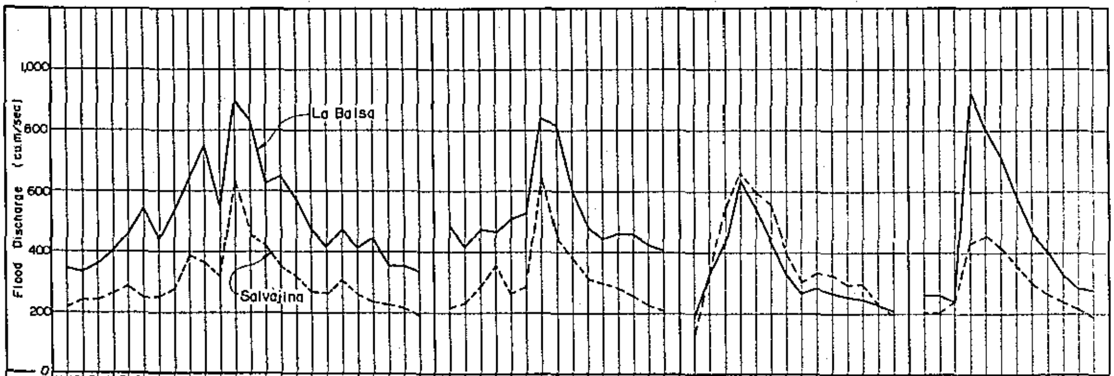
(1) Flood Hydrograph

The magnitude of flood discharge (volume and peak) at the Salvajina site (catchment area 3,830 sq.km) estimated by statistical procedures for the 23 years records is given in Table 6.6. And also, the representative past four flood hydrographs of Salvajina and La Balsa is exhibited in Fig. 6.7 (1). Based on this figure, the flood hydrographs at Salvajina corresponding to the probability magnitude of flood were estimated as shown in Fig. 6.7 (2).

Table 6.6 Total Flood Volume and Peak Discharge for Each Magnitude of Flood at Salvajina Site

Return Period	Total Flood (10^6 cu.m)	Max. Daily Average Discharge (cu.m/s)	Peak Discharge (cu.m/s)
5	350	650	770
10	480	750	880
15	540	820	950
20	600	850	980
30	700	900	1,030
40	750	950	1,080
50	800	1,000	1,100

Fig. 6.7 (1) Flood Hydrograph at La Balsa and Salvajina



Flood Discharge (cu.m/sec)

1950 - Nov~Dec

Date	Salvajina	La Balsa
11	218	349
12	237	333
13	237	359
14	260	402
15	287	460
16	248	545
17	247	436
18	273	539
19	389	637
20	358	749
21	316	550
22	636	897
23	450	833
24	413	625
25	344	645
26	312	568
27	263	463
28	258	412
29	306	468
30	258	406
1	229	443
2	223	347
3	204	346
4	185	322

1955 - Dec~Jan

Date	Salvajina	La Balsa
	216	479
30	232	417
31	280	475
1	351	464
2	265	507
3	287	525
4	641	837
5	441	815
6	376	600
7	308	478
8	292	442
9	282	459
10	250	458
11	224	423
12	226	403

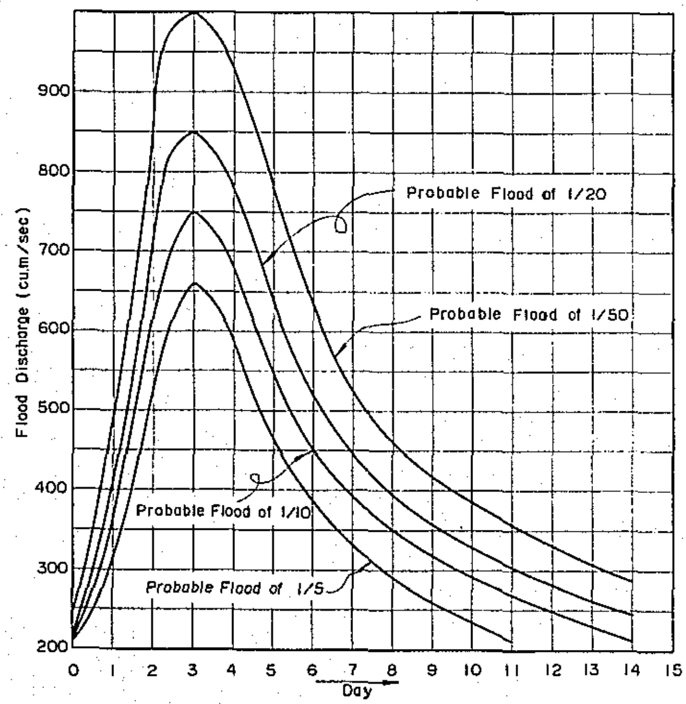
1960 - Dec~Jan

Date	Salvajina	La Balsa
30	181	121
31	315	230
1	540	422
2	660	637
3	597	543
4	556	433
5	397	326
6	309	267
7	331	283
8	323	266
9	293	252
10	298	246
11	235	230
12	197	208

1960 - Dec.

Date	Salvajina	La Balsa
10	209	267
11	206	262
12	240	240
13	432	923
14	457	803
15	411	718
16	356	583
17	298	468
18	262	409
19	234	329
20	216	285
21	200	281

Fig. 6.7 (2) Estimated Flood Hydrograph at Salvajina



(2) Flood Control by Reservoir

In general, there is a fairly good correlation between peak discharge at the Salvajina site and those of Juanchito and La Victoria as indicated in Fig. 6.8. When the peak discharge at Salvajina reaches 300 cu.m/s, those at Juanchito and La Victoria are considered to be approximately 600 cu.m/s and 900 cu.m/s respectively. The operation of the reservoir is to be carried out with this in mind to maintain an allowance in downstream river channel capacity at all times. When applying reservoir operation rule of the Salvajina Reservoir to the various magnitude of floods, relation between necessary reservoir volume and reduction of flood discharges at Juanchito are shown in Table 6.7. Fig. 6.9 gives flood control effect at Juanchito by the reservoir in case of once in ten year flood.

Table 6.7 Relation between Storage Capacity of Salvajina Reservoir and Controlled Flood Discharges at Juanchito

Return Period	10	15	20	30	50
Max. Flood Discharge at Salvajina (cu.m/s)	750	820	850	900	1,000
Max. Flood Discharge at Juanchito (cu.m/s)	1,400	1,450	1,550	1,650	1,800
Storage Capacity at Salvajina (10^6 cu.m)	350	403	445	502	586
Water Release from Salvajina Reservoir (cu.m/s)	0	0	0	0	0
Runoff from the Basin downstream of Salvajina Dam1/ (cu.m/s)	720	770	830	880	950
Flood Discharge Regulated by River Storage at Juanchito (cu.m/s)	700	750	810	865	935
Design High Water Discharge for Levees at Juanchito2/ (cu.m/s)	720	770	830	880	950

1/ See Table 6.8.

2/ See 6.3.6 (2)

(3) Criteria of Reservoir Water Level

It can be considered that flood seasons of the Cauca River come roughly twice a year. The first one in which flooding is severest is from November to December and 80% of past floods have occurred in this period. The floods occurring from April to June are comparatively smaller than those of the first one and 20% of past floods correspond to this category. Therefore, except for extremely dry years, it is necessary to establish a criteria of reservoir water level based on the magnitude of frequency of past floods. The criterion of the proposed reservoir operation is shown in Fig. 6.10.

Concerning this criterion, in the future when operation is started, it will be possible to improve this criterion by coordinating flood control and power generation in order to achieve efficient operation of Salvajina Power Plant which is operated in combination with Calima I and Alto Anchicaya Power Plants without impairing the flood control effects, etc.

Fig. 6.8 Relation between Annual Max. Undeformed Discharge at Juanchito, La Victoria and Salvajina

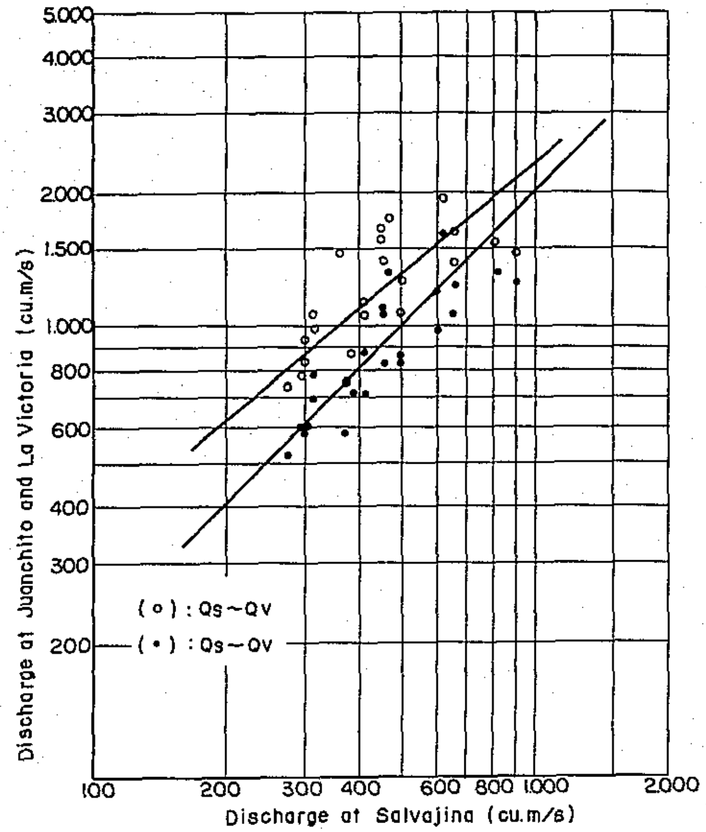


Fig. 6.9 Flood Control Effect at Juanchito by Salvajina Reservoir in Case of Once in Ten Years' Flood

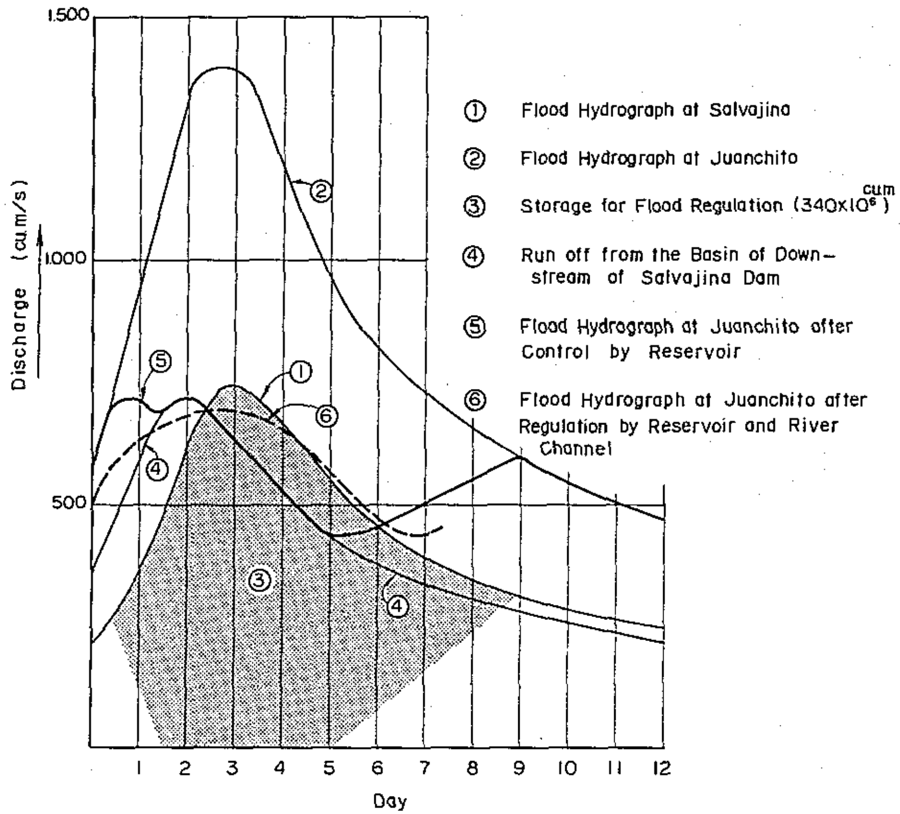
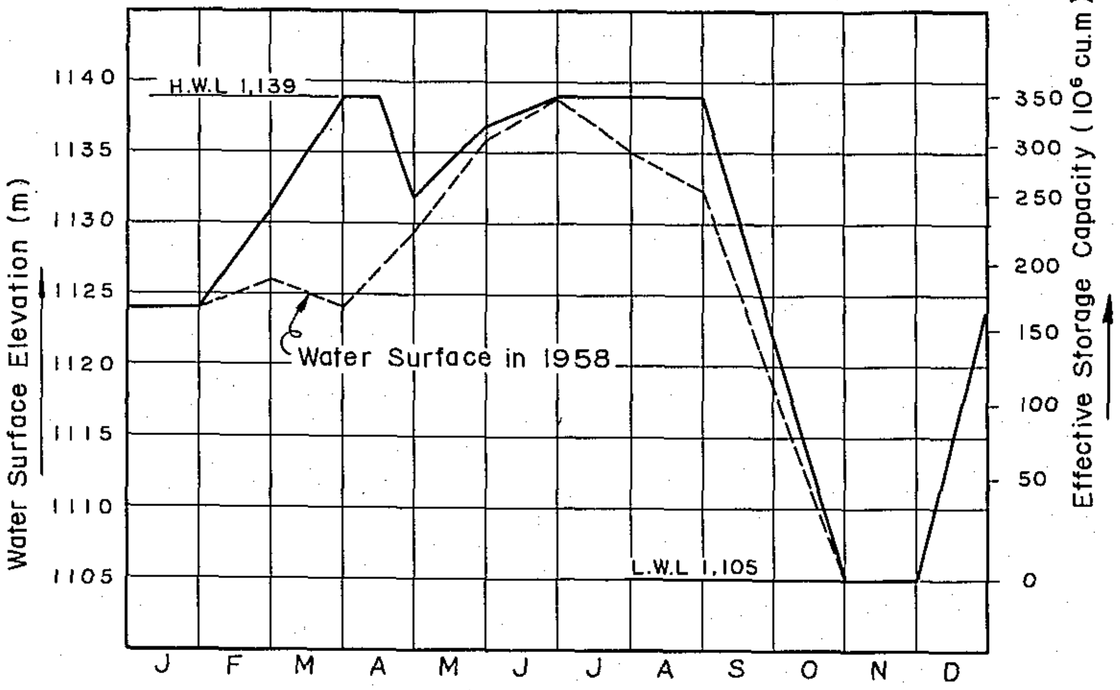


Fig. 6.10 Operation Rule of Salvajina Reservoir

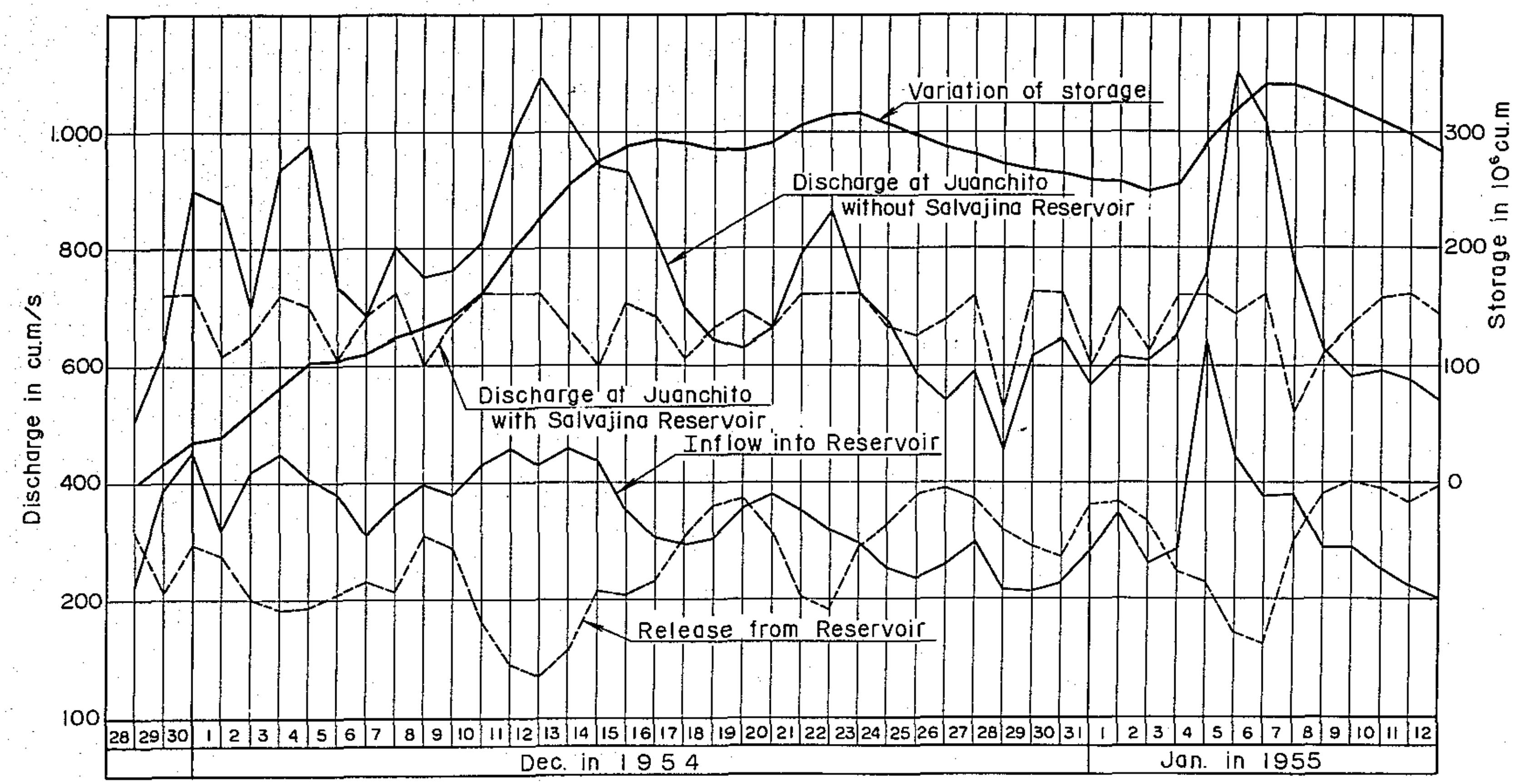


(4) Release from the Reservoir

From past experience it is seen that the flood of the Cauca River is not necessarily one peak hydrograph. Reservoir water level rising by the first flood wave has to be lowered to the criterion water level as soon as possible whenever there is allowance in downstream river channel capacity using the outlets in addition to power generation discharge in preparation for the second and third flood waves.

The possible discharge capacity including power releases has been set at 400 cu.m/s at the reservoir low water level of EL. 1,105 m. As an example, applying the reservoir operation rule of the Salvajina Reservoir to the flood of 1954 corresponding to return period of 10 or 15 years, the results of reservoir operations are as shown in Fig. 6.11.

Fig. 6.11 Flood Control by Reservoir for 1954 Flood



6.3.6 Design of River Channel

(1) Flood Discharge from Drainage Area downstream of Salvajina

The levees to be constructed on both banks of the river are to function with the storage capacity of the upstream reservoir for the purpose of flood control. In planning these levees, the discharges from the drainage area downstream of Salvajina must be taken into consideration. This is because, regardless of the size of the dam to be constructed at Salvajina, the flood discharge from the drainage area downstream of Salvajina can not be controlled by the dam and flooding must be protected by the river levees only.

The flood discharges from the drainage area downstream of Salvajina were estimated for both Juanchito and La Victoria on the basis of the beforementioned undeformed hydrographs of the two sites deducting the inflow at Salvajina and allowing a three days time lag between Salvajina and La Victoria. Applying statistical methods to these values, the magnitude of flood discharge at Juanchito and La Victoria from the drainage area downstream of Salvajina were obtained as shown in Table 6.8.

Table 6.8 Magnitude of Flood from the Basin down stream of Salvajina

	Probable Discharge in(cu.m/s)	
Return Period	Juanchito 1/	La Victoria 1/
10	720	1,120
20	830	1,290
30	880	1,370
40	910	1,430
50	950	1,470

1/ Flood from the basin between Salvajina and Juanchito.

2/ Flood from the basin between Salvajina and La Victoria.

(2) Design River Channel Capacity

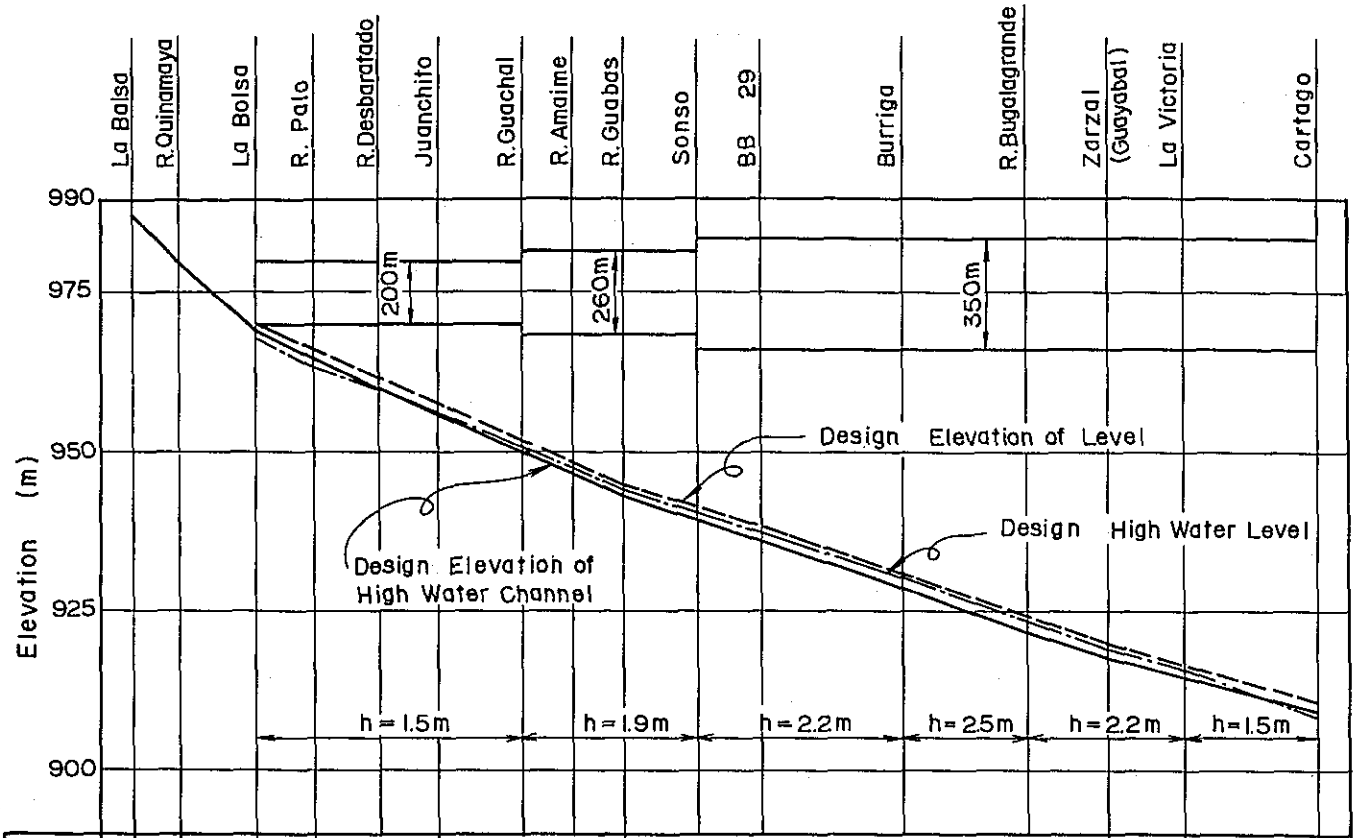
As indicated in Fig. 6.12, the Cauca River between La Balsa and Cartago was divided by the junction points of major tributaries into fifteen sections from section A to section O and the design river channel capacity for each section were determined to be from 400 cu.m/s to 1,000 cu.m/s based on the assumptions given below.

(i) The effective storage capacity of Salvajina Reservoir of 350 x 10^6 cu.m is capable to completely impound flood discharge of probability of 1:10 and therefore the downstream river levees were also designed to sustain the peak discharge from the drainage area downstream of the dam with probability of 1:10. According to statistical calculation, the design high water discharge at Juanchito and La Victoria were estimated to be 720 cu.m/s and 1,120 cu.m/s respectively taking a safety margin into consideration as shown in Table 6.8. (Actual flood discharges will be smaller due to channel storage.)

(ii) The design high water discharges of other sections were interpolated from the ratio of drainage area on the basis of the above two values.

(iii) The magnitude of peak discharges controlled by Laguna Sonso and Cienaga Burriga was estimated at 80 cu.m/s and 40 cu.m/s respectively at the time of flood.

Fig. 6.12 General of River Scheme

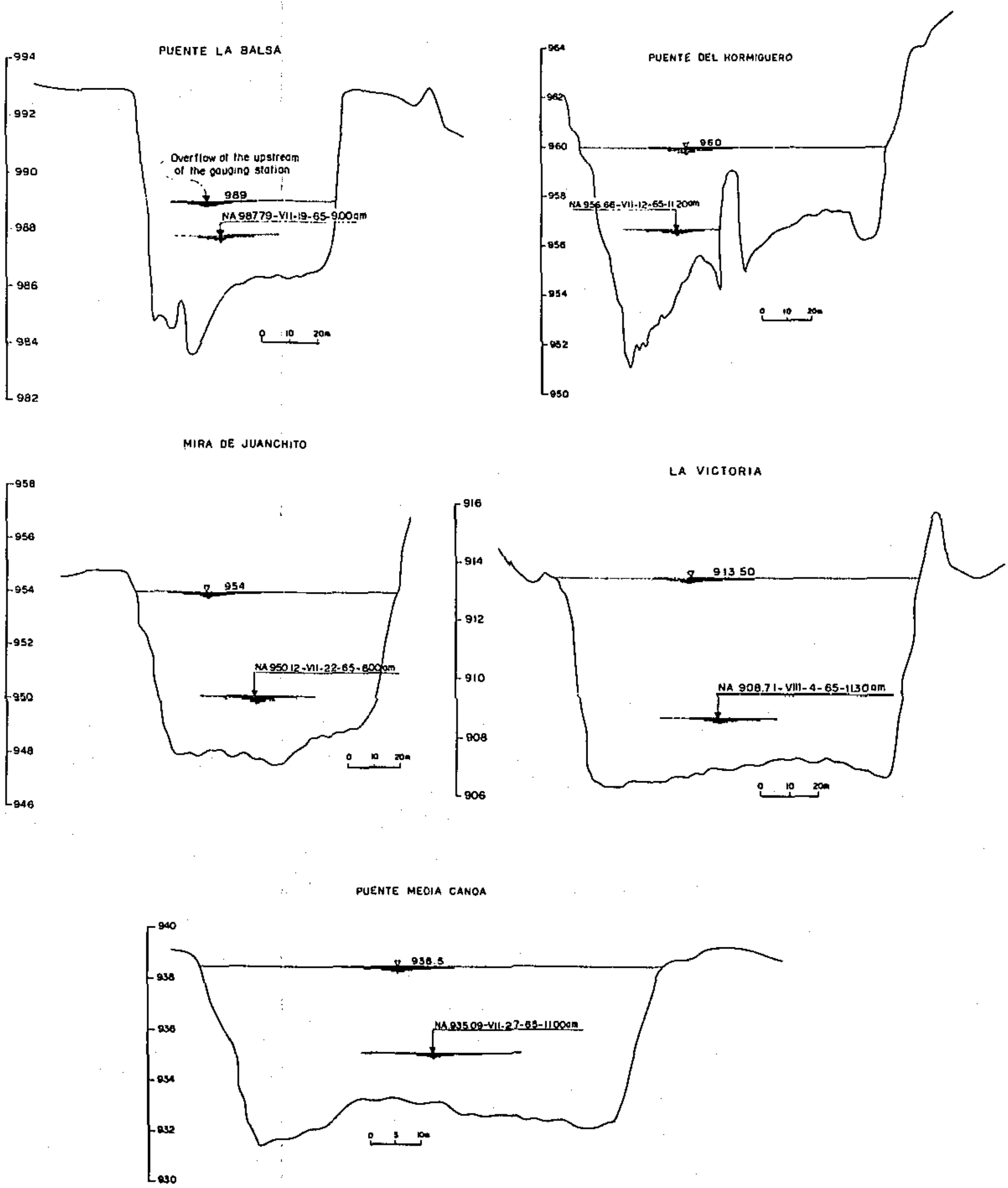


Station	NO.	Dist. (km)	Q1 (cum/s)	Q2 (cum/s)	E1 (El.m)	E2 (El.m)	E3 (El.m)
La Balsa	TN 0	0	290	580	987.3		
R.Quinamaya	TN 32	13.5	350	600	979.6		
La Bolsa	TN 85	38.1	590	600	969.0	967.9	970.5
R. Palo	TN 122	56.3	650	690	964.4	963.3	965.9
R.Desbaratado	TN 161	76.5	680	690	959.7	959.6	961.2
Juanchito	NB 20	94.5	720	720	955.8	955.9	957.3
R.Guachal	NB 72	121.0	800	870	949.9	950.4	951.8
R.Amaime	NB 99	135.7	890	840	946.5	947.3	948.4
R.Guabas	NB 127A	151.9	930	840	942.9	943.9	944.8
Sonso	NB 163	174.4	950 (800)	680	939.2	940.2	941.4
BB 29	BB 29	193.7	980 (830)	680	936.0	937.3	938.2
Burriga	BB 7813	237.6	1.010 (790)	540	928.4	930.1	930.9
R.Bugalagrande	BB 119	276.8	1.150 (930)	540	921.7	923.4	924.2
Zarzal (Guayabal)		301.8	1.190 (970)	760	917.7	918.9	919.9
La Victoria		324.8	1.220 (1.000)	760	914.5	915.8	916.7
Cartago		366.8	1.240 (1.020)	1.060	909.3	908.2	910.8

I	Reach
1/3,900	La Bolsa – R. Palo
1/4,500	R. Palo – R.Guabas
1/6,000	R.Guabas – Zarzal
1/7,500	Zarzal – La Victoria
1/8,000	La Victoria – Cartago

Sect.														
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O

CROSS SECTIONS OF GAUGING STATION ON CAUCA RIVER



h = Height of level

I = Gradient of river

E_3 = Design elevation of level

E_2 = Design high water level

E_1 = Design elevation of high water channel

Q_2 = Present river capacity

Q_1 = Design high water discharge

(3) Regulating Ponds

There are many oxbow lakes and marshes along the Cauca River. Lag. Sonso has especially an important role as a protection and preservation district of wildlife such as fish and animals. Lag. Sonso and Cga. Burriga can be utilized as regulating ponds for flood control also. The area-capacity curves of these regulation ponds are as shown in Fig. 6.13 and it will be possible to impound 35 million cu.m at Lag. Sonso and 15 million cu.m at Cga. Burriga with a depth of approximately 3 m.

The peak flood discharge which can be controlled by these regulating ponds through gate operations are calculated at 80 - 100 cu.m/s at Lag. Sonso and 40 - 60 cu.m/s at Cga. Burriga. These values have been obtained by means of the storage capacities of two regulating ponds and the flood hydrograph at these ponds, which has been estimated on the basis of the hydrograph at Juanchito. (See Fig. 6.14.)

Fig. 6.13 Area Capacity Curve of Lag. Sonso and Cga. Burriga

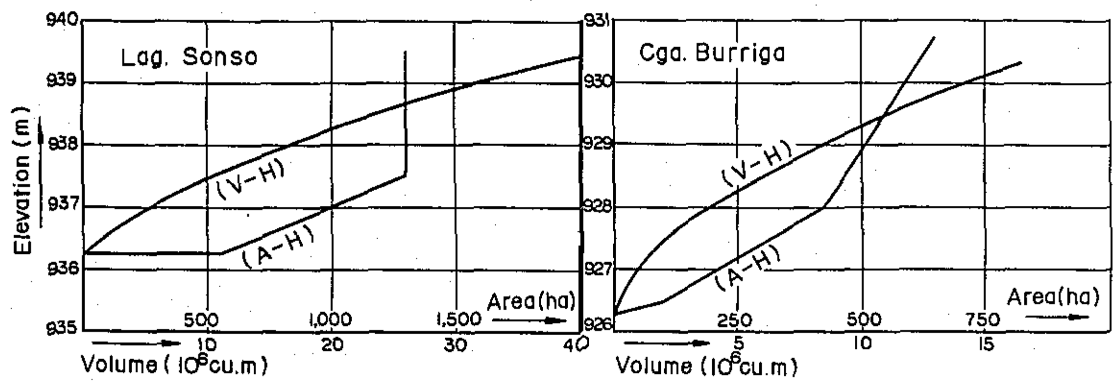
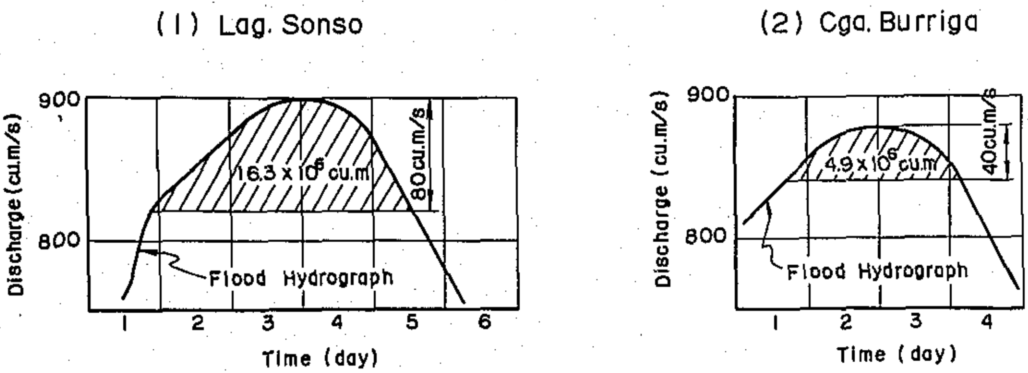


Fig. 6.14 Regulation of Flood at Lag. Sonso and Cga. Burriga



6.3.7 Design Discharge of Tributaries

There are fifteen major tributaries of the Cauca River which are listed in Table 6.9. The relation between specific runoff per sq.km corresponding to a magnitude of once in ten years and catchment areas are shown in Fig. 6.15.

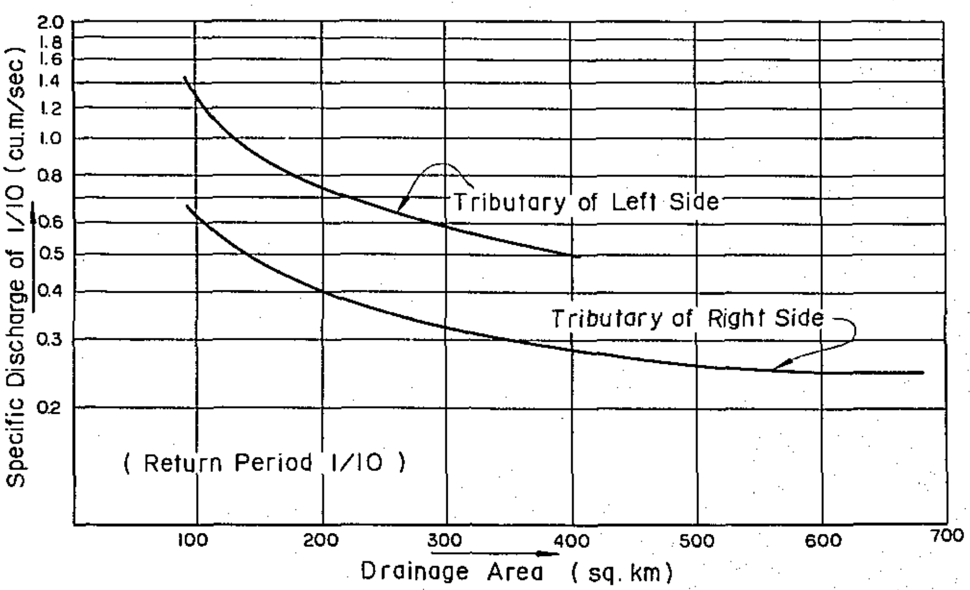
The design discharges of the various tributaries at their junctions with the mainstream are shown in Table 6.9. Out of the aforementioned tributaries eleven rivers indicated with "1/" in Table 6.9, should be protected by levees. The extent of levees is to cover the area where the back water of the Cauca River reaches.

Table 6.9 Main Tributaries in Cauca Plain and its Discharge

Tributary	Catchment Area (sq.km)	Specific Discharge (cu.m/s per sq.km)	Design Discharge (cu.m/s)
Rio Quinamayo	340	0.31	110
Rio Palo 1/	1,550	0.21	330
Rio Desbaratado 1/	190	0.41	80
Rio Amaime 1/	820	0.24	200
Rio Zabaletas 1/	150	0.47	70
Rio Guabas 1/	190	0.41	80
Rio Guadalajara 1/	220	0.38	70
Rio Tulua 1/	720	0.24	170
Rio Burriga 1/	180	0.42	80
Rio Bugalagrande	860	0.24	210
Rio Guachinte	100	1.30	130
Rio Jamundi 1/	400	0.50	200
Rio Cali 1/	120	1.03	120
Rio Frio 1/	140	0.92	130
Rio Pescador	140	0.92	130

1/ Levees were proposed.

Fig. 6.15 Specifie Discharge of Tributaries



6.4 Alleviation of Cauca River Contamination

6.4.1 Increase of River Discharge in Drought Season

The low runoff season of the Cauca River is from August to September and contamination of the river downstream of Cali becomes the worst during this season.

According to runoff records at Juanchito since 1946, the smallest discharge in the dry season from July to October is from 74 cu.m/s to 117 cu.m/s (average 100 cu.m/s) in 1958, the next smallest is 82 cu.m/s to 148 cu.m/s (average 109 cu.m/s) in 1946 and the third smallest is 72 cu.m/s to 180 cu.m/s (average 117 cu.m/s) in 1961. (See Table 6.10).

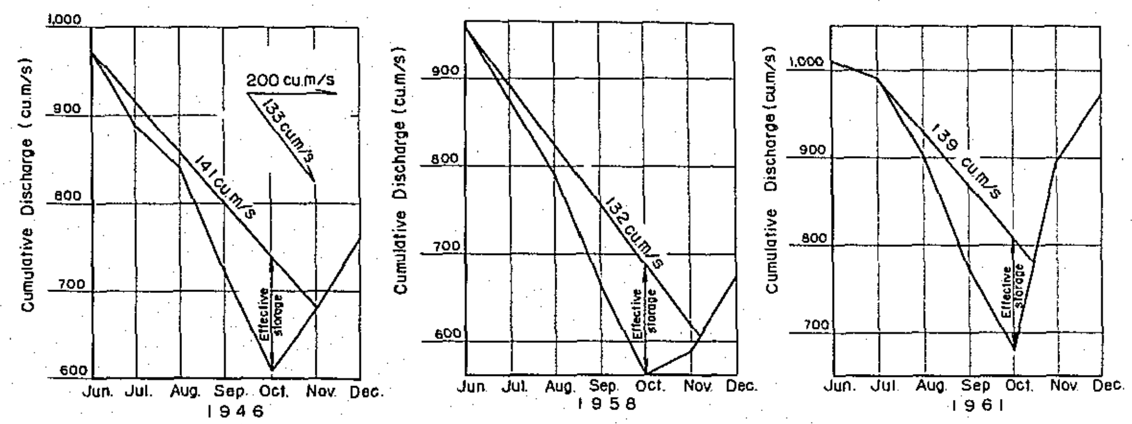
The seven days continuous runoff in the driest month of September, which has a probability of once in ten years, is approximately 70 cu.m/s shown in Fig. 5.5.

When the Salvajina Dam is built, the increase of river flow at Juanchito, which is brought about by the Salvajina Reservoir operations in the abovementioned three dry seasons is as indicated in Fig. 6.16 and a runoff of approximately 130 cu.m/s to 140 cu.m/s can be secured.

Table 6.10 Average Monthly Discharge in Dry Season at Juanchito (Unit: cu.m/s)

Year	1946	1958	1961
July	116	113	180
August	148	117	112
September	82	74	72
October	91	95	104
Total	437	399	468

Fig. 6.16 Discharge in Dry Season at Juanchito with Reservoir



6.4.2 Effect of Alleviation of River Contamination

The effect of alleviation of river contamination can be expressed by the difference between the construction cost of the sewage disposal plant which will be required for dry season discharges of 70 cu.m/s and 130 cu.m/s.

According to the studies[1/] by Hazen & Sawyer Co., the construction cost of sewage disposal facilities required up to 2000 A.D., if the discharge at Juanchito is the present 70 cu.m/s, will be 1,458 million pesos, and the cost, if the discharge is 130 cu.m/s, will be 1,067 million pesos. The savings in plant costs in terms of present worth at the end of 1976 becomes 230 million pesos, while the annual cost will be 23.4 million pesos as shown in Table 6.11.

In the above estimations, the discount rate of 8.5%[2/] is applied, while annual maintenance and operation costs were taken at 1.5% of the capital investment.

As mentioned in 3.3, when discharging water from the Salvajina Reservoir in dry season, the plant is to operate as a base load plant to keep constant increased river discharge at the downstream. This operation is considered possible under the cooperation with Calima No. 1 and Alto Anchicaya, using their ample peak capacity.

Table 6.11 Reduction of Annual Expense for Sewage Disposal

Year	Waste Water Flow (cu.m/s)	Qmin. = 70 cu.m/s: Construction Cost 1/ (10^6 pesos)	Qmin. = 70 cu.m/s: Present Worth Factor in 1976 3/	Qmin. = 70 cu.m/s: Present Worth in 1976 (10^6 pesos)	Qmin. = 130 cu.m/s: Construction Cost 2/ (10^6 pesos)	Qmin. = 130 cu.m/s: Present Worth in 1976 (10^6 pesos)	Reduction of Construction Cost in 1976 (10^6 pesos)
1976	4.4	193	1.0000	193	-	-	193
1980	6.0	178	0.7216	128	-	-	128
1985	8.2	-	0.4700	-	364	171	(-) 171
1990	10.5	390	0.3191	124	238	76	48
2000	15.9	697	0.1412	98	465	66	32
Total		1,458		543	1,067	313	230

Amortization for 50 years of service life	p.s. 19.9×10^6
Operation and maintenance expense (1.5% of reduction of construction cost)	p.s. 3.5×10^6
Annual expense	p.s. 23.4×10^6 (US$$1.35 \times 10^6$)
Total annual expense for 50 years	p.s. 270.6×10^6 (US$$15.6 \times 10^6$)

1/ Construction cost of sewage disposal facilities for 70 cu.m/s of minimum discharge at Juanchito.
2/ Construction cost of sewage disposal facilities for 130 cu.m/s of minimum discharge at Juanchito.
3/ Discount rate of 8.5% is applied.

1/ Refer to memorandum (6) in Chapter 12.
2/ See Chapter 10.

6.5 Power Generation

The power produced at Salvajina Power Plant will be consumed at the load centers of the CVC System. However, the interconnection transmission line will be completed at the end of 1971 and it will become possible to interchange power between EEEB, EPM and CVC systems. Therefore, the start of operation of the Salvajina Power Plant will be influenced by this interconnection line and it is necessary to study the Salvajina Power Plant on the basis of this interconnection also.

6.5.1 Operation of Reservoir for Power Generation

The main purposes of Salvajina Reservoir are flood control and alleviation of contamination of the Cauca River, consequently reservoir operation rules must be established to satisfy these purposes. In other words, as indicated in Fig. 6.10, it is necessary to draw down the reservoir to low water level before November for flood control purpose. While on the other hand, the reservoir level should be maintained at the highest possible elevation in other months in order to operate the power plant at its full potential.

For this reason, it will not be possible to regulate inflow from year to year or to operate the reservoir for power generation only. However, at the time the Salvajina Power Plant is commissioned, Alto Anchicaya Power Plant (340 MW) presently under construction will be in service, and together with Calima I Power Plant (120 MW) already in operation, there will be in operation three reservoir-controlled power plants within the CVC System. Table 6.12 gives a description of Calima I and Alto Anchicaya Power Plants.

Table 6.12 Summary of Calima I and Alto Anchicaya Power Plants

Item	Calima I	Alto Anchicaya
Reservoir		
Catchment Area (sq.km)	350	520
Annual Average Discharge (cu.m/s)	18.3	56.0
Total Storage Capacity (10^6 cu.m)	581	45
Effective Storage Capacity (10^6 cu.m)	441	30
Max. Water Surface Level (El.m)	1,400	646
Power Plant		
Output (MW)	120	340
Number of Unit	4	4
Max. Discharge (cu.m/s)	76	104
Effective Head (m)	212	390
Average Annual Energy (10^6 kWh)	360	1,760

Calima I and Alto Anchicaya are located in the basin draining into the Pacific Ocean and the high-water season comes in October one month earlier than the Cauca River basin as shown in Fig. 6.17. In order to provide storage space in November for flood control purpose, Salvajina Power Plant has to operate at low water level of the reservoir using only natural flow, but this demerit can be made up by the combined operation with Calima I and Alto Anchicaya Power Plants, because of the large reservoir capacity of Calima I and abundant flow at Alto Anchicaya at this period.

Therefore, through the coordinated operation of the three reservoir controlled power plants, taking advantages of the different hydrological conditions in the two basins, the demerits to power generation arising from the restrictions on use of the Salvajina Reservoir can be covered and economic operation can be achieved. The Salvajina reservoir operation which is simulated on the basis of past dry years of 1956 to 1958 is as shown in Fig. 6.18.

Fig. 6.17 Runoff in MW at Calima I, Alto Anchicaya and Salvajina Power Plant

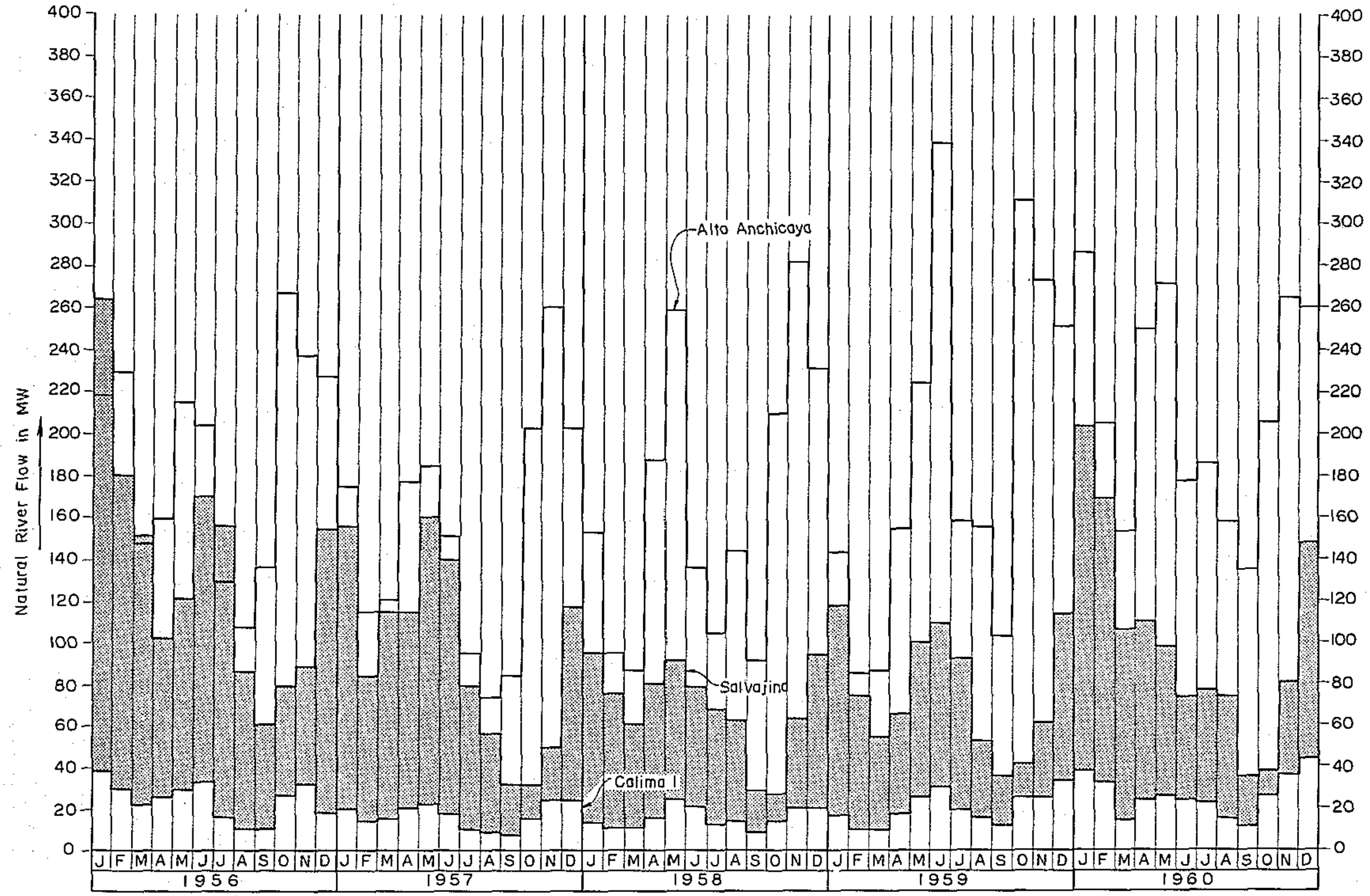
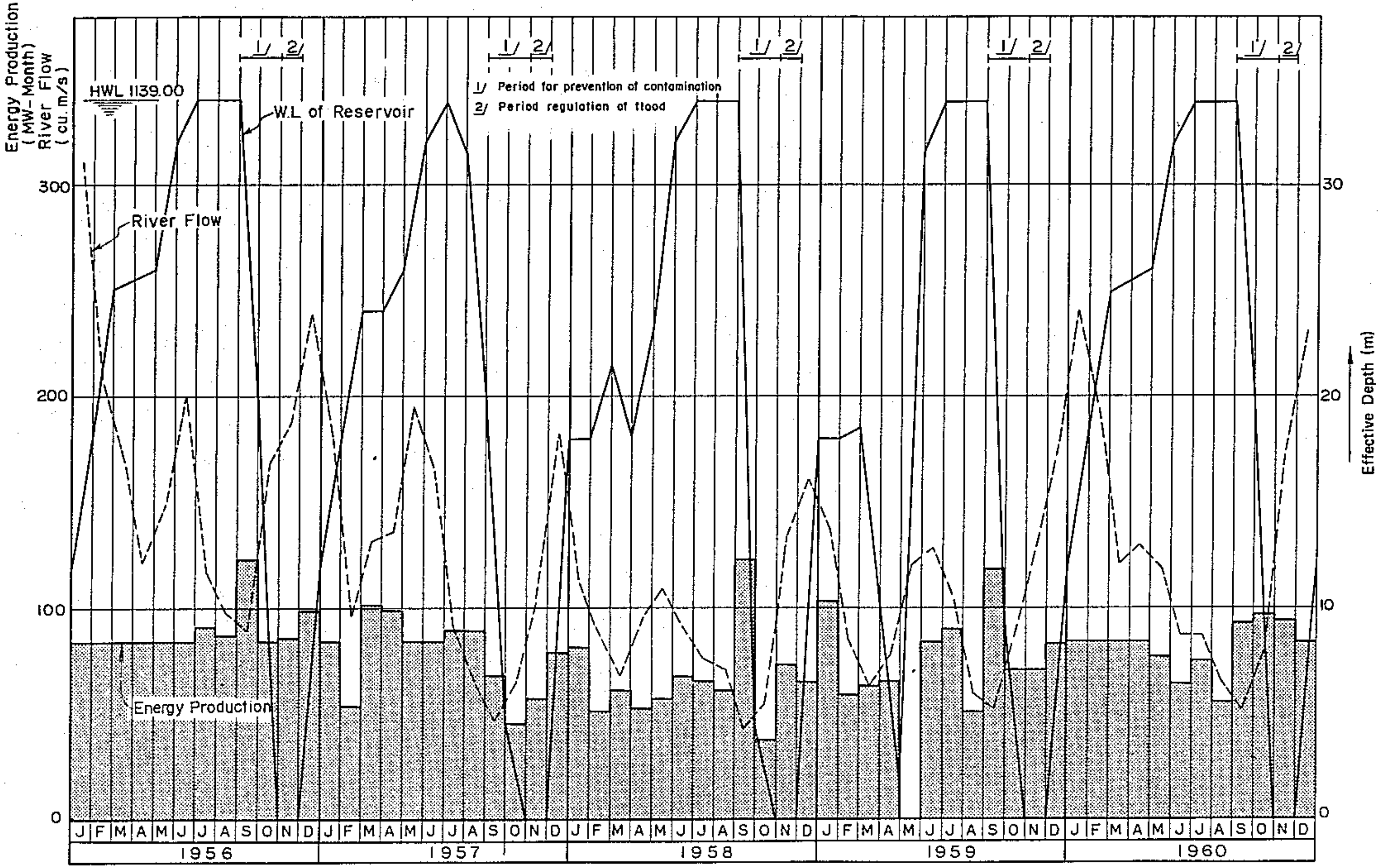


Fig. 6.18 Water Level Variation of Salvajina Reservoir and Energy Production in Dry Year



6.5.2 Optimum Scale of the Salvajina Power Plant

On the basis of the study of scale of development mentioned in Table 6.2, several alternatives of scale of the plant were studied in Table 6.13 according to the following basic assumptions.

(i) Dam height, reservoir capacity, etc. for case C-b in the Table 6.2.

(ii) Power generation according to the reservoir operation rule mentioned in 6.3.5.

(iii) The plant will supply the peak load above the average line of load duration curve lasting for eight hours in the CVC power system except for dry months of August and September, during which time the peak load is to be supplied by Calima I and Alto Anchicaya.

(iv) Evaluation of power and energy output of the plant was made on the basis of standard thermal power plant and benefits of U.S.$21.0/kW and U.S.$0.0028/kWh were applied.

(v) The alternative output considered for the Salvajina Power Plant are 80 MW, 140 MW, 210 MW and 280 MW.

The result of the study is shown in Fig. 6.19, indicating that an installed capacity of 210 MW is the optimum giving a benefit-cost ratio of 1.68 and annual surplus benefit of U.S.$3,838,000. From the standpoint of the size of the power system, a unit capacity of 70 MW was adopted. As stated in 6.5.4, two units of 70 MW are to be installed at the end of 1976 with the third unit to be added at the end of 1978 corresponding to growth of demand.

Fig. 6.19 Relation between Installed Capacity and B/C of Salvajina Power Plant

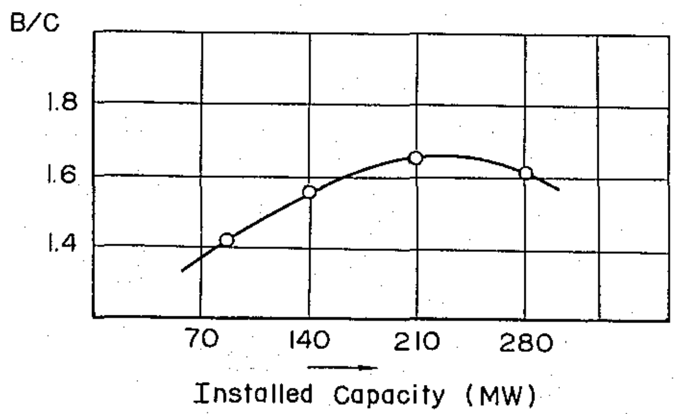


Table 6.13 Optimum Scale of Salvajina Power Plant

Installed Capacity (MW)		80	140	210	280
Total Storage Capacity	(10^6 cu.m)	500	500	500	500
Storage Capacity for Flood Control	(10^6 cu.m)	350	350	350	350
High Water Level	(m)	1,139	1,139	1,139	1,139
Low Water Level	(m)	1,105	1,105	1,105	1,105
Max. Discharge	(cu.m/s)	103	180	270	360
Equalized Salable Capacity 1/	(MW)	80.0	133.9	189.2	217.9
Equalized Salable Energy	(MWh)	646,600	646,600	646,600	646,600
Annual Benefit (10^3\$)					
KW		1,681	2,812	3,973	4,576
kWh		1,810	1,810	1,810	1,810
Flood Control		2,370	2,370	2,370	2,370
Alleviation of River Contamination		1,350	1,350	1,350	1,350
Total Annual Benefit [B]		7,211	8,342	9,503	10,106
Construction Cost 2/ (10^3\$)					
Dam		31,281	31,281	31,281	31,281
Levees		11,600	11,600	11,600	11,600
Power Plant		8,657	11,049	15,459	20,525
Total		51,538	53,930	58,340	63,406
Annual Cost (10^3\$)					
Interest and Depreciation 3/		4,458	4,665	5,046	5,485
Operation and Maintenance					
Dam		313	313	313	313
Levees		151	151	151	151
Power Plant		87	117	155	205
Total Annual Cost [C]		5,009	5,246	5,665	6,154
B/C		1.44	1.59	1.68	1.64
B–C (10^3\$)		2,112	3,096	3,838	3,952
Energy Cost (\$/kWh)		0.0077	0.0081	0.0088	0.0095

1/ 7 hours peaking time.

2/ Net construction cost excluding interest during construction.

3/ (Construction Cost) x 0.0865.

6.5.3 Annual Energy Output

The annual energy output of the palnt was calculated in two cases–one, the Salvajina operated independently and the other, the plant operated in combination with Calima I and Alto Anchicaya.

Generally speaking, in a large power system composed of fairly large thermal capacity, it may be considered that all inflow into reservoirs will be effective, including secondary energy output. However, in the CVC System and the entire interconnected system, thermal generating capacity is 71 MW and 188 MW respectively and the ratio of thermal power to installed capacity in the respective systems will be only 14% and 8.7% in 1977 when the Salvajina Power Plant is scheduled to be in operation. Therefore, because of this small thermal capacity, it is necessary to evaluate the capability of Salvajina Power Plant on the basis of firm energy output in dry years.

(1) Energy Output of Independent Operation

Based on the reservoir operation rule for the purpose of flood control described in 6.3.5 and the abatement of river contamination in 6.4.1, the energy output was calculated with an IBM 360-50H electronic computer on the basis of daily runoff records from October 1946 through to September 1968. The energy output for the four dry year period, including the historically driest year of 1958, is shown in Table 6.14.

A review of the history of drought conditions of the Cauca River indicate that it can be divided into two periods, of 1946 through to 1950, and of 1957 through to 1966. During these periods, the four years from 1957 through 1960 was the worst condition as shown in Table 6.14. During this period, 1958 was the driest in the past 22 years and the firm energy output for this year calculated on the basis of the average energy output of February, March and April is 477 million kWh per annum (54 MW-year). The average annual energy output during the 23 years from 1946 up to 1968 is 813 million kWh.

(2) Energy Output in Combination with Calima I and Alto Anchicaya Power Plants

Generally speaking, when there are two or more reservoir-controlled power plants in an interconnected power system, it is possible to increase the firm energy output by taking advantage of the different hydrological conditions in different drainage basins.

As shown in Table 6.15, the firm energy output of Calima I and Alto Anchicaya Power Plants in the three-year period of 1957 through 1959, is 1,419.1 million kWh (162 MW-year). On the other hand, as indicated in Table 6.16, the firm energy output by coordinated operation of three power plants for the five years from 1956 through to 1960 is 2,067.4 million kWh (236 MW-year). Therefore, the firm energy output of Salvajina Power Plant is the difference between the above two values, or 648.3 million kWh (74 MW-year) per annum.

As seen from the above calculations, the firm energy output of Salvajina Power Plant can be increased by 170.7 million kWh or 35.8% through coordinated operation of the three reservoirs in comparison with isolated operation.

6.5.4 Timing of Commissioning of Salvajina Power Plant

In the determination of the timing of start-up of Salvajina Power Plant, it is essential to study the balance of demand and supply of the CVC System, and also that of the entire interconnected central system.

(1) Timing of Commissioning of Salvajina Power Plant considering the CVC System Only

It will be most reasonable to schedule the start-up of Salvajina Power Plant at the beginning of 1976 on the premise that Alto Anchicaya Power Plant (340 MW) now under construction will be completed in 1973 and from the balance of demand and supply of the CVC System only. In other words, as seen in Fig. 5.8, the balance of demand and supply can be maintained until 1975 if Yumbo Thermal Power Plant (53 MW) is in operation. However, from 1976, there will arise a shortage of supply capability.

Table 6.14 Available Energy of Salvajina Power Plant (Isolated System)

(Unit: 10^6 kWh)

Installed Capacity	140 MW				210 MW			
Year	1957	1958	1959	1960	1957	1958	1959	1960
Jan.	99.7	65.9	65.5	97.1	110.5	65.9	65.5	103.4
Feb.	62.0	37.8	45.1	89.1	62.0	37.8	45.1	89.1
Mar.	65.8	41.6	46.4	75.9	65.8	41.6	46.4	75.9
Apr.	62.3	40.0	39.9	75.2	62.3	40.0	39.9	75.2
May	70.2	45.8	45.4	59.8	70.2	45.8	45.4	59.9
Jun.	86.0	47.1	47.7	58.3	86.7	47.1	47.7	58.3
Jul.	52.2	46.7	54.0	59.9	52.1	46.7	54.0	59.9
Aug.	64.0	61.0	51.4	56.7	64.0	61.0	51.4	56.7
Sept.	55.2	54.4	45.1	48.5	55.2	54.4	45.1	48.5
Oct.	35.6	46.1	42.5	34.6	35.6	46.1	42.5	38.4
Nov.	37.6	47.7	48.1	56.6	41.6	51.7	52.2	66.9
Dec.	61.1	53.9	61.6	82.5	61.1	53.9	72.0	87.0
Total	751.7	588.0	592.7	794.2	767.1	592.0	607.2	819.2

Table 6.15 Firm Energy of Calima and Alto Anchicaya Power Plant by Combined Operation of Reservoirs

(Unit: MW-Month)

Year	Service Condition		January		February		March		April		May		June		July		August		September		October		November		December	
	River Flow	Calima I	38.4		29.9		22.4		25.7		28.6		32.8		16.1		10.4		10.0		26.2		31.8		28.4	
		Alto Anchicaya	217.6		228.6		146.5		159.1		215.3		203.8		128.9		106.9		135.7		267.1		236.5		226.8	
		Total	256.0		258.5		168.9		184.8		243.9		236.6		145.0		117.3		145.7		293.3		268.3		255.2	
1956	Reservoir Storage	Calima I	0	270	0	270	0	270	0	270	0	270	0	270	0	270	−20.7	249.3	−16.3	233.0	+26.2	259.2	+10.8	270	0	270
		Alto Anchicaya	0	41	0	41	0	41	0	41	0	41	0	41	−17	24	−24	0	0	0	+41	41	0	41	0	41
	Power Generation	Calima I		38.4		29.9		22.4		25.7		28.6		32.8		16.1		31.1		26.3		0		0		0
		Alto Anchicaya		123.6		132.1		139.6		136.3		133.4		129.2		145.9		130.9		135.7		162.0		162.0		162.0
		Total		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0
	River Flow	Calima I	20.2		14.1		14.9		19.7		21.8		16.7		9.7		7.5		7.0		14.6		23.5		23.6	
		Alto Anchicaya	175.7		114.8		121.0		177.1		185.0		150.5		95.4		72.7		83.9		202.7		261.0		202.7	
		Total	195.9		128.9		135.9		196.8		206.8		167.2		105.1		80.2		90.9		217.3		284.5		226.3	
1957	Reservoir Storage	Calima I	0	270	−33.1	236.9	−26.1	210.8	+19.7	230.5	+21.8	252.3	+5.2	257.5	−15.9	241.6	−81.8	159.8	−71.1	88.7	+14.6	103.3	+23.5	126.8	+23.6	150.4
		Alto Anchicaya	0	41	0	41	0	41	0	41	0	41	0	41	−41	0	0	0	0	0	+40.7	40.7	+0.3	41	0	41
	Power Generation	Calima I		20.2		47.2		41.0		0		0		11.5		25.6		89.3		78.1		0		0		0
		Alto Anchicaya		141.8		114.8		121.0		162.0		162.0		150.5		136.4		72.7		83.9		162.0		162.0		162.0
		Total		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0
	River Flow	Calima I	12.9		10.0		10.2		14.8		24.1		19.4		11.6		12.9		7.8		12.8		19.7		20.2	
		Alto Anchicaya	153.4		94.7		86.0		187.9		258.8		136.1		104.4		144.4		91.4		209.5		281.9		230.8	
		Total	166.3		104.7		96.2		202.7		282.9		155.5		116.0		157.3		99.2		222.3		301.6		251.0	
1958	Reservoir Storage	Calima I	+4.3	154.7	−57.3	97.4	−24.8	72.6	+14.8	87.4	+24.1	111.5	−6.5	105.0	−5	100.0	−4.7	95.3	−62.8	32.5	+12.8	45.3	+19.7	65.0	+20.2	85.2
		Alto Anchicaya	0	41	0	41	−41	0	+25.9	25.9	+15.1	41	0	41	−41	0	0	0	0	0	+41.0	41.0	0	41.0	0	41.0
	Power Generation	Calima I		8.6		67.3		35.0		0		0		25.9		16.6		17.6		70.6		0		0		0
		Alto Anchicaya		153.4		94.7		127.0		162.0		162.0		136.1		145.4		144.4		91.4		162.0		162.0		162.0
		Total		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0		162.0

(Unit: MW–Month)

Year	Service Condition		January	February	March	April	May	June	July	August	September	October	November	December
1956	River Flow	Calima I	38.4	29.9	22.4	25.7	28.6	32.8	16.1	10.4	10.0	26.2	31.8	28.4
		Alto Anchicaya	217.6	228.6	146.5	159.1	215.3	203.8	128.9	106.9	135.7	267.1	236.5	226.8
		Salvajina	218.3	157.4	135.4	95.7	120.9	169.4	100.9	83.8	70.4	106.7	102.1	145.1
		Total	474.3	415.9	304.3	280.5	364.8	406.0	245.9	201.1	216.1	400.0	370.4	400.3
	Reservoir Storage	Calima I	0 270	0 270	0 270	0 270	0 270	0 270	0 270	0 270	0 270	0 270	0 270	0 270
		Alto Anchicaya	0 41	0 41	0 41	0 41	0 41	0 41	0 41	–34.9 6.1	+34.9 41	0 41	0 41	0 41
		Salvajina	+18 41	+21 62	+2 64	+1 65	+21 86	+11 97	0 97	0 97	–60 37	–37 0	0 0	+22 22
	W.L. of Salvajina Reservoir (m)		1,123.9	1,130.1	1,130.5	1,131.0	1,136.8	1,139.0	1,139.0	1,139.0	1,122.4	1,105.0	1,105.0	1,116.7
	River Flow of Salvajina (m^3/s)		311	206	172	121	148	200	118	98	89	168	187	239
	Conversion Factor ($kW/m^3/s$)		702	764	787	791	817	847	855	855	791	635	546	607
	Power Generation	Calima I	38.4	29.9	22.4	25.7	28.6	32.8	16.1	10.4	10.0	26.2	31.8	28.4
		Alto Anchicaya	113.6	122.1	129.6	126.3	123.4	119.2	128.9	141.8	95.6	125.8	120.2	123.6
		Salvajina	84.0	84.0	84.0	84.0	84.0	84.0	91.0	83.8	130.4	84.0	84.0	84.0
		Total	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0
1957	River Flow	Calima I	20.2	14.1	14.9	19.7	21.8	16.7	9.7	7.5	7.0	14.6	23.5	23.6
		Alto Anchicaya	175.7	114.8	121.0	177.1	185.0	150.5	95.4	72.7	83.9	202.7	261.0	202.7
		Salvajina	128.1	72.2	101.7	106.8	159.9	139.6	76.1	52.3	30.9	37.6	56.8	116.1
		Total	324.0	201.1	237.6	303.6	366.7	306.8	181.2	132.5	121.8	254.9	341.3	342.4
	Reservoir Storage	Calima I	0 270	– 1.9 268.1	+ 1.6 269.7	+ 0.3 270	0 270	0 270	– 6.8 263.2	– 65.5 197.7	– 76.2 121.5	+ 14.6 136.1	+ 23.5 159.6	+ 23.6 183.2
		Alto Anchicaya	0 41	– 41 0	0 0	+ 41 41	0 41	0 41	– 41 0	0 0	0 0	+ 12.3 12.3	+ 28.7 41	0 41
		Salvajina	+ 30 52	+ 8 60	0 60	+ 5 65	+ 21 86	+ 11 97	– 7 84	– 38 46	– 38 8	– 8 0	0 0	+ 39 39
	W.L. of Salvajina Reservoir (m)		1,116.7 1,123.0	1,129.0	1,129.0	1,131.0	1,136.8	1,138.9	1,136.5	1,125.0	1,109.5	1,105.0	1,105.0	1,122.9
	River Flow of Salvajina (m^3/s)		184	96	131	136	196	165	90	64	46	65	104	182
	Conversion Factor ($kW/m^3/s$)		696	752	776	785	816	846	846	817	672	579	546	638
	Power Generation	Calima I	20.2	16.0	13.3	19.4	21.8	16.7	16.5	73.0	83.2	0	0	0
		Alto Anchicaya	117.7	155.8	121.0	114.8	130.2	135.3	136.4	72.7	83.9	190.4	179.2	158.9
		Salvajina	98.1	64.2	101.7	101.8	84.0	84.0	83.1	90.3	68.9	45.6	56.8	77.1
		Total	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0
1958	River Flow	Calima I	12.9	10.0	10.2	14.8	24.1	19.4	11.6	12.9	7.8	12.8	19.7	20.2
		Alto Anchicaya	153.4	94.7	86.0	187.9	258.8	136.1	104.4	144.4	91.4	209.5	281.9	230.8
		Salvajina	81.1	63.6	50.4	70.5	98.0	77.2	65.0	60.7	31.6	32.9	72.6	102.7
		Total	247.4	168.3	146.6	273.2	380.9	232.7	181.0	218.0	130.8	255.2	374.2	353.7
	Reservoir Storage	Calima I	+ 11.4 194.6	– 37.7 156.9	– 78.4 78.5	+ 14.8 93.3	+ 24.1 117.4	+ 19.4 136.8	– 47.7 89.1	– 18 71.1	+ 7.8 78.9	+ 12.8 91.7	+ 19.7 111.4	+ 20.2 131.6
		Alto Anchicaya	0 41	– 41 0	0 0	+ 4.4 4.4	+ 36.6 41	– 33.7 7.3	– 7.3 0	0 0	+ 21 21	+ 19.4 40.4	+ 0.6 41	0 41
		Salvajina	0 39	+ 11 50	– 11 39	+ 18 57	+ 29.0 86	+ 11 97	0 97	0 97	– 84 13	– 13 0	0 0	+ 39.0 39
	W.L. of Salvajina Reservoir (m)		1,122.9 1,122.9	1,126.4	1,123.2	1,128.2	1,137.1	1,139.0	1,139.0	1,139.0	1,113.0	1,105.0	1,105.0	1,123.0
	River Flow of Salvajina (m^3/s)		112	86	68	94	109	91	76	71	42	56	133	161
	Conversion Factor ($kW/m^3/s$)		724	740	741	750	807	848	855	855	752	588	546	638
	Power Generation	Calima I	1.5	47.7	88.6	0	0	0	59.3	30.9	0	0	0	0
		Alto Anchicaya	153.4	135.7	86.0	183.5	167.0	169.8	111.7	144.4	70.4	190.1	163.4	172.3
		Salvajina	81.1	52.6	61.4	52.5	69.0	66.2	65.0	60.7	165.6	45.9	72.6	63.7
		Total	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0
1959	River Flow	Calima I	15.8	9.4	8.5	17.4	25.3	30.3	18.9	14.5	10.5	25.2	25.3	32.6
		Alto Anchicaya	142.9	85.3	85.7	153.7	224.3	339.1	148.0	145.1	102.6	312.1	273.2	250.6
		Salvajina	88.7	61.1	43.5	47.4	85.7	108.2	89.8	50.4	39.7	52.6	70.4	106.7
		Total	247.4	155.8	137.7	218.5	335.3	477.6	256.7	210.0	152.8	389.9	368.9	389.9
	Reservoir Storage	Calima I	+ 15.8 147.4	– 44.8 102.6	– 77.3 25.3	– 0.5 24.8	– 22.7 2.1	+ 30.3 32.4	+ 18.9 51.3	0 51.3	0 51.3	+ 25.2 76.5	+ 25.3 101.8	+ 32.6 134.4
		Alto Anchicaya	– 4.4 36.4	– 36.4 0	0 0	0 0	+ 41 41	0 41	0 41	– 26 15	– 5.2 9.8	+ 31.2 41	0 41	0 41
		Salvajina	0 39	+ 1 40	– 21 19	– 17 2	+ 81 83	+ 14 97	0 97	0 97	– 78 19	– 19 0	0 0	+ 22 22
	W.L. of Salvajina Reservoir (m)		1,123.0 1,123.0	1,123.5	1,115.0	1,107.0	1,136.5	1,139.0	1,139.0	1,139.0	1,115.0	1,105.0	1,105.0	1,116.5
	River Flow of Salvajina (m^3/s)		139	84	63	78	120	128	105	59	52	88	129	176
	Conversion Factor ($kW/m^3/s$)		638	727	690	608	714	845	855	855	764	598	546	606
	Power Generation	Calima I	0	54.2	85.8	17.9	48.0	0	0	14.5	10.5	0	0	0
		Alto Anchicaya	147.3	121.7	85.7	153.7	183.3	141.8	146.2	171.1	107.8	164.4	165.6	151.3
		Salvajina	88.7	60.1	64.5	64.4	4.7	94.2	89.8	50.4	117.7	71.6	70.4	84.7
		Total	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0
1960	River Flow	Calima I	38.2	31.8	14.3	23.8	25.7	24.3	23.3	14.6	11.4	26.2	36.4	44.4
		Alto Anchicaya	287.3	204.8	152.6	250.2	272.2	177.1	186.1	158.0	134.6	205.6	265.0	259.9
		Salvajina	168.0	146.3	95.2	103.0	98.0	73.6	75.2	55.6	41.1	50.9	94.5	139.8
		Total	493.5	382.9	262.1	377.0	395.9	275.0	284.6	228.2	187.1	282.7	395.9	444.1
	Reservoir Storage	Calima I	+ 38.2 172.6	+ 31.8 204.4	0 204.4	0 204.4	0 204.4	0 204.4	0 204.4	– 7.8 196.6	+ 11.1 207.7	+ 26.2 233.9	+ 36.1 270	0 270
		Alto Anchicaya	0 41	0 41	0 41	0 41	0 41	0 41	0 41.0	0 41	0 41	0 41	0 41	0 41
		Salvajina	+ 18 40	+ 22 62	+ 2 64	+ 1 65	+ 21 86	+ 11 97	0 97	0 97	– 60 37	– 37 0	0 0	+ 22 22
	W.L. of Salvajina Reservoir (m)		1,116.5 1,123.4	1,129.9	1,130.5	1,131.0	1,136.8	1,139.0	1,139.0	1,139.0	1,122.4	1,105.0	1,105.0	1,117.0
	River Flow of Salvajina (m^3/s)		241	193	121	130	120	87	88	65	52	80	173	230
	Conversion Factor ($kW/m^3/s$)		697	758	787	792	817	846	855	855	791	636	546	608
	Power Generation	Calima I	0	0	14.3	23.8	25.7	24.3	23.3	22.4	0.3	0	0.3	44.4
		Alto Anchicaya	152	152	128.5	128.2	133.3	149.1	137.5	158.0	134.6	148.1	141.2	107.6
		Salvajina	84	84	93.2	84.0	77.0	62.6	75.2	55.6	101.1	87.9	94.5	84.0
		Total	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0	236.0

Table 6.16 Firm Energy of Calima, Alto Anchicaya and Salvajina Power Plant by Combined Operation of Reservoirs

(2) Timing of Commissioning of Salvajina Power Plant considering the Interconnected System

When considering the balance of demand and supply of the interconnected system on the basis of the balance of each regional power system described in 5.5.2, the appropriate time to start operation of Salvajina Power Plant will still be in 1976 as in the case of the independent CVC System. However, as described in Chapter 8, it will be physically difficult to start-up the plant at the beginning of 1976 because of the construction schedule and the earliest start-up date will probably be in January 1977. Therefore, it was tentatively scheduled to start operation of Salvajina Power Plant at the beginning of 1977.

As a note, in 1976, the year before the scheduled start-up of Salvajina Power Plant, balance of demand and supply can be barely maintained by operation of existing thermal power plants as shown in Fig. 5.8 (1), but there will be no reserve capacity. The balance of demand and supply of the interconnected system in this year is shown in Table 6.17.

Table 6.17 Supply and Demand Balance of Interconnected System in 1976

		1st Quater	2nd Quater	3rd Quater	4th Quater
kW Margine	(MW)	10	20	40	20
	(%)	0.7	1.5	2.9	1.5
kWh Margine	(10^6kWh)	(–) 152	113	(–) 61	157
	(%)	(–) 3.5	2.6	(–) 1.4	3.6

Note: As supply capacity only hydroelectric power plants are considered, while thermal power plants are regarded as reserve and are not included in the above margin.

(3) Timing of Start of Operation of No.3 Unit of Salvajina Power Plant

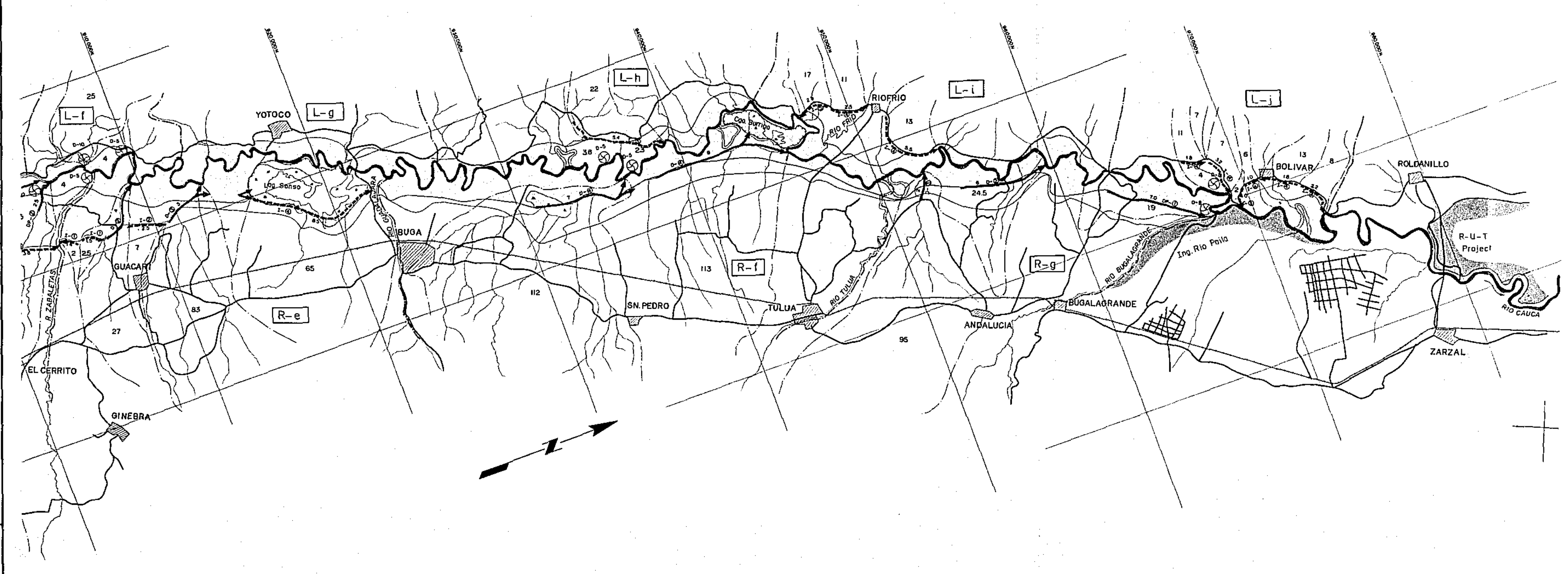
If two units totalling 140 MW are put in operation in 1977, taking into consideration the CVC System only, there will again arise kW shortage in 1979 based on the balance of demand and supply in November when Salvajina Power Plant has to operate at the lowest water level and, therefore, the No.3 unit will become necessary. On the other hand, from the standpoint of the interconnected system as a whole, as shown in Fig. 5.8 (5), the load carried at peak hours by existing reservoir controlled power plants including the No. 3 and No. 4 units of Chivor Power Plant will be 93% in 1978, which means operation at roughly full installed capacity. Therefore, the third unit of Salvajina will be required in 1979.

Consequently, it has been tentatively determined to have the third unit in operation in January 1979. The installed capacity of Salvajina Plant in 1977 will be only 6.5% of the interconnected system. Therefore, start-up of Salvajina Plant will not have great influence on the timing of start-up of Chivor Power Plant's No. 3 and No. 4 units, and it will be appropriate for these two units to be on the line in 1977, two years after start-up of the No. 1 and No. 2 units. However, if the existing thermal power stations are to be in service, it will be possible to delay commissioning of the third and fourth units of Chivor to 1978.

6.6 Drainage

6.6.1 Scope of Drainage Work and Location of Facilities

In determining the scope of the drainage program, there are many related factors to be considered. Among these are the topography, soil and sub-surface water of the low basin lands comprising the major part of both sides of the Cauca River, the land utilization program and irrigation plans anticipated in the future for the Cauca Plain.



Summary of Structurs for Irrigation and Drainage Works

Left Side Bank Area

Item \ Job Division		L-a		L-b		L-c		L-d		L-e		L-f		L-g		L-h		L-i		L-j		Sub-total	
Project Area (ha)		9,000		6,000		6,300		500		1,500		500		1,500		1,800		2,300		1,400		32,800	
Drainage Area (D.A: Sq.km) and Canal Length (C.L: km)		DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL
Drainage Works (Main) – Drainage Canal – Intercepting Canal	I-①	-	-	-	-	-	-									-	-	-	-	-	-	-	-
	I-②	1.0	1.0	-	-	-	-									-	-	-	-	-	-	1.0	1.0
	I-③	8.0	3.5	5.0	5.6	-	-									-	-	-	-	2.0	1.0	15.0	8.1
	I-④	-	-	-		7.0	5.0									-	-	24.0	8.0	52.0	10.0	83.0	23.0
	I-⑤	-	-	14.5	5.8	-	-									22.0	5.4	17.0	2.5	-	-	53.5	13.7
	Total	9.0	4.5	19.5	9.4	7.0	5.0	-	-	-	-	-	-	-	-	22.0	5.4	41.0	10.5	54.0	11.0	152.5	45.8
Drainage Canal Only	D-①	-	-	-	-					-	-											-	-
	D-②	-	-	-	-					5.5	2.0											5.5	2.0
	D-③	24.0	10.0	40.0	6.5					24.5	5.0											86.5	19.5
	D-④	-	-	-	-					-	-											-	-
	D-⑤	-	-	-	-					-	-											-	-
	Total	24.0	10.0	40.0	6.5	-	-	-	-	30.0	5.0	-	-	-	-	-	-	-	-	-	-	94.0	21.5
Drainage Canal + Drainage pump	DP-①					43.0	11.0															43.0	11.0
	DP-②					-	-															-	-
	DP-③					-	-															-	-
	Total	-	-			43.0	11.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	43.0	11.0
Drainage pump	Drainage Area (sq.km)	9.0		-		43.0		-		-		25.0 , 4.0		-		3.6 2.3		-		4.0		90.9	
	Drainage Discharge (Cu.m/min)	126		-		594		-		-		345 , 94		-		50 , 32		-		55		-	
	No. of Units ∅500mm	-		-		-		-		-		2 x 1		-		2 x 1, 1 x 1		-		2 x 1		7 units	
	& pumping 800	2 x 1		-		-		-		-		-		-		-		-		-		2 units	
	Stations 1000	-		-		5 x 1		-		-		3 x 1		-		- -		-		-		8 units	
	Total kW	170		-		780		-		-		460 , 70		-		70, 40		-		70		1,660	

Right Side Bank Area

Item \ Job Division		R-a		R-b		R-c		R-d		R-e		R-f		R-g		Sub-total		Total	
Project Area (ha)		6,600		9,600		9,800		9,300		3,800		5,300		4,200		48,800		81,600	
Drainage Area (D.A: Sq.km) and Canal Length (C.L: km)		DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL	DA	CL
Intercepting Canal	I-①	13.9	9.4	2.3	1.7	23.5	13.1	6.5	3.3	4.5	2.9					50.7	30.4	50.7	30.4
	I-②	-	-	20.6	8.7	6.0	1.5	8.0	4.5	7.0	2.5					41.6	17.2	42.6	18.2
	I-③	-	-	34.2	9.2	-	-	44.0	9.3	-	-					98.2	18.5	113.2	26.6
	I-④	-	-	-	-	-	-	-	-	64.5	8.5					64.5	8.5	147.5	31.5
	I-⑤	-	-	-	-	-	-	-	-	-	-					-	-	53.5	13.7
	Total	13.9	9.4	77.1	19.6	29.5	16.6	58.5	17.1	76.0	13.9	-	-	-	-	255.0	74.6	407.5	120.4
Drainage Canal Only	D-①	8.9	5.5	4.0	2.0	-	-	-	-	-	-	-	-	-	-	12.9	7.5	12.9	7.5
	D-②	44.5	8.0	45.5	1.0	-	-	-	-	31.0	4.0	-	-	24.5	6.0	145.5	19.0	151.0	21.0
	D-③	-	-	-	-	-	-	56.0	6.0	89.5	3.0	-	-	95.0	2.0	240.5	11.0	329.0	30.5
	D-④	-	-	346.5	5.0	-	-	-	-	-	-	225.0	16.0	-	-	371.5	21.0	371.5	21.0
	D-⑤	-	-	-	-	892.0	30.0	-	-	-	-	-	-	-	-	892.0	30.0	892.0	30.0
	Total	53.4	13.5	196.0	8.0	892.0	30.0	56.0	6.0	120.5	7.0	225.0	16.0	119.5	8.0	1,662.4	86.5	1,756.4	110.0
Drainage Canal + Drainage pump	DP-①	24.0	2.0	-	-			-	-					19.0	7.0	43.0	9.0	86.0	20.0
	DP-②	-	-	50.0	14.0			55.5	10.5					-	-	105.5	24.5	105.5	24.5
	DP-③	-	-	-	-			-	-	-	-			-	-	-	-	-	-
	Total	24.0	2.0	50.0	14.0	-	-	55.5	10.5	-	-	-	-	19.0	7.0	148.5	33.5	191.5	44.5
Drainage pump	Drainage Area (sq.km)	24.0, 41.0		50.0		-		[illegible]		-		-		19.0		254.5		345.4	
	Drainage Discharge (Cu.m/min)	330, 570		690		-		[illegible]		-		-		264		-		-	
	No. of Units ∅500mm	-		-		-		2 x 1		-		-		-		2 units		9 units	
	& pumping 800	4 x 1,		-		-		-		-		-		1 x 1		7 units		9 units	
	Stations 1000	5 x 1		6 x 1		-		10 x 3, 9 x 1		-		-		-		30 units		38 units	
	Total kW	430, 750		900		-		[illegible]		-		-		350		5,670		7,330	

LEGEND

- River
- Irrigated Area by Cauca River
- Irrigated Area by Subterranean Water and Tributary
- Drainage Pumping Station
- Drainage Canal (Symbol ; D-1, Canal Length ; 5 km)
- Intercepting Canal (Symbol ; I-3, Canal Length ; 3 km)
- Drainage Area (10 sq.km)
- Job Division
- Main Road

0 5 10 km

Fig. 6.20 General Plan in Cauca Plain

The studies for the relation between flood flows and inundation area reveal that 57,600 ha (actual survey) and 100,000 ha (estimated) were inundated in the floods of December 1966 and February 1950 respectively. These flood discharges are of return periods of 8 years and 45 years.

The drainage works area considered for the present project, taking into account the above factors and the R-U-T and Aguablanca Projects already carried out by CVC, was decided as 81,600 ha according to 1/50,000 scale maps and aerial photographs between La Balsa and R-U-T on the left bank and between La Balsa and the Rio Bugalagrande on the right bank respectively. This area is divided into small districts by major tributaries flowing in from both sides of the Cauca River. The location of the projected drainage works, the locations of the intercepting canals, principal drainage canals, gravity outlets and pumping stations and the drainage area of each canal are listed in Fig. 6.20.

As mentioned above, it is necessary to keep in mind future irrigation schedule in contemplating drainage works. A study of the irrigation for the Cauca Plain including this 81,600 ha area is given separately in Appendix 6.

6.6.2 Design Drainage Discharge

(1) Drainage Discharge per Unit Area

(i) Runoff from Mountain Area

The runoff of medium or small tributaries were calculated by the Rational Formula. In the calculations, the time of concentration (T) was taken at four hrs. for drainage areas of less than 50 sq.km. and six hrs. for 50 sq.km. to 100 sq.km. The average rainfall intensity (R_T) for this period was estimated on the basis of the once in ten year probable daily rainfall at Jamundi and Cali.

For this purpose, the relation between daily precipitation and average rainfall intensity of T hr. was determined as shown in Fig. 6.21 using eight samples selected from automatic recorder data for the period from 1952 through 1967 (Table 6.18). The runoff coefficient (f) of 0.7 was adopted. As a result, the drainage discharge per one sq.km will be as given in Table 6.19.

Fig. 6.21 Daily Precipitation and Rainfall Intensity

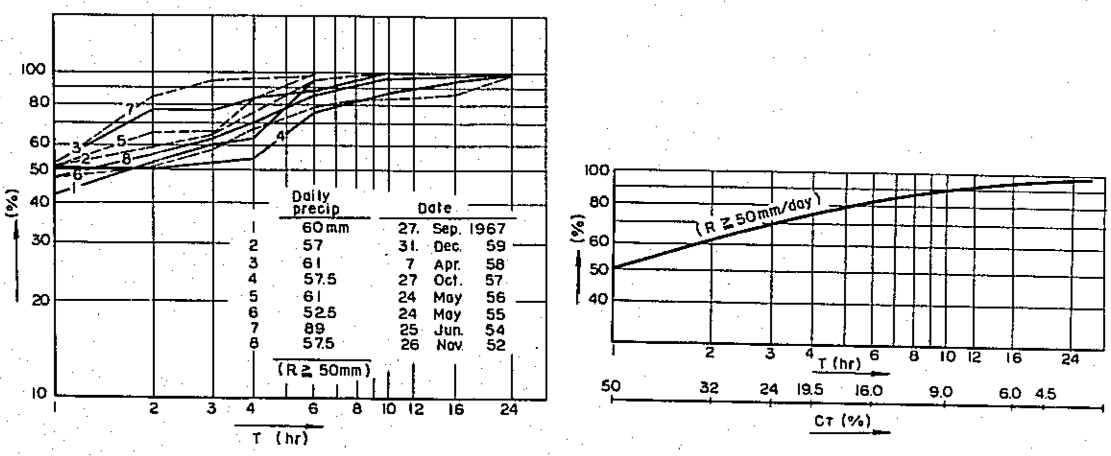


Table 6.18 Max. Depth of Precipitation in T hours at Cali Station

(Unit: mm)

Date	Daily Precipitation (mm/day)	Max. Depth of Precipitation in T hr 1hr	2hr	3hr	4hr	6hr	10hr	12hr	16hr	20hr
27.Sep. 1967	60	25	32	36	38	56	60			
10.Feb. 1966	46	23	34	39	44	46				
6.Oct. 1964	45	35	41	43	44	44	45			
29.Dec. 1963	36.5	18	22	27	31	32	36.5			
14.Nov. 1962	37	13	18	21	25	30	37			
18.Aug. 1962	46.5	42.5	46	46	46.5					
12.Dec. 1960	39	8	10	15	18	25	28	37	38	39
31.Dec. 1959	57	29	34	37	43	54	57			
12.Aug. 1959	40	40								
7.Apr. 1958	61	32	47	47	51	53	61			
18.May 1958	57.5	44	45	45	45	45	45	45	57.5	
27.Oct. 1957	57.5	29	29	30	31	43	47	50	55	57.5
24.May 1957	61	29	40	40	51	61				
9.Feb. 1956	34	12	17	19	21	22	22	29	33	34
24.May 1955	52.5	20	27	31	35	41	43	44	45	52.5
25.Jun. 1954	89	45	75	85	86	87	88	88	89	
26.Nov. 1952	57.5	27	32	36	41	50	57	57	57	57.5

Table 6.19 Runoff from Mountain Area

Location	Drainage Basin [A] (sq.km)	Critical Time [T] (hours)	Max. Daily 1/ Precipitation [R_{24}] (mm/day)	C_T 2/ (%)	Average Intensity in T hrs. [R_T] (mm/hr)	Drainage 3/ Discharge [Q] (cu.m/s/sq.km)
Basin in the Left Side of Cauca River near Jamundi	~ 50	4	96.2	19.5	18.7	3.58
	50 ~ 100	6		14.0	13.5	2.63
Basin in the Left Side of Remaining Area of Cauca River	~ 50	4	79.3	19.5	15.5	3.01
	50 ~ 100	6		14.0	11.1	2.16

1/ Return period; once in ten years
2/ Ratio of average intensity to maximum daily precipitation
3/ $Q = 0.2778 \times f \times R_T \times A$

Q : cu.m/s/sq.km
R_T : mm/hr
A : sq.km
f : Runoff coefficient; 0.7

(ii) Runoff from Flat Area

The runoff from the flat area is chiefly from farmland and with the runoff coefficient taken at 0.5, it was determined to be as shown in Table 6.20 in consideration of the relation between length (in time) of inundation and damages inflicted. In other words, for areas where natural drainage is possible, it was considered that daily rainfall corresponding to a return period of ten years should be drained in one day.

Where natural drainage is not feasible, pumping facilities are to be installed to drain in three days consecutive three days precipitation of the second heaviest recorded rainfall.

Table 6.20 Runoff from Flat Basin

	Design Daily Precipitation [R] (mm)	Drainage Discharge [Q] (cu.m/s/sq.km)
*Gravity Drainage excluded*1/ Jamundi District	79.3	0.46
Gravity Drainage in 1/ Jamundi District	96.2	0.56
Pumping Drainage in 2/ *Flat Basin*	117.0	0.23

1/ Maximum daily precipitation corresponding with once in ten years probability.

2/ Maximum consecutive three days precipitation.

(2) Design Drainage Discharge

Based on the unit drainage discharge obtained in 6.6.2 (1), the design drainage discharge for each drainage canal and pumping station was obtained as given in Fig. 6.20.

6.6.3 Agricultural Production

(1) Agricultural Production without Project

Even in the case the project is not implemented, the cropping ratio will change because of demand and other conditions and it is thought the production per unit area will increase to some extent in the long run. But on the basis of agricultural production will not be improved, it is assumed the degree of change would be small. From the above consideration, the gross income and net income by crops per ha. of farmland was estimated to be 5,000 pesos and 2,100 pesos respectively as calculated according to the following assumptions and shown in Table 6.21 (1) in the case the project is not carried out.

(i) The present yield of crops per unit area varies according to district and season of cultivation but based on the reference data 1/ and oral questionnarie, the average value assumed is shown in Table 4.7.

(ii) Gross income was evaluated on the premise that all agricultural products can be marketed at the price of farm.

(iii) Although agricultural production costs will fluctuate to a considerable degree depending on the type of agricultural management, they were estimated at the price level between 1968 and 1969 using the average expense factor given in the reference data. 1/

(iv) The yield per unit area of sugar cane was converted into equivalent annual yield although the cultivation period is one and a half years.

(v) The profit from milch cows and beef cattle raised on pasture land was regarded as agricultural income from grasslands. The number per ha was taken at 1.6 heads with the ratio of milch cows to beef cattle being 4:6. The raising period was taken to be eight years for milch cows and two years for beef cattle.

(vi) The cropping ratio was set as given in Table 6.21 (1) referring to the present cropping ratio.

(2) Agricultural Production after Project Completion

(i) Estimation of Cropping Ratio

If flooding of land is eliminated and drainage is improved, it is thought the cropping ratio will greatly change from the present pattern. The cropping pattern after the project is built was assumed as indicated in Table 6.21 (2) taking the following factors into consideration.

(a) It is thought that the number of livestock raised per unit area of grassland would increase by improving growth of grass and introducing concentrated dairy farming, while pasture land will be moved to hilly areas where land prices are cheaper, converting grasslands in flat areas to general agricultural fields.

(b) Of the major crops in general fields, it was considered that the demand for maize, soybean and sorghum will increase in the future and that it will also be easier to secure markets for processing them so that the cropping ratio of these crops will increase; while rice, bean and cotton will stay at a level not very much different from the present.

(ii) Gross and Net Incomes per Unit Area

When the project is completed, agriculture will be established on a firm basis and it will become possible to introduce high yield cash crops and also widely introduce the use of fertilizers. As for cultivation season, it will no longer be necessary to be bound by present customs and highly advanced cultivation techniques can be introduced so that production will increase year after year.

1/ (1) Rentabilidad de Diversos Cultivos Agricolas y Explotaciones Ganaderas en el Valle del Cauca (Universidad del Valle, Facultad de Ciencias Economicas, Cali, Marzo de 1966)

(2) Desarrollo Agricola del Valle del Cauca, Censo de Seis Cultivos. (Instituto de Fomento Algodonero, Bogota, 1967)

(3) The Elaboration compiled from data of "Banco Republica, etc." by CVC, 1968.

In estimating agricultural income after completion of the project, the following premises were considered.

(a) With ten years after completion of the flood control and drainage works, it was assumed that irrigation facilities would become widely distributed.1/

(b) Yield per unit area was considered to increase up to the standard of areas where reclamation projects are already completed or where advanced practices are creating high yields.

(c) Production cost will vary according to crops but it was considered to be 20% up compared to the figures adopted in 6.6.3 (1).

(d) The number of milch cows and beef cattle raised in grasslands was set at 2.5 heads per ha.

As a result, the average gross and net incomes per ha of farmland after the project is completed were taken to be 9,100 pesos and 4,200 pesos respectively as shown in Table 6.21 (2).

Table 6.21 (1) Agricultural Income without Project1/

	Cultivated Area		Income per ha2/		Total Income	
	1st Season (ha)	2nd Season (ha)	Gross (ps/ha)	Net (ps/ha)	Gross (10^3 ps)	Net (10^3 ps)
Field Crop						
Cotton	370		9,600	3,310	3,550	1,220
Rice	180	180	4,800	1,300	1,730	470
Bean	180	180	6,000	2,580	2,160	930
Maize	1,600	1,370	3,750	1,700	11,140	5,050
Sorghum	370	480	2,500	1,360	2,130	1,160
Soy Bean	930	1,420	4,000	1,440	9,400	3,380
Others	70	70	10,000	4,000	1,400	560
Sub-total	3,700	3,700			31,510	12,770
Perennial Crop						
Sugar Cane	340		5,600	3,000	1,900	1,020
Platano	180		10,000	7,700	1,800	1,390
Others	80		15,000	4,000	1,200	320
Sub-total	600				4,900	2,730
Pasture Land	5,200		2,570	1,030	13,360	5,360
Other Use	500					
Total	10,000				49,770	20,860

1/ Estimation per 10,000 ha.

2/ See Table 14 in App.6.

1/ In the present study, irrigation scheme is incorporated with the drainage program. The respective benefit for irrigation and drainage was allocated in proportion to construction cost. (See 10.1.4).

Table 6.21 (2) Agricultural Income with Project 1/

	Cultivated Area		Income per ha. 1/		Total Income	
	1st Season	2nd Season	Gross	Net	Gross	Net
	(ha)	(ha)	(ps/ha)	(ps/ha)	(10^3 ps)	(10^3 ps)
Field Crop						
Cotton	500		12,000	4,450	6,000	2,230
Rice	200	200	6,400	2,200	2,560	880
Bean	200	200	8,000	3,900	3,200	1,560
Maize	2,700	2,200	5,250	2,790	25,730	13,670
Sorghum	700	800	5,200	1,830	4,800	2,750
Soy Bean	1,600	2,500	5,200	2,130	21,320	8,730
Others	100	100	12,000	4,800	2,400	960
Sub-total	6,000	6,000			66,010	30,780
Perennial Crop						
Sugar Cane	400		7,000	3,880	2,800	1,550
Platano	200		11,390	8,640	2,280	1,730
Others	400		18,000	4,800	7,200	1,920
Sub-total	1,000				12,280	5,200
Pasture Land	2,000		6,400	2,800	12,800	5,600
Other Use	1,000		–	–	–	–
Total	10,000				91,090	41,580

1/ Estimation per 10,000 ha.

2/ See Table 15 in App. 6.

CHAPTER 7

PRELIMINARY DESIGN

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF DRAWINGS

CHAPTER 7 PRELIMINARY DESIGN

7.1 Design of Dam and Power Plant

7.1.1 Civil Structures

(1) Dam

Three alternative types of dam – rockfill, gravity and arch-gravity – were compared and as described in Appendix 5. It was decided that an arch-gravity dam will be the most economical for the site.

Compared to a thin arch dam, the thrust forces at the abutments are smaller with an arch-gravity dam and the contact area with bedrock is greater so that the safety of the foundation rock is much higher. As the problems of foundation rock are less severe than for a thin arch dam in consideration of the geology of the site, it is much favorable to build an arch-gravity dam which requires lesser volume of concrete than a gravity dam.

An arch-gravity dam is to be constructed at the gorge where both banks come close and gravity dam is to be constructed to sustain the thrust forces of the arch-gravity dam on both wings of the dam. It is thought there will be no particular problem in the foundation of the dam, but further detailed investigation is necessary to determine the excavation line, bearing strength of the bedrock, etc., in the definite study of the project.

Diversion of the river during construction is to be conducted through a tunnel with an inner diameter of 8 m at the right bank. This tunnel with a water level at the upstream of EL. 1,045 m can discharge approximately 600 cu.m/s which is equivalent to a flood probability discharge of once in five years in Fig. 7.1.

As there is a deep sand and gravel deposit in the river bed, grouting in the deposit at the cofferdam site must be executed to prevent seepage of water.

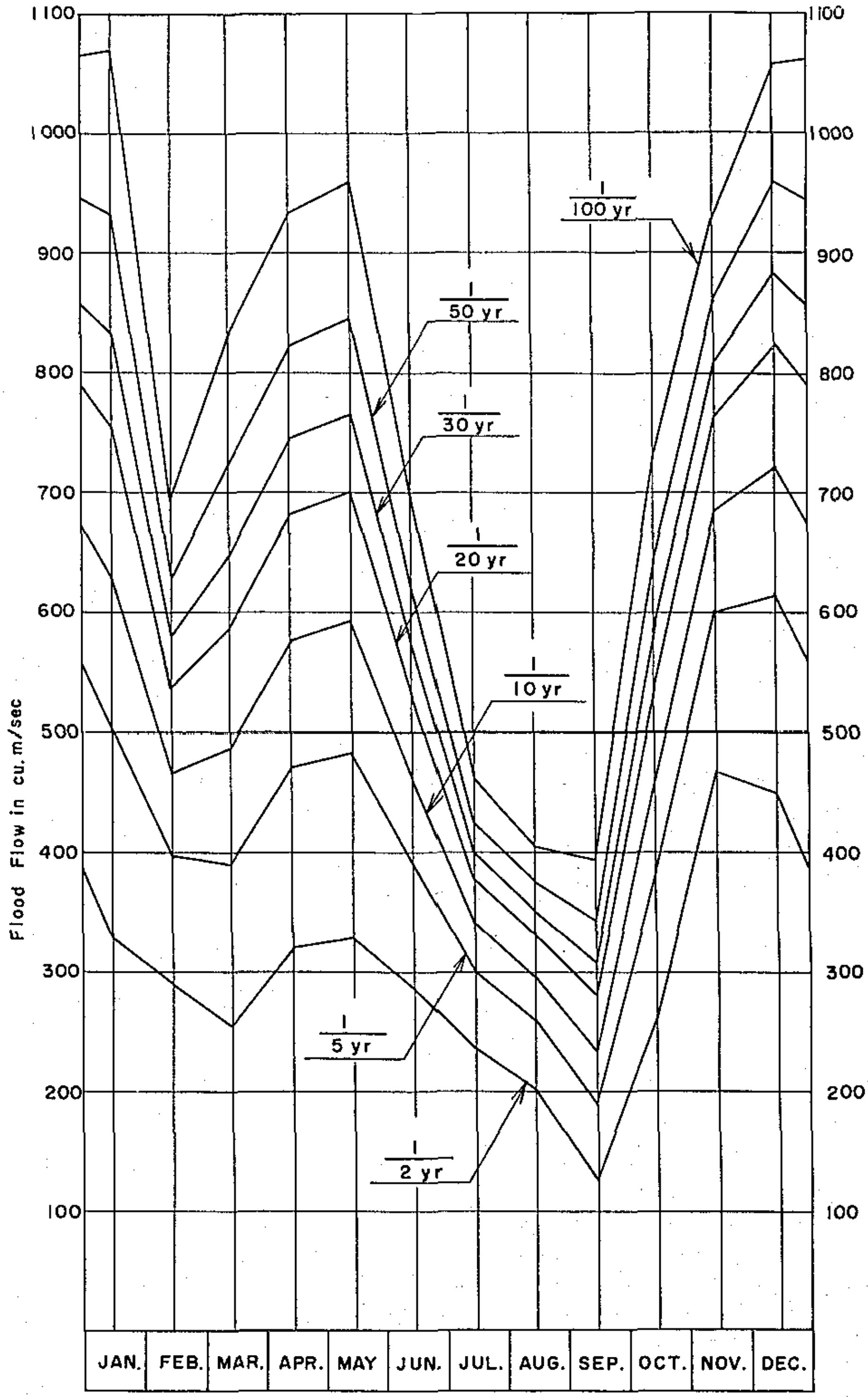
(2) Spillway

The design flood discharge at the dam site was determined to be 3,500 cu.m/s in consideration of the probable maximum flood discharge described in Appendix 4. This flood flow can be discharged through the spillway at a design flood level of EL. 1,140 m. The spillway is a gated overflow structure located at the center of the dam. Water released through the spillway is to be discharged into the river bed over the roof of the powerhouse. Alternative plans to construct chute-type spillways on both banks were studied. After the preliminary designs, it was found that a center gated overflow spillway is the best judging from the layout of structures such as the outlet works and powerhouse. The discharge through the spillway is to be regulated by four radial gates each 12.0 m wide and 10.5 m high. The layout of gates was decided from the necessity of using the piers of the spillway gates for operating the intake and outlet works gates also.

(3) Intake

The intake structure is to be constructed immediately below the piers of the spillway gates. Sediment encroachment in 100 years is estimated to reach EL. 1,074 m and the low water level is at EL. 1,105 m. The sill of the intake is designed at EL. 1,081 m to conduct a maximum discharge of 90 cu.m/s for each turbine without entrainment of air. Therefore, there is some allowance of reservoir capacity even if sedimentation reaches a higher level and the design reservoir capacity can be maintained by drawing water down to a lower level during an abnormal dry year for power and flood control purposes. Trashracks are to be installed in front of the intake. Also, one caterpillar gate operated by a gantry crane on the dam crest is to be installed for the purpose of maintenance and inspection of penstocks.

Fig. 7.1 Monthly Flood Flow Frequency at Salvajina Dam Site



(4) Outlet Works

During the flood season from November to December, the reservoir water level has to be maintained in accordance with the operation rule curve. For this purpose, water has to be released through the outlet work to drawdown the water stored by the first flood wave. The outlet works will have a capacity of 220 cu.m/s at the low water level of the reservoir. There will be two outlet works controlled by gates installed in inside chambers, constructed on both sides of the intake structure. These outlet works will discharge into the downstream chute portion of the spillway of the dam. The gates to be installed in the gate chambers are 2.5 m wide and 3.0 m high roller gates with separate sliding gates for emergency and maintenance and inspection.

(5) Penstock

There will be three welded steel penstocks fabricated with ASTM A440 or equivalent material. The inner diameter was determined to provide the smallest sum of annual costs and annual loss of benefits due to head loss. Electrical equipment are to be installed in two stages. The second stage work is to be carried out within 2 years after completion of the first stage, but all three of the penstocks will be installed in the first stage because they must be embedded in the dam concrete. The downstream end of the penstock for the second stage will be closed off by bulkhead with a valve for dewatering.

(6) Powerhouse

The powerhouse is to be located immediately downstream of the dam. This layout was adopted in considerations of topography and geology at the site. Alternative plans to locate the powerhouse on either the left or right bank was considered but the plan to construct the powerhouse immediately downstream of the dam was adopted because it was found to be the most favorable. Draft tubes are L-types and one sluice gate is to be installed for inspection purpose.

Because of the spillway chute to be constructed on top of the power plant, there might be some influence on power generating operations. Therefore, in the stage of the definite study it is necessary to conduct hydraulic model tests of the spillway to study the flow condition of the spillway, fluctuation of water level downstream of the power plant and scouring of the river bed. In the preliminary design, the costs of works for preventing inflow of sediment to the tailrace and for preventing scouring of the river banks are not included.

(7) Outdoor Switchyard

The outdoor switchyard is to be located on the tableland at the left bank and will be connected to the step-up transformers to be installed inside the tailrace training wall at the left side of the powerhouse.

7.1.2 Powerhouse Equipment

The main transformers are planned to be accommodated inside the tailrace training wall at the left bank side. The powerhouse equipment and main transformers are to be delivered by an outdoor crane into the erection bay through a hatch in the ceiling of the powerhouse and installed with an overhead travelling crane.

The Salvajina Power Plant will be a very important plant with a capacity next to Alto Anchicaya Power Plant in the CVC System. Therefore, close attention was paid to assure the highest reliability in the design of electrical facilities.

The turbine is of the vertical shaft Francis type having an output of 72.2 MW operating under an effective head of 90 m and maximum discharge of 90 cu.m/s. The effective head will vary between a maximum of 102 m to a minimum of 68 m which is a fluctuation of 37% of the rated head. In view of this fairly large fluctuation, adoption of diagonal flow turbines which give high efficiency against variable head was studied, but taking into consideration maintenance and operation, the Francis type with simpler structure was selected. The output at low water level will be 43 MW per unit. Butterfly valve is to be installed at the inlet of the turbine.

Only two of the three turbine and generator units are to be installed in the first stage of the project, but the draft tube liner of the third unit should be installed at the same time.

The generator is of the rotating field, vertical-shaft, 3-phase, synchronous alternator, 180 rpm, with a capacity of 78 MVA at rated power factor of 0.9 (lagging). The generators will be connected to the main transformers by metal enclosed buses and stepped up to 115 kV and transmitted to Pance Substation in the suburb of Cali via outdoor switchyard. Since the main transformers are to be accommodated inside the powerhouse building, they will be of 3-phase type in order to reduce installation space. Taking into account the crane capacity, it is probable that the transformer will be assembled at the site of installation. The cooling system adopted is forced-oil water-cooled method, but since the water of the Cauca River contains great quantity of fine particles of volcanic ash material which would adversely affect the cooling apparatus, and also causes cavitation of the turbines, careful attention must be paid in the use of this water. The high tension side of the main transformers will have elephant bushing connected to 110 kV oil-filled cable which will have sealing end.

Since suitable space cannot be found near the powerhouse, the outdoor switchyard is to be located on the left bank approximately 200 m downstream of the powerhouse. It is planned to connect the transformers to the switchyard by overhead lines.

The outdoor switchyard will have switch gears for lead-out of 115 kV 2-circuit transmission lines, parallel breakers for 3 generator units, a breaker to connect the bus lines, investment transformers, lightning arresters and other necessary equipment. The bus line system of the outdoor switchyard is of the double bus system which has high reliability and a large degree of freedom in system operation taking into consideration the importance of the power station in CVC System. Each generator is paralleled to the transmission line at the high-tension side of the transformer. The tie breaker connecting the double bus lines will be installed in the second stage of the project.

The turbines, generators and outdoor switchgears are to be of the one-man control system operated from the powerhouse control room. This system is provided with supplementary manual control at each equipment. Protection of transmission lines will be by means of protective system using power line carrier relays in order to provide the greatest safety. Single line diagram of electrical circuits is attached hereto.

7.1.3 Particulars of Major Structures

The major particulars of the various structures of Salvajina Power Plant are as tabulated in Table 7.1.

7.2 Transmission Line

7.2.1 Scale of Transmission Line

In order to transmit the power generated at Salvajina Power Plant to Cali, the load center, a transmission line is to be built connecting the plant and Pance Substation located 15 km south of Cali. The present highest transmission voltage is 115 kV in this country and 230 kV is scheduled to be adopted for the interconnection system. In consideration of the transmission voltage adopted in Colombia, the following alternative plans including conductor size and number of circuits were studied based on the transmission line capacity required.

A.	115 kV	330 sq.mm ACSR	2 cct
		410 sq.mm ACSR	2 cct
B.	230 kV	520 sq.mm ACSR	1 cct

In general, in order to increase the reliability of a transmission line, it is desirable to have a multi-circuit system. On the other hand, for the purpose to prevent as much as possible lowering of the transmission capacity at the time of line fault in one circuit, transmission capacity of double circuits should be designed to have 1.5 times the capacity of a single circuit.

Table 7.1· Description on Main Structures of Dam and Power Generation

Items	Description
Hydraulic Structures	
Dam	
Type	Main; Arch-Gravity Dam Wing; Gravity Dam
Elevation of Crest	1,143.00 m
Crest Length	402.60 m
Crest Width	6.00 m
Height (foundation to crest)	133.00 m
Freeboard	3.00 m
Downstream Slope	1 : 0.6 1 : 0.85
Volume	700,000 cu.m
Spillway	
Type	Chute Spillway with Control Gates
Design Flood Discharge	3,500 cu.m/s
Type of Gate	Radial Gate
Number of Gates	4 gates
Dimension of Gate	W; 12.00 m H; 10.50 m
Outlet	
Maximum Discharge	220 cu.m/s at water surface level of 1,105 m
Type and Number of Gate	Sliding Gate .... 2 gates Roller Gate............... 2 gates
Dimension of Gate	W; 25.0 m H; 3.0 m
Intake	
Type	Reinforced Concrete Structure
Maximum Discharge	2.70 cu.m/s
Dimension of Structure	W; 12.00 m H; 24.50 m
Number of Structures	3 places
Type of Gate	Caterpillar Gate
Dimension of Gate	W; 4.80 m H; 4.80 m

Items	Description
Penstock	
Type	Welded Steel
Materials	ASTM A440
Length	108.00 m
Number of Lines	3 lines
Inside Diameter	3.60 m ~ 4.80 m
Type of Control Valve	Butterfly Valve
Powerhouse	
Type	Reinforced Concrete Structure
Power Generation Facilities	
Unit Capacity	70 MW
Number of Unit	3 units
Turbine	
Type	Vertical Shaft Francis Type
Rated Head	90 m
Max. Discharge	90 cu.m/s
Rated Output	72,200 kW
Speed	180 rpm
Generator	
Type	3-Phase Synchronous Generator Vertical Shaft, Rotating Field, Enclosed Type
Capacity	78,000 kVA
Voltage	13.8 kV
Frequency	60 Hz
Power Factor	0.9 (lagging)
Transformer	
Type	3-Phase Outdoor, Forced Oil Water-Cooled Type
Capacity	78,000 kVA
Voltage	13.2 kV/115-110-120 kV

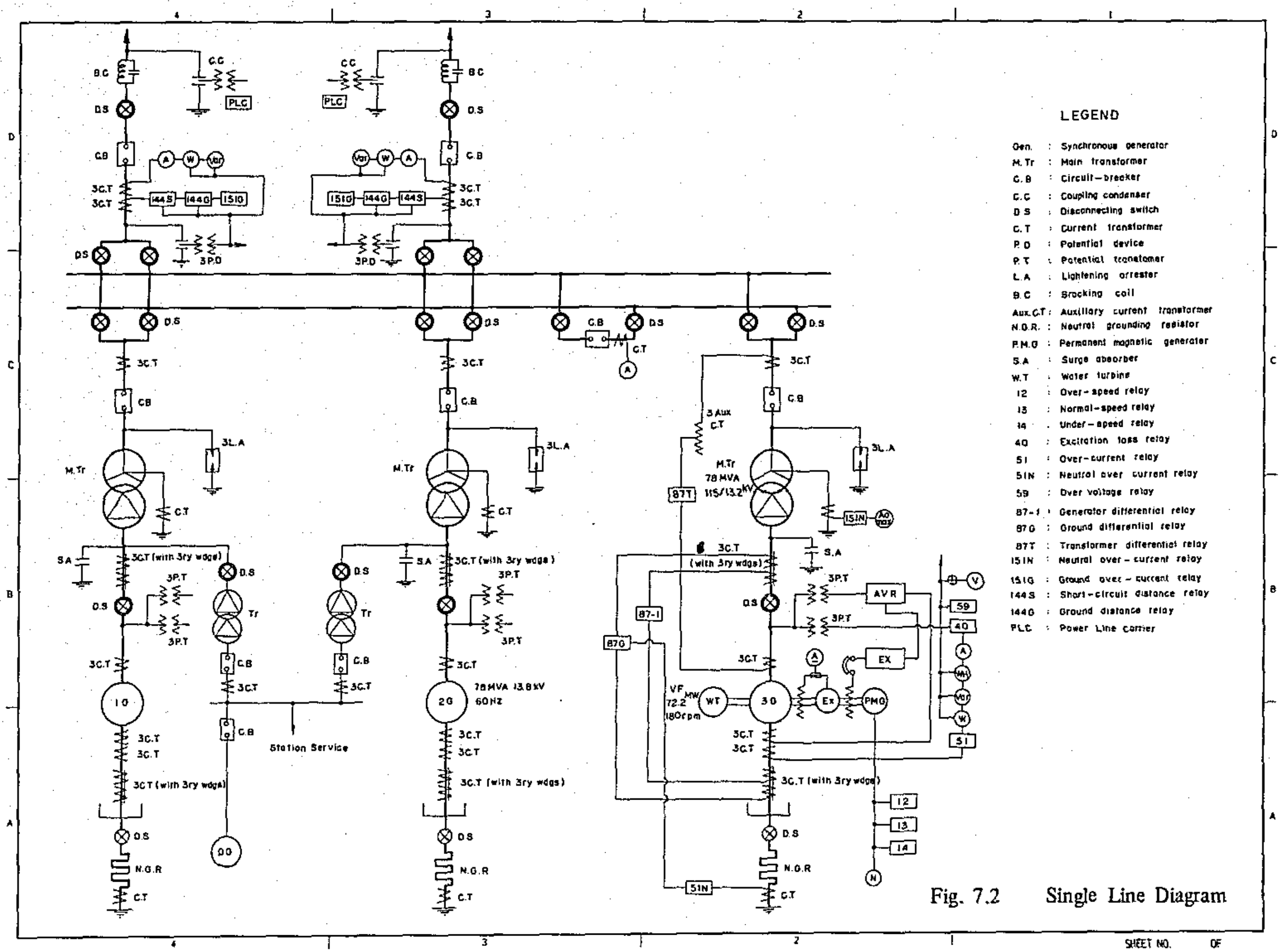
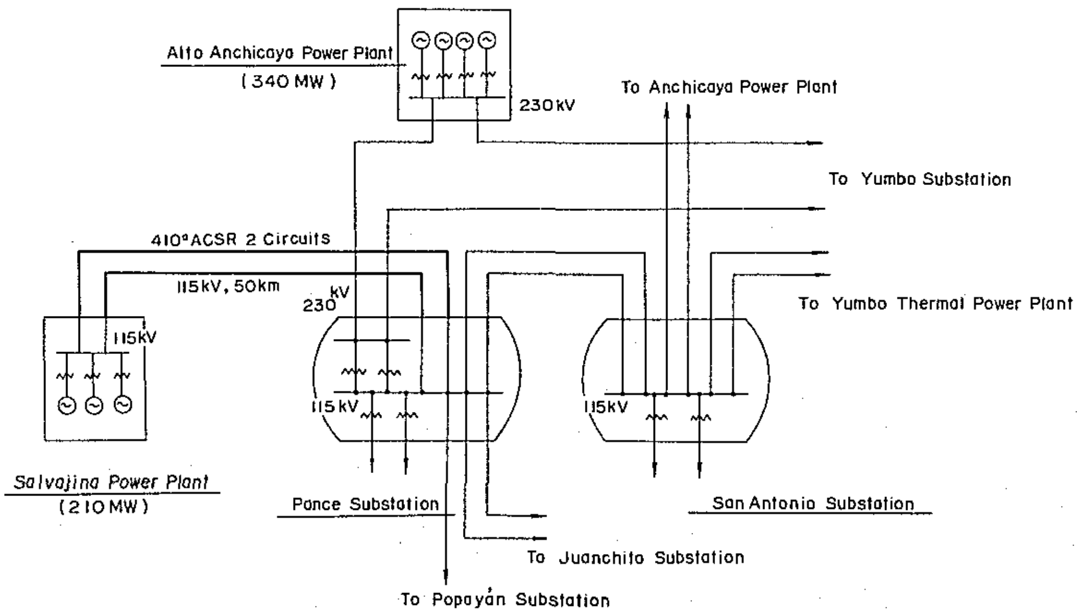


Fig. 7.2 Single Line Diagram

If this criterion is applied, the conductor size for 115 kV line is 410 sq.mm or larger. In the case of a 230 kV line, there is a restriction on conductor size from the standpoint of corona noise and the minimum size is 520 sq.mm. As a result of comparison of annual cost including transmission losses for *115 kV, 410 sq.mm ACSR, 2 cct line and 230 kV, 520 sq.mm ACSR, 1 cct line, the former is economi*cally superior and also of higher reliability. Figs. 7.3 and 7.4 show the power transmission system, and transmission line system. Pertinent information of the transmission line adopted is given in Table 7.2.

Fig. 7.3 Transmission Line System



7.2.2 Design of Transmission Line

(1) Route

The proposed route of the transmission line is in gently rolling hill mountain except for the immediate vicinity of the power plant and there are no special problems in the construction and maintenance of the transmission line. It is aligned along the Cauca River in order to reduce the line length. The route is indicated in Fig. 7.4.

(2) Insulation Design

At a maximum system voltage 120 kV, the number of insulators and arcing horn gap were determined so that flash over against switching surge and abnormal voltage occurring within the system could be prevented. The particulars of insulation design are given below.

Fig. 7.4 General Plan of Transmission Line

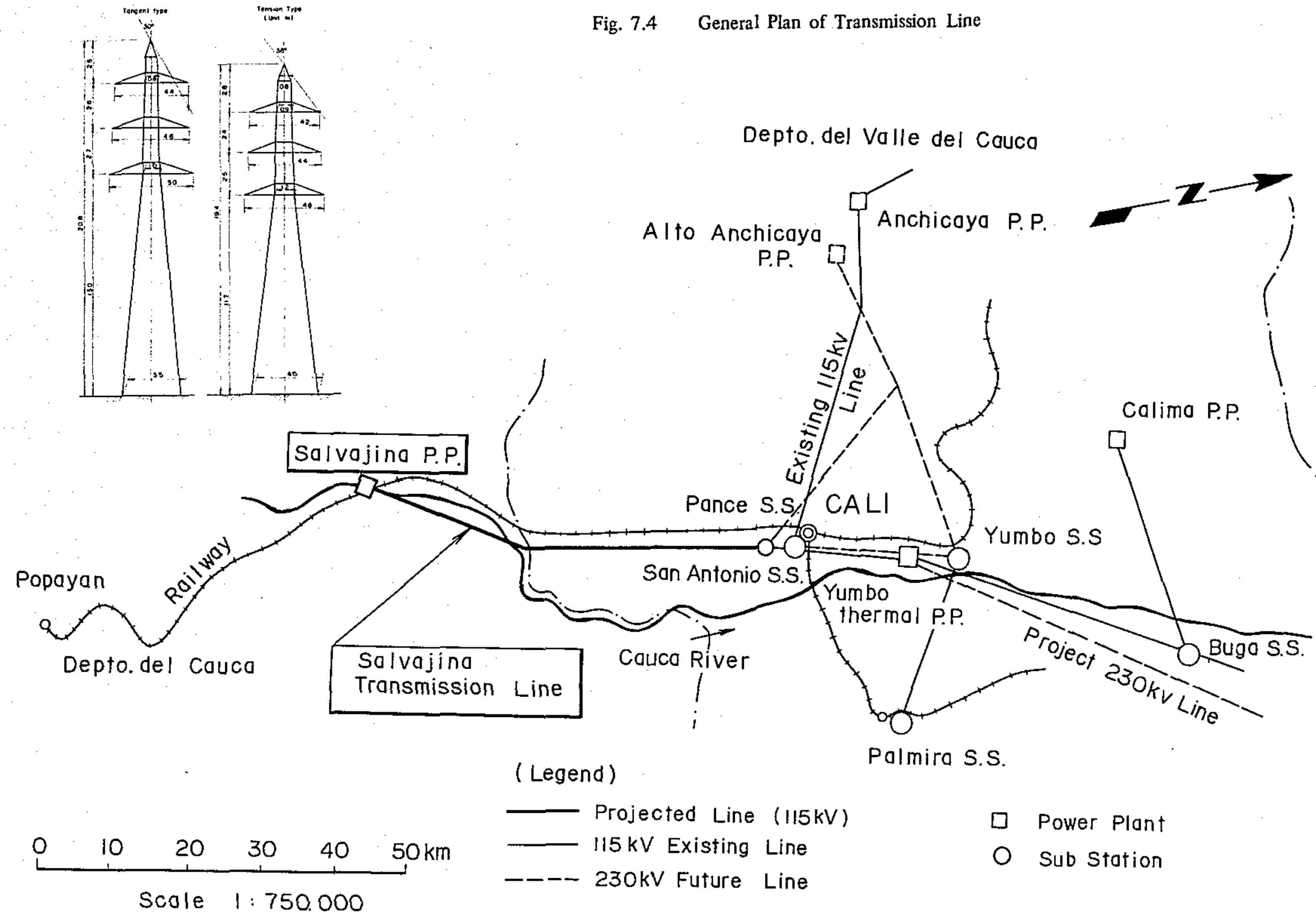


Table 7.2 Description of Transmission Line and Telecommunication Equipment

Transmission Line	
Location	Salvajina Power Plant Pance Substation
Distance	50 km
No. of Circuit	2
Voltage	115 kV
Frequency	60 Hz
Conductor	410 sq.mm ACSR
Overhead Ground Wire	55 sq.mm GSC
Insulator	250 mm Suspension Insulator Ball and Socket Type
No. of Insulator per String	6
Support	Galvanized Steel Tower
Telecommunication Equipment	
Power Line Carrier Telephone	1 channel for load dispatching use and 2 channels for administrative use.
Power Line Carrier Relay	2 channels for Power Line Carrier Relaying

Design Elevation	2,000 m
Insulator Type	250 mm, suspension insulator
Number per String	6
Standard Insulation Gap	950 mm
Minimum Insulation Gap	600 mm

(3) Conductor Size and Supports

The conductor size adopted, as described before, is 410 sq.mm ACSR which is both economically and technically appropriate. In consideration of the importance of the transmission line, steel towers which have high mechanical strength and of good reliability are adopted. The standard steel tower design is given in Fig. 7.4.

7.2.3 Substation

Pance Substation is presently being planned as part of the Alto Anchicaya Project and it is thought that it will be in operation at the time the Salvajina Plant is completed. The 115 kV, 2-cct transmission line from Salvajina Power Plant is planned to be connected to the 115 kV bus line of this substation and the switchgear required for this connection are included in the project.

7.2.4 Telecommunication Facilities

The telecommunication facilities considered for Salvajina Power Plant and Pance Substation are as follows.

(a) Load dispatching and administrative use
(b) Carrier relay equipment

Telemetering and supervisory systems have been considered for installation in the future, corresponding to expansion of the electric power system and are not included in the present study. However, in order to facilitate the installation of such facilities in the future, the power line carrier equipment is designed to have signal transmitting circuits. It is assumed that load dispatching of the plant would be carried out at Pance Substation.

Since the length of the transmission line is short and the geographical conditions along the route are extremely good, telecommunication facilities for transmission line maintenance have not been considered.

(1) Load Dispatching and Administrative Use

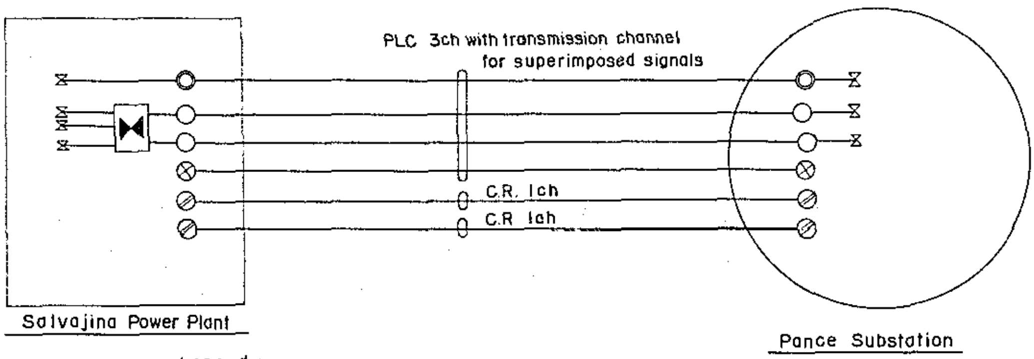
A 3-channel, power line carrier telephone system is to be installed between Salvajina Power Plant and Pance Substation to compose a direct load dispatching telephone channel and a dial telephone channel for administrative use. At Salvajina Power Plant, a 20-circuit automatic telephone exchange is to be installed for operation and maintenance use. The telecommunication channels are composed of the following:

Load dispatching telephone	1 channel
Administrative use telephone	2 channels
Signal transmission channel	1 channel

(2) Power Line Carrier Relay Facilities

For protection of the 115 kV transmission line, a power line carrier relay system is adopted and 3-channel type carrier facilities for carrier relay are to be installed at Salvajina Power Plant and Pance Substation. Fig. 7.5 gives the proposed telecommunication system diagram for the project.

Fig. 7.5 Telecommunication System



Legend :
- ○ Power line carrier telephone channel for load dispatching
- ○ Power line carrier telephone channel for administration
- ⊗ Power line carrier transmission channal for superimposed signals
- ⊘ Power line carrier relaying circuit
- ⧓ Automatic telephone exchange
- x Telephone set

7.3 River Levees

River levees are to be constructed from La Bolsa to R-U-T on the left bank and to the Rio Bugalagrande on the right bank. Summary of works is given in Table 7.3. The height of the levees includes freeboard for flood peaks and waves are determined based on the following assumptions:

(1) The river flow is assumed as uniform flow, for the section between the junction of one tributary to the next tributary and the Manning Formula was applied for each section.

(2) The roughness coefficient (n) for the Manning Formula is estimated from the rating curves at the seven runoff gauging stations[1/] and river profile. As a result, 0.02 to 0.03 was obtained as (n) value for various water levels and it was decided to use 0.03 in the study.

(3) Taking into consideration the meandering of the river, it is reasonable to align the routes of levees somewhat away from the river banks, but on the other hand, if this distance is too great the area benefited will be reduced. Therefore, the design river width was determined based on comparison of const-

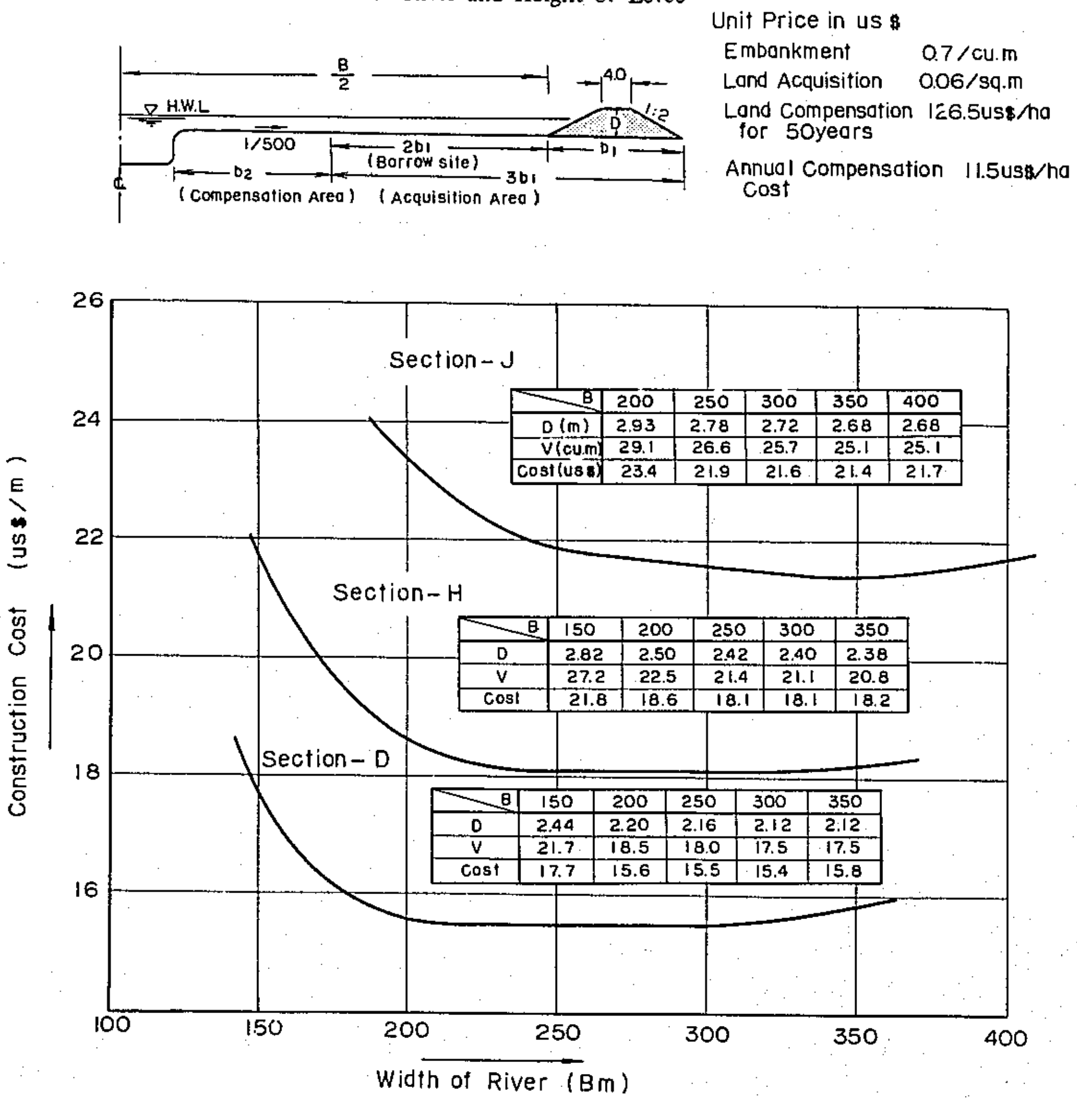
1/ La Balsa, Juanchito, Hormiguero, Guayabal, Mediacanoa, La Victoria, Anacaro ruction costs and compensation cost for three cross sections of D, H and J on the assumption that damages in the river side land by floods will be compensated, while the area occupied by levees and borrow areas will be purchased.

As shown in Fig. 7.6, it will be most economical for the river width to be 200 m to 300 m at cross section D, 250 m to 300 m at cross section H and 300 m to 350 m at cross section J.

The width of the river in each section was determined as shown in Fig. 6.12. It should be noted that in the above comparisons, since topographical maps of the levee area are not available, it is assumed that the transverse lines including the river are inclined down at a gradient of 1 : 500 from both banks of the river. Therefore, it will be necessary to carry out check of location and height of levees when topographical maps of the area have been prepared.

(4) Where the river meanders greatly, short cuts are applied where the ratio of river length to short cut length exceeded 10. Also for meandering part of the river, when the annual cost of a levee along the river exceeds the annual net benefit from the farmland surrounded by that levee, short cut of levees is adopted to connect to the downstream levee.

Fig. 7.6 Relation between Width of River and Height of Levee



Section - J

B	200	250	300	350	400
D (m)	2.93	2.78	2.72	2.68	2.68
V(cu.m)	29.1	26.6	25.7	25.1	25.1
Cost(us$)	23.4	21.9	21.6	21.4	21.7

Section - H

B	150	200	250	300	350
D	2.82	2.50	2.42	2.40	2.38
V	27.2	22.5	21.4	21.1	20.8
Cost	21.8	18.6	18.1	18.1	18.2

Section - D

B	150	200	250	300	350
D	2.44	2.20	2.16	2.12	2.12
V	21.7	18.5	18.0	17.5	17.5
Cost	17.7	15.6	15.5	15.4	15.8

(5) The standard levee cross section is decided as shown in Dwg. No. 7 and according to the criteria given below. Levee materials can be obtained from the nearest borrow areas (See Table 7.3 for physical properties of soil material), and taking the coefficient of permeability (k) of the levee to be 0.001 cm/s including a margin of safety, the b - T curve was obtained by the Strahl Formula1/ (Fig. 7.7), from which the crest width (b) is determined to be 4 m for the condition of duration of floods of 700 hours to 1,000 hours.

Table 7.3 Characteristics of Soil Material for Levees

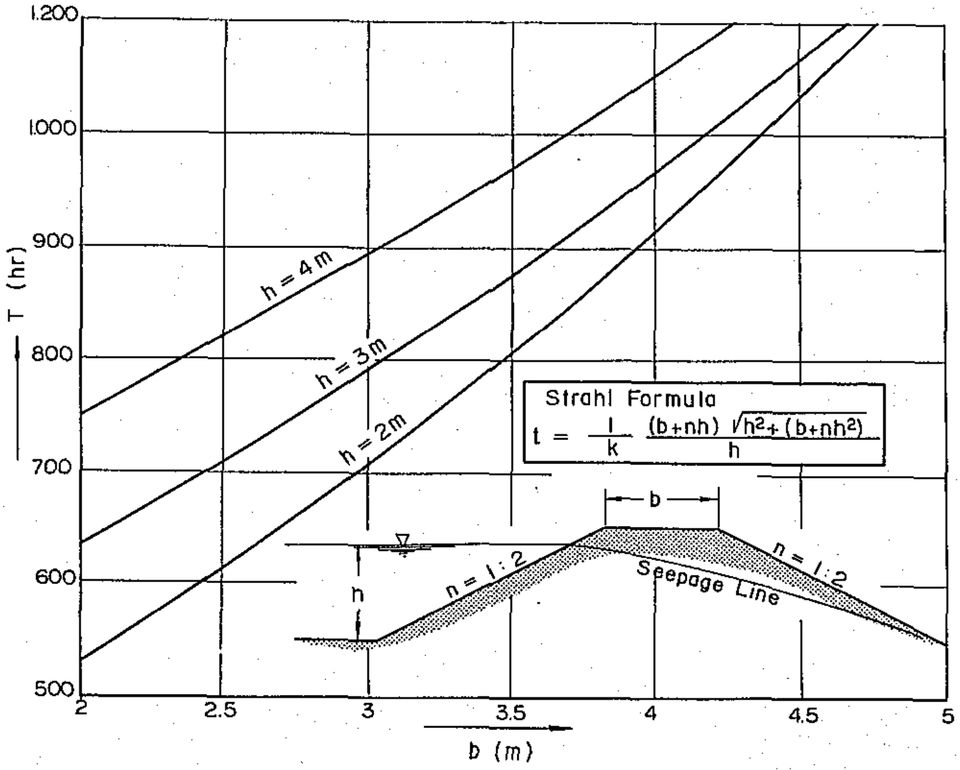
Test \ Sample No.	1 Aguablanca	2 R-U-T	3 Mediacanoa (0 - 2 m)	4 Bugaragrande (0 - 1.8 m)
Soil Character	Clayey Loam with Fine Sand	Loam	Loam - Clay	Loam - Clay
Permeability Coefficient (cm/s)	-	(Compacted Sample $10^{-6} \sim 10^{-9}$)	(? 1.65×10^{-6})	(? 0.47×10^{-7})
Cohesion (kg/sq.cm)	-	-	0.70	1.40
Angle of Internal Friction	-	-	26.6°	28.9°
Specific Gravity	-	2.69~ 2.80	2.56	2.58
Natural Water Content (%)	29.3	16.5 ~ 36.3	40.0(0.7 1/) 39.7(1.3 1/) 52.1(2.0 1/)	31.5(0.7 1/) 43.8(1.3 1/) 41.5(1.8 1/)
Maximum Dry Density (Pb/cu.ft)	97	109.5~117.8	110.6	104.6
Optimum Water Content (%)	26	12.5~ 18.0	15.5	20.5
Atterberg Limit (%)				
LL	48.5	32 ~ 68	41.7 28.4 46.1	44.5 45.8 40.1
PL	-	-	28.5 23.0 26.4	31.0 30.6 25.1
PI	19.2	8 ~ 39	-	-

1/ Depth (m)

1/ $t = \frac{1}{K} \cdot \frac{(b+nh)\sqrt{h^2 + (b+nh)^2}}{h}$

where:
h : depth of water (m)
b : width of crest (m)
n : slope gradient (taken at 1 : 2)
t : flood duration in hours
k : coefficient of permeability (k=0.036 m/hr.)

Fig. 7.7 Relation between T (hr) and b (m) by Strahl Formula



For the height of the levee, the following freeboard is added to the design discharge.

(i) Difference between design daily average discharge and peak discharge to be 130 cu.m/s. (See Table 6.7)

(ii) Freeboard against waves to be 0.5 m.

Table 7.4 Description of River Scheme (Levees)

Items	La Bolsa ~ Juanchito	Juanchito ~ Sonso	Sonso ~ Burriga	Downstream from Burriga	Total
Length of Levee (km)					
Right Bank	45.0	75.6	46.6	26.0	193.2
Left Bank	35.0	53.0	46.6	27.5	162.1
Total	80.0	128.6	93.2	53.5	355.3
Height of Levee (m)	1.5	1.5 ~ 1.9	2.2	2.2 ~ 2.5	
Width of Crest (m)	4.0	4.0	4.0	4.0	
Slope of Levee	1 : 2.0	1 : 2.0	1 : 2.0	1 : 2.0	
Volume of Embankment (10^3 cu.m)	1,280	2,638	2,844	1,990	8,752
Length of levees of Tributary (km)	14.8 (3)	17.2 (4)	14.0 (4)	0	46.0 (11 Tributaries)
Regulation Pond	–	Lag. Sonso (Q=80 cu.m/s)	Cga. Burriga (Q=40 cu.m/s)	–	2 (Q=120cu.m/s)
Gate for Flood Control	–	1	1	–	2 gates
Gate for Fishery	–	1	1	–	2 gates
Improvement of Bridge	2	2	2	–	6 bridges

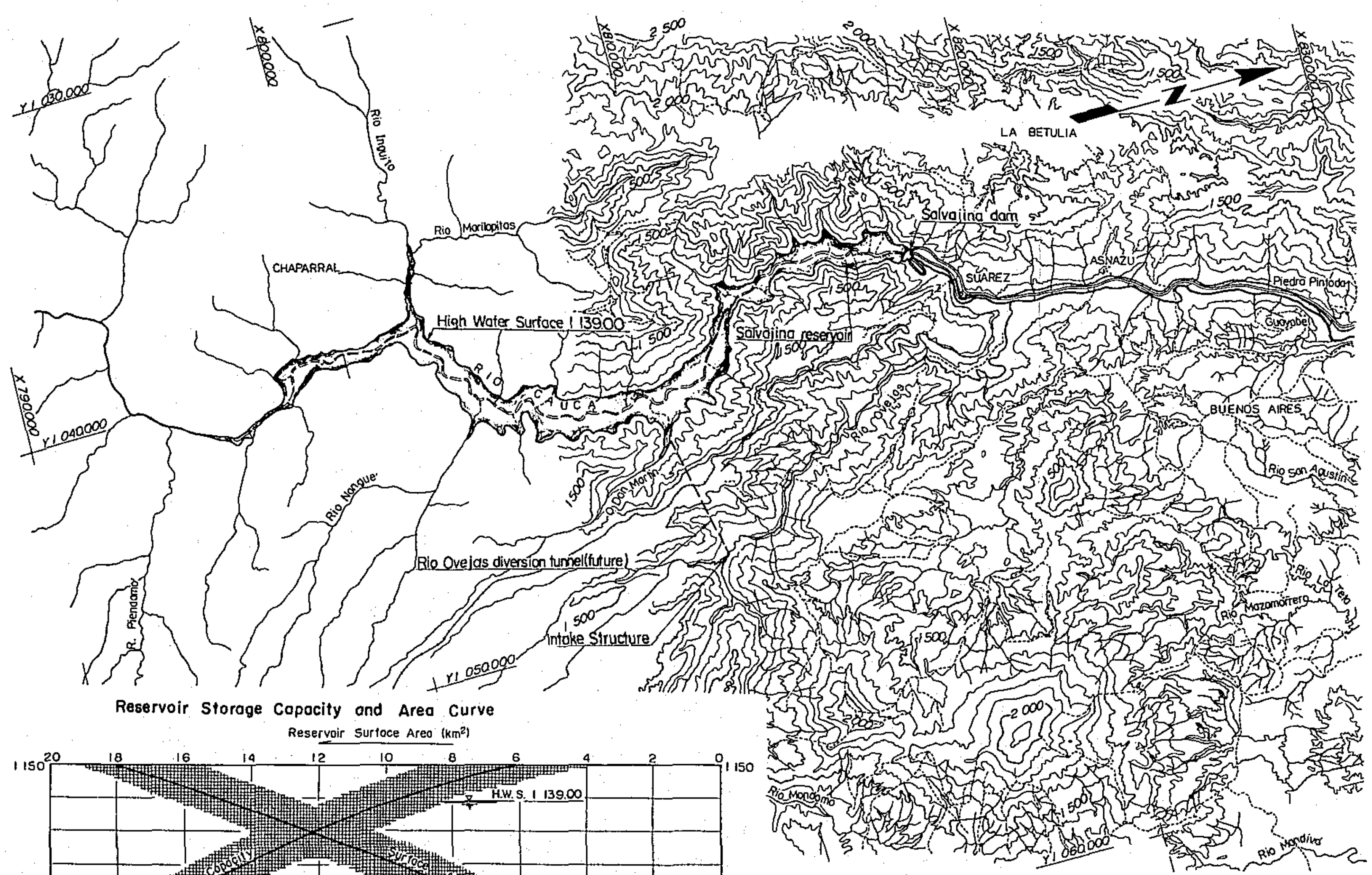
7.4 Drainage Facilities

The outline of drainage facilities is given below.

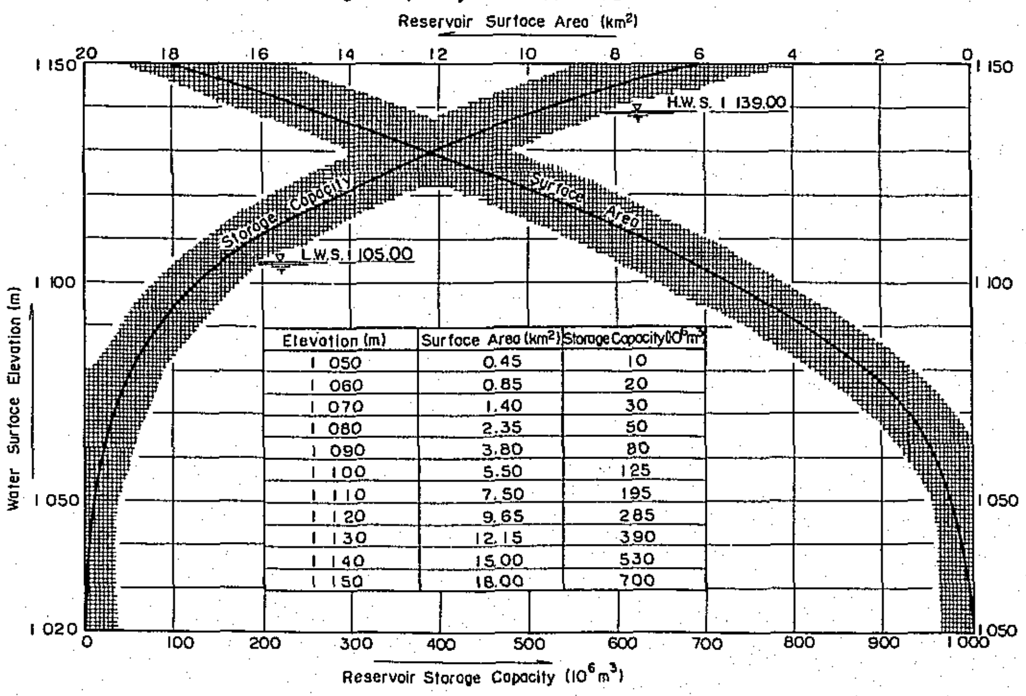
Table 7.5 Description of Drainage Works

Block[1]	Area (ha)	Principal Drainage Canal (km)	Pumping Plant No.	Pumping Plant kW	Intercepting Canal (km)
L - a	9,000	10.0	1	170	4.5
L - b	8,000	6.5	-	-	9.4
L - c	6,300	11.0	1	780	5.0
L - d	500	-	-	-	-
L - e	1,500	5.0	-	-	-
L - f	500	-	2	530	-
L - g	1,500	-	-	-	-
L - h	1,800	-	2	110	5.4
L - i	2,300	-	-	-	10.5
L - j	1,400	-	1	70	11.0
Sub-Total	32,800	32.5	7	1,660	45.8
R - a	6,600	15.5	2	1,180	9.4
R - b	9,600	22.0	1	900	19.6
R - c	9,800	30.0	-	-	14.6
R - d	9,300	16.5	3	3,240	17.9
R - e	3,800	7.0	-	-	13.9
R - f	5,500	16.0	-	-	-
R - g	4,200	15.0	1	350	-
Sub-Total	48,800	122.0	7	5,670	75.4
Total	81,600	154.5	14	7,330	121.2

1/ See Fig. 6.20



Reservoir Storage Capacity and Area Curve



Elevation (m)	Surface Area (km^2)	Storage Capacity ($10^6 m^3$)
1 050	0.45	10
1 060	0.85	20
1 070	1.40	30
1 080	2.35	50
1 090	3.80	80
1 100	5.50	125
1 110	7.50	195
1 120	9.65	285
1 130	12.15	390
1 140	15.00	530
1 150	18.00	700

NOTE

Based on the 1:10 000 maps of the Instituto Geografico de Colombia

0 1 2 3 4 5 km

LOCATION	DATE	DESCRIPTION	BY

REVISION

REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

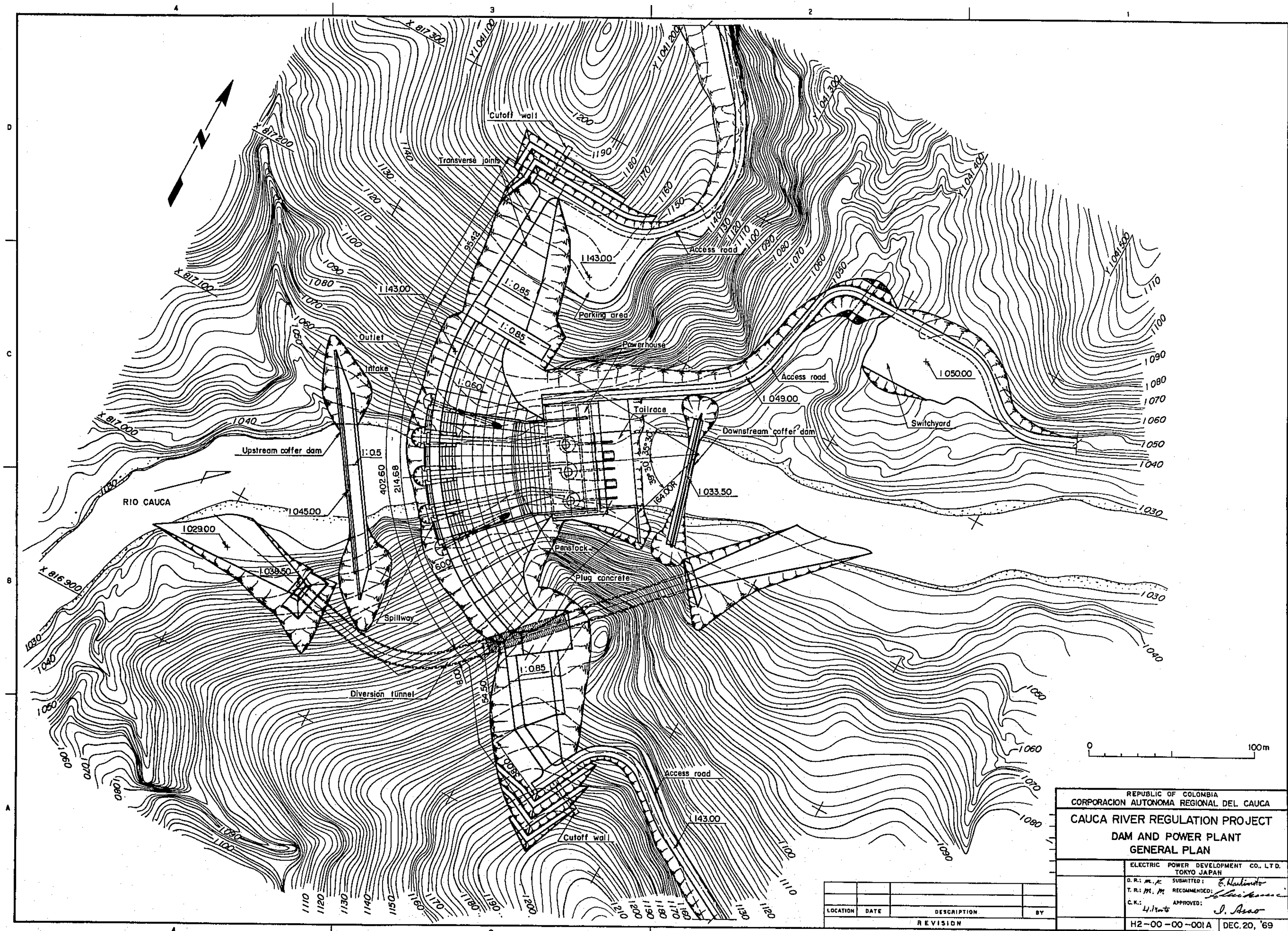
CAUCA RIVER REGULATION PROJECT
RESERVOIR
PLAN

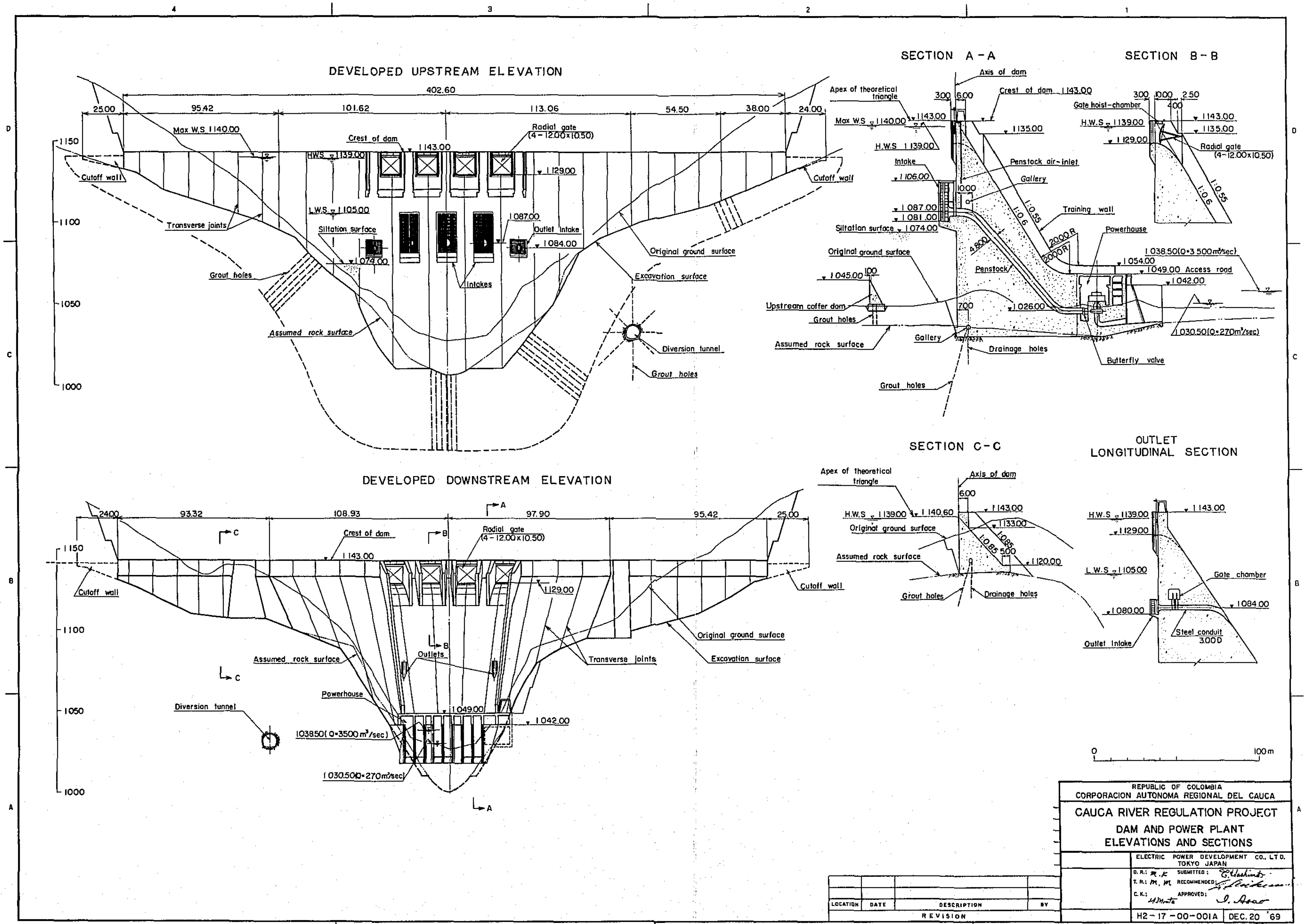
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN

D.R.: SUBMITTED:
T.R.: RECOMMENDED:
C.R.: APPROVED:

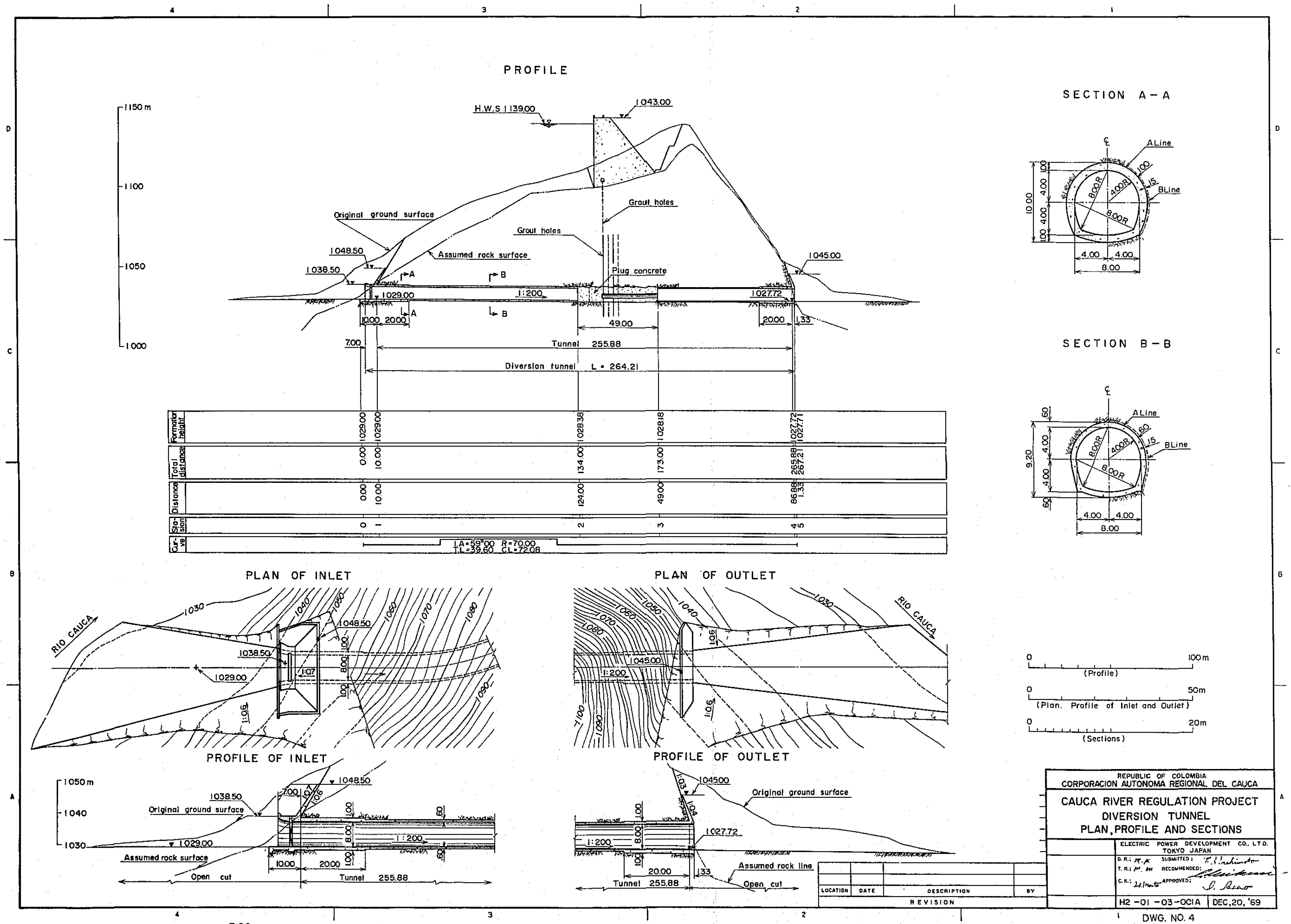
HO-04-01-001A DEC. 20, '69

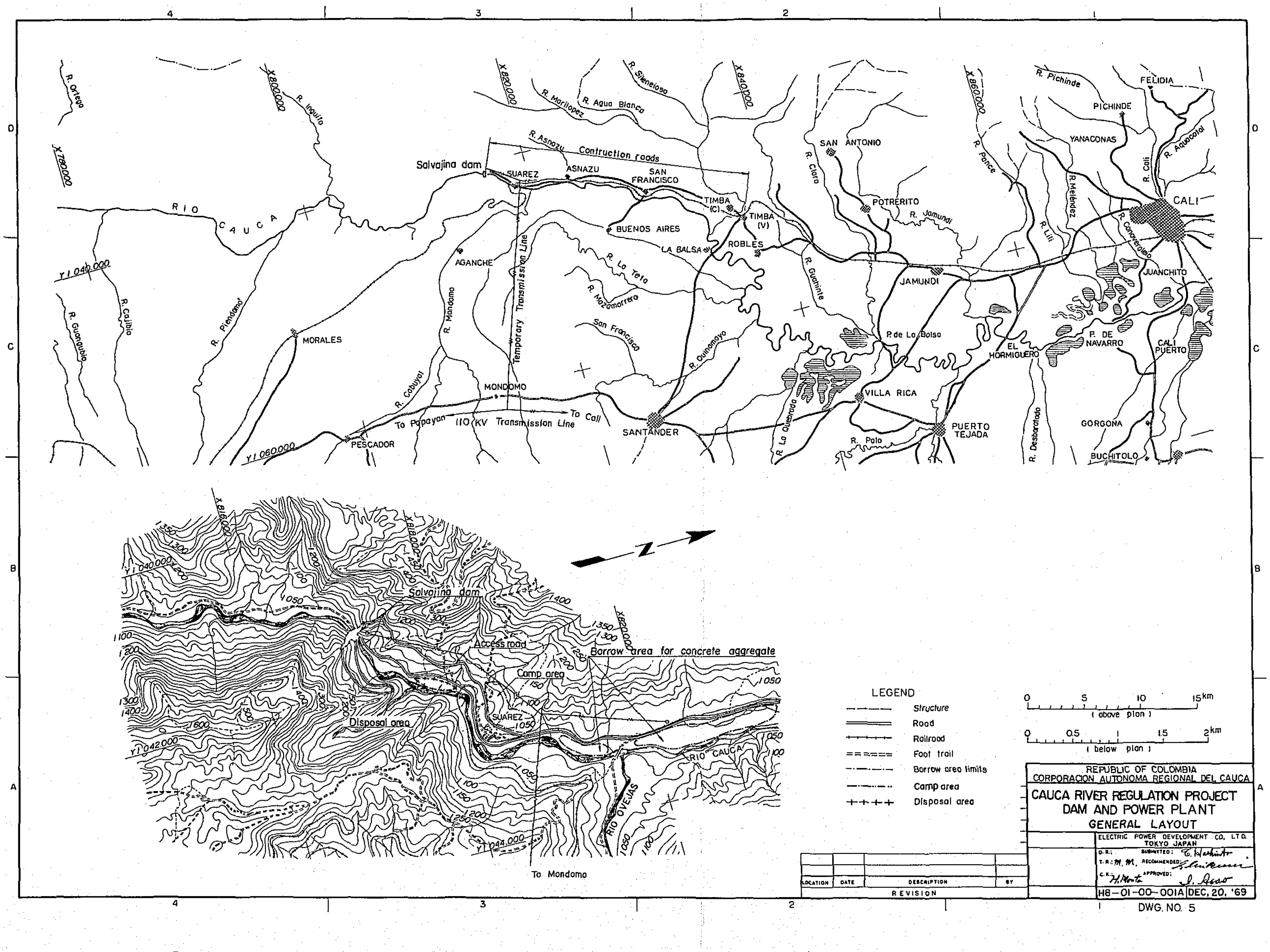
DWG. NO. 1


REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
DAM AND POWER PLANT
GENERAL PLAN
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN
H2-00-00-001A
DEC. 20, '69
LOCATION
DATE
DESCRIPTION
BY
REVISION
Cutoff wall
Transverse joints
Access road
Parking area
Powerhouse
Outlet
Intake
Tailrace
Downstream coffer dam
Switchyard
Upstream coffer dam
RIO CAUCA
Penstock
Plug concrete
Spillway
Diversion tunnel
1 143.00
1 050.00
1 049.00
1 045.00
1 033.50
1 029.00
1 038.50
1:0.85
1:0.60
1:0.5
0
100m
DWG. NO. 2

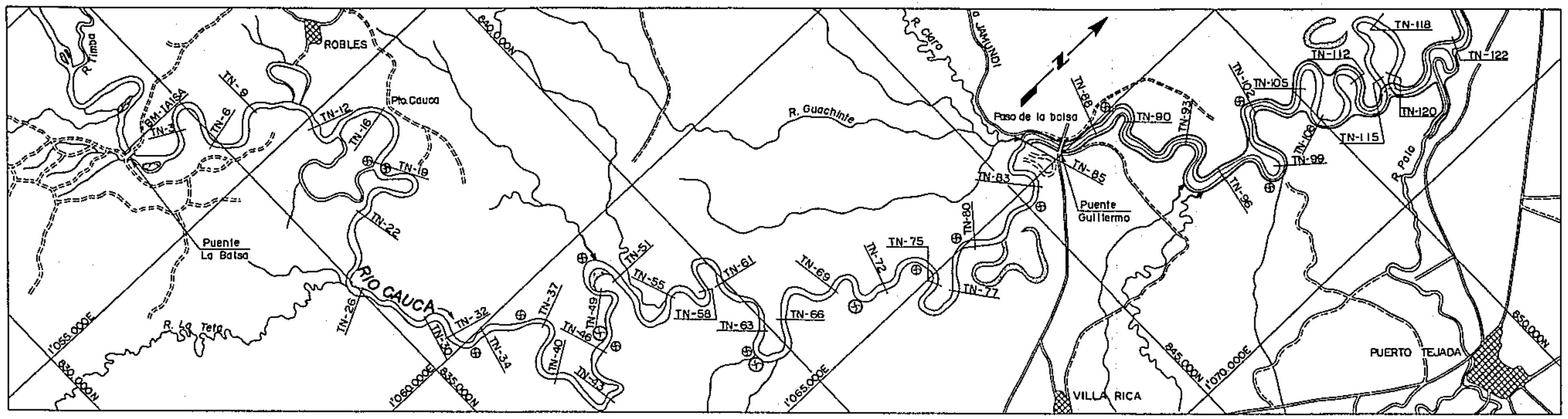


DEVELOPED UPSTREAM ELEVATION
402.60
25.00
95.42
101.62
113.06
54.50
38.00
24.00
Max W.S 1140.00
Crest of dam
1143.00
Radial gate (4-12.00x10.50)
HWS 1139.00
1129.00
Cutoff wall
L.W.S 1105.00
1087.00
Outlet intake
1084.00
Siltation surface
1074.00
Transverse joints
Intakes
Original ground surface
Excavation surface
Grout holes
Assumed rock surface
Diversion tunnel
1150
1100
1050
1000
DEVELOPED DOWNSTREAM ELEVATION
24.00
93.32
108.93
97.90
95.42
25.00
Powerhouse
1049.00
1042.00
1038.50(Q=3500m³/sec)
1030.50(Q=270m³/sec)
Outlets
SECTION A-A
Axis of dam
Apex of theoretical triangle
Crest of dam 1143.00
Max W.S 1140.00
H.W.S 1139.00
1135.00
Intake
1106.00
Penstock air-inlet
Gallery
1087.00
1081.00
Siltation surface 1074.00
Training wall
Powerhouse
1038.50(Q=3500m³/sec)
1054.00
1049.00 Access road
1042.00
Penstock
1045.00
Upstream coffer dam
1026.00
1030.50(Q=270m³/sec)
Drainage holes
Butterfly valve
SECTION B-B
Gate hoist-chamber
H.W.S 1139.00
1129.00
1143.00
1135.00
Radial gate (4-12.00x10.50)
SECTION C-C
H.W.S 1139.00
1140.60
1143.00
1133.00
1120.00
OUTLET LONGITUDINAL SECTION
H.W.S 1139.00
1129.00
L.W.S 1105.00
Gate chamber
1084.00
1080.00
Steel conduit 3.000
Outlet intake
0
100m
LOCATION
DATE
DESCRIPTION
BY
REVISION
REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
DAM AND POWER PLANT
ELEVATIONS AND SECTIONS
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN
SUBMITTED:
RECOMMENDED:
APPROVED:
H2-17-00-001A
DEC. 20 '69
DWG. NO. 3

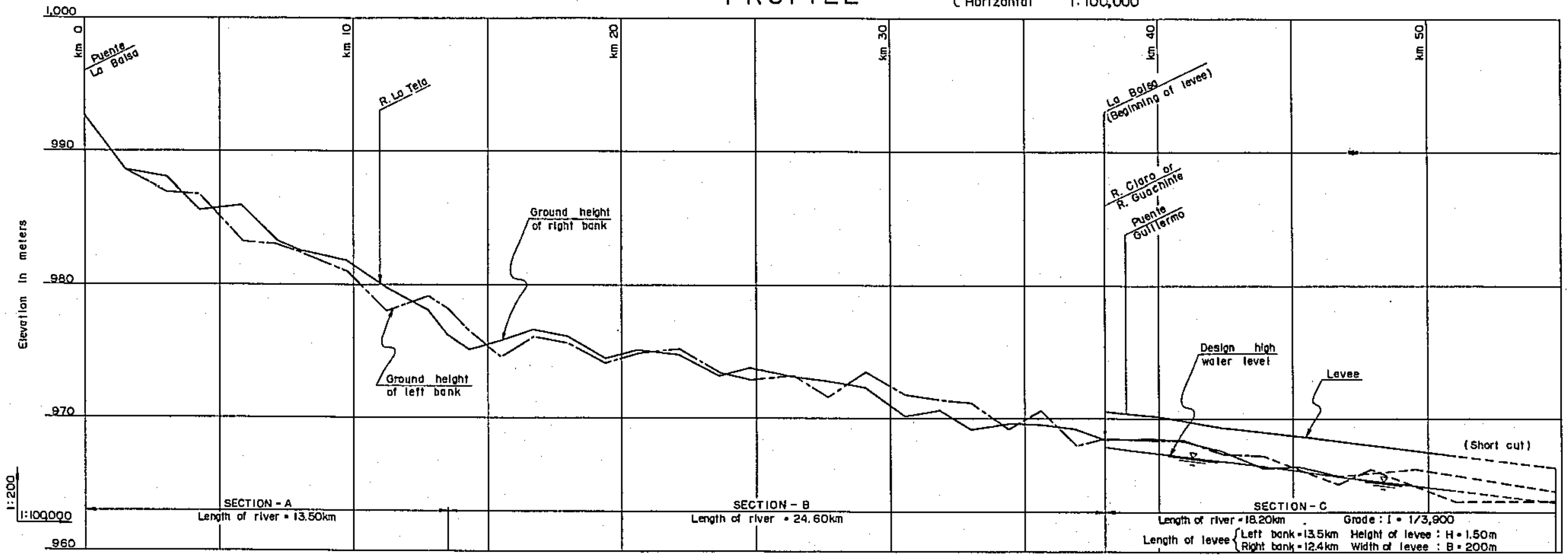

PROFILE
H.W.S 1139.00
1043.00
Grout holes
Original ground surface
Assumed rock surface
Plug concrete
1048.50
1038.50
1029.00
1:200
1027.72
1045.00
Tunnel 255.88
Diversion tunnel L = 264.21
Formation height
Total distance
Distance
Station
Curve
I.A=59°00 R=70.00
T.L=39.60 C.L=72.08
SECTION A-A
A Line
B Line
SECTION B-B
PLAN OF INLET
RIO CAUCA
PLAN OF OUTLET
PROFILE OF INLET
Open cut
PROFILE OF OUTLET
Assumed rock line
(Profile)
(Plan, Profile of Inlet and Outlet)
(Sections)
LOCATION
DATE
DESCRIPTION
BY
REVISION
REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
DIVERSION TUNNEL
PLAN, PROFILE AND SECTIONS
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN
SUBMITTED:
RECOMMENDED:
APPROVED:
H2-01-03-OCIA
DEC.20,'69
DWG. NO. 4


Salvajina dam
SUAREZ
ASNAZU
SAN FRANCISCO
TIMBA (C)
TIMBA (V)
BUENOS AIRES
LA BALSA
ROBLES
AGANCHE
MORALES
MONDOMO
PESCADOR
SANTANDER
VILLA RICA
PUERTO TEJADA
JAMUNDI
P. de La Balsa
EL HORMIGUERO
P. DE NAVARRO
CALI PUERTO
JUANCHITO
CALI
SAN ANTONIO
POTRERITO
YANACONAS
PICHINDE
FELIDIA
GORGONA
BUCHITOLO
RIO CAUCA
Contruction roads
Temporary Transmission Line
To Popayan 110 KV Transmission Line To Cali
Salvajina dam
Access road
Borrow area for concrete aggregate
Camp area
Disposal area
SUAREZ
RIO CAUCA
RIO OVEJAS
To Mondomo
LEGEND
Structure
Road
Railroad
Foot trail
Borrow area limits
Camp area
Disposal area
0 5 10 15km (above plan)
0 0.5 1 1.5 2km (below plan)
REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA
CAUCA RIVER REGULATION PROJECT
DAM AND POWER PLANT
GENERAL LAYOUT
ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN
LOCATION DATE DESCRIPTION BY
REVISION
H8-01-00-001A DEC. 20, '69
DWG. NO. 5

PLAN (La. Balsa ~ PUERTO TEJADA) Scale 1:50,000

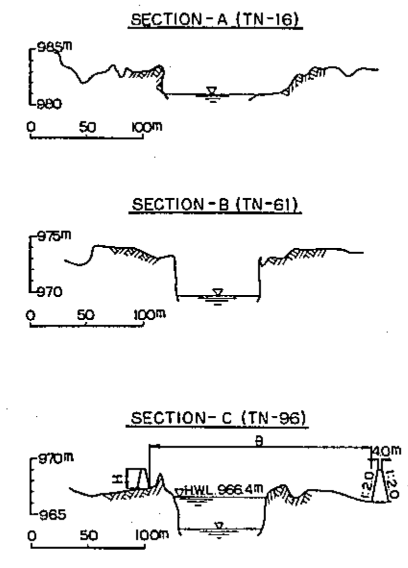


PROFILE Scale { Vertical 1:200 / Horizontal 1:100,000 }



No.	El. of Levee (m)	Design H.W.L. (m)	G.H of Right Bank (m)	G.H of Left Bank (m)	Total Dist. (km)
BM-IAISA			992.7	-	0
TN-3			988.6	988.6	1.48
TN-6			988.0	987.0	3.04
TN-9			985.6	986.8	4.26
TN-12			985.9	983.2	5.82
TN-16			983.2	983.0	7.19
TN-19			982.6	982.4	8.47
TN-22			981.8	981.0	9.76
TN-26			979.7	978.0	11.26
TN-30			978.0	979.1	12.82
TN-32			976.2	978.2	13.50
TN-34			975.1	976.5	14.29
TN-37			975.8	974.6	15.51
TN-40			976.6	976.1	16.76
TN-43			976.1	975.6	18.06
TN-46			974.5	974.1	19.40
TN-49			975.1	974.9	20.67
TN-51			974.7	975.2	22.15
TN-55			973.2	973.5	23.66
TN-58			973.8	972.9	24.78
TN-61			973.1	973.2	26.39
TN-63			972.8	971.6	27.69
TN-66			972.3	973.5	28.07
TN-69			970.2	971.8	30.53
TN-72			970.6	971.4	31.85
TN-75			969.2	971.2	33.02
TN-77			969.6	969.2	34.39
TN-80			969.5	970.6	35.59
TN-83			969.2	968.0	36.96
TN-85	970.5	967.9	968.4	968.5	38.10
TN-88	970.1	967.5	968.5	968.4	39.64
TN-90	969.8	967.2	968.3	968.4	40.89
TN-93	969.3	966.8	967.6	967.4	42.37
TN-96	969.0	966.4	966.3	967.2	43.86
TN-99	968.7	966.1	966.4	-	45.27
TN-102	968.3	965.7	965.7	965.1	46.71
TN-105	968.0	965.4	-	966.2	47.88
TN-108	967.6	965.0	966.2	-	49.49
TN-112	967.2	964.6	-	963.8	51.00
TN-115	-	-	-	-	52.50
TN-118	-	-	-	-	53.81
TN-120	-	-	-	-	54.76

TYPICAL SECTION



LEGEND

Total Dist.	:	Total distance of Cauca River downstream from La Balsa (km).
G. H	:	Elevation of ground in meters.
(1)		Elevations for La Balsa (BM-IAISA) through La Balsa (No. TN-85) are according to the profile prepared by CVC.
(2)		Elevations for La Balsa (No. TN-85) through Bolivar (No. BB-119) are at the center line of levee, and are not identical to figures in the profile prepared by CVC.
Design HWL	:	Design high water level (Elevation in meters).
El. of Levee	:	Elevation at the top of levee (Elevation in meters).
————	:	Center line of proposed levee.
– – – –	:	Center line of existing levee.
⊕	:	Pumping station for drainage.
⊕	:	Pumping station for irrigation.
——→	:	Outlet work of main drainage canal.

SCALE

PLAN: 0 — 1 — 2km (1:50,000)

PROFILE: Vertical 0 — 5 — 10m (1:200); Horizontal 0 1 2 3 4 5km (1:100,000)

REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT
RIVER CHANNEL PLAN AND PROFILE (1-6)

ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN

D. R.: SUBMITTED:
T. R.: RECOMMENDED:
C.K.: APPROVED:

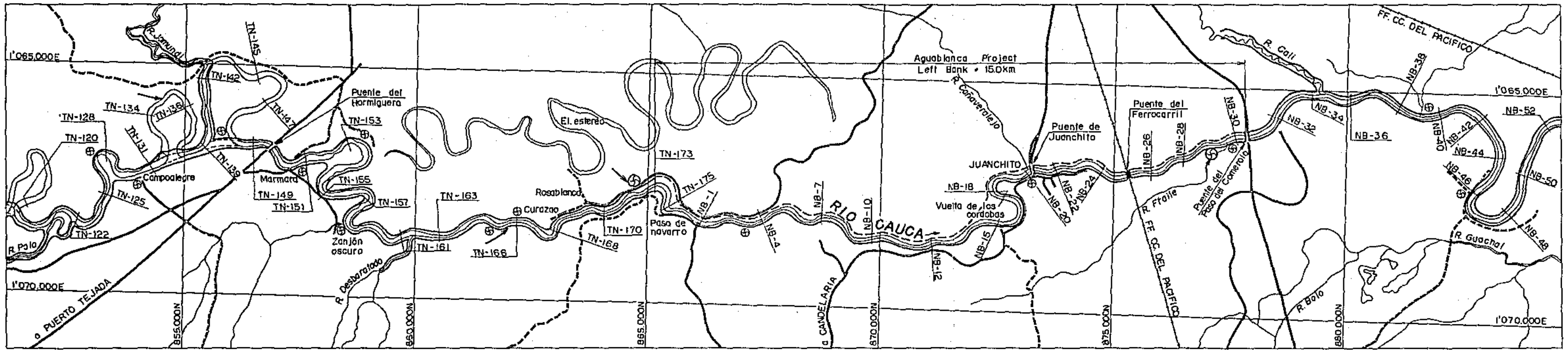
LOCATION	DATE	DESCRIPTION	BY

REVISION

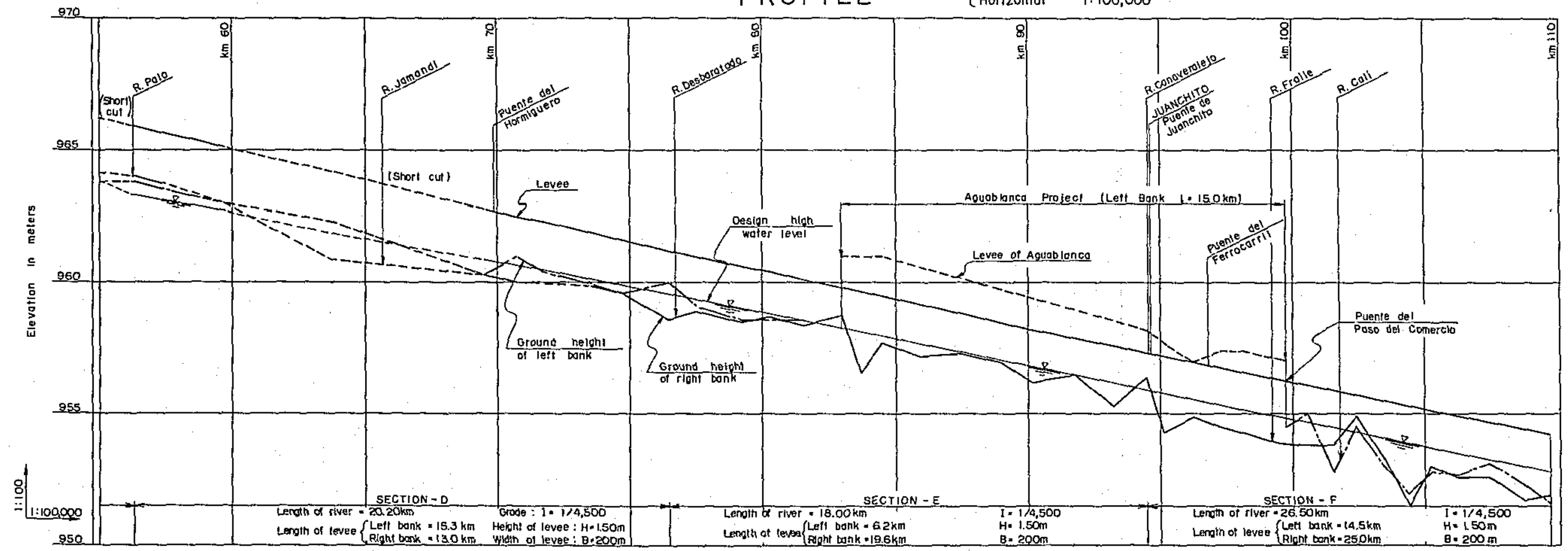
— — — Jan. 16 '70

DWG. NO. 7

PLAN (R. Palo ~ R. Cali) Scale 1:50,000



PROFILE Scale {Vertical 1:100, Horizontal 1:100,000}

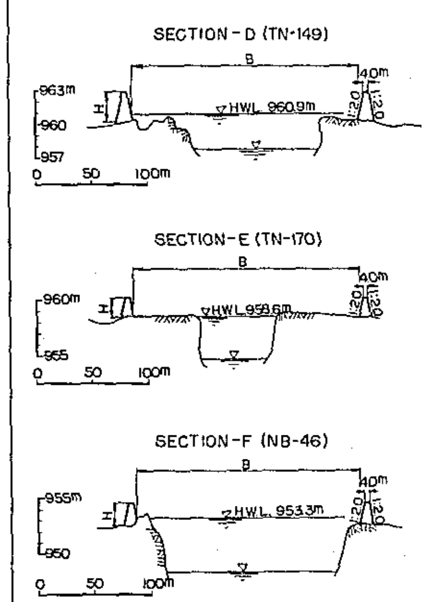


No.	TN-120	TN-122	TN-125	TN-128	TN-131	TN-134	TN-136	TN-139	TN-142	TN-145	TN-147	TN-149	TN-151	TN-153	TN-155
El. of Levee (m)	-	965.9	965.6	965.4	965.1	-	-	964.2	-	-	-	962.8	962.5	962.3	961.9
Design H.W.L (m)	-	963.3	963.1	962.9	962.7	-	-	961.9	-	-	-	960.9	960.7	960.5	960.2
G.H of Right Bank (m)	-	964.0	963.7	-	963.0	-	-	962.3	-	-	-	960.3	960.0	-	959.9
G.H of Left Bank (m)	-	963.8	963.5	963.0	963.0	-	-	960.9	-	-	-	960.3	961.0	960.4	960.0
Total Dist. (km)	54.76	56.30	57.55	58.64	59.76	61.07	62.27	63.74	65.22	66.67	68.00	69.48	70.73	71.77	73.42

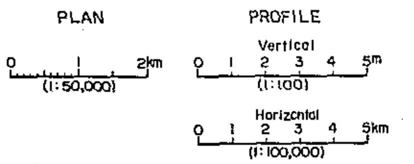
No.	TN-157	TN-161	TN-163	TN-166	TN-168	TN-170	TN-173	TN-175	NB-1	NB-4	NB-7	NB-10	NB-12	NB-15	NB-18
El. of Levee (m)	961.6	961.2	961.0	960.6	960.4	960.1	959.8	959.6	959.5	959.2	958.8	958.5	958.2	957.9	957.6
Design H.W.L (m)	959.9	959.6	959.4	959.0	958.8	958.6	958.3	958.1	958.0	957.7	957.4	957.1	956.8	956.5	956.2
G.H of Right Bank (m)	959.6	958.6	958.9	958.5	958.7	958.4	958.8	956.6	957.7	957.2	957.3	957.0	956.2	956.5	955.3
G.H of Left Bank (m)	959.6	960.0	959.1	958.6	958.6	958.6	958.3 961.0	961.0	961.0	960.6	960.2	959.8	959.4	959.0	958.6
Total Dist. (km)	74.73	76.50	77.54	79.29	80.35	81.62	83.02	83.69	84.48	85.92	87.46	88.88	90.18	91.75	93.17

No.	NB-20	NB-22	NB-24	NB-26	NB-28	NB-30	NB-32	NB-34	NB-36	NB-38	NB-40	NB-42	NB-44	NB-46	NB-48	NB-50
El. of Levee (m)	957.3	957.2	957.0	956.7	956.6	956.3	956.1	955.9	955.7	955.5	955.3	955.1	954.9	954.7	954.4	954.2
Design H.W.L (m)	955.9	955.8	955.6	955.3	955.2	954.9	954.7	954.5	954.3	954.1	953.9	953.7	953.5	953.3	953.0	952.8
G.H of Right Bank (m)	956.4	954.3	954.9	954.5	954.3	953.9	953.8	953.8	954.9	953.3	951.5	953.0	952.6	952.6	951.7	951.9
G.H of Left Bank (m)	958.2	957.7	957.0	957.4	957.4	957.1	955.0	952.8	954.5	953.0	952.0	952.8	952.7	953.1	952.3	951.6
Total Dist. (km)	94.50	95.13	96.25	97.35	98.14	99.42	100.52	101.48	102.33	103.44	104.37	105.27	106.28	107.40	108.70	109.66

TYPICAL SECTION



SCALE



LOCATION	DATE	DESCRIPTION	BY

REVISION

REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT
RIVER CHANNEL
PLAN AND PROFILE (2-6)

ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN

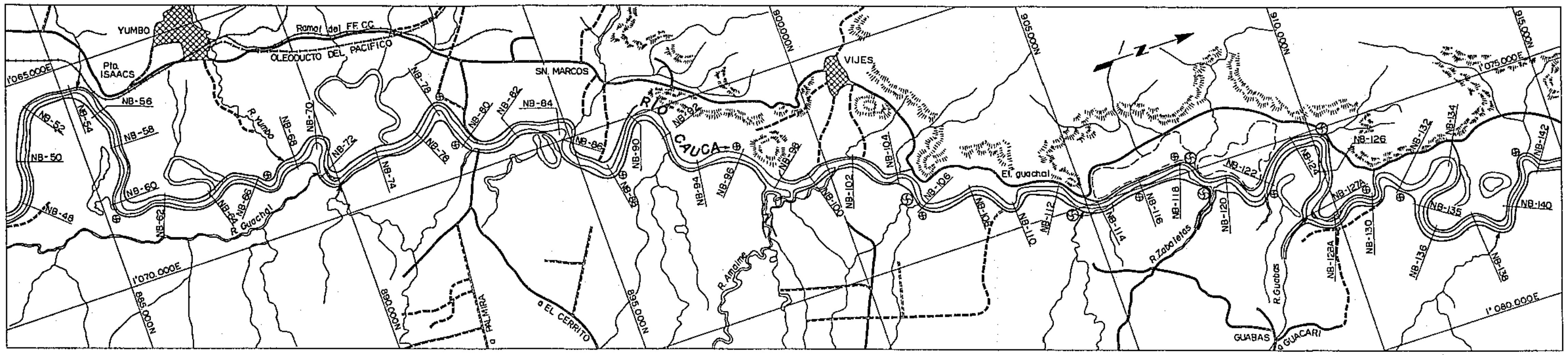
D. R.: Nakajima SUBMITTED: N. Ishimura
T. R.: RECOMMENDED: H. Watanabe
C. K.: A. Noda APPROVED: T. Yasuda

- - - Jan. 16 '70

DWG. NO. 7

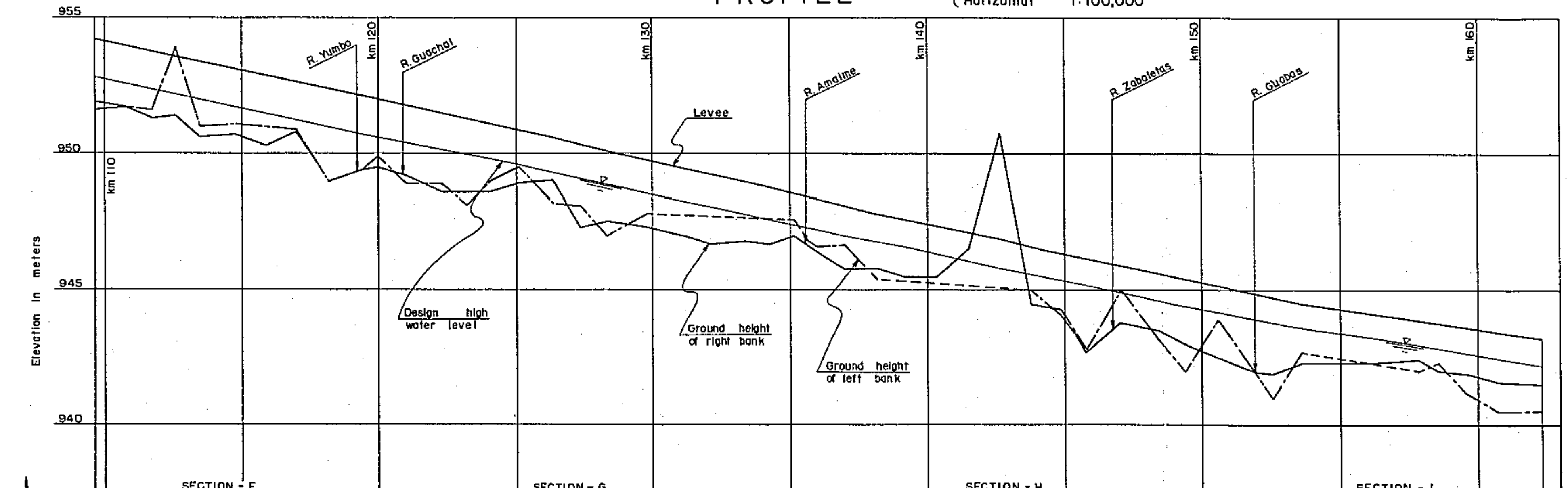
PLAN (YUMBO ~ GUACARI)

Scale 1:50,000



PROFILE

Scale { Vertical 1:100, Horizontal 1:100,000 }



SECTION - F: Length of river = 26.50km; Length of levee {Left bank = 14.5km, Right bank = 25.0km}; I = 1/4,500; H = 1.50m; B = 200m

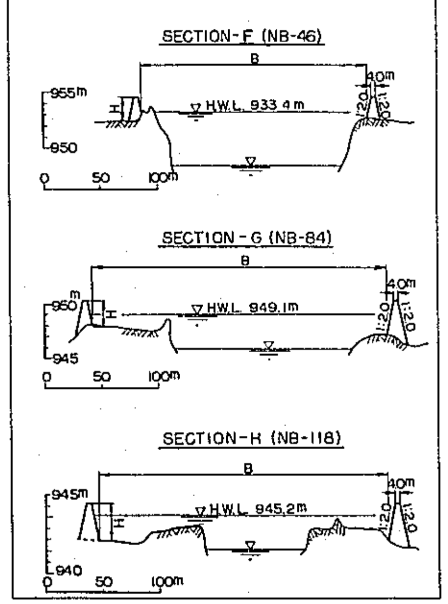
SECTION - G: Length of river = 14.70km; Length of levee {Left bank = 9.0km, Right bank = 13.6km}; Grade : I = 1/4,500; Height of levee : H = 1.90m; Width of levee : B = 260m

SECTION - H: Length of river = 16.20km; Length of levee {Left bank = 11.5km, Right bank = 15.0km}; I = 1/4,500; H = 1.90m; B = 260m

SECTION - I: Length of river = 22.50km; Length of levee {Left bank = 18.0km, Right bank = 22.0km}; I = 1/6,000; H = 1.90m; B = 260m

No.	El. of Levee (m)	Design H.W.L (m)	G.H of Right Bank (m)	G.H of Left Bank (m)	Total Dist. (km)
NB-50	954.2	952.8	951.9	951.6	109.66
NB-52	953.9	952.5	951.7	951.7	110.78
NB-54	953.7	952.3	951.3	951.6	111.75
NB-56	953.6	952.2	951.4	953.9	112.56
NB-58	953.4	952.0	950.6	951.0	113.50
NB-60	953.1	951.7	950.7	951.1	114.74
NB-62	952.9	951.5	950.3	951.0	115.88
NB-64	952.6	951.2	950.8	950.9	116.98
NB-66	952.4	951.0	949.0	949.0	118.15
NB-68	952.1	950.7	949.4	949.4	119.38
NB-70	952.0	950.6	949.5	949.9	120.00
NB-72	951.8	950.4	949.2	948.9	121.00
NB-74	951.5	950.1	948.6	948.9	122.30
NB-76	951.3	949.9	948.6	948.1	123.20
NB-78	951.1	949.8	948.6	949.0	124.08
NB-80	950.9	949.6	948.9	947.6	125.07
NB-82	950.6	949.3	949.0	948.2	126.36
NB-84	950.3	949.1	947.3	948.1	127.40
NB-86	950.1	948.9	947.5	947.0	128.33
NB-88	949.8	948.5	947.3	947.8	129.78
NB-90	949.5	948.3	947.0	–	131.11
NB-92	949.2	948.1	946.7	–	132.13
NB-94	949.0	947.8	946.8	–	133.24
NB-96	948.8	947.6	946.7	–	134.25
NB-98	948.5	947.4	947.0	947.6	135.17
NB-99	948.4	947.3	947.2	946.8	135.70
NB-100	948.3	947.2	946.4	946.6	136.02
NB-102	948.1	947.0	945.8	946.7	137.01
NB-104	947.8	946.8	945.8	945.4	138.18
NB-106	947.6	946.6	945.5	–	139.18
NB-108	947.4	946.3	945.5	–	140.33
NB-110	947.1	946.1	946.5	–	141.48
NB-112	946.9	945.8	950.7	–	142.63
NB-114	946.6	945.6	944.5	945.0	143.78
NB-116	946.4	945.4	944.3	944.1	144.85
NB-118	946.2	945.2	942.7	942.8	145.80
NB-120	945.9	944.9	943.8	945.0	147.07
NB-122	945.6	944.6	943.5	943.2	148.38
NB-124	945.4	944.4	943.0	942.0	149.40
NB-126	945.1	944.2	942.5	943.9	150.58
NB-127A	944.8	943.9	942.0	942.0	151.90
NB-128A	944.7	943.8	941.9	941.0	152.55
NB-130	944.5	943.6	942.3	942.7	153.61
NB-132	944.3	943.4	942.3	–	154.98
NB-134	944.1	943.2	942.3	–	156.36
NB-135	943.9	942.9	942.4	942.0	157.66
NB-136	943.8	942.8	942.0	942.3	158.56
NB-138	943.6	942.6	941.9	941.2	159.53
NB-140	943.4	942.4	941.6	940.5	160.72
NB-142	943.2	942.2	941.5	940.5	162.33

TYPICAL SECTION



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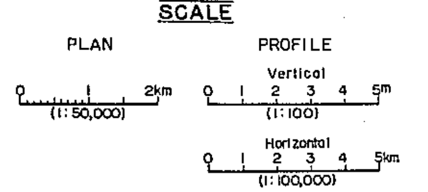


LOCATION	DATE	DESCRIPTION	BY

REVISION

REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT
RIVER CHANNEL
PLAN AND PROFILE (3-6)

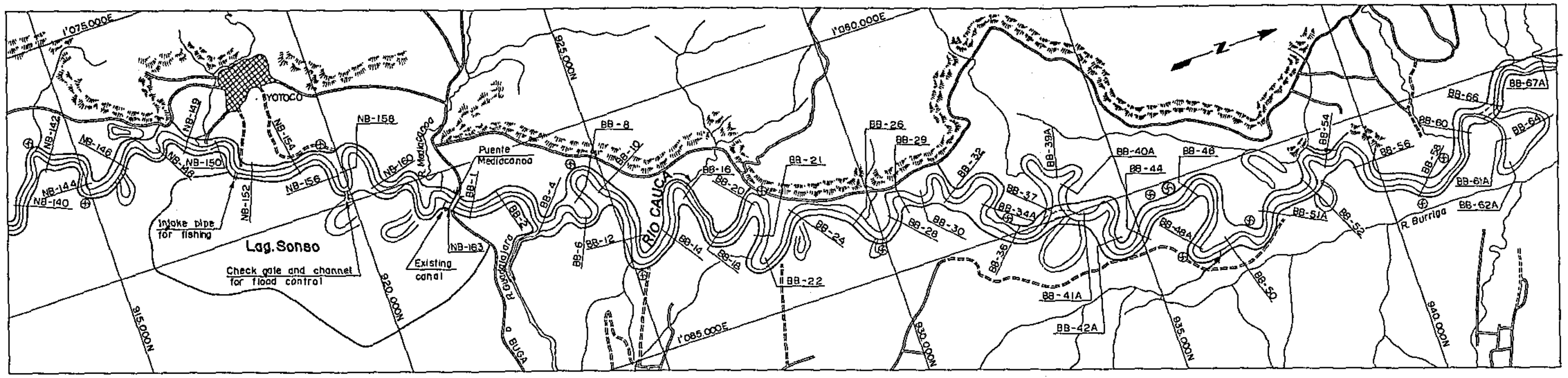
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN

D.R.: SUBMITTED:
T.R.: RECOMMENDED:
C.K.: APPROVED:

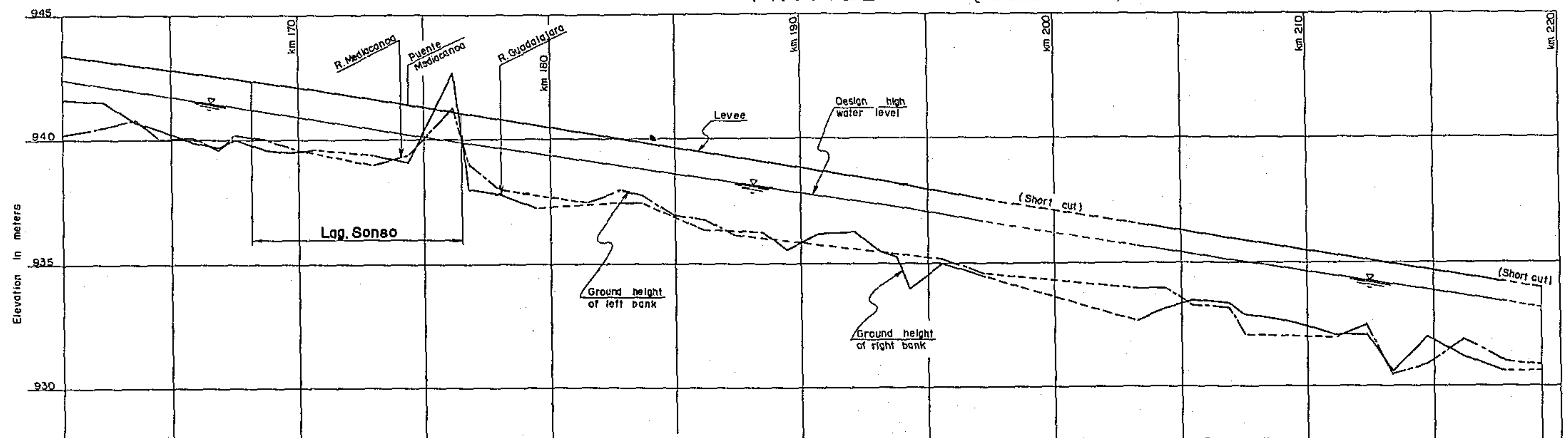
Jan. 16 '70

DWG. NO. 7

PLAN (YOTOCO ~ Cga. Burriga) Scale 1:50,000



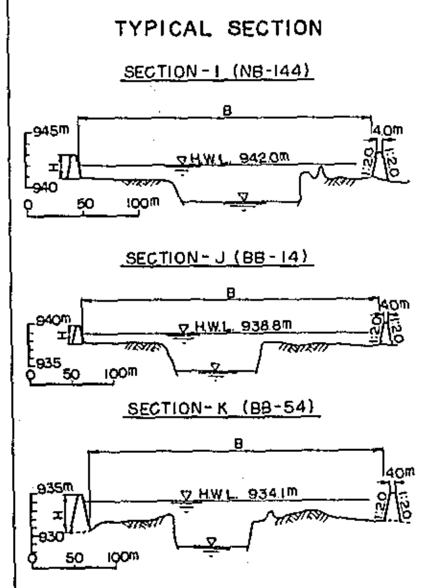
PROFILE Scale { Vertical 1:100, Horizontal 1:100,000 }



SECTION - I		SECTION - J		SECTION - K	
Length of river = 22.50km; Length of levee { Left bank = 18.0km, Right bank = 22.0km }	I = 1/6,000; H = 1.90m; B = 260m	Length of river = 19.30km; Length of levee { Left bank = 10.5km, Right bank = 15.0km }	Grade : I = 1/6,000; Height of levee : H = 2.20m; Width of levee : B = 350m	Length of river = 43.90km; Length of levee { Left bank = 29.1 km, Right bank = 29.1 km }	I = 1/6,000; H = 2.20m; B = 350m

No.	Total Dist (km)	G.H of Left Bank (m)	G.H of Right Bank (m)	Design H.W.L (m)	El. of Levee (m)
NB-140	160.72	940.2	941.6	942.4	943.4
NB-142	162.33	940.5	941.5	942.2	943.2
NB-144	163.62	940.8	940.7	942.0	943.0
NB-146	164.60	940.0	940.4	941.8	942.9
NB-148	165.87	940.1	939.9	941.6	942.7
NB-149	166.91	939.6	939.7	941.4	942.5
NB-150	167.57	940.2	940.0	941.3	942.4
NB-152	168.76	940.0	939.6	941.1	942.3
NB-154	169.66	939.7	939.5	941.0	942.1
NB-156	170.68	-	939.6	940.8	942.0
NB-158	171.59	-	-	940.7	941.8
NB-160	173.03	939.0	939.4	940.4	941.6
NB-163	174.40	939.4	939.1	940.2	941.4
BB-1	176.13	941.3	942.7	939.9	941.1
BB-2	176.78	939.0	938.0	939.8	941.0
BB-4	178.04	938.0	937.8	939.7	940.8
BB-6	179.43	-	937.3	939.4	940.6
BB-8	180.38	-	-	939.3	940.4
BB-10	181.45	937.5	-	939.1	940.2
BB-12	182.77	938.0	937.5	938.9	940.0
BB-14	183.70	937.8	937.5	938.8	939.9
BB-16	184.95	937.0	-	938.6	939.7
BB-18	186.13	936.8	936.4	938.4	939.5
BB-20	187.34	946.2	-	938.3	939.3
BB-21	188.44	-	936.3	938.1	939.1
BB-22	189.44	-	935.6	938.0	939.0
BB-24	190.70	-	936.2	937.8	938.7
BB-26	192.13	-	936.3	937.5	938.5
BB-28	193.13	-	935.5	937.4	938.3
BB-29	193.79	-	935.3	937.3	938.2
BB-30	194.31	-	934.0	937.2	938.1
BB-32	195.55	935.2	935.0	937.0	937.9
BB-34A	197.21	934.6	934.5	936.7	937.6
BB-37	199.26	-	-	-	-
BB-39A	201.34	-	-	-	-
BB-40A	202.27	-	-	-	-
BB-41A	203.30	934.0	932.7	935.7	936.6
BB-42A	204.36	934.0	933.2	935.5	936.4
BB-44	205.46	933.3	933.5	935.4	936.3
BB-46	206.90	933.2	933.4	935.1	936.0
BB-47	207.56	932.1	932.9	935.0	935.9
BB-48A	208.91	-	932.7	934.8	935.7
BB-50	209.79	-	932.5	934.7	935.5
BB-51A	211.13	932.0	932.1	934.5	935.3
BB-52	212.34	932.5	932.1	934.3	935.1
BB-54	213.40	930.5	930.6	934.1	934.9
BB-56	214.75	930.9	932.0	933.9	934.7
BB-58	216.19	931.9	931.2	933.7	934.5
BB-60	217.84	931.0	930.6	933.4	934.2
BB-61A	219.24	-	-	-	-

TYPICAL SECTION



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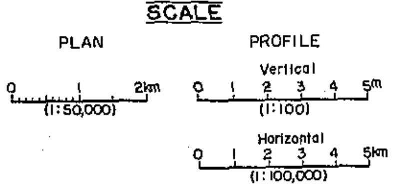


REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT
RIVER CHANNEL
PLAN AND PROFILE (4-6)

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

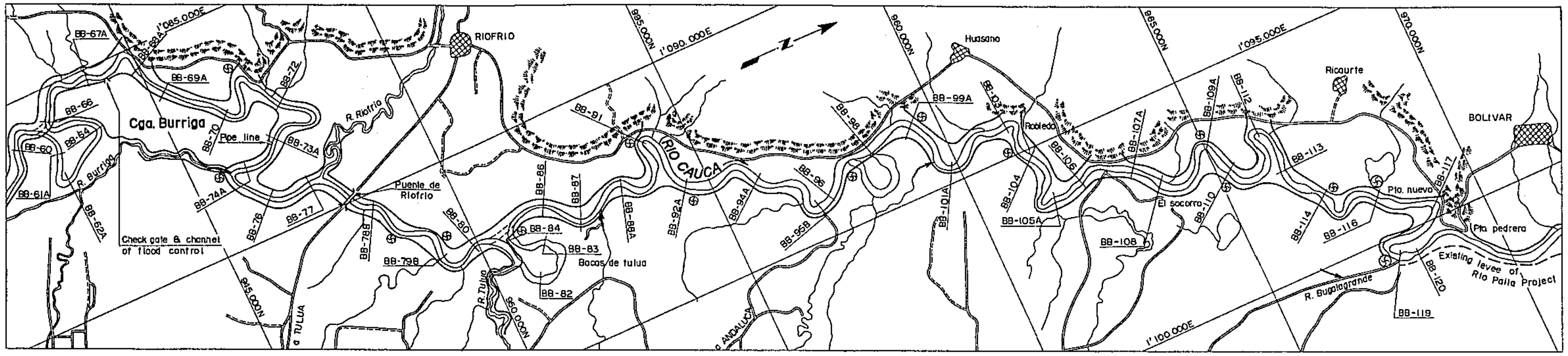
LOCATION	DATE	DESCRIPTION	BY
REVISION			

D.R.: SUBMITTED:
T.R.: RECOMMENDED:
C.K.: A. Noda APPROVED:

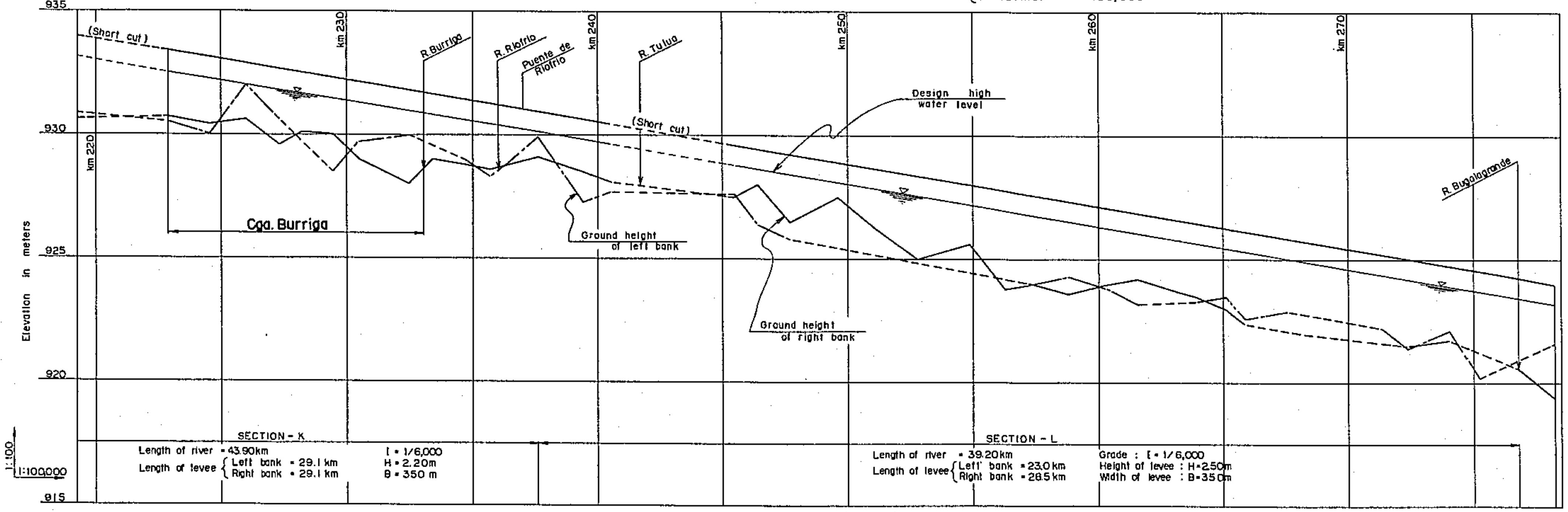
— — — Jan. 16 '70

DWG. NO. 7

PLAN (Cga. Burriga ~ BOLIVAR) Scale 1:50,000



PROFILE Scale {Vertical 1:100, Horizontal 1:100,000}

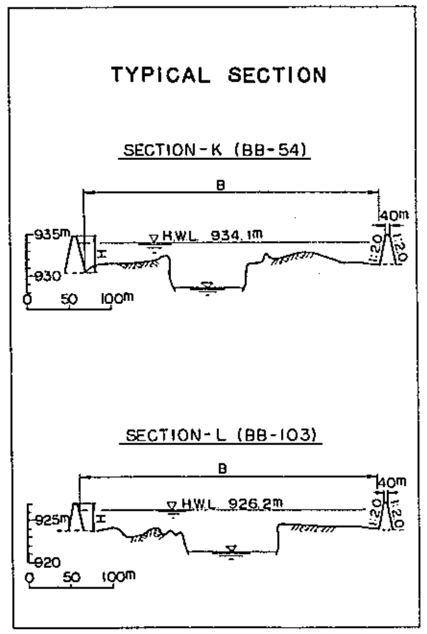


SECTION - K
Length of river = 43.90km
Length of levee {Left bank = 29.1 km, Right bank = 29.1 km}
I = 1/6,000
H = 2.20m
B = 350 m

SECTION - L
Length of river = 39.20km
Length of levee {Left bank = 23.0 km, Right bank = 28.5 km}
Grade : I = 1/6,000
Height of levee : H = 2.50m
Width of levee : B = 350m

No.	Total Dist. (km)	El. of Levee (m)	Design H.W.L (m)	G.H of Right Bank (m)	G.H of Left Bank (m)
BB-61A	219.24	-	-	-	-
BB-62A	220.21	-	-	-	-
BB-64	221.52	-	-	-	-
BB-66	222.89	933.4	932.5	930.7	930.5
BB-67A	224.56	933.1	932.3	930.4	930.0
BB-68A	225.96	932.9	932.0	930.6	932.0
BB-69A	227.33	932.6	931.9	929.6	930.6
BB-70	228.21	932.5	931.7	930.1	-
BB-71A	229.43	932.3	931.5	930.0	928.5
BB-72	230.45	932.1	931.3	929.0	929.7
BB-73A	232.43	931.8	931.0	928.0	930.0
BB-74A	233.41	931.6	930.8	929.0	-
BB-76	234.69	931.4	930.6	928.8	929.0
BB-77	235.68	931.3	930.4	928.6	928.3
BB-78B	237.60	930.9	930.1	929.1	929.9
BB-79B	239.40	930.6	929.8	928.5	927.3
BB-80	240.48	930.4	929.6	928.1	927.7
BB-82	242.33	-	-	-	-
BB-83	243.53	-	-	-	-
BB-84	244.36	-	-	-	-
BB-86	245.49	929.6	928.8	927.5	927.6
BB-87	246.37	929.4	928.6	928.0	928.4
BB-88A	247.70	929.2	928.4	926.5	925.8
BB-91	249.58	928.9	928.1	927.5	-
BB-92A	251.15	928.6	927.8	926.2	-
BB-94A	252.82	928.4	927.5	925.0	-
BB-96	254.92	928.0	927.2	925.6	-
BB-98	256.32	927.8	926.9	923.8	-
BB-99A	257.39	927.6	926.7	924.0	924.0
BB-101A	258.79	927.3	926.5	923.6	924.3
BB-103	260.41	927.1	926.2	924.0	923.8
BB-104	261.56	926.9	926.0	924.2	923.2
BB-105A	263.13	926.6	925.8	923.7	-
BB-106	263.83	926.5	925.6	923.5	923.3
BB-107A	265.11	926.3	925.4	923.0	923.5
BB-108	265.91	926.1	925.3	922.4	922.6
BB-109A	267.47	925.8	925.0	-	922.9
BB-110	268.19	925.7	924.9	922.0	922.8
BB-112	270.05	-	-	-	-
BB-113	271.37	925.2	924.4	-	921.7
BB-114	272.37	925.0	924.2	921.5	921.4
BB-116	274.03	924.7	923.9	921.7	922.1
BB-117	275.27	924.5	923.7	-	920.2
BB-119	276.80	924.2	923.5	920.5	-
BB-120	278.25	924.0	923.4	919.4	921.6

TYPICAL SECTION



SCALE

PLAN: 0 1 2km (1:50,000)

PROFILE: Vertical 0 1 2 3 4 5m (1:100); Horizontal 0 1 2 3 4 5km (1:100,000)

LOCATION	DATE	DESCRIPTION	BY

REVISION

REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT
RIVER CHANNEL
PLAN AND PROFILE (5-6)

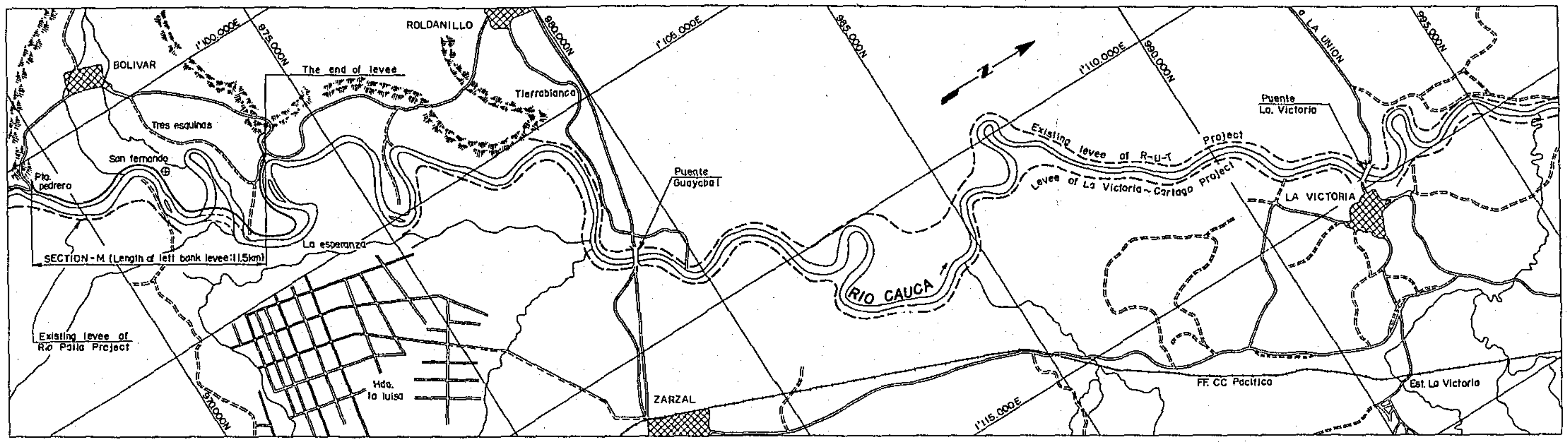
ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN

D.R.: SUBMITTED:
T.R.: RECOMMENDED: H. Watanabe
C.K.: APPROVED:

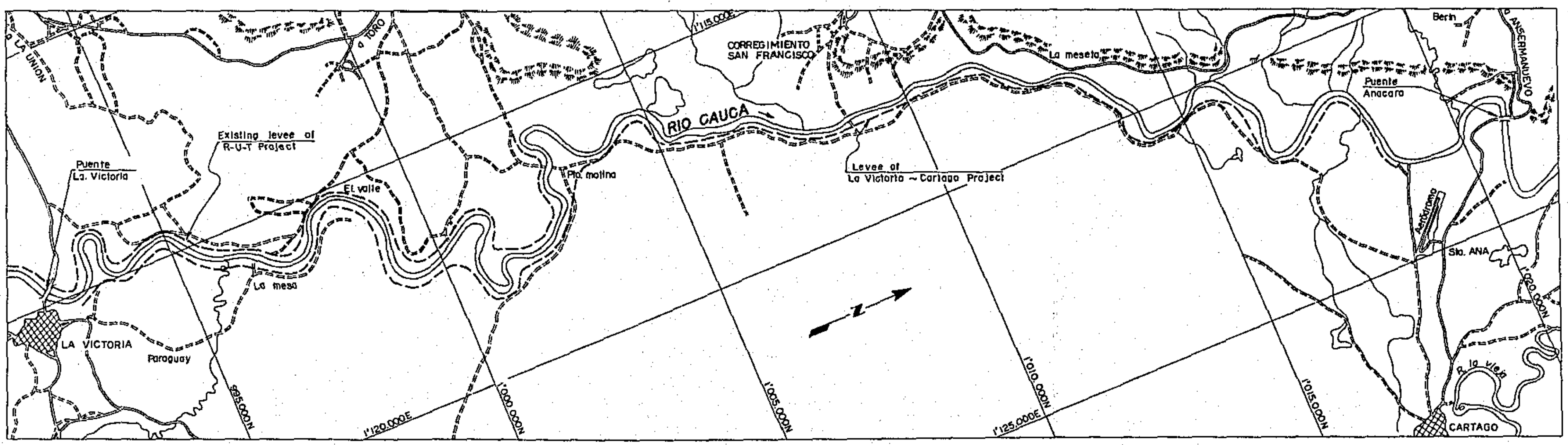
- - - Jan. 16 '70

DWG. NO. 7

PLAN (BOLIVAR ~ LA VICTORIA)



PLAN (LA VICTORIA ~ CARTAGO)



SCALE

PLAN

0 1 2km (1:50,000)

LOCATION	DATE	DESCRIPTION	BY
REVISION			

REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT
RIVER CHANNEL
PLAN (6-6)

ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN

D. R.: SUBMITTED:
T. R.: RECOMMENDED: H. Watanabe
C. K.: APPROVED:

Jan. 16 '70

DWG. NO. 7

CHAPTER 8

CONSTRUCTION SCHEDULE

CONTENTS

LIST OF FIGURE

LIST OF DRAWINGS

CHAPTER 8 CONSTRUCTION SCHEDULE

The general schedule of the project is proposed in Fig. 8.1 and detailed description of works is as given below.

8.1 Dam and Power Plant

8.1.1 Construction Schedule

(1) First Stage Work

The first stage work includes the construction of the dam, spillway and installation of two of the three units of turbines and generators. The first stage work will require a construction period of four years. The Salvajina Power Plant is to be on the line in January 1977 from the necessities of power demand and the construction schedule is indicated in Dwg. No. 6.

In the first year, along with preparatory works such as construction of temporary buildings, improvement and construction of roads and installation of power facilities for construction purpose, the diversion tunnel is to be completed during the dry season and excavation of the dam foundation will begin.

In the second year, excavation for the foundation of the dam and the powerhouse will be completed and placing of concrete of the dam and substructure of the powerhouse and installation of penstock to be embedded in the dam will commence.

In the third year, most of the dam concrete will be placed and accompanying the rise of the dam, the penstocks will be installed and outlet works and intake structure will be constructed. The powerhouse building will be essentially completed and installation of turbines, generators and accessories will start from the end of the third year.

In the fourth year, placing of concrete in the spillway and other structures will be completed and installation of gates and powerhouse equipment is to be completed. The diversion tunnel will be plugged before the rainy season to store water. The power plant will be put in operation in January 1977.

In order to execute the above field works, preparatory works and contracts for main equipment must be awarded according to the schedules given in Dwg. No. 6.

(2) Second Stage Work

The second stage of the project is the installation of the No. 3 unit of turbine and generator. The start of operation of the No. 3 unit is scheduled to be at the beginning of 1979. The work mainly consists of installation of electrical equipments and there are no difficult problems.

8.1.2 Construction Plan

(1) Regional Conditions

(i) Transportation Route

Two alternative routes are conceivable for access from Cali to the construction site. The first one is a route leading from Jamundi via Guachinte, while the second one is via Santander and Timba. The lengths of these routes are 62 km and 84 km respectively. The former is shorter in distance, but there are some sections which require improvement.

Therefore, in consideration of these factors it will be better to select the latter route, but the final decision should be based on thorough investigations. The section from Timba to the dam site will require improvement in many places and it is ncessary to conduct topographical surveys and other investigations.

(ii) Power for Construction

The power requirements for construction of Salvajina Dam and Power Plant are estimated to be approximately 4,000 kW. To meet these needs, it was planned to supply the power for construction by tapping to the 115-kV transmission line to be constructed by ICEL between Cali and Popayan at the vicinity of Mondomo. The power will be stepped-down to 34.5 kV and transmitted to the project site by a distribution line of 25 km in length. This is presently thought most economical method of supplying power for construction, but further study should be made before the work is started.

(iii) Water Supply Facilities

The probable source of water for construction is the gully on the left bank downstream of the dam.

(2) Procurement of Construction Materials

The required materials for the project are estimated to amount 180,000 tons of cement, 3,500 tons of reinforcing steel, 1,000 tons of other steel, 200 tons of explosives, 5,000 cu.m of lumber and 1,000 tons of petroleum products including kerosene, gasoline, heavy oil and lubricants.

Most of these materials are produced in Colombia but the penstock pipes, gates, turbines and generators and other equipments, outdoor steel structures, steel forms and supports, rods, bits, etc. which can not be produced in the country must be imported.

Aggregate for concrete is available from the natural deposit between Suarez and Asunazu 2 km downstream of the dam. This river gravel is tailings of gold mine dredging and is short of fine sand. Sufficient quantities of cement can be procured at the Yumbo cement factory near Cali[1/]. The hauling distance to the dam site is relatively short so that transportation costs will be low. It will be necessary to carry out the mortar and concrete tests with the abovementioned aggregate and cement at the time of the definite study.

(3) Construction of Major Structures

(i) Dam

According to the construction schedule, the diversion tunnel should be completed immediately before the rainy season of 1973. Excavation for the dam foundation will be started immediately after diversion of the river. This work is to be executed from the crest elevation of the dam, working down to the riverbed. After excavation for the foundation of the dam is completed, the bedrock will be treated by curtain grouting to prevent seepage of water and consolidation grouting to improve the bearing strength.

The concrete volume of the dam is 592,000 cu.m and 108,000 cu.m for the thrust blocks on the both banks. This volume of concrete will be placed in a period of two years beginning from the end of 1974. For this purpose a batching plant with four units of 1.5 cu.m mixers will be installed near the dam site. Concrete will be placed by a combination of 18-ton travelling cable crane and supplementary jib crane.

The aggregate plant to be constructed at Suarez will have a capacity of about 300 ton/hr. Before dam concrete is placed, concrete tests should be conducted to produce the best concrete mixture and strict quality control should be applied to obtain good uniform quality of concrete. Thorough investigations and tests must be carried out on the various materials for concrete.

The contraction joints of the dam in the transverse direction will be provided at spacings of 15 m to 22 m. Grouting of these joints will be performed after concrete is cooled with water circulated through embedded pipes in the concrete and according to the water filling plan.

1/ Refer to Memorandum (1) in Chapter 12.

The permanent plugging of the diversion tunnel must be started in the early part of October 1976 so that the river discharge in rainy season of the year could be impounded. Prior to plugging the tunnel, it will be desirable to install the spillway and outlet work gates.

(ii) Powerhouse and Other Structures

Construction of the powerhouse will be started in the latter half of 1974, following excavation of the dam foundation and concrete in substructure will be placed before the rainy season begins. The powerhouse structure should be completed in the middle of 1975 and preparations should be made for installation of turbines and generators. Two of the turbine and generator units will be installed in the first stage of the project.

Draft tube for the third unit will be installed in the first stage in order that the third unit can be installed at any later date.

There are no special problems to be anticipated in the construction of the intake and penstocks. The three penstocks will be installed in the first stage.

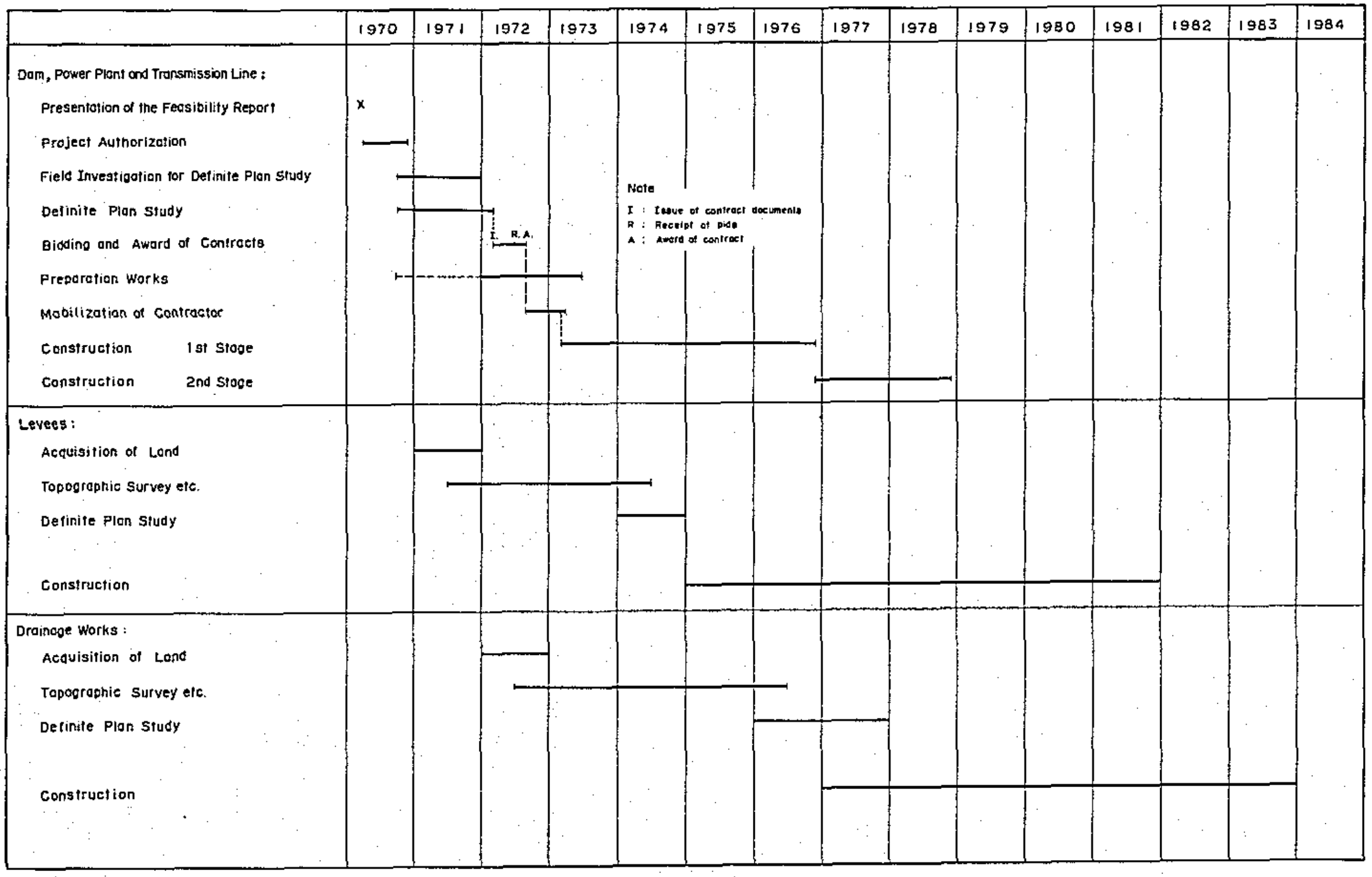
8.2 Levees

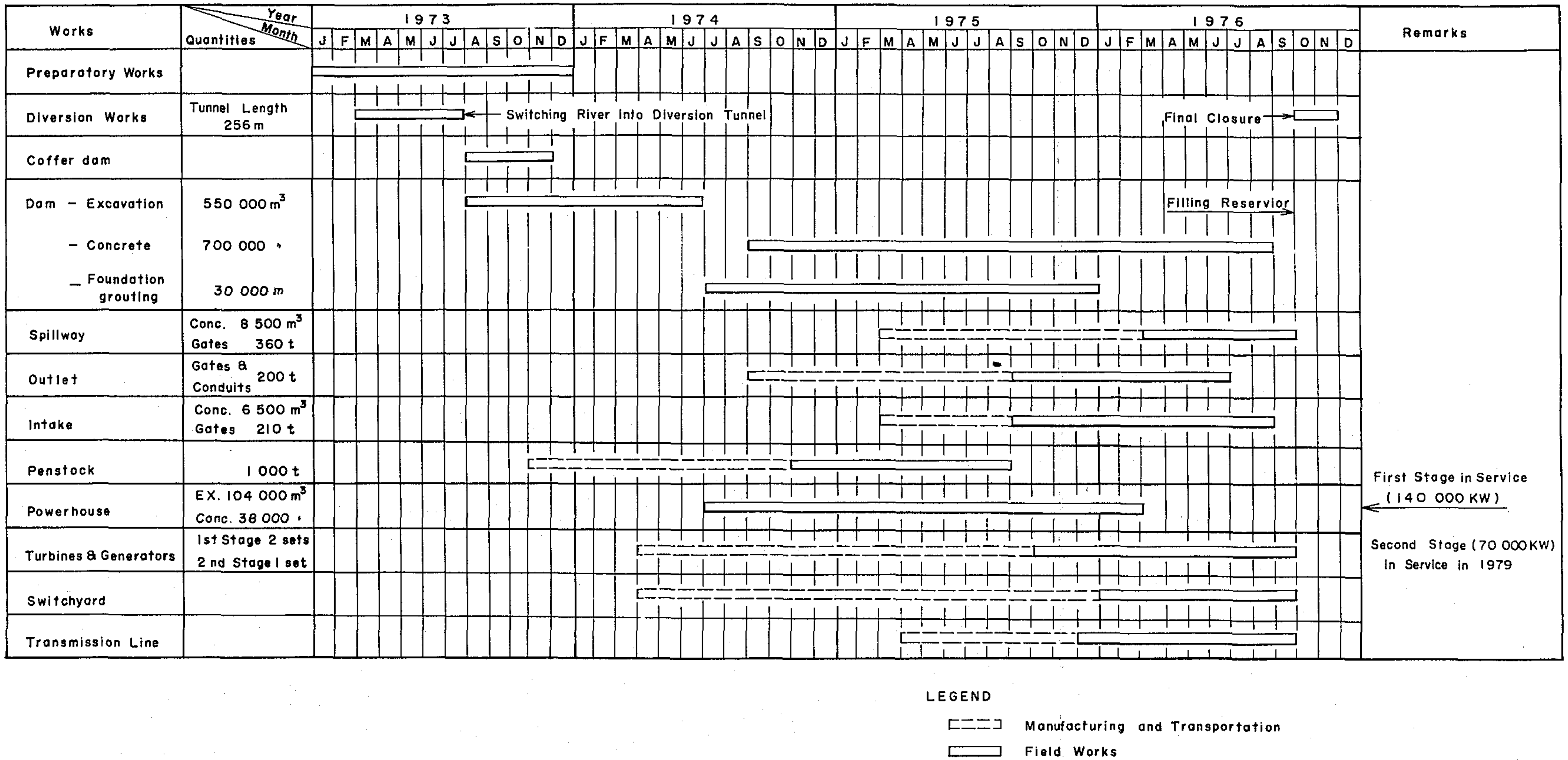
In view of the great social and economic benefit which will accrue by the construction of levees for flood protection, it would be desirable to start the work as early as practicable and completed within a short period of time. However, since the beneficiaries of the works involve many persons who may have to share some cost of the structure, and also since it is necessary to allow some time for topographical survey and negotiation of right-of-way because of the great length of the levees, start of the construction is projected in 1975 with a construction period of seven years. The work will be divided into four sections, La Bolsa to Juanchito, Juanchito to Rio Guabas, Rio Guabas to Rio Tulua and Rio Tulua to Rio Bugalagrande on the right bank and R-U-T on the left bank. It was assumed that the work will be commenced from the upstream section. The scope of work to be performed by year is indicated in Dwg. No. 8.

8.3 Drainage Works

In connection with drainage works, it is conceivable that much more effort than for levee construction would be necessary to reach agreement with land owners involved. From this standpoint, start of the work is scheduled in 1977 to provide allowance for a preparatory period. The work is envisioned as to start from the section where levee construction has been finished. The scope of work to be performed each year is shown in Dwg. No. 8.

Fig. 8.1 General Schedule of Project





REPUBLIC OF COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT
DAM AND POWER PLANT
CONSTRUCTION SCHEDULE

ELECTRIC POWER DEVELOPMENT CO., LTD.
TOKYO JAPAN

D.R.: SUBMITTED:
T.R.: M. M. RECOMMENDED:
C.K.: APPROVED:

LOCATION	DATE	DESCRIPTION	BY

REVISION

HO-08-07-001A DEC. 20, '69

DWG. NO. 6

Works	Quantities	1975	1976	1977	1978	1979	1980	1981
Levee (Rio Cauca)	L = 355 km V = 8,750 x 10^3 cu.m	La Bolsa ~ (80km,	Juanchito 1.280 x 10^3 cu.m)	Juanchito ~ (129 km,	Rio Guabas 2.640 x 10^3 cu.m)	Rio Guabas ~ (93km,	Rio Tulua 2.840 x 10^3 cu.m)	R.Tulua ~ La Victoria (53km, 1.990 x 10^3 cu.m)
Levee (Tributary)	11 Tributaries L = 46 km		3 Tributaries		4 Tributaries		4 Tributaries	
Flood Storage Basin	2 Basins				Log. Sonso		Cga. Burriga	
Bridge	6 Bridges	Hormiguero	Juanchito	Ferrocarril	Paso de la Comercio	Mediacanoa	Rio Frio	

Works	Quautities	1977	1978	1979	1980	1981	1982	1983
Intercepting Canal	L = 121 km	L-a, L-b,	R-a, R-b (43 km)	L-c, L-d,	L-e, L-f, R-c (37 km)	R-d	L-g, L-h, L-i, L-j, R-e, R-f, R-g (41 km)	
Drainage Canal	L = 155 km	L-a, L-b,	R-a, R-b (54 km)	L-c, L-d,	L-e, L-f, R-c, R-d (63 km)		L-g, L-h, L-i, L-j, R-e, R-f, R-g (38 km)	
Pumping Station	14 Pumping Stations		L-a, L-b, R-a, R-b (4 pumping stations)		L-c, L-d, L-e, L-f, R-c, R-d (6 pumping stations)			L-g, L-h, L-i, L-j, R-e, R-f, R-g (4 pumping stations)

REPUBLICA DE COLOMBIA
CORPORACION AUTONOMA REGIONAL DEL CAUCA

CAUCA RIVER REGULATION PROJECT

LEVEE AND DRAINAGE WORKS CONSTRUCTION SCHEDULE

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

D.R.: SUBMITTED: T.R.: RECOMMENDED: C.K.: APPROVED:

LOCATION	DATE	DESCRIPTION	BY

REVISION

DWG. NO. 8

CHAPTER 9

CONSTRUCTION COST

CONTENTS

LIST OF TABLES

CHAPTER 9 CONSTRUCTION COST

The total costs of the project have been estimated to be 91.3 million dollars, of which the foreign currency requirements are 44.3 million dollars and the domestic currency requirements are an equivalent of 47.0 million dollars. The cost of dam, spillway, power plant, levees and regulating ponds is 69.4 million dollars, of which 40.7 million dollars are foreign currency and 28.7 million dollars are domestic currency, and the cost of drainage works is 21.9 million dollars, of which 3.7 million dollars are foreign currency and 18.2 million dollars are domestic currency.

The project costs have been estimated on the basis of prices as of 1969 and exchange rate of 17.35 pesos to one U.S. dollar. The land acquisition cost was estimated to be 10,000 pesos per ha for cultivated land and 3,100 pesos per ha for forestland. Compensation costs were calculated for buildings and houses to be submerged in the reservoir, but compensation to mining rights was not included.

Construction of the project will be performed by contracts with construction firm. Materials, equipment and facilities, which can not be procure domestically are to be imported. Prices of labor, materials, machinery and equipment were determined on the basis of prevailing prices of similar work in the country while import duties were not taken into account.

As contingency, 15% was estimated for civil works and 5% for equipment. The engineering fee was calculated at 6.25% of construction cost (not including interest during construction) while interest during construction was calculated at 9% per annum for foreign currency and 12% per annum for domestic currency. 1/ Field investigation costs for the definite plan study and administration cost are not included in the project cost.

The breakdown of the construction costs by category of work and by year is given in Table 9.1 (1),

Table 9.1 (1) Construction Costs

(Unit: 10^3\$)

Item	Total Costs	Foreign Currency	Domestic Currency
Dam and Reservoir	36,978 (31,281)	22,404 (19,266)	14,574 (12,015)
Power Plant	17,806 (15,459)	14,478 (12,687)	3,328 (2,772)
Transmission Line, Sub-Station and Telecommunication Equipments	1,751 (1,590)	1,303 (1,180)	448 (410)
Levee	12,817 (11,600)	2,445 (2,250)	10,372 (9,350)
Sub-Total	69,352 (59,930)	40,630 (35,383)	28,722 (24,547)
Drainage Works	21,951 (19,198)	3,719 (3,335)	18,232 (15,863)
Total	91,303 (79,128)	44,349 (38,718)	46,954 (40,410)

Note: Figures in parentheses are excluding interest during construction.

1/ See Memorandum (3) in Chapter 12.

Table 9.1 (2) Breakdown of Construction Costs

Items	Unit	Quantity	Amount (10^3\$)
Dam and Reservoir			
Lands and Rights	L.S.	1	290
Coffer Dam	L.S.	1	631
Diversion and Care of River	L.S.	1	983
Dam	L.S.	1	22,446
Spillway	L.S.	1	417
Access Road, Electrical Plants for Construction & Camps 1/	L.S.	1	834
Contingencies			3,840
Sub-Total			29,441
Engineering Fee			1,840
Total			31,281
Interest during Construction			5,697
Grand Total			36,978
Power Plant			
Lands and Rights	L.S.	1	10
Civil Works			
Intake	L.S.	1	712
Penstock	L.S.	1	1,390
Power House	L.S.	1	3,280
Switchyard	L.S.	1	61
Access Road, Electrical Plants for Construction & Camps 1/	L.S.	1	184
Contingencies			762
Sub-Total			6,399
Equipments			
Turbines, 70MW,	Unit	3	2,820
Generators, 78MVA	Unit	3	3,070
Transformers, 78MVA	Unit	3	770
Outdoor Equipments	L.S.	1	265
Measurement Equipments and Others	L.S.	1	835
Contingencies			390
Sub-Total			8,150
Engineering Fee			910
Total			15,459
Interest during Construction			2,347
Grand Total			17,806
Transmission Line, Substations and Telecommunications Equipments			
Transmission Line, 115kV 2 cct	km	50	1,140
Substations, Pance SS	L.S.	1	130
Telecommunication Equipments	L.S.	1	100
Contingencies			120
Sub-Total			1,490
Engineering Fee			100
Total			1,590
Interest during Construction			161
Grand Total			1,751

Items	Unit	Quantity	Amount ($10^3$$)
Levee			
Lands and Rights	ha	1,690	960
Embankment of Levee			
Right Bank	10^3cu.m	4,580	3,206
Left Bank	10^3cu.m	4,172	2,920
Improvement of Tributaries	tributary	11	405
Gates of Regulating Pond	gate	4	406
Improvement of Bridges	bridge	6	1,200
Contingencies			1,803
Sub-Total			10,900
Engineering Fee			700
Total			11,600
Interest during Construction			1,217
Grand Total			12,817
Drainage Works			
Lands and Rights	ha	848	166
Principal Drainage Canals	km	154.5	2,099
Pumping Stations, 7.33 kW	place	14	2,701
Intercepting Canals	km	121.2	1,154
Lateral Drain and Others	L.S.	1	9,550
Contingencies			2,400
Sub-Total			18,070
Engineering Fee			1,128
Total			19,198
Interest during Construction			2,753
Grand Total			21,951

1/ Construction costs of access road and electrical plants for construction and camps.

Items	Unit	Quantity	Amount ($10^3$$)
Access Road	L.S.	1	653
Electrical Plants for Construction	L.S.	1	300
Camps	L.S.	1	65
Total			1,018

For dam and reservoir (82%) : $834,000
For power plant (18%) : $184,000

Table 9.2 Schedule of Annual Construction Costs (Unit: 10^3\$)

Items	Currency 1/	Total Costs	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Dam and Reservoir	F	19,266	230	220	2,331	3,036	7,784	5,665							
	D	12,015	70	80	1,365	1,808	5,179	3,513							
	T	31,281	300	300	3,696	4,844	12,963	9,178							
Levees	F	2,250	-	-	-	60	198	298	338	339	339	339	339		
	D	9,350	-	-	-	82	494	1,295	1,475	1,476	1,476	1,476	1,576		
	T	11,600	-	-	-	142	692	1,593	1,813	1,815	1,815	1,815	1,915		
Power Plant	F	12,687	170	170	327	1,424	5,429	2,631	1,687	849					
	D	2,772	50	50	146	371	1,193	725	42	195					
	T	15,459	220	220	473	1,795	6,622	3,356	1,729	1,044					
Transmission Line Sub-Stations and Telecommunication Equipment	F	1,180	-	-	10	20	672	478							
	D	410	-	-	10	20	20	360							
	T	1,590	-	-	20	40	692	838							
Sub-Total	F	35,383	400	390	2,668	4,540	14,083	9,072	2,025	1,188	339	339	339		
	D	24,547	120	130	1,521	2,281	6,886	5,893	1,517	1,671	1,476	1,476	1,576		
	T	59,930	520	520	4,189	6,821	20,969	14,965	3,542	2,859	1,815	1,815	1,915		
Drainage Works	F	3,335	-	-	-	-	-	35	594	594	502	502	503	310	295
	D	15,863	-	-	-	-	-	55	2,831	2,831	1,994	1,994	1,993	2,085	2,080
	T	19,198	-	-	-	-	-	90	3,425	3,425	2,496	2,496	2,496	2,395	2,375
Total	F	38,718	400	390	2,668	4,540	14,083	9,107	2,617	1,782	841	841	842	310	295
	D	40,410	120	130	1,521	2,281	6,886	5,948	4,348	4,502	3,470	3,470	3,569	2,085	2,080
	T	79,128	520	520	4,189	6,821	20,969	15,055	6,967	6,284	4,311	4,311	4,411	2,395	2,375

1/ F ; Foreign Currency D ; Domestic Currency T ; Total

CHAPTER 10

ECONOMIC EVALUATION

CONTENTS

LIST OF TABLES

CHAPTER 10 ECONOMIC EVALUATION

10.1 Annual Benefit

10.1.1 Benefit from Flood Control

The benefit by flood control is composed of the reduction of flood damage which is being incurred annually as well as a part of the increase of agricultural production in the future after the construction of irrigation and drainage works in the areas presently afflicted by floods. The flood damage based on present agricultural production is described in detail in 6.3.4.

The average annual flood losses at present are 69.7 million pesos for the entire Cauca Plain, while the annual flood losses when the reservoir and levees are completed will be 13.9 million pesos as shown in Table 10.1 (1). (for a flood with a return period of once in ten years). Therefore, the difference between the two values of 55.8 million pesos is the reduction of flood damages and can be considered as benefit by flood control. Flood control benefit which is attributable to reservoir only before construction of levees is calculated to be 36.1 million pesos annually in Table 10.1 (2).

The annual flood control benefit converted into 1976 value at a discount rate of 8.5% 1/ would give a total benefit for 50 years of 478.0 million pesos (27.53 million dollars) and the annual benefit would be 41.2 million pesos (2.37 million dollars) as given in Table 10.1 (3). Another flood control benefit after construction of drainage works completed is included in the benefit by land reclamation works as mentioned above and in 10.1.4.

Table 10.1 (1) Expectation of Annual Flood Damage without Project

Return Period (year)	Probability of Flood Occurrence	Flood Volume 1/ (10^6cu.m)	Inundation Area 2/ (10^3 ha)	Flood Damage (10^6 pesos)	Expectation of Damage (10^6 pesos)
2	0.500	130	30	44	22.0
5	0.300	460	47	78	23.4
7	0.057	670	55	94	5.4
10	0.043	1,050	66	116	5.0
15	0.033	1,580	79	142	4.7
20	0.017	2,100	89	162	2.8
30	0.017	3,080	106	197	3.3
50	0.013	4,600	128	240	3.1
Total					69.7

Annual flood losses when the reservoir and levees are completed :
$(4.7 + 2.8 + 3.3 + 3.1) \times 10^6 = 13.9 \times 10^6$ pesos

1/ Flood volume exceeding 750 cu.m/s of the river channel at La Victoria.
2/ Excluding the damages for Aguablanca and R-U-T Projects area.

1/ The discount rate of 7% for foreign currency of 38.7 million dollars and 9% for domestic currency of 40.4 million dollars was applied and the average discount rate is 8.5% (Refer to memorandum (2), (3) in Chapter 12).

Table 10.1 (2) Flood Control Benefit with Reservoir Only

Return Period (year)	Probability of Flood Occurrence	Flood Volume[1/] (10^6 cu.m.)	Inundation Area (10^3 ha)	Flood Damage (10^6 pesos)	Expectation of Flood Damages (10^6 pesos)
2	0.500	–	–	–	–
5	0.300	120	29	42	12.6
7	0.057	350	43	70	4.0
10	0.043	710	57	98	4.2
15	0.033	1,240	73	130	4.3
20	0.017	1,760	84	150	2.6
30	0.017	2,740	100	184	3.1
50	0.013	4,260	116	216	2.8
Total					33.6

Annual benefits by reservoir operation only: $(69.7 - 33.6) \times 10^6 = 36.1 \times 10^6$ pesos.

1/ Flood volume exceeding 750 cu.m/s of river channel after completion of reservoir.

Table 10.1 (3) Flood Control Benefit with Reservoir and Levees

Year	Annual Benefits (10^6 pesos)	Present[1/] Worth Factor	Present Worth in 1976 (10^6 pesos)
1977	36.1	0.922	33.3
1978	40.0	0.849	34.0
1979	43.9	0.783	34.4
1980	47.8	0.722	34.5
1981	51.7	0.665	34.4
1981～2026	55.8	7.65[2/]	426.9

1.	Total benefit in Cauca Plain	597.5	(34.4×10^6\$)
2.	Annual average benefit in Cauca Plain	51.5	(2.97×10^6\$)
3.	Total benefit in project area	478.0[3/]	(27.53×10^6\$)
4.	Annual average benefit in project area	41.2	(2.37×10^6\$)

1/ Discount Rate : 8.5%

2/ 11.5 x 0.665 = 7.65,
(Uniform Series – Present Worth Factor for 45 years : 11.5)

3/ 80% of total benefit (Adjustment ratio between the inundation area from La Bolsa to Roldanillo in this project and flooded area from La Balsa to Cartago).

10.1.2 Benefit from Alleviation of River Contamination

The benefit from alleviation of river contamination can be considered to be the annual cost of alternative sewage disposal facilities, which is required in case the project is not carried out. The average value of the savings in annual cost of sewage disposal facilities during the 50 years from 1976 is 23.4 million pesos (1.35 million dollars) as indicated in 6.4.2 and Table 6.11. Total benefit for 50 years at the 1976 value would be 271 million pesos (15.6 million dollars) at a discount rate of 8.5%.

10.1.3 Benefit from Power Generation

(1) Basic Assumption

Although Colombia is a petroleum producing country, it is also extremely favored with hydroelectric resources and since petroleum plays an important role of earning foreign exchange, development of hydroelectric resources will continue to be promoted in the future. Therefore, uniform criteria for economic evaluation of projects will be necessary for evaluating new hydroelectric projects and for deciding the order of development.

In the past, because of different evaluation standards adopted by owners and for each project, there was a tendency to justify a project only by the benefit-cost ratio or surplus benefit cited in each report. Most of the reports have thermal power plants as alternatives, but all of the conditions such as size, construction cost, interest rate, unit fuel price and economic life have been conspicuously different.

With the coming transmission interconnection as a timely point, it is strongly recommended that the past practice be corrected and evaluation of hydroelectric projects made with a standard thermal power plant such as described herein.

(2) Salable Electric Energy

As described in 6.5, the annual firm energy from Salvajina Power Plant at generating end will be as indicated in Table 10.2. As seen in the table, the entire amount will be effectively consumed from the second year of operation. Assuming a transmission loss between the power plant and Pance Substation to be 2.5%, the salable energy at the substation will be as indicated in Table 10.2 also.

Table 10.2 Salable Energy of Salvajina Power Plant

Year	Generating End		Primary Substation End	
	(10^3 kWh)	(10^3 kW)	(10^3 kWh)	(10^3 kW)
1977	622,710	97	607,140	93
1978	648,300	103	632,090	98
1979	648,300	153	632,090	146
1980	648,300	207	632,090	197
1981	648,300	210	632,090	200

Notes: Loss factor of kW: 4.6%
Loss factor of kWh: 2.5%

(3) Selection of Alternative Thermal Power Plant

In the selection of alternative thermal power plant, the following assumptions have been considered:

(i) The plant capacity and unit capacity must be appropriate in relation to the power demand in the interconnected central system, the growth rate and the structure of supply capability. In this case, the standard thermal power plant is used only as a measure to evaluate hydro power; it need not to be an alternative of the same capacity of the hydro project which is being evaluated.

(ii) The alternative must be a modern thermal power plant of the required capability of the power system it will serve at the given time, if the proposed hydro plant is not constructed.

(iii) The alternative must be located at the most suitable site in relation to the power system it will serve.

On the basis of the above assumption, steam plant of units of 100 MW or larger are appropriate around 1977 and an oil-fired thermal power plant of 125 MW x 2 units was adopted as the alternative. This plant was selected to be located in Buenaventura which is near the center of the CVC System and convenient for procurement of fuel, cooling water, etc. The particulars of this alternative thermal power plant, transmission line and construction costs are given in Table 10.3 (1) and Table 10.2 (2).

As shown in Table 10.3 (3), the annual costs of this alternative thermal power plant was divided into fixed and variable costs. Fixed costs are expenses required regardless of the electric energy produced, while variable costs are the expenses which increase or decrease in proportion to the amount of electric energy produced. The fixed cost per kW will be 16.5 dollars and the variable cost per kWh will be 2.8 mills at sending end. The reason of this separation of annual cost is to properly evaluate the benefit of hydro power both in kW and kWh.

(4) Unit Price of Benefit

The annual benefit of a hydroelectric power plant is calculated using the benefit per kW and per kWh. The unit price of benefit per kW is the annual fixed cost per kW of the alternative thermal plant multiplied by kW correction factor. The reason for applying kW correction factor is given below.

Thermal power plant, compared with hydroelectric power, has a higher rate of stoppage due to accidents and periodical repairs. Therefore, in order to assure the same degree of dependability as a hydroelectric power, it will be necessary to provide additional capacity to make up the abovementioned difference. This additional capacity requirement is considered as a benefit of the hydroelectric power and the kW correction factor is used.

On the other hand, the benefit per kWh of a hydroelectric power is estimated on the basis of the annual variable cost per kWh of the alternative thermal power plant. The unit price of benefit per kW and per kWh of Salvajina Power Plant thus estimated is as indicated below.

Unit price of benefit per kW	21.0 dollars
Unit price of benefit per kWh	2.8 mills

(5) Annual Benefit

The effective annual firm energy output of the Salvajina Power Plant and the effective peaking capacity is shown in Table 10.2. Using the unit price of benefit described above and a discount rate of 8.5% to calculate the benefit expected in 50 years from start-up, the 1976 value of total benefit would be 64.19 million dollars and this benefit equalized over a 50-year period would give an annual benefit of 5.55 million dollars (Table 10.4).

Table 10.3 (1) General Features of Standard Thermal Power Plant (125 MW x 2 = 250 MW)

Installed Capacity	250 MW
Unit Capacity x Number of Unit	125 MW x 2
Annual Capacity Factor	60%
Annual Generation	1,314 x 10^6 kWh
Percent of Station Service	5.5%
Annual Energy Supply	1,242 x 10^6 kWh
Thermal Efficiency at Sending End	32.7%
Annual Fuel Consumption	331 x 10^3 kl
Construction Cost	28.4 x 10^6\$

Table 10.3 (2) General Features of Transmission Line

Distance	Buenaventura – Cali Primary Substation	
Length	90 km	
Voltage	230 kV	
Number of Circuit	2	
Construction Cost	1,800 x 10^3\$	
Foreign Currency	1,170 x 10^3\$	
Domestic Currency	630 x 10^3\$	
Loss Factor		
for kW	1.5%	
for kWh	2%	
Annual Cost Factor		
Administration	0.5%	
Operation and Maintenance	2.2%	
Interest and Depreciation		
Foreign Currency	8.58%	(Interest Rate 7%)
Domestic Currency	11.02%	(Interest Rate 10%)
Annual Cost		
Foreign Currency	1,170 x 10^3 x 11.58% =	135.4 x 10^3\$
Domestic Currency	630 x 10^3 x 14.02% =	88.4 x 10^3\$
Total		223.8 x 10^3\$

Table 10.3 (3) Annual Cost and Unit Cost of Standard Thermal Power Plant

Item	Fixed Cost ($)	Variable Cost ($)	Remarks
1. Interest and Depreciation	3,020,000	–	
			Capital Recovery Factor
Foreign Currency Portion	2,462,000	–	0.0858
Domestic Currency Portion	558,000	–	0.1102
2. Operation and Maintenance	823,700	135,000	
Wages and Salaries	213,400		96 persons x $2,200
Repair Expenses	542,800	135,900	Construction Cost x 2% (Fixed Cost: 80%, Variable Cost: 20%)
Miscellaneous Expenses	67,500	–	Construction Cost x 0.2%
3. Administration	61,200	15,300	Operation and Maintenance Costs x 8% (Fixed Cost: 80%, Variable Cost: 20%)
4. Tax and Duty	0	0	
5. Fuel Cost	–	3,265,300	9.86 mill/lit x 331 x 10^3 kl
6. Total	3,904,900	3,415,600	
7. Unit Cost at Sending End			
Power Cost	16.5$/kW	–	$3,704,900/250(1–0.055) x 10^3
Energy Cost	–	2.78 mill/kWh	3,415,600/1,242 x 10^6
8. Unit Cost at Primary Substation			
Power Cost	21.0$/kW	–	
Energy Cost	–	2.80 mill/kWh	kW adjustment factor: 1.2

Table 10.4 Power Generation Benefit

	1977	1978	1979	1980	1981	2026	Total	Annual Benefit[4]
Salable Power at Primary Sub-Station End (MW)	93	98	146	197	200			
kW Benefits[1] (10^3 \$)	1,953	2,058	3,066	4,137	4,200			
Salable Energy (10^6 kWh)	607	632	632	632	632			
kWh Benefits[2] (10^3 \$)	1,700	1,770	1,770	1,770	1,770			
Total Benefits (10^3 \$)	3,653	3,828	4,836	5,907	5,970			
Present Worth Factor (i = 8.5%)	0.922	0.849	0.783	0.722	8.295[3]			
Present Worth in 1976 (10^3 \$)	3,368	3,250	3,787	4,265	49,521		64,191	5,553
kW Benefits (10^3 \$)	1,801	1,747	2,401	2,987	34,839		43,775	3,787
kWh Benefits (10^3 \$)	1,567	1,503	1,386	1,278	14,682		20,416	1,766

1/ Unit Price : 21\$/kW

2/ Unit Price : 2.8 mill/kWh

3/ 11.489 x 0.722 = 8.295 (Uniform Series – Present Worth Factor for 46 years : 11.489)

4/ (Total Benefit) x 0.0865

10.1.4 Benefit from Drainage Works

The benefit by drainage works was considered to be the difference between the net revenues from farmland with and without the project. The net revenues with and without drainage and irrigation facilities have been discussed in 6.6.3. But in order to achieve the target income, it is thought several years would be required to disseminate cultivation technicques corresponding to soil conditions. In this project it was estimated that the target value of net revenues (approximately 2,100 pesos per ha) will be achieved in the 10th year after completion of the work with an annual increase of 1% in subsequent years. Summing up the annual benefit for the 50 years after completion of the project by applying a discount rate of 8.5%, the total present worth at the time of completion of the works would be 18,260 pesos per ha. (Table 10.5).

Assuming the benefit from drainage works to be 50%[1] of the total for drainage and irrigation, the benefit of drainage works becomes 9,130 pesos per ha. The present worth in 1976 of the benefit would be 530 million pesos (30.63 million dollars) for 50 years taking into consideration the lag time of construction[2] for the project area of 81,600 ha and the annual benefit would be 46 million pesos (2.65 million dollars).

1/ Construction cost of drainage works is 235 dollars per ha and that of irrigation works is 260 dollars per ha. (See Table 17 in Appendix 6)
Consequently, the ratio of benefit from each purpose was taken to be approximately 50:50.

2/ Construction schedule (See Dwg. No. 8)
L–a.b, R–a.b (33,200 ha) completion in 1978
L–c -f, R–c.d (27,900 ha) completion in 1981
L–g -j, R–c.g (20,500 ha) completion in 1983

Table 10.5 Irrigation and Drainage Benefit per Ha.

Year	Benefit (pesos)	Present Worth Factor 1/	Present Worth (pesos)	Year	Benefit (pesos)	Present Worth Factor 1/	Present Worth (pesos)
1	208	0.922	192	26	2,434	0.120	292
2	415	0.849	352	27	2,457	0.111	273
3	623	0.783	488	28	2,482	0.102	253
4	830	0.722	599	29	2,507	0.094	236
5	1,075	0.665	715	30	2,532	0.087	220
6	1,245	0.613	763	31	2,556	0.080	204
7	1,453	0.565	821	32	2,583	0.073	189
8	1,660	0.521	865	33	2,608	0.068	177
9	1,868	0.480	897	34	2,635	0.062	163
10	2,075	0.443	919	35	2,660	0.058	154
11	2,096	0.408	855	36	2,687	0.053	142
12	2,117	0.376	796	37	2,714	0.049	133
13	2,137	0.346	739	38	2,741	0.045	122
14	2,160	0.319	689	39	2,770	0.042	116
15	2,181	0.294	641	40	2,797	0.038	106
16	2,204	0.271	597	41	2,824	0.035	99
17	2,224	0.250	556	42	2,853	0.033	94
18	2,247	0.230	517	43	2,882	0.030	86
19	2,270	0.212	481	44	2,911	0.028	82
20	2,291	0.196	449	45	2,940	0.025	74
21	2,316	0.180	417	46	2,969	0.023	68
22	2,339	0.166	388	47	2,998	0.022	66
23	2,361	0.153	361	48	3,000	0.020	61
24	2,384	0.141	336	49	3,059	0.018	55
25	2,409	0.130	313	50	3,090	0.017	53
				Total Benefit			P.S. 18,264(US$1,050)

1/ Discount rate i = 8.5%

10.2 Annual Cost

The annual cost was calculated for each purpose for the period of 50 years after completion of the project. The basic assumptions used in the calculations were as follows.

Amortization	Equal installments in 50 years	
Discount Rate	Foreign currency	7%
	Domestic currency	10%
	Overall	8.5%

Replacement, Repair, Maintenance and Administration Cost

Dam and Power Station:	1.0% of construction cost 1/
Levees:	1.3% of construction cost 1/
Drainage Facilities:	2.5% of construction cost 1/
Transmission line, substation and telecommunication	3.0% of construction cost 1/

The annual costs calculated are given in Table 10.6.

1/ Not including interest during construction.

Table 10.6 Annual Cost

(Unit : 10^3\$)

	Present Worth Capital Cost	Amortization	Amount of Costs for 50 Years	Annual O&M Replacement Costs	Total Costs	Annual Costs
Dam & Reservoir	34,530	2,990	3,620	310	38,150	3,300
Levees	9,730	840	1,740	150	11,470	990
Drainage Works	14,380	1,240	5,550	480	19,930	1,720
Power Plant	16,370	1,420	1,790	160	18,160	1,580
Transmission Line, Substation and Telecommunication Equipment	1,660	140	560	50	2,220	190
Total	76,670	6,630	13,260	1,150	89,930	7,780

Note : *These figures are present worth in 1976*
Discount rate : 8.5%

10.3 Cost Allocation and Benefit-Cost Ratio

The joint costs1/ were allocated to each purpose by the "Separable Cost Remaining Benefit Method". After this procedure shown in Table 10.7 , the assignable cost for each purpose is as follows.

	Construction Cost 2/ (10^3\$)	Operation and Maintenance Cost 3/ (10^3\$)	Total (10^3\$)	Equalized Annual Cost over 50 years
Flood Control (including Drainage Works)	34,850	8,420	43,270	3,740
Power Generation	35,570	4,190	39,760	3,440
Alleviation of River Contamination	6,250	650	6,900	600
Total	76,670	13,260	89,930	7,780

1/ Construction cost, Operation and Maintenance cost for the dam
2/ Present worth at the end of 1976
3/ Total present worth for 50 years at the end of 1976

The benefit-cost ratio for each purpose is 1.34 for flood control and drainage, 1.61 for power generation, 2.26 for allevation of river contamination or an overall ratio of 1.53.

Table 10.7 Cost Allocation by Separable Cost - Remaining Benefit Method

(Unit : 10^3\$)

Item	Flood Control and Drainage	Power Generation	Alleviation of River Contamination	Total
1. Benefit	58,160 1/	64,190	15,600	137,950
2. Alternate Cost	67,750 2/	64,190	15,600	147,540
3. Benefit limited by Alternate Cost	58,160	64,190	15,600	137,950
4. Separable Cost				
Installation	24,110 3/	18,030 4/	-	42,140
O & M	7,290	2,350	-	9,640
Total	31,400	20,380	-	51,780
5. Remaining Benefit	26,760	43,810	15,600	86,170
(%)	(31.1)	(50.8)	(18.1)	(100)
6. Allocated Joint Cost				
Installation	10,740	17,540	6,250	34,530
O & M	1,130	1,840	650	3,620
Total	11,870	19,380	6,900	38,150 5/
7. Total Allocated Cost				
Installation	34,850	35,570	6,250	76,670
O & M	8,420	4,190	650	13,260
Total	43,270	39,760	6,900	89,930
8. Benefit - Cost Ratio	1.34	1.61	2.26	1.53

1/ Flood control benefit (10^3\$): 27,530
Drainage benefit (10^3\$) : 30,630
Total (10^3\$) : 58,160

2/ Alternative construction cost (10^3\$): 40,600 (Levee only)
O & M costs (10^3\$) : 7,220
Total costs of drainage works (10^3\$): 19,930 (See Table 10.6)
Total (10^3\$): 67,750

3/	Installation	O & M
Levee (10^3\$):	9,730	1,740
Drainage (10^3\$):	14,380	5,550
Total (10^3\$):	24,110	7,290

4/	Installation	O & M
Power plant (10^3\$):	16,370	1,790
Transmission Line (10^3\$):	1,660	560
Total (10^3\$):	18,030	2,350

5/ Costs of dam and reservoir (See Table 10.6)

Note: All values in this table were shifted to present worth in 1976.

10.4 Energy Cost

On the basis of the annual cost of power generation after cost allocation and the salable energy, the energy cost per kWh of the Salvajina Power Plant delivered at Pance Substation will be 9 centavos (5.4 mills) per kWh. In consideration of the fact that the wholesale energy rate of the CVC System at present is 18.5 centavos per kWh, it can be seen that the power phase of the project is extremely good and will produce adequate revenues to repay the investments.

CHAPTER 11

REPAYMENT OF INVESTMENT

CONTENTS

LIST OF TABLES

CHAPTER 11. REPAYMENT OF INVESTMENT

11.1 Fund Requirement and Financing of Funds

The annual fund requirements for the project construction are as follows.

Table 11.1 Annual Funds Requirements

(Unit : 10^3 \$)

	Currency	Total Costs	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Dam and Reservoir	F.C.	22,404	240	252	2,480	3,440	8,711	7,281							
		(3,138)	(10)	(32)	(149)	(404)	(927)	(1,616)							
	D.C.	14,574	74	94	1,467	2,113	5,940	4,886							
		(2,559)	(4)	(14)	(102)	(305)	(761)	(1,373)							
	Total	36,978	314	346	3,947	5,553	14,651	12,167							
		(5,697)	(14)	(46)	(251)	(709)	(1,688)	(2,989)							
Levee	F.C.	2,445				63	213	336	353	386	354	386	354		
		(195)				(3)	(15)	(38)	(15)	(47)	(15)	(47)	(15)		
	D.C.	10,372				87	534	1,447	1,564	1,752	1,565	1,752	1,676		
		(1,022)				(5)	(40)	(152)	(89)	(276)	(89)	(276)	(95)		
	Total	12,817				150	747	1,783	1,917	2,138	1,919	2,138	2,025		
		(1,217)				(8)	(55)	(190)	(104)	(323)	(104)	(323)	(110)		
Power Plant	F.C.	14,478	178	194	375	1,555	5,881	3,486	1,763	1,046					
		(1,791)	(8)	(24)	(48)	(131)	(452)	(855)	(76)	(197)					
	D.C.	3,328	53	59	168	427	1,349	1,015	45	212					
		(556)	(3)	(9)	(22)	(56)	(156)	(290)	(3)	(17)					
	Total	17,806	231	253	543	1,982	7,230	4,501	1,808	1,258					
		(2,347)	(11)	(33)	(70)	(187)	(608)	(1,145)	(79)	(214)					
Transmission Line, Substation and Telecommunication Equipment	F.C.	1,303			10	22	705	566							
		(123)			(-)	(2)	(33)	(88)							
	D.C.	448			11	23	25	389							
		(38)			(1)	(3)	(5)	(29)							
	Total	1,751			21	45	730	955							
		(161)			(1)	(5)	(38)	(117)							
Total	F.C.	40,630	418	446	2,865	5,080	15,510	11,669	2,116	1,432	354	386	354		
		(5,247)	(18)	(56)	(197)	(540)	(1,427)	(2,597)	(91)	(244)	(15)	(47)	(15)		
	D.C.	28,722	127	153	1,646	2,650	7,848	7,737	1,609	1,964	1,565	1,752	1,671		
		(4,175)	(7)	(23)	(125)	(369)	(962)	(1,844)	(92)	(293)	(89)	(276)	(95)		
	Total	69,352	545	599	4,511	7,730	23,358	19,406	3,725	3,396	1,919	2,138	2,025		
		(9,422)	(25)	(79)	(322)	(909)	(2,389)	(4,441)	(183)	(537)	(104)	(323)	(110)		
Drainage Works	F.C.	3,719						37	624	680	525	570	622	324	337
		(384)						(2)	(30)	(86)	(23)	(68)	(119)	(14)	(42)
	D.C.	18,232						58	3,008	3,369	2,114	2,367	2,636	2,210	2,470
		(2,369)						(3)	(177)	(538)	(120)	(373)	(643)	(125)	(390)
	Total	21,951						95	3,632	4,049	2,639	2,937	3,258	2,534	2,807
		(2,753)						(5)	(207)	(624)	(143)	(441)	(762)	(139)	(432)
Ground Total	F.C.	44,349	418	446	2,865	5,080	15,510	11,706	2,740	2,112	879	956	976	324	337
		(5,631)	(18)	(56)	(197)	(540)	(1,427)	(2,599)	(121)	(330)	(38)	(115)	(134)	(14)	(42)
	D.C.	46,954	127	153	1,646	2,650	7,848	7,795	4,617	5,333	3,679	4,119	4,307	2,210	2,470
		(6,544)	(7)	(23)	(125)	(369)	(962)	(1,847)	(269)	(831)	(209)	(649)	(738)	(125)	(390)
	Total	91,303	545	599	4,511	7,730	23,358	19,501	7,357	7,445	4,558	5,075	5,283	2,534	2,807
		(12,175))	(25)	(79)	(322)	(909)	(2,389)	(4,446)	(390)	(1,161)	(247)	(764)	(872)	(139)	(432)

Note : Figures in parentheses are interest during construction and are included in the figures for respective years.

It is assumed that the foreign currency will be financed with loans from international financing institutions while domestic currency will be borrowed from domestic financing organizations. Interest rates and the terms of repayment assumed are as follows.

Foreign currency:	Interest rate, 9% per annum; Amortization, 5 years grace period, 20 years uniform annual repayment of principal plus interest.
Domestic currency:	Interest rate, 12% per annum; Amortization, 15 years uniform annual repayment of principal plus interest after completion of project.

11.2 Income and Expense

11.2.1 Income from Wholesale of Energy

The salable energy at Pance receiving end substation will be as follows as stated in Chapter 6.

1977	607×10^6 kWh
1978 and after	632×10^6 kWh

The wholesale rate of 0.185 pesos per kWh (10.7 mills 1/) which is the prevailing wholesale rate was applied to estimate revenues from sales of electricity. The income from energy sales will be as follows:

1977	6,496 thousand dollars
1978 and after	6,763 thousand dollars

11.2.2 Income from Other Sources

As for the source of revenues to repay borrowings and to pay operation and maintenance costs of all project features, income from wholesale of energy will be a big source. Almost 77 percent of annual fund requirements will be generated by income from power sales, while the remainder will be from subsidy from the national treasury or contribution from beneficiaries of flood control and alleviation of river contamination. The annual costs for drainage facilities were considered to be borne entirely by beneficiaries of the project.

11.2.3 Operation and Maintenance Expenses

The operation and maintenance expenses for the project were estimated as follows:

Dam and power plant	1% of construction cost 1/
Transmission line, substation and telecommunication facilities	3% of construction cost 1/
Levees	1.3% of construction cost 1/
Drainage facilities	2.5% of construction cost 1/

11.2.4 Depreciation

Depreciation was calculated by the straight line method with no salvage value. The serviceable years of the various facilities were taken as follows:

Turbine, generator and other equipment	35 years
Transmission line, substation and telecommunication facilities	45 years
Civil structures such as dam, powerhouse, levees, and drainage facilities.	50 years

1/ Not including interest during construction.

11.2.5 Operating Income

Operating income after deducting operation and maintenance cost, depreciation cost and interest on loans is given in Table 11.2 (1) and Table 11.2 (2).

11.3 Amortization Schedule

Sources for repayment of loans will be the sum of operating income and depreciation reserves. Cash flow statements prepared on the basis of repayment schedules of foreign and domestic loans stated in 11.1 are shown in Table 11.2 (1) and Table 11.2 (2).

From the above study, it can be said that the project is financially sound and feasible.

Table 11.3 gives the relation between benefit, cost and repayment for the capital investment and operation and maintenance. The power generating project will greatly contribute to this multi-purpose project from the point of financial view.

Table 11.3 Relation between Benefit, Cost and Repayment

(Unit: 10^3\$)

	Power	Flood Control and Alleviation of River Contamination			Total	Drainage
		Flood Control	Alleviation of River Contamination	Subtotal		
Economical Analysis						
Benefit (B)	64,190	27,530	15,600	43,130	107,320	30,630
Allocated Cost (C)	39,760	20,480 1/	6,900	27,380	67,140	22,790 2/
B/C	1.61	1.34	2.26	1.58	1.60	1.34
Financial Analysis						
Present Worth of Repayment Sources in 1976 3/	55,934	4,492	5,651	10,143 4/	66,077	17,398
(%)	(84.6)			(15.4)	(100)	

1/ $43,270 \times 10^3 \times \frac{27,530 \times 10^3}{58,160 \times 10^3} = 20,480 \times 10^3$

where $43,270 \times 10^3$\$: Allocated cost to flood control and drainage given in Table 10.7
$27,530 \times 10^3$\$: Flood control benefit described in 10.1.1
$58,160 \times 10^3$\$: Amount of benefits of flood control and drainage

2/ $43,270 \times 10^3 - 20,480 \times 10^3 = 22,790 \times 10^3$\$

3/ These figures indicate concurrent costs as of the end of 1976 which are calculated based on the repayment for the periods of economic life of 50 years given in Table 11.2 (1) by applying a discount rate of 12%.

4/ Amount to be subsidized by the national treasury or by beneficiaries.

Note: Discount rate of economical analysis is 8.5%
Interest rate of financial analysis is 12%

Table 11.2 (1) Financial Analysis (Power Generation, Flood Control and Alleviation of River Contamination)

(Unit : 10^3\$)

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
[Income Statement]																										
(A) Gross Revenue																										
1. Power Generation							6,496	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763
2. Alleviation of River Contamination							1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	-	-	-	-	-	-	-	-	-	-
3. Flood Control							500	600	700	800	900	1,000	1,000	1,000	1,000	1,000	-	-	-	-	-	-	-	-	-	-
Total - (A).							7,996	8,363	8,463	8,563	8,663	8,763	8,763	8,763	8,763	8,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763
(B) Operating Cost																										
1. O&M Expense							430	430	480	650	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670
2. Depreciation							1,007	1,007	1,082	1,162	1,237	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277
Total - (B)							1,437	1,437	1,562	1,812	1,907	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947
(C) Operating Income (A) - (B)							6,559	6,926	6,901	6,751	6,756	6,816	6,816	6,816	6,816	6,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0
(D) Financial Expenditure																										
1. Interest for Foreign Loan	18.0	56.0	197.0	540.0	1,427.0	2,597.0	2,904.4	3,074.2	3,206.7	3,414.9	3,740.6	3,256.5	3,635.1	3,562.1	3,482.7	3,394.3	3,293.0	3,176.2	3,042.8	2,892.5	2,723.1	2,536.3	2,333.2	2,111.5	1,870.0	1,606.2
2. Interest for Domestic Loan	7.0	23.0	125.0	369.0	962.0	1,844.0	2,510.3	2,636.8	2,768.3	2,853.2	2,977.3	2,957.2	2,810.1	2,646.4	2,462.7	2,256.7	2,026.1	1,767.9	1,478.8	1,154.8	792.1	383.3	283.1	170.6	103.3	27.6
Total - (D)	25.0	79.0	322.0	909.0	2,389.0	4,441.0	5,414.7	5,711.0	5,975.0	6,268.1	6,717.9	6,213.7	6,445.2	6,208.5	5,945.4	5,651.0	5,319.1	4,944.1	4,521.6	4,047.3	3,515.2	2,919.6	2,616.3	2,282.1	1,973.3	1,633.8
(E) Net Income (C) - (D)	-25.0	-79.0	-322.0	-909.0	-2,389.0	-4,441.0	1,144.3	1,215.0	926.0	482.9	38.1	602.3	370.8	607.5	870.6	1,165.0	-503.	-128.1	294.4	768.7	1,300.8	1,896.4	2,199.7	2,533.9	2,842.7	3,182.2
[Cash Flow Statement]																										
(F) Cash Receipt																										
1. Net Income	-25.0	-79.0	-322.0	-909.0	-2,389.0	-4,441.0	1,144.3	1,215.0	926.0	482.9	38.1	602.3	370.8	607.5	870.6	1,165.0	-503.1	-128.1	294.4	768.7	1,300.8	1,896.4	2,199.7	2,533.9	2,842.7	3,182.2
2. Depreciation	-	-	-	-	-	-	1,007.0	1,007.0	1,082.0	1,162.0	1,237.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0
3. Borrowing from F.L.	418.0	446.0	2,865.0	5,080.0	15,510.0	11,669.0	2,090.2	1,283.7	462.5	481.4	489.6	137.7	106.8	76.3	45.3	15.3	-	-	-	-	-	-	-	-	-	-
4. Borrowing from D.L.	127.0	153.0	1,646.0	2,650.0	7,848.0	7,741.0	1,605.3	1,936.6	1,564.6	1,741.7	1,670.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total - (F)	520.0	520.0	4,189.0	6,821.0	20,969.0	14,969.0	5,846.8	5,442.3	4,035.1	3,868.0	3,435.3	2,017.0	1,754.6	1,960.8	2,192.9	2,457.3	773.9	1,148.9	1,571.4	2,055.7	2,577.8	3,173.4	3,476.7	3,810.9	4,119.7	4,459.2
(G) Cash Disbursement																										
1. Construction Expenditure	520.0	520.0	4,189.0	6,821.0	20,969.0	14,965.0	3,542.0	2,859.0	1,815.0	1,815.0	1,815.0															
Foreign Currency	400.0	390.0	2,668.0	4,540.0	14,083.0	9,072.0	2,025.0	1,188.0	339.0	339.0	339.0															
Domestic Currency	120.0	130.0	1,521.0	2,281.0	6,886.0	5,893.0	1,517.0	1,671.0	1,476.0	1,476.0	1,476.0															
2. Repayment of Debit	-	-	-	-	-	4.0	555.1	656.6	911.5	1,237.1	1,759.3	2,103.7	2,364.3	2,637.5	2,921.8	3,257.2	3,615.5	4,008.4	4,443.9	4,925.9	5,460.6	3,095.3	3,399.2	3,247.1	3,556.8	3,383.5
Foreign Loan	-	-	-	-	-	4.0	14.2	50.8	144.4	377.7	708.4	882.5	996.0	1,105.1	1,214.7	1,335.1	1,462.8	1,597.5	1,743.9	1,901.8	2,073.9	2,260.0	2,463.7	2,685.4	2,928.0	3,165.8
Domestic Loan	-	-	-	-	-	-	540.9	605.8	767.1	859.4	1,050.9	1,221.4	1,368.3	1,532.4	1,707.1	1,922.1	2,152.7	2,410.9	2,700.0	3,024.0	3,386.7	835.3	935.5	561.7	628.8	217.7
Total - (G)	520.0	520.0	4,189.0	6,821.0	20,969.0	14,969.0	4,096.4	3,514.9	2,725.8	3,051.4	3,573.6	2,103.2	2,363.6	2,636.8	2,921.1	3,256.5	3,614.8	4,007.7	4,443.2	4,925.1	5,459.9	3,095.3	3,399.2	3,247.1	3,556.8	3,383.5
(H) Cash Balance (F) - (G)	0	0	0	0	0	0	1,749.7	1,926.7	1,308.6	815.9	-139.0	-86.9	-609.7	-676.7	-728.9	-799.9	-2,841.6	-2,859.5	-2,872.5	-2,870.1	-2,882.8	78.1	77.5	563.8	562.9	1,075.7
(I) Deposit							0	1,959.7	4,352.8	6,340.8	8,015.5	8,821.7	9,783.0	10,274.1	10,749.1	11,222.6	11,673.4	9,891.6	7,876.0	5,603.9	3,061.9	200.6	312.1	436.4	1,120.2	1,885.2
(J) Accumulated Total							1,749.7	3,886.4	5,661.4	7,156.7	7,876.5	8,734.8	9,173.3	9,597.4	10,020.2	10,422.7	8,831.8	7,032.1	5,003.5	2,733.8	179.1	278.7	389.6	1,000.2	1,683.2	2,960.9

Table 11.2 (1) Financial Analysis (Power Generation, Flood Control and Alleviation of River Contamination)

(Unit : 10^3\$)

	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
[Income Statement]																										
(A) Gross Revenue																										
1. Power Generation							6,496	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763
2. Alleviation of River Contamination							1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	-	-	-	-	-	-	-	-	-	-
3. Flood Control							500	600	700	800	900	1,000	1,000	1,000	1,000	1,000	-	-	-	-	-	-	-	-	-	-
Total - (A)							7,996	8,363	8,463	8,563	8,663	8,763	8,763	8,763	8,763	8,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763	6,763
(B) Operating Cost																										
1. O&M Expense							430	430	480	650	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670	670
2. Depreciation							1,007	1,007	1,082	1,162	1,237	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277	1,277
Total - (B)							1,437	1,437	1,562	1,812	1,907	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947	1,947
(C) Operating Income (A) - (B)							6,559	6,926	6,901	6,751	6,756	6,816	6,816	6,816	6,816	6,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0	4,816.0
(D) Financial Expenditure																										
1. Interest for Foreign Loan	18.0	56.0	197.0	540.0	1,427.0	2,597.0	2,904.4	3,074.2	3,206.7	3,414.9	3,740.6	3,256.5	3,635.1	3,562.1	3,482.7	3,394.3	3,293.0	3,176.2	3,042.8	2,892.5	2,723.1	2,536.3	2,333.2	2,111.5	1,870.0	1,606.2
2. Interest for Domestic Loan	7.0	23.0	125.0	369.0	962.0	1,844.0	2,510.3	2,636.8	2,768.3	2,853.2	2,977.3	2,957.2	2,810.1	2,646.4	2,462.7	2,256.7	2,026.1	1,767.9	1,478.8	1,154.8	792.1	383.3	283.1	170.6	103.3	27.6
Total - (D)	25.0	79.0	322.0	909.0	2,389.0	4,441.0	5,414.7	5,711.0	5,975.0	6,268.1	6,717.9	6,213.7	6,445.2	6,208.5	5,945.4	5,651.0	5,319.1	4,944.1	4,521.6	4,047.3	3,515.2	2,919.6	2,616.3	2,282.1	1,973.3	1,633.8
(E) Net Income (C) - (D)	-25.0	-79.0	-322.0	-909.0	-2,389.0	-4,441.0	1,144.3	1,215.0	926.0	482.9	38.1	602.3	370.8	607.5	870.6	1,165.0	-503.	-128.1	294.4	768.7	1,300.8	1,896.4	2,199.7	2,533.9	2,842.7	3,182.2
[Cash Flow Statement]																										
(F) Cash Receipt																										
1. Net Income	-25.0	-79.0	-322.0	-909.0	-2,389.0	-4,441.0	1,144.3	1,215.0	926.0	482.9	38.1	602.3	370.8	607.5	870.6	1,165.0	-503.1	-128.1	294.4	768.7	1,300.8	1,896.4	2,199.7	2,533.9	2,842.7	3,182.2
2. Depreciation	-	-	-	-	-	-	1,007.0	1,007.0	1,082.0	1,162.0	1,237.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0	1,277.0
3. Borrowing from F.L.	418.0	446.0	2,865.0	5,080.0	15,510.0	11,669.0	2,090.2	1,283.7	462.5	481.4	489.6	137.7	106.8	76.3	45.3	15.3	-	-	-	-	-	-	-	-	-	-
4. Borrowing from D.L.	127.0	153.0	1,646.0	2,650.0	7,848.0	7,741.0	1,605.3	1,936.6	1,564.6	1,741.7	1,670.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total - (F)	520.0	520.0	4,189.0	6,821.0	20,969.0	14,969.0	5,846.8	5,442.3	4,035.1	3,868.0	3,435.3	2,017.0	1,754.6	1,960.8	2,192.9	2,457.3	773.9	1,148.9	1,571.4	2,055.7	2,577.8	3,173.4	3,476.7	3,810.9	4,119.7	4,459.2
(G) Cash Disbursement																										
1. Construction Expenditure	520.0	520.0	4,189.0	6,821.0	20,969.0	14,965.0	3,542.0	2,859.0	1,815.0	1,815.0	1,815.0															
Foreign Currency	400.0	390.0	2,668.0	4,540.0	14,083.0	9,072.0	2,025.0	1,188.0	339.0	339.0	339.0															
Domestic Currency	120.0	130.0	1,521.0	2,281.0	6,886.0	5,893.0	1,517.0	1,671.0	1,476.0	1,476.0	1,476.0															
2. Repayment of Debit	-	-	-	-	-	4.0	555.1	656.6	911.5	1,237.1	1,759.3	2,103.7	2,364.3	2,637.5	2,921.8	3,257.2	3,615.5	4,008.4	4,443.9	4,925.9	5,460.6	3,095.3	3,399.2	3,247.1	3,556.8	3,383.5
Foreign Loan	-	-	-	-	-	4.0	14.2	50.8	144.4	377.7	708.4	882.5	996.0	1,105.1	1,214.7	1,335.1	1,462.8	1,597.5	1,743.9	1,901.8	2,073.9	2,260.0	2,463.7	2,685.4	2,928.0	3,165.8
Domestic Loan	-	-	-	-	-	-	540.9	605.8	767.1	859.4	1,050.9	1,221.4	1,368.3	1,532.4	1,707.1	1,922.1	2,152.7	2,410.9	2,700.0	3,024.0	3,386.7	835.3	935.5	561.7	628.8	217.7
Total - (G)	520.0	520.0	4,189.0	6,821.0	20,969.0	14,969.0	4,096.4	3,514.9	2,725.8	3,051.4	3,573.6	2,103.2	2,363.6	2,636.8	2,921.1	3,256.5	3,614.8	4,007.7	4,443.2	4,925.1	5,459.9	3,095.3	3,399.2	3,247.1	3,556.8	3,383.5
(H) Cash Balance (F) - (G)	0	0	0	0	0	0	1,749.7	1,926.7	1,308.6	815.9	-139.0	-86.9	-609.7	-676.7	-728.9	-799.9	-2,841.6	-2,859.5	-2,872.5	-2,870.1	-2,882.8	78.1	77.5	563.8	562.9	1,075.7
(I) Deposit							0	1,959.7	4,352.8	6,340.8	8,015.5	8,821.7	9,783.0	10,274.1	10,749.1	11,222.6	11,673.4	9,891.6	7,876.0	5,603.9	3,061.9	200.6	312.1	436.4	1,120.2	1,885.2
(J) Accumulated Total							1,749.7	3,886.4	5,661.4	7,156.7	7,876.5	8,734.8	9,173.3	9,597.4	10,020.2	10,422.7	8,831.8	7,032.1	5,003.5	2,733.8	179.1	278.7	389.6	1,000.2	1,683.2	2,960.9

Table 11.2 (2) Financial Analysis (Drainage)

(Unit : 10^3\$)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
[Income Statement]																				
(A) Gross Revenue																				
1. Revenue for Annual O&M Expense				174.0	174.0	174.0	361.0	361.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0
2. Revenue for Amortization of Construction Cost				1,000.0	1,000.0	1,000.0	2,000.0	2,000.0	3,000.0	3,000.0	3,000.0	3,000.0	3,200.0	3,200.0	3,200.0	3,200.0	3,200.0	3,200.0	2,500.0	2,500.0
Total - (A)				1,174.0	1,174.0	1,174.0	2,361.0	2,361.0	3,480.0	3,480.0	3,480.0	3,480.0	3,680.0	3,680.0	3,680.0	3,680.0	3,680.0	3,680.0	2,980.0	2,980.0
(B) Operating Cost																				
1. O&M Expense				174.0	174.0	174.0	361.0	361.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0
2. Depreciation				139.0	139.0	139.0	289.0	289.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0
Total - (B)				313.0	313.0	313.0	650.0	650.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0
(C) Operating Income (A) - (B)				861.0	861.0	861.0	1,711.0	1,711.0	2,616.0	2,616.0	2,616.0	2,616.0	2,816.0	2,816.0	2,816.0	2,816.0	2,816.0	2,816.0	2,114.0	2,114.0
(D) Financial Expenditure																				
1. Interest for Foreign Loan	2.0	30.0	86.0	212.3	407.1	669.1	964.4	1,213.2	1,363.4	1,399.4	1,317.0	1,154.6	969.2	780.0	618.9	510.7	445.9	414.5	398.0	378.5
2. Interest for Domestic Loan	3.0	177.0	538.0	892.2	1,124.6	1,371.4	1,682.6	1,895.5	2,008.9	1,928.6	1,838.8	1,738.0	1,625.3	1,498.8	1,357.3	1,198.8	1,021.2	822.3	600.7	464.7
Total - (D)	5.0	207.0	624.0	1,104.5	1,531.7	2,040.5	2,647.0	3,108.7	3,372.3	3,328.0	3,155.8	2,892.6	2,594.5	2,278.8	1,976.2	1,709.5	1,467.1	1,236.8	998.7	843.2
(E) Net Income (C) - (D)	-5.0	-207.0	-624.0	-243.5	-670.7	-1,179.5	-936.0	-1,397.7	-756.3	-712.0	-539.8	-276.6	221.5	537.2	839.8	1,106.5	1,348.9	1,579.2	1,115.3	1,270.8
[Cash Flow Statement]																				
(F) Cash Receipt																				
1. Net Income	-5.0	-207.0	-624.0	-243.5	-670.7	-1,179.5	-936.0	-1,397.7	-756.3	-712.0	-539.8	-276.6	221.5	537.2	839.8	1,106.5	1,348.9	1,579.2	1,115.3	1,270.8
2. Depreciation				139.0	139.0	139.0	289.0	289.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0
3. Borrowing from F.L.	36.5	624.0	680.1	714.8	909.7	1,170.2	1,244.1	1,421.1	1,217.3	1,192.6	1,045.1	821.6	585.5	365.1	192.9	81.1	20.5			
4. Borrowing from D.L.	58.4	3,007.9	3,368.8	2,113.7	2,366.6	2,636.6	2,209.8	2,470.2												
Total - (F)	89.9	3,424.9	3,424.9	2,724.0	2,744.6	2,766.3	2,806.9	2,782.6	845.0	864.6	889.3	929.0	1,191.0	1,286.3	1,416.7	1,571.6	1,753.4	1,963.2	1,499.3	1,654.8
(G) Cash Disbursement																				
1. Construction Expenditure	89.9	3,424.9	3,424.9	2,496.2	2,496.2	2,496.3	2,394.5	2,375.1												
Foreign Loan	34.5	594.0	594.1	502.5	502.6	502.7	309.7	294.9												
Domestic Loan	55.4	2,830.9	2,830.8	1,993.7	1,993.6	1,993.6	2,084.8	2,080.2												
2. Repayment of Debit																				
Foreign Loan						0.3	6.6	19.6	34.5	51.2	71.1	91.8	112.9	132.1	149.2	166.2	183.4	201.1	219.8	239.3
Domestic Loan				172.2	192.8	222.1	433.6	485.7	669.3	749.6	839.4	940.2	1,052.9	1,179.4	1,321.0	1,479.4	1,657.0	1,855.9	1,133.1	1,269.1
Total - (G)	89.9	3,424.9	3,424.9	2,668.4	2,689.0	2,718.7	2,834.7	2,880.4	703.8	800.8	910.5	1,032.0	1,165.8	1,311.5	1,740.2	1,645.6	1,840.4	2,057.0	1,352.9	1,508.4
(H) Cash Balance (F)-(G)	0	0	0	55.6	55.6	47.6	-27.8	-97.8	141.2	63.8	-21.2	-103.0	25.2	-25.2	-53.5	-74.0	-87.0	-93.8	146.4	146.4
(I) Deposit				0	62.3	132.0	201.2	194.2	108.0	279.1	384.0	406.3	339.7	408.7	429.5	421.2	388.8	338.0	273.5	470.3
(J) Accumulated Total				55.6	117.9	179.6	173.4	96.4	249.2	342.9	362.8	303.3	364.9	383.5	376.0	347.1	301.8	244.2	419.9	616.7

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
[Income Statement]																			
(A) Gross Revenue																			
1. Revenue for Annual O&M Expense	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0
2. Revenue for Amortization of Construction Cost	2,500.0	2,500.0	2,500.0																
Total - (A)	2,980.0	2,980.0	2,980.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0
(B) Operating Cost																			
1. O&M Expense	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0	480.0
2. Depreciation	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0	384.0
Total - (B)	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0	864.0
(C) Operating Income (A) - (B)	2,114.0	2,114.0	2,114.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0	-384.0
(D) Financial Expenditure																			
1. Interest for Foreign Loan	356.7	333.3	307.9	279.8	249.3	216.2	180.3	143.4	109.7	80.3	55.1	34.9	20.5	11.5	6.1	2.7	1.1	0.3	
2. Interest for Domestic Loan	312.4	139.8	74.1																
Total - (D)	669.1	473.1	382.0	279.8	249.3	216.2	180.3	143.4	109.7	80.3	55.1	34.9	20.5	11.5	6.1	2.7	1.1	0.3	
(E) Net Income (C) - (D)	1,444.9	1,640.9	1,732.0	-663.8	-663.3	-600.2	-564.3	-527.4	-493.7	-464.3	-439.1	-418.9	-404.5	-395.5	-390.1	-386.7	-385.1	-384.3	-384.0
[Cash Flow Statement]																			
(F) Cash Receipt																			
1. Net Income	1,444.9	1,640.9	1,732.0	-663.8	-633.3	-600.2													
2. Depreciation	384.0	384.0	384.0	384.0	384.0	384.0													
3. Borrowing from F.L.																			
4. Borrowing from D.L.																			
Total - (F)	1,833.0	2,024.9	2,116.0	-279.8	-249.3	-216.2													
(G) Cash Disbursement																			
1. Construction Expenditure																			
Foreign Loan																			
Domestic Loan																			
2. Repayment of Debit																			
Foreign Loan	261.1	284.5	309.8	338.0	368.5	399.7													
Domestic Loan	1,420.8	547.2	612.9																
Total - (G)	1,681.9	831.7	922.7	338.0	368.5	399.7													
(H) Cash Balance (F)-(G)	151.1	1,193.2	1,193.3	-617.8	-617.8	-615.9													
(I) Deposit	690.7	942.8	2,392.3	4,015.9	3,805.9	3,570.7													
(J) Accumulated Total	841.8	2,136.0	3,585.6	3,398.1	3,188.1	2,954.8													

CHAPTER 12

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CHAPTER 12. BIBLIOGRAPHY

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Analisis de la Expansion en Capacidad Generadora del Sistema Interconectado Central	Departamento Nacional de Planeacion	May 1969
La Energia Electrica y el Progreso del Valle	CVC	1968
Hydrological Record and Autocorrelation Coefficients	Departamento Nacional de Planeacion Div. Energia Electrica	1969
Roldanillo-La Union-Toro Project Status of Development	CVC, INGETEC, G & H, TAMS	Apr. 1962
Proyecto La Victoria-Cartago Estudio de Factibilidad	CVC	Ago. 1966
Proyecto de la Laguna de Sonso del Chircal	CVC	Nov. 1967
Reconnaissance Soils Survey of the Flat Part of the Cauca Valley	William E. Rosse, Dock Goosen of F.A.O.	1957
Clasificacion por Capacidad de Uso del Suelo de Valle Geografico del Rio Cauca	Seccion Suelos de la CVC	Nov. 1966

Analisis Quimicos y Fiscos de los Suelos por Palmira	Seccion Suelos de la CVC	
Estudio Detallado de Suelos Municipio de Palmira Coloreado por Zona Afectadas de Soles	Seccion Suelos de la CVC	
Propiedades Fisicas de Algunos Suelos del Municipio de Palmira (Tesis de Grado 1964)	Univ. Nacional de Colombia, Facultado de Agronomia	1964
Resumen Geomorfico y Pedologico del Valle Geografico del Alto Cauca	Carlos A. Otero S de la CVC	
Censo Agropecuario del Valle del Cauca - 1959	Univarsidad del Valle Facultad de Ciencias Economicas	Sep. 1963
XIII. Censo Nacional de Poblacion Resumen General	Departamento Administrativo Nacional de Estadistica	Jul. 1964
Encuesta Agricola Nacional - 1966	Departamento Administrativo Nacional de Estadistica	1968
Desarrollo Agricola del Valle del Cauca, Censo de Seis Cultivos	Instituto de Fomento Algodonero	1967
Rentabilidad de Diversos Cultivos Agricolas y Explotaciones Ganaderas en el Valle del Cauca	Universidad del Valle, Facultad de Ciencias Economicas	Mar. 1966
El Sector Agropecuario (Una Evaluacion Preliminar)	CVC	Sep. 1965
Information on Subterranean Water and Well in the Cauca Valley	Seccion de Aguas Subterraneas de la CVC	Sep. 1968
Informe sobre Prueba de Pozo y Bombeo	COLPOZOS–Cali	1968
The CVC : Challenge to Underdevelopment and Traditionalism	Antonio J. Posada F. Jeanne Anderson Posada	May 1966
Colombia, Estadisticas Basicos	Banco de la Republicas	1969
Valle del Cauca (1910 - 1960) Medio Siglo de Riqueza	La Industrial Vallecaucaña MCMLX	1960
Informe sobre Evaluacion de Perdidas Causadas por las Inundaciones en los Departamentos del Valle y Norte del Cauca en Diciembre 1966	Comite de Emergencia sobre Inundaciones	Feb. 1967
An Investigation of Water-Borne Wastes Contributing to the Pollution of the Rio Cauca	Jacques Eduard Donaldson	Aug. 1963
A Study of the Pollution and the Natural Purification of the Cauca River - Colombia S.A.	Tulane University	

Preliminary Treatment Requirements and Construction Cost for the City of Cali	Hazen & Sawyer Co.	1968
Situacion Pasada y Presente de la Pesca Continiental en el Area del Alto Rio Cauca, desde La Virginia hasta Suarez	Anibal Patiño R. Univ. del Valle	Ago. 1969
Desviacion Cauca - Pacifico	CVC, OLAP, G&H, TAMS	Nov. 1967
Spillway Design Flood for Cauca River above Timba Dam	CVC, INGETEC, G&H, TAMS	Jul. 1962

Memorandum (1)

Para : Jorge Llanos

De : Bayardo Materón — Archivo : 512A

Fecha : Agosto 22 de 1969 — Memo : C-14000

Asunto : Información para Timba

Reference a su Memo C-13987 puedo comentar los siguientes puntos:

1) Otras fábricas diferentes a Yumbo no han sido consideradas para los proyectos anteriores por dos razones:

   a) La capacidad de la planta de Yumbo es adecuada para satisfacer en la actualidad la demanda de cemento de un proyecto grande; y

   b) El costo de transporte, actualmente del orden de $1.00 Ton-km. afecta notoriamente la movilización de cemento de otras fuentes.

2) La Fábrica de Yumbo está produciendo en la actualidad aproximadamente el 65% de su capacidad total que es de 540.000 Ton/año.

3) En nuestros archivos tenemos ensayos recientes del cemento y concreto que estoy poniendo a la disposición del Señor Watanabe para su estudio.

BMN/mcs.

Memorandum (2)

Para : Ing. H. Watanabe

De : Ing. Cornelio Flórez M. Archivo : 512A

Fecha : Julio 30, 1969 Memo : C-13887

Asunto : Datos solicitados por Misión EPDC.

A propósito del punto 9 del cuestionario, le adjuntamos tres cuadros que resumen los datos recolectados. Por lo que hace al primer item, TASAS DE INTERES, se insertan en el Cuadro No. 1. Tanto las casas para préstamos bancarios como para evaluación económica, han sido discutidos con el Departamento de Estudios Económicos y con la Señorita Rosario Moreno de la División de Finanzas. Al indicar la tasa de interés de los préstamos externos, del 9% se ha tenido en cuenta la tendencia al alza registrada últimamente en el mercado mundial de capitales.

Para efecto de la evaluación económica, la tasa del 7%, es la que actualmente tiende a imponerse en Estados Unidos para inversiones sin riesgo.

En cuanto al Item 2, se adjunta el Cuadro No. 2 que contiene los años de servicio para las distintas clases de activos, siendo de advertir que para las plantas hidroeléctricas se toma una vida de 43 años teniendo en cuenta que al equipo eléctrico se asigna un tiempo de servicio inferior al de las estructuras. Para éstas es de 50 años Estos datos son los que utiliza la Contabilidad de la CVC y ANCHICAYA LTDA. Sinembargo, en los Informes de Factibilidad, para Plantas Hidroeléctricas, inclusive su equipo, se han tomado 50 años.

Item 3. Los datos concernientes a este item; Interim Replacement, - Insurance, etc., conviene adoptar las mismas del Informe de Factibilidad del Alto Anchicayá de 1968. En cuanto al Capital Covery Factor, puesto que depende de la vida de servicio y de la tasa de interés, variará en cada caso.

Item 4. Costo de Combustible - En el Cuadro No. 1 se incluyen los datos tanto para Cali como para Buenaventura. Los precios que figuran son para ventas al por mayor en Planta de la ESSO COLOMBIANA.

Item 5. La tasa actual de conversión de dólares a Pesos es de $ Col. 17.38/Dólar a la fecha.

Memorandum (3) - 1

EPDC QUESTIONNAIRE

No. 9 - Data for evaluation purposes

1. Interest Rate:

a.	For Bank Loans:	Foreign:	9%
		Local:	12%
b.	For economical evaluation: (Sinking Funds, Discount rates, etc.)	Foreign:	7%
		Local:	10%

Memorandum (3) - 2

Para : Ing. H. Watanabe

De : Ing. Cornelio Flórez M. Archivo : 512A

Fecha : Julio 31, 1969 Memo : C-13898

Asunto : Datos para evaluación Proyectos EPDC.

De acuerdo con lo anticipado en nuestra conversación de ayer, nos permitimos informarle acerca de las tasas de descuento utilizadas en estudios de proyectos de regadio y recuperación de tierras, asi:

Tasa asumida por el BID en su estudio para proyectos de Roldanillo-La Unión-Toro y Bolivar No. 1 .... 6%

Tasa asumida en el estudio del proyecto Roldanillo-La Unión-Toro, llevado a cabo en 1964 por el economista Antonio Posada 7%

Con base en las tasas de interés anteriores, se han descontado los beneficios y los costos anuales para efecto del cálculo de la relación B/C.

Es de advertir que el BID en el estudio antes mencionado, para fines comparativos hizo sus cómputos también sobre la base de una tasa del 8%.

CFM : src.
cc. : Dr. O. Mazuera.

EPDC QUESTIONNAIRE - INFORMATION ON LOANS

No. 9 - Data for evaluation purposes

	I B R D (World Bank) Calima		I B D Interamerican (BID)
FOR HYDROELECTRIC PROJECTS	255-CO Loan	339-CO Loan	Alto Anchicaya Loan
Rate of Interest	6%	5½	7¾%
Service Commission	-	-	1%
Interest on funds not disbursed	3/8%	3/8%	2%
Total period of loan - Years	25	20	20
Grace period "	3	3	5
Amortization period "	22	17	15
Amount (millions US$)	25.0	8.8	43.3

FOR LAND RECLAMATION AND IRRIGATION PROJECT (Loan 92/SF-CO granted by BID Bank to INCORA)	I B D (BID)
Rate of Interest	2¼%
Service Commission	¾%
Interest on funds not disbursed	½%
Total period of Loan-Years	28
Grace period "	3
Amortization period "	25
Amount (millions US$)	9.7

VII-30-1969

CFM/Mol.

Memorandum (4)

Julio 30, 1969 — Anchivo : 512A

Hoja No. 2 — Memo : C-13887

En el Cuadro No. 3 se han incluido los datos concernientes a los préstamos otorgados a la CVC por el Banco Mundial y por el Banco Interamericano, BID, para plantas hidroeléctricas y también los datos del Préstamo del BID para obras de irrigación hecho el INCORA.

Finalmente anotamos que la tarifa de venta de energia en bloque, por ANCHICAYA a la CVC y a EMPRESAS MUNICIPALES DE CALI, es de 18.5 centavos.

CFM : src.
cc. : Dr. K. Shindo
Dr. J. Llanos

Memorandum (5)

Dependencia: Depto. de Biologia

SITUACION PASADA Y PRESENTE DE LA PESCA CONTINENTAL (FLUVIAL Y LACUSTRE) EN EL AREA DEL ALTO RIO CAUCA, DESDE LA VIRGINIA HASTA SUAREZ.

Este estudio es preliminar y necesariamente aproximado, por falta de estadisticas confiables. Ha sido elaborado a solicitud de la comisión de ingenieros japoneses que actualmente prestan su colaboración a la C.V.C. en el estudio del proyecto de La Salvajina.

La información aqui presentada se basa en algunos datos obtenidos en la Secretaria Departamental de Agricultura y en las observaciones del autor, quien ha venido estudiando desde hace dos años la incidencia que la creciente polución acuática está determinando sobre las poblaciones de peces del alto rio Cauca.

Las cifras sobre los tonelajes de pescado se refieren exclusivamente al que es capturado y vendido en el área de estudio. No se contabiliza por tanto el que es introducido a la región desde el bajo rio Cauca y el Magdalena.

ESPECIES DE VALOR ECONOMICO Y SU VALOR COMERCIAL RELATIVO:

Bocachico (Prochilodus reticulatus)	50%
Barbudo (Pimelodus grosskopfi)	25%
Bagre sapo (Cephalosirus zungaro)	15%
Tilapia mossambica (desde enero 1.969)	6%
Otros	4%

PRINCIPALES SITIOS DE MERCADEO Y VOLUMEN DE VENTAS:

Santander de Quilichao (Depto. de Cauca)	8%
Puerto Tejada (Depto. de Cauca)	8%
Cali (Depto. de Valle)	32%
Palmira (Depto. de Valle)	12%
Buga (Depto. de Valle)	10%
Tuluá (Depto. de Valle)	10%
Cartago (Depto. de Valle)	10%
La Virginia (Depto. Risaralda)	10%

ESTIMACION DEL VOLUMEN DE LA PESCA, NUMERO DE PESCADORES Y VALOR COMERCIAL DEL PESCADO CAPTURADO (DESDE 1.950 HASTA 1.968):

CAUSAS DE LA DISMINUCION DE LA PESCA, EN ORDEN DECRECIENTE DE IMPORTANCIA.

1a.- La creciente polución acuática (industrial, urbana y agricola principalmente), muy severa frente a la zona de Cali- Yumbo.

2a.- Los efectos biológicos de la polución acuática en el rio Cauca se han visto agravados por la notoria disminución del caudal del rio en la época en que se inicia la migración de los peces (septiembre). Al alcanzar el factor de dilución de los residuos industriales su valor minimo durante esa época, los efectos tóxicos sobre los peces son máximos.

3a.- El proceso de desecación de la mayoria de las lagunas y madreviejas del Cauca, que ha eliminado gran parte del habitat de alimentación del bocachico. Si este proceso continúa, el bocachico terminará por extinguirse en la región.

4a.- A partir de 1.955, la Laguna de Sonso se ha ido cubriendo de vegetación acuática flotante, lo cual ha impedido la pesca y deteriorado ese precioso habitat del bocachico. Nada se ha hecho por remediar esta situación.

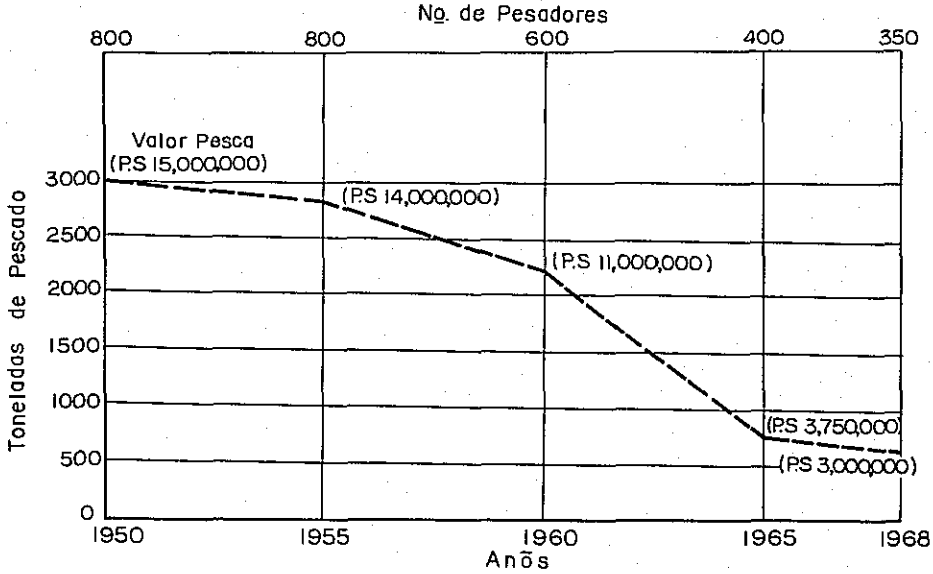
5a.- A medida que la población del Valle del Cauca ha aumentado (actualmente sobrepasa los dos millones), la presión de pesca se ha incrementado excesivamente. Para agravar las cosas, el control y la vigilancia de las autoridades es muy deficiente (sólo existen cinco inspectores de pesca en todo el Departamento y carecen de vehiculo para movilizarse). No se cumplen las reglamentaciones sobre tallas y pesos minimos.

6a.- Lamentablemente, no ha existido interés eficial para financiar investigaciones ictiológicas y limnológicas. La ecologia de casi todas las especies de peces de la zona es en gran parte desconocida: se ignora casi todo acerca de sus rutas de migración, épocas de desove, comportamiento alimenticio, parásitos etc. No se practica entre nosotros la restitución de las condiciones de habitat de cada especie, ni se ponen en vigor vedas, ni se repueblan los rios y lagunas.

Cali, 2 de agosto de 1.969

Atentamente,

Anibal Patiño R.
Profesor auxiliar
Depto. de Biologia
Universidad del Valle.



Memorandum (6)

January 5, 1970

Mr. Hiroshi Watanabe
Señor Civil Engineer
Electric Power Development Co., Ltd.
1-1-Marunouchi, Chiyoda-ku,
Tokyo, Japan

Dear Mr. Watanabe:

Re: Treatment Requirements and Construction Costs for the City of Cali, Colombia

Enclosed herewith are the data on treatment requirements and construction costs you requested through EMCALI. We have based our construction costs on the 1968 value of the Colombian peso.

Please disregard all prior data furnished to you. If you have any questions regarding the above, please contact the writer.

Very truly yours,

HAZEN AND SAWYER
Florida Office
Carlos T. de Navarra, Jr.

CTN/ram
cc: Mr. Hernando Gonzalez Hurtado
Mr. F. P. Coughlan, Jr.

Encls.

TABLE I

DEGREE OF WASTEWATER TREATMENT

REQUIRED AT VARIOUS DROUGHT FLOWS

	CAUCA RIVER - FLOWS					
	70 M^3/S		130 M^3/S		200 M^3/S	
YEAR	CITY OF CALI	INDUSTRIES DISCHARGING ORGANIC WASTES	CITY OF CALI	INDUSTRIES DISCHARGING ORGANIC WASTES	CITY OF CALI	INDUSTRIES DISCHARGING ORGANIC WASTES
1975	P	P	N.T.	N.T.	N.T.	N.T.
1980	I	I	N.T.	N.T.	N.T.	N.T.
1985	I	S	P	P	N.T.	N.T.
1990	I	S	I	I	P	P
2000	S	S	I	S	P	I

N.T. - NO TREATMENT REQUIRED

P - PRIMARY TREATMENT - The removal of a substantial amount of suspended matter (by sedimentation), but little or no colloidal and dissolved matter.

I - INTERMEDIATE TREATMENT - The removal of a high percentage of suspended matter and a substantial percentage of colloidal matter, but little dissolved matter.

S - SECONDARY TREATMENT - The treatment of wastewater by biological methods after primary treatment by sedimentation.

Drought flows defined as minimum seven day flow in Rio Cauca at Juanchito gage occurring one day in ten. Regulation required for 130 and 200 M^3/S.

TABLE II

INVESTMENT BY CITY OF CALI

IN WASTEWATER TREATMENT FACILITIES

	WASTEWATER FLOWS	CONSTRUCTION COSTS (IN COLOMBIAN PESOS)			REDUCTIONS IN COST OF WASTEWATER TREATMENT FACILITIES WITH REGULATED FLOWS IN RIO CAUCA		
		CAUCA RIVER DROUGHT FLOWS			AT 130 M^3/S	AT 200 M^3/S	
YEAR	(M^3/S)	70 M^3/S	130 M^3/S	200 M^3/S	vs.-70 M^3/S	vs.-70 M^3/S	vs.-130 M^3/S
1975	4.4	$\$193x10^6$	-	-	$\$193x10^6$	$\$193x10^6$	$\$193x10^6$
1980	6.0	$178x10^6$	-	-	$178x10^6$	$178x10^6$	$178x10^6$
1985	8.2	-	$\$364x10^6$	-	-	-	$364x10^6$
1990	10.5	$390x10^6$	$238x10^6$	$\$435x10^6$	$152x10^6$	-	-
2000	15.9	$697x10^6$	$465x10^6$	$222x10^6$	$232x10^6$	$475x10^6$	$243x10^6$
TOTAL :		$\$1,458x10^6$	$\$1,067x10^6$	$\$657x10^6$	$\$391x10^6$	$\$801x10^6$	$\$410x10^6$

RIVER REGULATION PROJECT VOL. 1