REPORT ON THE BASIC STUDIES FOR DEVELOPMENT OF HYDRO-ELECTRIC POTENTIALS IN THE REPUBLIC OF BOLIVIA

MARCH 1964

OVERSEAS TECHNICAL COOPERATION AGENCY OF JAPAN

Report of a Japanese Mission Organized by
the Overseas Technical Cooperation Agency of Gervenment of Japan
at the request of
The Government of the Republic of Bolivia

REPORT ON THE BASIC STUDIES FOR DEVELOPMENT OF HYDRO-ELECTRIC POTENTIALS IN THE REPUBLIC OF BOLIVIA

P r e f a c e

Submitted herewith as per the request of the Government of Republic of Bolivia is an engineering report of basic studies and investigations which were conducted on the development of hydro-electricity potentials of Bolivia by a Japanese mission which was organized and sent to Bolivia by Overseas Technical Cooperation Agency of Japan.

The six-member mission headed by Mr. Hatsuro Suzuki of Electric Power Development Company Ltd., Tokyo, left Tokyo on November 5, 1963 in order to carry out field investigations for a period of about 2 months in Bolivia. During the period the mission reconnoitered several project sites and areas, and basic engineering data and informations necessary for the studies of development plan were made available to the Mission. Discussions and studies were also made during the period on each phase of development plan with concerned officials of the government of Bolivia, to whom the mission is much obliged for their hearty assistance and cooperation which enabled us to go through with the investigations smoothly.

In this report, comparative studies, as well as recommendations, were made over several projects which, the mission considers, will facilitate and expedite the development of hydro-electricity potentials of Bolivia. In this respect, the mission believes that this report will be of use in planning of specific development projects when general consideration is combined thereto on social and economic conditions of the proposed project areas.

The Overseas Technical Cooperation Agency, executive agency for the technical cooperation programs of the Government of Japan, has been, since its establishment in June 1962, performing various activities including dispatching of technical experts, training in Japan of engineers from abroad, conducting preliminary survey relating to development projects in foreign countries. The happiness of the Agency will be unlimited if the achievements of the mission contribute to technical and economic interchange between people of Bolivia and Japan.

The Agency hereby acknowledges hearty assistance and help extended by the people and organizations of Bolivia, especially administrative agencies of the government of Bolivia.

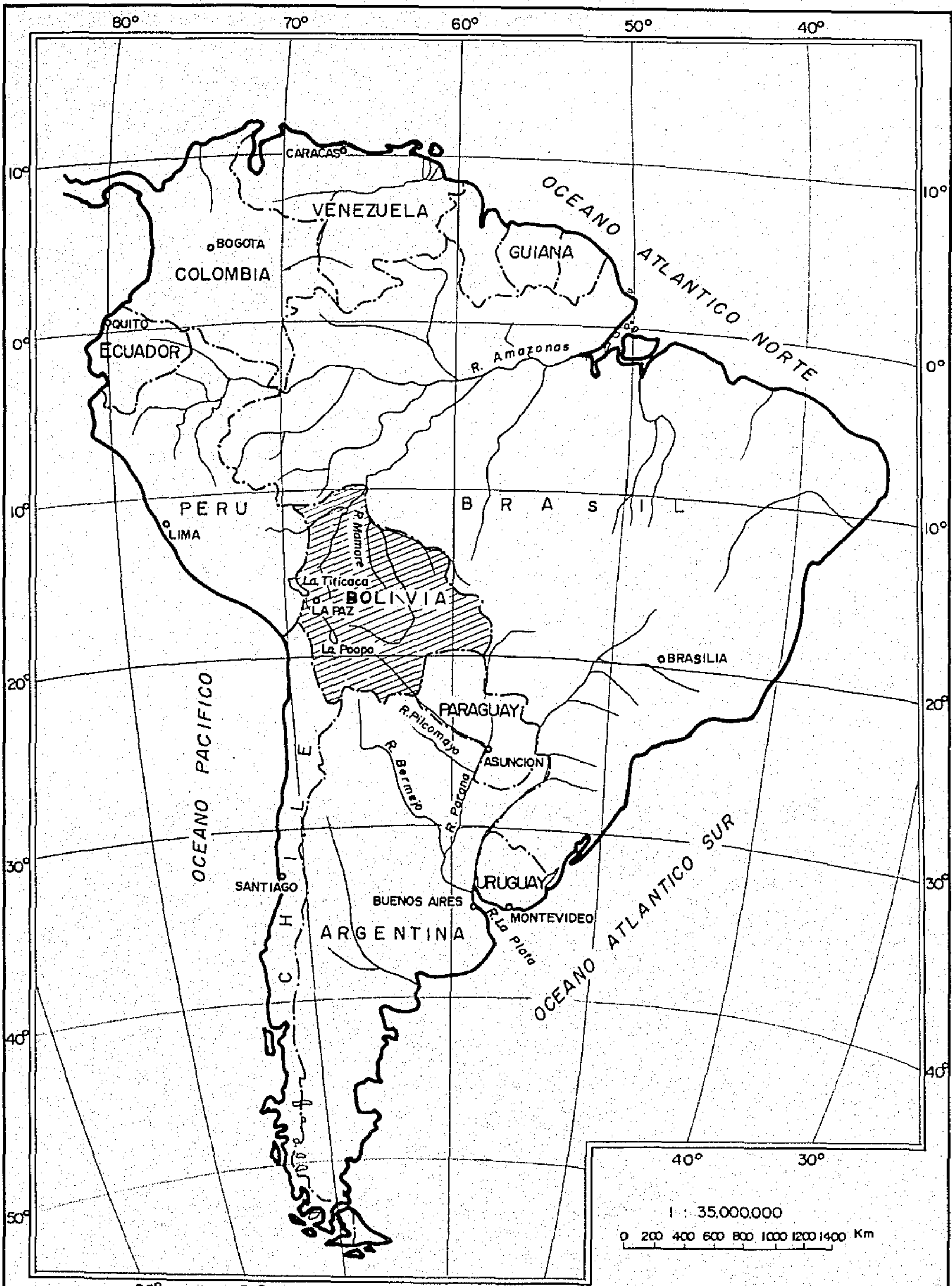
March, 1964

Shinichi Shibusawa

S. Shibusawa

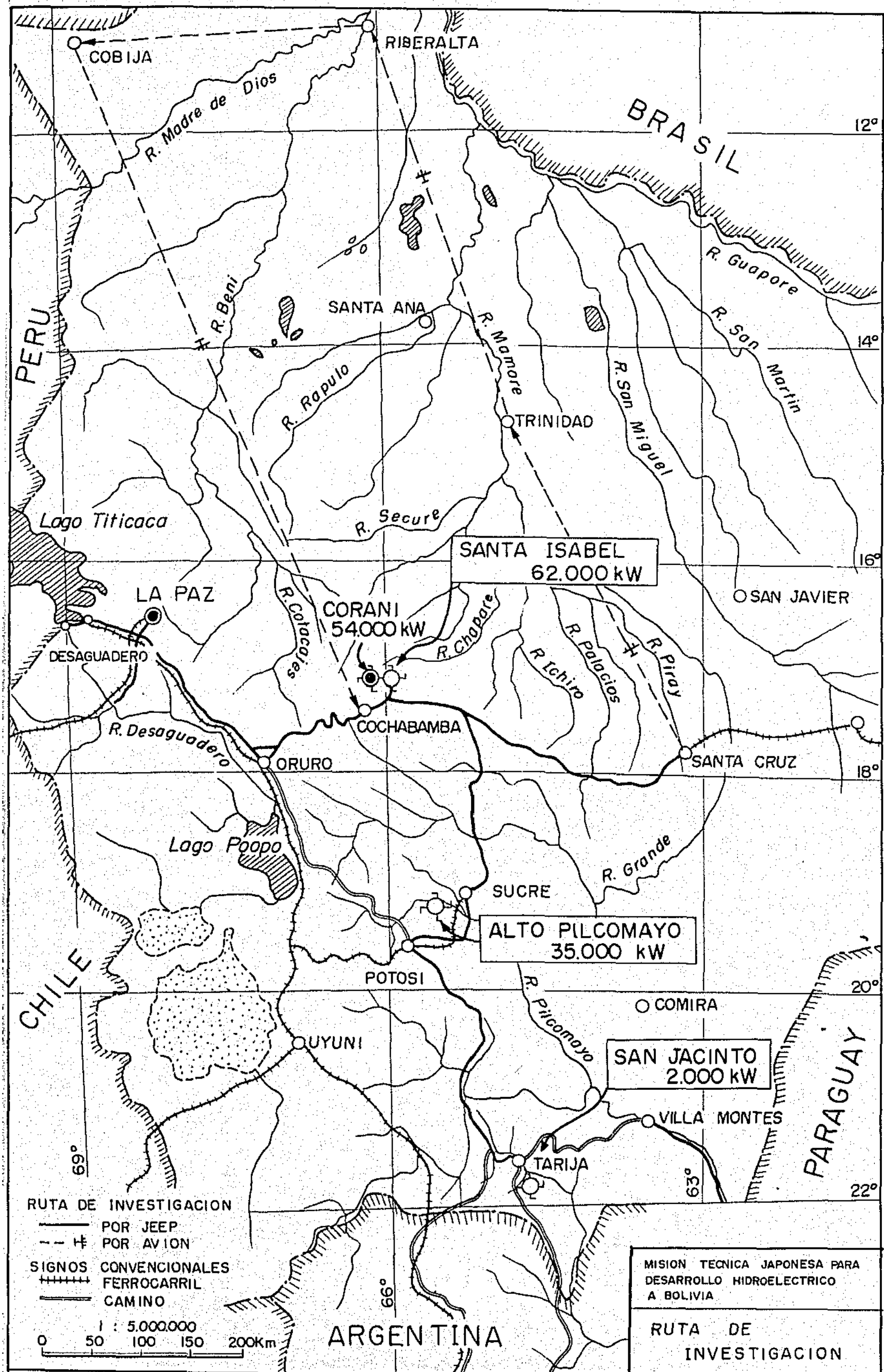
Director general,

Overseas Technical Cooperation Agency



MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

MAPA DE SUDAMERICA



COBIJA
RIBERALTA
R. Madre de Dios
BRASIL
12°
R. Beni
SANTA ANA
R. Mamore
R. Guapore
R. San Martin
PERU
14°
R. Rapulo
TRINIDAD
R. San Miguel
Lago Titicaca
R. Secure
SANTA ISABEL
62.000 kW
16°
LA PAZ
CORANI
54.000 kW
SAN JAVIER
R. Cotacajes
R. Chapare
R. Ichiro
R. Palacios
R. Piray
DESAGUADERO
COCHABAMBA
R. Desaguadero
ORURO
SANTA CRUZ
18°
Lago Poopo
R. Grande
SUCRE
ALTO PILCOMAYO
35.000 kW
POTOSI
CHILE
R. Pilcomayo
20°
COMIRA
UYUNI
SAN JACINTO
2.000 kW
PARAGUAY
VILLA MONTES
TARIJA
69°
63°
22°
RUTA DE INVESTIGACION
POR JEEP
POR AVION
SIGNOS CONVENCIONALES
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ARGENTINA
MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA
RUTA DE INVESTIGACION

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1. FOREWORD

1. Foreword

1-1 Authority

The Government of the Republic of Bolivia has established "El Plan Decenal de Desarrollo Económico y Social" with the object of improving the standard of living of its people. The Government initiated the implementation of the plan by the creation under the Minstries concerned, official agencies, such as, Corporación Boliviana de Fomento (CBF), Corporación Mineria de Bolivia (Comibol), Yacimientos Petroliferos Fiscales Bolivianos (YPFB) and other agencies, and has been receiving economic and technical cooperation from friendly nations. It is evident that development of the electric power sector of the national economy is lagging behind the other sectors. Accordingly, the Government, in 1962, established Empresa Nacional de Electricidad under Corporación Boliviána de Fomento to promote aggressively the development of electric power.

Under these conditions, the Government of Bolivia, on 15th October 1963, officially requested the Government of Japan to dispatch a mission to Bolivia for the purpose of conducting basic studies of the development of hydro-electric potentials of the country.

In response to the said request, the Government of Japan decided to cooperate with the Government of Bolivia and to strengthen the bonds of friendly relations between the two countries. The Government of Japan entrusted this work to the Overseas Technical Cooperation Agency which organized "Misión Técnica Japonesa para Desarrollo Hidroeléctrico a Bolivia". The Agency organized and dispatched to Bolivia the said Mission which consisted mainly of engineers of Electric Power Development Company.

1-2 Purposes

The purposes of the Mission were to study the possibilities of the development of hydro-electric potentials of Santa Isabel, Alto Pilcomayo and San Jacinto projects which were proposed by the Government of Bolivia. For this purpose the Mission conducted the following studies and investigations:

(1) basic studies including field investigations in connection with the selection of dam sites and powerhouse sites of proposed projects on the Río Santa Isabel, Río Alto Pilcomayo and Río San Jacinto, and collect relevant data.

(2) collect hydrological, meteorological and other relevant data including river water level, run-off, rainfall etc.

(3) investigate the present situation of demand and supply of electricity and power supply systems in the areas which are to be influenced by the three projects, as well as collect relevant data.

The members of the Mission were as follows:

Chief Engineer	Hatsuro Suzuki	Civil Engineer, Electric Power Development Co.
	Tetsuo Takagi	Civil Engineer, Ministry of International Trade and Industry.
	Tomozo Kimura	Electrical Engineer, Electric Power Development Co.
	Kenzo Aoki	Civil Engineer, Electric Power Development Co.
	Kokichi Yoshizawa	Civil Engineer, Electric Power Development Co.

Tateshi Murai	Economist, Electric Power Development Co.

The Mission visited Bolivia for a period of approximately two months from November 1963 to December 1963.

1-3 Acknowledgement

The Mission takes this occassion to express its deep appreciation to the Government of Bolivia and to the people of Bolivia for the cooperation and assistance extended to it. In spite of the short period of stay in Bolivia, the Mission was able to accomplish its work and to visit the three proposed project sites which are located in different parts of the country.

The Mission wishes to especially express its gratitude to Corporación Boliviana de Fomento and Empresa Nacional de Electricidad which furnished the Mission various conveniences including aereal photos and other data, transportation such as vehicles and military aeroplane, interpreters, and others. Furthermore, the Mission acknowledges and thanks the Prefectural Governments, Cooprativa Electricidad, University and private companies that actively cooperated with the Mission.

The members of the Mission are thankful and appreciate the many kindness, hospitality, conveniences and friendship shown by the presidents, prefectural governors, directors, managers, engineers, officers and other people of organizations and agencies that the Mission came into contact with during the course of its visit to Bolivia.

1-4 Schedule

No. of days	Date	Itinerary
1, 2, 3	Nov.5 to 7	Tokyo - La Paz
4, 5	Nov.8, 9	La Paz, conference with CBF
6	Nov.10	La Paz - Cochabamba by jeeps
7,8	Nov.11, 12	Cochabamba, conference with CBF and ENE
9	Nov.13	Cochabamba - Corani by jeeps
10	Nov.14	Corani - Santa Isabel by jeeps and on foot
11, 12	Nov.15, 16	Santa Isabel, reconnaissance of the project site
13	Nov.17	Cochabamba, study of electric power situation
14	Nov.18	Cochabamba - Sucre by jeeps
15	Nov.19	Sucre, study of electric power situation
16	Nov.20	Sucre - Alto Pilcomayo by jeeps and on foot
17, 18	Nov.21, 22	Alto Pilcomayo, reconnaissance of the project site
19, 20	Nov.23, 24	Sucre, study of electric power situation
21	Nov. 25	Sucre - Potosí by jeeps
		Potosí, study of electric power situation
22	Nov.26	Potosí - Tarija by jeeps
23, 24	Nov.27, 28	San Jacinto, reconnaissance of the project site
25	Nov.29	Tarija - Potosí by jeeps
26	Nov.30	Potosí - Cochabamba by jeeps
27	Dec.1	Cochabamba, study of electric power situation
28	Dec.2	Cochabamba - Santa Cruz by jeeps
29	Dec.3	Santa Cruz, study of electric power situation
30	Dec.4	Santa Cruz - San Juan by jeeps
31	Dec.5	San Juan - Santa Cruz by jeeps
32	Dec.6	Santa Cruz - Trinidad by Military aeroplane

No. of days	Date	Itinerary
33	Dec.7	Trinidad - Riberalta - Cobija - Cochabamba by Military aeroplane
34, 35	Dec.8, 9	Cochabamba, study of electric power situation and collection of relevant data
36	Dec.10	Cochabamba - La Paz : part of members by air and by jeeps
37, 38	Dec.11, 12	La Paz - Desaguadero - La Paz
39	Dec.13	La Paz, conference with CBF
40	Dec.14	La Paz, meeting with President of Republic of Bolivia
41, 45	Dec.15 to 19	La Paz - Tokyo

2. CONCLUSIONS AND RECOMMENDATIONS

2. Conclusions and Recommendations

2-1 General

The possibilities of the development of the hydroelectric potentials of Santa Isabel, Alto Pilcomayo and San Jacinto were studied from the results of reconnaissance of the three sites by the Mission and from aerial photos, hydrological and meteorological data which were made available to the Mission by CBF. As a result of the studies, fundamental schemes on the scale of development, economic feasibility and timing of development which are conceivable of the three proposed sites at this stage have been prepared. These fundamental schemes together with recommendations are described in section 2-3 which follows.

It must be pointed out that the presentation of the fundamental schemes were made possible by insertion of many assumed values, due to lack or inaccuracy in the original data. Therefore, in order to develop concrete development plans based on the fundamental schemes, studies of basic matters, such as, forecast of demand, interconnection of transmission lines, preparation of topographical maps, recording and compilation of hydrological and meteorological data, will be prerequisite conditions. These fundamental problems and matters common to the three sites are given in section 2-2 together with recommendations.

One of the important issues which has been excluded from the recommendations is the matter of rates for electric services. Corresponding with the addition of new capacities, capital costs including depreciation, interest charge, etc. will increase, and the growth in the number of electric utility enterprises and the expansion of transmission system network will tend to create complication of transactions between the enterprises. Therefore, it is essential that carefull studies be pursued and a basic policy be established in respect of the structure of the electric utility industry and system of rates for electric services in parallel with the expansion of generating capacities.

2-2 Recommendations Concerning Fundamentally Common Matters.

2-2-1 Forecast of Demand.

Economic and optimum development and timing of development of a proposed project will be governed by the magnitude and pattern of growth of demand forecasted over a long-range into the future. Therefore, a relatively reliable demand forecast of the future years must be made. For this purpose, the establishment of an economic development program and the compilation of accurate records of electricity consumption are essential. Therefore, it is recommended that a uniform form for the country as a whole be prepared immediately to compile records of electricity consumption. This record should include electricity consumption of industries that have their own generating plant. In preparing the uniform form for the compilation and recording of electricity consumption, the following items should be included in addition to those data which are at present being recorded.

(i) records of load supression (duration in hours and restricted load).

(ii) records of plant outage by forced outage and scheduled maintenance outage (give particulars of type of plant, cause of outage and hours of outage).

(iii) records of spilled water caused by outage of hydroelectric plant and load curtailment by restricted generation of power.

(iv) records of the output at the power plants and tap-out points on the main distribution lines and consumption by the general consumers to measure transmission and distribution losses.

2-2-2 Interconnection of Transmission Lines

The economic scale and timing of development of a proposed project will be governed by the magnitude and pattern of growth of the forecasted demand. The magnitude and pattern of the forecasted demand will, of course, differ appreciably by the mode of transmission line interconnection, i.e., whether the lines are independent or are interconnected with other lines. This difference will be more pronounced in the early stages of transmission system interconnection.

In the early stages of transmission system interconnection, the economic scale of development and timing of development of a project, and the method of economic interconnection of transmission lines and timing of the interconnection are closely interrrelated. Therefore, these issues must be considered together. In this connection, it will be necessary to prepare basic data which have been carefully examined from both technical and economic standpoints in order to determine the method and timing of transmission line interconnection. Therefore, the following studies would be desirable.

a) In addition to the proposed transmission line interconnection between Cochabamba and Oruro, it is recommended that studies be started immediately on the transmission line interconnection between Oruro and Potosi and Sucre, as well as between Oruro and La Paz.

b) In the interconnection of transmission lines, a strong policy of nationwide standardized frequency must be adapted because if the nation is not standardized on one frequency detrimental economic obstacles will be encountered.

c) With the progress of transmission interconnection and expansion of power system, problems of technical nature in respect of plant equipment, as well as problems of economic nature, such as standardization of plant equipment and determination of types and quantities of necessary spare parts, etc. will arise. To cope with these problems, it would be necessary to prepare as soon as possible a nationwide register on a standardized form recording equipment classified into generation plant, transmission line, sub-station and distribution line.

2-2-3 Preparation of Topographical Map

In preparing a development plan of a project, it is necessary to prepare topographical maps of required scales at the various stages of investigations and planning. Triangulation and levelling surveys in the preparation of topographical maps should be connected to the standardized nationwide triangulation and levelling networks established by Instituto Geográfico Militar (IGM), coordinates and bench marks employed by IGM should be adopted.

The only topographical map of Bolivia as a whole, is Mapa aproximado de Bolivia en 58 Hojas on a scale of 1/250,000 issued by Ministerio de Colonización. This topographical map was prepared between 1933 and 1935, and the accuracy is relatively low. In addition, the map is prepared with contour intervals of 500 m which is inadequate for planning a hydroelectric project.

IGM is now preparing aerial photos on a scale of 1/100,000 of principal industrial districts. It is recommended that CBF consult with IGM, to prepare with priority aerial maps of the proposed project areas.

Mapping of the project areas would include aerial maps on a scale of 1/25,000 of the reservoir area, dam site, powerhouse site, transmission line route and access road route, etc. For especially essential areas manually surveyed topographical maps on a scale of 1/5,000 to 1/2000 should be prepared. At the stage of finalizing the development plans it will be necessary to prepare topographical maps on a scale of 1/500 to 1/200 of the areas where structures are to be constructed and of particularly essential sections it may be necessary to prepare topographical maps on a scale of 1/100 to 1/50.

2-2-4 Hydrological Data

In preparing a hydroelectric development plan, hydrological and meteorological data uniformly observed and recorded continuously over a number of years are necessary for the analytical study of streamflow data which forms the basis of hydroelectric development plan. At least 2 to 3 years of continuous observation and recording of streamflow are necessary, and meteorological data, such as, streamflow and rainfall, snowfall and evaporation, etc. should be correlated. It will also be necessary to observe temperature, humidity, wind direction, wind velocity, etc. as these meteorological data are related with the design of structures.

In establishing new hydrological and meteorological observation stations, their location, number and instruments should be carefully studied. In consideration of the vast area to be observed and the shortage of skilled personnel, it might be worth considering the establishment of unmanned stations by installing self-recording apparatus or automatic recording device powered with solar batteries

In connection with the gaging of streamflow, in order to improve the accuracy of records, it is a matter of first importance to take discharge measurements, by current meters, more often and for higher water levels (up to normal water level minimum available flow 185 days of a year) than before. Also, streamflow gagings during flood periods, using buoy are recommended.

Discharge of a river at an existing power station can be computed by the following way. The power station discharge can be computed from the station output. And water level observation at the intake of the station will enable the calculation of quantity of spilled water by using ordinary overflow formulae. The sum of the above two quantities of water,represents natural flow of the river at the site of the power station. This method of stream gaging is very convenient and correct, so far as the basic data are reliable. However, records of this type have not been reported nor are they available, and it is recommended that this type of stream measurements be made as soon as possible.

2-3 Conclusions and Recommendations of Sites Investigated

2-3-1 Santa Isabel Site

The development plan of this site should be prepared as a component of the integrated development of the basin including the Corani Project which is under construction and the Locotal Project, a description of which is given later in this report.

From this standpoint the Mission reconnoitered the proposed project site, and it is our finding that the topography and geology of the proposed site is favorable for the construction of a hydroelectric plant. By constructing a waterway, open canal and partly tunnel, from the tailrace of the Corani Power Station, a very high hydraulic head can be utilized at the Santa Isabel site to develop approximately 62,000 kW of power and generate approximately 241,200,000 kWh of energy annually. The output of this project can be transmitted on a 110 kV transmission line, about 4.8 km long, to the switchyard of Corani Power Station, and thereafter transmitted to Cochabamba and Oruro together with the output of Corani Power Station. However, upon completion of the integrated development of the basin described above, the interconnection between Cochabamba and Oruro will require further studies depending upon the electricity demand in Cochabamba.

According to rough estimates made by the Mission, the total cost of the project is about US $11,600,000 and in terms of unit cost it is about US $187 per kW and about US $0.048 per kWh. It will be noted, therefore, that this site is economical and low cost power can be developed.

The proposed Santa Isable site is located immediately downstream of the tailrace of Corani Power Station, and the plant capacity and output at this this site will be governed by the regulated discharge from the Corani Power

Station. Consequently, the economic feasibility of this project should be considered together with Corani Power Station. The timing of the development of the site and the decision of whether to develop the entire capacity in one stage or two stages should be determined in relation to the growth of load in the industrial and mining districts of Cochabamba and Oruro. In connection with the determination of the priority of projects, the trend of growth of demand after the completion of Corani Power Station (installed capacity 54,000 kW) might create a condition which may favor the development of small projects in the basin before construction of the Santa Isabel Project. Therefore, it is suggested that this factor be duly considered in determining the priority of projects.

Other probable sites in the basin that the Mission thought worthy of study are (1) near Locotal where a dam can be constructed to store the run-off from Río Santa Isabel and Río Paracti to develop 10,000 kW to 20,000 KW of power, and (2) a run-of-river type plant with a capacity of 5,000 kW to 8,000 kW that can be constructed on the downstream of the existing Incachaca Power Station. In consideration of the foregoing reasons, it is recommended that studies of these sites be initiated immediately.

The following studies will be necessary to prepare development plans of the Santa Isabel site.

(a) Surveys

<u>Topographic survey</u>

Route survey of canal	S = 1/2,000 L = about 2.4km
Topographic survey of surge tank, penstock line and powerhouse sites	S = 1/500 A = about 1.5km^2
Topographic survey of intake and aqueduct sites	S = 1/200 A = about 0.01km^2

(b) Geologic Survey

Reconnaissance survey

Reconnaissance survey of the entire project area.

Test pit and trench

Excavation of test pits and trenches to ascertain the depth of talus deposits in the penstock route and powerhouse site.

(c) Hydrological and Meteorological Surveys

Improvement of existing streamflow gaging station

Prevailing conditions at the existing Vinto Gaging Station are not satisfactory. The river bed at the site should be treated to permit normal run-off. And it may be advisable to measure streamflow by utilizing an overflow weir.

Staff gaging

A staff gage should be installed near the proposed powerhouse site, and the river water level, particularly during flood run-off, should be measured.

In order to study the other probable projects within the basin which the Mission has considered, the following field studies should be made.

(a) Surveys

Aerial survey (S = 1/25,000)

Mapping area A = about 100km^2

Mapping district Basin of Río Santa Isabel and Río Paracti

These surveys are necessary for computation of catchment area, study of run-off conditions of the basin and study of interrelated projects.

River profile survey

Río Santa Isabel	S = 1/2,000 L = about 3km (from powerhouse site to river confluence)
Río Paracti	S = 1/2,000 L = about 6km (from Incachaca Power Station to river confluence)

Río Paracti S = 1/2,000
L = about 3km (from river confluence to Locotal)

The river profile levelling should be checked against the bench-marks on AM Line, Levelling Line of the First Degree, between Cochabamba and Todos Santos, shown on "Red de Nivelación en Bolivia". Bench marks should be installed along the river banks, and interrelation between elevations of Incachaca and Corani Power Stations should be established. All elevations should be expressed in terms of IGM standard.

(b) Hydrological and Meteorological Surveys

Streamflow gaging station

For planning the Locotal Project a streamflow gaging station should be established on the Río Paracti near the village of Paracti.

Rainfall and evaporation observation station

A station to measure rainfall and evaporation should be established near Paracti.

Tabulation of discharge records at existing Incachaca Power Station

Compute the power station discharge from record of electric energy generated, and quantity of spilled water by overflow depth over the intake weir. The sum of the station discharge and the spilled water represent the natural run-off of Río Paracti, and these data should be compiled year by year.

2-3-2 Alto Pilcomayo Site

The Mission reconnoitered this proposed project site, and after returning to Japan, a topographical map was prepared from aerial photos which were made available to it.

Streamflow data which were available are records of very short periods, and consequently run-off conditions of the river could not be estimated. The Mission estimated and analysed the run-off of the river from the rainfall records at Potosí.

The results of the analytical studies revealed that a dam creating a reservoir with an effective storage capacity of 100,000,000 m^3 (regulation factor: $\frac{\text{effective storage capacity}}{\text{annual inflow}} = 10\%$) can be constructed at this site, and an underground powerhouse with an estimated capacity of 35,000 kW producing 212,000,000 kWh annually can be built immediately downstream of the dam (tailrace about 5 km long).

It is believed that the markets for the output of the project would be Potosí, a distance of about 95km, which can be served by 2 circuits of 66 kV transmission lines and Sucre, a distance of about 25 km, which can be served by a 66 kV transmission line. It should be borne in mind, however, that a study of an integrated transmission network will be necessary when transmission interconnection with another district and/or development of other proposed sites come under consideration in the future.

According to rough estimates made by the Mission, the total construction costs are about US$18,000,000 which is approximately US$514 per kW of installed capacity and approximately US$0.085 per kWh. It is believed that this site is economically feasible.

As to the timing of this project, in consideration of the fact that large initial capital investments will be required for the construction of dam and other ancilliary structures, it would be advisable to determine the time when the growth of demand justifies the development of this project. In this connection, careful studies will be required of the trend of growth of demand of mining and other industries in the Sucre and Potosí districts, and timing of transmission interconnection. However, depending upon the trend of growth of demand, it may be more favorable to develop other probable sites in the region before the Alto Pilcomayo site. Therefore, the determination of priority of projects should be made with due care.

One of the other probable sites which the Mission thought would be worthy of consideration is on the Río Cachimayo near Potolo. This project will consist of the construction of a dam to divert the flow into the Alto Pilcomayo reservior, and to develop 10,000 to 20,000 kW of power utilizing available hydraulic head. If this project is constructed, the inflow to Alto Pilcomayo reservoir will be supplemented, and as a result the capacity and annual energy output of the Alto Pilcomayo Project may be increased. From an overall standpoint, it is believed that the diversion scheme will increase the economic feasibility of the project.

Another possible site is on the downstream of the Alto Pilcomayo powerhouse site. Utilizing the regulated discharge from the upstream Alto Pilcomayo Project and available head, a run-of-river type plant with a capacity of about 10,000 kW seems possible. These probable sites should be considered an integral part of the Alto Pilcomayo Project, and it is recommended that concrete studies be initiated.

The following studies are necessary to prepare plans for the Alto Pilcomayo Project.

(a) Surveys

Topographic Survey

Reservoir area, dam, powerhouse and access road	S = 1/5,000 A = about 20 km^2
Dam, powerhouse and tailrace sites	S = 1/500 A = about 1.5 km^2
River profile survey (between dam site and tailrace)	S = 1/2,000 L = about 7 km

(b) Geologic Survey

Reconnaissance Survey

Reconnaissance of project area including the reservoir.

Boring

Test borings, total length about 100 m, to investigate the bedrock of the dam site and depth of deposit on river bed.

Exploratory Adits

Excavate adits, total length about 150m, in both abutments to study the condition of weathering of bedrock and talus deposits.

Investigation of Hotsprings

Investigate the distribution, temperature and mineral contents of hotsprings in the reservoir area.

(c) Hydrological and Meteorological Surveys

Streamflow Gaging Station

Establish two streamflow gaging stations near Culta and Yocalla on the Río Alto Pilcomayo.

Rainfall and Evaporation Observation Stations

Establish rainfall and evaporation observation stations adjoining the two streamflow gaging stations mentioned above.

(d) Sedimentation and River Deposit Surveys

Sedimentation Survey

Expedite the installation of sedimentation measuring apparatus which CBF is planning to install at Talula.

River Deposit Survey

Conduct survey of topography, configuration, geology and land erosion in the entire basin, and survey of flood run-off conditions, condition of sedimentary deposit on the river bed and its movement.

In order to study the other probable sites in the basin that the Mission thought feasible, the following investigations should be conducted.

(a) Survey

Aerial Survey (S = 1/100,000)

Mapping area A = about 9,000 km^2

Mapping district Entire bain of Río Alto Pilcomayo and Río Cachimayo, and Sucre, Betanzos and Potosí

These surveys are necessary to obtain data to calculate catchment area, run-off conditions of rivers and in the studies of inter-related projects.

Some measures should be taken to expedite aerial mapping of a part of the aforementioned area which is being undertaken by IGM.

Aerial Survey (S = 1/25,000)

Mapping area A = about 80 km^2

Mapping district Reservoir area, and dam, powerhouse, tailrace and access road sites, as well as the area of the diversion scheme from Potolo.

These surveys are necessary to obtain data to study the river run-off conditions and studies of interralated projects.

River Profile Survey

Rió Alto Pilcomayo S=1/2,000

L=about 75 km (between Ancoma and Puente Sucre)

Río Cochimayo S=1/2,000

L=about 25 km (between Potolo and San Juan)

The river profile levelling should be checked against bench marks on Q Line, levelling line of the First Degree, between Sucre, Betanzos and Potosí, shown on "Red de Nivelación en Volivia". Bench-mark should be installed along the river banks.

(b) Hydrological and Meteorological Surveys

Streamflow Gaging Station

In order to obtain data for the integrated development plan of the Alto Pilcomayo Project, a streamflow gaging station should be established near Potolo and Puente Sucre on the Río Cachimayo.

Rainfall and Evaporation Observation Station

A rainfall and evaporation observation station should be established adjacent to the streamflow gaging station at Potolo.

2-3-3 San Jacinto Site

The Mission reconnoitered the site of the proposed San Jacinto Project and conducted supplementary surveys based on the topographic map of the area which was made available.
Streamflow data of three gaging stations were available, but the periods of observation were very short and in many cases records were missing. Based on the available data, a most probable discharge of the river at the proposed site was estimated, and analytical studies were made.

As a result of the studies, the Mission considers that a dam creating a reservoir with an effective storage capacity of 10,000,000 m^3 (regulation factor 8%) can be constructed at the proposed site, and, the inflow to the reservoir can be supplemented by diverting water from the headwaters of the Río Guadalqivir.
It is estimated that the project can develop 2,000 kW of power and generate 11,500,000 kWh annually.

The probable market for the power is the city of Tarija, a distance of about 7 km, which can be served by a 11 kV transmission line. However, if there are other potential sites in the area, the transmission line should be reconsidered.

The estimated construction costs of this project is about US$1,700,000 or about US$850 per kW and about US$0.148 per kWh. It will be noted that this site is not very economical. However, the site is located in close proximity to the city of Tarija and it is believed the output of the project will be optimum to meet the load growth in the said city. Consequently, it may be advisable to develop this site.

The timing of this project should be determined taking into consideration the trend of growth of demand in the city of Tarija and environs, the extent of potential demand in the area and the operating condition of existing diesel electric plants.

Another probable project in the area which the Mission has considered is to divert water from the basin of Lagunas de Taxara (catchment area 300 km^2) by a canal approximately 10 km long to the Río Victoria. Utilizing the high head between the two points, a run-of-river type plant with a capacity of 6,000 to 10,000 kW can be developed. The capacity of this plant can be increased in stages corresponding with the growth of demand. It is recommended that concrete studies of this project be made immediately, and comparative studies should be made with the San Jacinto Project to examine the economic feasibility of the two projects.

In connection with the San Jacinto Project, Ministerio de Agricultura, Ganadería, Colonización y Riegos has prepared a development plan which is primarily irrigation and includes hydroelectric power. The description of this project is given in "Informe Agro-económico del Proyecto San Jacinto - Tarija" prepared by the said Ministry.

The development plan of San Jacinto Project proposed by the Mission and that by the Ministry are different in nature. Therefore, coordination between the two plans should be carefully studied in preparing the development plan of this site.

The following studies are necessary in order to prepare the development plan of the San Jacinto site.

(a) Surveys

Topographic Survey

Topographic survey of Guadalquivir intake dam site	S = 1/500 A = about 0.05 km^2
Route survey of Gaudalquiver diversion canal	S = 1,2000 L = about 12 km
Topographic survey of dam, headrace, powerhouse and tailrace sites	S = 1,500 A = about 1.05 km^2

(b) Geologic Survey

Reconnaissance Survey

Reconnaissance survey of the project area including the reservoir.

Exploratory Pits

Excavate pits to study the geology of the erroded area in the saddle section of the left abutment of the dam site. Where necessary conduct permeability tests.

(c) Hydrological and Meteorological Surveys

Relocation of Existing Streamflow Gaging Station

Site condition of the existing streamflow gaging station on the Río San Jacinto is not favorable, and as the station is located in the reservoir area of the proposed San Jacinto Project, it is recommended that the station be transferred to a site on the downstream of the proposed San Jacinto powerhouse site.

Streamflow Gaging Station

In consideration of the importance of diverting water from the headwaters of Río Guadalquivir, it is recommended that a gaging station be established near the proposed site of the intake dam on the said river.

Rainfall and Evaporation Observation Station

It is recommended that a rainfall and evaporation observation station be established at San Loranzo in the Río Guadalquivir basin.

(d) Sedimentation and River Deposit Surveys

Sedimentation Survey

Land erosion in the Río San Jacinto basin is very extensive and the river run-off is heavily silt laden.

It is recommended that a sedimentation measuring instrument be installed.

River Deposit Survey

Conduct studies of the topography, configuration, land erosion conditions, flood discharge conditions, and conditions and movement of deposits on river bed.

The following investigations will be necessary to study the other probable site that the Mission considered during the course of reconnaissance surveys.

(a) Surveys

Aerial Survey (S = 1/100,000)

Mapping area A = about 1,800 km^2

Mapping district	Entire basin of Río San Lorenzo, Río Victoria, Río Guadalquivir, Río Zola, Río Tolomosa and Río San
Lagu	Jacinto, and basin of Lagunas de Taxara

The above maps are necessary to compute the catchment area of the respective rivers, and to study the river conditions as well as the study of interrelated projects.

IGM should be contacted in connection with the preparation of the maps.

Aerial Survey (S = 1/25,000)

Mapping area	A = about 25 km^2
Mapping district	Intake site on Río Guadalquivir; dam, headrace, powerhouse and tailrace sites; route of access road; and site of diversion canal from Lagunas de Taxara.

These maps are necessary to study the river condition and interrelated projects.

River Profile Survey

Río Victoria	S = 1/2,000
	L = about 15 km (between proposed powerhouse site and river confluence)
Río Guadalquivir	S = 1/2,000
	L = about 15 km (between proposed intake dam site and Angosto Powerhouse)
Río San Jacinto	S = 1/2,000
	L = about 2 km (between proposed dam site and river confluence)

Lagunas de Taxara S = 1/2,000

L = about 15 km (between the lake and proposed intake site)

The river profile levelling should be checked against bench-marks on W Line, between Tarija and Iscayachi, and V Line, between Tarija and Villamontes, both of which are the levelling line of the First Degree shown on "Red de Nivellación en Bolivia". Bench-marks should be installed along the river banks.

(b) Hydrological and Meteorological Surveys

Streamflow Gaging Station

Establish a gaging station near Iscayachi to record run-off data. This data will be necessary in planning the diversion scheme from Lagunas de Taxara.

Rainfall and Evaporation Observation Station

This observatory should be established adjacent to the abovementioned streamflow gaging station.

Compilation of Discharge Records at Existing Angosto Power Station

The discharge through the powerhouse should be computed from the energy generated. To the discharge computed in this manner, add the discharge spilled during flood run-off and during normal run-off periods, and compile discharge records of the Río Guadalquivir. Streamflow gaging conditions of the existing San Luis Gaging Station is not favorable due to backwater effects of an intake dam. River run-off at this site should be compiled according to the method suggested above.

3. GENERAL CONDITIONS OF THE PROPOSED PROJECT AREAS

3. General Conditions of the Proposed Project Areas

3-1 General

The Mission studied prevailing electricity demand and supply situation in the major centers of consumption principally in relation to the three proposed projects, namely, Santa Isabel, Alto Piocomayo and San Jacinto.

This report gives the general conditions of those districts that are closely and directly related with the three project sites specifically referred to above.

In this chapter, for the sake of convenience, Cochabamba, Oruro and Comibol Central are assumed the area of supply of Santa Isabel Project; Sucre, Potosí and Comibol South the area of supply of Alto Pilcomayo Project; and Tarija the area of supply of San Jacinto Project. If future interconnection of transmission lines is taken into consideration, this regional grouping may be somewhat improper, but the Mission believes it will help greatly in understanding the present situation.

3-2 Cochabamba Area in relation to Santa Isabel Project

3-2-1 General

The population of the city of Cochabamba in 1962 was estimated to be approximately 92,000 and about 190,000 inhabitants are estimated to be living in the outskirts of the city. The city is situated near the center of Cochabamba Basin. Its elevation is about 2600 m above mean sea level, the average annual temperature is between 17°C and 18°C, and the annual average precipitation is between 450 mm and 600 mm.

The area around Cochabamba is endowed with relatively abundant water, compared with other regions, and animal husbandry and farming are very actively carried out. On a cultivated area of about 70,000 hectare, wheat, barley, maize, potato and alfalfa are grown. In this area, irrigation is most widely practiced and agricultural productivity is high.

As for industries, there are a few small-scale factories including a brewery, and hat and shoe factories. On the outskirts of the city is an oil refinery with daily capacity of 6,000 barrels owned and operated by YPFB.

As regards highway network, the existing highway between Cochabamba and Santa Cruz is asphalt paved. The road extending from Chochabamba to La Paz is not paved but is being improved gradually. There is a plan to construct a highway connecting La Paz, Cochabamba, Todos Santos and Santa Cruz. In the future, Cochambamba will develop to be the center of communication and transportation.

3-2-2 Electricity Supply

Electricity is supplied to the cities of Cochabamba and Quilacollo by Empresa de Luz y Fuerza Eléctrica Cochabamba S.A. which owns and operates generation, transmission and distribution facilities. The Empresa's power system is operated on 50 cicles and consists of 5,812 kW of hydro power and 6,742 kW of diesel power. The principal hydro-stations owned by it are Incachaca Power Station which is a run-of-river type plant having an installed capacity of 3,500 kW and Angostura Power Station which is a reservoir controlled plant having an installed capacity of 2,100 kW. The latter is a multiple purpose project including irrigation. Under construction is Corani Hydroelectric Power Station which will have an installed capacity of 27,000 kW in the initial stage and ultimately increased to 54,000 kW. The output of this plant is planned to be transmitted on a 110 kV transmission line to Cochabamba and Oruro.

Major transmission lines in this area are Angostura Line (11 kV, one circuit, 9 km long), Chocay Line (11 kV, one circuit, 17 km long) and Incachaca Line (33 kV, one circuit, 47 km long) all of which are connected to the 11 kV bus of the diesel station in Cochabamba City. Electricity is distributed to the city by a 11 kV loop line from the diesel station. Secondary distribution lines to serve residential, public and hospital demands are operated at

220 V (3-phase, 3-wire system).

Load adjustment of the Cochabamba power system is made chiefly by diesel stations in view of the fact that the two existing hydro-stations have very little regulating capacity to adjust output correspondingly to fluctuation of load and because of operating restrictions imposed by irrigation uses.

Supply capability of the Cochabamba power system is faced with a shortage during the dry season of winter from June to September. During this season load restriction, except hospital and other emergency loads, are imposed by switching off secondary distribution lines in rotation.

The demand on the Cochabamba power system is principally lighting. In 1962, total energy consumed in the system was 20,300,000 kWh, of which 16,440,000 kWh or about 81 per cent was by lighting and the remainder of 3,860,000 kWh (about 19%) was by industries. Under this circumstance, the system load factor is naturally very low. The annual load factor is about 32% and the daily load factor is about 46%. Seasonal heaviest demand occurs during the winter from June to September and restrictive means are taken to curtail power demand during the season. Though the trend of growth of demand can not be precisely estimated on account of the restrictions practiced, the annual rate of growth of energy demand in the past several years (1958 to 1962) were estimated to be 9% for lighting and 4% for industries (average 7.5%), and the annual average rate of growth of maximum demand for the period from 1955 to 1962 was 10%.

Remarkable growth is expected of power demand in Cochabamba area in consideration of the significance of the city being the center of communication and industries, and of the possibilities of the development of industries, such as, processing of agricultural products.

3-3 Oruro and Comibol Central in relation to Santa Isabel Project

3-3-1 General

The population of the city of Oruro was estimated to be about 87,000 in 1962. There are several well known mines around the city, such as, those at

Catavi, Colquiri, Huanuni, San Jose, Viloco, Caracoles and Santa Fe. These mines are all owned by Comibol. The principal minerals produced at these mines are tin and copper, and their production occupies a substantial part of the minerals produced in Bolivia. The city of Oruro is situated about 3,900 m above mean sea level in the Altiplano, and its annual average temperature and precipitation range respectively from 7.5°C to 9°C and from 180 mm to 500 mm. This area is favorably endowed with mineral resources, while to the contrary, agricultural activities in the area are not worthy of mentioning. Raising of alpaca and llama and planting of barley, wheat and quinua are being done on a small scale.

3-3-2 Electricity Supply

The city of Oruro and Comibol Central are incorporated under the some system of electricity supply. The installed capacity in the system is approximately 29,000 kW, of which about 20,000 kW of hydro capacity is owned by Bolivian Power Co., and the remainder belongs to Comibol. The transmission system consists of one (1) circuit of 66 kV transmission line extending over total distance of 220 km.

Power demand in the area was as follows in 1961.

	Maximum demand (kW)	Total energy consumption (kWh)	Annual load factor (%)
Comibol	28,000	132,000,000	54.0
Oruro and Vicinity	4,000	18,000,000	51.5
Total	32,000	150,000,000	53.5

Further growth of power demand in the area will depend upon the production schedule and modernization plan of the mining industries in the area. According to El Plan de Rehabilitación de la minería, the estimated energy and power demands in 1965 are 261,000,000 to 310,000,000 kWh and 41,000 to

49,000 kW respectively.

3-4 Sucre Area in relation to Alto Pilcomayo Project

The population of the city of Sucre was estimated to be about 54,000 in 1962. The city is situated in a hilly zone about 2,800 m above mean sea level. The average annual temperature and precipitation in the city are almost on the same level as Cochabamba and its vicinity.

Stock-farming is considerably prosperous but arable land is very limited. Hat manufacturing and shoe manufacturing factories of small size are found in a few numbers. There is a cement factory with an annual capacity of 28,000 ton owned by CBF and an oil refinery operated by YPFB.

3-4-2 Electricity Supply

Cooperativa Electrica Sucre S.A. is in charge of supply of electricity of the area. Generation, transmission and distribution facilities are owned and managed by the Cooperativa. The power system consists of two hydro plants, namely, Tullma with an installed capacity of 350 kW and Duraznillo with an installed capacity of 100 kW, as well as one diesel station of 1,368 kW capacity situated in the city.

Tullma and Duraznillo power stations are run-of-river type plants and were completed in 1915 and 1922 respectively. The diesel station was completed in 1950. One (1) circuit of 11 kV transmission line 13 km long from Tullma Power Station and another circuit, 9 km long, of the same voltage from Duraznillo Power Station connect into the bus bar of the diesel power plant. Primary distribution lines of 11 kV radially extend from the diesel plant, and at the points of supply, the voltage is reduced to 220 kV for distribution to the consumers. Primary component of demand in the area is lighting for residential and commercial uses. In 1962 the maximum system load was 1,580 kW and the total energy consumption was 4,252,000 kWh. The annual average load factor of the system was 30.7%. The annual rate of growth registered in the period of 1955 through 1962 was 9.5% and 5.3% respectively for power demand

and energy demand.

In the area there are several generating units owned and operated by some industries exclusively for their own use and independently of the public supply system. They are 500 kW of capacity at YPFB's oil refinery and 1,820 kVA of capacity (two units of 370 kVA and 1 unit of 360 kVA as a stand-by) at CBF's cement factory. The per capita energy consumption in 1962, based on the estimated population, were 395 kWh for La Paz, 220 kWh for Cochabamba and 78 kWh for Sucre. The figure for Sucre seems rather small when compared with the general standard of living of the inhabitants in the other cities. This is probably due to load restrictions caused by insufficiency of supply capability and there appears to be a sizeable potential demand in the city.

When the system capability is increased by the addition of hydroelectric capacity in the future and reserve capacity is created, it may be possible to supply electricity to the said cement factory and oil refinery provided that the cost of power is more economical than the prevailing costs to them.

3-5 Potosí and Comibol South in relation to Alto Pilcomayo Project

3-5-1 General

The city of Potosí is situated about 4,000 m above mean sea level. The population of the city was about 55,000 in 1962. Several mines of private management are operated around the city in addition to Quechisla and Unificada mines of Comibol. These mines mostly produce tin. Certain mines have their own refining plant.

3-5-2 Electricity Supply

In this area, the power systems of the two mines of Comibol, the city of Potosí and the several private mines are interconnected and operate as one system.

The power system comprises of 9,000 kW (firm capacity) Yura Hydroelectric Station and a diesel station of 6,000 kW capacity owned by Comibol, and the Cayara Hydroelectric Station with a capacity of 55 kVA and Yocalla Hydroelectric Station with an installed capacity of 1,040 kW owned by private mining companies.

The transmission line network consists of one (1) circuit of 44 kV transmission line of Comibol extending from its Yura Hydroelectric Station to the Quechisla Mine and several mines of Unificada around the city of Potosí. One (1) circuit each of 16.5 kV transmission line from the Cayara and Yocalla hydro stations is connected to the secondary voltage side of Unificada sub-station.

The city of Potosí is served by two (2) circuits (16.5 kV and 2.5 kV) of transmission lines branching out from Unificada sub-station. This voltage is reduced to 220 V and 110 V before distribution to the general consumers.

Power demand in the area was as follows in 1962.

	Maximum demand (kW)	Total energy consumption (kWh)	Annual load factor (%)
Comibol Unificada	3,000	15,963,000	61
Potosí City	1,000	3,852,000	44
Sub Total	4,000	19,815,000	56.5
Comibol Quechisla		26,400,000*	

Note: * for 1961

Energy consumption at the nine (9) mines in Comibol Central and Comibol South was as follows for 9 years beginning from 1953.

(Unit: kWh/ton)

	1953	1954	1955	1956	1957	1958	1959	1960	1961
Mining use	39.5	36.8	38.5	37.5	38.2	43.7	45.5	46.5	43.8
Inclusive of Resident-ial use	51.5	47.3	49.8	50.0	50.8	60.0	64.4	67.0	64.8

3-6 Tarija Area in relation to San Jacinto Project

3-6-1 General

The population of the city of Tarija was estimated to be about 21,000 in 1962. The city is situated about 2,000 m above mean sea level. Humidity is comparatively high, the annual average temperature is 16°C to 18°C, and the annual average precipitation is about 600 mm.

Animal husbandry and farming are the typical activities of the inhabitants around the city. Wheat, maize ahd potato are cultivated though not in substantial quantities. Cattle, sheep and goat are raised and plays an important role in the economy of the area.

No industry worthy of mentioning is found in the area but for a brewery. However, a gradual development of industries may be expected in the future, stimulated by the activities of sugar and oil producing Bermejo which is situated about 250 km to the south of the city and by the existence of air transportation between Cochabamba and La Paz.

3-6-2 Electricity Supply

Electric service in the area is supplied exclusively by CBF which owns and operates generation, transmission and distribution facilities. Generating plants are the Angosto Hydro Station with an installed capacity of 100 kW and a diesel power station of 975 kW, totalling 1,075 kW. The hydro station is a round-of-river type plant completed in 1911, and subsequently in 1963 capacity addition was made. As for the diesel power station, two units of 200 kW were installed in 1953 and another unit of 575 kW was added in 1963. In the dry season, the diesel station is often shut down because continuous operation is impossible due to shortage of cooling water.

Distribution voltage is 6.6 kV on the primary side. General consumers are supplied at a voltage of 220 (3-phase, 4-wire system).

The hydro station is operated to supply base loads and peak demands are supplied with diesel power. However, demand is heavily restricted on account of shut-down of the diesel station for maintenance and shortage of cooling water.

The demand on August 15, 1963 was as follows.

Maximum demand (kW)	Emergy consumption (kWh)	Average demand (kW)	Load factor for the day (%)
759	8,769	364	48

4. DEVELOPMEHT PLAN OF PROJECT SITES

4. Development Plan of Project Sites

4-1 General

Optimum size and timing of development of a project should not be determined according to the results of engineering and economic feasibility studies only, but also in consideration of several environmental factors of economic or political nature, including source of financing of the project. However, for the sake of convenience, the Mission determined the optimum size of the proposed projects on the basis of unit cost of energy available.

The criteria which the Mission, as a principle, took into consideration are described hereinafter.

In the comparative studies of various output of a proposed project, if a given output is able to meet demand throughout a year, the unit cost of available energy is taken. If a given output is not able to meet demand, then the deficiency is supplied by thermal power and the combined unit cost of available energy is obtained. In either case, the lowest cost per unit of energy available is the basis to determine the optimum capacity of a project.

In connection with the timing of a project, the various development projects determined in the manner described above are given priority by comparative studies of several combinations of project priority over a long range period (normally 15 to 20 years) taking into consideration future growth tendency of demand. The priority or timing of a project is determined on the basis of the least cost over a long period within the available source of financing.

In this case, the estimated values of the magnitude and structure of future load growth would naturally vary according to the power system under consideration. Therefore, it would be advisable to study, at the same time, the timing of transmission line interconnection and its contributions.

However, in the studies made by the Mission, the optimum size of a project was determined by general judgement on the basis of rough estimates made according to the aforementioned criteria because basic data were lacking and the degree of reliability of data available was low. In respect of timing of a project, computations were not made as basic conditions necessary to make such computations were not available. In view of the circumstance, the Mission studied the probable situation on the basis of constructing a project within the fastest period from an engineering standpoint on the assumption that the various basic conditions were in order.

4-2 Forecast of Demand

4-2-1 General

It is generally said that the growth of power demand viewed over a long range is correlated to gross national product and consumption. However, in forecasting future power demand of countries in the early stages of economic development, it should be borne in mind that electric power acts as a pilot in the development of the national economy.

In many cases, growth of power demand is likely to be stimulated and accelerated by the introduction of new power consuming industries or by the rapid expansion of existing industries. Especially in developing countries where present power demand remains small, the effect is more pronounced and the demand for power does not grow in a straight line, but the normal growth trend is in steps.

In forecasting future power demand of the areas related to the proposed projects, the Mission has duely taken into account the following seven (7) factors and estimated the general trend over a long-range from a macro point of view.

(1) Trend of power demand in the past, and estimates of future trend based

on data made available to the Mission

(2) Production plan

(3) Per capita energy consumption

(4) Trend of demand growth in other countries with similar conditions as Bolivia

(5) Economic situation of Bolivia

(6) Economic characteristics of the project areas

(7) Future expansion of power system through interconnection of transmission lines with factories which are situated in the environs of the projects and have their own generating plants.

4-2-2 Annual Energy Demand

Annual energy demand was estimated on the basis of data of actual demand and taking into account estimates for isolated independent power system and forced curtailment of demand due to shortage of supply capability. About 9% was estimated as the annual rate of growth of demand for the period 1961 to 1968 taking into account potential demand and economic growth in the regions. It is believed that the potential power demand will be completely absorved by 1968 if addition of capacity proceeds as scheduled.

Bolivia seems to be in the stage of building a foundation for industrial development based on a policy to raise the educational level of its people, to improve the nations road network and to increase agricultural production. These activities to prepare the foundation, we believe, will require 15 to 20 years. Therefore, the rate of growth of demand is likely to slow down during the period from 1968 to 1975 after the potential demand is completely absorved as aforementioned. The estimated annual rate of growth during the said period is around 6%.

If the building of a foundation for economic development progresses as scheduled, it is believed that around 1975 or 1980, the demand for electricity will grow very rapidly and may reach to about 18% annually.

4-2-3 Annual Power Demand

Firstly, the annual load factor was estimated on the basis of actual annual load factors of the past and taking into consideration present restriction of demand due to shortage of supply capability as well as future trend in the growth of load factor due to increase of demand for mining and industrial uses. Then, the annual power demands for each region of consumption were estimated by relating the aforementioned annual load factor to annual energy demand.

4-2-4 Combined Transmission, Transformation and Distribution Losses

Combined loss factor is influenced by several elements, such as, composition of low voltage demand and high voltage demand, regional distribution of demand, location of generating plants, and maintenance condition of distribution network. However, the Mission referred to records of loss factors in the past, maintenance condition of existing distribution networks, transmission-transformation-distribution network improvement and construction plan, as well as data of other countries, and arrived at an estimated annual loss factor of 8% which was used in the calculation of loss for both power and energy. If the estimated loss factor is not conspicuously improper, it may be used for the relative comparison of a project.

4-2-5 Load Curve

Load curve is a necessary factor for the determination of the size of development of a project. Therefore, it is a general practice to draw load curves on a seasonal, week-end and week-day basis.

Load curves were assumed for each region on the basis of actual load curves and duly taking into consideration the present restriction of demand created by the shortage of supply capability and relative increase of day time load corresponding with future development of mining and other industries.

As for power systems for which actual load curve were not available, these were estimated on the basis of load curves of other regions having similarity in demand composition.

However, in consideration of the degree of reliability of data obtained, load curves of each region were assumed to be the same throughout a year.

Table 4-2-1 Estimated Power Demand at Consuming End

		1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
(1) La Paz	Maximum demand (10^3kW)	*39.2 (38.5)	42.7	46.0	49.8	54.2	58.8	62.2	65.9	70.2	73.0	77.6	80.4	85.7	89.2	94.9
	Annual available energy (10^6 kWh)	*137.0 (133.2)	148.7	161.3	175.0	189.9	206.0	223.5	243.0	258.4	274.8	292.2	310.8	330.5	351.5	374.0
	Annual load factor (%)	40.0	40.0	40.0	40.0	40.0	40.0	41.0	42.0	42.0	43.0	43.0	44.0	44.0	45.0	45.0
	Growth rate over the previous year (%)	---	8.5	8.5	8.5	8.5	8.5	8.5	8.5	6.4	6.4	6.4	6.4	6.4	6.4	6.4
(2) Cochabanba	Maximum demand (10^3 kW)	*7.7 (6.2)	8.5	9.4	10.4	11.5	12.6	13.6	15.0	16.1	16.9	18.0	19.3	20.2	21.7	23.4
	Annual available energy (10^6 kWh)	*27.0 (19.7)	29.8	32.9	36.4	40.2	44.3	49.0	54.0	57.9	62.0	66.4	71.1	76.2	81.6	88.0
	Annual load factor (%)	40.0	40.0	40.0	40.0	40.0	40.0	41.0	41.0	41.0	42.0	42.0	42.0	43.0	43.0	43.0
	Growth rate over the previous year (%)	---	10.4	10.4	10.4	10.4	10.4	10.4	10.4	7.1	7.1	7.1	7.1	7.1	7.1	7.1
(3) Oruro and Comibol Central	Maximum demand (10^3 kW)	*34.9 (33.2)	38.1	41.7	44.5	48.9	53.4	57.2	62.4	66.3	68.7	72.9	76.9	81.6	86.4	91.3
	Annual available energy (10^6 kWh)	*159.0 (149.6)	173.8	190.0	207.6	226.9	248.0	271.1	296.0	313.3	331.5	350.9	371.3	393.0	415.9	440.0
	Annual load factor (%)		52.0	52.0	53.0	53.0	53.0	54.0	54.0	54.0	55.0	55.0	55.0	55.0	55.0	55.0
	Growth rate over the previous year (%)	---	9.3	9.3	9.3	9.3	9.3	9.3	9.3	5.8	5.8	5.8	5.8	5.8	5.8	5.8
(4) (2) - (3)	Maximum demand (10^3 kW)	41.4	45.2	49.6	53.3	58.6	64.1	68.7	75.1	80.0	83.1	88.3	93.4	98.8	105.0	111.4
	Annual available energy (10^6 kWh)	*186.0 (169.3)	203.6	222.9	244.0	267.1	292.3	320.1	350.0	371.2	393.5	417.3	442.4	469.2	497.5	528.0
	Annual load factor (%)	51.2	51.3	51.2	52.2	52.0	52.1	53.1	53.0	53.0	54.0	53.9	54.0	54.3	54.1	54.1
	Growth rate over the previous year (%)	---	9.5	9.5	9.5	9.5	9.4	9.5	9.3	6.1	6.0	6.0	6.0	6.0	6.0	6.1
(5) Sucre	Maximum demand (10^3 kW)	*3.1	3.3	3.6	3.8	4.3	4.6	4.9	5.3	5.6	6.0	6.2	6.5	6.8	7.1	7.4
	Annual available energy (10^6 kWh)	*11.0 (3.9)	11.9	12.8	13.8	14.9	16.1	17.3	18.7	19.5	20.4	21.3	22.2	23.2	24.2	25.2
	Annual load factor (%)	41.0	41.0	41.0	41.0	40.0	40.0	40.0	40.0	40.0	39.0	39.0	39.0	39.0	39.0	39.0
	Growth rate over the previous year (%)	---	7.9	7.9	7.9	7.9	7.9	7.9	7.9	4.4	4.4	4.4	4.4	4.4	4.4	4.4
(6) Potosí and Comibol South	Maximum demand (10^3 kW)	*16.0 (15.2)	17.5	18.3	19.8	21.5	22.6	24.5	26.4	27.2	28.6	29.3	30.7	32.3	33.1	34.7
	Annual available energy (10^6 kWh)	*55.5 (47.6)	60.2	65.3	70.8	76.7	83.1	90.1	97.7	102.5	107.5	112.8	118.3	124.1	130.2	136.6
	Annual load factor (%)	40.0	40.0	41.0	41.0	41.0	42.0	42.0	42.0	43.0	43.0	44.0	44.0	44.0	45.0	45.0
	Growth rate over the previous year (%)	---	8.4	8.4	8.4	8.4	8.4	8.4	8.4	4.9	4.9	4.9	4.9	4.9	4.9	4.9
(7) (5) + (6)	Maximum demand (10^3 kW)	18.5	20.0	21.3	22.9	25.0	26.4	28.5	30.8	31.8	33.6	34.5	36.1	38.0	39.0	40.9
	Annual available energy (10^6 kWh)	*66.5 (51.5)	72.1	78.1	84.6	91.6	99.2	107.4	116.4	122.0	127.9	134.1	140.5	147.3	154.4	161.8
	Annual load factor (%)	41.1	41.0	41.8	41.9	42.0	42.8	42.8	43.2	43.7	43.5	44.3	44.3	44.2	45.1	45.2
	Growth rate over the previous year (%)	---	8.4	8.3	8.3	8.3	8.3	8.3	8.4	4.8	4.8	4.8	4.8	4.8	4.8	4.8
(8) (4) + (7)	Maximum demand (10^3 kW)	57.0	62.1	67.5	72.6	79.6	86.2	92.6	100.9	106.5	111.1	117.0	123.3	130.3	137.1	145.0
	Annual available energy (10^6 kWh)	*252.5 (220.8)	275.7	310.0	328.6	358.7	391.5	427.5	466.4	493.2	521.4	551.4	582.9	616.5	651.9	689.8
	Annual load factor (%)	50.5	50.7	51.0	51.5	51.4	51.9	52.7	52.6	52.9	53.6	53.8	53.9	54.0	54.3	54.3
	Growth rate over the previous year (%)	---	9.2	9.2	9.2	9.2	9.1	9.2	9.1	5.7	5.7	5.8	5.7	5.8	5.7	5.8
(9) Tarija	Maximum demand (10^3 kW)	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.7	1.8	1.8	1.9	2.0	2.1	2.2	2.3
	Annual available energy (10^6 kWh)	*3.6 (2.5)	3.9	4.2	4.5	4.9	5.3	5.7	6.1	6.3	6.6	6.9	7.2	7.5	7.9	8.2
	Annual load factor (%)	45.0	45.0	44.0	44.0	43.0	43.0	42.0	42.0	41.0	41.0	41.0	41.0	41.0	41.0	41.0
	Growth rate over the previous year (%)	---	7.8	7.8	7.8	7.8	7.8	7.8	7.8	4.3	4.3	4.3	4.3	4.3	4.3	4.3
Total	Maximum demand (10^3 kW)	101.8	110.6	120.1	129.5	141.7	153.4	163.9	176.7	187.2	195.0	205.9	215.8	228.7	239.7	254.0
	Annual available energy (10^6 kWh)	*393.1 (356.5)	428.3	466.5	508.1	553.5	602.8	656.7	715.5	757.9	802.8	850.5	900.4	954.5	1,011.3	1,072.0
	Annual load factor (%)	44.1	44.2	44.4	44.6	44.6	44.9	45.8	46.1	46.2	47.0	47.2	47.5	47.7	48.1	48.2
	Growth rate over the previous year (%)	---	9.0	8.9	8.9	8.9	8.9	8.9	9.0	5.9	5.9	5.9	5.9	5.9	6.0	6.0

Notes: (1) Figures in parenthesis are actual and does not include industrial plants.
(2) Figures marked with asterisk include potential demand and industrial plants.
(3) Diversity factor 1.03 for (2), (3), (5) and (6) and 1.05 for (4) and (7).

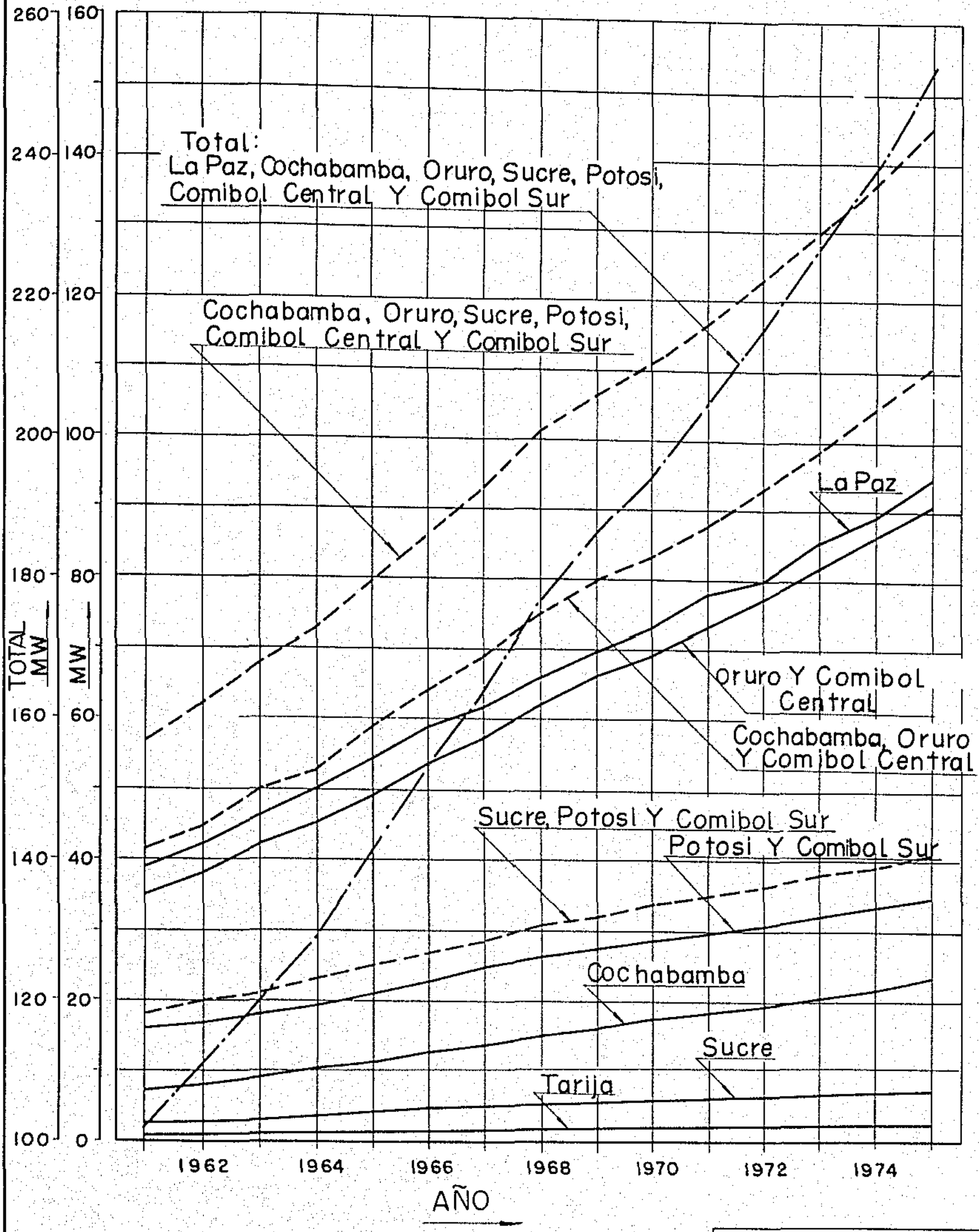


FIG. 4-2-1 DEMANDA MAXIMA

MISION TECNICA JAPONESA PARA DESARROLLO HIDRO-ELECTRICO A BOLIVIA
DEMANDA MAXIMA
FECHA : mar. 1964

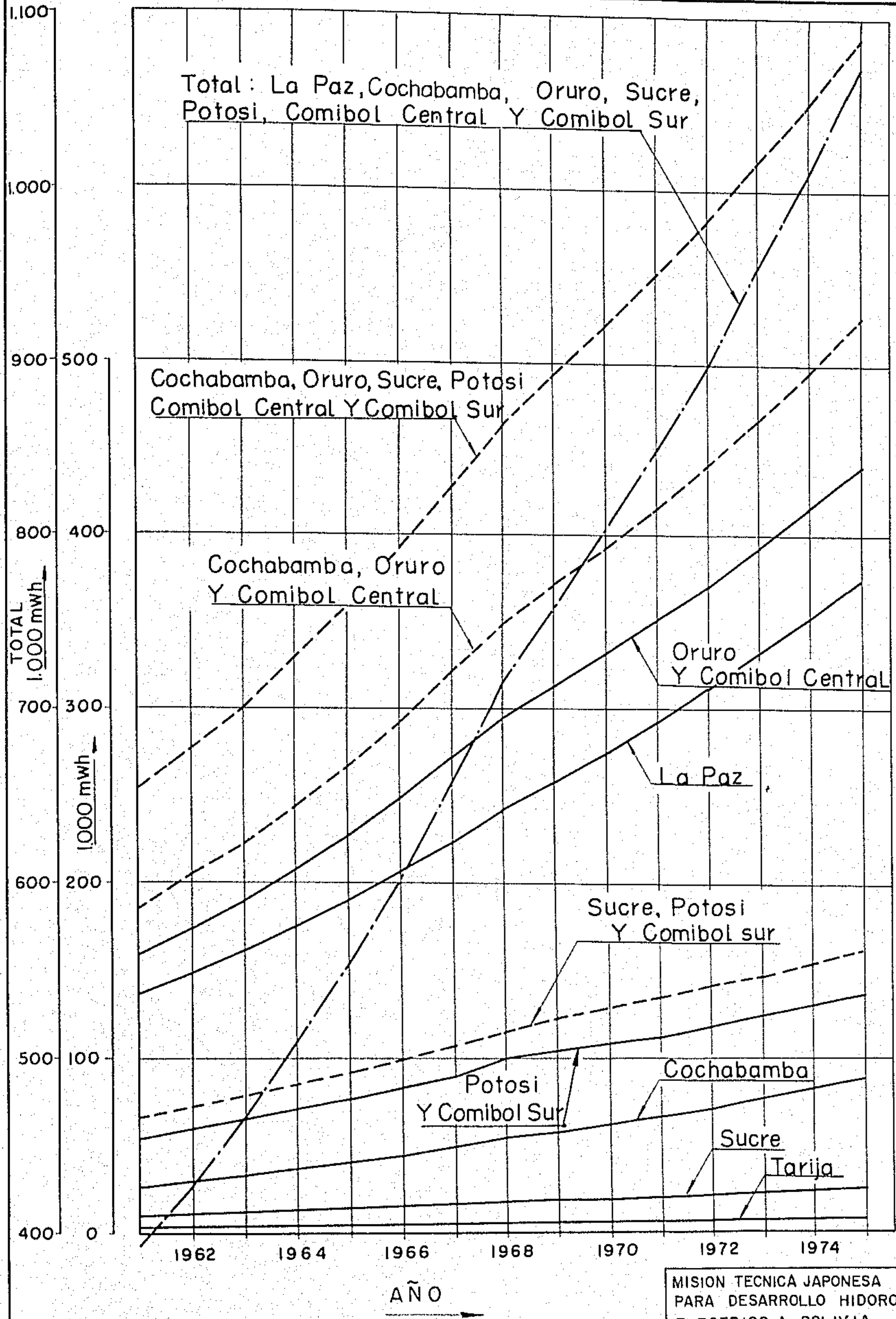
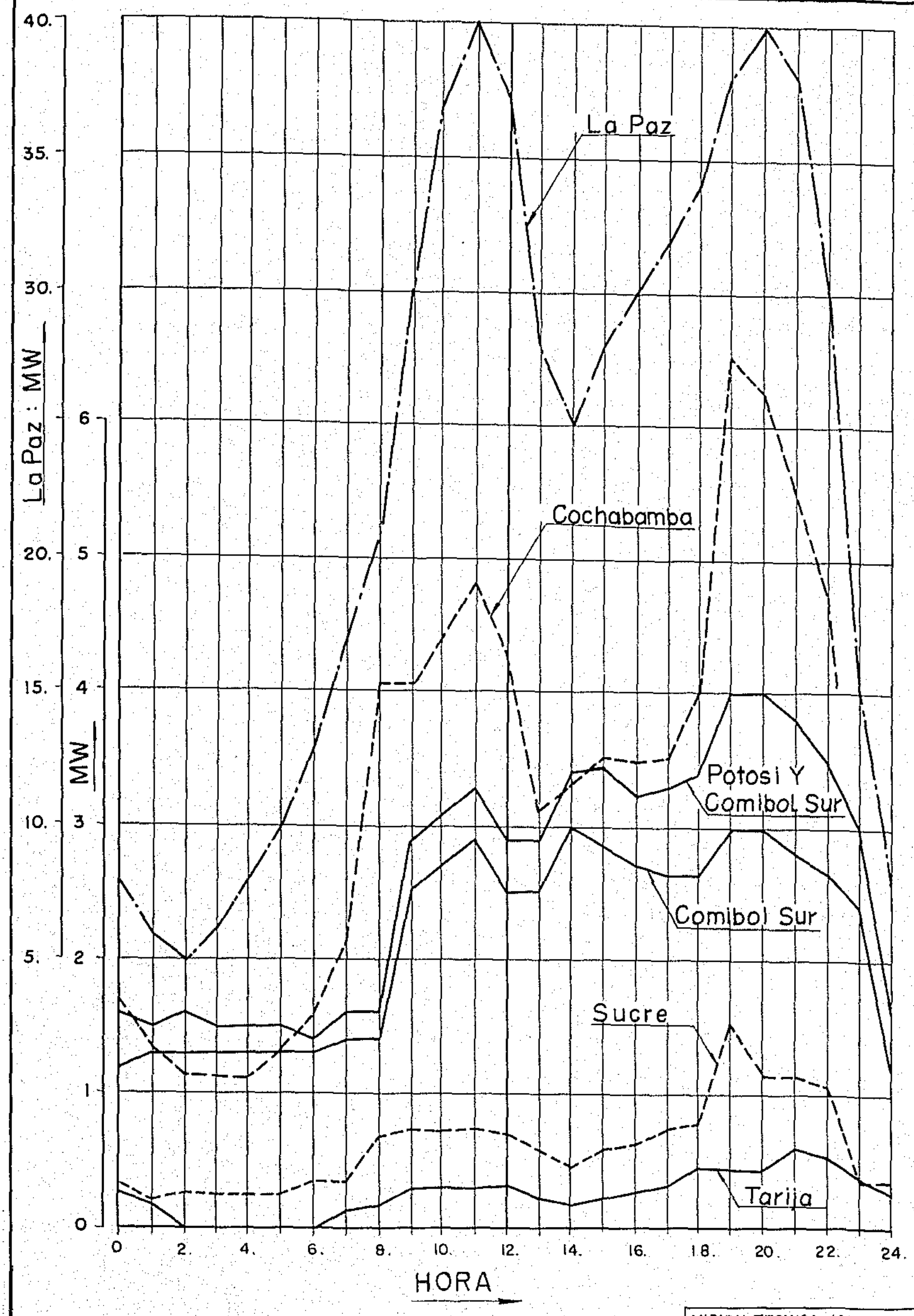


FIG. 4-2-2 CONSUMO DE ENERGIA

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

CONSUMO DE ENERGIA

FECHA mar, 1964



MISION TECNICA JAPONESA PARA DESARROLLO HIDRO-ELECTRICO A BOLIVIA
CURVA DE CARGA REAL (EN 1 - Julio - 1962)
FECHA : mar. 1964

FIG. 4-2-3 CURVA DE CARGA REAL
(EN 1 - Julio - 1962)

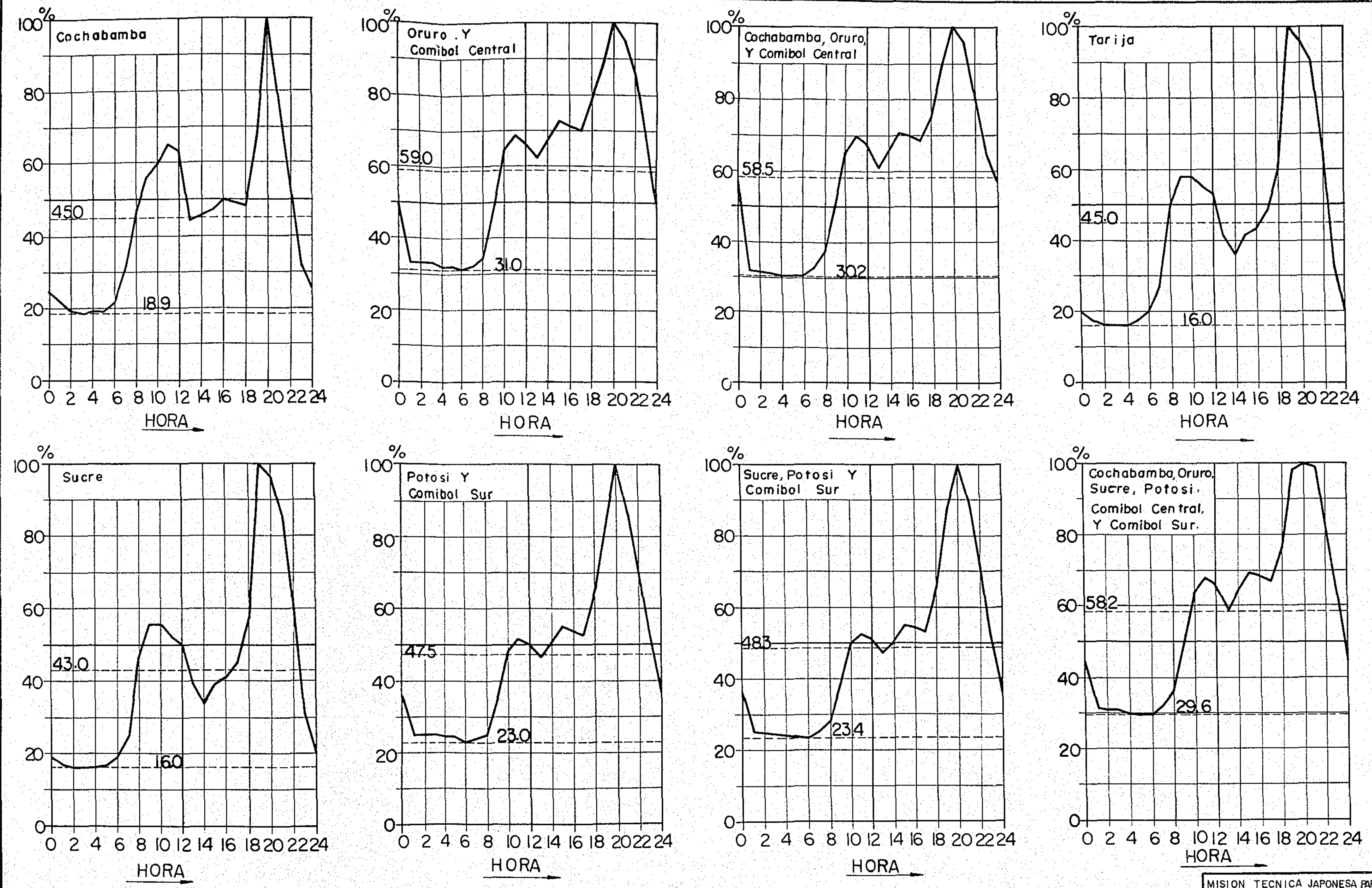


FIG. 4-2-4 CURVA DE CARGA ESTIMADA

MISION TECNICA JAPONESA PARA DESARROLLO HIDRO ELECTRICO A BOLIVIA

CURVA DE CARGA ESTIMADA

FECHA : mar. 1964

4-3 Santa Isabel Project

4-3-1 General

The Santa Isabel Project should be planned as a component of the integrated development of the area, including the Corani and Locotal Projects.

However, concrete plans have not been developed for the Santa Isabel Project at this stage when the construction works of the Corani Project is about to get underway. CBF thought of the development of this site and in April 1963 established a gaging station on the Río Vinto as the first step of the investigation of this site. With the assistance of CBF the Mission conducted reconnaissance and simplified survey of the proposed site, as well as, collection of basic data.

4-3-2 Location

The site of the Santa Isabel Project is located on the Río Santa Isabel 5 km downstream of the site of the Corani Project (54,000 kW) which is situated 50 km to the northeast of the city of Cochabamba. Access to the site is by means of a road passing from Cochabamba to Paracti. The section of the road from Cochabamba to the proposed dam site of the Corani Project is well maintained to allow uninterrupted motor traffic, but the section on the hillside beyond this point to the proposed Santa Isabel site is not well maintained. When this section of the road is improved in the future, access to site of the Santa Isabel Project will be possible within 3 hours from the city of Cochabamba.

There are almost no inhabitants settled around the project area, and the Mission was compelled to utilize the camp facilities of the Corani Project as the base camp during the reconnaissance of the Santa Isabel site.

4-3-3 Hydrology and Meteorology

Hydrological and meteorological data made available to the Mission are given in the following Table 4-3-1.

Table 4-3-1 Hydrological and Meteorological

Data of the Santa Isabel Project

	Period of Recording			Remarks
	from	to	for	
Corani Gaging Station and Observatory				
Discharge measurement by current meter	Jan- 3-'53	Feb-22-'59	6 years and 2 months	Measured 21 times during the period
Daily water level	Oct-28-'52	Dec-31-'62	10 years and 2 months	Records are not available for Nov. and Dec. 1956 and Mar. Apr. and May 1957
Daily precipitation	Jul- 1-'53	Dec-31-'62	9 years and 6 months	Records are not available for the period from Aug. to Dec. 1956 and Jan. to Dec. 1957
Daily evaporation	Jan- 1-'58	Dec-31-'62	5 years	
Daily atmospheric temperature	Jan- 1-'58	Dec-31-'61	5 years	Maximum and minimum
Daily water temperature	Jan- 1-'58	Dec-31-'61	5 years	
Daily wind	Jan- 1-'58	Dec-31-'60	4 years	
Vinto Gaging Station				
Discharge measurement by current meter	Apr-24-'63	Oct- 3-'63		Measured 6 times during the period
Daily water level	Jan- 1-'63	Sep-30-'63	10 months	Records are not available for Feb. 1963
Daily precipitation	Jan- 1-'62	Sep-30-'63	1 year and 10 months	Observed at Pampa Tombo Records are not available for Feb. and Apr. 1963

Water level and discharge were not recorded at the Corani Gaging Station in November and December 1956 and March, April and May 1957. Daily precipitation records of these months are also not available. It was impossible to estimate run-off from precipitation records. Therefore, the average discharge for the 9 year period, excluding the missing months, was obtained and this value was taken as the discharge of the months, for which records are missing, to make a complete run-off data over the past 10 years. Of the estimated annual run-off for the said 10 year period, the run-off during the period of September 1961 to August 1962, which is closest to the average annual run-off of the said 10 years, was taken as the typical run-off year.

Records of water level of the Río Vinto are available for eight months in 1962. However, the data could not be used as a basis to estimate the run-off of the Río Vinto because a formula to calculate run-off has not been established, and it was not possible to estimate run-off from the data made available to the Mission.

Accordingly, the run-off at the proposed intake site on the Río Vinto was estimated from the run-off at the gaging station on the Río Corani on the basis of the ratio of catchment area. (See Table 4-3-2 and Fig. 4-3-1)

Table 4-3-2 Monthly run-off at the Corani Gaging Station and Intake Site on the Río Vinto

(Unit: m^3/s - day)

	Corani Gaging Station (CA = 269 km^2)	(CA = 100 km^2)	Intake site Río Vinto (CA = 23.5 km^2)
September	54.4	20.4	4.8
October	42.8	15.9	3.7
November	57.4	21.3	5.0
December	270.7	100.5	23.6
January	383.6	143.0	33.6
February	123.4	45.7	10.7
March	333.1	123.8	29.1
April	87.6	32.6	7.7
May	44.9	16.7	3.9
June	16.8	6.4	1.5
July	18.7	6.8	1.6
August	9.7	3.6	0.8
Total	1,443.1	536.7	126.0

Note: (1) Twelve months from September 1961 to August 1962 being taken as typical annual run-off.

(2) CA means catchment area.

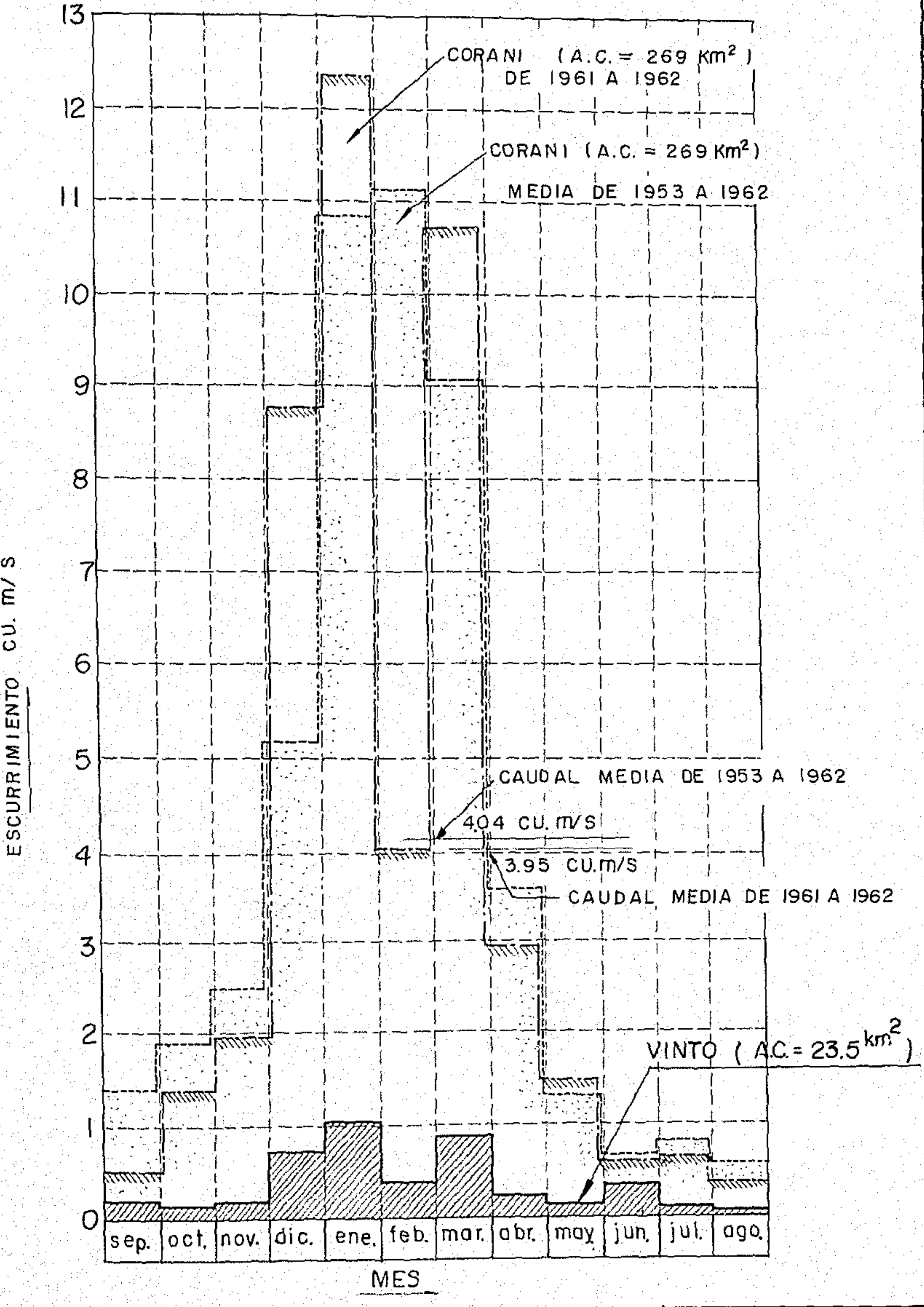


FIG. 4-3-1

ESCURRIMIENTO MEDIA DE MES EN CORANI Y VINTO.

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA
PROYECTO DE SANTA ISABEL
ESCURRIMIENTO MEDIA DE MES EN CORANI Y VINTO
FECHA : mar. 1964

4-3-4 Topography and Geology

The topographical map to a scale of 1/10,000 which was made available to the Mission by CBF covers the areas of the Corani, the Santa Isabel and the Local projects. It was found by altimeter survey conducted by the Mission that there is an error of 100 m in elevation on the said map.

In order to locate correctly the proposed intake site on the Río Vinto, altimeter survey and traverse survey were conducted over a distance of 1.6 km along the river upstream from the site of the Vínto Bridge. On the basis of the data obtained by the said surveys the elevation in the map was corrected by the Mission. The project area is a steep valley extending from the eastern side of the Andes Mountains to the Amazonian marshland. The Río Corani and the Río Santa Isabel run parallel to each other separated by a mountain divide and there is an available hydraulic head of about 1500 m between the two rivers. The Corani and Santa Isabel are designed to utilize this head.

The geology of the area is generally composed of sandstone, quartzite and slate. The site of the Corani powerhouse appears to be marshland, but geological surveys by means of drilling have indicated that the bedrock of this site is a formation of the glacial period.

The route of the proposed canal from the intake on the Río Vinto to the proposed powerhouse site is a gently sloping plateau covered heavily with trees. From observations there appears to be no danger of landslides. The Río Vinto is a steep river on a gradient of 1/6 to 1/25. Certain sections of the riverbed is covered with a gravel deposit including boulders. The river upstream of the point around EL 2,600 m is separated into two streams. It is proposed to construct an intake structure on both streams. Bedrock is exposed at both proposed intake sites, and the rock appears to be sound and adequate to construct an intake structure. The geology of No. 1 Intake is slate dipping at an angle of 20 to 30 degrees. The No. 2 Intake site is sound sandstone or quartzite dipping at an angle of 45 degrees. The route of the proposed non-pressure tunnel from the intake site on the Río Vinto to the head tank runs through hard sandstone and it is believed that the tunnel will not require lining.

As for the proposed route of penstock, the upper part of which (down to existing road) is on a slope of 35 degrees. Bedrock is exposed and it appears that the rock is adequate for the foundation of penstock. Downwards therefrom the mountain slope is 15 degrees and is covered heavily with trees. From observations, it appears that in certain places overburden is relatively thick.

A spillway is proposed at a site which is about 600 m upstream of the head tank. Water spilled through the spillway will be discharged into a valley on the eastern slope of Río Vinto. Bedrock is exposed on the site of the proposed spillway and it is believed that there should be no difficulty in constructing it.

The river bed at the proposed powerhouse site is covered with gravel deposit including boulders. There are outcrops of slate on both banks of the river, and from observations it appears that the gravel deposit is not very deep.

The run-off of the Río Santa Isabel and Río Vinto is clear water and judging from the nature of the geology of the basin, it appears that the river is not silt-carrying.

4-3-5 Development Scheme.

Studies of the Project

The Santa Isabel Project is to utilize the discharge of the Corani Project and the non-regulated run-off of the Río Vinto. However, in view of the fact that the run-off of Río Vinto is very small, the maximum discharge of the project will be $10m^3/s$ which is the same as that of the Corani Project. The annual average discharge of the Santa Isabel Project is around $4m^3/s$. In consideration of the topography and geology of the proposed site, no power plant other than a run-of-river type plant is conceivable for the project.

The site of the plant as well as the tailrace elevation should be determined in relation to the proposed Locotal Project on the downstream. However, topographical conditions and other elements will create an idle head between the two projects.

Electricity available from the Santa Isabel Project is to supply demands in the areas of Cochabamba and Oruro. Therefore, the decision of whether to develop the project in one stage or several stages should be made upon carefully study of the trend of growth of demand in the said areas of consumption.

The plan proposed by the Mission is a one-stage development in which the available head is to be developed in a single stage. As an alternative plan, the available head can be developed in two stages, i.e., by two power plants located in series. However, comparative studies show that development of the available head in one plant is much more economical than the alternative.

Plant Capacity and Energy Output

According to the studies aforementioned, a maximum output of 62,000kW is available under an effective head of 780m and maximum discharge of $10m^3/s$. Annual available energy of the plant will be 241,200,000kWh including the available discharge of the Río Vinto. The estimated monthly energy output is given in the following table.

Table 4-3-3 Monthly Energy Output of Santa Isabel Project

(unit: kWh)

January	21,800,000
February	19,100,000
March	21,800,000
April	19,800,000
May	20,000,000
June	18,900,000
July	19,600,000
August	19,500,000
September	19,500,000
October	20,000,000
November	19,500,000
December	21,700,000
Total	241,200,000

Descriptive Data

Power Plant	Type	run-of-river
	Maximum capacity	62,000 kW
	Maximum discharge	10 m^3/s
	Effective head	780 m
	Annual available energy	241,200,000 kWh
Catchment area		292.5 km^2 (Río Corani 269 km^2, Río Vinto 23.5 km^2)

Structures

Water way	Wet masonry lined trapezoidal cross section	
	Maximum capacity	10 m^3/s
	Width at bottom	1.5 m
	Slope of wall	1:1
	Depth	3 m
	Gradient	1/1,000
	Length	approx. 2.3 km
No.1 Aqueduct	Reinforced concrete structure	
	Maximum capacity	10 m^3/s
	Length	approx. 40 m
No.1 Intake	Non-reinforced concrete structure	
No.2 Aqueduct	Reinforced concrete structure	
	Maximum capacity	10 m^3/s
	Length	approx. 40 m
No.2 Intake	Non-reinforced concrete structure	
Tunnel	Maximum capacity	10 m^3/s
	Cross section	semi-circular and rectangular shape 3 m wide, 3 m high
	Gradient	1/1,000
	Length	approx. 2 km
Head tank	Type	tunnel
	Cross section	semi-circular and rectangular shape 4 m wide, 4 m high
	Length	approx. 0.6 km
	Length of overflow section	approx. 50 m

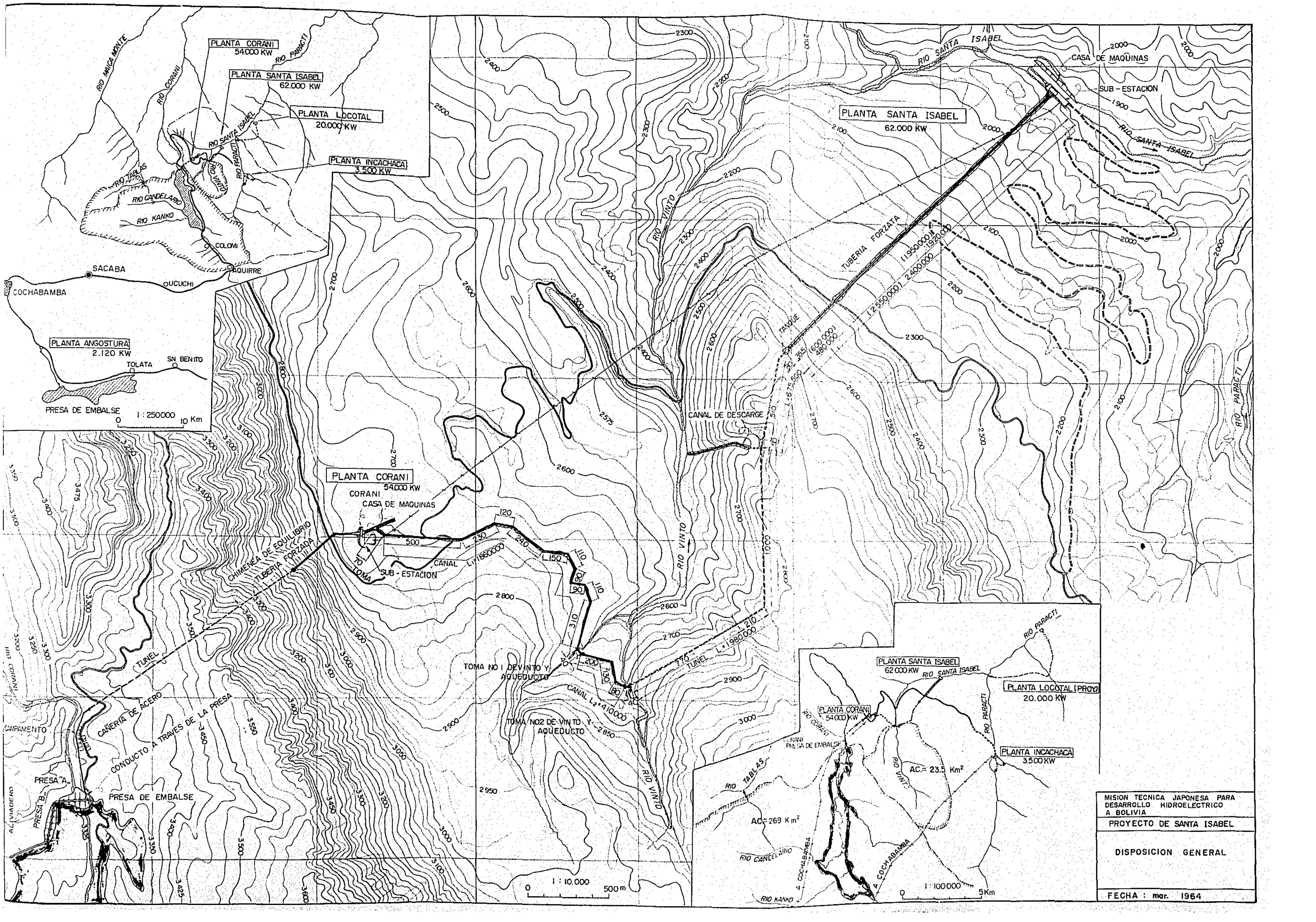
Penstock	Upper section	
	Gradient	approx. 35°
	Number of pipe	1
	Inside diameter	tapering from 2.0 to 1.8 m
	Length	approx. 0.6 km
	Lower section	
	Gradient	approx. 25°
	Number of pipe	2
	Inside diameter	tapering from 1.3 to 0.9 m
	Length	approx. 1.95 km each
Powerhouse	Type	indoor type
Turbines	Type	horizontal shaft Pelton turbine
	Capacity	62,000 kW (15,500kW, 4 units)
Generators	Type	synchronous generator
	Capacity	72,800kVA (18,200kVA, 4 units)
Transmission Line	Santa Isabel Power Station to Corani Substation	
	Length	approx. 4.8 km
	Voltage	110 kV

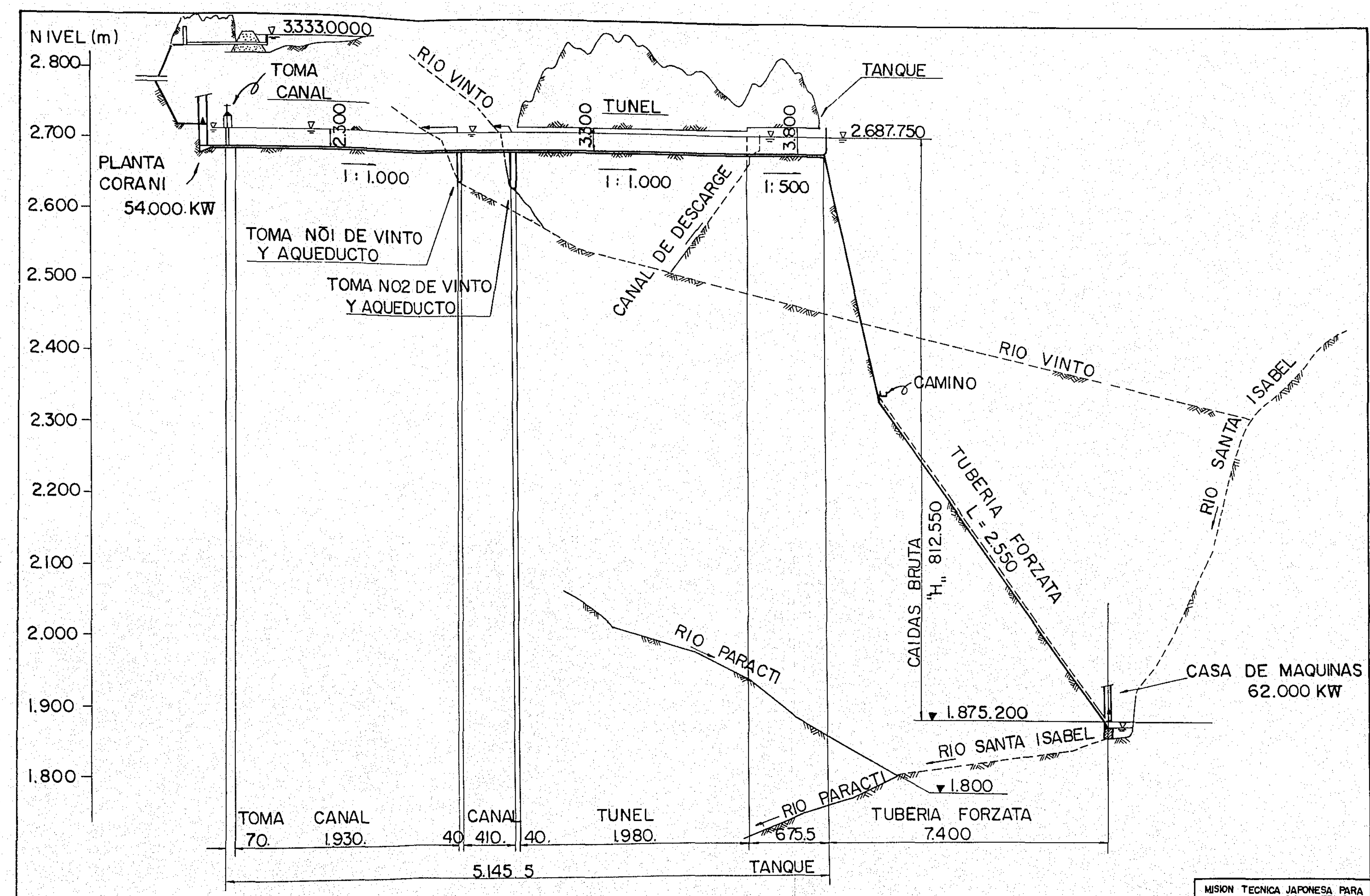
<u>Estimated Construction Costs and Cost of Power</u>

Total construction costs	US$ 11,600,000
Waterway (inclusive of canal, No.1 and No.2 aqueducts, No.1 and No.2 intakes, tunnel, head tank and penstock)	4,600,000
Power plant (inclusive of powerhouse building, substation, equipment and others)	6,800,000
Transmission Line	60,000
Others	140,000
Unit construction costs	
Per kW of capacity	US$ 187
Per kWh of available energy	US$ 0.048

Power cost

Assuming an annual cost of 8% against the construction cost, the unit cost of energy produced is US$ 0.00384. This 8% annual cost is based on an annual interest charge of 6% and other costs including depreciation of 4% which were averaged over a 45 years serviceable life of the plant.


PLANTA CORANI
54000 KW
PLANTA SANTA ISABEL
62.000 KW
PLANTA LOCOTAL
20.000 KW
PLANTA INCACHACA
3.500 KW
RIO MALGA MONTE
RIO CORANI
RIO PARACTI
RIO SANTA ISABEL
RIO VINTO
RIO TABLAS
RIO CANDELARIO
RIO KANKO
COLOMI
AGUIRRE
SACABA
UCUCHI
COCHABAMBA
PLANTA ANGOSTURA
2.120 KW
TOLATA
SN BENITO
PRESA DE EMBALSE
1 : 250000
0
10 Km
CASA DE MAQUINAS
SUB - ESTACION
TUBERIA FORZATA
TANQUE
CANAL DE DESCARGE
PLANTA CORANI
54000 KW
CORANI
CASA DE MAQUINAS
CANAL
TOMA
SUB - ESTACION
CHIMENEA DE EQUILIBRIO
TUBERIA FORZADA
TUNEL
CAÑERIA DE ACERO
CONDUCTO A TRAVES DE LA PRESA
CAMPAMENTO
PRESA "A"
PRESA "B"
ALIVIADERO
PRESA DE EMBALSE
TOMA NO 1 DE VINTO Y AQUEDUCTO
TOMA NO 2 DE VINTO Y AQUEDUCTO
CANAL
TUNEL
1 : 10.000
0
500 m
PLANTA SANTA ISABEL
62.000 KW
PLANTA LOCOTAL (PROY)
20.000 KW
PLANTA CORANI
54000 KW
PRESA DE EMBALSE
PLANTA INCACHACA
3.500 KW
AC = 23.5 Km²
AC = 269 Km²
A COCHABAMBA
1 : 100000
0
5 Km
MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA
PROYECTO DE SANTA ISABEL
DISPOSICION GENERAL
FECHA : mar. 1964



PERFIL DE PLANTA

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE SANTA ISABEL

PERFIL DE PLANTA

FECHA : mar. 1964

4-4 Alto Pilcomayo Project

4-4-1 General

Development of the Alto Pilcomayo site was originally proposed by Canutillos Mining Company which in 1928 investigated the feasibility of its development. In 1943 the Patino Groupe Mining Company conducted studies and investigations of the site as a potential source of supplying the electricity required for the operation of several mines, such as, Catavi, Huanuni, Japo, Calavi etc. However, the data obtained through these investigations are not available, at present.

In 1956, the development of this site was studied by Cooperativa Electrica Sucre S.A., but the project was not realized from financial and other reasons.

CBF started reconnaissance in this project area in 1961 and since then it has improved the roads to the site. In 1963, CBF established a streamflow gaging station and meteorological observatory as the first step of studying this site in detail.

The proposed project covers a vast catchment area of 7,300 km^2, and in order to prepare a development plan of the site, adequate kinds and numbers of reliable data are essential. However, recording of data was started very recently and at this stage, only a few data have been available for the purpose of planning. It is essential that continuous and uninterrupted observations are conducted.

Topographical map of the project area was not available, and the Mission was compelled to conduct simple surveying for the topography around the site.

The Mission recognized the necessity of reconnoitering an extensive area, but in view of its limited schedule, this was not possible. Neither was the Mission able to confirm the available hydraulic head at this site. Under the circumstances, the Mission discussed prevailing conditions at the proposed site with engineers of CBF as a means of determining the degree of realiability of data collected.

4-4-2 Location

The proposed site of the Alto Pilcomayo Project is located in the Talula Valley on the Río Pilcomayo. The site is 25km to the southwest of the city of Sucre and 56km to the northeast of the city of Potosí. A road leads from the city of Sucre to Chullchuta crossing the Río Cachimayo at San Juan. The road is negotiable by jeep but is not passable on large trucks.

Beyond this point, access to Tulala Valley via the Village of Quilaquila, a distance of about 15km, is on foot or horse back. Travel time between Sucre and Talula is about ten hours. A road is under construction up to Talula, and when this section is completed and the existing road is improved it will become possible to travel between Sucre and the proposed dam site by small truck in about two hours.

Camping facilities which may be used during field investigations are the lookout post maintained by CBF and residences in the village of Quilaquila. However, these accommodations will be inadequate when full scale field investigations are started.

In the rainy season, crossing of the Río Cachimayo and the Río Talula is normally interrupted for about 4 months. Therefore, measures should be taken to overcome this situation in order that investigation may be continued even in the rainy season.

4-4-3 Hydrology and Meteorology

As a whole hydrological and meteological data, which are indispensable in planning a hydroelectric development, are not available. Data made available to the Mission are the records of Alto Pilcomayo Gaging Station (at Talula), as well as Sucre and Potosí meteorological observatories. These data are given in the table which follows.

Table 4-4-1 Hydrological and Meteorological Data of the Alto Pilcomayo Project

	Period			Remarks
	from	to	for	
Alto Pilcomayo Gaging Station				
Discharge measurement by current meter	Feb-22-'63	Sep-18-'63	7 months	Measured 11 times during the period.
Daily water level	Aug- 1-'62	Jan-10-'63	5 months	*
Daily water level	Feb- 1-'63	Aug-31-'63	7 months	**
Daily precipitation	May- 1-'62	Aug-31-'63	14 months	***
Sucre Observatory				
Daily Precipitation	1950	1961	12 years	
Monthly average temperature	1950	1961	12 years	
Wind velocity & direction	1950	1961	12 years	****
Potosí Observatory				
Monthly average precipitation	1946	1960	15 years	*****

Note: * Corresponding measurement were not made, and discharge could not be computed.
** Discharge could be computed based on the 11 measurement records.
*** Records are missing for Jan. and Feb., 1963.
**** Monthly mean value for the period.
***** Mean value for the period.

The Mission, after its return to Japan, estimated discharge for the purpose of planning based on the data shown in Table 4-4-1, by the following way.

Based on the eleven discharge measurements made during Feb. through Sept., 1963, a formula between water level and discharge were established as shown in Fig. 4-4-1. From the formula, monthly discharge could be computed for the period from February to August 1963 as shown in Fig. 4-4-2. (As it is shown in Fig. 4-4-1). All the discharge measurements were made for water levels lower than 2 m, and therefore, for a water level higher than 2 m, the above formula may not be reliable. So, the discharges shown in Fig. 4-4-2, may be used for months of April through August, as the water level in these months are always lower than 2 m. However, for months of February and March when the water level often exceed 2 m, and for months September through January when the water level were not recorded, some other method should be necessary.

From reasons shown above, the following method was utilized in estimating the discharge for the Alto Pilcomayo Project.

Discharges, April through August, were computed based on the above formula and recorded water level in 1963. However, because the Mission was not able to tell whether the year, 1963, was a wet or dry year, due to lack of precipitation data, 80% of the computed values were used, to be on the safe side in preparing the project plan.

Discharges, September through March, were computed based on average monthly precipitation of Sucre and Potosí, and on an assumed coefficient of run-off. As no reliable information concerning run-off coefficient in Bolivia was available, reference was made to the average run-off coefficient of Pasto Grande in Perú, where precipitation, topographic and geologic conditions are quite similar to the area under consideration. Thus a run-off coefficient of 23% was used for the Project, giving the quantity of flow by the following formula.

$$Qm = Rm \times 0.23 \times \frac{100,000}{86,400} = 0.266 \times Rm$$

where: Qm Monthly discharge (m^3/s-day/100 km^2)

Rm Monthly average precipitation of Sucre & Potosí (mm)

The results obtained by the above method, are shown in the following Table 4-4-2.

Table 4-4-2 Monthly Run-off at the Site of the Alto Pilcomayo Project

	R_1(mm) Average precipitation in Sucre	R_2(mm) Average precipitation in Potosí	$\frac{R_1 + R_2}{2}$ (mm)	Design run-off (CA = 100km^2)		Run-off at the site (CA = 7,280km^2)
				Estimated from precipitation (m^3/s-day)	Recorded (m^3/s-day)	(m^3/s-day)
September	36.1	7.9	22.0	6.0	-	437
October	34.4	8.1	21.3	5.8	-	422
November	75.8	22.0	48.9	13.3	-	965
December	119.5	49.8	84.7	22.8	-	1,660
January	182.4	90.2	136.3	36.8	-	2,680
February	124.4	83.0	103.7	28.0	-	2,040
March	74.1	58.1	66.1	17.8	-	1,300
April	24.4	6.9	15.7	-	10.3	750
May	3.3	1.4	2.4	-	4.7	342
June	0.5	2.4	1.5	-	2.7	197
July	3.0	0.3	1.7	-	2.4	172
August	7.4	0.1	3.8	-	2.4	173
Total	685.6	330.2	508.1	153.0		11,138

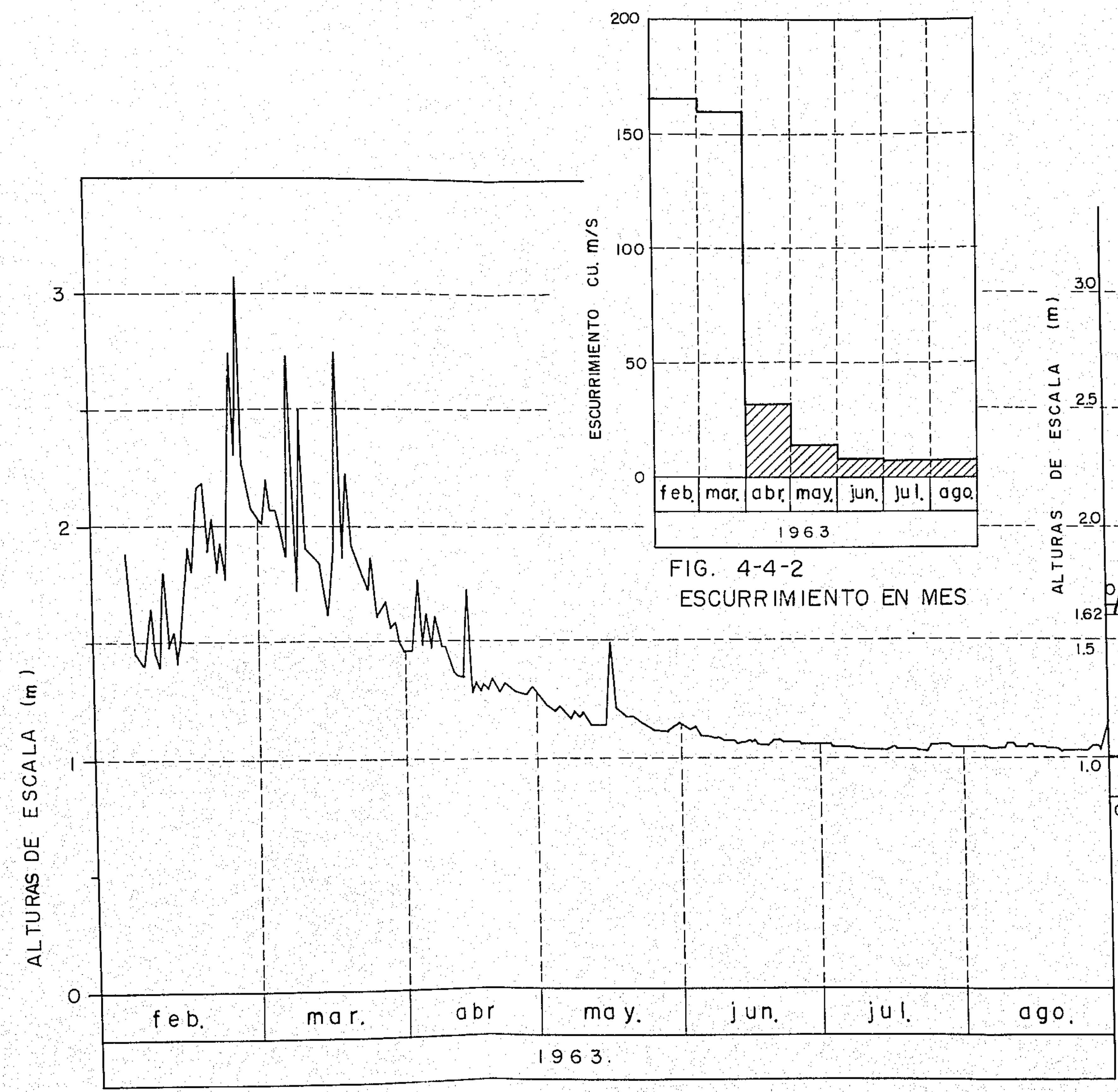
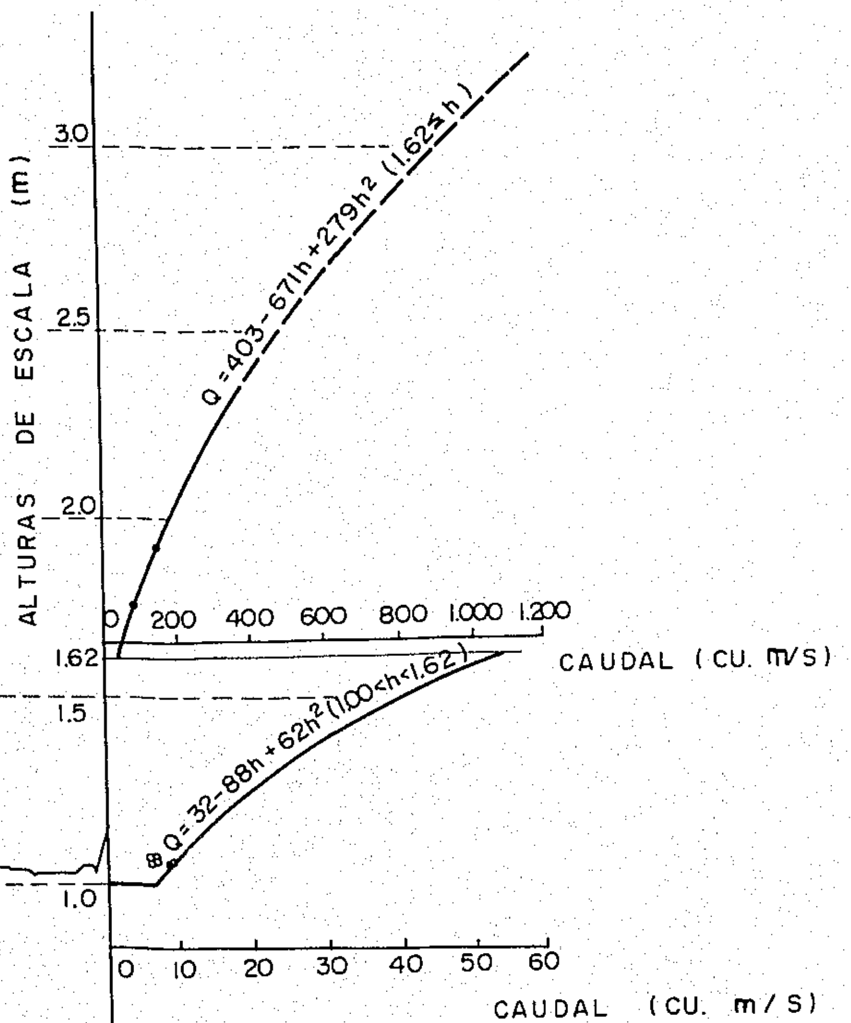


FIG 4-4-1
ALTURAS DE ESCALA ALTO PILCOMAYO



CAUDALES CLASIFICADOS

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE ALTO PILCOMAYO

ALTURAS DE ESCALA ALTO PILCOMAYO

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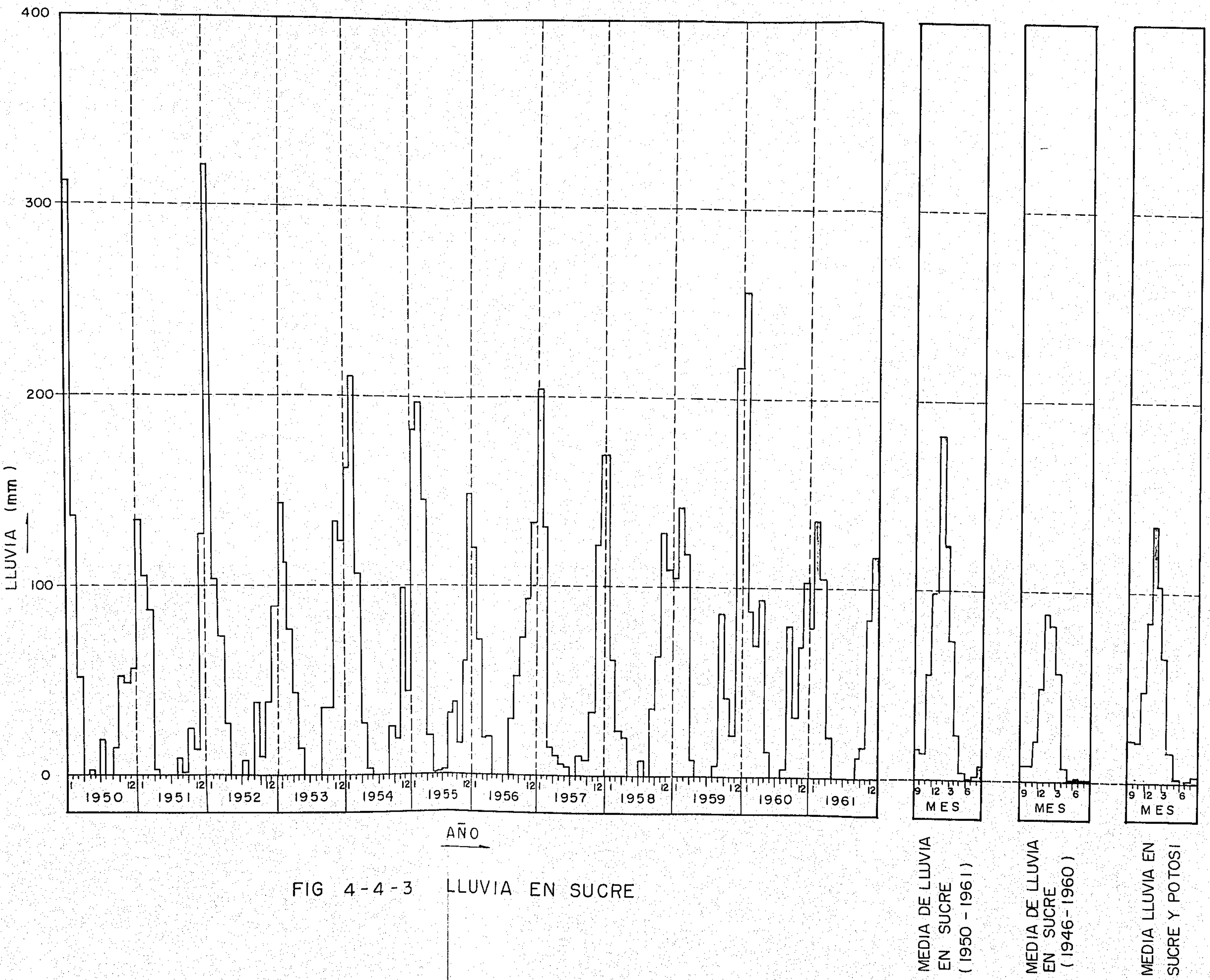

FIG 4-4-3 LLUVIA EN SUCRE

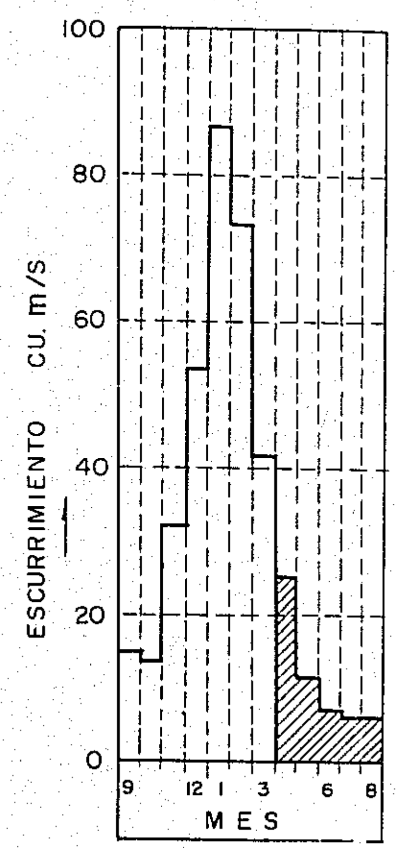

FIG. 4-4-4
ESCURRIMIENTO EN MES

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE ALTO PILCOMAYO

ESCURRIMIENTO EN ALTO PILCOMAYO

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4-4-4 Topography and Geology

In the reconnaissance of the project area, the Mission referred to a topographical map to a scale of 1/250,000 since a more detailed map was not available.

After return to Japan, the Mission prepared topographical maps of the area to a scale of 1/50,000 and 1/10,000 on the basis of air-photos of the area which were made available to the Mission by CBF. The reliability of the maps is not sufficiently high because of absence of datum points and bench-marks in the areial photos. However, it was judged that the maps can be used to prepare a rough plan of the project.

The topography of the Río Alto Pilcomayo between the Talula Valley and the Saire Valley which is about 9km upstream therefrom is suitable for the creation of a storage reservoir.

About 10km of the downstream section of the Talula Valley is V-shaped, 40 to 50m wide at the river bed, and there are several sites which appear suitable for the construction of a dam. As a result of reconnoitering the area, the Mission selected two probable dam sites. One site, hereinafter referred to as Site A, is located at the entrance of Talula Valley and the other site, referred to as Site B, is located about 450m downstream of the former.

As a result of comparative studies, the Mission selected Site B for the dam site. The geology of the B site is generally composed of sandstone and quartzite of the cretaceous period. There is a continuous outcrop of brown sandstone on the left bank which is a precipitous cliff. The right bank is a relatively gentle slope. The geology is sandstone, highly cracked and joints and seams have considerably developed in the longitudinal direction. There is a deposit of sand and gravel including rocks and boulders on the river bed, but, the deposit seems to be not very deep.

As for Site A, there is a fault zone or seam running in the direction of N10°E/65°SE on both banks extending towards the downstream. Especially in the left bank, the fault or seam is filled with loose rock which are unstable and in certain places the rock is overhanging. Deposit of sand and gravel is widely distributed on the river bed, and the deposit appears to be very deep. Rocks and boulders are scarcely found in the deposit. At Site A and upstream therefrom, there are active hot springs containing saline, emitting hot water, the temperature of which is about 50°C.

From a geological point of view, Site B is favorable than Site A in consideration of degree of weathering of rock, depth of river bed deposits and influence of the hot springs. Construction of either a concrete dam or a fill type dam will be possible at Site B.

The proposed site of the powerhouse is of hard rock and the leakage of water is very little. No unfavorable factors of geological nature seem to exist at the site. Though actual reconnaissance of the proposed tailrace route was not conducted by the Mission due to the limitation of time and since there was no access road, the geology of the route seems to bear no unfavorable elements so far as it is examined through aerial photos.

Sedimentation after creation of the reservoir will probably be one of the essential problems to be considered.

As no data concerning silt-carrying characteristics of the river were available, the Mission referred to the data of Río Mendoza of Argentine, which also originates in the Andes, as a basis of judgement of this problem. On the basis of the data, the annual sediment load of the Río Alto Pilcomayo at the project site is assumed at 20,000m^3 per 100km^2 of catchment area. On this assumption, sedimentation will not reach the design sedimentation surface line estimated by the Mission until 45 years after completion of the dam.

4-4-5 Development Scheme

Basic Consideration

The project site has a vast catchment area of 7,200km^2, and besides, the topography around the site seems very suitable for the creation of a large storage reservoir. Hence, it is preferable to develop this site to create a reservoir and build a powerhouse on a scale or capacity as large as possible in order to most advantageously utilize the annual run-off of the river.

The project is situated almost midway between the cities of Sucre and Potosí. Therefore, the output of the project will play an important part in the operation of the power systems in the respective cities. In this connection and in the light of present demand in the cities the project should preferably be developed to have regulating capacity to correspond to fluctuation of demand.

Studies of the Project

o The following elements were considered in the studies.

(i) The gradient of the river course around the project site is 1/100. The Mission was informed by CBF's engineer that there is a rapid about 5km downstream from the site which has a drop of 40 to 50m. Based on the information, the Mission has judged that a head of about 90m can be developed by constructing a waterway about 5.3km long. It is recommended that field investigations be conducted immediately to ascertain this point.

(ii) The cross section of the proposed dam site employed in the development plan is on the basis of rough surveys which was conducted during the course of reconnaissance by the Mission.

(iii) The storage capacity of the reservoir was computed on the basis of topographical map which had been prepared by the Mission from aerial photographs covering the project area that were made available by CBF.

o Determination of powerhouse discharge

The average run-off at the proposed dam site in the dry season from May to October is $9.45m^3/s$ and the annual average run-off is $33.20m^3/s$. Consequently, the run-off of the river should be regulated seasonably by the reservoir. Effective storage capacity of the reservoir will be $100,000,000m^3$ at a high water level of EL 2,600m and an available depth of 20m. In this case the ratio of the effective storage capacity against annual total run-off is 10 per cent. Accordingly, $6.23m^3/s$ on an average can be released in the dry season, which is 184 in terms of number of days. Therefore, during this season $14.7m^3/s$ including natural run-off will be available for the generation of power. Under an assumed load factor of 50%, the maximum powerhouse discharge will be $30m^3/s$.

o Determination of type of development

Three cases of development which the Mission considered possible in the light of the several factors as hereinabove described have been studied. (See Fig. 4-4-5)

The first case (hereinafter referred to as A-plan) is to construct a concrete gravity dam 70m high at Site B in the Talula Valley to create a reservoir which an effective storage capacity of $100,000,000m^3$ at a drawdown of 20m. An underground power plant with a maximum installed capacity of 35,000kW is to be built immediately downstream of the dam utilizing an effective head of 140m. The powerhouse discharge of $30m^3/s$ is to be released into the Río Pilcomayo through a tailrace about 5.3km long.

The second case (hereinafter referred to as B-plan) is to lead the stored water of the said reservoir through an intake structure and a pressure tunnel of about 5km to a surge tank, then to the power plant by means of a penstock. A maximum capacity of 35,000kW is available at a discharge of

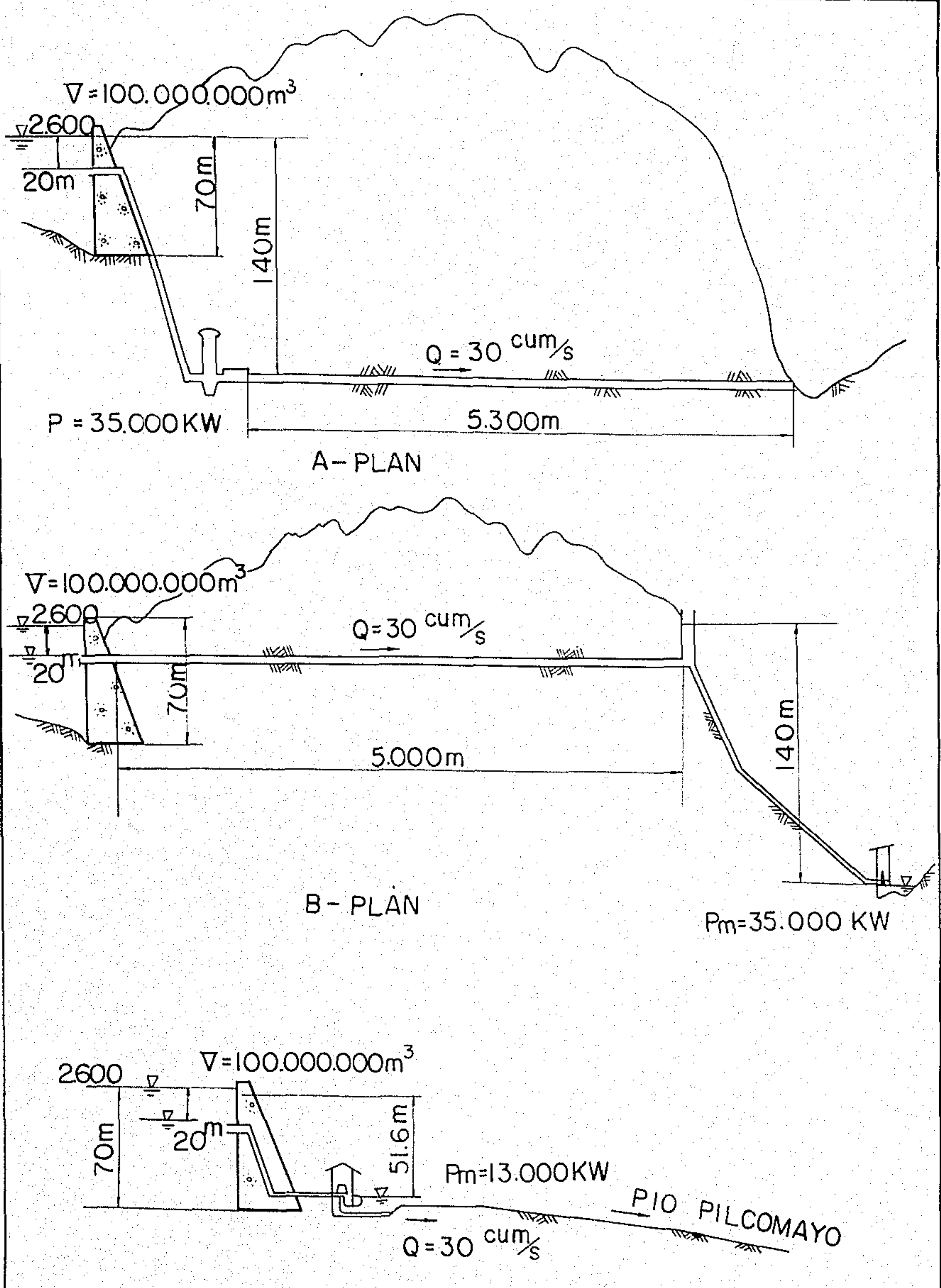

FIG. 4-4-5 A-PLAN, B-PLAN Y C-PLAN

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRIO A BOLIVIA
PROYECTO DE ALTO PILCOMAYO
A-PLAN. B-PLAN Y C-PLAN
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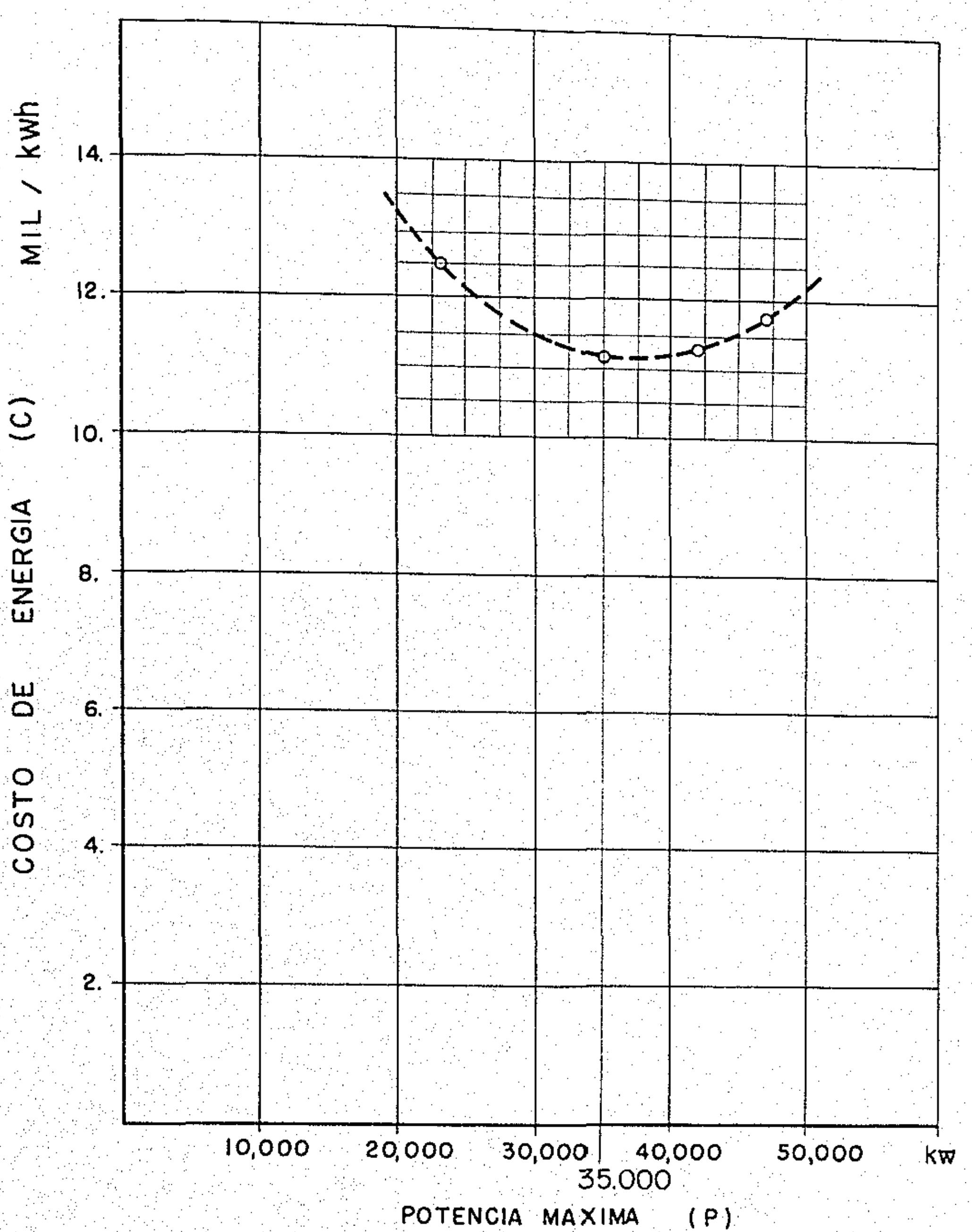

FIG. 4-4-6 VALOR DE (C) EN FUNCION DE (P)

MISION TECNICA JAPONESA PARA DESARROLLO HIDRO-ELECTRICO A BOLIVIA
VALOR DE (C) EN FUNCION DE (P)
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$30m^3/s$ under an effective head of 140m.

The third case (hereinafter referred to as C-plan) is to construct a power plant with a maximum capacity of 13,000kW under a discharge of $30m^3/s$ and effective head of 51.6m immediately downstream of the said dam.

The result of the comparative studies of these three plans is that A-plan is most favorable. B-plan will necessitate the construction of an access road to the power plant and besides, site condition for the powerhouse is not favorable. C-plan has the demerit of the plant capacity being reduced to 13,000kW which is very small in relation to the cost of the dam. (See Table 4-4-5 and Fig. 4-4-5)

Table 4-4-3 Comparison of the Three Plans

	A-plan	B-plan	C-plan
Maximum Capacity (kW)	35,000	35,000	13,000
Annual energy output (kWh)	212,000,000	212,000,000	76,650,000
Estimated construction costs (US$)	18,000,000	20,800,000	8,890,000
Per kW Construction costs (US$)	514	594	684
Per kWh Construction costs (US$)	0.085	0.098	0.116

o Determination of scale of development

On the basis of the criteria described in paragraph 4-1, comparative studies of A-plan with power outputs of 23,000kW, 35,000kW, 42,000kW and 47,000kW were made in relation to the estimated unit costs (per kWh) of energy available at the said outputs.

The results of the comparative studies are shown on Fig. 4-4-6. It will be noted that the results show that the optimum plant output is 35,000kW.

Therefore, 35,000kW was taken as the output of the project.

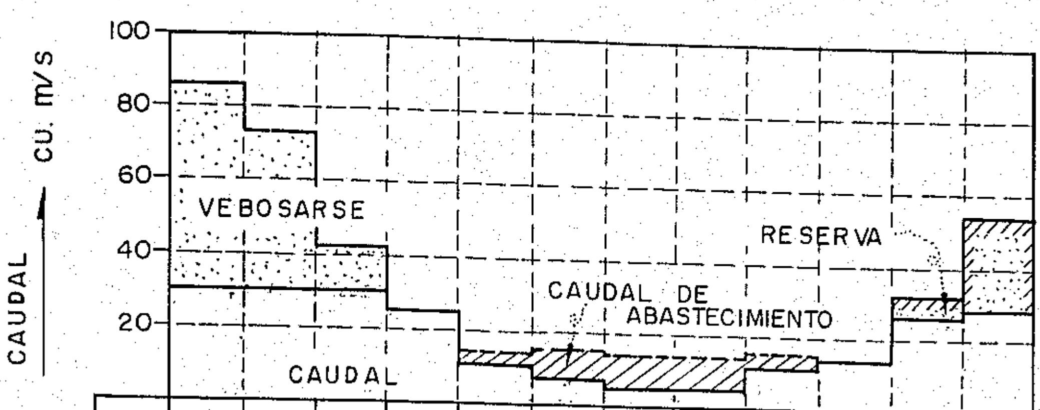
Plant capacity and Energy Output

On the basis of the several studies as described hereinabove, the conclusion of the Mission is that the optimum output of the project is 35,000kW which can be generated in an underground powerhouse operating under an effective head of 140m and maximum discharge of 30m/s. Energy amounting to 212,000,000kWh will be available annually at the plant. However, judging from the present demand situation, the total energy output of the project cannot be consumed in the related areas. Assuming a 50 per cent load factor, then the marketable energy is 147,350,000kWh per annum.

Monthly energy output of the plant is given in Table 4-4-4, Fig. 4-4-7 and Fig. 4-4-8.

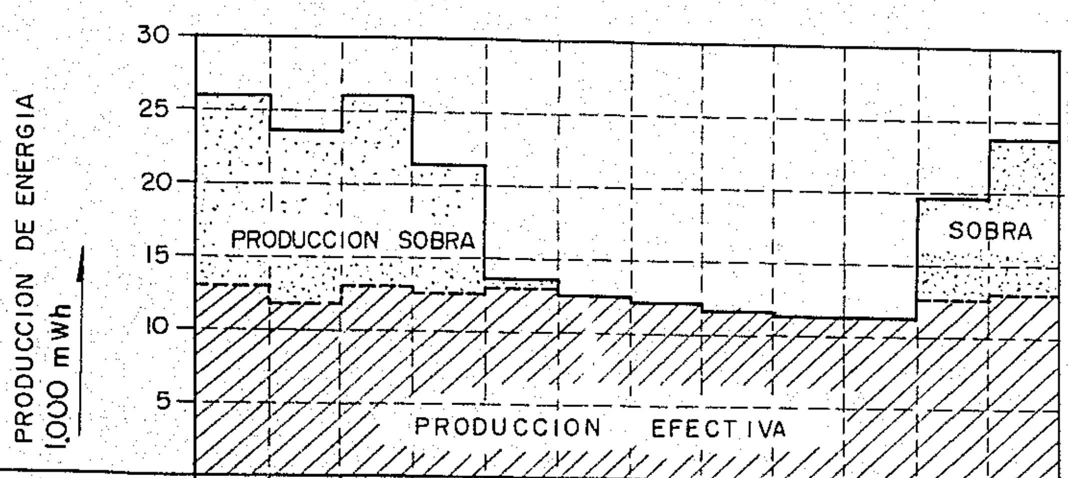
Table 4-4-4 Monthly Discharge and Corresponding Energy Output of the Alto Pilcomayo Power Station.

	Inflow		Available discharge	Discharge	Available Energy	Effective energy
	(m^3/s)	(m^3/s-day)	(m^3/s-day)	(m^3/s-day)	(MWh)	(MWh)
January	86.50	2,680	930	930	26,000	13,000
February	73.00	2,040	840	840	23,500	11,750
March	42.00	1,300	930	930	26,000	13,000
April	25.00	750	750	750	21,200	12,600
May	11.00	342	342	450	13,400	13,000
June	6.56	197	197	450	12,400	12,400
July	5.55	172	172	450	12,000	12,000
August	5.58	173	173	450	11,500	11,500
September	11.20	437	437	450	11,300	11,300
October	13.60	422	422	450	11,200	11,200
November	32.20	965	965	783	19,700	12,600
December	53.60	1,660	1,660	885	23,800	13,000
Total		11,138	7,818	7,818	212,000	147,350



mes.	ene.	feb.	mar.	abr.	may.	jun.	jul.	ago.	sep.	oct.	nov.	dic.
CAUDAL	30.0	30.0	30.0	25.0	14.5	15.0	14.5	14.5	15.0	14.5	26.0	28.6
ESCURRIMIENTO	86.50	73.00	42.00	25.00	11.00	6.56	5.55	5.58	11.20	13.60	32.20	53.60

FIG. 4-4-7 CAUDAL DE ALTO PILCOMAYO



	ene.	feb.	mar.	abr.	may.	jun.	jul.	ago.	sep.	oct.	nov.	dic.	anu.
PRODUCCION SOBRA DE ENERGIA 1000 mwh	13.00	11.75	13.00	8.60	0.40	0	0	0	0	0	7.10	10.80	64.65
PRODUCCION EFECTIVO DE ENERGIA 1000 mwh	13.00	11.75	13.00	12.60	13.00	12.40	12.00	11.50	11.30	11.20	12.60	13.00	147.35
PRODUCCION POSIBLE DE ENERGIA 1000 mwh	26.00	23.50	26.00	21.20	13.40	12.40	12.00	11.50	11.30	11.20	19.70	23.80	212.00

FIG. 4-4-8 PRODUCCION DE ALTO PILCOMAYO

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE ALTO PILCOMAYO

PRODUCCION ANUAL DE ENERGIA EN ALTO PILCOMAYO

FECHA : mar. 1964

Descriptive Data

Power Plant	Type	dam and waterway type
	Maximum capacity	35,000kW
	Maximum discharge	30m^3/s
	Effective head	140m
	Annual available energy	212,000,000kWh
Catchment area		7,280km^2
Structures		
Dam	Type	concrete gravity dam with overflow spillway
	Height	70m
	Crest length	125m
	Width of spillway section	41.5m
	Volume	100,000m^3
	Design flood discharge	2,600m^3/s
	Sluice gates	4, each, 8.5m wide and 10m high
	Available drawdown	20m
Intake	Height	34m
	Width	6m
Penstock (underground)	Inside diameter	tapering from 3m to 1.6m
	Length	approx. 202m
Powerhouse	Type	underground
Turbines	Type	vertical shaft Francis turbine
	Capacity	35,000kW (17,500kW, 2 units)
Generators	Type	synchronous generator
	Capacity	2 units of 20,600kVA each total 41,200kVA
Surge chamber	Cross section	semi-circular and rectangular 7.5m high 9m wide
	Length	approx. 45m
Tailrace	Cross section	Horseshoe shape, 5.6m in radius
	Gradient	1/1,000
	Length	approx. 5.3km
Reservoir	High water level	EL. 2,600m
	Low water level	EL. 2,580m
	Available drawdown	20m
	Surface area	6,490,000m^2
	Cross storage capacity	170,000,000m^3
	Effective storage capacity	100,000,000m^3

Transmission Line	Alto Pilcomayo Power Station to Sucre	
	Length	approx. 25km
	Voltage	66kV
	Number of Circuit	1
	Alto Pilcomayo Power Station to Potosí	
	Length	approx. 95km
	Voltage	66kV
	Number of Circuit	2

Estimated Construction Costs and Economic Justification

Total Construction cost	US$18,000,000
Waterway (inclusive of intake, penstock, surge chamber and tailrace)	5,610,000
Dam	3,863,000
Power plant (inclusive of powerhouse building, outdoor substation, machinery, etc.)	4,290,000
Transmission Line	2,000,000
Others	2,237,000

Unit construction costs

Per kW of capacity	US$514
Per kWh of annual available energy	US$0.085
Per kWh of annual effective energy	US$0.122

o Economic justification

Assuming annual expenses at 8% against the estimated construction costs, the cost per unit of effective energy will be US$0.00976. Corresponding with the growth of demand in the related areas in the future, the said unit cost will gradually decrease to US$0.0068/kWh which is the cost based on the available energy of the project.

The unit cost of energy of this project compared with thermal energy and prevailing rates of electric services is given below.

The per unit cost of energy produced by a new diesel electric plant is US$0.0189 per kWh on the assumption that the plant load factor is 50%, per kW construction cost is US$200, annual expenses are 11.2%, fuel consumption rate is 0.3 liters per kWh, and the cost of fuel is US$0.046 per liter. The cost of fuel per unit of energy produced is US$0.0138.

According to information that became available to the Mission, the prevailing rate of electric services in the city of Potosí is US$0.0155/kWh. This rate of service is the cheapest in the region including Sucre. It will be noted that the cost of power of the Alto Pilcomayo Project is much lower than the above costs. Development of this site for hydroelectric power will not only reinforce supply capability of the region, but will contribute to lowering the cost of electricity charges.

o Timing of the project

In order to establish concrete plans towards the realization of the project, further investigations and studies in detail are necessary of the several problems which were pointed out in the recommendations. Assuming that the investigations and studies are started immediately and the work progresses satisfactorily, at least six years will be required for the detailed investigations, preparation of final designs and construction of the project. Therefore, the project will be ready for commissioning in or after 1970 at the earliest. (See Fig. 4-4-9).

In view of the situation, the incremental demand in the cities of Sucre and Potosí, for the time being up to the completion of the project, should be supplied from the Corani project by means of interconnection of transmission lines between the said cities and Cochabamba or Oruro, or by power from other sources which may become available before the Alto Pilcomayo Project.

4-5 San Jacinto Project

4-5-1 General

As for the San Jacinto Project, there had been a plan to construct a dam

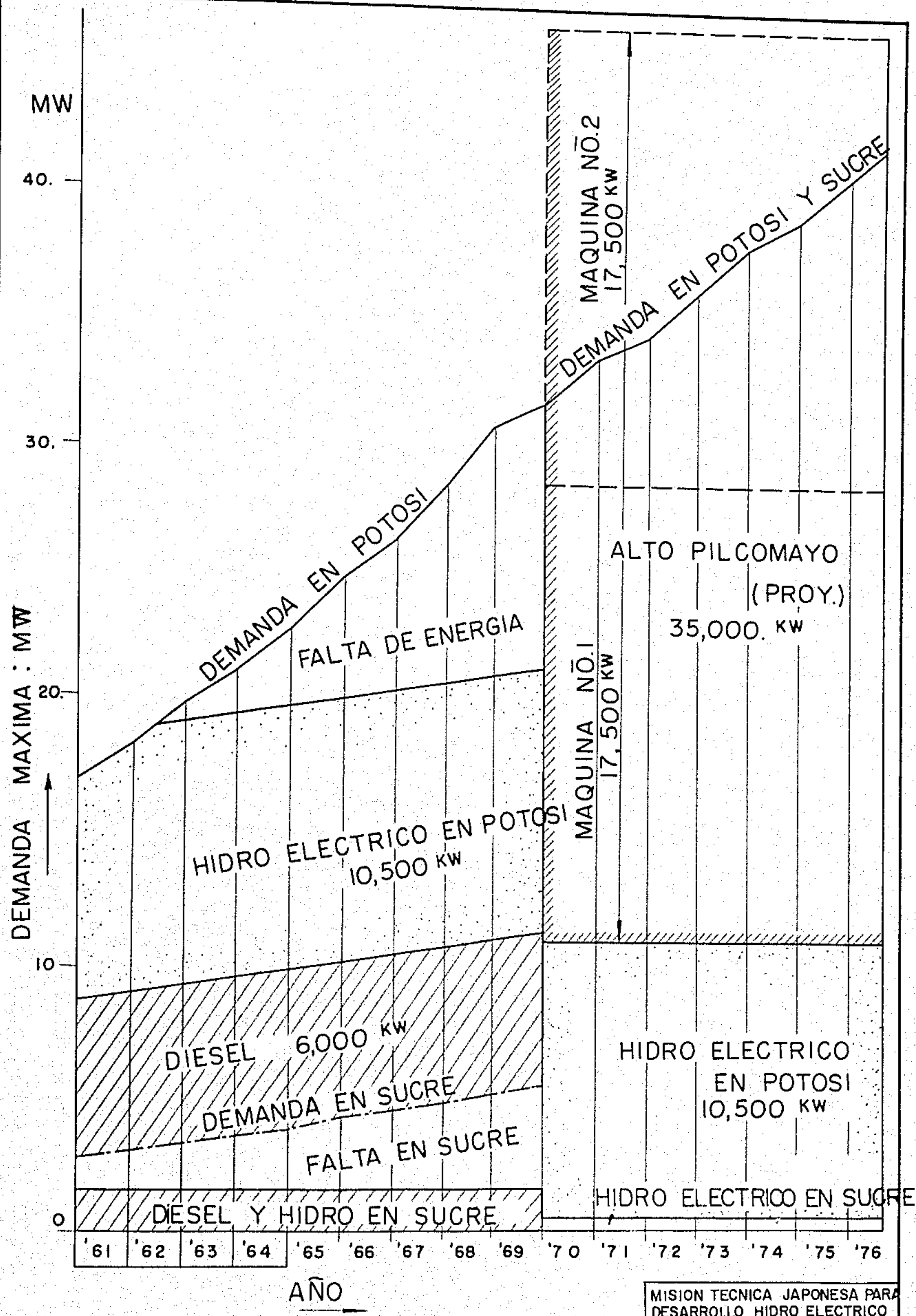
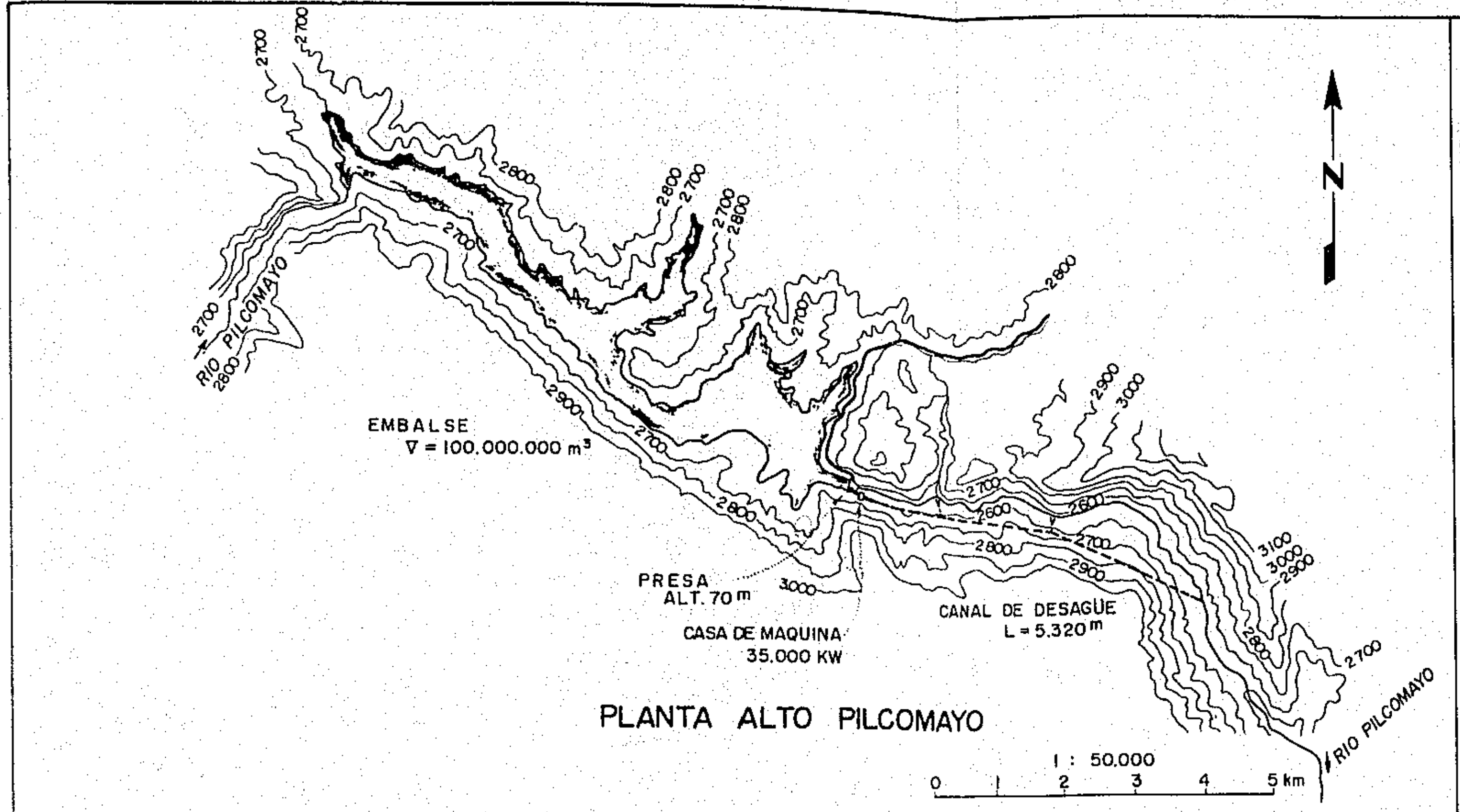


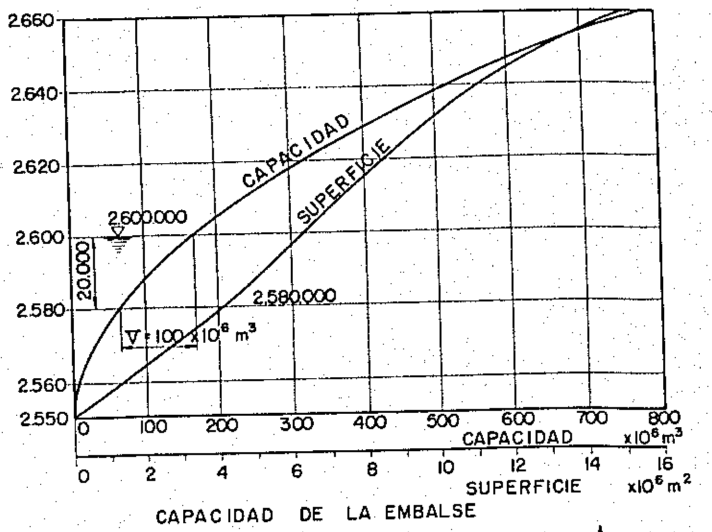
FIG. 4-4-9 DEMANDA MAXIMA EN POTOSI Y SUCRE

MISION TECNICA JAPONESA PARA DESARROLLO HIDRO ELECTRICO A BOLIVIA
PROYECTO DE ALTO PILCOMAYO
DEMANDA MAXIMA EN POTOSI Y SUCRE
FECHA : mar. 1964

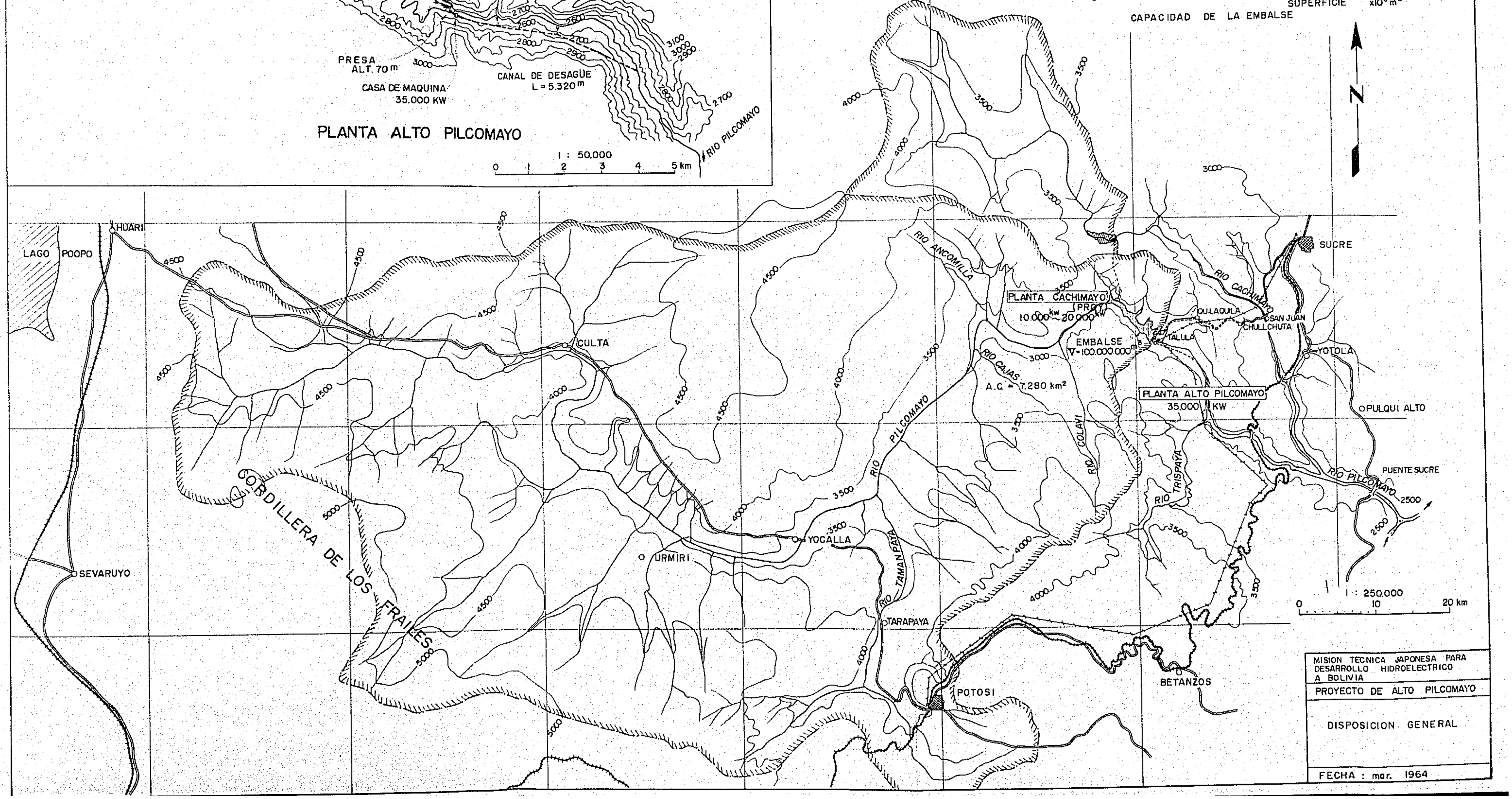


PLANTA ALTO PILCOMAYO

NIVEL(m)	SUPERFICIE ($10^6 m^2$)	CAPACIDAD ($10^6 m^3$)
2.660	15.08	782.2
2.640	11.25	518.9
2.620	8.58	320.7
2.600	6.49	170.0
2.580	4.20	63.2
2.560	1.40	7.1
2.550	0	0



CAPACIDAD DE LA EMBALSE

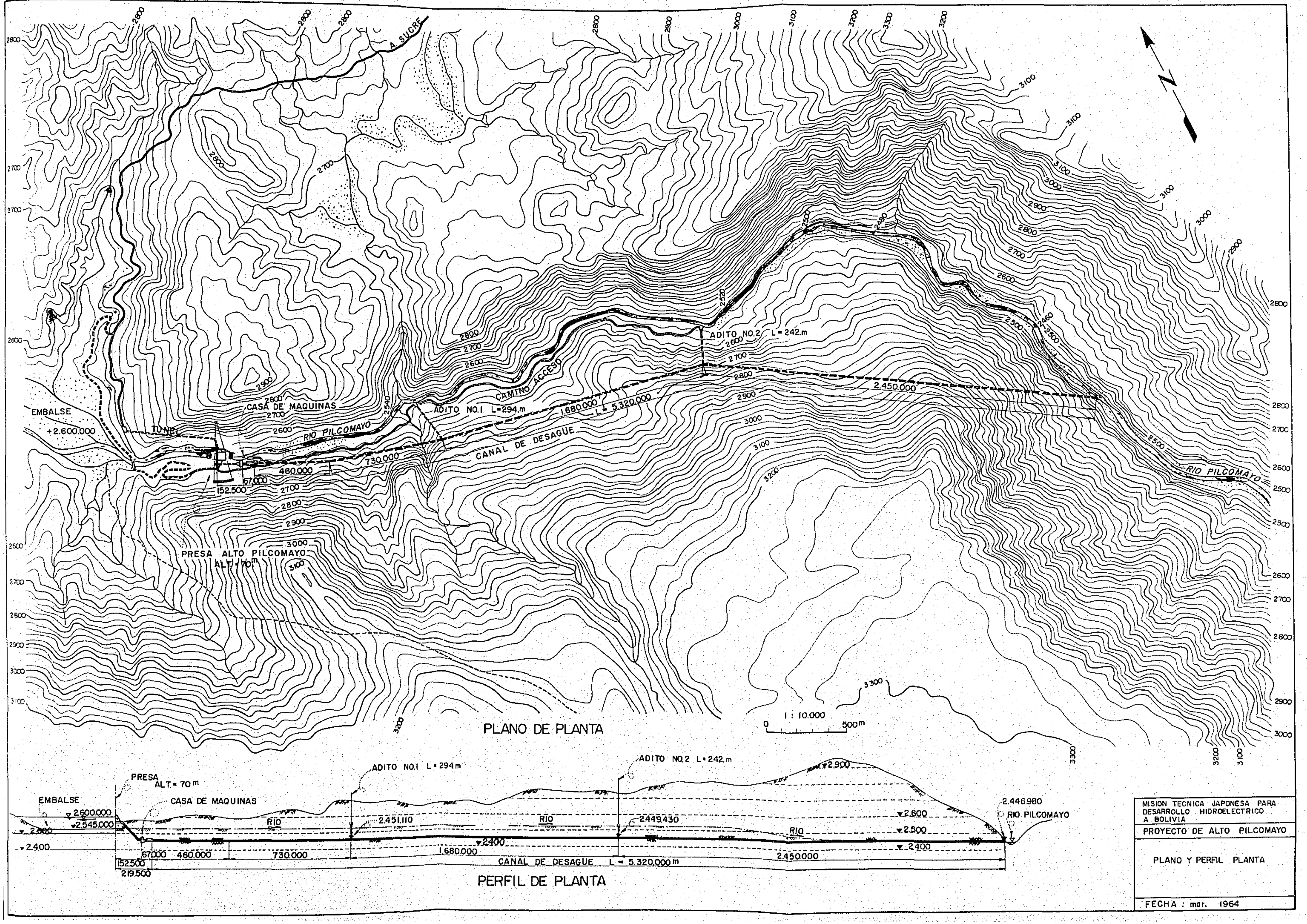


MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE ALTO PILCOMAYO

DISPOSICION GENERAL

FECHA : mar. 1964



A SUCRE
N
EMBALSE
+2.600.000
TUNEL
CASA DE MAQUINAS
RIO PILCOMAYO
CAMINO ACCESO
ADITO NO.1 L=294.m
ADITO NO.2 L=242.m
1.680.000
L=5.320.000
2.450.000
CANAL DE DESAGUE
730.000
460.000
67.000
152.500
PRESA ALTO PILCOMAYO
ALT.=70m
RIO PILCOMAYO
1 : 10.000
0
500m
PLANO DE PLANTA
PRESA
ALT.=70m
EMBALSE
CASA DE MAQUINAS
2.600.000
2.545.000
2.500
2.400
ADITO NO.1 L=294m
ADITO NO.2 L=242m
2.451.110
2.449.430
RIO
2.900
2.600
2.500
2.400
2.446.980
RIO PILCOMAYO
67.000
460.000
730.000
1.680.000
2.450.000
152.500
219.500
CANAL DE DESAGUE L=5.320.000m
PERFIL DE PLANTA
MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA
PROYECTO DE ALTO PILCOMAYO
PLANO Y PERFIL PLANTA
FECHA : mar. 1964

in the San Jacinto Valley for multiple purposes including power generation and irrigation. In the city of Tarija which is situated very close to the project site, electricity is supplied by a diesel power plant and a hydro power plant of small capacity. There is a deficiency of supply capability in the city and, to aggravate the situation, demand is anticipated to grow notably in the future.

In 1962, CBF installed a gaging station near the project site to record the water level of the river, and evaporation measuring instrument were installed in 1963.

While in 1963, Ministerio de Agricultura, Ganaderia, Colonización y Riegos established a multi-purpose development plan of the San Jacinto site. This project is primarily irrigation and includes hydroelectric power. A report has already been prepared concerning the plan.

In addition to the said plan, there are several draft development plans of the said site that have been proposed by government agencies including local interests. However, neither of the proposed plans have been prepared to a definite stage nor have basic data which are necessary for the preparation of development plans been systematically collected and compiled. The Mission conducted a reconnaissance of the project area with the object of hydroelectric power development only of the site.

4-5-2 Location

The site of the proposed San Jacinto Project is in the San Jacinto Valley 1.5 km downstream from the confluence of the Río Zola with the Río Tolomosa, which confluence is located 8 km to the south of the city of Tarija. Access to the site is possible by jeep or truck from the said city and the travelling time is about one hour. There are a few people sparcely settled around the project site who are primarily engaged in the raising of livestock. As there were no accommodation available near the project site, the Mission travelled daily from the city of Tarija during the reconnaissance study.

4-5-3 Hydrology and Meteorology

Hydrological and meteorological data of the project area were generally lacking and incomplete. Particulars of the data which were made available to the Mission are given in Table 4-5-1 which follows.

Table 4-5-1 Hydrological and Meteorological Data of San Jacinto Project

	Period of Recording			Remarks
	from	to	for	
San Jacinto Gaging Station Discharge measurement by current meter	Oct.-23-'62	Sept.-26-'63	11 months	Measured 6 times during the period. C.A.=200km^2
Daily water level	Oct.-26-'62	Aug.-31-'63	10 months	Recording being continued
San Luis Gaging Station Discharge measurement by current meter	Oct.-26-'62	Sept.-26-'63	11 months	Measured 5 times during the period C.A.=1460km^2
Daily water level	Oct.-26-'62	June-30-'63	8 months	Recording being continued
Guadalquivir Gaging Station Run-off	Dec.-1-'50	Dec.-31-'61		Generally incomplete, continuous records are available only for 1951 and 1961.
Tarija Observatory Daily precipitation	Jan.-1-'50	Dec.-31-'61		Includes daily average temperature, daily average wind velocity and direction

Note: C.A. means catchment area.

As no formula had been developed to show the relationship between water level and discharge at the San Jacinto Gaging Station, the discharge could not be converted from the records of water level.

Therefore, on the basis of discharge which had been recorded 6 times during Oct. 1962 through Sept. 1963 at the said station, the Mission obtained a formula to show the said relationship in order to compute run-off. The result of the computation by means of the said formula showed an unreasonably large run-off in relation to a catchment area of $200km^2$. This may be attributable to the fact that the gaging station, which is located on the upstream end of San Jacinto valley, is influenced by back water effects during flood discharges.

Consequently, the Mission did not use the records of San Jacinto Gaging Station. Neither were used the records of San Luis Gaging Station because data necessary for the computation of a formula to show the relationship between run-off and river water level were not available. Therefore, run-off records of the Guadalquivir Gaging Station were employed in the studies of the project.

Records of the Guadalquivir Gaging Station are missing in parts except for the two years of 1951 and 1962 for which records are completely available. It was, however, impossible to judge whether the run-off conditions of the two years, for which records are complete, were high, normal or low run-off years. Therefore, this judgement was made by relating the said run-off to the precipitation data of Tarija. On the basis of studies made by relating the said precipitation data, 1951 and 1962 were judged to be normal run-off years, and accordingly, the average values of the records of the two years were employed in preparing a development plan of the proposed San Jacinto Project. (See Table 4-5-2, Fig. 4-5-1, Fig. 4-5-2, Fig. 4-5-3, Fig. 4-5-4)

Table 4-5-2 Monthly Run-off at the Proposed Site of San Jacinto Project

(Unit: m^3/s-day)

	Run-off at Gaging Station (CA = 1000 km^2)			Average Run-off (CA = 100km^2)	Proposed dam site on Río Guadalquivir (CA=1,000km^2)	Proposed dam-site of San Jacinto Project (CA=200km^2)
	1950 - 1951	1961	Average			
September	43.7	26.8	35.3	3.5	35.3	7
October	38.0	41.0	39.5	4.0	39.5	8
November	142.2	46.4	94.3	9.4	94.3	19
December	100.7	142.7	121.7	12.2	121.7	24
January	390.4	543.6	467.0	46.7	467.0	93
February	512.5	489.0	500.8	50.1	500.8	100
March	401.5	343.2	372.4	37.2	372.4	74
April	191.1	93.6	142.4	14.2	142.4	29
May	95.4	119.1	107.3	10.7	107.3	22
June	64.8	64.7	64.8	6.5	64.8	13
July	65.0	47.1	56.1	5.6	56.1	11
August	53.8	30.0	41.9	4.2	41.9	8
Total	2,099.1	1,987.2	2,043.5	204.4	2,043.5	408

Note: 1. CA means catchment area.

2. Average run-off was computed by taking the value of December 1950 which was assumed the value for 1951.

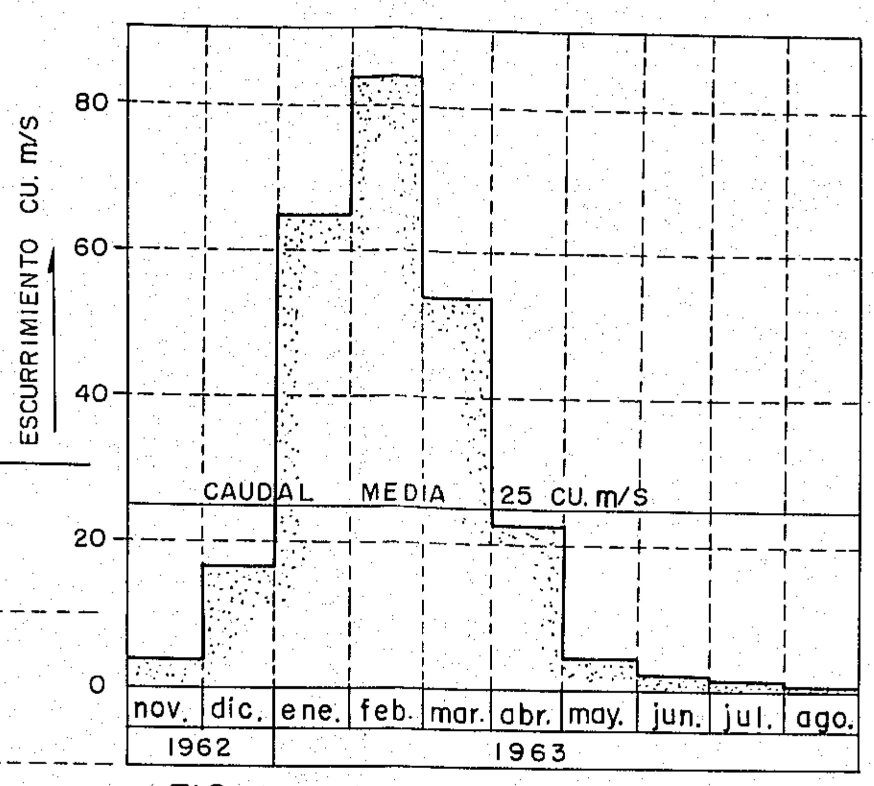


FIG. 4 - 5 - 2
ESCRRIMIENTO SAN JACINTO
EN MÉS

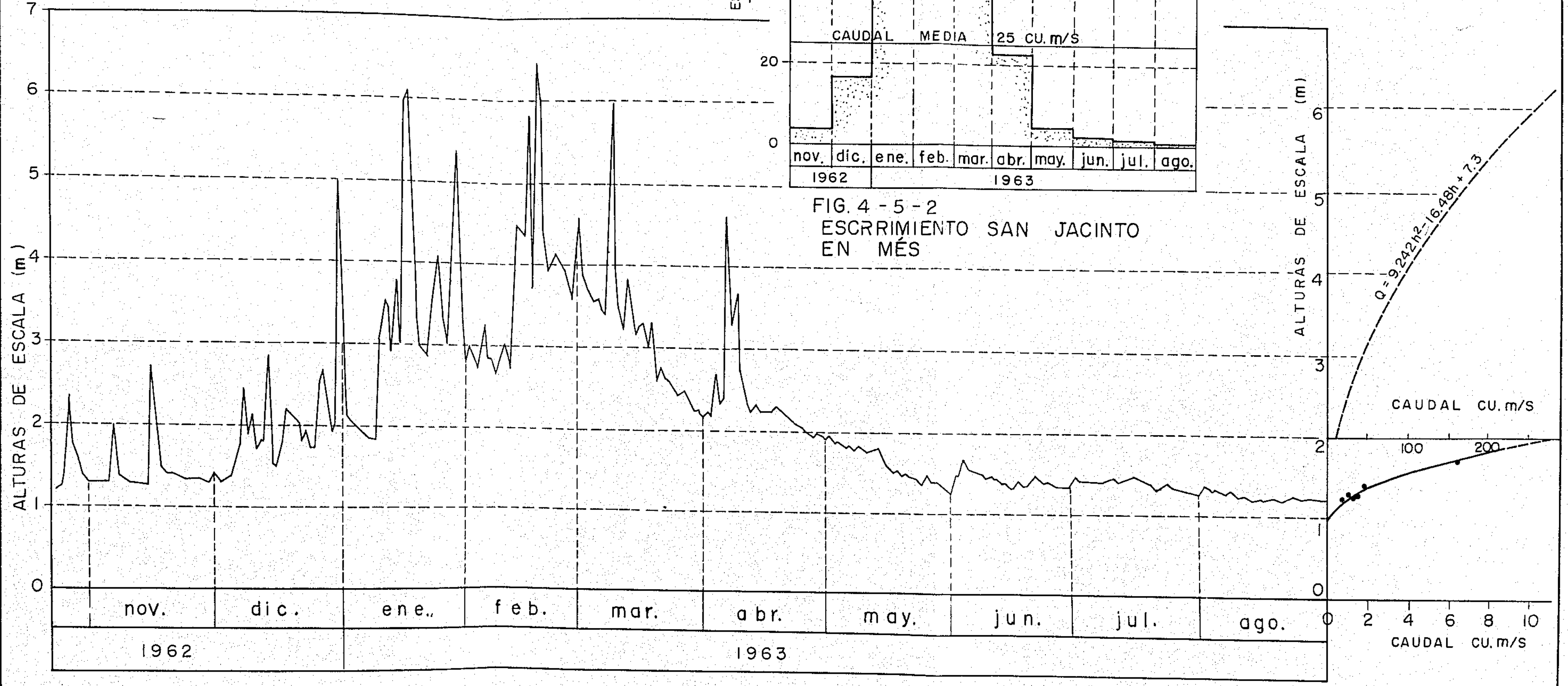


FIG. 4 - 5 - 1
ALTURAS DE ESCALA SAN JACINTO

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE SAN JACINTO

ALTURAS DE ESCALA SAN JACINTO

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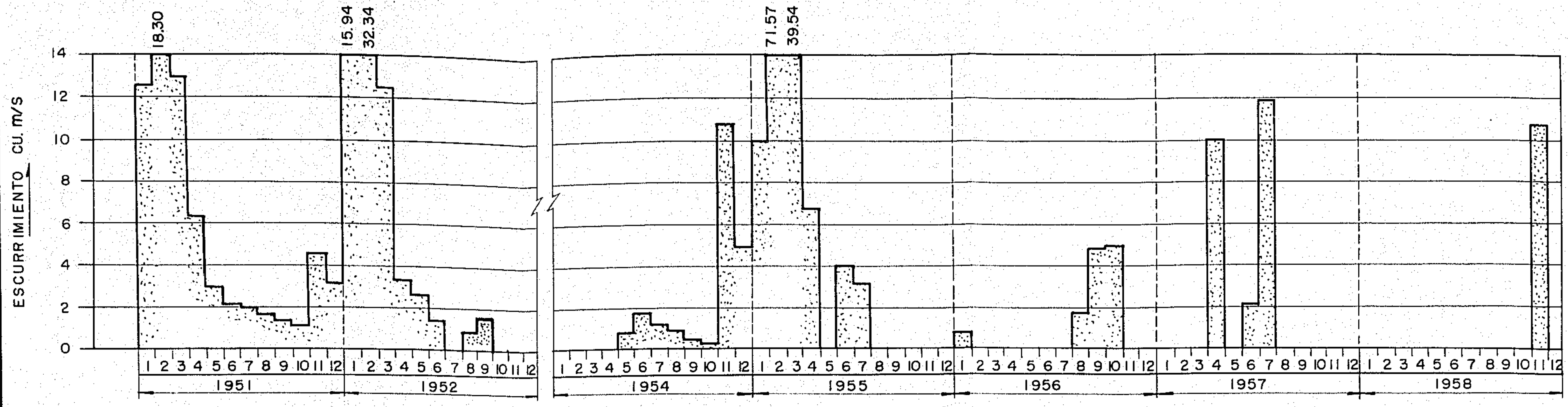


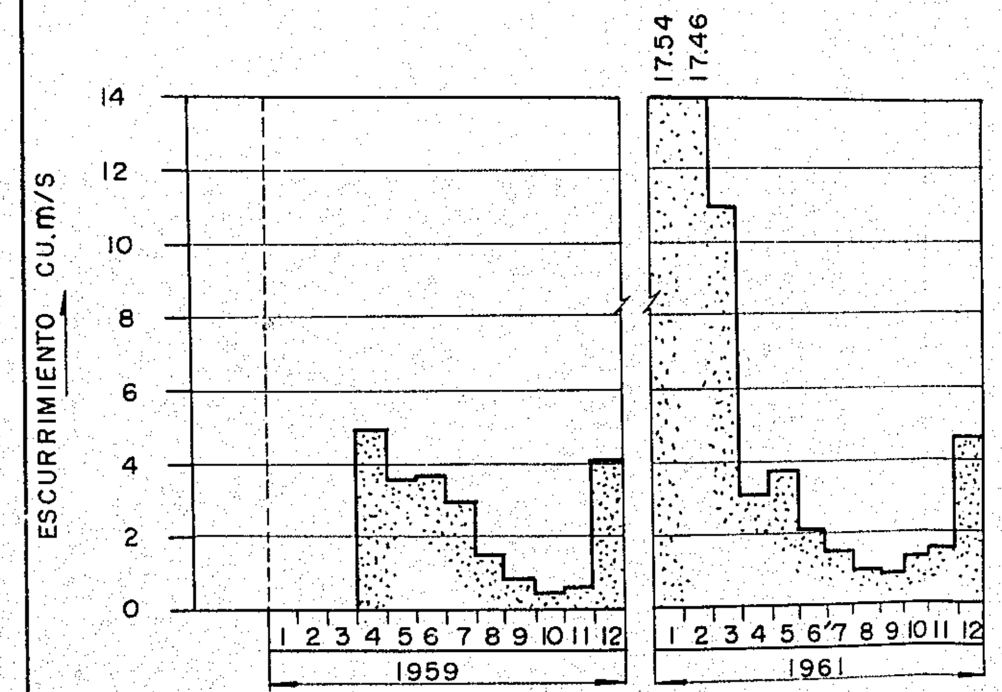


FIG. 4-5-3

ESCURRIMIENTO MEDIA EN GUADALQUIVIR

(1951 - 1961)

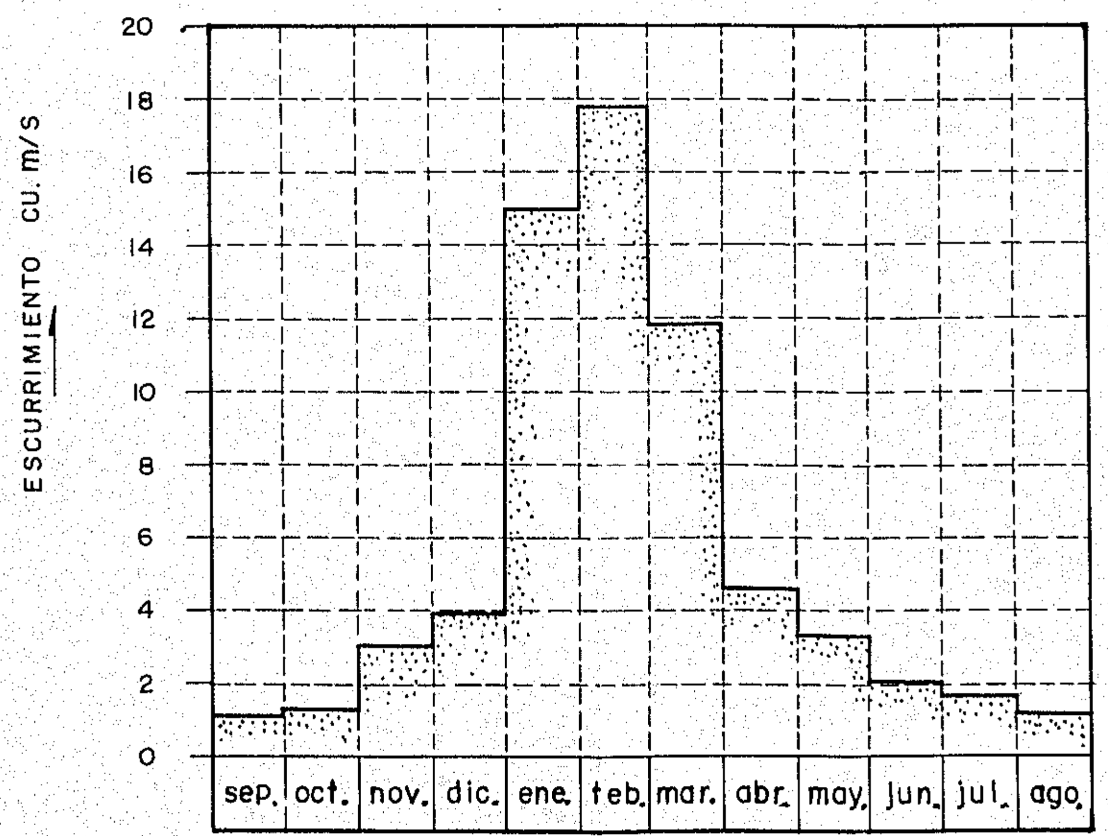


FIG 4-5-4

ESCURRIMIENTO MEDIA EN AÑO 1951 Y 1961

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA
PROYECTO DE SAN JACINTO
ESCURRIMIENTO MEDIA EN GUADALQUIVIR
FECHA : mar. 1964

4-5-4 Topography and Geology

The Mission conducted reconnaissance of the project area based on a topographic map to a scale of 1/2000 which was made available to it by CBF. The map principally covered the area of the proposed dam site and did not cover the proposed sites of power plant and a part of the reservoir area. In addition, the degree of reliability of survey of the saddle section in the left bank was not satisfactory. The Mission conducted survey and levelling of the missing part and the saddle section. On the basis of the results of the said complementary surveys the Mission after return to Japan has corrected the map and prepared a map to a scale 1/10,000. The studies of the project was made based on these two maps.

The project area is a slightly rolling hilly zone, through which the Río Zola and the Río Tolomosa flow before merging to form the Río San Jacinto. Terraces have considerably developed along the river courses to the confluence. About 1.5 km downstream from the confluence is the San Jacinto Valley. The river downstream of the valley meanders for some distance and joins the Río Guadalquivir.

The proposed site of the dam is in a precipitous V-shaped gorge of the San Jacinto Valley. Bedrock is exposed on the river bed and on both abutments. The geology of the site is sandy shale and sandy mudstone, and the upper part of both abutments is alternate layers of sandstone and slate. The bedrock will adequately sustain the load of a dam 30 m to 40 m high. The foundation bedrock, which is layered is running at strike and dip of N40° - 80°E/40° - 50°SE towards the downstream. Bedrock is completely exposed on the river bed at the proposed dam site, and, therefore, it suggests that stand and gravel deposite is not very deep on the upstream and downstream of the said site.

The poposed reservoir area is generally covered with deposits of sand, gravel and sandy soil. The left bank of the area is a gently sloped hill which is covered with soil overburden. The opposite side of the hill is deeply creased in places by erosive action caused by rainfall. Earth pillars of clayey soil and cliffs created by the erosion are found on the hillside. Preventative measures against erosion is an important problem which should be considered in the development of the site.

Slight rainfall in the basin will cause the river run-off to be silt-laden. Over a long period, it is believed that there would be considerable sedimentation of sand and silt. Therefore, this is another important problem which should be studied.

No geological problems should be encountered at the proposed intake site on the Río San Jacinto and the pressure tunnel to be connected to it, because the geology of the said sites is generally the same as that of the proposed dam site.

The proposed surge tank and penstock sites are on a slope of about 25 degrees. The geology is alternate layers of sandstone and slate which is covered with overburden of debris 1 m to 2 m deep. There should be no problems from a geological standpoint of installing a penstock at this site.

Exposures of slate are found at the sites of the proposed powerhouse and tailrace, but the deposit seems considerably deep on the river bed. The geology of the sites should present no foundation troubles for the structures.

4-5-5 Development Scheme

Basic Consideration

The proposed power plant when completed will be a major source of electricity supply in the Tarija area. In this connection, the power plant should be designed in such a way that output can be regulated to correspond to fluctuation of demand throughout a year.

Studies of the Project

o The following elements were considered in the studies.

(i) The catchment area of the basin at the proposed dam site is only $200km^2$. Though the annual average is $1.12m^3/s$, the run-off decreases to $0.36m^3/s$ in the dry season.

Therefore, in consideration of a stable supply of electricity, the creation of reservoir as large as possible is desirable in order to most effectively utilize the annual run-off of the river. However, in determining the high water level of the reservoir, it should be borne in mind that the saddle section in the left abutment of the proposed dam is realtively low in elevation and is heavily eroded.

(ii) Studies should be made of sedimentation of the river before a final plan of the reservoir is established.

(iii) It is said that water is seeping from Lagunas de Taxara basin into the Río Tolomosa, though no evidence is available. In this connection, investigations will be necessary.

The Mission has established a development plan on the assumption that there is no seepage from the said basin. In the case data becomes available from future investigations showing that seepage is taking place, the development plan will naturally require modification.

Determination of powerhouse discharge

Run-off at the proposed dam site averages $1.12m^3/s$ throughout a year. Average run-off during the wet season from December to May is $1.88m^3/s$, while it is $0.36m^3/s$ in the dry season from June to November. In view of this seasonal variation of run-off, it is desirable to regulate the run-off by creating a storage reservoir.

High water level of the reservoir cannot exceed EL.2,055m on account of topographical features around the proposed site. Under this topographic restriction, the effective storage capacity of the reservoir will be $10,000,000m^3$ assuming an available depth of 4m. Accordingly, $0.62m^3/s$ of water can be supplemented by the reservoir in the dry season. By diverting $1.52m^3/s$ of water (average during dry season) from the Río Guadarquivir the total available discharge including natural run-off will be $2.5m^3/s$ on the average. Therefore, the maximum discharge of the powerhouse will be approximately $5m^3/s$ at an assumed load factor of 50%.

Determination of type of development

Three cases of development which the Mission considered possible in consideration of several factors as hereinabove mentioned were studied. (See Fig. 4-5-5)

The first case (hereinafter referred to as A-plan) is to construct a concrete gravity dam 33m high in the San Jacinto Valley to create a reservoir with an effective storage capacity of $10,000,000m^3$ at an available depth of 4m. In order to supplement the inflow into the reservoir, a maximum of $3m^3/s$ is to be diverted from Río Guadilquivir. The power plant will have a maximum capacity of 2,000kW at a discharge of $5m^3/s$ under an effective head of 48m.

The second case (hereinafter referred to as B-plan) is identical to A-plan, except that diversion from the Río Guadalquivir is not included. The power plant will have a maximum capacity of 650kW at a discharge of $1.62m^3/s$.

The last case (hereinafter referred to as C-plan) is a run-of-river type development by utilizing the run-off of the Río Guadalquivir instead of the Río San Jacinto. The power plant will have a maximum capacity of 400kW at a discharge of $1m^3/s$ under an effective head of 48m.

As a result of comparative studies of the three plans the Mission believes that A-plan is most favorable.

In B-plan, initial investment for the dam and other structures is relatively high in comparison with the plant output and, consequently, the economic justification is very low.

C-plan, will not be able to regulate the run-off of the river and is not recommendable from an economic point of view. (See Table 4-5-3)

Table 4-5-3 Comparison of the Three Plans

	A-plan	B-plan	C-plan
Maximum capacity (kW)	2,000	650	400
Annual energy output (kWh)	11,500,000	3,960,000	2,300,000
Estimated construction costs (US$)	1,700,000	890,000	453,000
Per kW construction costs (US$)	850	1,370	1,130
Per kWh construction costs (US$)	0.148	0.224	0.197

Determination of scale of development

On the basis of the criteria for determination of scale of development which is described in chapter 4-1 of this report, several plant capacities were studied for A-plan, and the cost per kWh of available energy was computed. The result indicated that 2,000kW would be the most economical size of development.

Plant Capacity and Energy Output

On the basis of the several studies as described hereinabove, the type of development adopted is a dam and waterway type power plant with a maximum capacity of 2,000kW at a discharge of $5m^3/s$ under an effective head of

48 m. Annual available energy will be 11,500,000 kWh and the monthly energy output will be as given in Table 4-5-4, Fig. 4-5-6, Fig. 4-5-7, and Fig. 4-5-8.

However, judging from the present situation of demand, it is unlikely that the said available energy can be completely consumed in the very near future. Accordingly, assuming a 50% load factor, then the marketable energy will be 8,700,000 kWh annually.

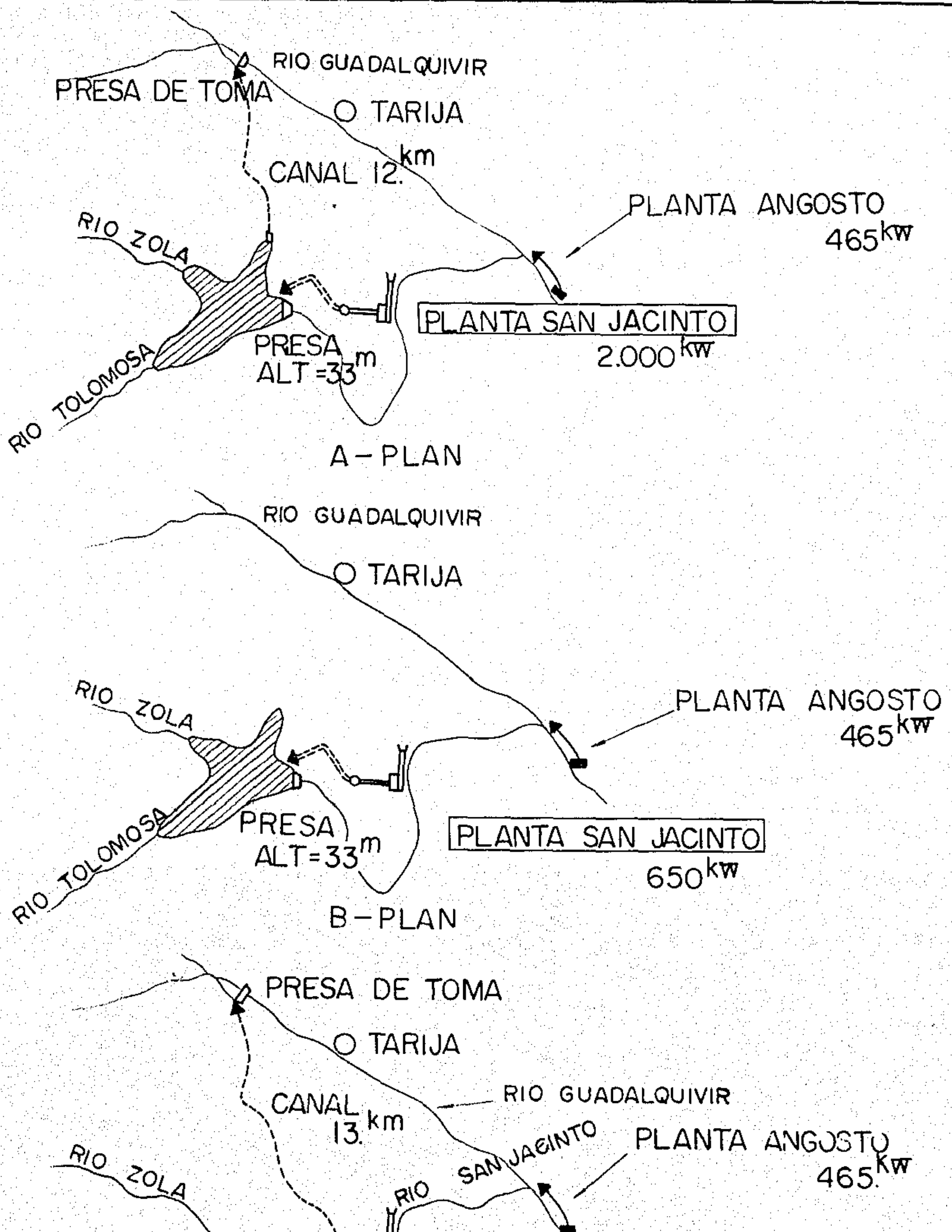
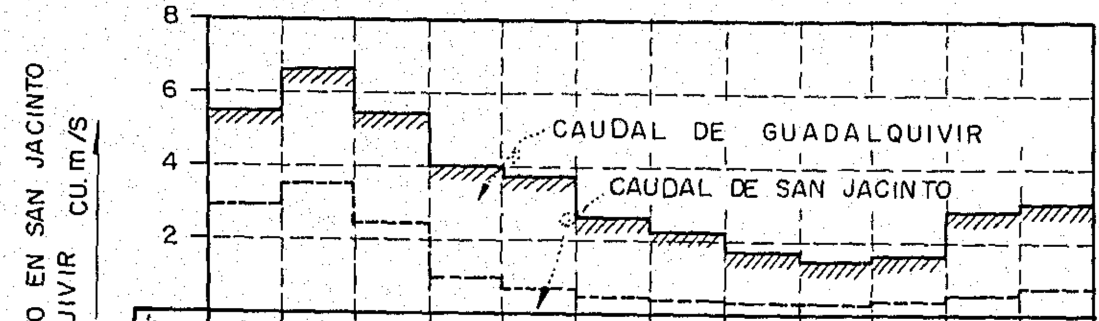


FIG. 4-5-5
A PLAN, B-PLAN Y C-PLAN

MISION TECNICA JAPONES PARA DESARROLLO HIDORO-ELECTRICO A BOLIVIA
PROYECTO DE SAN JACINTO
A-PLAN, B-PLAN Y C-PLAN
FECHA: mar. 1964

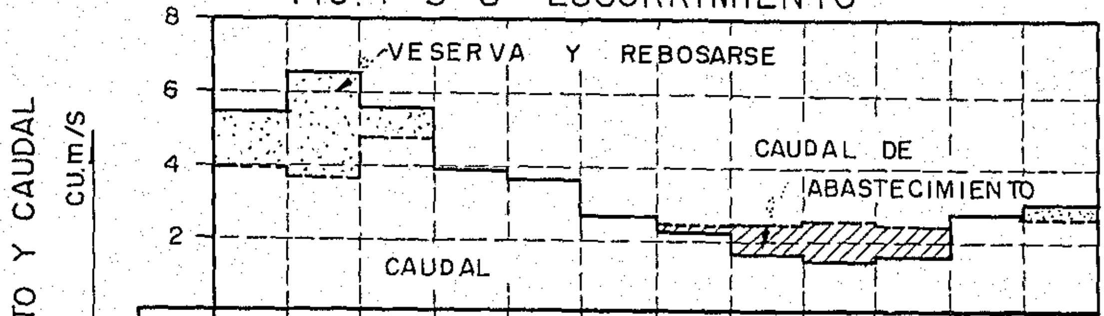
Table 4-5-4 Monthly Discharge and Corresponding Energy Output of San Jacinto Power Station

	(1) Diversion from Río Guadal-quivir (m^3/s)	(2) Natural run-off of Río San Jacinto (m^3/s)	(1)+(2) (m^3/s)	(m^3/s-day)	Available discharge (m^3/s-day)	Discharge (m^3/s-day)	Available energy (MWh)	Effective Energy (MWh)
January	2.40	3.00	5.29	164.0	155.0	119.6	1,540	740
February	2.95	3.54	6.49	182.0	140.0	100.0	980	670
March	3.00	2.50	5.50	171.0	155.0	146.0	1,450	740
April	2.98	0.95	3.93	118.0	118.0	118.0	1,180	720
May	2.96	0.68	3.64	113.0	113.0	113.0	1,130	740
June	2.14	0.43	2.58	77.4	77.4	77.4	800	720
July	1.80	0.38	2.18	67.5	67.5	75.0	750	740
August	1.35	0.26	1.61	50.0	50.05	75.0	750	740
September	1.18	0.21	1.39	41.6	41.6	75.0	720	720
October	1.24	0.26	1.50	46.5	46.5	75.0	710	710
November	2.18	0.55	2.73	82.0	82.0	82.0	720	720
December	2.20	0.76	2.96	91.8	91.8	81.8	770	740
Total				1,204.8	1,137.8	1,137.8	11,500	8,700



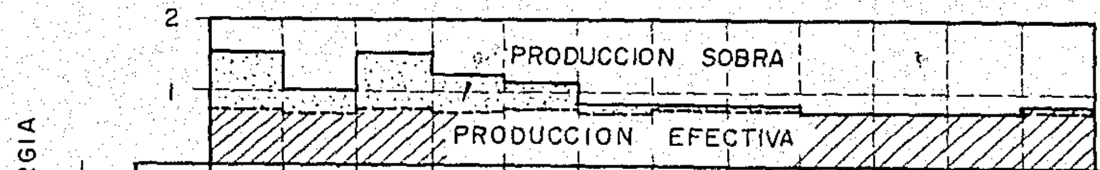
GUADALQUIVIR	2.40	2.95	3.00	2.98	2.96	2.14	1.80	1.35	1.18	1.24	2.18	2.20
SAN JACINTO	3.00	3.54	2.50	0.95	0.68	0.43	0.38	0.26	0.21	0.26	0.55	0.76
mes	ene.	feb.	mar.	abr.	may.	jun.	jul.	ago.	sep.	oct.	nov.	dic.

FIG. 4-5-6 ESCURRIMIENTO



CAUDAL	3.86	3.57	4.71	3.94	3.65	2.58	2.42	2.42	2.50	2.42	2.73	2.64
ESCURRIMIENTO	5.40	6.49	5.50	3.93	3.64	2.57	2.18	1.61	1.39	1.50	2.73	2.96
més	ene	feb.	mar.	abr.	may.	jun.	jul.	ago.	sep.	oct.	nov.	dic.

FIG. 4-5-7 ESCURRIMIENTO Y CAUDAL



SOBRA	0.80	0.31	0.71	0.46	0.39	0.08	0.01	0.01	0	0	0	0.03	2.80
EFECTIVO	0.74	0.67	0.74	0.72	0.74	0.72	0.74	0.74	0.72	0.71	0.72	0.74	8.70
POSIBLE	1.54	0.98	1.45	1.18	1.13	0.80	0.75	0.75	0.72	0.71	0.72	0.77	11.50
mes.	ene.	feb.	mar.	abr.	may.	jun.	jul.	ago.	sep.	oct.	nov.	dic.	anu.

FIG. 4-5-8 PRODUCCION DE ENERGIA

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE SAN JACINTO

PRODUCCION ANUAL DE ENERGIA EN SAN JACINTO

FECHA : mar. 1964

Descriptive Data

Power plant	Type	dam and waterway
	Maximum capacity	2,000 kW
	Maximum discharge	$5m^3/s$
	Effective head	48 m
	Annual available energy	11,500,000 kWh
Catchment area		$1,200\ km^2$ (Río San Jacinto $200\ km^2$) (Río Guadalquivir $1,000\ km^2$)

Structures

Guadalquivir diversion dam	Type	concrete intake dam
	Height	2.5 m
	Crest length	137 m
Guadalquivir canal	Maximum capacity	$3m^3/s$
	Cross section	trapezoidal (wet masonry construction) 1.5 m wide at the bottom 2 m high slope 1:1
	Gradient	1/1,000
	Length	approx. 12 km
Dam	Type	concrete gravity dam with overflow spillway
	Height	33 m
	Crest length	61 m
	Volume	$15,000\ m^3$
	Design flood discharge	$300m^3/s$
	Sluice gates	2, each 8 m wide and 10 m high
Intake	Drawdown	4 m
	Maximum capacity	$5m^3/s$
	Cross section	2 m inside diameter, concrete lined
	Gradient	1/1,000
	Length	approx. 0.6 km
Tunnel	Maximum capacity	$5m^3/s$
	Cross section	2 m inside diameter, concrete lined
	Gradient	1/100
	Length	approx. 0.6 km
Surge tank	Type	simple surge tank
	Diameter	4.5 m
	Height	15 m
	Reinforced concrete structure	
Steel penstock	Inclination	25^o
	Inside diameter	tapering from 1.10 m to 0.8 m
	Number	2
	Length	approx. 97 m

Power house	Type	semi-underground
Turbine	Type	vertical shaft Francis turbine
	Capacity	2 units of 1,000 kW each total 2,000 kW
Generator	Type	synchronous generator
	Capacity	2 units of 1,200 kVA each total 2,400 kVA
Tailrace	Type	concrete culvert
	Cross section	semi-circular and rectangular shape, 2 m wide and 3 m high
	Gradient	1/100
	Length	approx. 90 m
Reservoir	High water level	EL. 2,055 m
	Low water level	EL. 2,051 m
	Available depth	4 m
	Surface area	3,225,000 m^2
	Gross storage capacity	20,710,000 m^3
	Effective storage Capacity	10,000,000 m^3
Transmission Line	San Jacinto Power Station to Tarija City	
	Length	approx. 7 km
	Voltage	11 kV

Estimated Construction Costs and Economic Justification

Total construction costs	US$1,700,000
Waterway (inclusive of Guadalquivir diversion dam, intake and canal, and intake, surge tank, penstock and tailrace)	676,000
Dam	480,000
Power plant (inclusive of powerhouse building, outdoor substation, machinery, etc.)	361,700
Transmission line	77,800
Others	104,500

Unit Construction costs

per kW of capacity	US$850/kW
per kWh of annual available energy	0.148/kWh
per kWh of effective energy	0.195/kWh

Economic justification

Assuming annual expenses at 8% against the estimated construction costs, the cost per unit of marketable energy (effective energy) will be US$0.0156/kWh. With the growth of demand in the related areas, there will be a corresponding increase in the amount of marketable energy of the project. It is estimated that the unit cost of energy produced will gradually decrease to US$0.0118 which is the cost based on total available energy of the project.

Cost comparisons of the proposed project with a diesel unit of comparable capacity and prevailing rates of electric services reveal that the per unit cost of energy generated at a diesel electric plant of comparable capacity would be about US$0.0189 under a 50% load factor on the assumption that its construction cost is US$200 per kW, the rate of annual expenses against construction cost is 11.2%, fuel consumption per unit of energy produced is 0.3 liter/kWh and the unit cost of fuel is US$0.046 per liter. The cost of fuel per unit of energy produced will be US$0.0138.

According to data made available to the Mission, the lowest charges in the prevailing rates for electric services in the city of Tarija is industrial uses, the charge for which category is US$0.025 per kWh. It will be noted, therefore, that the estimated cost of energy produced by the project is by far lower than the above costs.

Consequently, the project will not only contribute to reinforcing system supply capability, but will also contribute greatly to reducting the rates for electric services in the region.

Timing of the project

In order to establish a concrete plan towards the realization of the project, investigation and studies in detail of the several problems which are given in the recommendations of this report must be carried out. In this connection, assuming that the investigations and studies are initiated immediately and that they proceed satisfactorily it will take at least 5 years, including the time required for detailed studies and preparation of final plans, before construction of the project is completed. Therefore, the date of operation of the power plant will be after 1969. In view of the situation, the demand in and around the city of Tarija, until the time of completion of the project, will have to be supplied by power produced at either a diesel electric plant or hydro power plant which may become available before the San Jacinto Project. (See Fig. 4-5-9).

Assuming that the project is completed in 1969, the demand in and around the city of Tarija until about 1975 can be supplied by hydro power only including the existing Angosto Power Station. Thereupon the existing diesel power plants can be either operated on a stand-by basis or they can be transferred to other regions.

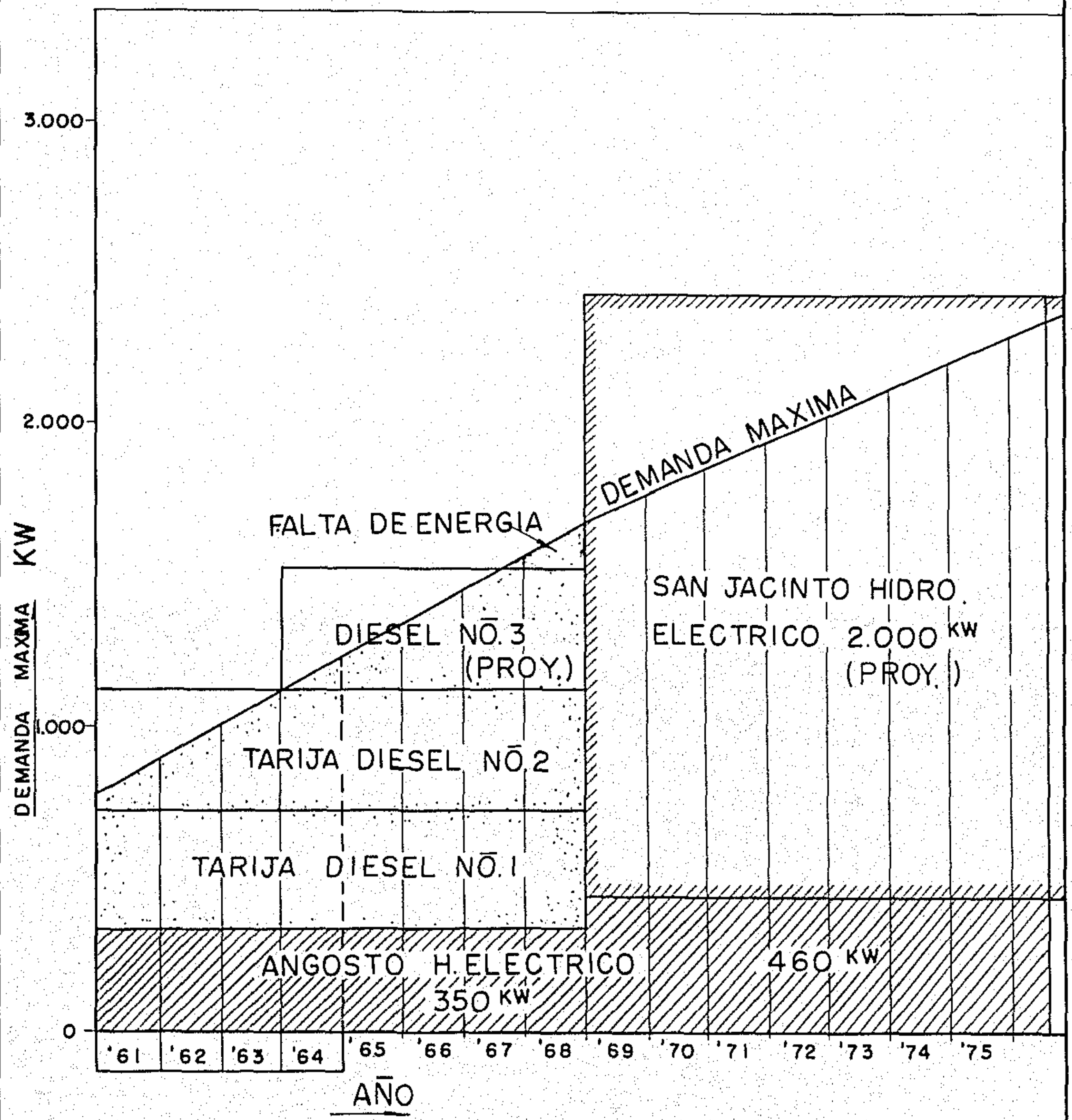
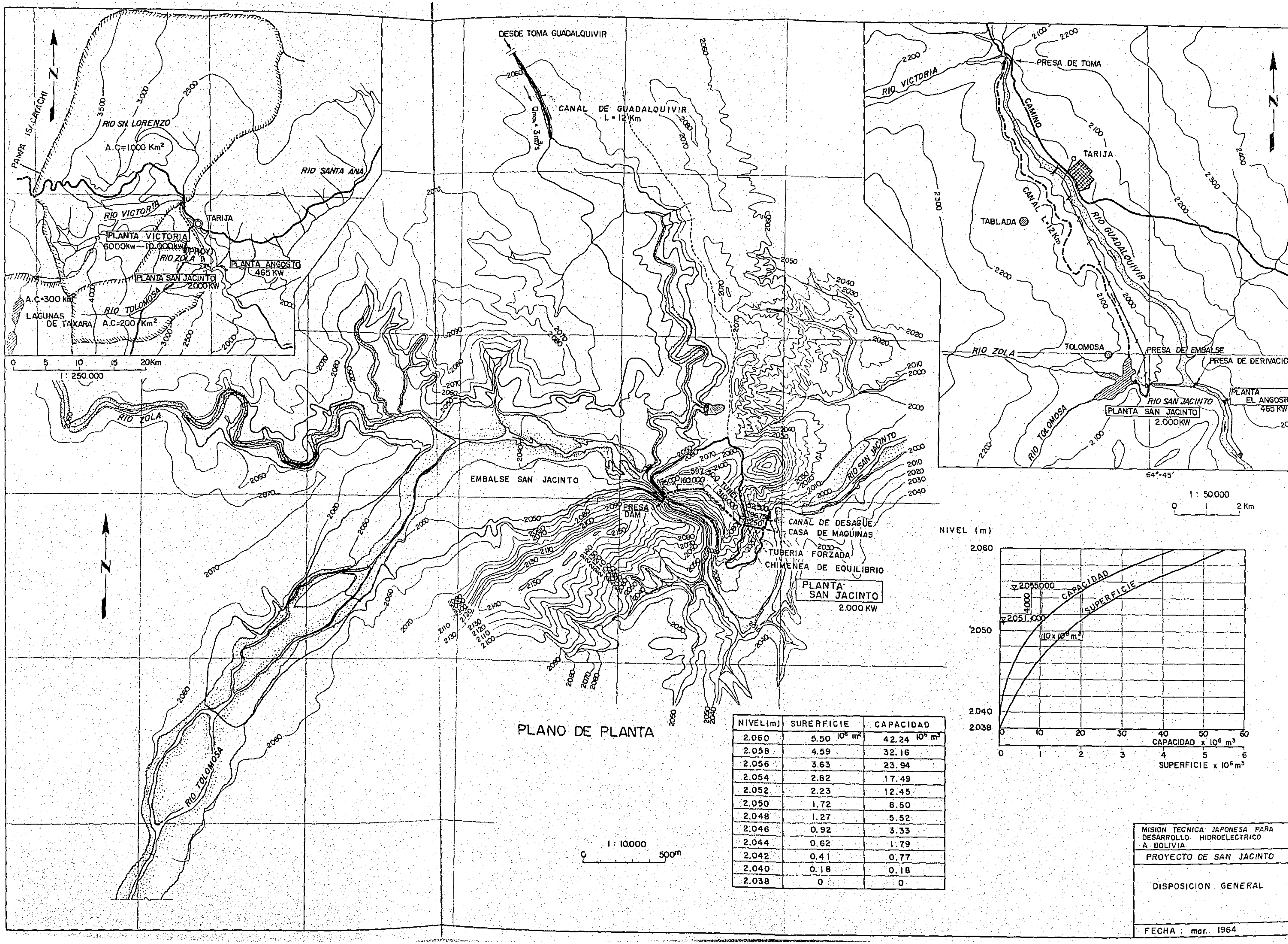


FIG. 4-5-9 DEMANDA MAXIMA EN TARIJA

MISION TECNICA JAPONESA PARA DESARROLLO HIDRO ELECTRICO A BOLIVIA
PROYECTO DE SAN JACINTO
DE MANDA MAXIMA EN TARIJA
FECHA: mar. 1964



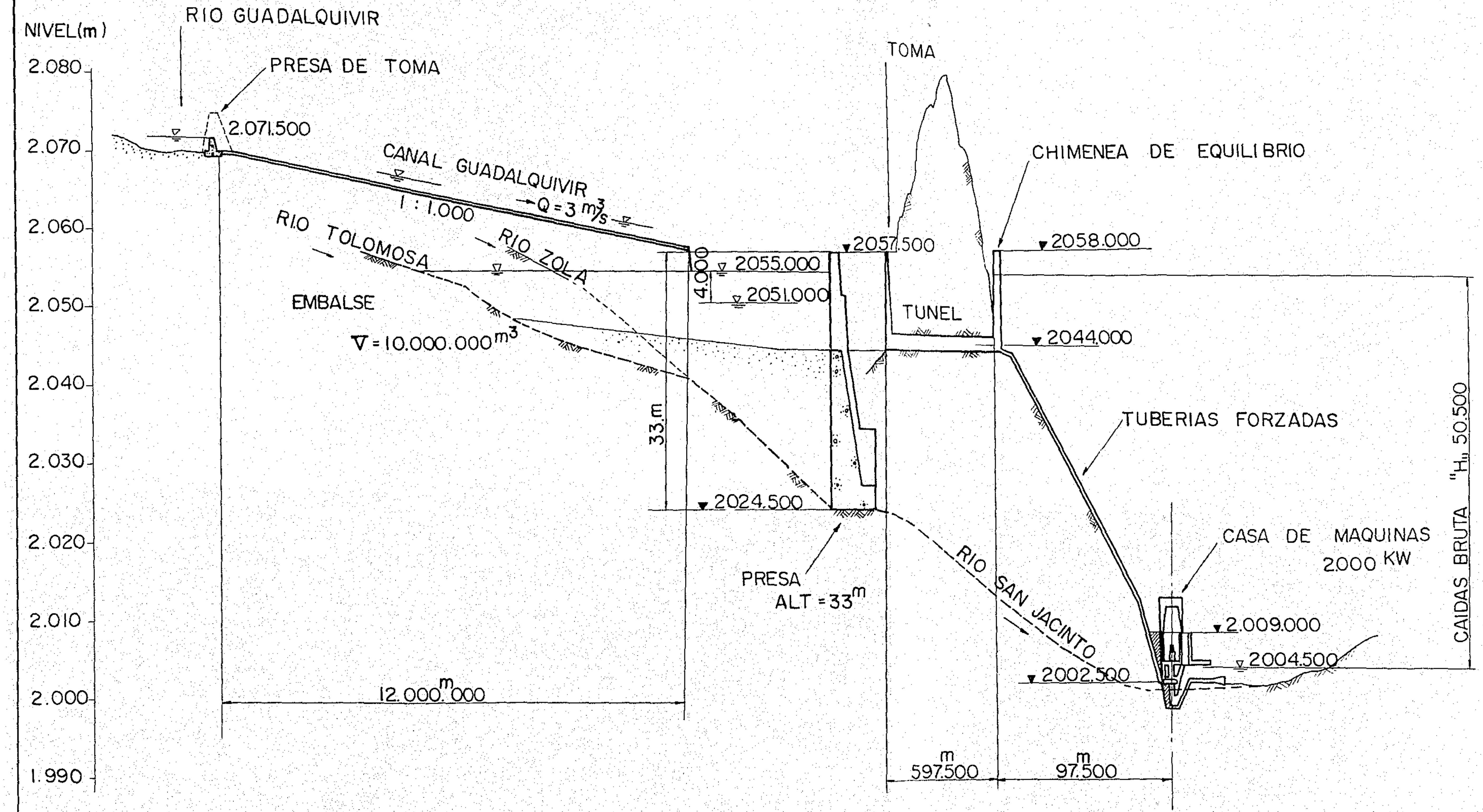
NIVEL (m)	SUPERFICIE	CAPACIDAD
2.060	5.50 10^6 m²	42.24 10^6 m³
2.058	4.59	32.16
2.056	3.63	23.94
2.054	2.82	17.49
2.052	2.23	12.45
2.050	1.72	8.50
2.048	1.27	5.52
2.046	0.92	3.33
2.044	0.62	1.79
2.042	0.41	0.77
2.040	0.18	0.18
2.038	0	0

MISION TECNICA JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA

PROYECTO DE SAN JACINTO

DISPOSICION GENERAL

FECHA : mar. 1964



PERFIL DE PLANTA

MISION TECNI JAPONESA PARA DESARROLLO HIDROELECTRICO A BOLIVIA
PROYECTO DE SAN JACINTO
PERFIL DE PLANTA
FECHA : mar. 1964

PHOTO-1 Distant view of Corani Project dam site

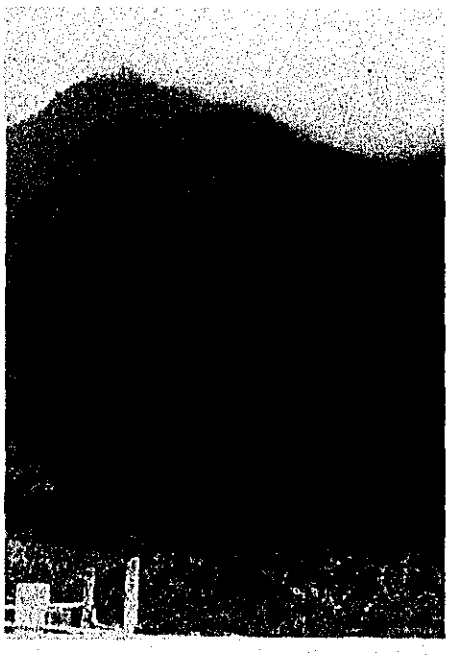


PHOTO-2 Proposed penstock route of Corani Project

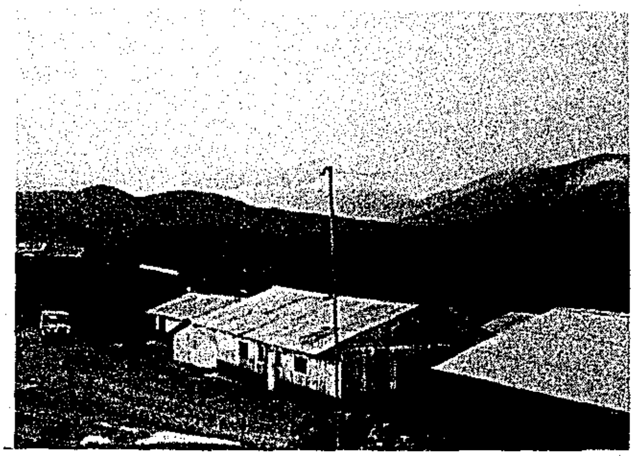


PHOTO-3 Base camp of Corani Project

PHOTO-4 Vinto Gaging Station

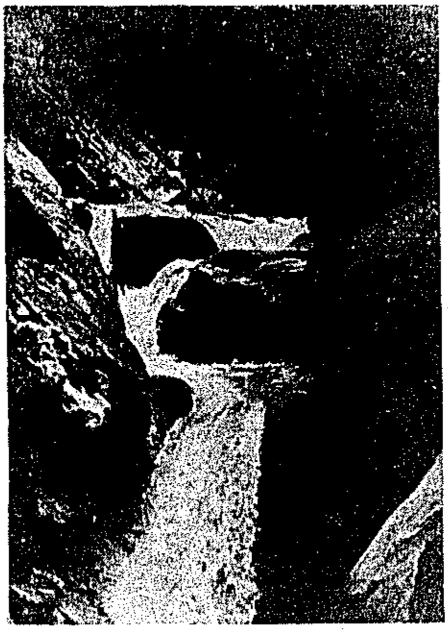


PHOTO-5 Río Vinto in November

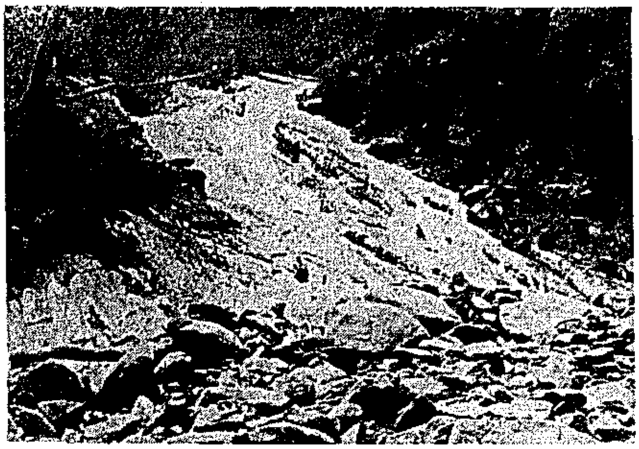


PHOTO-6 Río Vinto, 1.6 km upstream from the Vinto Bridge

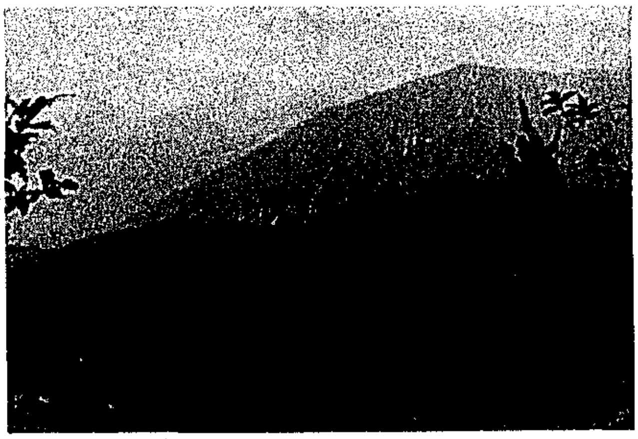


PHOTO-7 Santa Isabel Project, route of waterway and tunnel

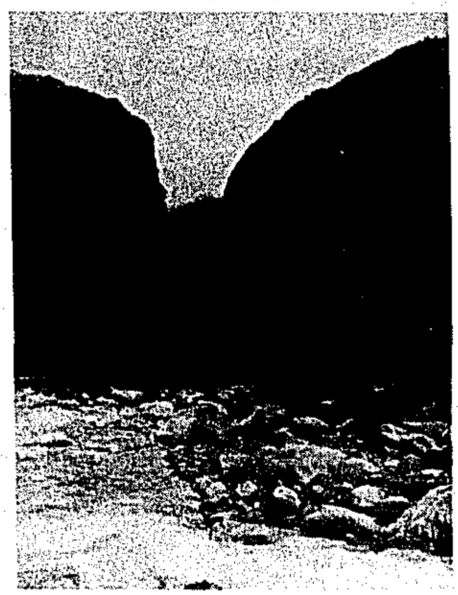


PHOTO-9 Río Santa Isabel around Proposed intake site of Locotal Project

PHOTO-8 Río Santa Isabel in November

PHOTO-10 Alto Pilcomayo Project, dam site A

PHOTO-11 Alto Pilcomayo Project, dam site A

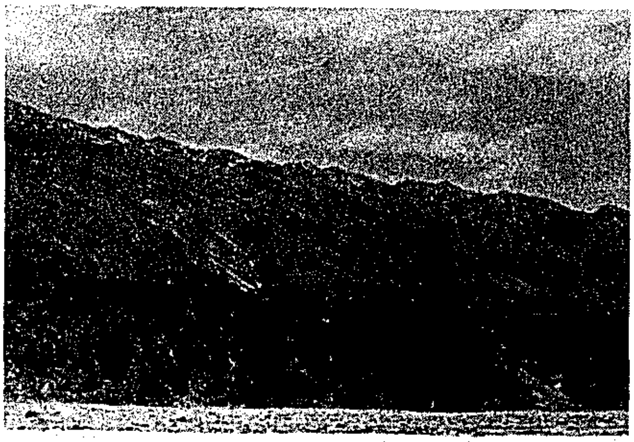


PHOTO-12 Alto Pilcomayo Project, proposed reservoir area

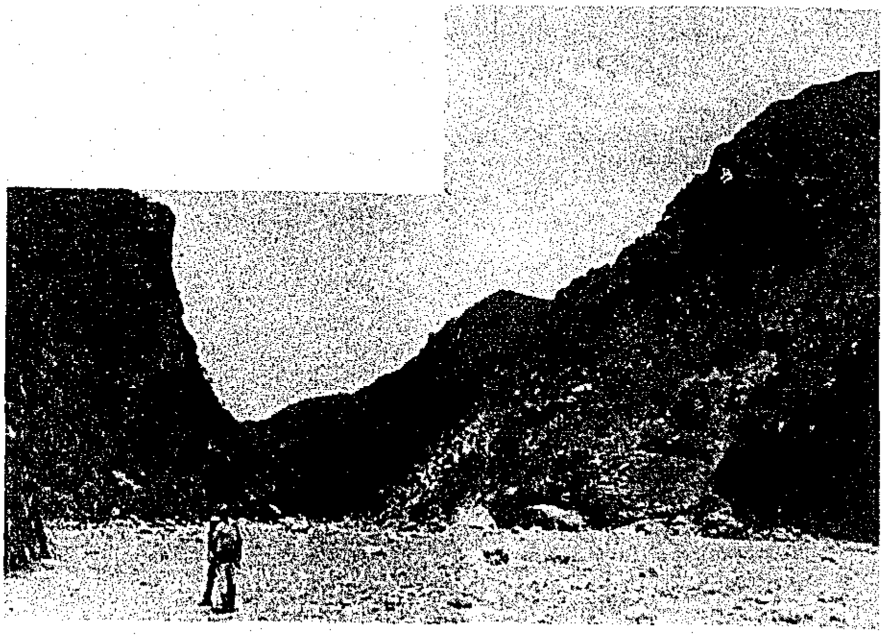


PHOTO-13 Alto Pilcomayo Project, dam site B


PHOTO-14 Alto Pilcomayo Project, dam site A at the entrance of Talula Valley

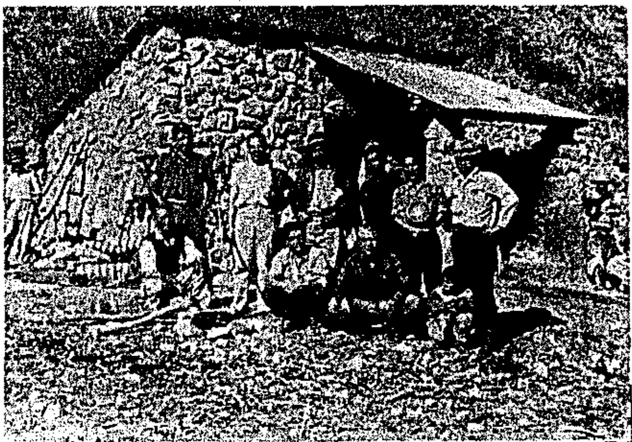


PHOTO-15 Members of the Mission at Talula Valley


PHOTO-16 San Jacinto Project, dam site


PHOTO-17 San Jacinto Project, back slope of reservoir bank

PHOTO-18 San Jacinto Project, dam site

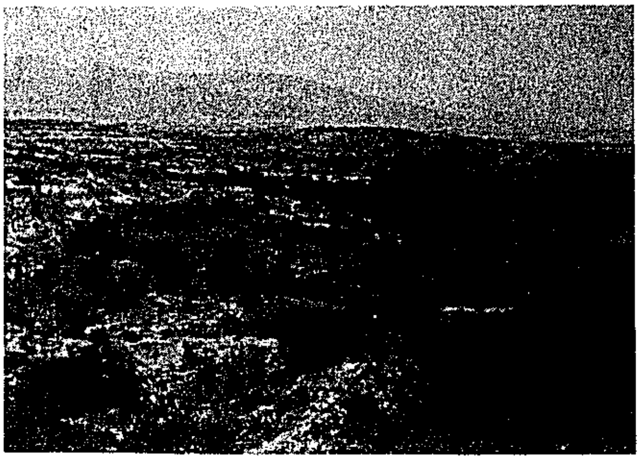


PHOTO-19 Río San Jacinto, downstream of dam site

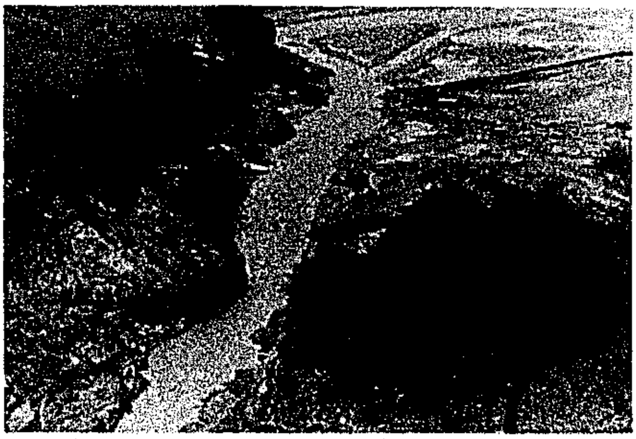


PHOTO-20 San Jacinto Project, dam site

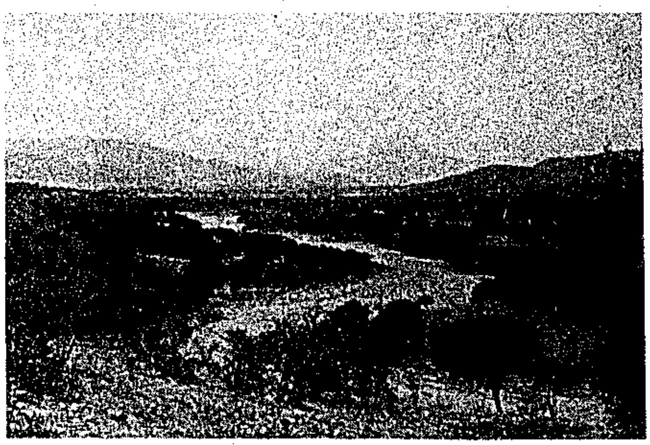


PHOTO-21 Río San Jacinto, downstream of the proposed powerhouse site

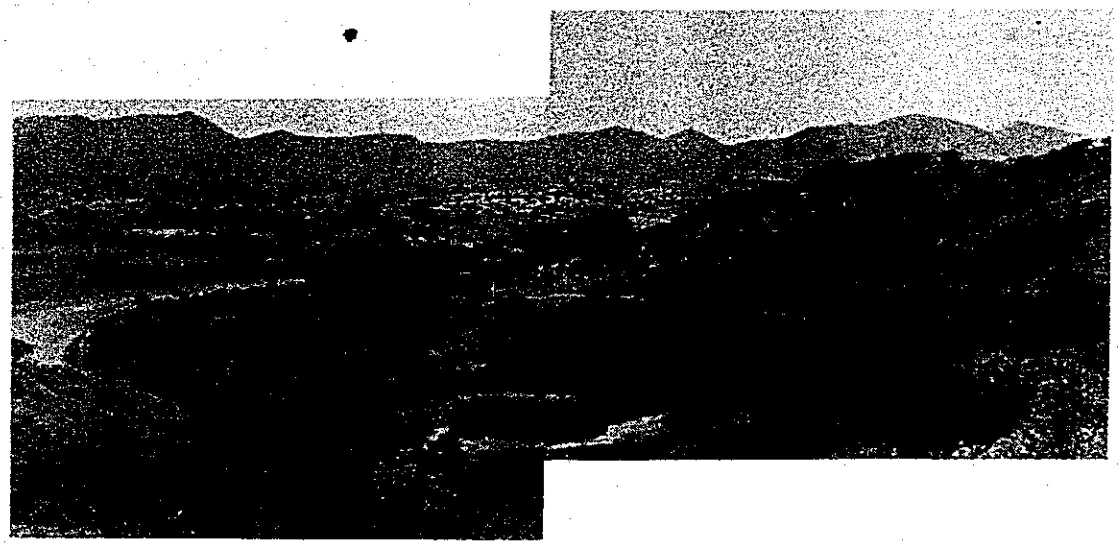


PHOTO-22 San Jacinto Project, proposed penstock route

PHOTO-23 San Jacinto Project, proposed reservoir area seen at the dam site