No. 4

THE REPUBLIC OF COSTA RICA

THE FEASIBILITY STUDY ON PIRRIS HYDROELECTRIC POWER DEVELOPMENT PROJECT

FINAL REPORT

SEPTEMBER 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to a request from the Government of the Republic of Costa Rica, the Government of Japan decided to conduct a feasibility study on Pirris Hydroelectric Power Development Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Costa Rica a study team headed by Mr. Mamoru Takaichi of Electric Power Development Co., Ltd., five times during the period from November 1989 to June 1992.

The team held discussions on the project with officials concerned of the Government of Costa Rica, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

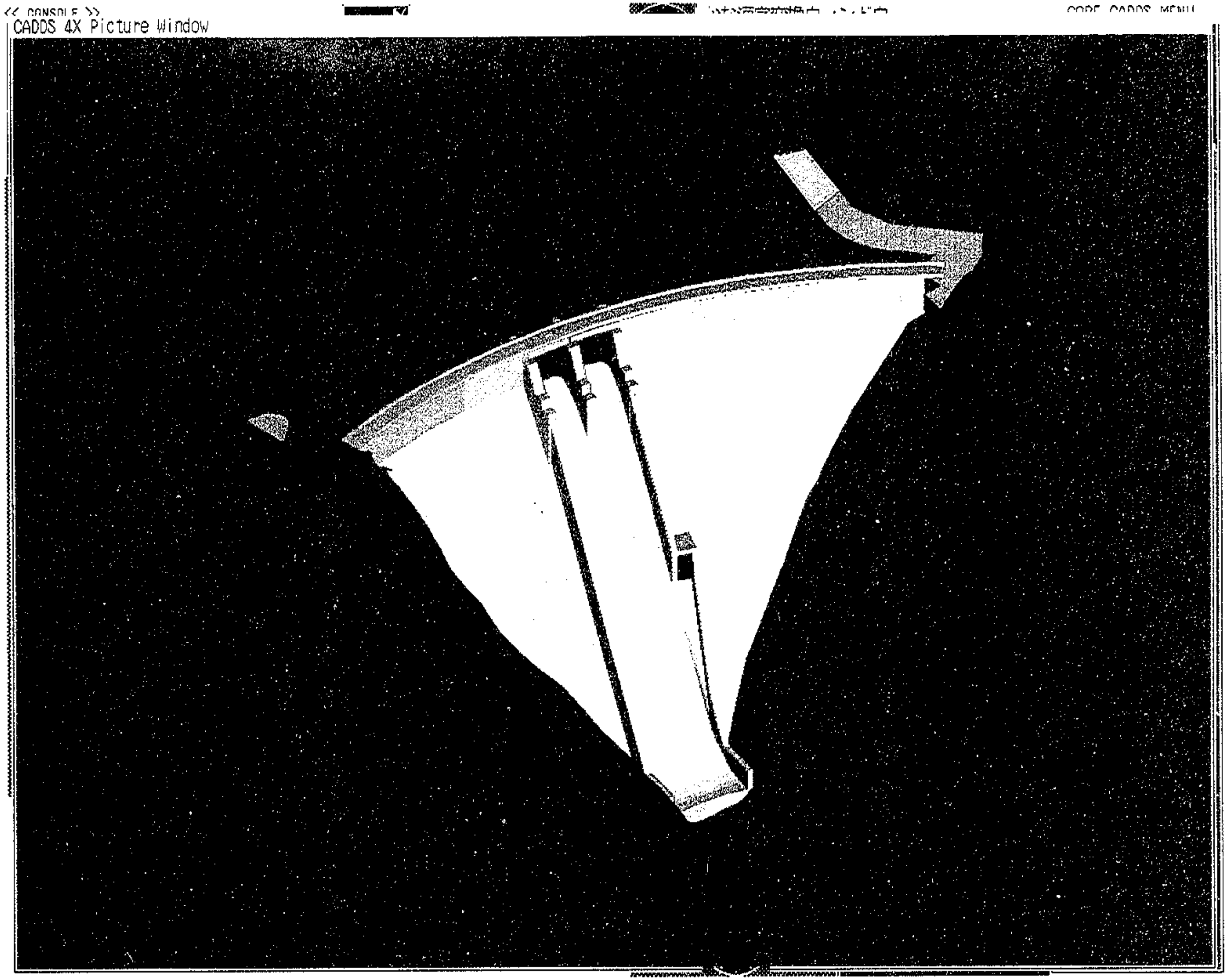
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Costa Rica for their close cooperation extended to the team.

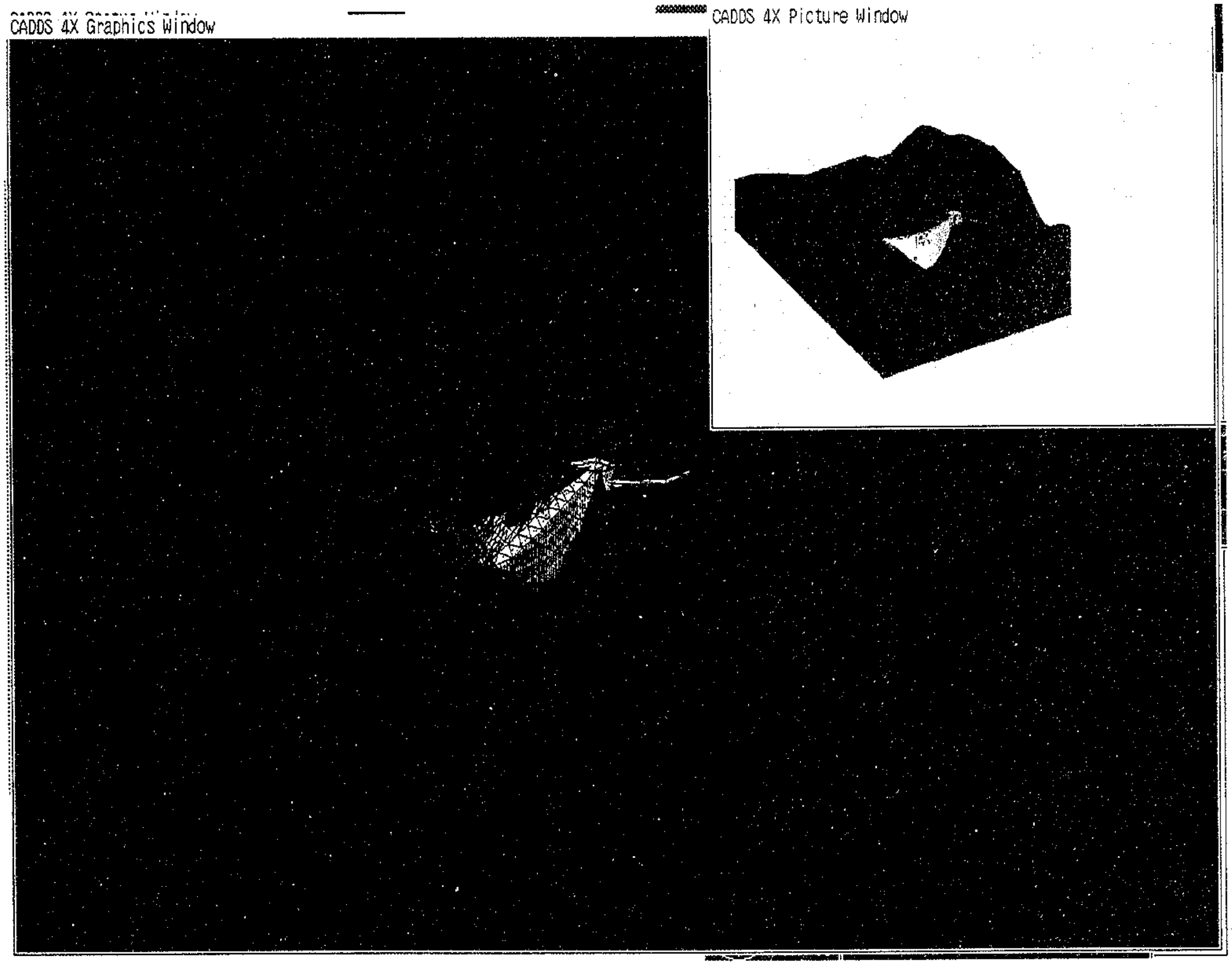
September 1992

Kensuke Yanagiya

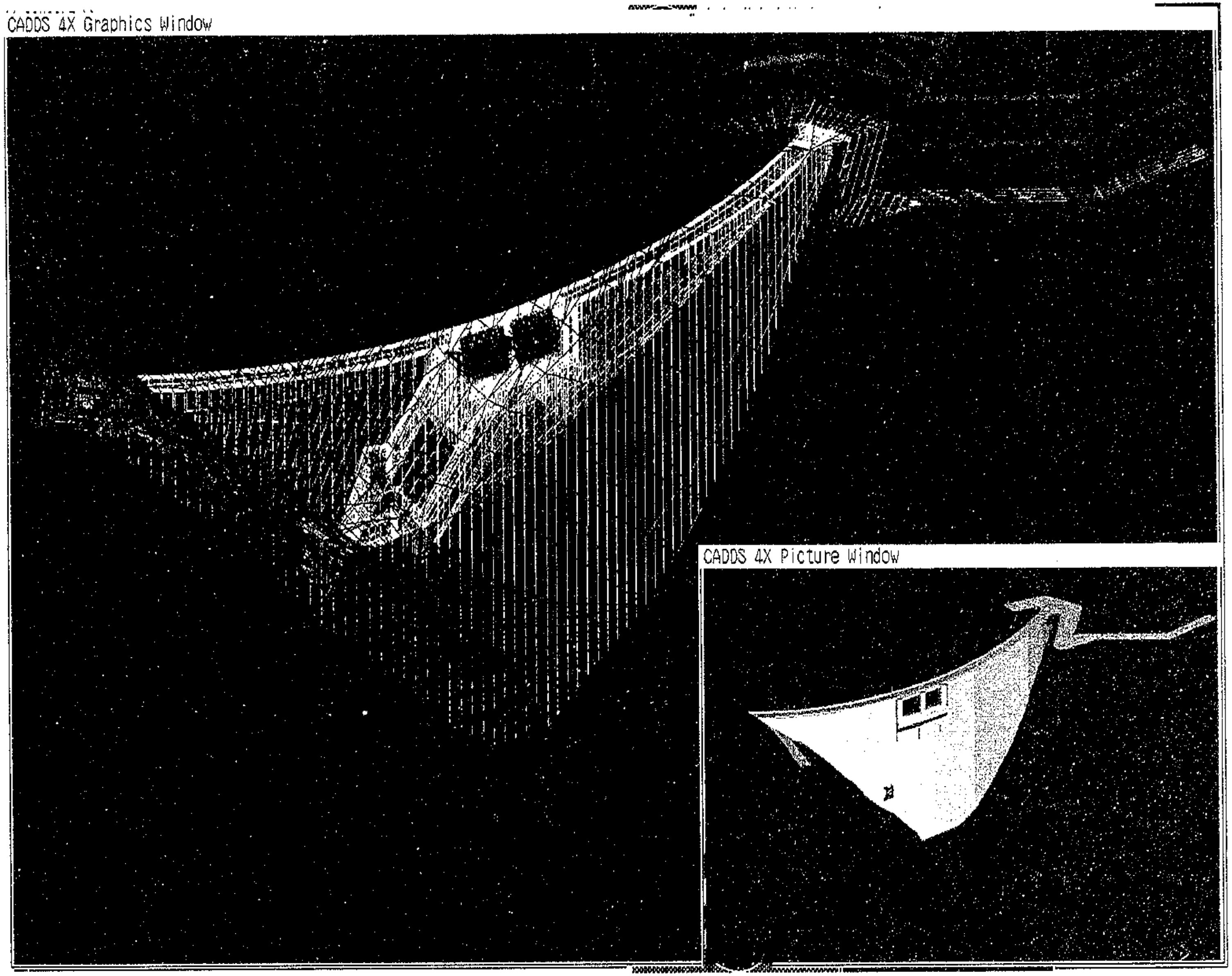
Kensuke Yanagiya
President
Japan International Cooperation Agency



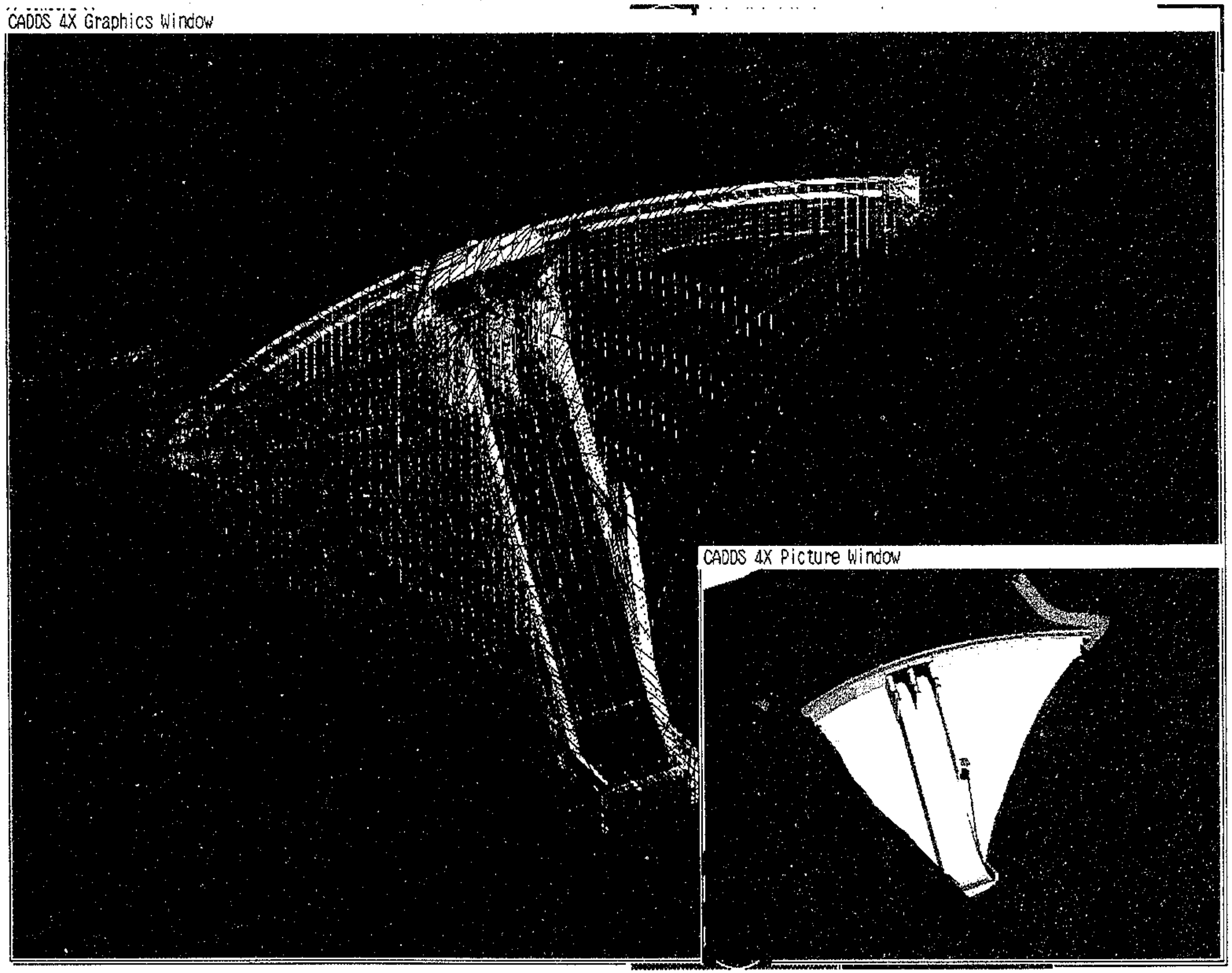
Downstream View of Dam [Drawn with CAD]



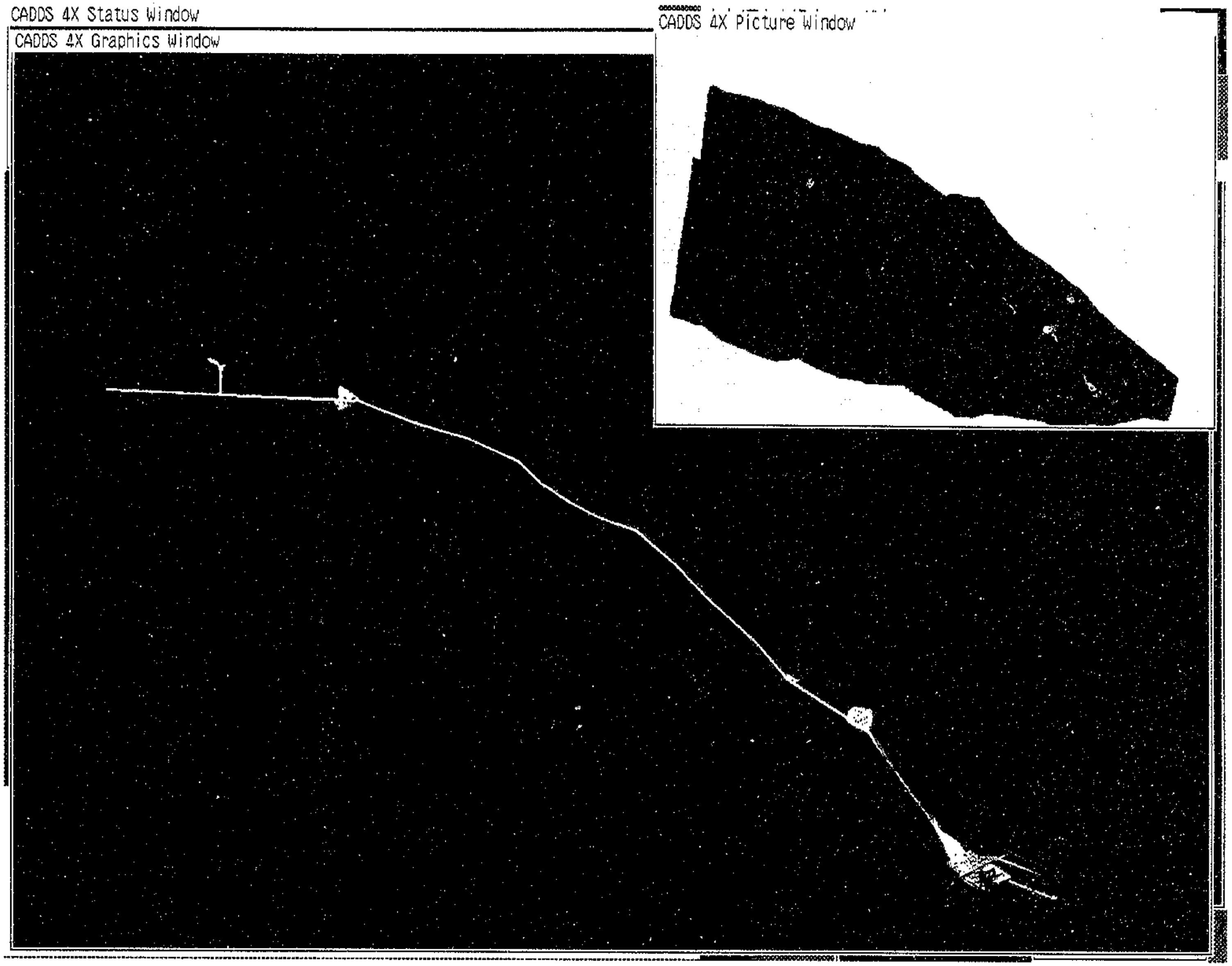
Bird Eye View of Dam [Drawn with CAD]



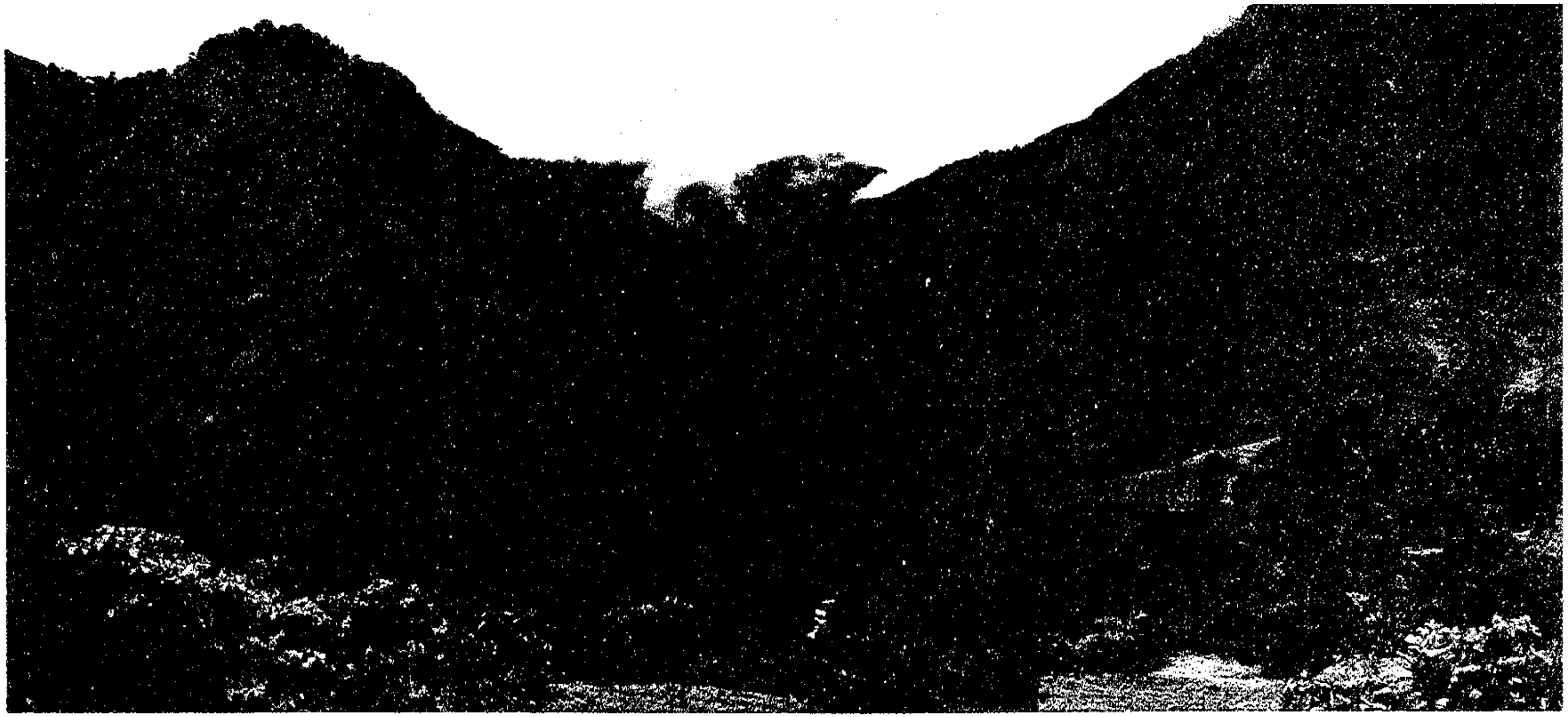
Upstream Wireframe View of Dam [Drawn with CAD]



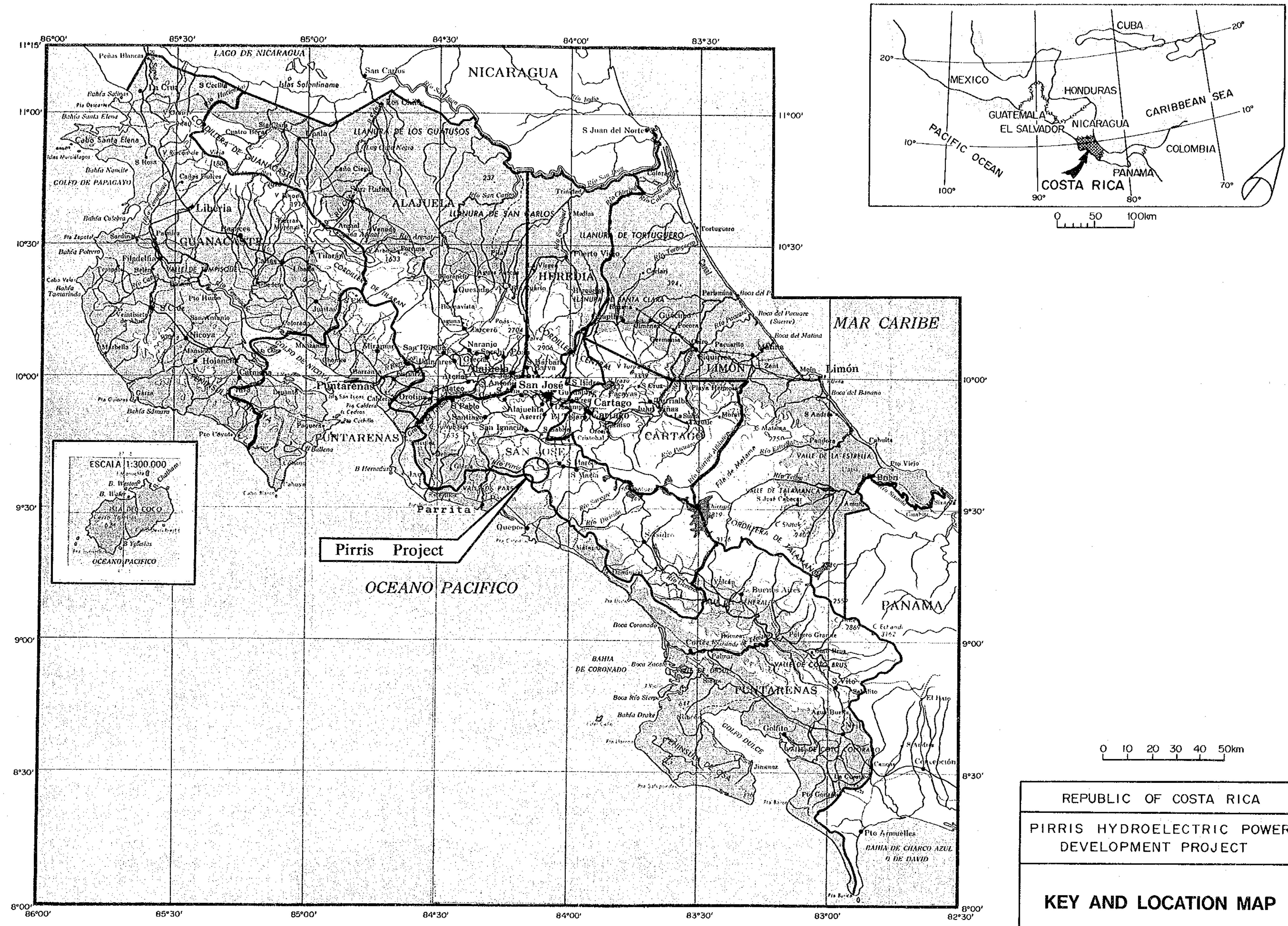
Downstream Wireframe View of Dam [Drawn with CAD]



Bird Eye View of Penstock and Powerhouse [Drawn with CAD]



Pirris Dam Site
(Looking from the upstream side)

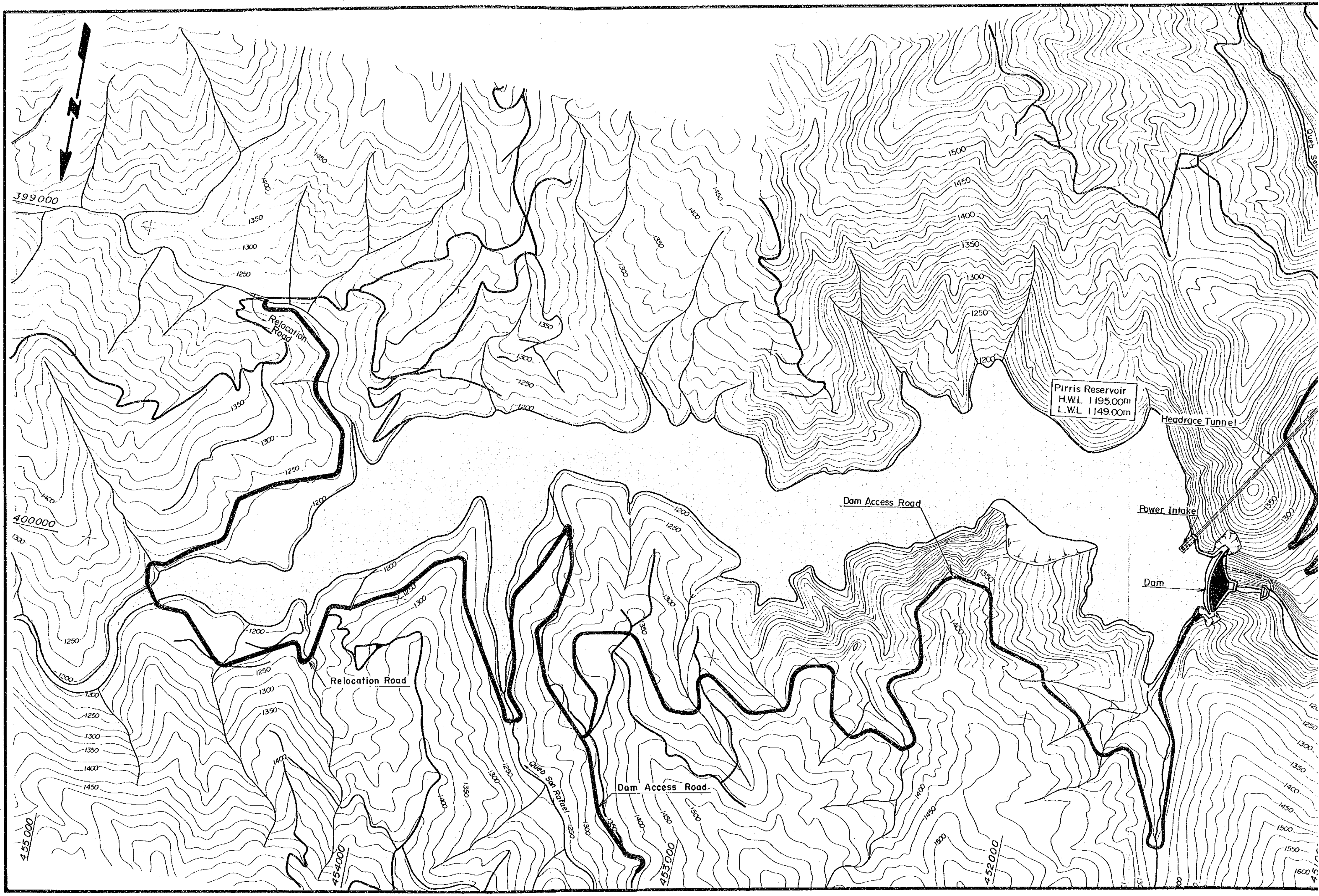


REPUBLIC OF COSTA RICA

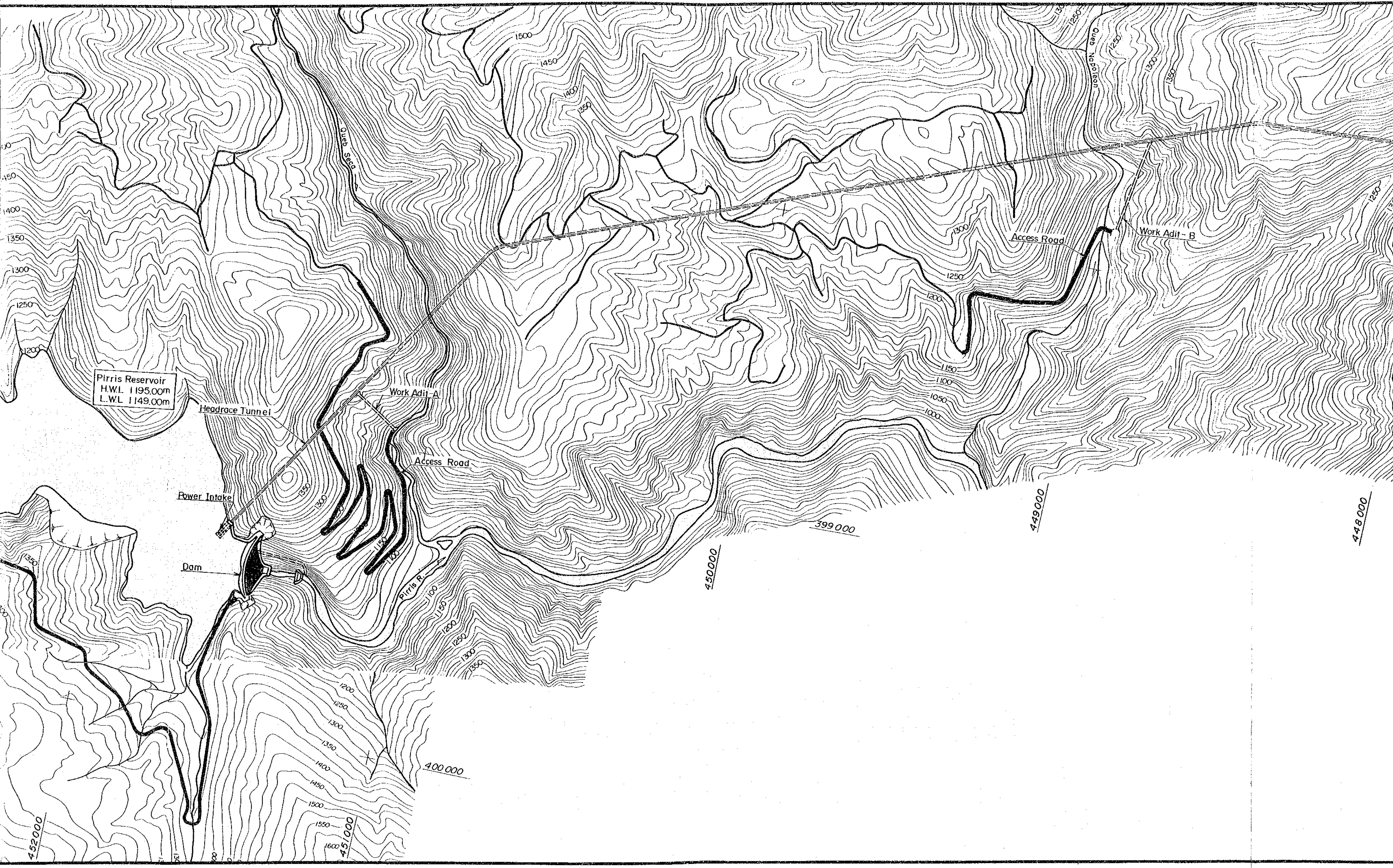
PIRRIS HYDROELECTRIC POWER DEVELOPMENT PROJECT

KEY AND LOCATION MAP

Fig. 1



Pirris Reservoir
H.W.L 1195.00m
L.W.L 1149.00m
Headrace Tunnel
Power Intake
Dam
Dam Access Road
Relocation Road
Relocation Road
Dam Access Road
Queb San Rafael
399000
400000
455000
454000
453000
452000



Pirris Reservoir
H.W.L 1195.00m
L.W.L 1149.00m
Headrace Tunnel
Power Intake
Dam
Work Adit-A
Access Road
Work Adit-B
Access Road
Queb Seca
Queb Napoleon
Pirris R.
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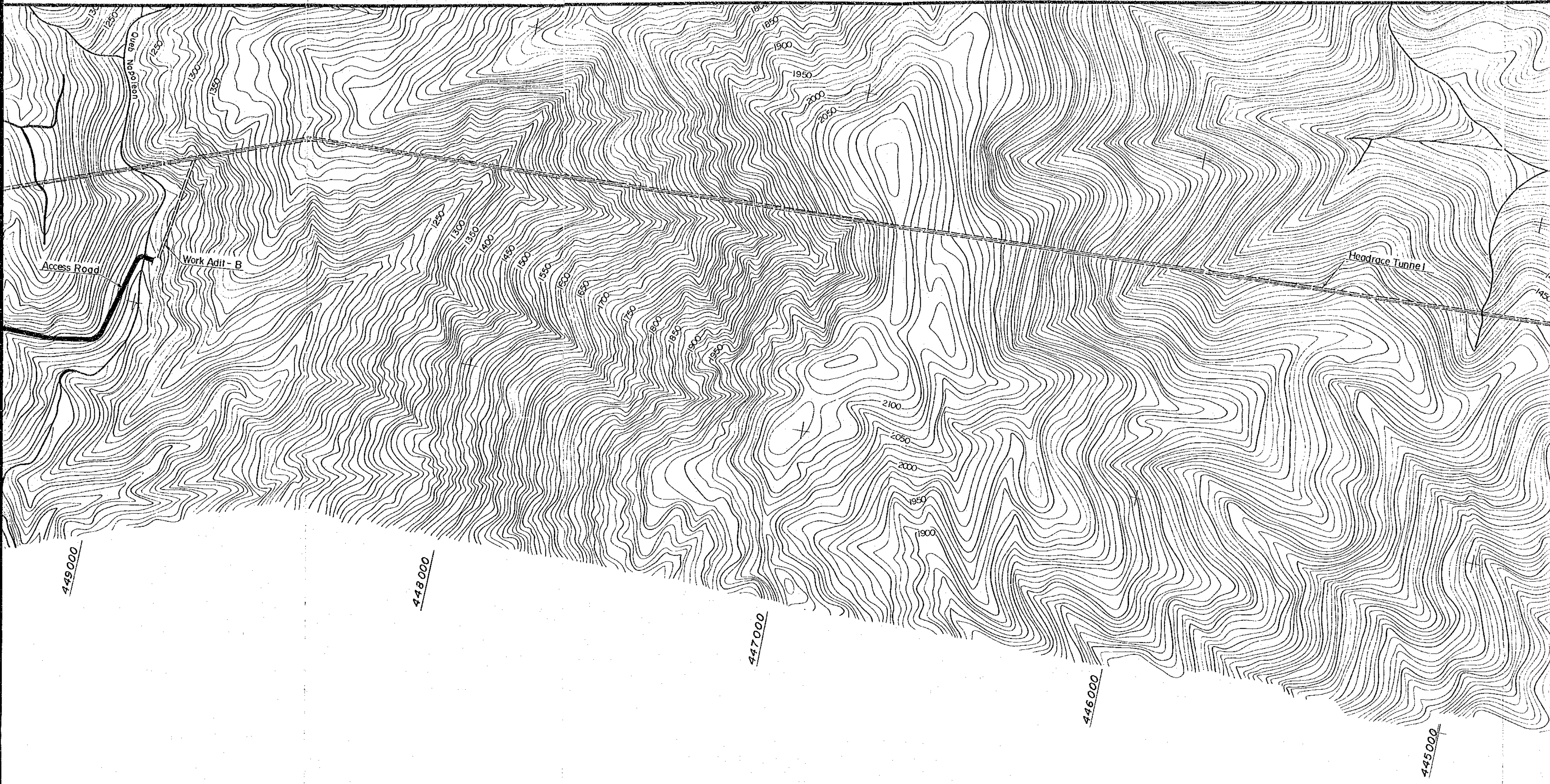

Oued Napoleon
Work Adit - B
Access Road
Headrace Tunnel
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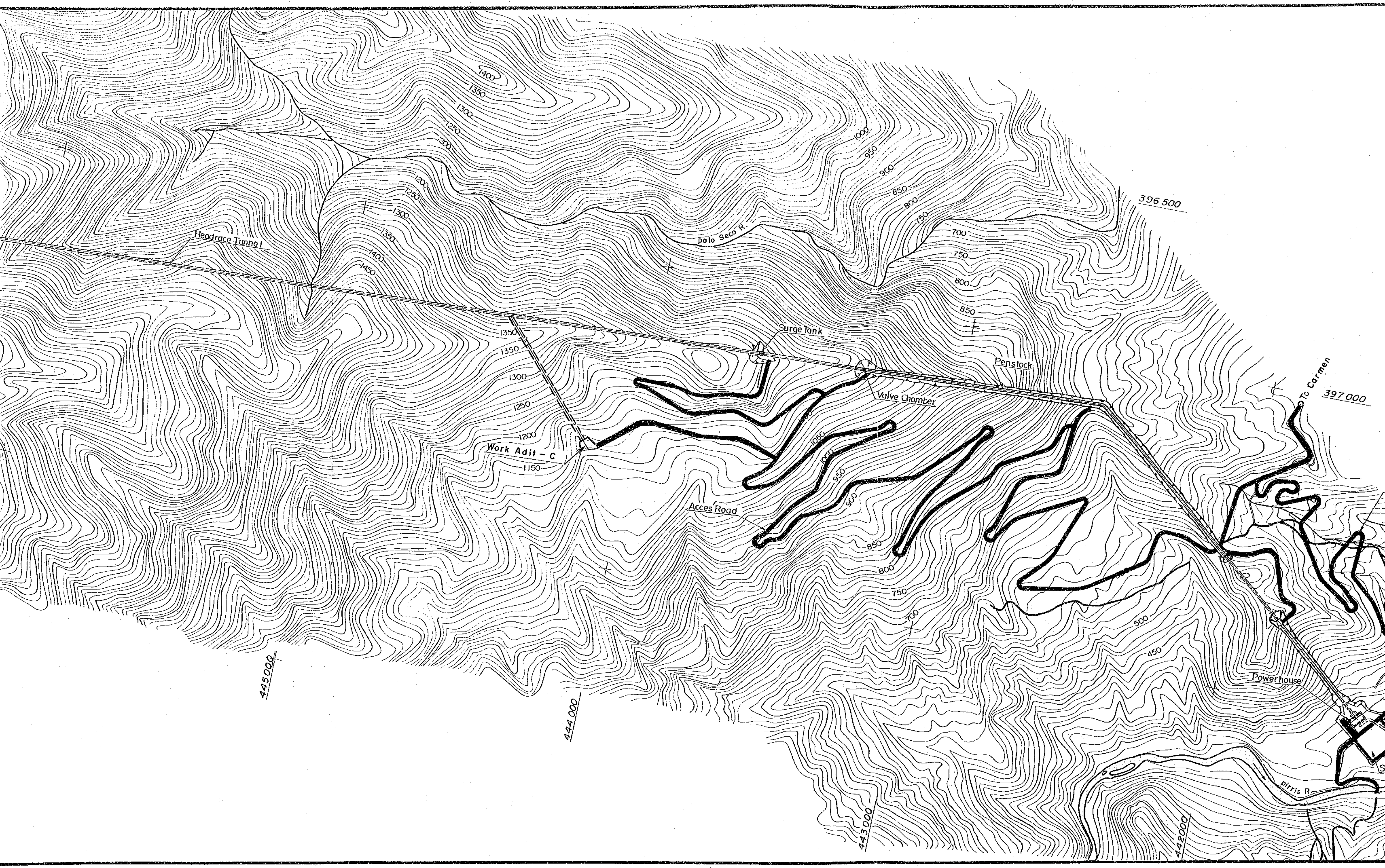

Headrace Tunnel
palo Seco R.
Surge Tank
Valve Chamber
Penstock
Work Adit - C
Acces Road
Powerhouse
To Carmen
pirris R.
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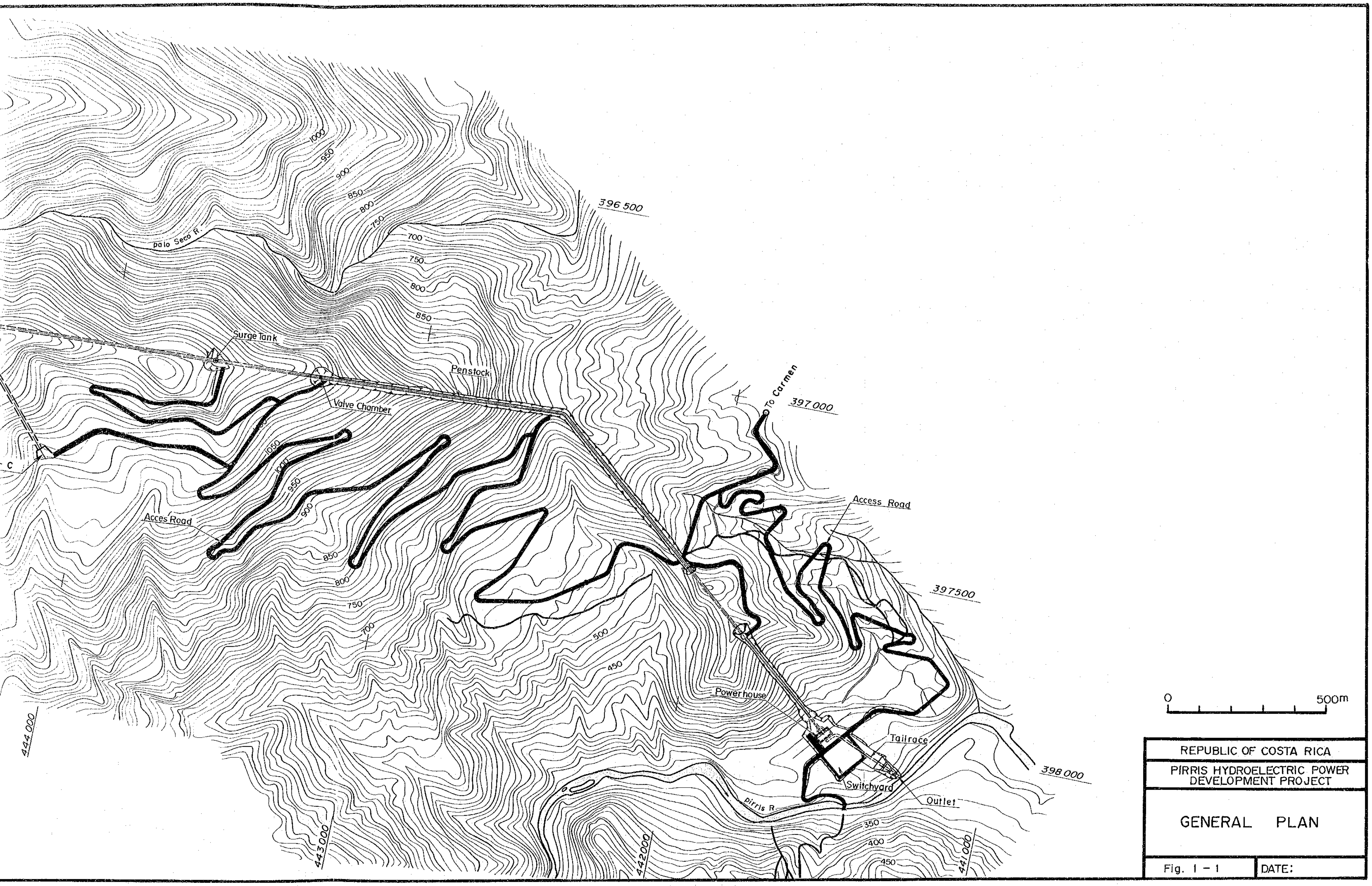
397 000
445 000
444 000
443 000
442 000



REPUBLIC OF COSTA RICA

PIRRIS HYDROELECTRIC POWER DEVELOPMENT PROJECT

GENERAL PLAN

Fig. 1 – 1

DATE:

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SUMMARY

SUMMARY

This is the feasibility study report of the Pirris Hydroelectric Power Development Project of the Republic of Costa Rica. The feasibility study was conducted from 1989 to 1992 by the Japan International Cooperation Agency (JICA) under a technical cooperation program of the Government of Japan.

This report is submitted by JICA through the Ministry of Foreign Affairs of Japan to Instituto Costarricence de Electricidad (ICE), a governmental organization of Costa Rica.

A brief summary of the results of the feasibility study is presented below:

(1) Features of the Project

The Pirris Hydroelectric Power Development Project (hereinafter called "the Project") described in this report comprises a power generation scheme including a dam, a waterway, a powerhouse, etc., and a power transmission scheme from Pirris Power Station to the entrance of Escazu Substation.

The Parrita River system consists of the Pirris River, Grande de Candelaria River, and the mainstream Parrita River. The river system has a catchment area of approximately 1,275 km^2, annual runoff approximately 2,179 x 10^6 m^3 (estimated) and a total length of approximately 85 km. The Parrita River mainstream has the Parrita Project planned at downstream site of the Pirris Project, and the La Ceiba Project and the El Ray Project on the Grande de Candelaria River. The Bijagual Project is located downstream junction of the two rivers. Among these projects, the Pirris Project is a scheme exclusively for power generation which will use the greatest head on the mainstream. It can be developed independent of the other projects. The Pirris Project is a hydroelectric power generation scheme which will use a high head and is favored with respect to siting characteristics and abundant runoff. Therefore, early development is looked forward to.

As mentioned above, there are two development schemes located at downstream site of the Project, and the runoff adjustment brought about by the Project will heighten the utilization effect of these downstream power stations. On the other hand, when considering the river system as a whole, the downstreammost Bijagual Project will serve as a re-regulating reservoir for the power discharge of the Project.

(2) Necessity for Development

The electric power facilities of the Republic of Costa Rica as of January 1991 amounted to 997.6 MW. The ratio between hydroelectric power (747.3 MW) and thermal power generating facilities (250.3 MW) is approximately 75:25. Meanwhile, Costa Rica has been making electric power interchanges with Nicaragua since 1982, with Honduras since 1983, and with Panama since 1986. Recently (1987-1990), import of electric power from Honduras has been conspicuous. In 1990, approximately 260 GWh were imported from Honduras while approximately 121 GWh were exported to Panama. It is considered that power interchanges among the four countries will continue in the future.

The results of forecasts made by ICE regarding future power demand (1991-2010) and the results of forecast by the macroscopic method are as follows:

Year	ICE Forecast (as of Aug. 1990)		Macroscopic Forecast	
	(GWh)	(MW)	(GWh)	(MW)
1991	3,878	744	3,887	740
1995	4,852	933	4,990	949
2000	6,550	1,261	6,632	1,262
2005	8,561	1,644	8,591	1,635
2010	10,649	2,031	10,863	2,067

To cope with the power demands, Sandillal Hydroelectric Project (32 MW) is scheduled to be commissioned in 1993, Toro I Hydroelectric Project (24 MW) in 1994, and Toro II Hydroelectric Project (66 MW) in 1995. In addition, Miravalles I Geothermal Project (55 MW) and Miravalles II

Geothermal Project (55 MW) are under construction for commissioning in 1994 and 1995, respectively.

Considered from the physical schedule of development, it is thought the commissioning of the Project will be in the year 2001. Seen from the electric power demand and supply plan, Pirris Project (128 MW) is desirable to be commissioned at that time following Angostura Hydro Project.

(3) Meteorology and Hydrology

The climate in the Pirris River Basin where the Pirris project site is located may be divided into 1) a humid, warm, rainy climate (clima templado lluvioso), 2) a tropical evergreen rain forest climate (clima tropical lluvioso y seco), and 3) a tropical rain forest climate (clima tropical lluvioso). The project area is located in regions having the climates of 1) and 3). The planned dam site which is central to the Project is in the region of 1), the catchment area being approximately 250 km^2, mean annual precipitation 2,600 mm, and mean annual temperature approximately 18°C.

The meteorological and hydrological quantities of the planned Pirris dam site obtained from analyses of meteorological and hydrological data concerning the Project are as follows:

Mean annual precipitation	:	2,600 mm
Annual inflow	:	351.61×10^6 m^3
Annual average runoff	:	11.10 m^3/sec
Suspended sediment	:	373 ton/year/km^2
Planned sedimentation	:	4.29×10^6 m^3
Annual reservoir surface evaporation	:	1,309 mm
Mean annual temperature	:	18°C
Existing maximum flood	:	710 m^3/sec (at No. 2604)
10-year return period flood	:	560 m^3/sec
Probable maximum flood (PMF)	:	1,670 m^3/sec

(4) Geology and Materials

(a) Geological Investigation Works

Geological investigation works carried out for the feasibility study of the Project were geological reconnaissance, aerial photo interpretation, core boring (including Lugeon test, in-hole water-level measurement), exploratory adit, test pit, seismic prospecting, in-situ rock tests, and laboratory rock test.

The quantities and results obtained may be summarized as follows:

Geological reconnaissances: carried out on roughly the entire damsite area, and parts of the reservoir, headrace tunnel, penstock, and powerhouse sites. Aerial photo interpretations were made of roughly the entire project area. These investigations made it possible to grasp the topographical and geological outlines of the project area and sites of the various principal structures.

Core Boring and Permeability Tests: 3 holes totalling 150 m in length, and 22 Legeon tests at the upper damsite; 4 holes totalling 290 m in length, and 43 Lugeon tests at the lower damsite; 2 holes totalling 55 m in length at the penstock and powerhouse sites. The groundwater levels were checked at all of these holes. The surface deposits, geological conditions of basement rock, geotechnical properties, and conditions of ground water of the various sites were confirmed through these investigations and tests.

Exploratory Adits: one, length 50 m, at the left bank of the upper damsite; one each, length each 50 m, at both banks of the lower damsite. The properties of the foundation rocks of the individual damsites were directly observed through these adits.

Test Pits: 3 pits, total depth 15 m, at the soil materials investigation site on the right-bank side of the reservoir area.

The distributions and properties of talus deposits and residual soil were revealed by these pits.

Seismic Prospecting: 6 traverses, total length 1,648.0 m, at the upper dam site; 6 traverses, total length 1,594.6 m, at the lower damsite; and 6 traverses, total length 4,824 m, at the penstock and powerhouse sites comprising surface prospecting; and 3 traverses, total length 150 m, at all of the upper and lower damsite adits comprising intra-adit prospecting. Through such prospecting, data were obtained concerning the states of loosening of the surface parts of basement rocks at the two damsites, the weathered conditions of bedrock at the ridge along the penstock route, and the distribution condition of terrace deposits at the powerhouse site.

In-situ Rock Test (Plate Bearing Tests): 6 sites, 3 sites each at 2 places in the side adits at the two banks of the lower dam site where a concrete-type dam is planned. Various moduli of elasticity were obtained for the dam foundation rock. (The results of in-situ rock tests will be described later.)

Laboratory Tests: Tests were conducted on 12 samples of concrete aggregates, 2 samples of rock materials, and 28 samples of soil materials. In order to learn about the physical character and mechanical properties of the dam foundation rock, various kinds of laboratory tests were performed on 28 boring core specimens collected from the upper and lower damsites.

(b) Geology

The project area is located in the basin of the Pirris River, a tributary of the Parrita River which is at roughly the central part of Costa Rica and empties into the Pacific Ocean. This river basin is in a mountainland generally presenting a mature topography with many steep slopes. Many of the rivers and gullies within the area have V-shaped valleys with swift streams.

The geology of the Project area consists of basement rocks of igneous rocks and sedimentary rocks of the Mesozoic Era Jurassic Period to the Quaternary Period Pleistocene Epoch, and overlying unconsolidated deposits of the Quaternary Period. These igneous rocks are mainly basic rocks and are distributed mainly at the right-bank side of Pirris River from the vicinity of the damsite to the powerhouse site, and locally at the left-bank side. On the other hand, the sedimentary rocks are distributed at the greater part of the reservoir area and most of the tunnel route. In the Project area, the igneous rocks are overlain in unconformity by the sedimentary rocks, but the two contact each other by faults at places.

River deposits and colluvial deposits covering the slope surface at parts mainly comprise the unconsolidated Quaternary deposits, but both are limited to partial distributions.

The reservoir area mainly has sedimentary rocks belonging to the Terraba Formation (Oligocene-Pleistocene) distributed. According to the investigations up to the present, it has been found there is no problem in particular concerning water-tightness, stability of slopes of the reservoir rim, and sedimentation.

The damsite is located on the middle stretch of the Pirris River in a mountainland with mountain peaks of elevations from 1,500 m to 2,000 m. Two sites, upstream and downstream, were compared and studied. Topographically, the upper site has a wider valley width compared with the lower site which has a V-shaped valley. The river-bed elevation of the damsite is approximately 1,100 m at the upper site and 1,080 to 1,090 m at the lower site.

Regarding dam-site geology, the upper site is composed of sandstone said to belong to the Terraba Formation and with intercalation of shale, siltstone, and conglomerate at parts, while the lower site is composed of dolerite-basalt said to belong to the Nicoya Complex mainly consisting of ophiolitic rocks.

With regard to the engineering geological properties of the foundations of the two damsites, both sites have little distributions of surface deposits, with basement rocks exposed at the greater parts of the surfaces of the dam foundations. Although the surface portions of these rocks are more or less loosened and groundwater tables are slightly low at the mountain bodies on both sides, they have been found to possess suitabilities as dam sites.

Waterway structures from intake to powerhouse are planned at the left-bank side of the Pirris River. These waterway routes pass entirely through mountainland.

The headrace tunnel route passes through mountain bodies of around EL. 1,400 m in the first-half section. It has grade crossings with comparatively large gullies at several places along the way, while the latter-half section passes under a single mountain body having an elevation at its peak of 2,150 m. The earth cover of the tunnel is approximately 45 m to approximately 360 m at the first half and approximately 100 m (in the vicinity of the surge tank) to approximately 1,000 m at the latter half.

The area along this route, other than having igneous rocks at the first-half section, mainly has sedimentary rocks distribution. It is expected that the tunnel will cross with at least 5 or 6 faults, either large or small.

Regarding the engineering geological properties of this tunnel revealed by investigations up to the present there are possibilities of undesirable conditions, such as, deterioration of lithological character, inflow of ground water in sections of cover for the tunnel less than 100 m (approximately 450 m) and near intersections with faults, rock bursts, and rises in ground temperatures. It has been found, however that there is no distribution of ground strata of low degree of consolidation, distribution of karstic rocks over a wide area, or active volcanism of a degree to have a fatal effect on the tunnel project. Further improvement in accuracy of investigations on the tunnel is necessary. However, taking the present level of tunnel engineering into account, it is possible to overcome any unfavorable conditions for the tunnel.

The surge tank site is located at the vicinity of EL. 1,240 m on a ridge extending in the WNW direction, the penstock route along a ridge bearing from a WNW direction to a NW direction partly along the way, and the powerhouse site on a terrace of EL. 330 to 340 m formed along the left bank of the Pirris River.

Sedimentary rocks of siltstone and sandstone are distributed from the surge tank site to the upper-half section of the penstock route. Basic rocks mainly of dolerite-basalt are distributed from the lower-half section of the penstock route to the powerhouse site.

These structures are planned avoiding the landslide topography seen in the vicinity. According to the results of investigations up to this time, it is thought there are no factors from an engineering geological standpoint to force changing of plans.

(c) Materials

Of construction materials for the Project, the most important are materials for constructing the dam. In case of the upstream site, the dam will be a fill type. In case of the downstream site, a concrete dam would be conceivable.

As rock and filter materials, the dolerite-basalt distributed at the lower dam site and its surroundings is of good quality according to the results of laboratory tests. There is no problem in quantity.

As soil materials, the topsoil and talus deposits on the right-bank slope approximately 1.5 km from the upstream dam site are usable both quality-wise and quantity-wise.

Either river-bed sand-gravel, or dolerite-basalt or sandstone among basic rocks may be considered for concrete aggregates near the damsite. According to the results of investigations and tests conducted up to this time, the sandstone distributed in the general area of the vicinity of the upstream dam site is conceivable to be used. The sandstone is possible to quarry both quality-wise and quantity-wise according to the results of investigations and laboratory tests conducted up to this time. With respect to this sandstone, it will be necessary to conduct tests on artificial crushed rock.

Other than this sandstone, it may be possible to use part of the dolerite-basalt in the form of excavation muck from the diversion tunnel for the dam and from the headrace tunnel as concrete aggregates.

(5) In-situ Rock Tests

Plate bearing tests were performed at 3 points each of 2 locations, a total of 6 points, in the adits at both banks of the downstream site where a concrete type dam is planned. The results of the tests may be summarized as follows:

In the adit LA-1 at the left bank of the downstream site, the test locations correspond to a part of fairly good condition for the bedrock at the downstream site. The moduli of elasticity were 28,000 to 31,000 kg/cm^2, secant moduli of elasticity 38,000 to 42,000 kg/cm^2, and tangential moduli of elasticity 42,000 to 48,000 kg/cm^2.

On the other hand, in the adit LA-2 at the right bank, the conditions of rock at the test locations were the best in this adit, but slightly inferior when compared with the left-bank side. This was reflected in the test results. The moduli of elasticity were from 12,000 to 30,000 kg/cm^2, secant moduli of elasticity 30,000 to 43,000 kg/cm^2, and tangential moduli of elasticity 36,000 to 48,000 kg/cm^2.

It may be said that the test results indicate that ample bearing capacity as the foundation for the concrete type dam planned is possessed at the lower damsite.

(6) Seismicity

The Pacific Ocean-side region of Costa Rica comprises the plate boundary where the Cocos Plate sinks under the Caribbean Plate, and many earthquakes occurred at this plate boundary in the past. There have been as many as approximately 50 earthquakes of magnitude 5.5 or higher which occurred within a radius of 200 km from the Pirris Project site covering the Pirris river basin since 1904. It is essential that thorough evaluation be made regarding earthquakes and proper considerations be given in the earthquake resistant design of electric power facilities. The seismic risk analysis based on the stochastic technique is performed. And the maximum acceleration at the dam site which is absolutely necessary as a fundamental condition in carrying out the earthquake-resistant design is evaluated.

In the seismic risk analysis here, the earthquake data from the earthquake data file of NOAA (National Oceanic and Atmospheric Administration of the United States Geophysical Data Center) were used.

The earthquakes occurred within a radius of 1,000 km from the Pirris Project site during the period from 1900 to 1991 and were 5,191 in number.

As a result of this study, design horizontal seismic coefficient for the Pirris dam site was set up as follows:

Dam Type	Design Horizontal Seismic Coefficient
Fill Type Dam	0.15
Concrete Gravity Dam	0.15
Concrete Arch Dam	0.30

The determination of optimum configuration and cross section of dam, and the basic stability evaluation of dam during earthquake are normally made according to the seismic coefficient method. The design seismic coefficient to be used in the seismic coefficient method, as previously mentioned, is evaluated considering a conversion factor for the maximum acceleration of earthquake motion assumed for the site. The value of the conversion factor can be thought to depend on the frequency characteristics of the earthquake motions assumed, and the dynamic characteristics of dam and foundation rock to be considered in the earthquake-resistant design. Therefore, it is desirable to ascertain the seismic stability of dam by dynamic analyses in the detailed design stage. The appropriateness of the design seismic coefficient can be verified by comparison of dynamic and static analyses.

(7) Environment

(a) Survey Method

As for environmental impact assessment, the site investigation was conducted by grasping the present environmental situation and the characteristics of the region where the project site is located and selecting environmentally-important items and items considered to have big environmental impact from existing and newly-obtained materials with reference to manuals, guidelines, etc., prepared by the World Bank, Japan International Cooperation Agency, etc.

The survey was conducted in cooperation with neutral organizations such as a national university, etc., in Costa Rica to make the survey and its environmental impact assessment fair.

In this survey, materials were collected, the site investigation was conducted in cooperation with ICE.

(b) Natural Conservation around the Project

There are designated areas in the Pirris River basin, such as four water source reserves required for maintaining water quality and quantity, one forest reserve and two reservations for aborigines, but they are away from the project site.

(c) Vegetation

Since the area to be submerged as the reservoir is used as pastures and cultivated land without any forests, the reservoir will have no impact on natural vegetation in its vicinity.

(d) Animals

Since there are no big forests in the vicinity of the project site, the phase of animals is also poor. The section with an area of 1.10 km^2 along Pirris River is planned to be submerged by the construction of the reservoir, but no forests are included in this section. The reservoir will provide the waterside while destroying a part of the habitable foundation for land animals. The bank of the lake can be a new living environment, but is expected to have no big impact on the living conditions of animals by giving consideration to the gradient of the slope and the size of water-level changes.

(e) Water Quality

i) Present Situation

Water in Pirris River at the project site is contaminated by organic matter discharged from coffee factories. Water quality is so bad that the water emits a foul odor. Fertilizer and livestock's manure, which are discharged respectively from coffer plantations and pastures upstream from the project site, have become the cause of further water contamination. It is characteristic of water quality to become the worst in the dry season which falls on the time to reap and process coffee fruits, and to improve considerably in the rainy season.

ii) Water Quality Changes in the Reservoir

It is obvious that the reservoir, which is planned to appear together with the construction of the dam, will largely change the process of water purification. The reservoir is cone-shaped and deep, and water is expected to be replaced not so often but about ten times a year. Since the temperature at the project site is constant all the year around, a vertical current of water in the reservoir will be difficult to be created by seasonable temperature differences.

When organic matter accumulates at the bottom of the lake near the dam in a reservoir of this kind, water in the lower part of the lake loses oxygen together with the decomposition of organic matter. While organic matter decomposes continuously in the anaerobic state, harmful gases such as methane, ammonia, hydrogen sulfide, etc., are expected to be generated by the action of reduction.

The present concentration of nitrogen and phosphor in the water of Pirris River is high, standing at 2.4 ppm and 8.2 ppm respectively. A nitrogen concentration of 0.3 ppm and a phosphor concentration of 0.015 ppm are regarded as the index to the start of lake eutrophication. The present concentration of them in the water of Pirris River is so high that the reservoir can not avoid becoming eutrophic.

Water quality in the reservoir is expected to deteriorate considerably in the future since a log of organic matter and nutrient salts flow into the reservoir from the river basin. However, since the contamination load factors of nitrogen and phosphor imposed by coffee waste matter are 62% and 87% respectively, the reduction of coffee waste matter is the most effective measure to prevent water contamination.

(f) Water System Utilization

The power station will have no impact on water utilization since it is conducted only in the area upstream from the reservoir. Most water utilization facilities consist of coffee processing factories and all the water utilized is returned to Pirris River.

There is no fishery, and no fishery right has been determined either.

(g) Land Utilization

What the Project is expected to most influence land utilization in its vicinity is to submerge land by the storage of water. Coffee plantations and pastures with a total area of 1.10 km^2 are expected to be submerged. But they account only for a small portion and the power station will have no impact on land utilization in the region.

(h) Local Community

Since the Project is located more than a few km away from the nearest village, it will have no big direct relationship with social life in this region although employment and consumption are expected to increase temporarily.

Roads in its vicinity will be improved or newly constructed by the establishment of the power station, and the situation of roads in this region are expected to be drastically improved.

(i) Cultural Assets

Investigations of archaeological-and-historically-important cultural assets, which should be protected, are not being conducted now in the vicinity of the Project site.

(j) Monitoring

Based on the estimation of the present environmental situation or the environmental impact, water quality is the most important problem among the problems of the environment in the vicinity, which may be caused by the implementation of the Project. In this regard, it is necessary to monitor the environment after the startup of the power station and during the construction work in trying to confirm the effects of various measures or get the feedback of those measures.

(k) Compensation

There are four houses required to be transferred and one suspension bridge. As for houses, ICE will purchase substitute land and provide it to them.

The means of transportation substitute for the suspension bridge, which is expected to be selected from a new bridge, a bypass road, ferry service, etc., but this should be included in the project costs after all.

The total compensation cost required for the Project is 84 million colons. The cost to substitute the suspension bridge should be added to this amount of money.

The accurate compensation costs will be determined in estimating the process of land planned to be purchased by ICE and negotiating with landowners in the execution process of the Project.

(8) Outline of Optimum Development Scheme

(a) Project Outline

The outline of the Pirris Project is as described below.

The Project is located in the central plateau approximately 30 km south of San Jose, the capital of Costa Rica. A concrete arch gravity dam of height 120 m and dam volume 390,000 m^3 is to be constructed at a point approximately 30 km upstream from the junction of the Grande de Candelaria River, a tributary of the Parrita River (Pirris River) and the Pirris River to obtain a gross storage capacity of 37.5 x 10^6 m^3 and effective storage capacity of 30.6 x 10^6 m^3. An annual average inflow of 351.6 x 10^6 m^3 is to be regulated with this reservoir. A maximum discharge of 18 m^3/sec is to be drawn by an intake provided at the left bank immediately upstream of the dam. It is conducted via a headrace tunnel of 8.7 km and a penstock of length approximately 2.6 km to a powerhouse provided at the left bank to attain a maximum output of 128 MW and annual energy production of 609.3 x 10^6 kWh. The electric power produced at Pirris Power Station would be transmitted by a 230-kV transmission line to Escazu Substation.

(b) Construction Cost and Economic Analysis

The total construction cost required for construction of the Project will be US$218,915,500. The period of construction is to be approximately 5 years. The construction costs at the generating end per kW and kWh will be US$1,599.0 and US$0.336, respectively. As for the construction costs at transmitted end (Escazu Substation entrance) per kW and kWh, they will be US$1,710.3 and US$0.359, respectively. The generating energy cost of the Project at the entrance of Escazu Substation will be US$0.0255/kWh.

The net present value (B - C) and the benefit-cost ratio (B/C) of the Project in case of a thermal power plant as the alternative power generating facility will be US$64,216,000 and 1.47, respectively.

The financial internal rate of return (FIRR) and economic internal rate of return (EIRR) of the Project are 12.02% and 12.85%, respectively.

(9) Construction Schedule and Construction Cost

(a) Construction Schedule

Considering the commissioning year of the Project as 2001, it will be necessary to make preparations for start of construction roughly according to the schedule below.

Period	Item
Dec. 1989 - Sep. 1992	Feasibility Study
Oct. 1991 - Apr. 1993	Further Investigation Works
Oct. 1992 - Sep. 1994	Final Design
June 1992 - Dec. 1992	Request of ICE to MIDEPLAN
Oct. 1993 - Sep. 1994	Finance Formalities
Sep. 1994 - Sep. 1995	Approval of Congress
Oct. 1994 - Apr. 1996	Bidding and Award of Contract for Construction
May 1996 - Apr. 2001	Construction

The construction work of the Project, as a result of examining the construction scale, layout or structures, preparatory works, etc., will require a construction period of approximately 5 years.

(b) Construction Cost

It was considered that designs, construction methods, materials, and products of the technical levels which can be expected at the present time will be applied to the construction cost. Estimation was made considering the geological and topographical conditions of the project site, construction scale, etc. The time of estimation was taken as January 1991. (The foreign exchange rate was considered as US$1 = 105 Colones.)

The construction cost will be US$218,915,500. Local and foreign currency requirements in terms of U.S. dollars are as follows:

Local currency:	US$ 85,880,300
Foreign currency:	US$133,035,200

Outline of Pirris Hydroelectric Power Development Project

Items	Unit	Description
Location		Pirris River
Hydrology		
Catchment Area	km^2	250.8
Average Annual Inflow	$10^6\ m^3$	351.6
Design Flood	m^3/sec	1,670
Reservoir		
Normal High Water Level (NHWL)	m	1,195.00
Low Water Level	m	1,149.00
Available Drawdown	m	46.00
Sedimentation Surface	m	1,140.00
Gross Storage Capacity	$10^6\ m^3$	37.47
Effective Storage Capacity	$10^6\ m^3$	30.59
Surface Area at NHWL	km^2	1.23
Diversion Tunnel		
Design Flood	m^3/sec	560
Type	-	Hose-shoe type
Number of Tunnel	-	1
Inner Diameter	m	6.50
Inlet Sill Elevation	m	1,086.00
Length	m	330.00
Dam		
Type	-	Concrete arch gravity dam
Crest Elevation	m	1,197.50
Crest Length	m	225.00
Crest Width	m	6.00
Dam Height	m	120.00
Dam Volume	m^3	387,000

Items	Unit	Description
Spillway		
Design Flood	m^3/sec	1,670
Type	-	Overflow with gates
Capacity of Spillway	m^3/sec	1,706
Crest Elevation	m	1,184.00
Crest Length	m	11.50 x 2
Outlet Works		
Capacity of Outlet	m^3/sec	75.0 (Maximum)
Type	-	Conduit with gate
Diameter of Conduit	m x m	Typical section Width 1.70 x Height 1.85
Elevation of Inlet Center	m	1,135.00
Power Intake		
Type	-	Inclined tower, Reinforcement concrete structure
Number	set	1
Maximum Discharge	m^3/sec	18.00
Inlet Sill Elevation	m	1,142.00
Size	m x m	Width 8.50 x Height 55.00
Headrace Tunnel		
Number	-	1
Maximum Discharge	m^3/sec	18.00
Inner Diameter	m	2.80
Length	m	8,686.32
Surge Tank		
Type	-	Orifice Type
Size, Height of shaft	m	15.00 + 88.50 = 103.55
Diameter	m	10.00 and 5.00
Port Diameter	m	1.20

Items	Unit	Description
Maximum Raising Water Level	m	1,207.54
Maximum Drawdown Water Level	m	1,115.91
Penstock		
Type	-	Open type (Part of the penstock is inbedded in the tunnel.)
Maximum Discharge	m^3/sec	18.00
Inner Diameter	m	Main 2.80 ~ 2.10 Branch 1.00
Length	m	Main 2,601.43
Length	m	Branch 22.91 x 2 = 45.82
Powerhouse		
Type	-	Semi-underground type
Size	m	Width 24.50 x Length 45.00 x Height 32.60
Center of Turbine	m	304.50
Maximum Output	MW	128
Tailrace		
Type	-	Concrete box culvert non pressure type
Maximum Discharge	m^3/sec	18.00
Inner Diameter	m	3.30 ~ 3.20
Length	m	Main 265.48
Length	m	Branch 25.00 x 2 = 50.00
Outlet		
Type	-	Concrete structure
Maximum Discharge	m^3/sec	18.00
Size	m	Width 3.30 x Height 3.30
Outlet Sill Elevation	m	298.50

Items	Unit	Description
Power Generating Facilities		
Standard Intake Water Level	m	1,179.70
Tail Water Level	m	304.50 (Turbine center)
Gross Head	m	875.20
Rated Effective Head	m	830.70
Maximum Discharge	m^3/sec	18.00
Unit Capacity	MW/Unit	64
Number of Unit	Unit	2
Rated Output	MW	128
Turbine		
Type	-	Vertical-shaft Pelton turbine (6 nozzles)
Number of Unit	Unit	2
Rated Output	MW	65
Revolving Speed	rpm	720
Generator		
Type	-	3-phase, AC, synchronous generator
Number of Unit	Unit	2
Rated Output	MVA	71
Voltage	kV	13.8
Frequency	Hz	60
Revolving Speed	rpm	720
Main Transformer		
Type	-	3-phase, forced oil, air-cooled type, outdoor-type
Number of Unit	Unit	2 (including 1 reserve)
Capacity	MVA	72
Voltage	kV	13.8/230

Items	Unit	Description
Switchyard		
Bus Composition	-	Double buses
Voltage	kV	230
Connecting Transmission Line	cct	2
Connecting Overhead Line		
Section	-	Pirris P/P to switchyard
Number of Circuits		2
Voltage	kV	230
Transmission Line		
Section	-	Pirris P/P switchyard to Escazu substation (44 km)
Number of Circuits	cct	2
Voltage	kV	230
Power Generation		
Annual Firm Energy	GWh	230.0
Annual Secondary Energy	GWh	379.3
Annual Total Energy	GWh	609.3
Construction Period	year	5
Project Cost		
Dam and Generating Facilities	US$	204,677,200
Transmission Line	US$	14,238,300
Total	US$	218,915,500
Unit Cost at End of Power Plant		
Per kW	US$	1,599.0
Per kWh	US$	0.336
Unit Cost at End of Transmission Line		
Per kW	US$	1,710.3
Per kWh	US$	0.359

Items	Unit	Description
Economics		
FIRR	%	12.02
EIRR	%	12.85
EDR	%	19.27
B-C (Net present value)	US$	64,216,000
B/C (Benefit cost ratio)		1.47
Foreign Exchange Rate		1 US$ = 105 Colones (As of Jan. 1991)

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS AND RECOMMENDATIONS

The Pirris Hydroelectric Power Development Project is located approximately 30 km south of San Jose, the capital of the Republic of Costa Rica, constructed at the middle stretch of the Pirris River.

According to the results of studies made based on data obtained up to the present, it is concluded that the Project is feasible from both technical and economic viewpoints. The conclusions are given below.

CONCLUSIONS

(1) The Project has the objective of supplying abundant and stable electric power to meet power demands effectively utilizing water power resources, an indigenous resource of Costa Rica.

(2) Electric power demand in the Republic of Costa Rica is steadily growing year after year. The annual average growth rate in power generation from 1980 to 1990 recorded 5.1%. The electric energy production of 1990 was 3,544 GWh (peak electric power 682 MW). Meanwhile, the electric power facilities as of 1990 amounted to 890 MW. The Costa Rican Government, in order meet the power demand is presently proceeding with construction of hydroelectric and geothermal power plants to make use of indigenous resources.

According to a load forecast made by ICE in August 1990, the demand is expected to reach 933 MW (4,852 GWh) in 1995, 1,261 MW (6,550 GWh) in 2000, 1,644 MW (8,561 GWh) in 2005, and 2,031 MW (10,649 GWh) in 2010.

(3) Regarding the timing of addition of the Project to the national electric power system, taking into consideration the period required for additional investigations, detailed design, and construction, it is judged appropriate for operation to be started around the year 2001.

(4) As a result of examining three alternative plans regarding development of the total head between the Pirris dam site and the vicinity of

Quebrada Sonzapote - development in a single stage and development in two stages (two versions) -, the single-stage development which is the most economically superior was selected as the basic development scheme.

(5) Two locations, the entrance to Pirris Gorge (lower dam site) and approximately 500 m upstream (upper dam site) were considered for the dam site of the Project.

The topography of the upper dam site is that of a gradual U-shape, while that of the lower dam site is a V-shape.

The geology of the upper dam site basement mainly consists of sandstone with partial intercalations of shale, siltsone, and conglomerate. As unconsolidated surface deposit overlying the basement rock, there are river deposits, terrace deposits, and talus.

On the other hand, the geology of the lower dam site basement, other than for distribution of siltstone extremely locally at the top of the right-bank ridge, consists on the whole of dolerite-basalt. The dolerite-basalt distributed at the dam foundation is lithologically hard, but there are cracks or joints developed at parts. Also, loosening at the right-bank mountain body becomes scraggier the higher the elevation. Therefore, it is necessary to thoroughly investigate the mechanical characteristics of the rock body above mid-height.

(6) Studies were made regarding the upper and lower dam sites comprehensively considering topography, geology, flood discharges, construction materials, etc., and the dam types below were selected. Comparison studies were made selecting for the upstream dam site a rockfill type, and for the downstream dam site, a concrete gravity type, a concrete arch gravity type, and a concrete arch type.

According to the results of the studies, it would be most economical apparently for a concrete arch dam to be constructed at the lower dam site, with a concrete gravity arch dam being the next most economical. However, the topography and geology of the right bank of the downstream site have been found to be such that the ridge is much scraggier than originally imagined, and has numerous cracks and joints to be of poor condition. The faint possibility for a concrete arch dam to be chosen needs to be examined based on the results of further geological investigations and geological assessments. Therefore, at the feasibility study stage, it is judged to be suitable for a concrete arch gravity dam to be selected at the lower dam site.

(7) For the development scale of Pirris Reservoir, comparison studies were carried out for the five cases of effective storage capacities of 10 x 10^6 m^3, 20 x 10^6 m^3, 30 x 10^6 m^3, 40 x 10^6 m^3, and 50 x 10^6 m^3 taking into consideration the geology, sedimentation, and effective storage capacity of the reservoir area. The examinations of these development scales were made simultaneously with the process of studying the dam site and the dam type, varying the reservoir scale. According to the results of the examinations, in case of adopting a concrete arch gravity dam, it is apparently suitable economically for the effective storage capacity to be 30 to 40 x 10^6 m^3. It is judged that effective storage capacity of approximately 30 x 10^6 m^3 and high water level of approximately 1,195 m will be suitable judging from the topographical and geological conditions at the right bank of lower dam site as mentioned in items (5) and (6). The height and volume of the dam selected in this manner will be 120 m and 390,000 m^3, respectively. The spillway would be located at roughly the middle of the dam body, and two radial gates of width 11.50 m and height 11.00 m capable of discharging the probable maximum flood of 1,670 m^3/sec are to be installed.

(8) Regarding the optimum scale for Pirris Power Station, comparison studies were made of maximum power discharges varied for five cases between 12 and 24 m^3/sec and peak durations of the three cases of 5, 7, and 9 hours with reservoir scale at 30 x 10^6 m^3. As a result of the studies, a maximum power discharge of 18 m^3/sec and installed capacity of 128 MW will be the most advantageous.

(9) The intake would be provided at the left bank approximately 90 m upstream of the dam. As a result of comparison studies of inclined

types (I) and (II), and a tower type, the inclined type (I) was selected.

The headrace tunnel route was selected to connect the intake and surge tank sites by the shortest route within limits that the tunnel would have adequate earth cover and work adits would be easy to provide. The length and inside diameter of the headrace tunnel would be approximately 8.7 km and 2.8 m, respectively.

For the surge tank, a simple type and a restricted orifice type were compared, and as a result of the study, the restricted orifice type was selected. The inside diameter of the vertical shaft and the orifice diameter are to be 5.0 m and 1.20 m, respectively.

Regarding the penstock route, comparison studies were made of a surface type and two tunnel types, (I) and (II). The surface type was selected as a result of the study. This penstock is to have a length of approximately 2.6 km and is to be bifurcated at the end. The inside diameter of the penstock pipe is to be 2.8 m at the connection with the surge tank and 2.1 m at the bifurcation point at the bottom, while after bifurcation, it is to be 1.0 m at the points where connecting with turbines.

(10) The powerhouse is to be located on the extension of the penstock at a flat piece of land of elevation around 330 m. This flat land is covered by terrace deposits, and because the rock line is deep and in consideration of the layout of outdoor structures such as the powerhouse and outdoor switchyard, it was decided to locate the powerhouse close to the side of the mountain as much as possible. A tailrace would be provided from the powerhouse to the Pirris River. The dimensions of the powerhouse are width of 24.50 m, length of 45.00 m, and height of 32.60 m. The number of main electro-mechanical equipment would be 2 units, with the turbine type and the generator being 6-nozzle Pelton turbine (65 MW) and 3-phase, alternating-current, synchronous generator (71,000 kVA), respectively.

The switchyard is to be provided building up a lot 86.00 m in width and 100 m in length on the river side of the powerhouse with a road for maintenance and inspection at the periphery.

The electric power generated at Pirris Power Station is to be transmitted from Pirris Switchyard to Escazu Substation by a 230-kV, 2-cct transmission line (length approximately 44 km).

(11) Inside the project site, there are no designated areas such as natural parks and forest reserves. A reservoir with an area of about 1.10 km^2 is planned to appear on the Pirris River after the completion of the dam, but it is not necessary to remove anything except several houses since the area required to be submerged is now used as cultivated land and pasture ground. The percentage of the submerged land on the entire cultivated land and pasture ground in this region is so small that there will be almost no influence on regional industries. The section of the Pirris River from the dam to the power station continuously has waterfalls, runs through a deep gorge and is not used at all. Therefore, the Project can coexist with industries in this region without any serious problems. It is expected to greatly contribute to the development of Costa Rica as well as this region through the construction and operation of the Project.

In Costa Rica, river contamination caused by organic substances discharged from coffee-processing factories, which are this country's major industry, is regarded as a national environmental issue, and the Pirris River is also not an exceptional case. According to the results of water quality examination as well as preliminary investigation of the reservoir's influence on water quality, deterioration in water quality in the reservoir can not be prevented unless the discharge of organic substances is regulated. Therefore, it is necessary to study countermeasures to avoid discarding waste matters directly in to the reservoir in addition to the regulation.

Since water downstream from the reservoir is not used and the reservoir is about a few km away from the nearest village, deterioration in water quality does not seem to become a social problem directly. However, it is necessary to monitor water quality, etc., in the reservoir and to grasp environmental changes since deterioration in the function of power generation facilities by noxious gas, the outbreak of detrimental plants in the reservoir, etc., are considered possible.

Research on the effective utilization of organic substances discharged from coffee-processing factories is conducted in technological cooperation with the government of Japan. The technology of producing biodegradable plastic of high added value from waste matter is coming near the stage of practical use. The effect of legal regulations on the discard of waste matter can not be anticipated even from now on, but it may result in improving the effect of environmental measures by adding value to waste matter and providing its profit to the industry. While all coffee-producing countries in Central America, South America and Africa have similar water contamination problems, this new technology is expected to contribute to environmental improvement in the world.

(12) The total initial investment required for development of the Pirris Project, as of January 1991, was US$218,915,500. The breakdown is as given below:

Dam, waterway, powerhouse, and appurtenant facilities	
Local currency	US$ 81,670,500
Foreign currency	US$123,006,700
Total	US$204,677,200
Transmission line facilities	
Local currency	US$ 4,209,800
Foreign currency	US$ 10,028,500
Total	US$ 14,238,800
Grand Total	
Local currency	US$ 85,880,300
Foreign currency	US$133,035,200
Total	US$218,915,500

The construction costs per kW and kWh of Pirris Power Station will be as follows:

	US$/kW	US$/kWh
Generating end	1,599.0	0.336
Transmitted end (substation inlet)	1,710.3	0.359

The unit energy cost of Pirris Power Station is estimated to be US$ 0.0255/kWh at the entrance of Escazu Substation. The construction period for the Project was estimated to be approximately 5 years.

(13) A combination of gas turbine and diesel (slow-speed engine) power plants was assumed at the alternative power generating facility and a comparison was made with the Project. As a result, the net present value (B - C) and benefit-cost ratio (B/C) of the Project is US$64,216,000 and 1.47, respectively.

(14) For evaluation of the Project, the financial soundness was first analyzed by comparison of the financial internal rate of return (FIRR) based on market prices and rate of interest on borrowings estimated. The FIRR of the Project is 12.02%. This is more advantageous than the estimated rate of interest of 8.5%. Next, economic prices were calculated modifying the market prices used in the financial analysis, and using these prices, the economic internal rate of return (EIRR) of the Project was obtained. The economics of the Project were analyzed by comparison of the EIRR with the opportunity cost of capital in the Republic of Costa Rica.

The EIRR of the Project is 12.85%. This exceeds the opportunity cost of capital in Costa Rica of 12%. Consequently, it may be concluded that the Project is feasible from both financial and economic points of view.

RECOMMENDATIONS

The Pirris Hydroelectric Power Development Project is technically and economically feasible, and it is recommended that the Project be implemented.

It is necessary to implement the following matters in order to realize the Project.

(1) To make preparations required for construction such as detailed design and composition of bid documents.

(2) The additional investigations mentioned in Chapter 16 "Further Investigations" should be carried out, to be reflected in the detailed design.

(3) For the commissioning of the Project in the year 2001, it is necessary to arrange for construction funds, to invite tenders; to select the contractor; and to start the main work at the beginning of 1996. Before starting the main work, it will be necessary to have completed construction of roads to the dam and powerhouse sites and repairs of existing roads.

(4) Vegetation, aquatic and land animals, historical relics, cultural properties, and others to pose problems do not exist in the area to be affected by implementation of the Project. It will be necessary, however, to study the change in water quality resulting from construction of the reservoir, with the conditions at existing reservoirs in Costa Rica as reference material though it cannot be considered to be serious problem judging by the present natural conditions. It is also necessary to examine measures to prevent organic wastes from coffee processing plants from being directly discharged into the reservoir to be constructed.

(5) Relocation of roads to be affected by implementation of the Project, compensation for land, houses, etc. to be submerged must be done for the smooth implementation of the Project.

CHAPTER 1 INTRODUCTION

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1.1 Background

Costa Rica depends on oil, an imported energy source, for approximately 45% of its energy (El Sector de Energía: ICE 1990). The Costa Rican Government has placed emphasis on development of domestic energy in its energy policy with the objective of this policy being to maintain balanced growth of its society and economy to release the country from excessive dependence on foreign countries by means of substitutes for imported energy.

Based on this principle, Instituto Costarricense de Electricidad (ICE), a government organization, is aggressively carrying out hydroelectric power development. Among others, the Pirrís Hydroelectric Power Development Project (hereinafter referred to as "the Project") located at 30 km south of San José, the capital of Costa Rica, in the central plateau area close to the Pacific Ocean, may be said to have a site with favorable siting conditions for electric power development. This is a hydroelectric power development project utilizing a high head favored with abundant runoff of the Pirrís River and site characteristics. ICE has focused on this development project, and started surveys and studies from 1966, with a concrete scheme established in 1974 as the Pirrís Hydroelectric Power Development Project. Later, in 1977, a full-fledged survey was commenced, and "Informe Preliminar del Proyecto Hidroeléctrico Pirrís, Dec. 1982" was prepared in 1982, and "Descripción del Proyecto Hidroeléctrico Pirrís, 1988" in 1988.

ICE has assessed the Project as one with excellent prospects among the domestic hydroelectric development projects of Costa Rica, and development at an early stage is aimed for. Under such circumstances, the Costa Rican Government requested the Japanese Government in July 1988 for technical cooperation concerning a feasibility study of the Project. The Japanese Government, in response to this request, commissioned the Japan International Cooperation Agency (JICA) in January 1989 to dispatch a preliminary survey team to Costa Rica and carry out a general reconnaissance of the project area along with exchanging opinions with the Costa Rican Government. Based on the results, a "Scope of Work for the Feasibility Study on Pirrís Hydroelectric