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1.1 Antecedents and Background

Placing political focus on the development of domestic energy, in 1949 the Government of Costa Rica established ICE (Instituto Costarricense de Electricidad) toward that end. Today, ICE electric power generation facilities (1,023.5 MW) account for 93.2% of Costa Rica's total capacity, supplying 80% of the nation's total demands in cooperation with the CNFL (National Power and Light Company). Regarding the composition of the energy sources, of a total installed capacity of 1,098 MW, thermal power produces 255 MW, representing 28% including geothermal power. Hydropower produces 788 MW, accounting for 72%. From the viewpoint of actual electric power generated each year, almost all is dependent on hydropower, indicating Costa Rica's heavy precipitation. While hydropower potential which can be developed economically are estimated at approximately 9,000 MW, the portion developed thus far is very small, at about 8%. However, over the past five years the average increase in electricity demands shows an annual increase of 6.5% a year with an increment ratio of 7.4% in 1993. Under these circumstances, Costa Rica has engaged strongly in the development of its hydropower resources as the main domestic energy source. Notwithstanding these efforts however, 54% of Costa Rica's total energy still remains dependent on import. As it is estimated that demands for oil and electricity will be 1.6 times and 3.0 times more than today's respectively, great hopes are now placed on hydropower development.
(Electricity and Sustainable Development in Costa Rica: ICE 1994)

The ICE is presently attempting to execute electric power development projects which are mainly hydropower projects. 4 projects out of 13 hydropower development plans that were at the stage of Master Plan in 1990 have been extracted in cooperation with LGL, a Canadian consultant. The Government of Costa Rica requested Japan to carry out a Feasibility Study (F/S) of the Los Llanos Project, being the most promising of the described projects. The Japan International Cooperation Agency (JICA) agreed to carry out this study, with ICE as their counterpart and the relevant agreement was signed by both parties in March, 1994.

1.1.1 Executing Agency

Instituto Costarricense de Electricidad (ICE) was established as an autonomous organ by Ordinance No.449 implemented April 8, 1949. ICE has stressed not only power development but also promotes stable supply and use of electricity and the development of hydropower, one of this country's domestic natural resources. ICE assumed control of a nation-wide communication network in 1963 and the communications industry was also brought under their control.

About 20% of electricity is supplied to large consumers directly by ICE. The remainder is supplied to other consumers including those in the capital city of San Jose through Compañía Nacional de Fuerza y Luz S.A. (CNFL), which accounts for 96% of the national demand.

1.1.2 Organization

The Executive President of ICE is also the Chairman of the Board which consists of 7 members. Two divisions, electricity and communications, are also under his control. The institute has about 8,800 employees of which 1,400 are in the clerical and accounting divisions, 3,800 in the electricity division and 3,300 in the communications division. The remainder are in a division which provides overall control. A organizational chart of electricity division is attached.

1.2 Contents of Study

1.2.1 Objectives of Study

The objectives of this study are to carry out a study in Costa Rica and domestic work concerning the Los Llanos Hydroelectric Power Development Project to produce, with environmental evaluation taken into consideration, a development plan that is technically feasible, economical, financially sound, and to prepare a Feasibility Study Report accordingly. In conjunction with these activities, to also attempt technical transfer to the Costa Rican counterpart through this study.

1.2.2 Object Area and Scope of Work

The hydropower development site of this study is located at Long. 84° 3" W, Lat. 9° 33" N. It is situated in the middle reaches of the Naranjo River, 50 km south of the capital city of San Jose. Here, a dam is to be constructed from which water will be conducted westward through a headrace tunnel to a power station to be located in the middle of the Paquita River in a bid to generate power by utilizing the head between these points. The areas to be influenced by this project, i.e., the entire area of the basin of the Naranjo River and the Paquita River and the area from the river mouths up to the Pacific coastline, have been designated as the subject area for this study.

1.2.3 Work Contents

The study was classified into Preliminary Investigation Stage, Detailed Stage and Feasibility Grade Stage in accordance with the accuracy of study, and the following studies were conducted.

(1) Preliminary Investigation Stage

(a) Collection and review of existing data and study reports.
(b) Field survey and present situation survey of the project area.
(c) Compare the comparable alternative plans to select the optimum development plan based on the existing data.
(d) Entrust the FUNDEVI with the initial environmental examination (IEE) to accurately and efficiently extract those items liable to be gravely and/or adversely affected by the development, while considering the contents of the development.
(e) Review all relevant information such as ICE's peak demands, electricity consumption characteristics etc. and analyze the same in accordance with the power expansion program.
(f) Prepare study plans and technical specifications with regard to the Detailed Study.

(2) Detailed Stage

Geographical measuring, geological survey and material testing, and hydrological and meteorological survey were conducted and environmental influence assessment (EIA) and compensation survey were begun.

(a) Geographical Survey

1) Aerial photography and mapping at 1:5000 scale
2) Installation of survey piles and bench marks
3) Ground survey (dam, powerhouse) at 1:1000 scale

(b) Geological Survey and Material Testing

1) Geological reconnaissance (main structures, reservoir, quarry site and others)
2) Core boring, permeability test (dam, waterway, powerhouse, quarry site)
3) Seismic prospecting (same as above)
4) Work adit excavation (dam site)
5) Test pit excavation (for construction materials)
6) In-situ test, laboratory test
7) Historical earthquake study

(c) Hydrological and Meteorological Survey

1) River flow
2) Survey of high water (flood), and low water (firm discharge) levels
3) Observation and analysis of hydrological and meteorological data
4) Analysis of sediment discharge and sedimentation by observation of floating sand, etc.
5) Establishment of hydrological and meteorological observation stations

(d) Environmenta Impact Assessment (EIA)

1) Preparation of EIA items with regard to the natural, social and economic environments determined by the initial environmental assessment.
2) Continuation of natural environmental survey (water quality, fluctuation of irrigation water flow, ecological system of the flora and fauna)

(e) Compensation Survey

1) Survey of compensatory items (houses and buildings, standing trees, land, rights and titles etc.)
2) Survey of moving compensation (public buildings)

1.3 Reports

1.3.1 Reports Submitted to ICE

The following reports/documents have been submitted to ICE:

(1) Inception Report (Sept.1, 1994)
(2) Questionnaire
(3) Contract for Aerial Photography and Survey
(4) Contract for Initial Environmental Examination
(5) Progress Report (Nov. 30, 1994)
(6) Progress Report Annex (Mar. 10, 1995)
(7) IEE Final Report - FUNDEVI (Dec. 1994)
(8) Final Result - Topographic Mapping (Mar. 1995)
(9) Interim Report (July 1995)
(10) Draft Final Report (Jan. 1996)
(11) Memorandum on Discussion (Sept. 1 - 5, 1994)
(12) Memorandum on Discussion No.2 (Sept. 6 - 24, 1994)
(13) Memorandum on Discussion No.3 (Nov. 15 - 29, 1994)
(Nov. 30 - Dec.9, 1994)
(14) Memorandum on Discussion No.4 (Feb. 20 - Mar.9 1995)
(15) Memorandum on Discussion No.5 (May 19 - Jun.2, 1995)
(16) Memorandum on Discussion No.6 (July 3 - Aug. 8, 1995)
(17) Memorandum on Discussion No.7 (Nov. 30 - Dec. 10, 1995)
(18) Memorandum on Discussion No.8 (Feb. 1 - Feb. 8, 1996)

1.3.2 Reports Submitted to JICA

The following reports/documents have been submitted to JICA:

(1) Study Planning Report for FY1994
(2) Inception Report (Japanese version)
(3) Progress Report (Japanese version)
(4) Final Results of Topographical Mapping and Satellite Image Analysis
(5) Interim Report (Japanese Version)
(6) Study Report for FY1994
(7) Study Planning Report for FY 1995
(8) Draft Final Report (Japanese Version)
(9) Technical Transfer Report
(10) Study Report for FY 1995

1.3.3 Existing Report

The outline of the Project is described in "Los Llanos Hydroelectric Power Project Description" compiled by ICE in June 1991. Afterward ICE elaborated a master plan "Plan Maestro de la Cuenca Hidrografia Rio Naranjo", in cooperation with Canadian consulting group LGL. And the Project has been confirmed as having the first priority within the hydroelectric power development projects in Costa Rica.

Based on these reports, the JICA study team examined the appropriateness; carried out comparative study; and implemented additional investigation work, study and tests. These data, as well as additional study conducted by ICE are compiled in Appendix. Also included in Appendix is a list of the data and information relevant to the project as obtained from ICE and/or other organizations.

1.4 Study in Costa Rica and Participants

1.4.1 Study in Costa Rica

JICA mission visited Costa Rica during the following period.

(1) 1st Mission: August 29 to October 27, 1994

Team Leader	- Yasumasa EBI	Aug.29 to Sep.27
Planning	- Senzo HAKOSHIMA	Aug.29 to Sep.27
Geology (Evaluation)	- Masahiro SHIBATA	Aug.29 to Sep.27
Geology (Study)	- Nobuhiro DEMBOYA	Aug.29 to Sep.27
Environment (Evaluation)	- Kiyoshi KIKUCHI	Aug.29 to Sep.27
Topographic Survey	- Isao IKESHIMA	Aug.29 to Sep.12
Power Plant	- Hisao SUDO	Sep.13 to Sep.27
Coordination	- Masashi YUKAWA	Sep.13 to Sep.27
Environment (Study)	- Nobuyuki HAMANO	Sep.13 to Oct.27

(2) 2nd Mission: November 13, 1994 to January 26, 1995

Team Leader	- Yasumasa EBI	Nov.13 to Dec.24
Planning	- Senzo HAKOSHIMA	Nov.13 to Dec.12
Design	- Mitsumasa KATO	Nov.13 to Dec.12

Power System	- Toshimasa FUJIUCHI	Nov.13 to Nov.27
Geology (Evaluation)	- Masahiro SHIBATA	Nov.28 to Dec.24
Geology (Study)	- Nobuhiro DEMBOYA	Nov.28 to Dec.24
Hydrology	- Koji MISHIMA	Nov.28 to Dec.21
Environment (Evaluation)	- Kiyoshi KIKUCHI	Nov.28 to Dec.12
Economic Evaluation	- Tetsuya HIRAHARA	Nov.28 to Dec.12
Topographic Survey	- Isao IKESHIMA	Nov.28 to Jan.26
Topographic Survey	- Kazuo FURUKATA	Dec.13 to Jan.26

(3) 3rd Mission: February 12 to March 13, 1995

Team Leader	- Yasumasa EBI	Feb.27 to Mar.13
Geology (Evaluation)	- Masahiro SHIBATA	Feb.27 to Mar.13
Geology (Study)	- Nobuhiro DEMBOYA	Feb.27 to Mar.13
Environment (Evaluation)	- Kiyoshi KIKUCHI	Feb.27 to Mar.13
Environment (Study)	- Nobuyuki HAMANO	Feb.12 to Mar.13
Coordination	- Niro OKAMOTO	Feb.27 to Mar.13

(4) 4th Mission: May 17 to June 6, 1995

Team Leader	- Yasumasa EBI	May 17 to May 31
Planning	- Senzo HAKOSHIMA	May 17 to May 31
Design	- Mitusmasa KATO	May 17 to May 31
Geology (Evaluation)	- Masahiro SHIBATA	May 17 to May 31
Hydrology (Analysis)	- Koji MISHIMA	May 17 to June 6
Hydrology (Study)	- Shigeo HAYAKAWA	May 17 to June 6

(5) 5th Mission: July 1 to August 14, 1995

Team Leader	- Yasumasa EBI	July 1 to Aug.14
Planning	- Senzo HAKOSHIMA	July 1 to July 30
Design	- Mitsumasa KATO	July 1 to Aug.14
Power System	- Toshimasa FUJIUCHI	July 16 to Aug.14
Power Plant	- Hisao SUDO	July 16 to Aug.14
Geology (Evaluation)	- Masahiro SHIBATA	July 1 to July 30
Environment (Evaluation)	- Kiyoshi KIKUCHI	July 16 to Aug.14
Environment (Study)	- Nobuyuki HAMANO	July 16 to Aug.14

Coordination	- Niro OKAMOTO	July 16 to July 30

(6) 6th Mission: November 26 to December 13, 1995

Team Leader	- Yasumasa EBI	Nov. 29 to Dec. 13
Environment (Evaluation)	- Kiyoshi KIKUCHI	Nov. 26 to Dec. 13
Environment (Study)	- Nobuyuki HAMANO	Nov. 26 to Dec. 13

(7) 7th Mission: January 30 to February 13, 1996

Team Leader	- Yasumasa EBI	Jan. 30 to Feb. 13
Design	- Mitsumasa KATO	Jan. 30 to Feb. 13
Power System	- Toshimasa FUJIUCHI	Jan. 30 to Feb. 13
Power Plant	- Hisao SUDO	Jan. 30 to Feb. 13
Environment (Evaluation)	- Kiyoshi KIKUCHI	Jan. 30 to Feb. 13
Economic Evaluation	- Tetsuya HIRAHARA	Jan. 30 to Feb. 13
Coordination	- Niro OKAMOTO	Jan. 30 to Feb. 13

1.4.2 List of Participants

(1) ICE

Presidencia Ejecutiva
- Ing. Teófilo de la Torre
- Dr. Roberto Dobles

Sub-Genencia

Ing. Carlos Obregón Q.	Desarrollo de Energía

Direccion

Ing. Agustín Rodríguez M.	Planificación Eléctrica
Ing. Edgar Robles F.	Planificación Eléctrica
Ing. Guillermo Rivera S.	Ingeniería Civil
Ing. Jorge Zamora	Ingeniería Electromecánica

Departamento

Ing. Mario López S.	Proyectos de Generación
Dr. Sergio Mora C.	Geología
Geol. Leonel Rojas C.	Geología
Ing. José A. Rodríguez B.	Ingeniería Geotécnica

Lic. Sadi Laporte M.	Hidrología
Ing. Johnny Granados B.	Estructuras
Ing. Jorge A. Monge	Topografía
Ing. Alejandro Hidalgo	Programa de Transmisión
Ing. Héctor Vargas F.	Económicos y Financieros
Ing. Jorge Valverde B.	Ambiente y Energía Alterna
Ing. Javier Orozco C.	Administración de Proyectos

Oficina

Ing. Roberto Jiménez V.	Proyectos Hidroeléctricos
Ing. José Antonio Aragón	
Ing. Carlos Amador Quesada	
Ing. German Freer H.	
Ing. Irene Cañas Díaz	
Ing. Julio Matamoros A.	
Ing. Daniel Acuña P.	
Ing. Oscar Jiménez R.	

Ing. Carlos Ramírez M.	Estudios Hidrológicos
Ing. Carlos Picado B.	
Ing. Carlos Roberto R.	
Ing. Manuel Sanabria S.	Estdios Hidrológicos
Ing. Alexis Rodríguez R.	
Ing. José Alberto Zuniga M.	
Ing. Jorge Granados C.	

Lic. Rafael Enríque Chacón M.	Hidrologia Operation
Lic. Porfirio Machado A.	
Lic. Alexia Pacheco H.	

P. T. Luis E. Acuña	Redes Hidrometeorológicas
Lic. Rafael Nunez M.	

Geol. Ricardo Granados V.	Geología de Proyectos
Geol. Carlos Rodríguez N.	
Geol. Alexis Cerdas S.	
Geol. Allan López M.	
Geol. Adolfo Estrada D.	

Ing. Miguel Bolaños S.	Mecánica de Suelos y Rocas
Geol. Jorge Salazar A.	

Geol. Luis Fdo. Saenz S.	Geofísica Aplicada
Geol. Fernando Montalto G.	Perforación e Inyección

Ing. Julio Delgado	Laboratorio Geotécnico
Ing. Alejandro Luna B.	Programa de Transmisión
Ing. Pablo Alvarado G.	Evaluación Económica
Lic. Laureano Montero	
M. Sc. Eduardo Peralta B.	Ambiente y Energía Alterna
Biol. Fernando Chavarría P.	
Albol. Rolando Nuñez	
Ing. Rody Rodríguez M.	Topografía
Ing. Samuel Argueta	
Ing. Marcos Navarro	
Ing. Carlos Llobet R.	Diseño Electromecánico
Ing. Rodolfo Brenes G.	
Ing. Mario Alfaroz	
Ing. Arturo Ordoñez	
Lic. Edgar Mesen Aroya	Asuntos Internacionales
Javier Romero B.	

(2) Danish Hydraulics Institute

Mr. Finn Hansen

(3) Universidad de Costa Rica

Mr. Luis Gmo. Brenes Quesada	Dpto. Geografía

1.5 Acceptance of Trainees

ICE requested JICA to accept one trainee for each fiscal year, i.e., two in all. Accordingly, Mr. Roberto Jimenez V. visited Japan for the period January 31, 1995 to March 2, 1995; and Mr. José Antonio Aragón S. from September 4, 1995 to September 24, 1995.

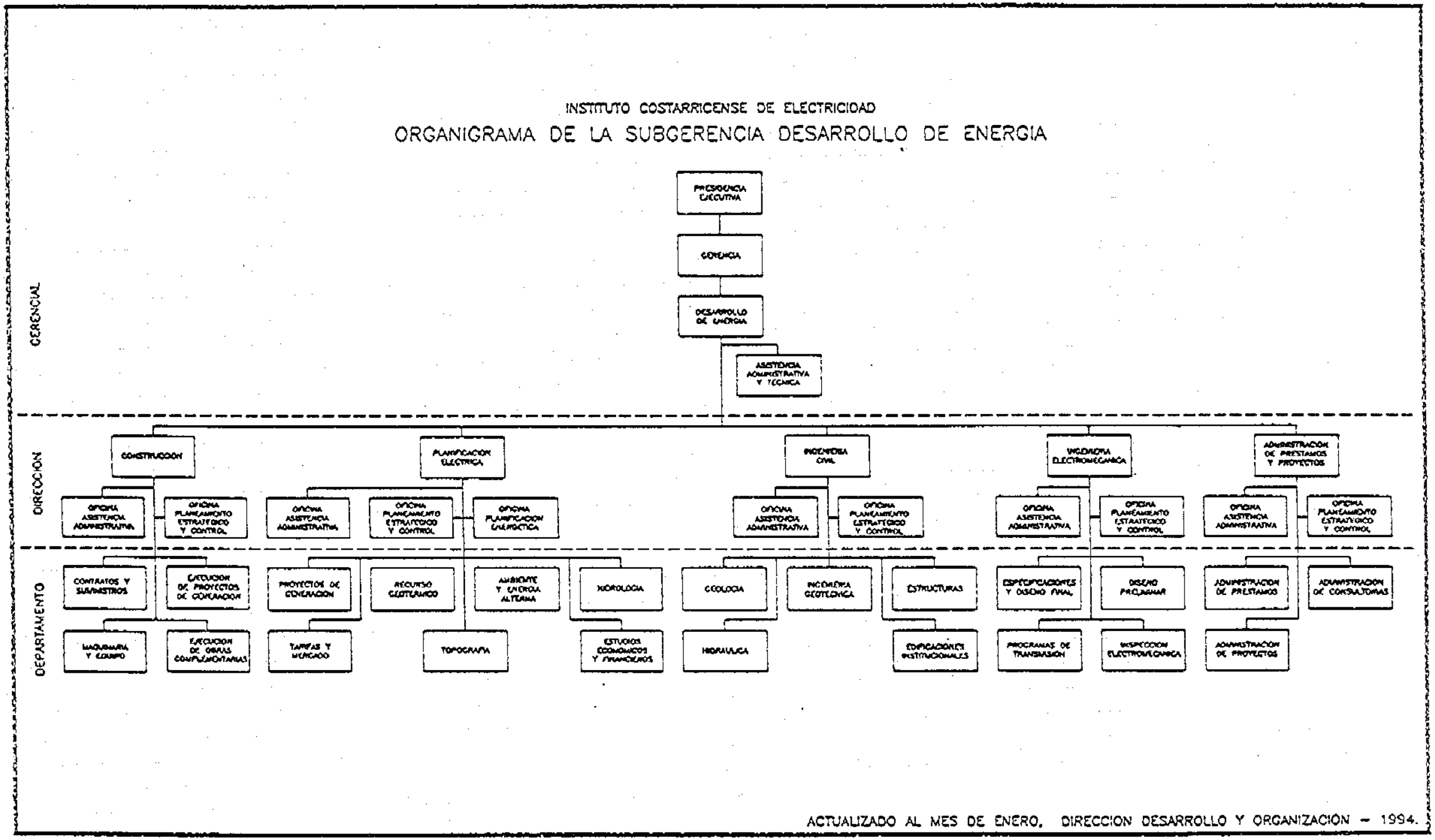

Fig. 1-1 Organization Chart of ICE Electricity Division

Chapter 2 General Description of the Republic of Costa Rica

Chapter 2 General Description of the Republic of Costa Rica

CHAPTER 2 GENERAL DESCRIPTION OF THE REPUBLIC OF COSTA RICA

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CHAPTER 2 GENERAL DESCRIPTION OF THE REPUBLIC OF COSTA RICA

2.1 Geography

The Republic of Costa Rica is located in Central America, between Lat. 8° to 11° 14" N. and between Long. 82° 32" and 85° 58" W. The country is bordered by the Republic of Nicaragua to the north and the Republic of Panama to the east. Costa Rica faces the Caribbean Sea to the northeast and the Pacific to the southwest. The Caribbean Sea coastline is 225 km long and the Pacific coastline is 1,103 km long. The total land area is 51,000 km^2, in which Coco Island, an isolated island in the Pacific, is included.

Geographically, Costa Rica is a long, narrow country, the narrowest section being 119 km across and 274 km at the widest. The majority of the land is mountainous. The highest peak is Mt. Chrripo Grande at 3,819 m. However, the land is generally covered by tropical forest and is, therefore, abundant in vegetation. 25% of the land is designated as National Parks and/or Forest Preserves where development is restricted. Many volcanoes such as Mt. Irazu (3,432 m), Mt. Poas (2,704 m), and Mt. Turrialba (3,328 m) are present and this is probably why Costa Rica is counted among the world's prominent countries with its frequent earthquakes.

The project area is located in the basin of the Naranjo River which runs southward from the Dota, the central mass of mountains, and includes the Paquita River which flows parallel to the west. Originating in hilly country in the southern part of San Marcos, the Naranjo River runs westward across the southern slopes of the hilly Dota district to run rapidly southward from the Dam site. Of the total 43 km length up to the river mouth, the lower reaches of 15 km are flat alluvial fans where coco palms are cultivated. On the other hand, the Paquita River shows similar conditions as a rapid stream in that it is only 100 m above sea level at the power station site which is 17 km from the river mouth, rising to 1,300 m above sea level at a point 7 km upstream from that area.

2.2 Climate

Costa Rica has a partial tropical forest/savanna climate, but is greatly influenced greatly by the topography and altitude. The temperature does differ between the dry season (December through April) and the rainy season (May through November), although it is a minimal difference as the year round mean temperature is between 20 - 30°C.

Precipitation ranges from 30 to 120 mm per month even in February, the time of the least rainfall. The 5,500 mm annual average precipitation in the Naranjo River valley is regarded as one of the heaviest in the world.

2.3 Population

Population in Costa Rica amounts to some 3.2 million, and the density is 62 persons/km^2. Population by province as of January 1993 is shown below.

Province	Population	Distribution	Annual Increase
San Jose	1,152,847	36.4%	2.03%
Alajuela	564,209	17.8%	2.21%
Cartago	356,198	11.3%	2.17%
Heredia	254,136	8.0%	2.08%
Guanacaste	252,386	8.0%	1.88%
Puntarenas	353,558	11.2%	2.12%
Limon	233,628	7.4%	3.02%
Total	3,155,962	100%	2.17%

Source: "Costa Rica Calculo de Poblacion (Enero 1993)", Ministerio de Economia, Industria y Comercio

2.4 Economy

The GDP of Costa Rica is 7,112.45 million Colons (1993), while GNP is US$6.2 billion. The GNP per capita is approximately US$2,000. Agriculture and cattle represent the major industries. Coffee, bananas, rice, corn, soy bean, sugar cane, potatoes, tomatoes, and citrus fruit are the main agricultural products. In addition to traditional products such as bananas, the cultivation of non-traditional products has become very popular recently, today accounting for 58% of national agricultural income.

Manufacturing accounts for 19% of the GDP with agriculture representing 16%, indicating that Costa Rica is the most industrialized of the five Central American countries. Although many of these are food processing industries, Costa Rica's light industries which are engaged in garment productions, sugar processing, cement, tires, fertilizer, cooking oil, footwear, matches and so forth are also well developed.

Costa Rica's major exports are bananas and coffee. Production of the former ranks 2nd in the world. Today, however, future prospects are not overly optimistic in the face of fallen coffee prices and the introduction by European countries of an import quota system for bananas. The following are the major Costa Rican export products:

Traditional products	:	coffee, bananas, meat, sugar, cocoa
Non-Traditional products	:	Fish, lobsters, prawns and shrimps, pineapples, garments, furniture, tires

As seen in Table 2-1, Costa Rica's balance of trade constantly shows a deficit and in light of this, the government now stresses the development of the Export Processing Industry District. Tourism has also grown as a source of acquiring foreign money. 25% of the land is designated as national parks and nature conservation areas which is emphasized to attract tourists by capitalizing on the country's rich natural environment. Approximately 700,000 tourists visited Costa Rica in 1993 to realize US$500 million in the tourist industry, 20% over the previous year and equal to the export of bananas.

2.5 Energy Resources

Due to its undulating topography and heavy precipitation, Costa Rica enjoys an abundance of hydropower resources. There are 4.2 million TEP (41,919 GWh/year) in available hydropower resources, although only 8.2% of these have been developed. This indicates that hydropower resources of 12 times the present hydropower electric generation plant capacity can be economically developed. This does not include generation facilities of less than 20 MW and private power generation. Listed hereunder is the potential water power shown by river.

River	CA (km^2)	MAR (mm)	Sites	Potential (MW)	Energy (GWh)
Sixaola	2,330	4,790	9	1,385	6,104
Matina	1,415.6	3,626	2	600	2,600
Pacuare	802.4	4,021	2	764	2,992
Reventazon/Parsmina	2,950.3	3,777	5	686	3,053
Chirripo Atlantico	1,635.1	4,326	3	365	1,768
Sarapiqui	1,923.3	5,156	3	256	1,147
San Carlos/No.20	2,646.3	3,961	5	967	2,631
Barranca	504.5	3,750	1	50	195
Grande de Tarcoles	2,168.5	2,456	3	350	1,720
Parrita	1,272.5	3,254	5	460	1,947
Naranjo	332.2	6,387	2	195	820
Savegre	593.2	5,090	3	650	2,652
Grande de Terraba	5,075.8	3,358	7	2,065	8,233

Note : CA - Catchment Area, MAR - Mean Annual Rainfall

Source : "Costa Rica Country Environmental Profile", USAID

Investigations have been made on geothermal and certain promising areas have been confirmed and priority has been placed on development at the Miravalles site. Power generation with an output of 55 MW was started in 1994 and the second phase development which is scheduled to be completed in September 1996, is now under way. Geothermal resources in the Miravalles area are estimated to be 250 MW. According to a national investigation of Costa Rica's geothermal resources, the entire national geothermal resources are estimated to be 1200 MW, including Miravalles. Tenorio Volcano (90 MW) was selected as a candidate site of geothermal resources. This was based on investigations at a reconnaissance level using funds provided by the Italian Government via the United Nations. The investigation covered an area of 25,000 square kilometers (Guanacaste Volcanic Mountain Range, Central Volcanic Mountain Range, and Talamanca Mountain Range) which was perceived to provide high potential as a geothermal resource zone.

ICE also conducted surveys on wind power generation in the Tejona region of Guanacaste Province with its Energy and Alternative Energy Division designated as the coordinating organ. ICE now plans to install a 20 MW generating facility which is expected to start operation in 1997, using funds from the Inter-American Development Bank and the World Bank (IDA). Aside from Tejona, ICE also plans to conduct surveys in other areas such as Guayabo, Fortuna, and Cañas of Guanacaste Province etc., to determine their suitability as wind power generation sites.

Shown below are the domestic energy resources which include hydropower and geothermal.

Resources	Thousand TEP/Year	Development (%)
Hydroelectricity	4,072.80	8.60
Firewood	44,609.70	14.60
Vegetable Residual	42.00	40.79
Bagasse	144.00	100.00
Biogas	238.20	Minimum
Geothermal	301.40	4.58
Coal	33,781.50	0.0
Alcohol	602.78	Minimum

Source : "Sector Energetico de Costa Rica" 1993 ICE

2.6 Transport and Communication

Costa Rica's domestic transportation infrastructures are roads, railways, marine transportation, and airways. In the overall system, highways play the most important role. The major trunk road is the approximately 840 km long Pan American Highway which runs from the Costa Rican/Nicaraguan border to the border with Panama via San Jose, the capital city. With this highway, well-maintained roads connect the capital to the Pacific coast (Puntarenas, Caldera Port) and to the Atlantic coast (Limon). In 1993, Costa Rica had 35,541 km of roads, of which 7,341 km (20.7%) were national highways and 28,192 km (79.3%) being local roads.

The country has three railroad lines, the Atlantic Line which runs between San Jose and Limon, the Pacific Line which runs between San Jose and Puntarenas and the Southern Line which runs between Cortes and Golfito. The total length of this rail network is 670 km, including its branch lines. Operation between San Jose and Siquirres on the Atlantic Line is now suspended.

For marine transportation, Puntarenas Port on the Pacific coast, and Limon Port on the Atlantic coast were traditionally regarded as the country's major trade ports. Today, however, the importance of Caldera Port on the Pacific coast and Moin Port on the Atlantic coast has been increasing as both provide well-equipped harbor facilities such as storage.

Other than Juan Santa Maria International Airport in San Jose, airports are established in cities such as Tobias Baloños (Pavas), Limon, Liberia (Tomas Guardia), and Golfito.

Domestic communication infrastructures include a postal service, and telephone and telegram services. There are 313 post offices nationwide. As Costa Rica has no mail delivery system except in a few areas, a great number of post office boxes are in use (44,346 boxes).

As of the end of 1994, there were approximately 500,000 regular telephone lines with 6,985 portable phone lines, the service for which was inaugurated in April 1994. Until recently, a 6-digit telephone number system was used. However, this was changed to a 7-digit system as of April 1994, due to rapid increases in the number of subscribers.

Costa Rica has 10 television and 78 radio stations. Radio stations broadcast on medium wave, short wave, and FM. Many are commercial stations. Some stations broadcast nationwide through strategically located relay stations.

Table 2-1 Basic Economic Indicator

	1987	1988	1989	1990	1991	1992	1993	1994 [1]	Unit
GDP Growth		3.2	5.5	3.4	2.1	7.3	6.1	4.5	Percent (%)
GDP/Capita Growth		0.4	2.6	0.7	-0.4	4.6	3.6	2.1	Percent (%)
Current Account Balance						-447	-537	-515	Million US Dollar
Capital Balance						587	518	295	Million US Dollar
General Balance						140	-19	-220	Million US Dollar
External Debt	4,384	4,470	4,488	3,930	4,015	4,050	4,052	4,100	Million US Dollar
Consumer Price Increase	16.4	25.3	10.0	27.3	25.3	17.0	9.0	17.4 [2]	Percent (%)
Public Sector Balance (against GDP)		-2.5	-4.1	-4.4	-3.2	-1.9	-1.9	-4.6	Percent (%)
Export (FOB)						1,714	1,947	2,165	Million US Dollar
Import (CIF)						2,212	2,610	2,815	Million US Dollar
Trade Balance						-498	-663	-650	Million US Dollar

Note 1) Tentative

2) Increase during Nov. 1993 - Nov. 1994

Source: "Balance Preliminar de la Economia de América Latina y el Caribe 1994" CEPAL

Chapter 3 General Description of the Project Area

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CHAPTER 3 GENERAL DESCRIPTION OF THE PROJECT AREA

3.1 Location and Access

The project site is located about 50 km from San Jose, the capital city. The upper stream belongs to San Jose Province and the lower reaches belong to Puntarenas Province. There are two access routes available to the site. The dam site in the upper stream can be reached by going southward on Highway No. 4 from San Jose and arriving at San Pablo and San Marcos. Another route is via Highway No. 2 (the Pan-American Highway) and passing through Santa Maria and San Marcos. To travel to the powerhouse in the lower reaches, there is also a route via Highway No. 11 westward from San Jose and going southward from Orotina and along the Pacific coast through Jaco Beach to Quepos. However, regardless of the route taken, it is 140 km from San Jose to Quepos and takes three hours by car in all cases.

It would be convenient to set up bases in San Marcos and Quepos to approach the dam site and the power plant site respectively. These towns are connected by gravel roads which are partially public roads, and by ICE's survey roads. There are flat gravel roads from Quepos along the Rio Noranjo and the water level and flow observatories in Londres can be easily reached even in the rainy season. An access route to the power plant is provided by a road running through the mountainous areas that form the watersheds to the Rio Paquita. It takes about an hour from Quepos. Steep survey roads in the mountainous areas have to be used to travel from the power plant to the dam site, and there are places which even a four-wheel drive vehicle would be hard pressed to traverse in the rainy season. It takes two hours by car between these points.

3.2 Natural Conditions

These areas belong to the Temperate Rainy Climate Zone (Clima templado lluvioso) and the Tropical Rain Climate Zone (Clima tropical lluvioso). The mountain regions are covered by forests. There are no special conservation districts in the Rio Naranjo valley except for forest preserves established in the northeastern region. The topography of the areas up from the dam site is rugged. Settlers now use this area as private land for coffee plantations. The coffee bushes are initially planted on the steep slopes but must be transplanted elsewhere as the land becomes impoverished. Due to this, totally stripped land is found throughout the region. It is assumed that this is because the trading centers for coffee beans are located outside the Rio Naranjo valley and tend to concentrate in this, the Los Santos region.

A part of the right bank of the mouth of the Rio Naranjo is conserved as the Manuel Antonio National Park. This is a resort area which includes the famed submerged rocks and coastline of Quepos. On the left bank of the river mouth are flatlands which are quite different from the terrain of the right bank due to the influences of the Rio Savegre being stronger than those of the Rio Naranjo. Here, the traditional cultivation of African palms is very popular. There are also mangrove trees in the swampland between the coastline and the palm plantations.

The Rio Naranjo that runs southward from the dam site changes course westward to bypass this flatland and then turns southward again to flow into the Pacific Ocean. Therefore, this waterway route was selected in the power generation plan to attain a head over a short distance by discharging water into the Rio Paquita that runs down straight in the west.

3.3 Social Environment

There are no large cities within the project area, although small villages, mainly home to cattle breeders, are scattered throughout the highlands along the river, except for Londres Village which is located at the point where the Rio Naranjo runs slowly into the flatlands. The base towns of San Marcos and Quepos are both outside the river basin, and both have populations of about 1,000. Both have a market and hotel etc., aside from public facilities such as schools, a hospital, churches, police stations, post offices, and town halls.

It is noteworthy that there is a local airport in Quepos which provides easy access from/to San Jose, the capital city. The coastline, which is well provided with hotels and restaurants, is well established as a tourist area as well being as a national park. Many tourists visit this area.

3.4 Environmental Protection

Today, various measures are promoted by each country as well as at the international level against global environmental problems. These include global warming, reduction of tropical forest, accelerating desertification and acid rain. There are deep concerns regarding the influences of individual development projects on the neighboring natural and social environments. Although a hydro power development is considered environmentally friendly, it is now required that the project plan provides adequate environmental protection measures to ensure that it co-exists with the natural and social environments of the developing area. Such environmental measures should, in principle, be provided according to the laws and regulations of the country concerned. However as no guidelines have been established in Costa Rica at this time, environmental assessment must be made with the complete study at the initial stage of the plan as much as possible to ensure its result is reflected in the plan.

In this study, the initial environmental examination (IEE) is carried out according to JICA guidelines. These guidelines are equivalent to the environmental protection measures concerning the development study/plan, currently established by various international organizations including the World Bank and the UN Environmental Plan Committee and also by bilateral aid organizations such as USAID and ODA. The environmental impact assessment (EIA) regarding the environmental concern which is required further in this study is then carried out. The data collection and on-site survey for this study are carried out in cooperation with ICE. Work related to IEE and EIA is consigned to a local firm. The study, prediction and assessment of environmental effect are conducted by the Study Team based on the results of this study. The goal for the environmental protection and the measures to prevent or reduce environmental influences are proposed accordingly.

Chapter 4 Present State of Electric Power Industry

Chapter 4 Present State of Electric Power Industry

CHAPTER 4 PRESENT STATE OF ELECTRIC POWER INDUSTRY

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CHAPTER 4 PRESENT STATE OF ELECTRIC POWER INDUSTRY

4.1 Electric Power Utility

Costa Rican electric power is provided by the following eight power distribution companies, with ICE being the leading company of that group.

1. ICE (Instituto Costarricense de Electricidad)
2. CNFL (Compañía Nacional de Fuerza y Luz)
3. JASEC (Junta Administrativa del Servicio Eléctrico de Cartago)
4. ESPH (Empresa de Servicios Públicos de Heredia)
5. COOPE GUANACASTE (Regional electrification cooperative)
6. COOPE LESCA (Regional electrification cooperative)
7. COOPE SANTOS (Regional electrification cooperative)
8. COOPE ALFARO (Regional electrification cooperative)

Fig. 4-1 shows the service area of each power company in Costa Rica.

Basically, ICE is responsible for the total integrated service, and also covers power generation, transmission and distribution. However, depending on local conditions, some of the regional power companies receive power from ICE for distribution within their respective service areas.

ICE controls the nation's major power stations (20 MW or more), substations, transmission lines and distribution lines, although some regional power companies, apart from ICE, operate and control smaller-sized hydroelectric power plants.

It is expected that in the future, private firms may be allowed to develop small-size power stations, thereby increasing the opportunities for non-public utilities to develop electric power, including cogeneration, themselves.

4.2 Present State of Power Supply Facilities

As of January, 1995, Costa Rican's total installed capacity was 1,177.8 MW, of which 1,103.5 MW is held by ICE, leaving the remainder with the other power companies to own individually.

Table 4-1 shows the installed capacity by company and by generation method. 74.1% of the total installation is hydroelectric with the remaining 25.1% being thermal electric. (The thermal portion includes the 55 MW Miravalles Geothermal Power Plant.)

In the nationwide ICE system, the rate of dependency on hydroelectric power is estimated at about 72%, of which 35% is provided by the three power plants of the Arenal water system, Arenal, Corobici and Sandillal. It is obvious that Lake Arenal, which serves these power plants as their common reservoir, is a most important water storage in view of its use in complementing the operations of Costa Rica's small-sized hydropower plants.

4.3 Transmission Systems

The transmission systems are interconnected from Peñas Blanca (Costa Rica/Nicaragua boarder) in the north to Paso Canoas (Costa Rica/Panama border) in the south.

Line voltages of 230 kV and 138 kV are employed. The transmission lines stretch 1,583.9 km (880 km of 230 kV and 703.9 km of 138 kV) overall.

There are a total of 10 step-up substations (1,300 MVA total installed capacity) and 20 step-down substations (1,530 MVA total installed capacity)

Fig. 4-2 is a map of the Electric Power System in Costa Rica. Table 4-2 shows the major transmission lines in operation.

To meet future demand increases, ICE is planning an expansion program for 230 kV and 138 kV lines respectively. Another program is under projecting a 500 kV Central American transmission line to attain an optimum electric power system which will interconnect five Central American nations and Panama. This program is currently being reviewed toward its commissioning in the first half of the year 2000.

Table 4-3 shows the transmission line expansion program as prepared by ICE.

4.4 Distribution System

In Costa Rica, power distribution is operated by eight power companies: ICE, its affiliate company, CNFL - two companies run by municipal authorities, ESPH and JASEC - and four regional electrification companies, COOPE GUANACASTE, COOPE LESCA, COOPE SANTOS and COOPE ALFARO.

As of December, 1994, the power demand met by the entire group of power companies was 4,204 GWh. The electrification rate was 93% with a total length of distribution lines of 20,794 km.

The following table is a break-down:

Company	Length (km)	No. of Application	Consumption of Energy (GWh)
ICE	12,002	332,892	1,562
CNFL	2,107	317,904	1,988
ESPH	262	34,410	158
JASEC	818	46,670	230
COOPE GUANACASTE	2,381	26,614	94
COOPE LESCA	1,832	31,134	119
COOPE SANTOS	1,177	20,256	42
COOPE ALFARO	215	3,848	11
Total	20,794	813,727	4,204

4.5 Present State of Power Demand

4.5.1 General Power Demand

Domestic power consumption in 1994 was 4,204 GWh as is broken down as follows:

Residential	1,915 GWh	(45.6%)
General	888 GWh	(21.1%)
Manufacturing	1,284 GWh	(30.5%)
Public	117 GWh	(2.8%)
Total	4,204 GWh	(100.0%)

The Costa Rican power market is expanding steadily, and the annual average growth rate of power consumption from 1985 to 1994 is rather high at 5.8%.

Table 4-4 shows actual power consumption by sector. As of 1994, the electrification rate in Costa Rica was 92.7%, a relatively high rate for a Central American countries. Changes in that rate since 1985 are shown in the following table.

(%)

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Electrification Rate	83.48	84.80	86.00	87.20	88.41	89.97	91.24	92.40	92.53	92.70

4.5.2 Daily and Seasonal Power Demand Fluctuations

(1) Daily Power Demand Fluctuations

Fig. 4-3 shows the daily load curve on the day of the highest demand in 1994. The peak load was 858 MW at 18:00 hrs. and the bottom load was 330 MW at midnight.

The load begins to rise at about 03:00 hrs. and shows a sudden increase at 06.00 hrs., attaining the morning peak at about 11.00 hrs. The demand drops by about 150 MW due to the custom of mid-day siesta (rest), but starts to rise again from 16:30 hrs. to reach the day's peak at 18:00 hrs.

The highest peak demand is followed by a gradual decrease which lasts for about an hour until the load drops to the same level as the midnight load level of the previous day.

This trend is almost unchanged during the weekdays. Based on the above, the daily load in Cost Rica is summarized as follows:

i) The highest peak demand comes at about 18:00 to 19:00 hrs. in a very large load relative to the other time bands.

ii) The lowest midnight load comes at about 02.00 to 03.00 hrs., being about 40% that of the highest peak demand.

iii) The daylight time bands in the afternoon have relatively little change, remaining at about 75% of the highest peak demand.

iv) The peak sustaining time lasts for 3 to 4 hours.

v) The shape of the load curve has been almost unchanged over the past 10 years and similar load distribution is expected to continue in the future. Power demand for the use of air-conditioning equipment, which would significantly influence the peak load behavior, is not expected to change very much in the future because the San Jose region, which is the largest consumer of electric power, is situated on at about 1,000 m altitude where the ambient temperature is not high enough to cause discomfort. It is comfortably cool, particularly at night, therefore requiring little air conditioning.

vi) The shape of the load curve indicates that more power is consumed in the evening and at night than in the daytime, suggesting that the general power demand (i.e. demand for residential and for commercial use) carries greater impact on the different forms of power demand.

(2) Seasonal Fluctuation of Power Demand

Fig. 4 shows the monthly maximum load fluctuation curve during the period 1987 through 1993, monitored at the San Isidro Substation. Based on the load curve, it is concluded:

i) The annual maximum peak usually takes place during November to December.
ii) The lowest demand occurs some time during the period June through August.
iii) The maximum power demand is clearly increasing each year.

4.6 Electricity Tariff

The monthly tariff in Costa Rica has three grades, depending on power consumption or usage: 0-3,000 kWh, 3,001-20,000 kWh, and 20,000 kWh more. These are further classified by different uses (residential, general, industrial, commercial and other).

In principle, the tariff is set on a combination of the base charge with charges graded by the amount of consumption, for each category of use. To revise any part of the tariff, ICE is required to prepare a proposal for submission to the government for approval.

The average tariff rates charged by ICE and the other power companies in practice as of February, 1995 are:

Residential	12.00 c/kWh
General	19.20 c/kWh
Industrial (large firms)	14.80 c/kWh
(small firms)	17.20 c/kWh
Construction	27.50 c/kWh
Public	4.60 c/kWh

4.7 Power Development Program by ICE

ICE assumes the future power demand in Costa Rica will continue to grow at an annual rate of about 5 to 6%. (This will be further detailed in Chapter 5 herein.) ICE also assumes that the highest peak demand in 2000 will be 1,241 MW, 1.5 times that of 1994, and 2,031 MW in 2010, 2.4 times. To meet the demand increase assumed in the future, ICE has been preparing its own electric power development program and specific plans for expanding its system of transmission lines and substations. Especially, ICE, in these plans, places the highest priority on the development of hydroelectric power, which is the only significant natural resource in the country as far as electric power is concerned.

Tables 4-3 and 5-4 illustrate the ICE-proposed expansion plans for power generations and transmission lines.

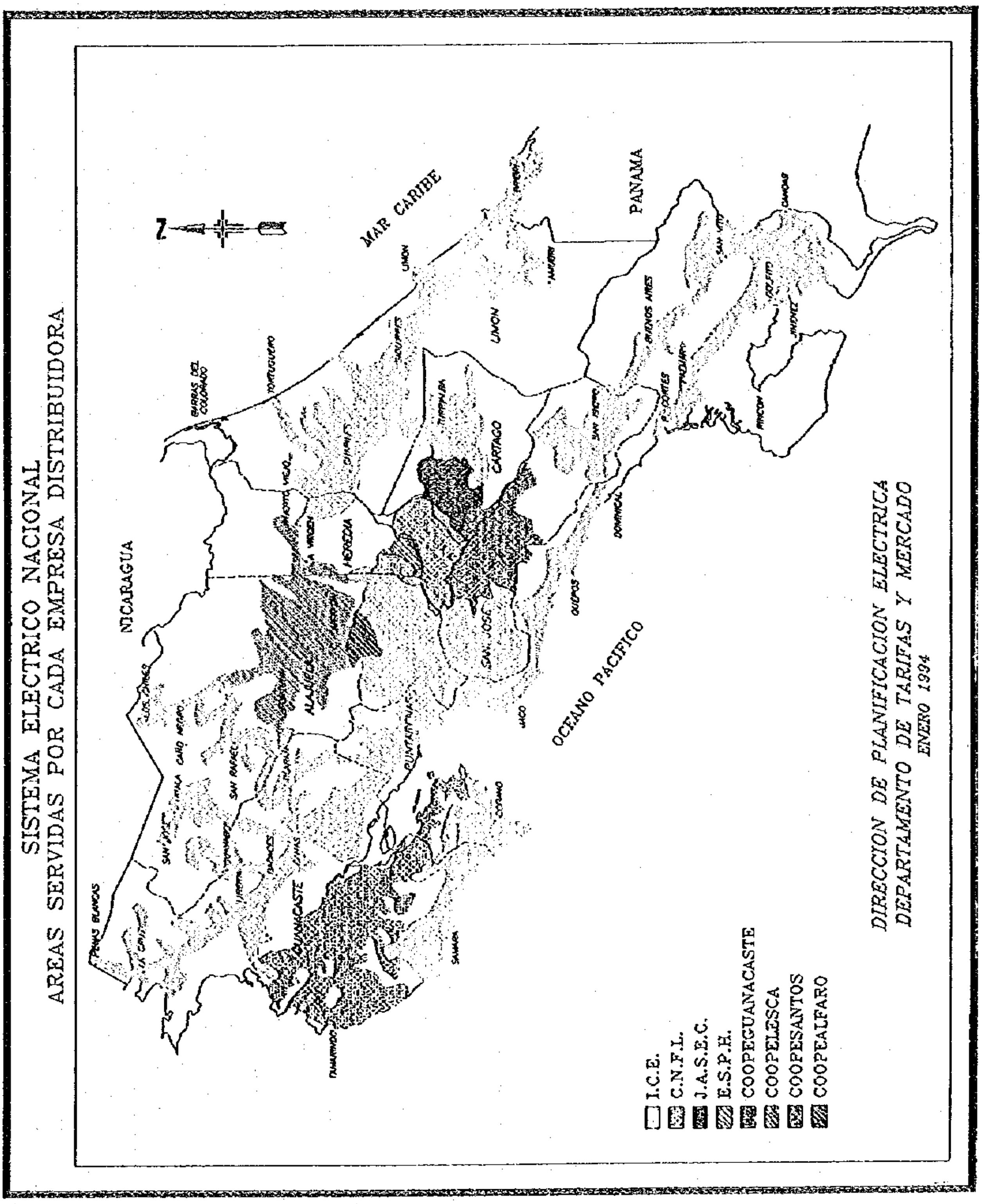
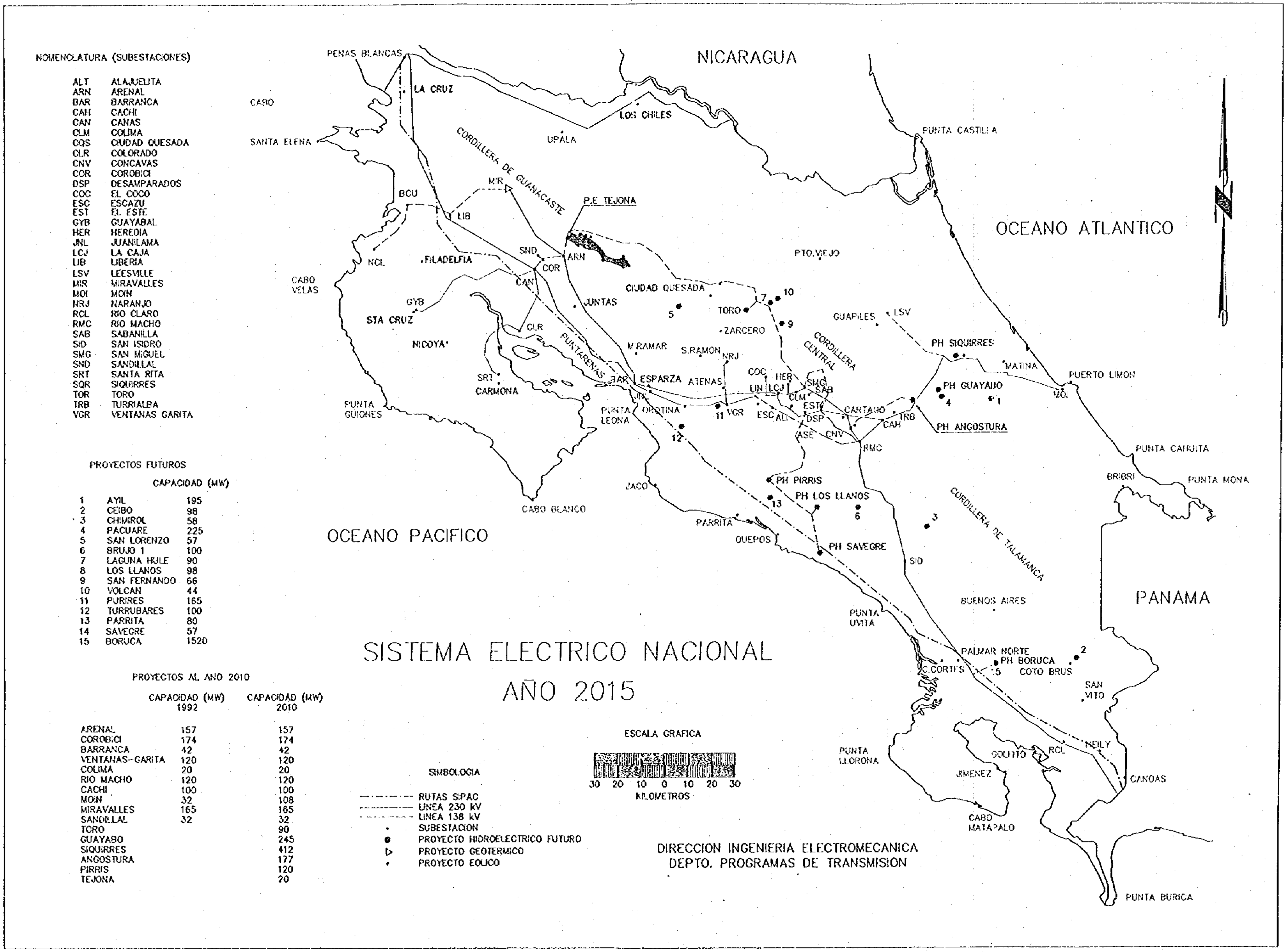


Fig. 4-1 Service Area Map



NOMENCLATURA (SUBESTACIONES)

ALT	ALAJUELITA
ARN	ARENAL
BAR	BARRANCA
CAH	CACHI
CAN	CANAS
CLM	COLIMA
CQS	CIUDAD QUESADA
CLR	COLORADO
CNV	CONCAVAS
COR	COROBICI
DSP	DESAMPARADOS
COC	EL COCO
ESC	ESCAZU
EST	EL ESTE
GYB	GUAYABAL
HER	HEREDIA
JNL	JUANILAMA
LCJ	LA CAJA
LIB	LIBERIA
LSV	LEESVILLE
MIR	MIRAVALLES
MOI	MOIN
NRJ	NARANJO
RCL	RIO CLARO
RMC	RIO MACHO
SAB	SABANILLA
SID	SAN ISIDRO
SMG	SAN MIGUEL
SND	SANDILLAL
SRT	SANTA RITA
SQR	SIQUIRRES
TOR	TORO
TRB	TURRIALBA
VGR	VENTANAS GARITA

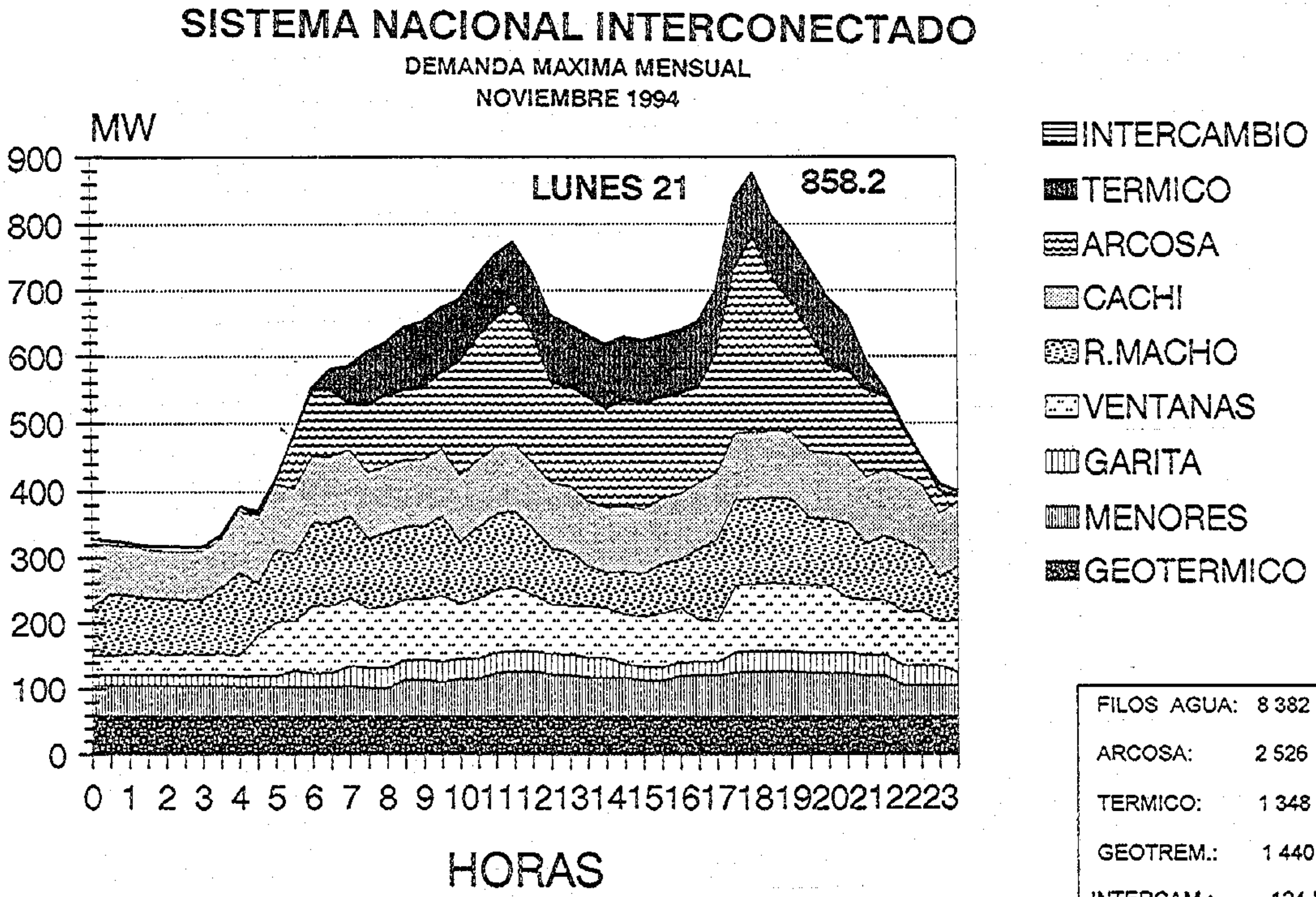
PROYECTOS FUTUROS

		CAPACIDAD (MW)
1	AYIL	195
2	CEIBO	98
3	CHIMIROL	58
4	PACUARE	225
5	SAN LORENZO	57
6	BRUJO 1	100
7	LAGUNA HULE	90
8	LOS LLANOS	98
9	SAN FERNANDO	66
10	VOLCAN	44
11	PURIRES	165
12	TURRUBARES	100
13	PARRITA	80
14	SAVEGRE	57
15	BORUCA	1520

PROYECTOS AL ANO 2010

	CAPACIDAD (MW) 1992	CAPACIDAD (MW) 2010
ARENAL	157	157
COROBICI	174	174
BARRANCA	42	42
VENTANAS-GARITA	120	120
COLIMA	20	20
RIO MACHO	120	120
CACHI	100	100
MOIN	32	108
MIRAVALLES	165	165
SANDILLAL	32	32
TORO		90
GUAYABO		245
SIQUIRRES		412
ANGOSTURA		177
PIRRIS		120
TEJONA		20

Fig. 4-2 Electric Power System in Costa Rica (2005)



FILOS AGUA:	8 382 MWH
ARCOSA:	2 526 MWH
TERMICO:	1 348 MWH
GEOTREM.:	1 440 MWH
INTERCAM.:	-124 MWH
CONSUMO:	13 572 MWH
Factor Carga:	65.89 %

INSTITUTO COSTARRICENSE DE ELECTRICIDAD

Fuente: Ofna. Centro de Información
Subdirección Control de Energía

Fig. 4-3 Daily Load Curve

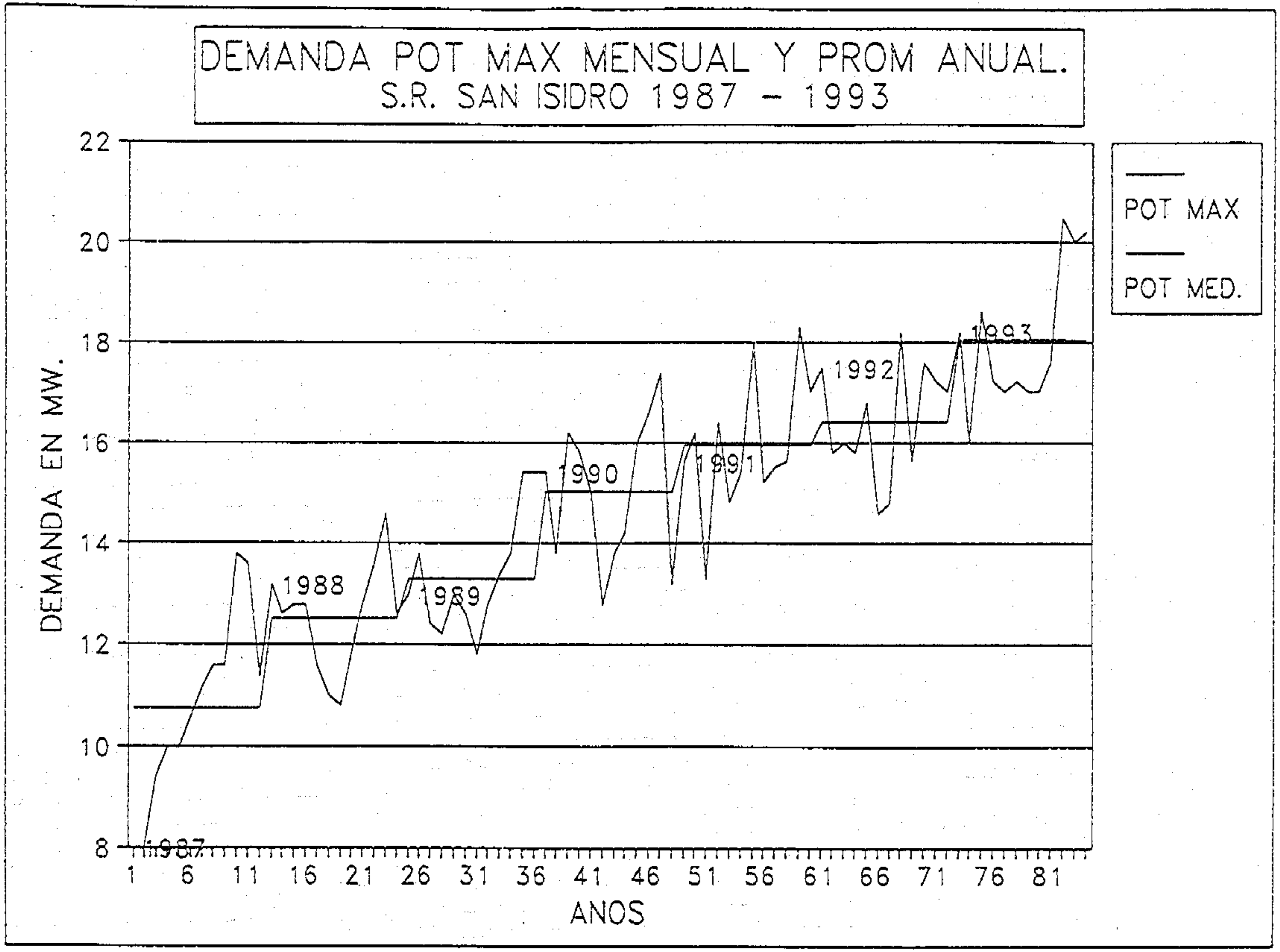


Fig. 4-4 Monthly Load Curve

Table 4-1 Installed Generating Capacity

As of end of 1994

		Plant Name	Type	No. of Machine	Capacity (MW)		Generation Engery (MWh)		Commission Year
					Installed	Dependable Available	Average	Firm	
ICE	Hydro	La Garita	F	2	30	20	162	162	1958
		Rio Macho	P	5	120	90	501	396	1963
		Cachi	F	3	100	90	596	565	1966
		Arenal	F	3	156	156	601	601	1979
		Corobici	F	3	174	174	672	672	1982
		Ventanas Garita	F	2	100	70	434	361	1987
		Sandillal	K	2	32	32	124	124	1993
		Plantas Menores	-	6	74	37	261	180	--
		Generacion Privada			12	6	68	20	--
		Sub Total			798	675	3,419	3,081	
	Thermal	Colima	D	6	19.5	14.0	136.6	136.6	1956
		San Antonio	V-G	4	48.1	40.0	170.1	170.1	1954
		Barranca	Gas	2	41.6	30.0	109.3	109.3	1974
		Moin	D Gas	7	140.3	125.0	508.0	508.0	1977
		Pto. Jimenez	D	4	1.3	1.2	9.1	9.1	--
		Miravalles	Ge.	1	55	52.3	433.6	433.6	1994
		Sub Total			305.5	262.5	1,366.7	1,366.7	
Another Company		ESPH	-	5	2.3	1.2	--	7.3	--
		JASEC	-	4	22.7	11.3	--	69.3	--
		CNFL	-	19	37.5	18.7	--	114.7	--
		Mata Moros	-	7	3.3	1.6	--	9.8	--
		Sub Total			65.8	32.8		201.1	
Co. Gene.		Varias	T	1	4	2		12.2	
		Varias	M	4	4.5	2.3		19.7	
		Sub Total			8.5	4.3		31.9	
		Total			1,177.8	974.6		4,680.7	

P : Pelton
F : Francis
D : Diesel
V-G : Vapor Gas
Gas : Gas Turbine
D Gas : Diesel Gas
Ge : Geo Thermal
T : Thermal
M :

Table 4-2 Major Transmission Lines in Operation

As of end of 1994

	Voltage	Location (From ~ To)	Length (km)	Conductor
Existent	230 kV	Peñas Blancas (Frontera Nicaragua) ~ Liberia	77.0	DRA
		Liberia ~ Canas	42.0	DRA
		Sandillal ~ Corobici	3.0	DRA
		Miravalles ~ Arenal	42.0	DRA
		Arenal ~ Corobici	11.0	DRA
		Corobici ~ Canas	7.0	DRA
		Canas ~ Barranca	70.0	GRO
		Arenal ~ Barranca (2 cct)	68.0	CON
		Arenal ~ Ciudad Quesada	83.0	2 x GRO
		Ciudad Quesada ~ Toro	30.0	2 x GRO
		Toro ~ San Miguel	50.0	2 x GRO
		Barranca ~ La Caja (2 cct)	62.0	DRA
		Rio Macho ~ San Isidro	65.0	DRA
		San Isidro ~ Rio Claro	110.0	DRA
		Rio Claro ~ Progreso (Panama)	30.0	DRA
		Total	880.0	
	138 kV	Guayabal ~ Canas	58.2	ORI
		Canas ~ Colorado	25.0	LIN
		Canas ~ Santa Rita	32.0	CAN
		Canas ~ Cempa	1.2	LIN
		Barranca ~ Ventanas Garita	34.4	LIN
		Ventanas Garita ~ Naranjo	17.3	ORI
		Naranjo ~ Daniel Guetierrez	25.0	GRO
		Ventanas Garita ~ El Coco	19.2	GRO
		El Coco ~ La Caja	15.9	GRO
		Ventana Garita ~ La Caja	21.8	GRO
		La Caja ~ Heredia	7.9	GRO
		Heredia ~ Colima	7.1	GRO
		La Caja ~ Colima	8.5	GRO
		Colima ~ San Miguel	10.0	GRO
		San Miguel ~ SBN	6.0	GRO
		SBN ~ Cachi	19.2	GRO
		Colima ~ El Este	8.5	GRO
		La Caja ~ El Este	18.5	GRO
		El Este ~ Cachi	29.0	GRO
		La Caja ~ Escazu	3.0	GRO
		Escazu ~ Desamparados	17.0	GRO
		Desamparados ~ El Este	10.4	GRO
		La Caja ~ Alajuelita	11.6	GRO
		Alajuelita ~ El Este	19.1	GRO
		El Este ~ Concavas	16.4	GRO
		Concavas ~ Rio Macho	9.1	GRO
		El Este ~ Rio Macho	25.5	GRO
		Rio Macho ~ Cachi (2 cct)	14.6	DRA
		Cachi ~ PIS	19.2	GRO
		Leesville ~ PIS	33.0	GRO
		PIS ~ Siquirres	20.0	GRO
		Siquirres ~ Moin (2 cct)	41.5	LIN
		Cachi ~ Siquires	42.7	GRO
		Total	703.9	

Table 4-3 Major Transmission Lines in Planning by ICE

As of end of 1994

	Voltage	Location (From ~ To)	Length (km)	Conductor
Future	500 kV	Ticuantepe (Nicaragua) ~ San Rafael	353.9	
		San Rafael ~ Boruca	119.8	
		Boruca ~ Veladero (Panama)	231.5	
		Total	705.2	
	230 kV	Liberia ~ Bahia Culebra	23.0	GRO
		Bahia Culebra ~ Nuevo Colon	25.0	GRO
		Nuevo Colon ~ Guayabal	20.0	GRO
		Liberia ~ Miravalles	33.0	DRA
		Canas ~ LIND	112.0	CAR
		La Caja ~ Val	14.0	CAR
		Val ~ San Miguel	11.0	CAR
		La Caja ~ LIND (2 cct)	5.5	
		LIND ~ Aserri (2 cct)	18.0	
		Aserri ~ Pirris (2 cct)	33.3	
		Pirris ~ San Rafael	10.8	
		Los Llanos ~ San Rafael	20.0	
		Savegre ~ Los Llanos	19.0	
		Aserri ~ El Este	14.0	
		Aserri ~ Rio Macho	27.0	
		San Miguel ~ Siquirres	80.0	2 x 795
		San Miguel ~ El Este	15.0	
		El Este ~ Gua (2 cct)	58.0	2 x 795
		El Este ~ Rio Macho	26.1	
		Gua ~ Siquirres	24.0	2 x 795
		Siquirres ~ Moin	40.0	2 x 795
		Total	743.5	
	138 kV	Con Cavas ~ Angostula	33.0	CAR
		San Pedro de Poas ~ Coco		
		Guayabal ~ Santa Rita	26.0	
		Naranjo ~ San Pedro de Poas		
		Total	59.0+2	

Table 4-4 Transitions of Electric Energy Consumption

: GWh

Year	Energy Consumption (GWh) and Number of User																	
	Residential				General				Industrial				Street Lighting		Construction		Total	
	User	Rate%	Coms.	Rate%	User	Rate%	Coms.	Rate%	User	Rate%	Coms.	Rate%	Coms.	Rate%	Coms.	Rate%	Coms.	Rate%
1985	420896	5.1	1123	7.1	54774	7.5	576	8.3	4605	7.4	675	0.2	81	3.0	17	131.2	2472	5.7
1986	448558	6.6	1242	10.6	58738	7.2	609	5.7	5127	7.4	738	0.2	82	0.9	26	53.6	2696	9.1
1987	481869	7.4	1359	9.4	61640	4.9	656	7.8	6185	11.3	793	9.3	86	5.2	11	-56.9	2905	7.7
1988	518855	7.7	1406	3.5	65818	6.8	677	3.1	7144	20.6	789	7.5	92	6.8	4	-60.4	2969	2.2
1989	552193	6.4	1458	3.7	68907	4.7	704	4.0	7583	15.5	869	-0.4	89	-2.9	4	-19.1	3125	5.3
1990	589635	6.8	1580	8.4	71535	3.8	730	3.6	8325	6.1	921	10.1	91	1.8	3	-26.8	3325	6.4
1991	622209	5.5	1614	2.1	74239	3.8	726	-0.5	9032	9.8	969	6.0	100	9.7	2	-16.6	3411	2.6
1992	655270	5.3	1682	4.2	77817	4.8	781	7.6	9674	8.5	1028	11.6	103	3.4	5	107.1	3599	5.5
1993	685139	4.6	1792	6.5	80589	3.6	813	4.1	10135	7.1	1173	21.1	108	4.5	4	-2.9	3890	8.1
1994	716885	4.6	1915	6.9	86266	7.0	888	9.2	10571	4.3	1284	9.5	114	5.5	3	-25.0	4204	8.1

Chapter 5 Demand Forecast and Power Supply Plan

Chapter 5 Demand Forecast and Power Supply Plan

CHAPTER 5 DEMAND FORECAST AND POWER SUPPLY PLAN

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CHAPTER 5 DEMAND FORECAST AND POWER SUPPLY PLAN

5.1 Power Demand Forecast

As described in Chapter 4, The Costa Rican power demandgrew at a high mean annual rate of 5.8% during the period 1985 to 1994.

A study in the relationship between the power demand and the economic growth revealed that the power demand has grown in proportion to the growth of the GDP.

Table 5-1 shows the record of the growth of GDP and power demand in Costa Rica, from 1980 to 1994.

Although the economy growth relative to the previous year was negative in 1981 and 1982, it showed positive growth thereafter, maintaining a growth rate of 4.5 to 5% from that time on. This is expected to continue.

5.1.1 Power Demand Forecast by ICE

ICE is conducting its own demand forecast to formulate a power development plan which will respond to future demand increases.

This forecast is based on the numbers of subscribers and the power consumption records of the subscribers classified into sectors (residence, industry and general), to estimate the future demand between 1995 and 2015.

In forecasting that demand, ICE adopted three growth scenarios, high, intermediate and low.

As the official demand forecast, ICE adopts one for the "intermediate" (called the "base") scenario.

Table 5-1 shows the power demand forecast by ICE. According to this forecast, both GWh and MW values will increase annually at a rate of 6.6% from 1995 to 2000. From 2000 to 2015, the growth rate is estimated to decline slightly to 5.3 - 5.7%. This means that the demand for 1994 of 4,723 GWh and 858 MW is to grow 1.5 times to 6,813 GWh and to 1,241 MW by 2000, 2.4 times to 11,153 GWh and 2,031 MW by 2010, and 3.0 times to 13,866 GWh and 2,526 MW by 2015.

5.1.2 Demand Forecast by Study Team

(1) Method of Demand Forecast

Only macroscopic demand forecast was conducted due to the limited time allowed for study which did not allow detailed collection of references and their verification.

The macroscopic method used here was to evaluate the power demand by focusing on the correlation between the per capita electric energy consumption and the economic growth rate, as published by EPDC in its document, "Method of Long Range Demand Forecast Of Energy For Developing Countries From The Worldwide Standpoint", EPDC, Sep. 1985.

With this method, the record value data up to the present of the country under study are plotted on the basis of the worldwide mean power demand trend diagram (Fig. 5-1) and the per capita GDP and its growth rate (Fig. 5-2).

The basic concept of this method is that normally, the power demand of developing countries tends to approach the world average growth curve gradually from the lower side. These actually achieved values are then extended until the curve intersects with the average curve and, from the intersection point(year) taken as the reference, the growth will desirably extend along this average growth curve over the long term, as viewed globally.

In the case of some countries, the growth is higher than the global average trend (high cases), but still, when viewed over long periods, that growth is considered to approach the average curve.

(2) Calculation Conditions

(a) Period of forecast: 21 years (1995 to 2015)

Although ICE has scheduled the start of operation of the Los Llanos Power Plant for 2005, the 21 years between 1995 and 2015 were adopted to provide some reserve.

(b) Reference year: 1993

On the basis of the actually achieved conditions during the past 24 years (1970 to 1993), the year 1993 when the growth is expected to reach the global average growth curve of Fig. 5-1 was adopted as the reference year for long-term forecast.

(c) **Per capita GDP: US$2,060/cap.**

This value is the result obtained from cross-checking the GDP data of the Costa Rica Central Bank supplied by ICE and the data of the OECD Annual Report.
The prices were calculated on the basis of the 1980 exchange rate between the Costa Rican Colon and the US$ with escalation.
From the above, the per capita GDP was set at US$2,060 /cap (1993). The growth rate of the per capita GDP was approx. 2% during the period 1985 to 1994, which is lower than the global average of 5%. However, since an upward turn is expected in the future, a value between this actual record and the global average, i.e., 3.5%, was adopted.

(d) **Population: 3,199,000 (1993)**

This figure was adopted from an ICE data (Población y PIB 1980~2015). For the period between 1995 and 2015, the figures were taken from the material listed in Table 5-2.

(e) **Per capita electric energy: 1,370 kWh (19993)**

This figure, 1,370 kWh, was obtained by dividing the actual power demand figure for the reference year 1993, 4,382 GWh, by the population of the year, 3,199,000.

(f) **Annual load factor**

The actual record for 1980 to 1994 was between 58.67% and 61.9%, fluctuating around 60%. Then, in the future, even when the peak load may rise sharply with the increase of air cooling units, etc., the factor is expected to remain more or less unchanged with no substantial drop, and an annual factor of 60% was adopted.

The result of the macroscopic demand forecast based on this method is given in Table 5-3 and Fig. 5-4.

5.1.3 Comparison of Demand Forecast Results

Generally, the result of the JICA shows no substantial difference from the value (base) estimated by ICE.

There is also almost no difference seen in the vicinity of 2005, when the Los Llanos Power Plant is scheduled to start operation, and the two forecasts agree quite well. For this reason, the decision was made to adopt the ICE forecast result in the demand-supply balance plan.

5.2 Power Supply Plan

In examining the power demand-supply balance, for short-term plans, the supply plan of electric energy is generallyemphasized.

On the other hand, for long-term plans over 10 years,the kW figures are generally emphasized.

The unique feature of the ICE power system is the predominance of hydroelectric power over thermalelectric power, the former accounting for 68% of the entire facilities.

For this reason, the power system of ICE is heavily influenced by hydraulic power supply which fluctuates with the fluctuation of river water volume. Accordingly, in studying the power demand-supply balance, the hydroelectric firm output is to be fully taken into consideration.

5.2.1 Prediction of Future Load Pattern

In studying the future supply plan, the seasonal and hourly patterns of the power demand need be fully understood.

For this, the past demand record was analyzed to predict the future load pattern.

(1) Peak Demand Month

The power demand of Costa Rica rises to its highest peak during the months of November and December. This is believed due to the power consumption situation where the power demand of the lighting load in winter is greater than the power demand of the cooling load in summer.

Although the use of air conditioning units has increased vastly, thereby greatly influencing the maximum power demand, the cooling load during summer (June to August) is not expected to rise sharply, because the city of San Jose, the power consumption center, is located at an altitude of about 1,000m above sea level where air conditioning units are not overly necessary, even in the summer. This trend is not expected to change for some time in the future.

Therefore, in the power demand-supply plan, November was considered the annual high peak month.

(2) Daily Load Curve

Although the daily load pattern varies with seasons and days in weeks, the highest load peak has occurred on weekdays for the last several years.

In addition, the load pattern on the peak days is almost always the same. Therefore, in studying the future kW peak balance, the daily load pattern for November 21 (Tuesday), 1994 (Fig. 4.3 in Chapter 4) is to be adopted as the basis.

The highest peak demand in this month was observed at around the time the majority of lighting is turned on, at 18:00 hrs. Another peak was also observedat around 11:00 hrs. The peak duration is approximately 3 to 4 hours, with a daily load factor of approximately 66%.

The estimated daily load curve for 2004 is shown in Fig. 5-5. The daily load continuous curve is shown in Fig. 5-6.

5.2.2 Power Supply Plan

The power development plan formulated by ICE for the period from 1995 to 2015 is shown in Table 5-4.

In this development plan, an optimum power development program called LOGOS (Logiciel du Gestion Optimal du System Electrique) is used.

The reliability target used here assumes the number of annual power deficiency days to be 2 days.

If this development plan is advanced as scheduled, the total power generation facilities would be 1,921 MW, or a level 1.75 times the level of 1994 by the year 2005 when the Los Llanos Power Plant is scheduled for operation start. Of the total power development of 2,170 MW projected up to 2015, hydroelectric power sources account for 1,600 MW, or 73%, indicating the continued high weight of hydroelectric power. In this way, hydroelectric power, as a domestic energy source, is seen tocontribute greatly to the power demand-supply situation.

5.2.3 Power Development Plan

The power development plan, was studied by basically referring to the electric power development plan of ICE.

(1) Study Conditions

(a) Power (kW) balance

The power (kW) balance was studied for the day when the highest peak demand in November, the month in which the peak demand occurs and which is generally a dry season.

(b) Energy (kWh) balance

The energy (kWh) balance was studied for the annual average energy demand.

(c) Thermal power plant

- It will be based on the decommissioning plan by ICE. The decommissioning plan by ICE is shown in table 5.5.
- Power failure: In the study of the power (kW) balance, one largest unit is assumed to fail and stop operation on the day the maximum peak occurs. However, the failure is assumed to be eliminated immediately and no influence on the annual power energy generation is considered.
- Annual utilization factor:
  Gas turbine: 30%, Diesel:80%, Geothermal: 90%
- Repair plan: No repair shall be undertaken in the month of peak demand.

(d) Hydroelectric power plant

- Decommissioning and accident: None is considered.

i) Annual energy (kWh) balance

Both the average energy (energy in average water flow rate year) and the firm energy were considered.

ii) Power (kW) balance of peak day

In studying the balance, the basic rule that hydroelectric output shall be allocated to the peak load toward the middle and base load in the declining priority, along the daily load continuous curve, and the deficit in the base load shall be supplemented by thermal power was adopted. For supplying power to the hydroelectric power peak, the dependable peak capacity was considered.

iii) Power import

No power import was considered in the study of the power (kW) balance. It will, however, be considered in the study of the energy (kWh) balance.

(2) Result of the Study

If the power demand grows as it is estimated, Los Llanos Hydroelectric Power Plant will be indispensable from a viewpoint of the power (kW) and energy (kWh) balance. It should be pointed out that the commissioning of Los Llanos Hydropower Plant will only be realized in 2005 or later, considering the practical construction schedule. In the event that the commissioning of Los Llanos Hydropower Plant is delayed beyond year 2005, the kW and kWh balance will become quite stringent. In such a case, appropriate alternative power generation facilities will be required.

5.3 Optimum Electric Power Development Plan

The optimum electric power development plan was studied in response to the power demand between 1995 and 2015. The study showed that the Los Llanos Power Plant should start operation in 2005. (See Table 5-8) The results of this study coinside with the results of the ICE study using LOGOS.

In the ICE long-term development plan up to 2015, however, the kWh balance will be lost after 2006. The reasons are that the proportion of hydro power generation is high in the entire power generation, and that ICE applies a different data processing program and calculation method.

If a water shortage similar to that in the past occurs, the hydro power generation will drop significantly. Regardless of a supplement by thermal power generation, power shortage may still occur. Although power accommodation from neighboring countries can be expected, its quantity is restricted.

In our study, therefore, 64MW base thermal power generation is added in 2007 to the ICE development plan. Regarding the other plan contents, the same study results were acquired as in the ICE development plan.

Considering the balance in power demand and supply, the Los Llanos Hydro Power Plant is a vital factor in the long development plan up to 2015 and its realization is strongly recommended.

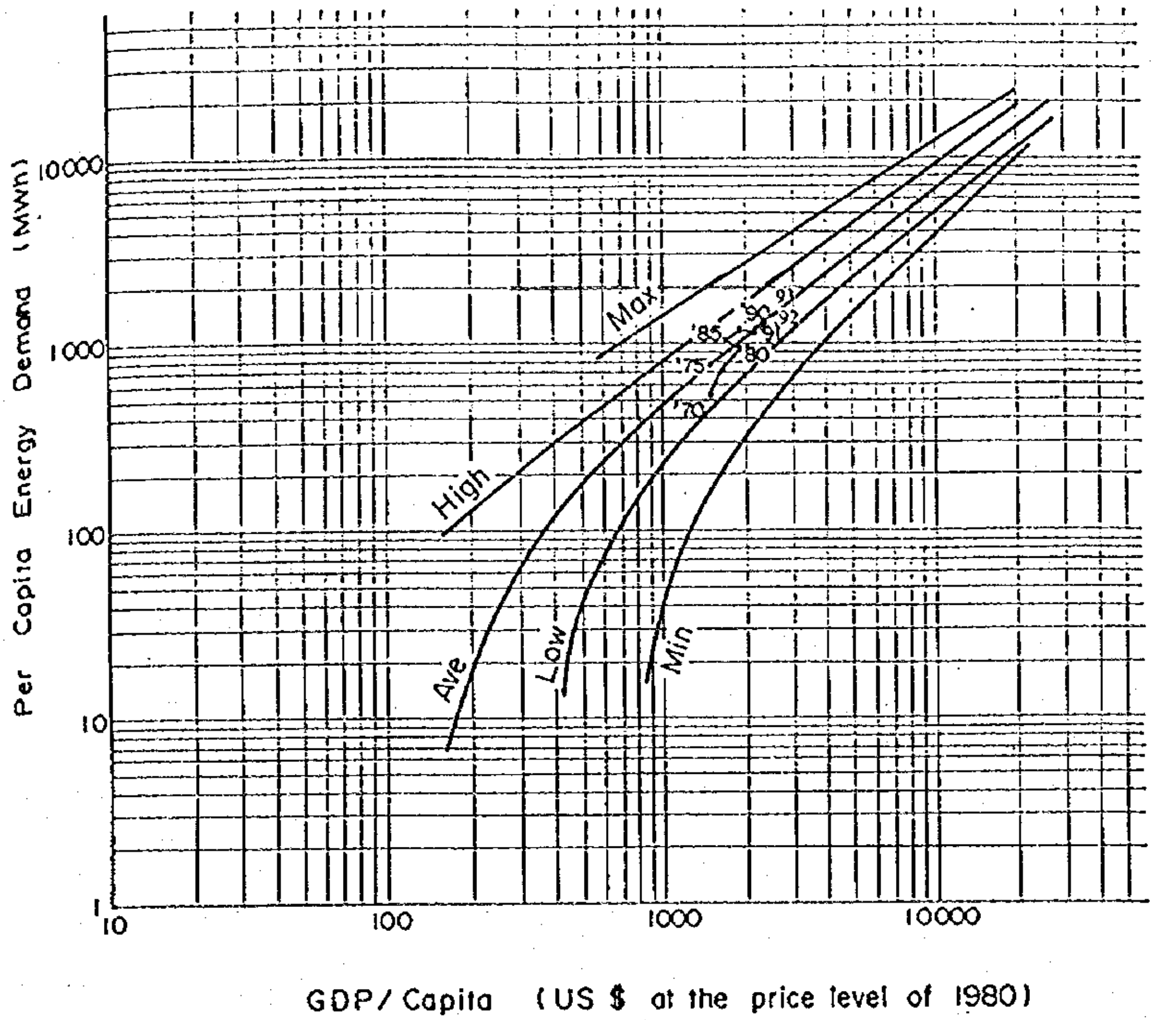

Fig. 5-1 Demand Pass Chart

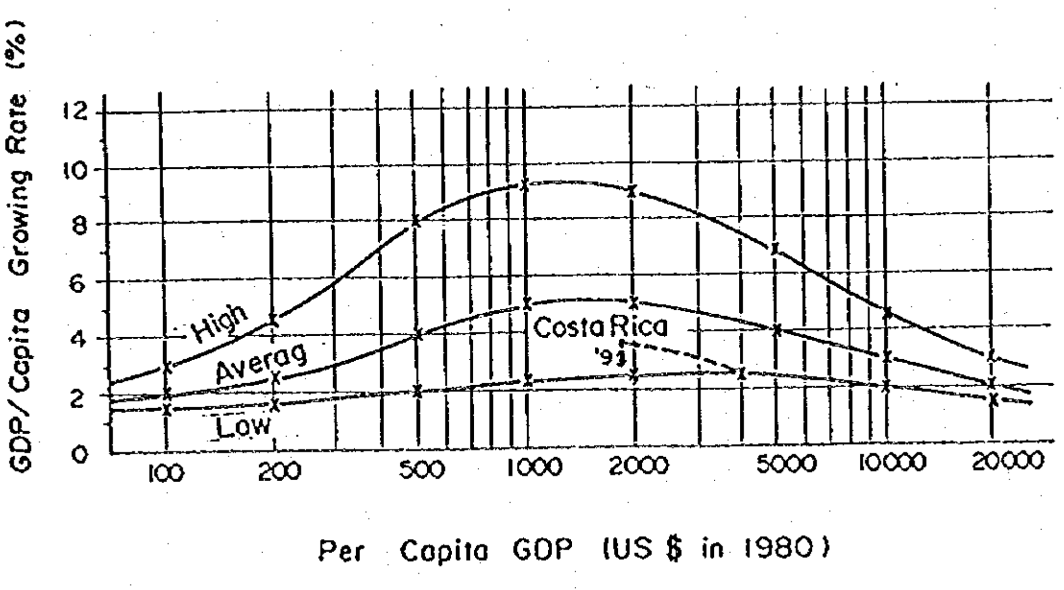

Fig. 5-2 GDP/Capita and its Growth Rate

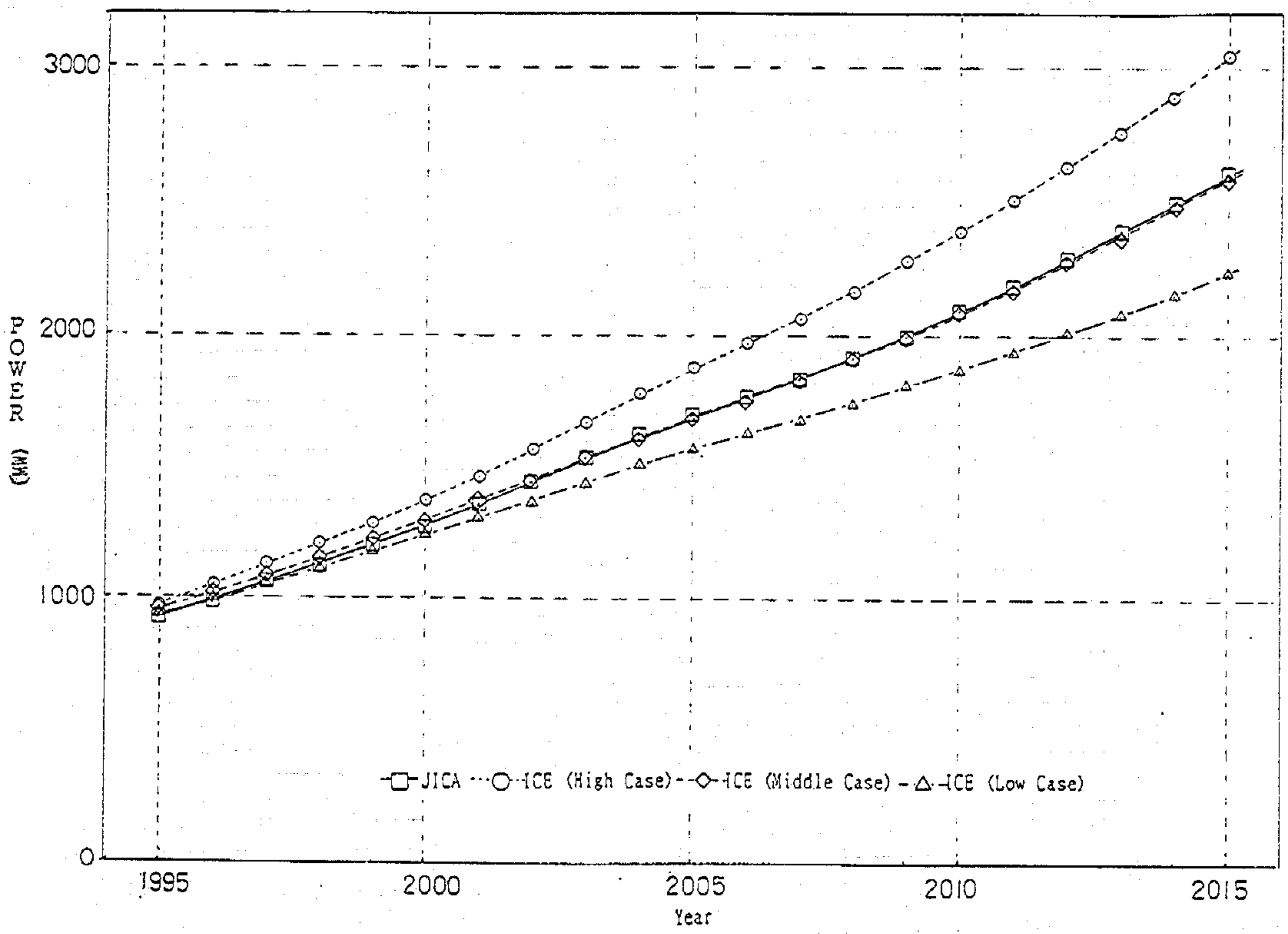

Fig. 5-3 Peak Power Forecast by ICE 1995 ~ 2015

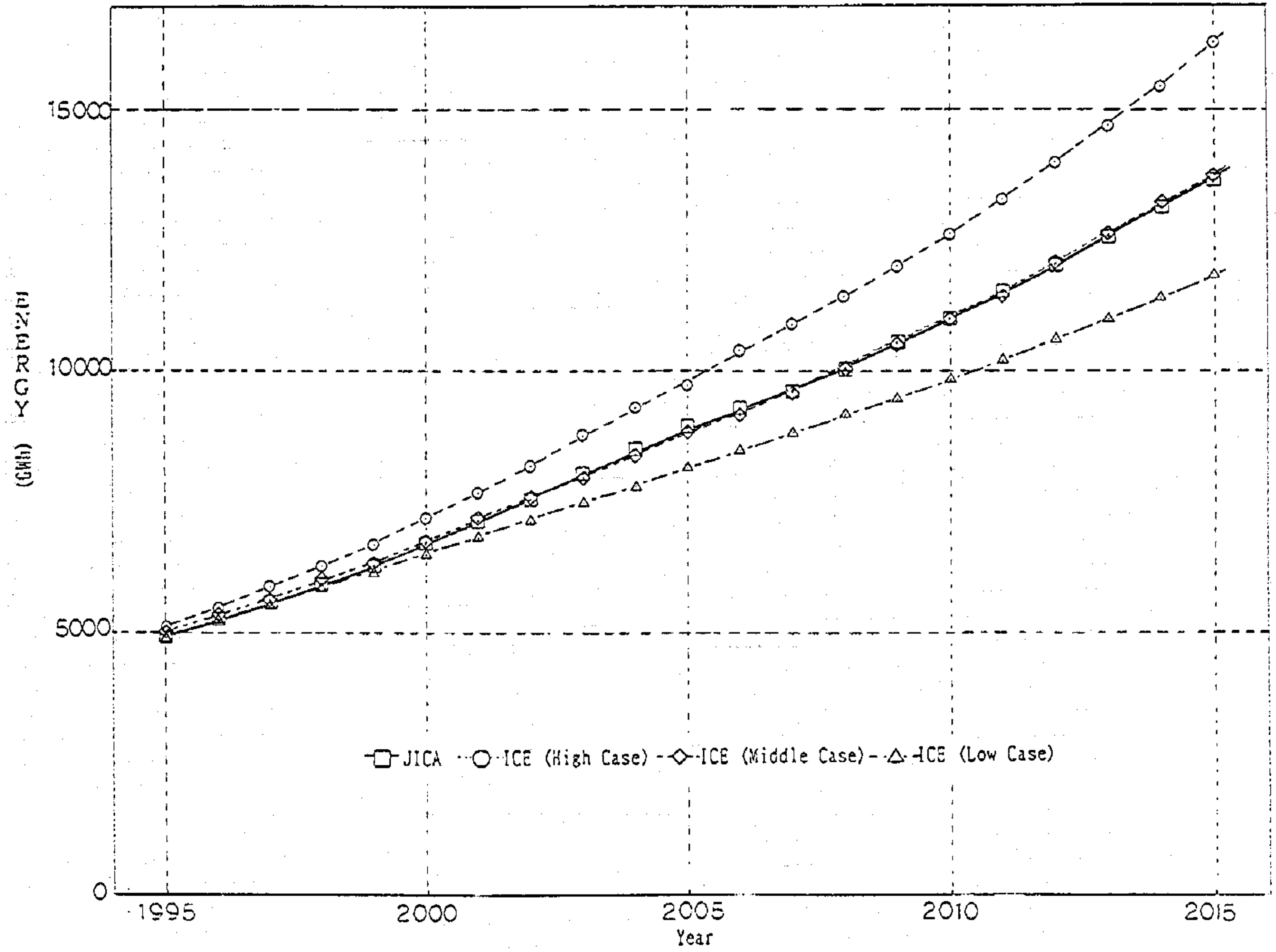

Fig. 5-4 Demand Forecast by ICE 1995 ~ 2015

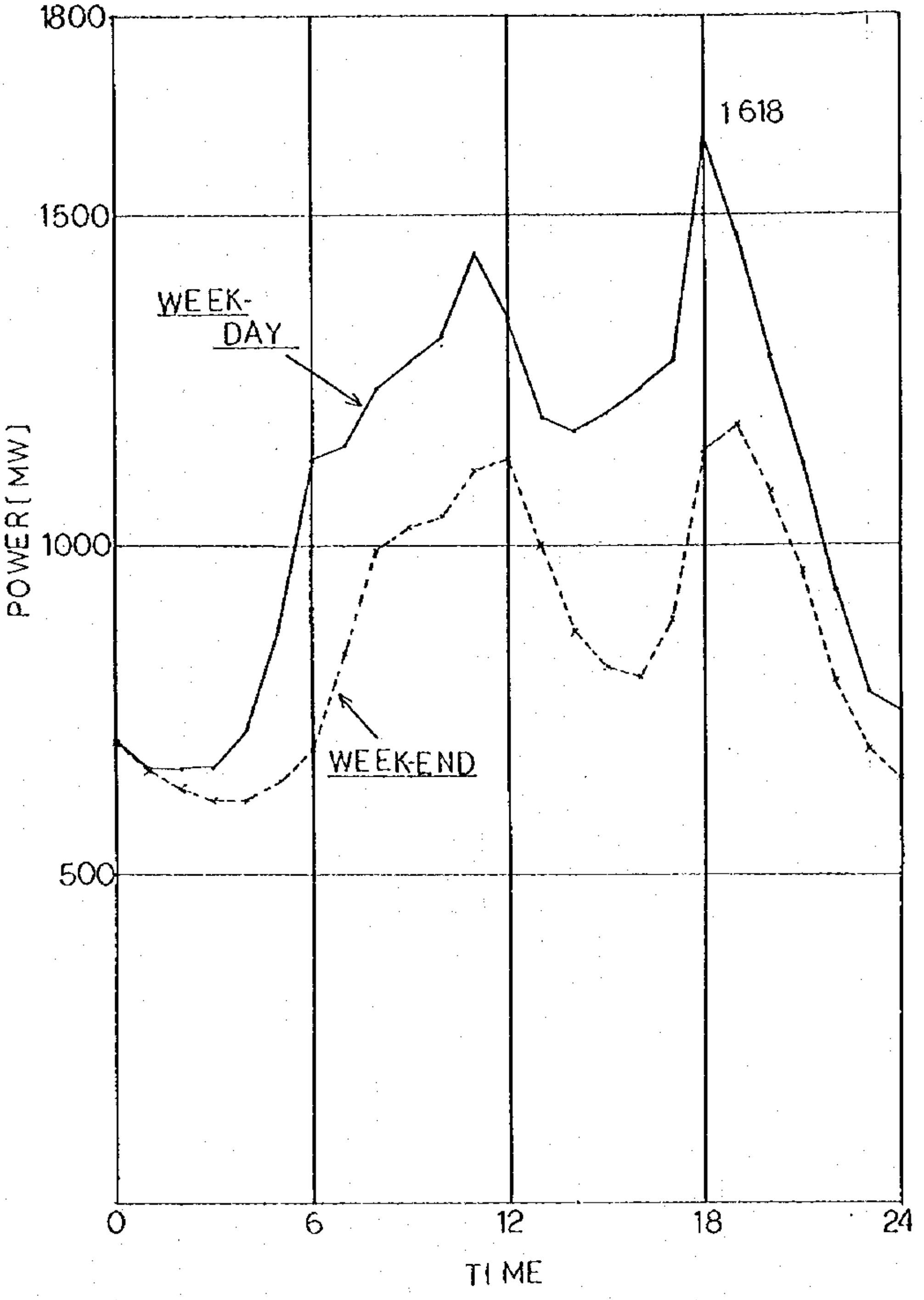

Fig. 5-5 Daily Load Curve (Peak day in 2004)

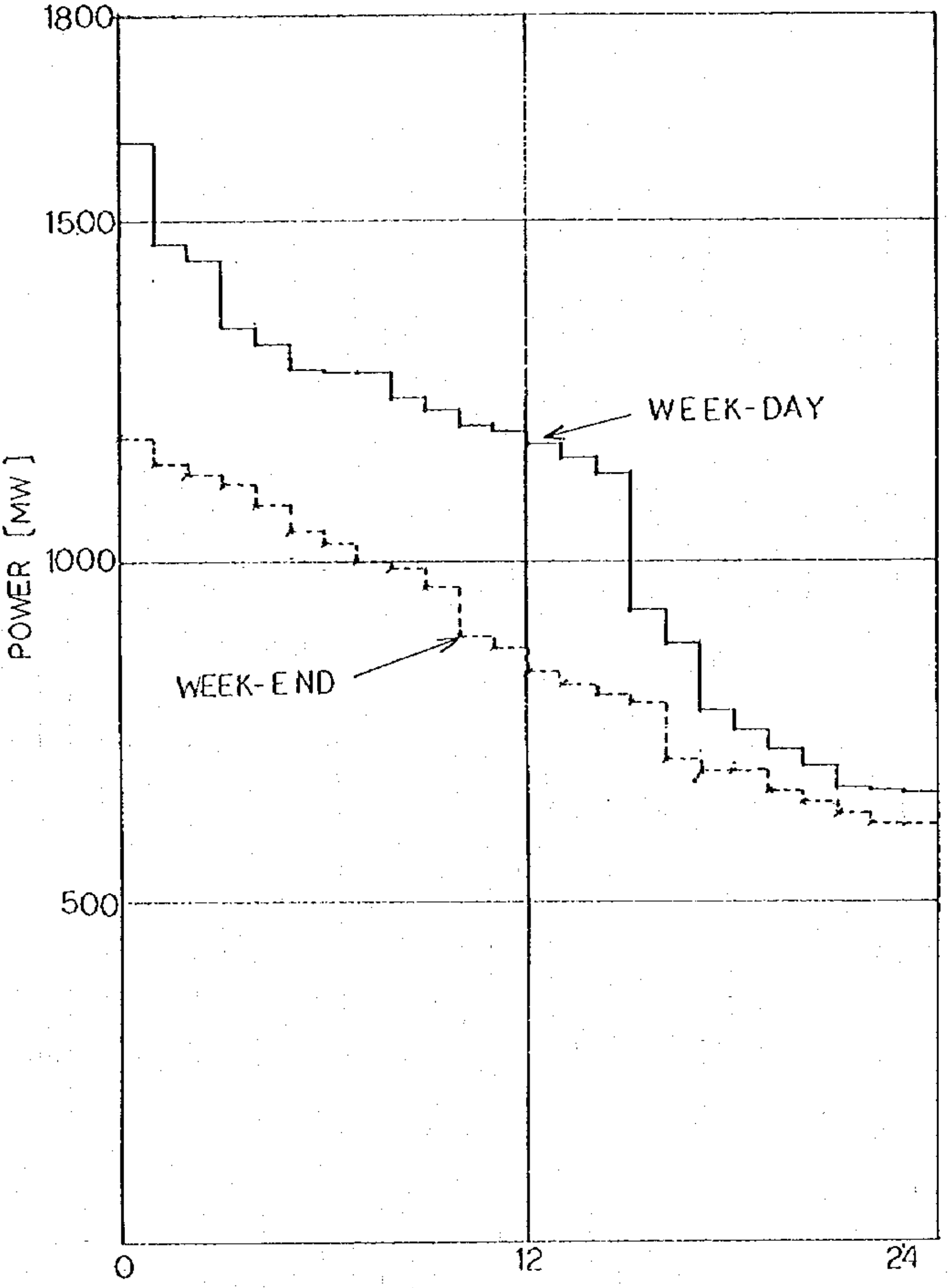

Fig. 5-6 Load Duration Curve (Peak day in 2004)

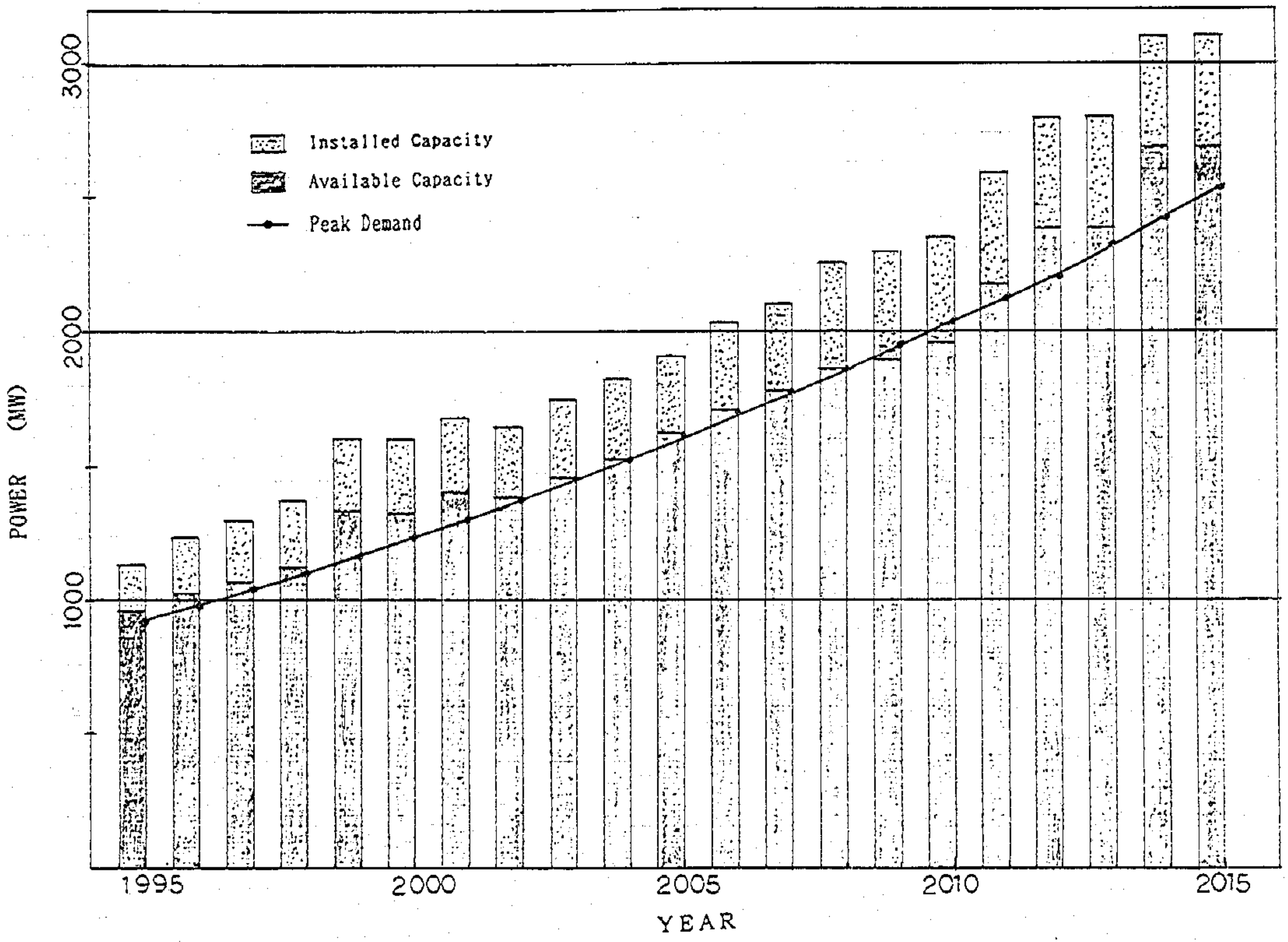

Fig. 5-7 Power (kW) Balance of Demand and Supply

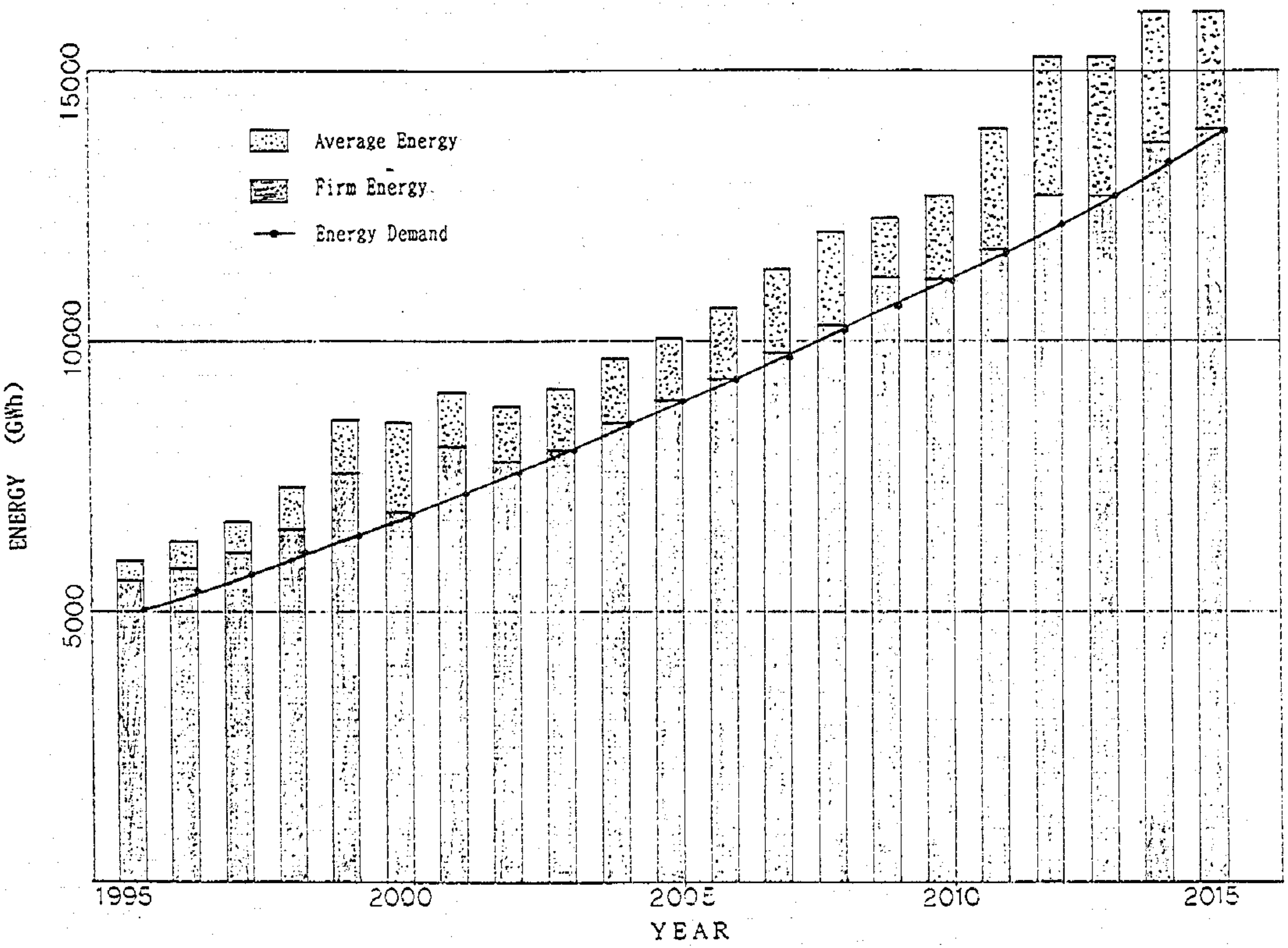

Fig. 5-8 Energy (kWh) Balance of Demand and Supply

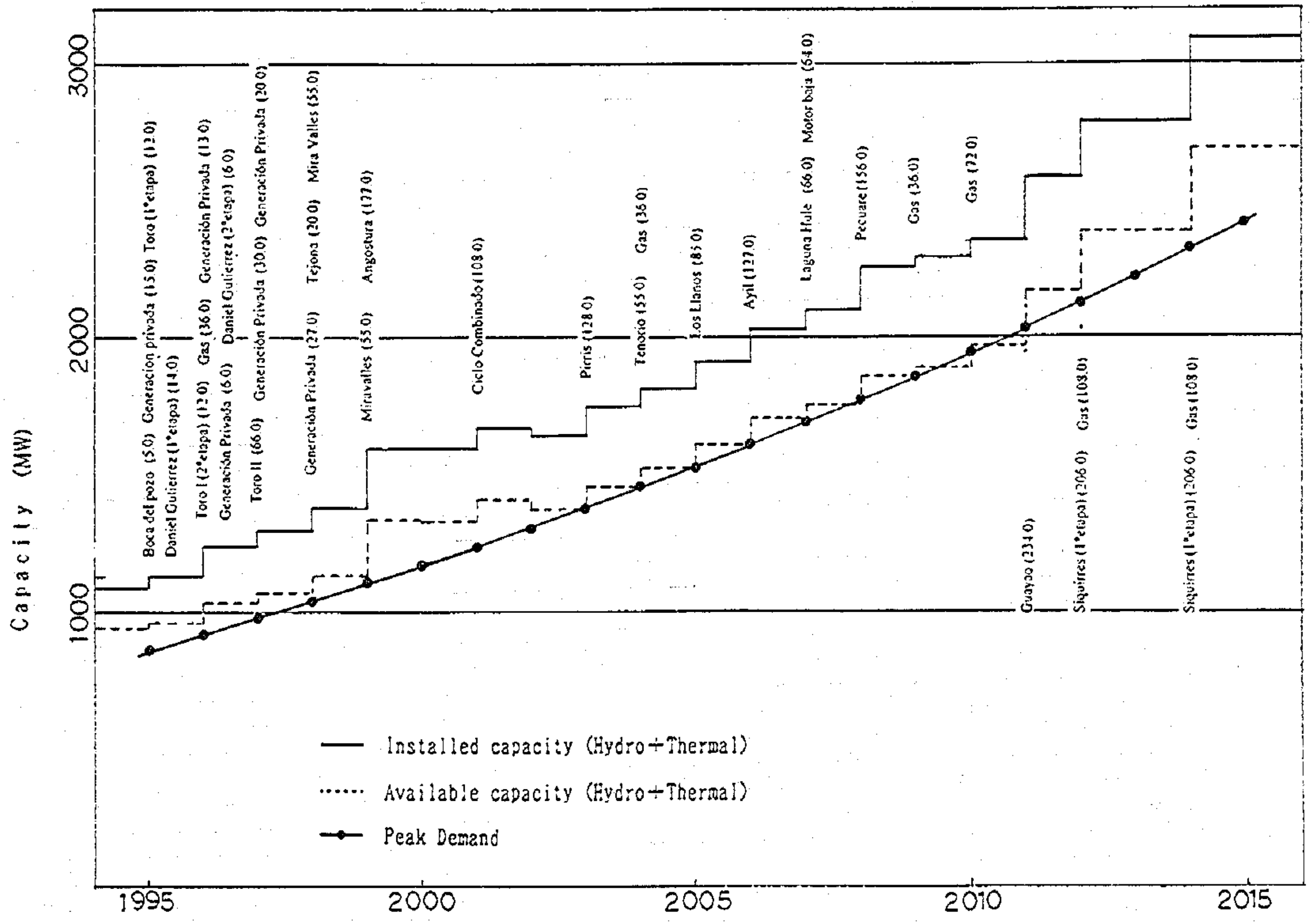

Fig. 5-9 Electric Power Development Schedule by Demand Supply Program

Table 5-1 Basic Data for Demand Forecast

(At the price levels and exchange rate of 1980)

Year	GDP US$		Energy (Generation)		Population		GDP/Capita		Energy/Capita	
	(Million)	Rate (%)	(GWh)	Rate (%)	(Thousand)	Rate (%)	(US$)	Rate (%)	(kWh)	Rate (%)
1980	4,482	0.81	2,144	12.25	2,296	3.02	1,952	-2.16	934	8.98
1981	4,380	-2.28	2,291	6.86	2,365	3.04	1,852	-5.12	969	3.75
1982	4,061	-7.28	2,292	0.04	2,437	3.04	1,666	-10.04	941	-2.89
1983	4,177	2.86	2,372	3.49	2,511	3.02	1,663	-0.12	945	0.43
1984	4,513	8.04	2,568	8.26	2,578	2.68	1,751	5.17	996	5.40
1985	4,545	0.71	2,708	5.45	2,646	2.61	1,718	-1.83	1,023	2.71
1986	4,796	5.53	2,968	9.60	2,713	2.53	1,768	2.91	1,094	6.94
1987	5,025	4.77	3,246	9.37	2,781	2.53	1,807	2.32	1,167	6.67
1988	5,198	3.44	3,324	2.40	2,851	2.53	1,823	2.71	1,166	-0.08
1989	5,492	5.66	3,493	5.08	2,941	3.13	1,867	0.00	1,188	1.89
1990	5,687	3.55	3,707	6.13	3,015	2.51	1,886	1.78	1,221	2.78
1991	5,816	2.27	3,827	3.24	3,086	2.35	1,885	2.96	1,240	1.56
1992	6,240	7.29	4,079	6.58	3,132	1.49	1,992	2.29	1,302	5.00
1993	6,615	6.01	4,382	7.43	3,199	2.14	2,068	2.84	1,370	5.22
1994	6,922	4.64	4,723	7.78	3,243	1.38	2,134	3.50	1,456	6.28

Table 5-2 Demand Forecast by ICE 1995 ~ 2015

Projecciones de Demanda de Energia Electrica 1995-2015, Mayo, 1995

Year	High Case			Base Case (Middle Case)			Low Case			Population	
	Energy (GWh)	Power (MW)	L.f (%)	Energy (GWh)	Power (MW)	L.f (%)	Energy (GWh)	Power (MW)	L.f (%)	(Thousand)	Rate (%)
1995	5,089	925	62.8	5,046	917	62.8	5,020	912	62.8	3,651	
1996	5,477	995	62.8	5,384	979	62.8	5,323	967	62.8	3,732	2.2
1997	5,883	1,069	62.8	5,729	1,041	62.8	5,627	1,024	62.7	3,829	2.6
1998	6,309	1,146	62.9	6,082	1,106	62.8	5,933	1,079	62.8	3,917	2.3
1999	6,707	1,216	63.0	6,439	1,171	62.8	6,239	1,135	62.8	4,005	2.2
2000	7,124	1,289	63.1	6,813	1,241	62.7	6,555	1,193	62.7	4,103	2.4
2001	7,561	1,368	63.1	7,201	1,311	62.7	6,890	1,254	62.7	4,202	2.4
2002	8,021	1,449	63.2	7,602	1,384	62.7	7,237	1,317	62.7	4,312	2.6
2003	8,497	1,532	63.3	8,017	1,459	62.7	7,600	1,382	62.8	4,412	2.3
2004	8,990	1,620	63.4	8,449	1,537	62.8	7,978	1,453	62.7	4,502	2.0
2005	9,504	1,712	63.4	8,885	1,618	62.7	8,359	1,522	62.7	4,558	1.2
2006	10,023	1,803	63.4	9,320	1,699	62.6	8,735	1,592	62.7	4,587	0.6
2007	10,556	1,898	63.5	9,764	1,778	62.7	9,117	1,660	62.7	4,614	0.6
2008	11,107	1,995	63.6	10,220	1,862	62.7	9,507	1,732	62.7	4,652	0.8
2009	11,670	2,093	63.6	10,681	1,947	62.6	9,898	1,804	62.6	4,723	1.5
2010	12,251	2,195	63.7	11,153	2,031	62.7	10,295	1,875	62.7	4,794	1.5
2011	12,862	2,302	63.8	11,647	2,122	62.7	10,710	1,951	62.7	4,866	1.5
2012	13,505	2,418	63.8	12,165	2,217	62.6	11,142	2,031	62.6	4,939	1.5
2013	14,182	2,536	63.8	12,705	2,316	62.6	11,591	2,110	62.7	5,013	1.5
2014	14,895	2,660	63.9	13,272	2,417	62.7	12,060	2,197	62.7	5,088	1.5
2015	15,647	2,795	63.9	13,866	2,526	62.7	12,550	2,287	62.6	5,165	1.5

Table 5-3 Demand Forecast by Macroscopic Method

(At the price levels and exchange rate of 1980)

Year	GDP/Capita		Energy/Capita		Population		GDP (USA)		Energy Demand		Power
	(US$)	Rate (%)	(KWh)	Rate (%)	(Thousand)	Rate (%)	(Million)	Rate (%)	(GWh)	Rate (%)	(MW)
1995	2,206	3.47	1,486	4.13	3,304	1.88	7,289	5.42	4,910	6.09	934
1996	2,282	3.44	1,547	4.10	3,378	2.22	7,709	5.76	5,226	6.43	994
1997	2,360	3.41	1,610	4.07	3,466	2.60	8,180	6.11	5,580	6.77	1,062
1998	2,439	3.38	1,673	3.91	3,545	2.29	8,646	5.70	5,931	6.29	1,128
1999	2,521	3.34	1,738	3.88	3,624	2.24	9,136	5.67	6,298	6.19	1,198
2000	2,604	3.30	1,804	3.80	3,713	2.45	9,669	5.83	6,698	6.35	1,274
2001	2,689	3.26	1,872	3.77	3,803	2.41	10,226	5.76	7,119	6.29	1,354
2002	2,776	3.22	1,942	3.74	3,902	2.61	10,832	5.93	7,578	6.45	1,442
2003	2,864	3.18	2,012	3.60	3,993	2.33	11,436	5.58	8,034	6.02	1,529
2004	2,954	3.14	2,083	3.53	4,075	2.05	12,038	5.26	8,488	5.65	1,615
2005	3,045	3.09	2,156	3.50	4,125	1.24	12,561	4.34	8,894	4.78	1,692
2006	3,138	3.04	2,230	3.43	4,151	0.63	13,026	3.70	9,257	4.08	1,761
2007	3,232	2.99	2,304	3.32	4,176	0.60	13,497	3.61	9,621	3.93	1,830
2008	3,327	2.94	2,379	3.26	4,210	0.81	14,007	3.78	10,016	4.11	1,906
2009	3,423	2.89	2,455	3.19	4,274	1.53	14,630	4.45	10,493	4.76	1,996
2010	3,520	2.84	2,532	3.14	4,339	1.50	15,273	4.40	10,986	4.70	2,090
2011	3,618	2.79	2,609	3.04	4,404	1.50	15,934	4.33	11,490	4.59	2,186
2012	3,717	2.74	2,687	2.99	4,470	1.50	16,615	4.27	12,011	4.53	2,285
2013	3,817	2.69	2,766	2.94	4,537	1.50	17,318	4.23	12,549	4.48	2,387
2014	3,918	2.63	2,845	2.86	4,605	1.50	18,042	4.18	13,101	4.40	2,493
2015	4,019	2.58	2,924	2.78	4,674	1.50	18,785	4.12	13,667	4.32	2,600

Table 5-4 Construction Schedule by ICE 1995 ~ 2015

Escenario de Demanda : Base (Abril 1995)
Escenario de Combustibles : Caso Base

Año	Energía (GWh)	Crecim. (%)	Pot. (MW)	Crecim. (%)	Proyectos de generación	Año	Mes
1994	4,723		858			1994	
1995	5,046	6.8	917	6.9	P.G. Boca del Pozo (5 MW)	1995	1
					P.H. Generación Privada (15 MW)		7
					P.H. Toro I (1° etapa, 12 MW)		9
					P.H. Daniel Gutiérrez (1° etapa, 14 MW)		11
1996	5,384	6.7	979	6.8	P.H. Toro I (2° etapa, 12 MW)	1996	1
					P.T. Gas (1 x 36 MW)		1
					P.H. Generación Privada (13 MW)		1
					P.H. Generación Privada (6 MW)		6
					P.H. Daniel Gutiérrez (2° etapa, 6 MW)		6
1997	5,729	6.4	1,041	6.3	P.H. Toro II (66 MW)	1997	1
					P.H. Generación Privada (30 MW)		1
					P.H. Generación Privada (20 MW)		1
1998	6,082	6.2	1,106	6.2	P.H. Generación Privada (27 MW)	1998	1
					P.E. Tejona (1 x 20 MW)		3
					P.G. Miravalles II (55 MW)		4
1999	6,439	5.9	1,171	5.9	P.G. Miravalles III (1 x 55 MW)	1999	1
					P.H. Angostura (177 MW)		6
2000	6,183	5.8	1,241	6.0	----------	2000	
2001	7,201	5.7	1,311	5.6	P.T. Ciclo Combinado (1 x 108 MW)	2001	1
2002	7,602	5.6	1,384	5.6	----------	2002	
2003	8,017	5.5	1,459	5.4	P.H. Pirrís (128 MW)	2003	1
2004	8,449	5.4	1,537	5.3	P.G. Tenorio (1 x 55 MW)	2004	1
					P.T. Gas (1 x 36 MW)		1
2005	8,885	5.2	1,618	5.3	P.H. Los Llanos (84 MW)	2005	1
2006	9,320	4.9	1,699	5.0	P.H. Ayil (127 MW)	2006	1
2007	6,764	4.8	1,778	4.6	P.H. Laguna Hule (66 MW)	2007	1
2008	10,220	4.7	1,862	4.7	P.H. Pacuare (156 MW)	2008	1
2009	10,681	4.5	1,947	4.6	P.T. Gas (1 x 36 MW)	2009	1
2010	11,153	4.4	2,031	4.3	P.T. Gas (2 x 36 MW)	2010	1
2011	11,647	4.4	2,122	4.5	P.H. Guayabo (234 MW)	2011	1
2012	12,165	4.6	2,217	4.5	P.H. Siquirres (1° etapa, 206 MW)	2012	1
2013	12,705	4.4	2,316	5.5	----------	2013	
2014	13,272	4.5	2,417	4.4	P.H. Siquirres (2° etapa, 206 MW)	2014	1
					P.T. Gas (3 x 36 MW)		1
2015	13,866	4.5	2,526	4.5	----------	2015	

- Período :	1995-2015
- Valor presente del plan de expansión : (Milliones de dólares)	1,447.32
- Costo marginal de largo plazo ($/MWh) :	58.59
- Nivel de precios :	Diciembre 1994
- Año base :	1994
- Actualización a :	Diciembre 1994
- Fecha :	Agosto 1995

Table 5-5 Decommissioning Plan by ICE

Year	Name of Power Station	TYPE	Unit No.	Capacity (MW)		Generation Energy	
				Installed	Dependable Available	Average	Firm
1995							
1996							
1997							
1998	Colima	DG	2	2.97	2	20.8	20.8
	Colima	DG	5	3.83	3	26.8	26.8
1999	Colima	DG	4	2.97	2	20.8	20.8
	Colima	DG	6	3.83	3	26.8	26.8
2000	Colima	DG	1	2.97	2	20.8	20.8
	Colima	DG	3	2.97	2	20.8	20.8
2001	Moin P	P	2	8	6.5	56	56
	Moin P	P	3	8	6.5	56	56
	San Ant. G	G	4	19	15	49.9	49.9
2002	Moin P	P	1	8	6.5	56	56
	San Ant	V	1	5	5	35	35
	San Ant	V	2	5	5	35	35
	Barranca	G	1	20.8	15	54.6	54.6
2003	Moin	P	4	8	6.5	56	56
	San Ant	G	3	19	15	49.9	49.9
2004	Barranca	G	2	20.8	15	54.6	54.6

Table 5-6 Power (KW) Balance of Demand and Supply

Year	(1) Peak Demand (MW)	(2) Hydro Installed Capacity (MW)	(3) Hydro Dependable Peak Capacity (MW)	(4) Thermal Available Capacity (MW)	(5) Maximum Thermal Unit Capacity (MW)	(6) Total Installed Capacity (2)+(4) (MW)	(7) Total Installed Capacity (2)+(4)-(5) (MW)	(8) {(6)-(1)} /(1)x100 (%)	(9) {(7)-(1)} /(1)x100 (%)
1995	917	922.3	744.1	267.5	52.3	1,137.5	959.3	24.1	4.6
1996	979	990.3	783.1	300.5	52.3	1,238.5	1,031.3	26.5	5.3
1997	1,041	1,053.3	821.1	300.5	52.3	1,301.5	1,069.3	25.1	2.7
1998	1,106	1,080.3	835.1	347.9	52.3	1,375.8	1,130.6	24.4	2.2
1999	1,171	1,257.3	994.1	395.1	52.3	1,599.4	1,336.2	36.6	14.1
2000	1,241	1,257.3	994.1	391.1	52.3	1,595.4	1,332.2	28.6	7.3
2001	1,311	1,257.3	994.1	471.1	52.3	1,675.4	1,412.2	27.8	7.7
2002	1,384	1,257.3	994.1	439.6	52.3	1,643.9	1,380.7	18.8	-0.2
2003	1,459	1,385.3	1,096.1	418.1	52.3	1,750.4	1,461.2	19.9	0.1
2004	1,537	1,385.3	1,096.1	488.4	52.3	1,820.7	1,531.5	18.5	-0.3
2005	1,618	1,470.3	1,174.8	488.4	52.3	1,905.7	1,610.2	17.8	-0.4
2006	1,699	1,597.3	1,276.8	488.4	52.3	2,032.7	1,712.2	19.6	0.8
2007	1,778	1,663.3	1,322.8	552.4	52.3	2,098.7	1,758.2	18.0	-1.1
2008	1,862	1,819.3	1,422.8	552.4	52.3	2,254.7	1,858.2	21.1	-0.2
2009	1,947	1,819.3	1,422.8	585.4	52.3	2,287.7	1,891.2	17.5	-2.8
2010	2,031	1,819.3	1,422.8	651.4	52.3	2,353.7	1,957.2	15.9	-3.6
2011	2,122	2,053.3	1,638.8	651.4	52.3	2,587.7	2,173.7	21.9	2.4
2012	2,217	2,259.3	1,844.8	651.4	52.3	2,793.7	2,379.2	26.0	7.3
2013	2,316	2,259.3	1,844.8	651.4	52.3	2,793.7	2,379.2	20.6	2.7
2014	2,417	2,465.3	2,050.8	750.4	52.3	3,098.7	2,684.2	28.2	11.1
2015	2,526	2,465.3	2,050.8	750.4	52.3	3,098.7	2,684.2	22.7	6.3

Table 5-7 Energy (kWh) Balance of Demand and Supply

Year	(1) Energy Demand (GWh)	(2) Hydro Average (GWh)	(3) Hydro Firm (GWh)	(4) Thermal Available (GWh)	(5) Gas Special Operation (GWh)	(6) Import (GWh)	(7) Average (2)+(4)-(5) (GWh)	(8) Firm Total (3)+(4)+(5) +(6) (GWh)	(9) {(7)-(1)} /(1)x100 (%)	(10) {(8)-(1)} /(1)x100 (%)
1995	5,046	3,874	3,537	1,400.3	657	-	5,931.3	5,594.4	17.7	10.9
1996	5,384	4,150	3,631	1,494.9	657	-	6,301.9	5,782.9	17.1	7.4
1997	5,729	4,447	3,836	1,582.5	657	-	6,685.5	6,075.5	16.7	6.1
1998	6,082	4,600	3,846	2,056.1	657	-	7,313.1	6,559.1	20.0	7.8
1999	6,439	5,464	4,474	2,442.1	657	-	8,563.1	7,573.1	33.0	17.6
2000	6,813	5,464	4,474	2,400.5	657	-	8,521.5	6,874.5	25.1	0.9
2001	7,201	5,464	4,474	2,995.4	590.5	-	9,049.9	8,059.9	25.7	11.9
2002	7,602	5,464	4,474	2,814.8	517.7	-	8,796.5	7,806.5	15.7	2.7
2003	8,017	5,992	4,799	2,708.9	451.2	60	9,152.1	8,019.1	14.2	0
2004	8,449	5,992	4,799	2,182.5	504.5	-	9,679.0	8,486.0	14.6	0.4
2005	8,885	6,363	5,081	3,182.5	504.5	125	10,050.0	8,893.0	13.1	0.1
2006	9,320	6,930	5,494	3,182.5	504.5	150	10,617.0	9,331.0	13.9	0.1
2007	9,764	7,201	5,666	3,631.0	504.5	-	11,336.5	9,801.5	16.1	0.3
2008	10,220	7,941	6,145	3,631.0	504.5	-	12,076.5	10,280.5	18.2	0.6
2009	10,681	7,941	6,145	3,725.6	630.6	185	12,297.2	10,686.2	15.1	0.1
2010	11,153	7,941	6,145	3,914.8	882.8	215	12,738.6	11,157.6	14.2	0.4
2011	11,647	9,102	6,950	3,914.8	882.8	-	13,899.6	11,747.6	19.3	0.9
2012	12,165	10,442	7,926	3,914.8	882.8	-	15,213.6	12,723.6	25.3	4.6
2013	12,705	10,442	7,926	3,914.8	882.8	-	15,239.6	12,723.6	19.9	0.2
2014	13,272	10,662	8,198	4,198.6	1,261.2	-	16,121.8	13,657.8	21.5	2.9
2015	13,866	10,662	8,198	4,198.6	1,261.2	215	16,121.8	13,872.8	16.3	0.1

Table 5-8 Electric Power Development Schedule

Year	Plant Name					
	LOGOS		(MW)	by Demand Supply Program		(MW)
1995	Boca del pozo	P.G.	(5.0)	Boca del Pozo	P.G.	(5.0)
	Generación privada	P.H.	(15.0)	Generación privada	P.H.	(15.0)
	Toro (1°etapa)	P.H.	(12.0)	Toro (1°etapa)	P.H.	(12.0)
	Daniel Gutierrez (1°etapa)	P.H.	(14.0)	Daniel Gutierrez (1°etapa)	P.H.	(14.0)
1996	Toro I (2°etapa)	P.H.	(12.0)	Toro I (2°etapa)	P.H.	(12.0)
	Gas	P.T.	(36.0)	Gas	P.T.	(36.0)
	Generación Privada	P.H.	(13.0)	Generación Privada	P.H.	(13.0)
	Generación Privada	P.H.	(6.0)	Generación Privada	P.H.	(6.0)
	Daniel Gutierrez (2°etapa)	P.H.	(6.0)	Daniel Gutierrez (2°etapa)	P.H.	(6.0)
1997	Toro II	P.H.	(66.0)	Toro II	P.H.	(66.0)
	Generación Privada	P.H.	(30.0)	Generación Privada	P.H.	(30.0)
	Generación Privada	P.E.	(20.0)	Generación Privada	P.E.	(20.0)
1998	Generación Privada	P.H.	(27.0)	Generación Privada	P.H.	(27.0)
	Tejona	P.E.	(20.0)	Tejona	P.E.	(20.0)
	Miravalles	P.G.	(55.0)	Miravalles	P.G.	(55.0)
1999	Miravalles	P.G.	(55.0)	Miravalles	P.G.	(55.0)
	Angostura	P.H.	(177.0)	Angostura	P.H.	(177.0)
2000						
2001	Ciclo Combinado	P.T.	(108.0)	Ciclo Combinado	P.T.	(108.0)
2002						
2003	Pirrís	P.T.	(128.0)	Pirrís	P.H.	(128.0)
2004	Tenorio	P.G.	(55.0)	Tenorio	P.G.	(55.0)
	Gas	P.T.	(36.0)	Gas	P.T.	(36.0)
2005	Los Llanos	P.H.	(85.0)	Los Llanos	P.H.	(85.0)
2006	Ayil	P.H.	(127.0)	Ayil	P.H.	(127.0)
2007	Laguna Hule	P.H.	(66.0)	Laguna Hule	P.H.	(66.0)
				Motor baja	P.T.	(64.0)
2008	Pacuare	P.H.	(156.0)	Pacuare	P.H.	(156.0)
2009	Gas	P.T.	(36.9)	Gas	P.T.	(36.9)
2010	Gas	P.T.	(72.0)	Gas	P.T.	(72.0)
2011	Guayabo	P.H.	(234.0)	Guayabo	P.H.	(234.0)
2012	Siquirres (1°etapa)	P.H.	(206.0)	Siquirres (1°etapa)	P.H.	(206.0)
	Gas	P.H.	(108.0)	Gas	P.H.	(108.0)
2013						
2014	Siquirres (2°etapa)	P.H.	(206.0)	Siquirres (2°etapa)	P.H.	(206.0)
	Gas	P.T.	(108.0)	Gas	P.T.	(108.0)
2015						

Chapter 6 Meteorology and Hydrology

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CHAPTER 6 METEOROLOGY AND HYDROLOGY

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CHAPTER 6 METEOROLOGY AND HYDROLOGY

6.1 Outline of Meteorology and Hydrology

6.1.1 General Remarks

The precipitation in Costa Rica is greatest along the Caribbean Sea and southern Pacific coast, and lowest in the central plateau and along the northern Pacific coast.

The project dam site is on the upper section of the Naranjo River, which runs along the southern part of Costa Rica to the Pacific Ocean.

The Naranjo River is situated between 83 degrees 55 minutes and 84 degrees 10 minutes east longitude, and between 9 degrees 20 minutes and 9 degrees 40 minutes north latitude. The basin of the river covers an area of 332 km^2. The major tributaries are the Naranjillo River and the Burujo River.
The project dam site is at the junction of a former tributary with the main river. The average inflow at the mouth of the river is approximately 35 to 40 m^3/s.

The power house site on the upper section of the Paquita River, bordering on the northwest side of the Naranjo River. The Paquita River is located between 84 degrees 4 minutes and 84 degrees 11 minutes east longitude, and between 9 degrees 26 minutes and 9 degrees 37 minutes north latitude. The basin of the river covers an area of 179 km^2. Average inflow at the mouth of the river is approximately 20-25 m^3/s .

Both rivers are situated in an area with two seasons--a dry season between December and March, and a rainy season between April and November. Precipitation in February (the month with the least precipitation throughout a year) is approximately 30-120 mm. In October, the peak of the rainy season, it reaches 600-1,000 mm. Precipitation in the basin of the Naranjo River averages approximately 5,500 mm/year, one of the highest in the world.

Temperatures fluctuate little throughout the year. The daily average temperature in the flatlands is 25-27 C°. The change of temperatures in the course of a day is approximately 10-12 C°. Located in a high-rain area, the relative humidity reaches an average of 70% during the dry season, and 80 to 90% during the rainy season.

6.1.2 Meteorology and Runoff Data

Figure 6-1 shows the meteorological gauging stations and runoff gauging stations located within or near the basin of the Los Llanos Project. In addition, Tables 6-1 and 6-2 show the observation record-keeping periods at the main observation stations. The following are the main meteorological gauging stations and runoff gauging stations:

* Londres Runoff Gauging Station:
At the middle section of the Naranjo River
C.A = 210.2 km^2

* Los Llanos Runoff Gauging Station:
At the upper section of the Naranjo River
(planned dam site)
C.A = 147.0 km^2

* Playon Meteorological Gauging Station:
Approximately 25 km west of the border of the project basin
(multiple kinds of data have been collected for a long period)

* Naranjillo Runoff gauging station:
Near the Project dam site
(only a short period has been spent collecting data related to dew points)

* Providencia Meteorological gauging station:
Approximately 7 km east of the border of the project catchment area
(only a short period has been spent on collecting data related to dew points)

6.1.3 Meteorology and Hydrology of the Project Basin

Figure 6-2 shows the annual average isohyetal map of the project basin.

The figures indicate a peak of 8,000 mm annual precipitation at the junction point with the Burujo River (located approximately 5 km downstream from the project dam site), and decreases upstream and downstream from that peak.

The catchment area at the dam is approximately 147 km^2, and annual average precipitation reaches 6,200 mm.

Figure 6-3 shows precipitation over the course of a year according to observations at Naranjillo Observation Station. There is a considerable difference between the dry and rainy seasons: the monthly average from December through March (the dry season) is 100-200 mm, while in September and October (the rainy season), it is 900-1,000 mm. The difference is caused by trade winds, which blow in from the Pacific Ocean during the rainy season and hit the mountainsides of the area (orographic regions). However, torrential rain and flood in the area are caused when hurricanes come in from the Atlantic Ocean (nonorographic regions).

6.2 Low-Water Analysis of the Project Site

6.2.1 Inflow at the Project Dam Site

(1) Inflow Data

In order to determine the inflow for the Los Llanos Project, daily inflow data have been accumulated since February 1993. However, since the observation period has been relatively short, the inflow for the Los Llanos Project will be determined by correlating additional data accumulated at Londres Runoff gauging station, located approximately 15 km downstream from the project dam site.

The following is a summary of the inflow data collected at Londres Runoff gauging station:

Annual average inflow: 28 m^3/s
Maximum monthly average inflow (average for October over a 23-year period): 56 m^3/s
Minimum monthly average inflow (average for March over a 23-year period): 5.7 m^3/s

Table 6-3 shows the monthly average inflow, and Figure 6-4 shows the average discharge-duration curve. The daily inflow is shown in Appendix 1.

(2) Correlation to Londres Runoff Gauging Station

Correlation of a total of 495 days of inflow data (gathered February 1993 through July 1994) between Los Llanos Runoff gauging station and Londres Runoff gauging station was examined.

The following were confirmed from the examination:

1) The correlation coefficient of the daily inflow between the two was a high value of 0.95.

2) The specific discharge of inflow at Los Llanos from May through November (the rainy season) was smaller than at Londres--namely, 70 to 80% of the amount at Londres. This was due to the precipitation distribution indicated in the previously cited Figure 6-2.

3) The specific discharge of inflow at Los Llanos from December through April (the dry season) was in proportion to the catchment area compared with at Londres--namely, 85-110% of the amount at Londres. This was presumably due to a greater ground-water run-off rate at Los Llanos.

Figure 6-5 is a graph of the correlation coefficient, and Figure 6-6 is a hydrograph (using actual measurements and calculated values) at Los Llanos.

(3) Inflow at the Planned Site of Los Llanos Dam

The inflow for a 23-year period (May 1971 through April 1994) was calculated according to an equation obtained from the data cited above. Measured values from February 1993 forward were also used.

The following is a conversion formula obtained by correlative analysis:

$$Qd = 1.041\ QL^{0.814} \qquad (m^3/s)$$

Qd: Inflow at the dam (Los Llanos Runoff gauging station) (m^3/s)
QL: Record at Londres Runoff gauging station) (m^3/s)

The following is a summary of the results:

Annual average inflow:	15 m^3/s
Maximum monthly average inflow (average of October over 23-year period):	27 m^3/s
Minimum monthly average inflow (average of March over 23-year period):	4.3 m^3/s
95% firm discharge:	3.91 m^3/s

Table 6-4 shows the monthly average inflow, and Figure 6-7 shows the average discharge-duration curve. The daily inflow is shown in Appendix 2.

6.2.2 Inflow Calculation at Other Sites

In this study, it is necessary to obtain inflow data at several locations apart from the planned dam site, mainly for the use in evaluating environmental impact.

Calculation has been done based on the data collected at Londres Runoff gauging station, and according to the area rate, considering the precipitation distribution indicated in Figure 6-2. The following are the equations used for the specific locations:

(1) Lower Naranjo River Irrigation-Water Intake Site

Located approximately 9 km downstream from Londres Runoff gauging station, it is an intake point for irrigation water for palm-tree farms situated on the plateau downstream on the right bank. The amount of inflow at the main river before the intake was used for the calculation.

$$Qnt = QL \times PNT \div PL \times C.ANT \div C.AL \qquad (m^3/s)$$

Qnt : Inflow at the intake point
PNT : Annual average precipitation at the intake point (6,167 mm)
C.ANT : Catchment area at the intake point (230 km^2)
QL : Inflow at Londres Runoff gauging station
PL : Annual average precipitation at Londres Runoff gauging station (6,577 mm)
C.AL : Catchment area at Londres Runoff gauging station (210.2 km^2)

The amount of inflow at this location after completion of the dam was calculated according to the following equation:

$$Qnt' = Qnt - Qnd \quad (m^3/s)$$

Qnd: Amount of diverted water from Los Llanos Power Station to the Paquita River

The following are the results of the calculations:

	Before Completion	After Completion
Annual average inflow:	28 m^3/s	14 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	58 m^3/s	32 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	5.8 m^3/s	1.6 m^3/s

Tables 6-5 and 6-6 show the monthly average inflow before and after completion of the dam.

(2) Naranjo River Estuary Site

$$Qnrm = QL \times PNm \div PL \times C.ANm \div C.AL \quad (m^3/s)$$

Qnrm	:	Inflow at the estuary
PNm	:	Annual average precipitation at the estuary (5,543 mm)
C.ANm	:	Catchment area at the estuary (332 km^2)
QL	:	Inflow at Londres Runoff gauging station
P L	:	Annual average precipitation at Londres Runoff gauging station (6,577mm)
C.AL	:	Catchment area at Londres Runoff gauging station (210.2 km^2)

The amount of inflow at this location after completion of the dam was calculated according to the following equation:

$$Qnrm' = Qnrm - Qud \quad (m^3/s)$$

Qud: Amount of water diverted from Los LlanosPower Station to the Paquita River

The following are the results of the calculations:

	Before Completion	After Completion
Annual average inflow:	37 m^3/s	22 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	75 m^3/s	49 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	7.6 m^3/s	3.3 m^3/s

Tables 6-7 and 6-8 show the monthly average inflow before and after completion of the dam.

(3) Paquita River Power Station Site

$$Qpp = QL \times Ppp \div PL \times C.App \div C.AL \qquad (m^3/s)$$

Qpp : Inflow at the power station
Ppp : Annual average precipitation at the power station (7,577 mm)
C.App : Catchment area at the power station (24.5 km^2)
QL : Inflow at Londres Runoff gauging station
PL : Annual average precipitation at Londres Runoff gauging station (6,577 mm)
C.AL : Catchment area at Londres Runoff gauging station(210.2 km^2)

The amount of inflow at this location after completion of the dam was calculated according to the following equation:

$$Qpp' = Qpp - Qud \qquad (m^3/s)$$

Qud: Amount of water diverted from Los Llanos Power Station to the Paquita River

The following are the results of the calculations:

	Before Completion	After Completion
Annual average inflow:	3.7 m^3/s	18 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	7.5 m^3/s	33 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	0.8 m^3/s	5.0 m^3/s

Tables 6-9 and 6-10 show the monthly average inflow before and after completion of the dam.

(4) Paquita River Cerritos Site

$$Qpc = QL \times Ppc \div PL \times C.Apc \div C.AL \qquad (m^3/s)$$

Qpc	:	Inflow at Cerritos
Ppc	:	Annual average precipitation at Cerritos (7,241 mm)
C.Apc	:	Catchment area at Cerritos (68.2 km^2)
QL	:	Inflow at Londres Runoff gauging station
PL	:	Annual average precipitation at Londres Runoff gauging station (6,577mm)
C.AL	:	Catchment area at Londres Runoff gauging station (210.2 km^2)

The amount of inflow at this location after completion of the dam was calculated according to the following equation:

$$Qpc' = Qpc - Qud \qquad (m^3/s)$$

Qud: Amount of water diverted from Los Llanos Power Station to the Paquita River

The following are the results of the calculations:

	Before Completion	After Completion
Annual average inflow:	10m^3/s	24 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	20 m^3/s	45 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	2.0 m^3/s	6.3 m^3/s

Tables 6-11 and 6-12 show the monthly average inflow before and after completion of the dam.

(5) Paquita River Tributary Tocori Valley Site

The precipitation at this location is 6,400-8,000 mm, as indicated in Figure 6-2. However, the small catchment area made the calculation difficult. Therefore, it has been conservatively calculated based on the assumption that the area is approximately the same as Londres Runoff gauging station area.

$$Qptc = QL \times C.Aptc \div C.A\,L \qquad (m^3/s)$$

Qptc : Inflow at Tocori Valley
C.Aptc : Catchment area at Tocori Valley ($5.0\ km^2$)
QL : Inflow at Londres Runoff gauging station
C.AL : Catchment area at Londres Runoff gauging station ($210.2\ km^2$)

The following are the results of the calculations:

Annual average inflow	:	$0.66\ m^3/s$
Annual total inflow	:	$21 \times 10^6\ m^3$
Maximum monthly average inflow	:	$1.3\ m^3/s$
Minimum monthly average inflow	:	$0.13\ m^3/s$

Table 6-13 shows the monthly average inflow, and Figure 6-8 shows the mass curve.

(6) Paquita River Estuary Site

$$Qprm = QL \times Pprm \div P\,L \times C.Aprm \div C.A\,L \qquad (m^3/s)$$

Qprm : Inflow at the estuary
Pprm : Annual average precipitation at the estuary (6,207 mm)
C.Aprm: Catchment area at the estuary ($178.5\ km^2$)
QL : Inflow at Londres Runoff gauging station
PL : Annual average precipitation at Londres Flow Gauging Station (6,577 mm)
C.AL : Catchment area at Londres Runoff gauging station ($210.2\ km^2$)

The amount of inflow at this location after completion of the dam was calculated according to the following equation:

$$Qprm' = Qprm - Qud \quad (m^3/s)$$

Qud: Amount of water diverted from Los Llanos Power Station to the Paquita River

The following are the results of the calculations:

	Before Completion	After Completion
Annual average inflow:	22 m^3/s	37 m^3/s
Maximum monthly average inflow (average for October over a 23-year period):	45 m^3/s	70 m^3/s
Minimum monthly average inflow (average for March over a 23-year period):	4.6 m^3/s	8.8 m^3/s

Tables 6-14 and 6-15 show the monthly average inflow before and after completion of the dam.