3. GENERAL DESCRIPTION OF PROJECT AREA AND SURROUNDINGS

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3. GENERAL DESCRIPTION OF PROJECT AREA AND ITS SURROUNDINGS

3.1 General Description of Project Area and its Surroundings

3.1.1 General Description

This project is planned on the Torola River, a tributary of the Lempa River. The Torola River is located in the northeast corner of El Salvador, between latitude 13°50'~13°53' north and longitude 88°22'~ 88°16' west. The Torola River originates in the mountainous area of Honduras, which borders with El Salvador. The river flows about 10 km toward the south, at which point changes its direction 90 degrees to the west in Morazan Prefecture of El Salvador. It then flows to the west through Morazan and San Miguel prefectures. Further down, it merges with the Lempa River at about 100 km upstream from the mouth to the Pacific Ocean. The basin of the Torola River runs through two prefectures, Morazan and San Miguel. The land area and population of these two prefectures are shown below. San Miguel city (whose population is about 245,000 persons), the third largest city of El Salvador, is situated about 40 km south of the Torola River.

	Area (km^2)	Population (persons)	Population density (persons/km^2)
Morazan Prefecture	1,447	176,646	122
San Miguel Prefecture	2,077	510,824	246

The major road in the basin is National Highway No. 7 going northward from Ruta Militar. This road crosses a bridge over the Torola River near Osicara, and it has been extended all the way to the Honduran border. A highway is located 130 km east of the capital city of San Salvador and intersects with the Pan-American Highway, which travels east to west thorough El Salvador. .

The La Union Port is located 50 km east of San Miguel. The harbor facilities are scheduled to be completed with the loan from Japan.

3.1.2 General Description of Hydro Power Development Plan

(1) Existing Hydro Power Plants

The Lempa River is a large river with a catchment area of 18,240 km^2. The area has been active in the development of hydro power plants from early on, and thus far, four hydro power plants (410.8 MW in total) have been completed to date. However, no hydro power plants have been built on the Torola River.

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Table 3.1 shows the generation features of the existing hydro power plants on the Lempa River, and Fig. 3.1 illustrates their positions.

Table 3.1 Existing Hydro Power Projects on Lempa River Basin

Name of Projects	HWL (EL. m)	Pmax (MW)	Annual Energy (GWh)	Maximum Discharge (m^3/s)	Maximum Head (m)	Effective Reservoir Storage ($\times10^6m^3$)
Guajoyo	430	19.8	64.2	39	53	452
Cerron Grande	243	135	457	196	56	1430
5 de Noviembre	180	99.4	457	196	56	87
15 de Septiembre	49	156.6	605	660	32	37

(2) Hydro Power Development Plan

The Simaron and the El Tigre Project Sites in the upstream are two of the main planned sites for hydro power development on the Lempa River. Table 3.2 shows the generation features of the hydro power development plans on the Lempa river and Fig.3.2 the positions of them.

The Pre-Feasibility Study (by Central American Bank for Economic Integration, CABEI) has been already completed for the Cimarrón Project. This will be followed by a Feasibility Study (FS), which is under planning. The FS will include an examination of possible environmental changes to be induced by the execution of the Project and a review of the Pre Feasibility Study for further improvement. The El Tigre Project is a bilateral Project, as part of the reservoir belongs to Honduras. El Salvador is under deliberation with Honduras, but has not reached an agreement yet.

As to the projects on the Torola River, a self-funded Pre-Feasibility Study was carried out between December 1997 and March 1999. In this Pre-Feasibility Study (Phase 1-B), comparative studies on the economy and social and natural environmental effects were carried out for possible power projects at El Chaparral, Carolina, La Honda, Las Marias, Las Mesas, Maroma and Las Cruces sites, located toward the downstream of the Torola River. As a result, two of the projects, El Chaparral and La Honda, were selected as the desirable projects for actual development. Table 3.3 shows the generation features of the hydro power development plans on the Torola River (Pre FS).

Table 3.2 Plans of Hydro Power Projects on Lempa River Basin

Name of Project	HWL (EL. m)	Pmax (MW)	Annual Energy (GWh)
Cimarron	700	243	863
El Tigre	137.5	704	1,815

Table 3.3 Plans of Hydro Power Project on Torola River Basin (Pre FS: Phase 1-B)

Name of Projects	HWL (EL. m)	Pmax (MW)	Annual Energy (GWh)
El Chaparral	202	58.8	205.6
Carolina	240	76.3	267.6
La Honda	285	59.6	207.8
Las Marias	285	19.7	55.2
Las Mesas	352	30.2	105
Maroma	456	42.7	148.4
Las Cruces	456	24.4	85.1

3.2 General Description of Project Area

3.2.1 Landform and National Environment

(1) Landform

The basin of the Torola River is surrounded by mountains whose terrains are relatively gentle, though with limited flat land. The catchment area (at conjunction point with the Lempa River) is about 1,575 km^2, of which 557 km^2 (or 35.4%) are on the side of Honduras and 1,018 km^2 (64.6%) on the El Salvador side. The length of the basin is about 77 km (58 km on the side of El Salvador). The average width of the basin is about 20km, with a height difference of 327 m.

The slope of the river is not very steep (about 1/100~1/200), and there are a limited number of large crooked parts. Therefore, the river is not suitable for a taking head by leading water of a cannel.

(2) Geology

The stratum formed by the volcanic activity during the time of the Tertiary and Quaternary underlies the basin of the Torola river. The stratum of the Tertiary and Quaternary is composed of volcanic rocks and volcaniclastic rocks. The geology at the El Chaparral project site consists of tuff breccia and basalt of the Morazon Formation. Surface deposits including the portion of riverbed

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deposits are generally thin. The water permeability of the basement rock is generally high, and the underground water level is expected to be low.

(3) Meteorology

The basin of the Torola River is divided mostly into the dry season (November to April) and the wet season (May to October). It experiences little precipitation in the least precipitation period (December to February), while the precipitation level reaches about 300~500 mm in June and September. The annual precipitation level in different areas within the basin varies from 1,200 millimeters to 2,900 millimeters. Temperatures vary very little throughout the year. The daily average temperature is about 25~30°C in the plain area (elevation of about 250 meters), and 19~23°C in the mountainous area (elevation of about 1,200 m).

3.2.2 Natural and Social Environment

(1) Natural Environment

1) *Vegetation*

The El Chaparral project area has a limited flat ground and a relatively small density of forest. On the other hand, however, completely naked land and the collapsed land are also very limited. The forest has been cut down, and the project area is mainly used for the cultivation of vegetables (corn, beans, etc.) and livestock. Result of an environmental survey indicates that in the tree strata of project area, 60 species were registered and included in 32 families. The Leguminous family is the one that has the largest number of species, 16, representing 27.12 % of the total.

The rest of the registered vegetation, pertaining to the bush and grass strata, was considered as a whole. This is because 61 species were registered considering the fact that they represent the vegetal coverage over the entire area of the project.

And, 10 species that have been identified as crops. The classification is based on the extensive coverage and the socioeconomic importance of the crops in the area. The survey also concludes that none of the precious plants found are limited to the area nor are their existence endangered by the proposed development.

2) Animals

Results of an environmental survey indicates that in total of project area, 100 species of animals were registered of which 19 correspond to mammals, 54 are birds, 20 are reptiles, and 7 are amphibians. But the project area has a high degree of human intervention and most of the animals found in the area are the standard ones.

3) Water Quality

The water quality of the Torola River is being affected by several activities that take place over the basin. Some of these activities are laundry, personal care, use of fertilizers, use of toxic products for fishing purposes and the discharge of sewer water. One actual case is the discharge from Carolina City that goes directly into the El Rastro creek that finally discharges the polluted water into the Torola River.

Results of an environmental survey indicates that the rivers in the project area are contaminated. The official regulation for potable water approved in 1996 by the Consejo Nacional para la Ciencia y la Tecnologia (CONACYT) establish the limits for 29 parameters. Taking this as a base we observed that 10 out of the total of parameters analyzed exceeded the limits: pH, turbidity, iron, manganese, phosphorous, mercury, fecal coliform bacteria, total coliform bacteria measured as NMP/100 (more probable number in 100 ml), oil and greases.

In relation with the quality of water needed for the aquatic life development, 5 out of 16 parameters used exceeded the established limits (EPA ref.): pH, color, manganese, mercury, and selenium.

Regarding agriculture use, 11 parameters were investigated. The results show that the pH and total coliform bacteria exceeded the limits established by FAO regulations.

(2) Social Environment

1) Population

There are three self-governing bodies in the project area. These are the municipalities of San Luis de La Reina, San Antonio del Mosco and Carolina, and all of them belong to San Miguel Prefecture. The population dynamics in the three municipalities has been fluctuating, specially in the last 3 decades, due to the impact caused by the social conflict in the country, reason why the rate of population growth is remaining low, reflected by an intense emigration of the population towards other zones to the interior and outside the country, as well as through mortality.

Municipality	Urban (inhabitants)	Rural (inhabitants)	Total (inhabitants)	Population density (inhabitants/km^2)
San Luis de La Reina	1,131	6,181	7,312	44
Carolina	2,196	6,926	9,122	175
San Antonio del Mosc	802	6,855	7,657	453
Total	4,192	19,962	24,091	-----

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2) Inundated House and Public Facilities

As of December of 2003, there were 79 families who will be directly affected by the formation from the dam. In addition, there is an school in the small village El Terrero, Canton Soledad Terrero de Carolina; and two small churches, the one in the small village Jocote, canton Soledad Terrero and another one in the small village Santa Clara a of the Rosas Nacaspilo, in Carolina.

3) Historical & Cultural Patrimony and Paleontological Resources

There were found in Carolina indications of possible existences of objects belonging to the archaic period that goes from the 6,000 to the 2,000 years B.C. The discoveries consisted on small obsidian pieces and stone fragments that could be used in human activities. These objects are also usually found outside the influence area of the project and due to there were no constructions nor artifacts that need to be preserved, this constitutes no impediment for the implementation of the project.

A fossil outcrop was found in a place called Vado Ancho. It consisted of calcareous, diatomite and slime that encase large quantities of fossilized invertebrates, with density in some cases of up to 30 individuals for each 20 square centimeters.

4) Others

There are no facilities for irrigation in the upstream or the downstream of the dam site and no water is taken from the river.

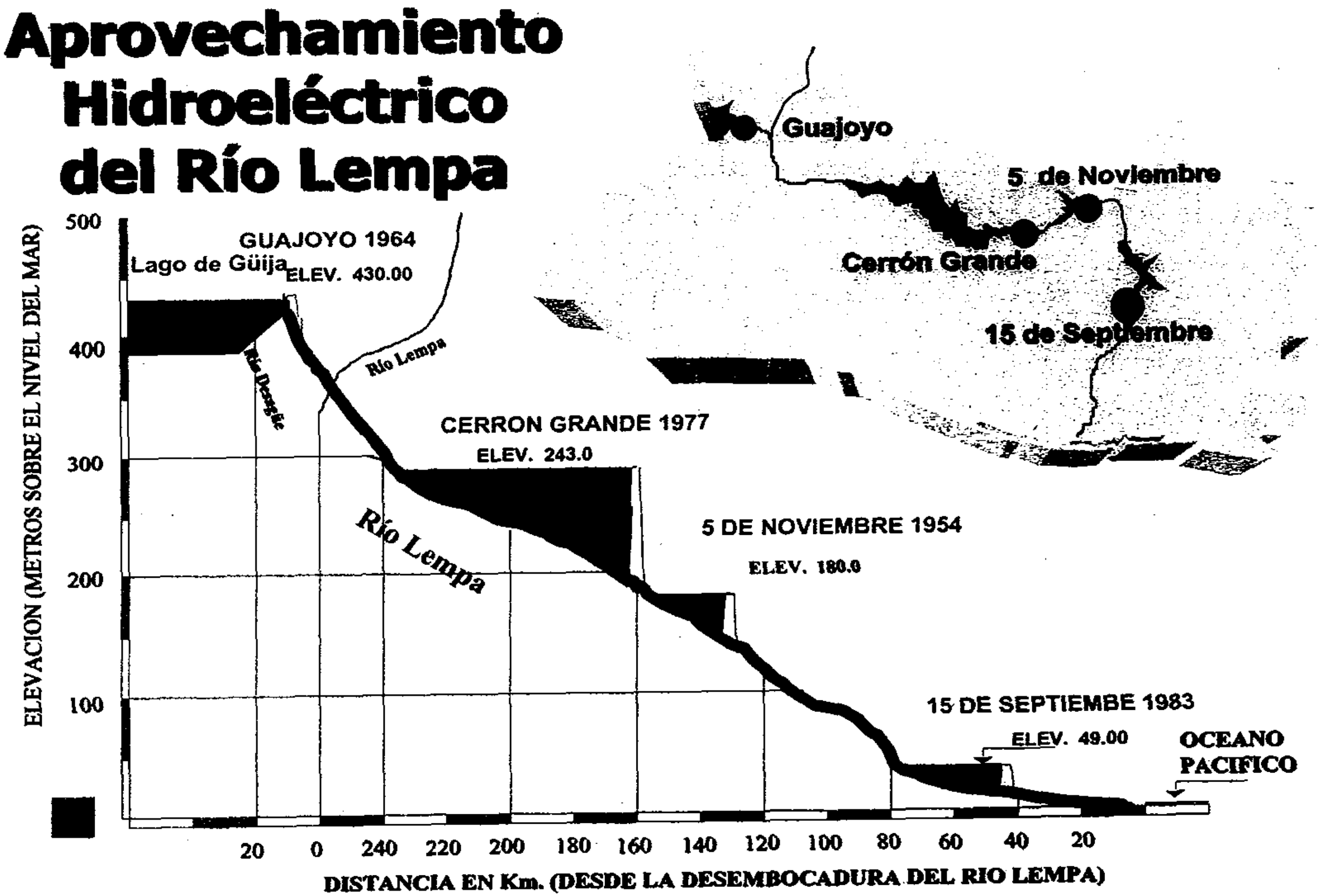

Fig. 3.1 Existing Hydro Power Projects on Lempa River Basin

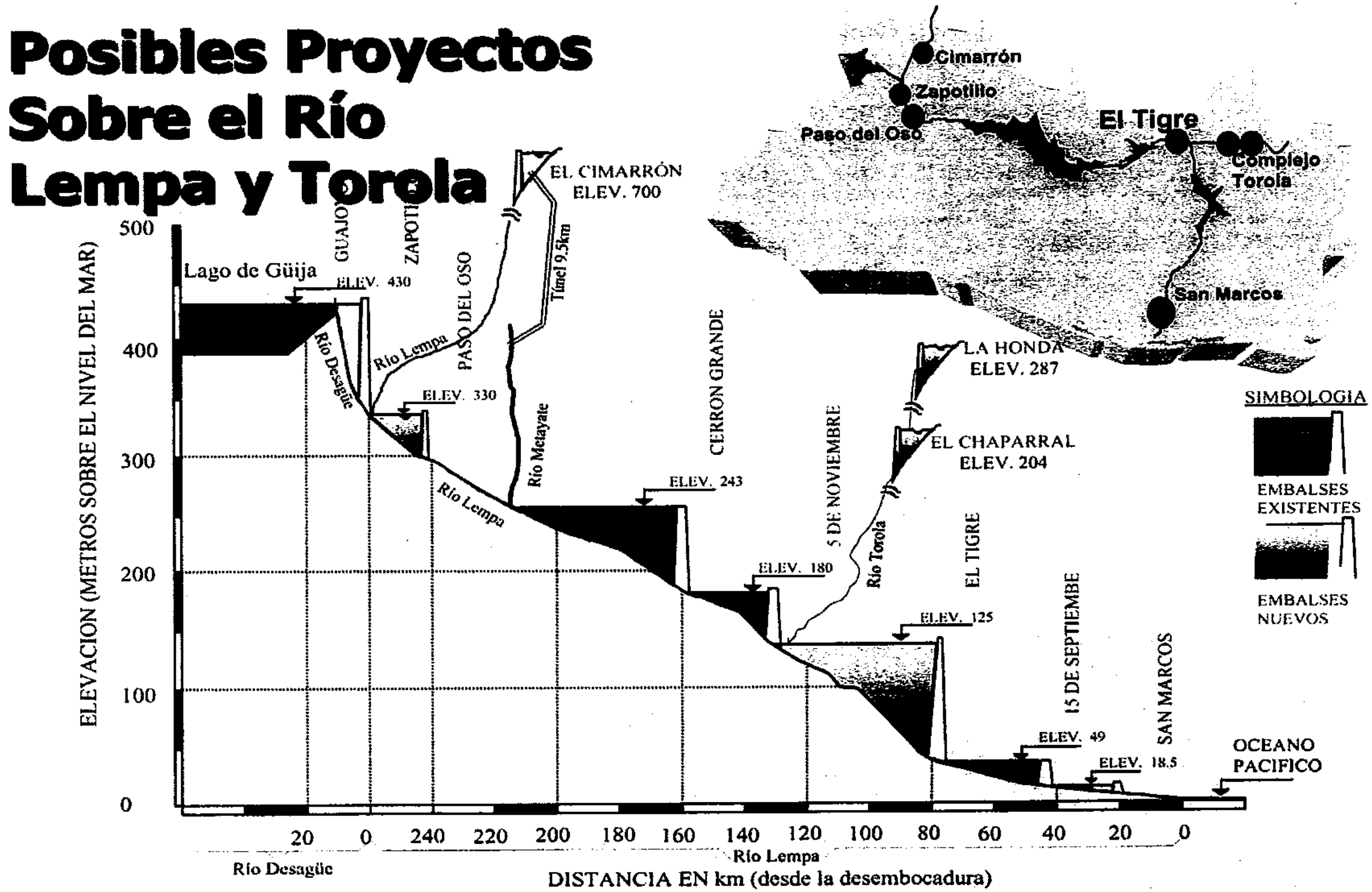

Fig. 3.2 Plants of Hydro Power Projects on Lempa River Basin

4. SITUATION OF POWER SECTOR

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4. SITUATION OF POWER SECTOR

4.1 Summary

El Salvador's dependency on imported oil accounts for over 46.6% of its total energy needs. Therefore, the development of domestic energy sources has been a focal point of the government's energy policy with a goal toward independence from imported energy sources. Since the oil embargo of the 1970s, the government has given priority to the strengthening of hydro power and geothermal power production.

The peak electric energy and the amount of electrical power generated grew steadily at average rates of 4.7% and 5.5% respectively from 1993 to 2002. The total install capacity in El Salvador, on the other hand, is about 1,070.2 MW (firm capacity was about 893.9 MW, at the end of 2002), whose breakdowns are: power from hydro power generation plants amounting to 410.8 MW, power from thermal power plants amounting to 633.4 MW, and power from other sources amounting 26.0 MW.

The present power system of El Salvador consists of main transmission lines (about 1,022 km), on 115kV, which runs through the land of El Salvador. Electric power is transmitted from hydro power stations in mountain areas, and geothermal power stations and thermal power stations (primarily using internal-combustion engines) in the suburbs of San Salvador, the capital city of El Salvador, and of several departmental capitals such as Santa Ana, San Miguel and Acajutla, among others.

There is an international connecting line between El Salvador and Guatemala, which runs on 230kV and has a transmission capacity of 120 MW. In addition to this line, two other plans are under preparation for construction, which entail the installation of international connecting lines including the 230kV connecting line (with a transmission capacity of 100MW) between El Salvador and Honduras and a power connecting system among six countries of Central America (Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama) called "SIEPAC" (Sistema de Interconexion Electrica de los Paises de America Central, transmission capacity of 300MW).

4.2 Electric Power Carrier

In El Salvador, Commission Ejecutiva Hidroelectrica del Rio Lempa (CEL), which is in charge of the electric power sector of El Salvador, was established in 1948. In 1996, CEL was divested into independent companies responsible for generation, transmission and distribution. In 1999 the thermal power generation division was privatized. Currently, CEL is responsible for the operations of the four major hydro power stations. The organization chart of CEL is shown in Fig.4.1.

The power law of El Salvador, which was promulgated as a set of general rules in 1996, calls for an effective utilization and operations of power facilities and encourages competition in the areas of power generation and power distribution, while delegating power-related pricing to the wholesale market.

The leasing fee of transmission lines and/or distribution lines is subject to approval by Superintendencia General de Electricidad y Telecomunicaciones (SIGET) and is controlled by Unidad de Transacciones (UT), which serves as coordinating body. This ensures safety in facilities and in the operations of power facilities, secures power supplies, and enables proper management of the electricity market.

The types of operators in the power sector as well as their business lines and activities are classified as follows:

• Generating enterprises:	Importation of electric power though generation (hydro, geothermal and thermal power) and through power systems by means of mutual connections.
• Transmission enterprises:	Transportation of electric power from power station to customers' locations.
• Coordination enterprises:	Monitoring of power system safety. Management of the wholesale segment of the power market.
• Distribution line operators	Operations of distribution lines for the delivery to customers
• Commercial dealers for distribution	Buying and selling of electric power for customers.

Operators in each of the above segment as well as their market shares are as follows.

• Generating enterprises	:	CEL (29.3%), Nejapa Power (20.5%), GESAL (24.1%), DUKE Energy (23.6%), CESSA (2%),
• Transmission enterprises	:	ETESAL (100%)
• Coordination enterprises	:	UT (100%)
• Distribution line operators	:	CAESS (40.5%), CLESA (14.8%), EEO (11.1%), DEUSEM (1%), DELSUR (23%)

- Commercial dealers for distribution : The business of the following operators accounts for 2.9% of the total business: Excelergy, Conexión, Energética Centroamericana El Salvador, Cartotécnia Centroamericana, Comercializadora de Electricidad Centroamericana

4.3 Electric Power Supply Facilities

The installed capacity of the existing power plants in El Salvador was about 1070.2 MW at the end of 2002 as shown in Table 4.1, and the percentages of the installed capacity of the hydro power stations, the thermal power stations and other small power plants were 38.4%, 59.2% and 2.4%, respectively. There has been no construction of large-size hydro power stations in the last 20 years, and the installed capacity of the hydro power stations increased only 2.0% in the past three-year period, which was accomplished through renovations. On the other hand, the installed capacity of thermal power stations increased after the privatization, and its share now accounts for about 60.6% as of 2002. Table 4.2 shows the trend of installed capacity of the last twelve years.

The existing hydro power stations in El Salvador include four (4) large capacity hydro power plants of Guajoyo, Cerron Grande, 5 de Noviembre and 15 de Septiembre, and they are either of the reservoir-type or the poundage-type. The installed capacity and the commencing year of each station, as shown in Table 4.1, are 15MW (it was increased to 19.8 MW by renovation in 2000) at Guajoyo, which began in 1963, 135 MW at Cerron Grande, which was launched in 1977, 84.5 MW (it was increased to 99.4 MW by renovation from 2000 to 2002) at 5 de Noviembre which went into operation between 1957 to 1966, and 156.6 MW at 15 de Septiembre, which began its operation in 1983. The installed capacity of these stations totaled about 410.8 MW at of the end of 2002. Facilities available at each hydro power plants and operating records are outlined in Appendices 4.1and 4.2.

The operation of each hydro power station is in line with the corresponding base load, as long as looking over actual record. Hydro power generation is the preferred mode of generation over thermal generation as the country attempts to cut fuel costs required for the latter. The hydro power stations are used during the peak load hours of 18:00 to 22:00 at night and had a difference seasonal generating energy for the dry and wet seasons of November ~ April and May ~ October, respectively. Therefore, the average annual operating hours for last ten (10) (1991~2000) years at each hydro power station were extremely long, as seen in the following data: 4,370 hours at Guajoyo, about 4,750 hours at Cerron Grande, about 6,890 hours at 5 de Noviembre and about 4,540 hours at 15 de Septiembre. On an average, the stations were in operation 12 to 19 hours per

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day. The annual capacity factor for each hydro power station has ranged from about 32% to 62% for the last 12 years. The actual energy produced by them is shown in Table 4.3.

The power system in El Salvador is composed mainly of 115 kV transmission lines whose length is 1,022 km. There is a 230 kV international interconnection line whose length is 107 km. The transmission lines across the country connects primary substations, such as San Miguel, 15 de Septiembre, San Martin, which is located in a suburb of San Salvador, Nejapa, Santa Ana, Acajutla, and Ahuachapan, among others. The voltages of the distribution lines that cover cities, towns and villages are 46, 34.5, 23, 13.2 and 4.16 kV. Five regional distribution companies own the lines in their respective areas, and their total length is about 16,135 km (as of the end of 2002). The low-tension distribution lines for customers are 440, 220 and 110 V. The length is about 17,366 km (as of the end of 2002). A breakdown of transmission line and distribution line length by power system voltage is presented in Table 4.4.

The SIEPAC arrangements have been under review since 1986, and it calls for an interconnecting line to connect a total of 15 substations from Valadero Substation in Panama to El Cajon substation in Honduras. The guaranteed capacity of the transmission line between each country is up to 300 MW. The total length is about 1,802 km, of which about 260 km (14.4 %) will be in El Salvador, where three locations (Ahuachapan, Nejapa and 15 de Septiembre) are expected to be connected by the line. Fig.4.2 shows the transmission route of SIEPAC. The topographical inspection for the route related to the transmission line will be completed by the end of December 2003 and the examination of the detailed study will be finalized by the end of June 2004. Subsequently, contractors will be decided before the end of 2004 and the facilities related to the transmission line are scheduled for completion by the middle of 2007.

There are twenty-three primary substations whose voltage is 115 kV, with the combined installed capacity of 1,640 MVA (as of the end of 2002), as shown in Table 4.5. The substations with most capacities are Ahuachapan Substation and 15 de Septiembre Substation (total installed capacity of 313 MW, which is served by the 230 kV international interconnection line.

4.4 Power Buying and Selling System in El Salvador

The actual total energy unit sales in El Salvador, as shown in Table 5.5, was about 4,100 GWh of the total domestic generation at the end of 2002. The energy available for supply amounted to about 4,525 GWh, which was derived by subtracting 12 kWh (the power consumed by the stations) from the 4,100 GWh net domestic energy generation of 4,088 GWh (or 90.1% of the total)) and by adding 2 GWh (0.1%) (energy obtained from IPP) and 435 GWh (9.6%) (imported energy).

The power consumed was about 4,379 GWh (96.8% of the total consumed) of the domestic power generation. The balance was the energy exported to third countries amounting to about 51 GWh (1.1%) and the energy loss of 95 GWh (2.1%) in the power system.

The power buying and selling in El Salvador are carried out in the wholesale market, which is supervised by UT. Electricity is traded between enterprises, which are operators with direct interconnections to the power system. To put it differently, the market is run on a two-tier system – the contract market (i.e., for the trading for fixed amounts) and the spot market (i.e., trading for system adjustments) – under the supervision of UT.

- Contract market (MC):

  It is the market in which details of agreements can be settled freely between enterprises belonging to the wholesale market (MM). (The buying and selling prices for power of Power Buying are not published.)
- Spot market (MRS):

  This is the market where excesses are sold and shortages are purchased. It is also in this market where the difference between the actual amounts required and the contracted amount can be squared.

In the contract market, a deal is concluded between two parties, both of whom are qualified participants, The market offers confidentiality. The parties are required to report only the general matters relating to the contract and some details of the deal between the parties (e.g., supply and demand and electricity sales point) to UT. UT checks the validity of the deal and may refuse to accept the deal if it contains any matters which, in its opinion, are technically impossible. Matters relating to the delivery and the taking over (demand and supply), upon approval, are communicated to the parities concerned, and they become an integral part of the deal, which defines the initial conditions for load dispatch instructions.

The market for system adjustments (MRS) functions as an exchange venue for electric power, where a uniform price is established to meet the fluctuating electric power as defined by the electric supply plan. All power generation contractors registered with UT are offer-side participants. The market allows participants with contracts and those without. The uniform price is expressed in terms of the unit price for an established amount of electric energy per prescribed time period. Moreover, the price for each pre-established time zones used in the MRS is determined by the marginal unit (final price), which is manipulated so that UT can fulfill demand.

The party receiving electricity from the MRS market makes a payment, which is shared by all of the operators who supply electricity at that time. Decisions regarding the utilization of power plants

are made based on the contract between two enterprises between different entrants, as well as on the offer price proposed by each generating enterprise on the previous day. The price fixed in this market is also applicable to imported and exported electric power.
Taking into account the changes in the levels of power generated and demand as well as bilateral deals in the MC market and forecasted demand, UT sends out load dispatch instructions for the next day on a daily basis. The MRS price ($MRS ex ante) for each time zone becomes available this way. While the system is in operation, UT attempts to ensure electric supply real time to meet the demand for the conventional load while paying close attention to power transmission restrictions and auxiliary services (e.g., voltage adjustment etc.) required for the maintenance of quality and safety of the power system. Operating records are kept by UT. The commercial process of the wholesale market is shown in Fig. 4.3.

The $MRS ex post for the electric-energy price system adjustment market (MRS) is computed for each time zone based on the actual generatable amount and demand records, after adjustment for the power not provided according to UT's instructions by deducting that portion, on the day following the actual supply date. This price is equivalent to the short-term margin price and is calculated based on fluctuating offers. In the event of power transmission trouble, the troubled segment of the MRS market is separated from the rest; therefore, the price for each MRS segment will then be decided separately. The difference between the amount of power generation and actual consumption, along with the contractual commitments stipulated in a contract are settled in the MRS market by UT.

The excess expense arisen from the actual employment including the expenses associated with the failure to provide electricity against the instructions of UT and with auxiliary service is treated as expenses associated with auxiliary service or power generation activities (depending on system conditions) and squared by payments. At the end of each month, UT settles its account with each participant belonging to the wholesale market, by adding up applicable transactions for the month including those associated with power generation performed in conjunction with MRS, the burden of power transmission (electrical overload), and auxiliary service. The expense associated with the service business of UT is also added. As for the loss of transmission system, UT determines the calculation method. Each of the power-generating enterprises takes the responsibility of sharing the expenses in proportion to the amount of electricity supplied.

UT's weighted market price, on a monthly basis, for the period between 1998 and 2002 is shown in Table 4.6. From this table, the average price for this period of about 67.3 $/MWh is derived.

The electricity tariff structures for customers in El Salvador was modified when organizational changes in CEL including the privatization of thermal power stations and the divestiture of transmission system were carried out in 1998. In 2002, it went through another revision involving detailed matters. The electricity tariff as it stands today is shown in Table 4.7.

The small-scale customers account for about 93% of all customers, with 53% of demand. The industrial customers occupy about 42%. Tables 4.8 and 4.9 show the number of electricity consumers and the trend of energy consumption in the power market for the last seven years.

El Salvador's electrification rate has reached the level of about 72% as of 2002.

4.5 Situation of Power Demand and Supply

(1) Maximum Power and Energy Generation

The balance of electricity-related demand and supply in El Salvador is based on the premise that all domestic needs should be met by domestic production. However, as a result of the deregulation of electric utilities, the balance has been maintained by imported energy from Guatemala and Honduras as well as energy from the IPP facility

Table 4.10 shows the trend of energy generation in 2002. The total volume of power generation is broken down into domestic generation of about 3,981 GWh (91.2%) and imported electricity amounting to about 384 GWh (8.8%). The yearly average figures for the past twelve years indicate that the domestic share has decreased (to about 96%) while the import share has risen (to about 4%). It should also be noted that the growth in power development has failed to keep up with the pace of demand growth in recent years. The yearly average growth rate of energy sales from 2000 to 2002 is about 3%. The past records of energy consumption by industrial sector are shown in Table 4.9 and Fig. 4.4. The average annual growth rate of maximum demand power was about 4.7% in a twelve-year period, as shown in Fig. 4.5. However, the average growth for more recent years from 2000 through 2002 was limited to about 2%.

(2) Load curve

The daily load curve in El Salvador is classified into three stages: Daytime zone from 7 to 18 hours, Night time (peak) zone from 18 to 22 hours and night time (midnight) zone from 22 to 7 hours. These are confirmed by the daily load curve of the existing hydro power stations shown in Fig. 4.7 , in addition to the daily load curve in the UT report shown in Table 4.11 and Fig.4.6

The Chaparral Project is designed for the peak-time operation. The Chaparral site is scheduled to supply power aimed at the peak time zone lasting three to four hours throughout the entire year together with the existing hydro power stations. Additionally, it will supply energy to fulfill part of the base load energy requirements during the raining season.

(3) Energy Loss

The total energy losses by transmission and distribution lines in the power system was about 15 ~ 16% before 1996. The losses during 2000 was about 13%. However, a further improvement in the loss rate to below 10% would require improvements to be made on the present conditions. Such as countermeasure as described below.

1) Loss of Station Service (own use)

The station service energy for the facilities of a hydro power station is less than the energy level required for the internal-combustion engine generator. Therefore, it is recommendable to promote the development of hydro power plants.

2) Loss of Transmission Line

High voltage transmission lines are effective in reducing the loss of transmission. Therefore, the expansion of 230 kV and 115 kV transmission lines will meet the purpose.

3) Loss of Distribution Line

A secondary substation should be installed at a point near the load center of the city and town as much as possible.

The table below shows the changes in transmission and distribution lines losses in the power system in El Salvador.

Energy Losses in the Power System

Year	Losses GWh (%)					
	Transmission		Distribution		Total	
1996	153	(4.6)	308	(9.6)	461	(14.2)
1997	98	(2.7)	383	(10.8)	481	(13.5)
1998	89	(2.4)	335	(9.0)	424	(11.4)
1999	116	(3.0)	393	(10.3)	509	(13.3)
2000	142	(3.5)				

(Reference) The total losses of the electric power system of Asian countries from data of 1998 are as follows:

Thailand	8%	Philippine	16%
Malaysia	10%	Japan	4%
Indonesia	12%	India	18%

(Source: World Bank, 1998)

Table 4.1 Existing Power Plant List (As of 2002)

Name of Power Station (units × MW)		Installed Capacity (MW)	Year of Commissioning
I. Hydro Power Station		(410.8)	
1. Guajoyo	(1 × 19.8)	19.8	1963 (renovation in 2000)
2. Cerrón Grande	(2 × 67.5)	135.0	1977
3. 5 de Noviembre	(4 × 19.5) + (1 × 21.4)	99.4	1957, 1961, 1966 (renovation in 2000, 2001 and 2002
4. 15 de Septiembre	(2 × 78.3)	156.6	1983
II. Thermal Power Station		(633.4)	
1. Ahuachapán	(2 × 30) + (1 × 35) (Geothermal)	95.0	1975, 1976, 1980
2. Berlin	(2 × 5.0) + (2 × 28.1) (Geothermal)	66.2	1992, 1999
3. Acajutla vapor	(1 × 30) + (1 × 33)	63.0	1966, 1969
4. Acajutla gas	(1 × 82.1)	82.1	1996
5. Acajutla motor	(6 × 16.5)+(3 × 17)	150.0	2000
6. Nejapa Power motor	(27 × 5.35)	144.5	1995
7. CESSA motor	(3 × 6.4) + (2 × 6.7)	32.6	1999, 2000
III. Others (Mini/Micro/etc.)		(26)	
1. CECSA	(7.3) 7 small hydroelectric power	7.3	---
2. Sensunapán	(1 × 3) 1 small hydroelectric power	3.0	---
3. De Matheu y Cía	(1 × 0.7) 1 small hydroelectric power	0.7	---
4. Cogeneradores	(15) 5 small thermal power	15.0	---
Total		1,070.2	

Note : 1) The firm capacity of the both Ahuachapan and Berlin geothermal power plants (GPP) are decreased because the Ahuachapan GPP is not enough steam and the Berlin GPP is impossible for operation of 2-units of 5.7 MW as follows;
a. Ahuachapan Geothermal Power Plant : 95 MW to 65 MW (Max.)
b. Berlin Geothermal Power Plant : 66.4 MW to 55 MW (Max.)

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Table 4.2 Trend of Installed Capacity of Power Resources

(without small capacity plant.) (Unit : MW)

Year	Hydro	Share (%)	Thermal	Share (%)	Geo-thermal	Share (%)	Private	Share (%)	Total	Growth (%)
1991	388	59.7	167	25.7	95	14.6	0	0.0	650	---
1992	388	55.6	205	29.4	105	15.0	0	0.0	698	7.4
1993	388	47.5	325	39.7	105	12.8	0	0.0	818	17.2
1994	388	47.5	325	39.7	105	12.8	0	0.0	818	0.0
1995	388	42.7	335	36.9	105	11.6	80	8.8	908	11.0
1996	388	41.1	306	32.4	105	11.1	145	15.4	944	4.0
1997	388	41.1	306	32.4	105	11.1	145	15.4	944	0.0
1998	388	41.1	306	32.4	105	11.1	145	15.4	944	0.0
1999	388	39.3	0	0.0	161	15.2	450	45.5	999	5.8
2000	396	34.8	0	0.0	161	14.2	579	51.0	1,136	13.7
2001	400	35.7	0	0	161	14.3	561	50.0	1,122	-1.2
2002	411	39.4	0	0	161	15.4	472	45.2	1,044	-7.0
Average	392	43.78	189	22.38	123	13.27	215	20.56	919	4.63

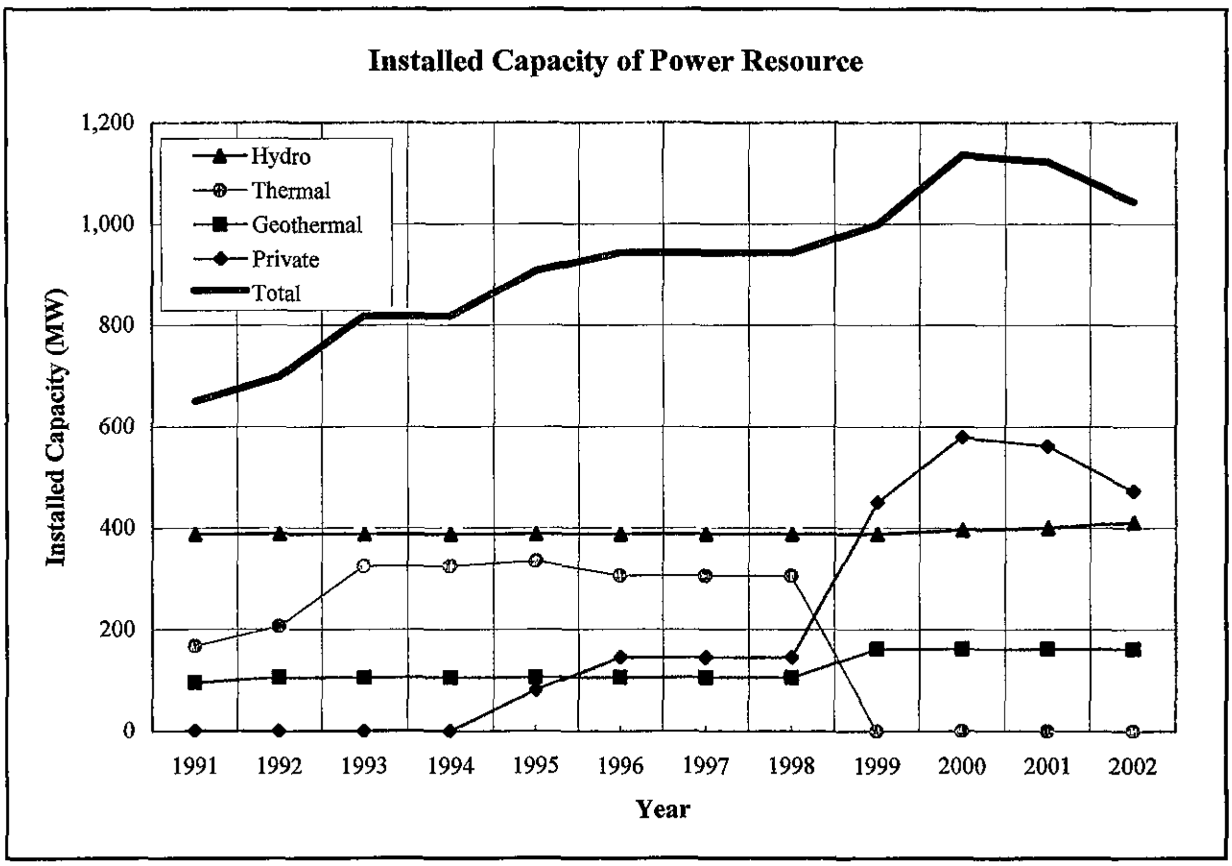

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Table 4.3 Trend of Energy Produced (1991~2002)

(Unit : MWh)

Year	Guajoyo	Cerrón Grande	5 de Noviembre	15 de Septiembre	Total
1991	58,115	374,123	346,231	490,021	1,268,489
1992	37,616	421,025	426,103	530,999	1,415,744
1993	54,305	433,428	473,055	557,303	1,518,090
1994	52,144	396,745	485,574	513,109	1,447,572
1995	50,693	410,162	469,235	541,188	1,471,278
1996	82,183	511,448	551,092	737,903	1,882,626
1997	36,102	400,262	478,077	514,460	1,428,902
1998	76,993	425,406	493,842	569,559	1,565,799
1999	91,988	546,615	530,086	545,623	1,714,312
2000	8,611	386,273	298,584	481,720	1,175,188
2001	52,543	350,831	336,859	423,565	1,163,798
2002	37,274	295,424	382,879	423,498	1,139,075
Avarage	53,214	412,645	439,301	527,412	1,432,573

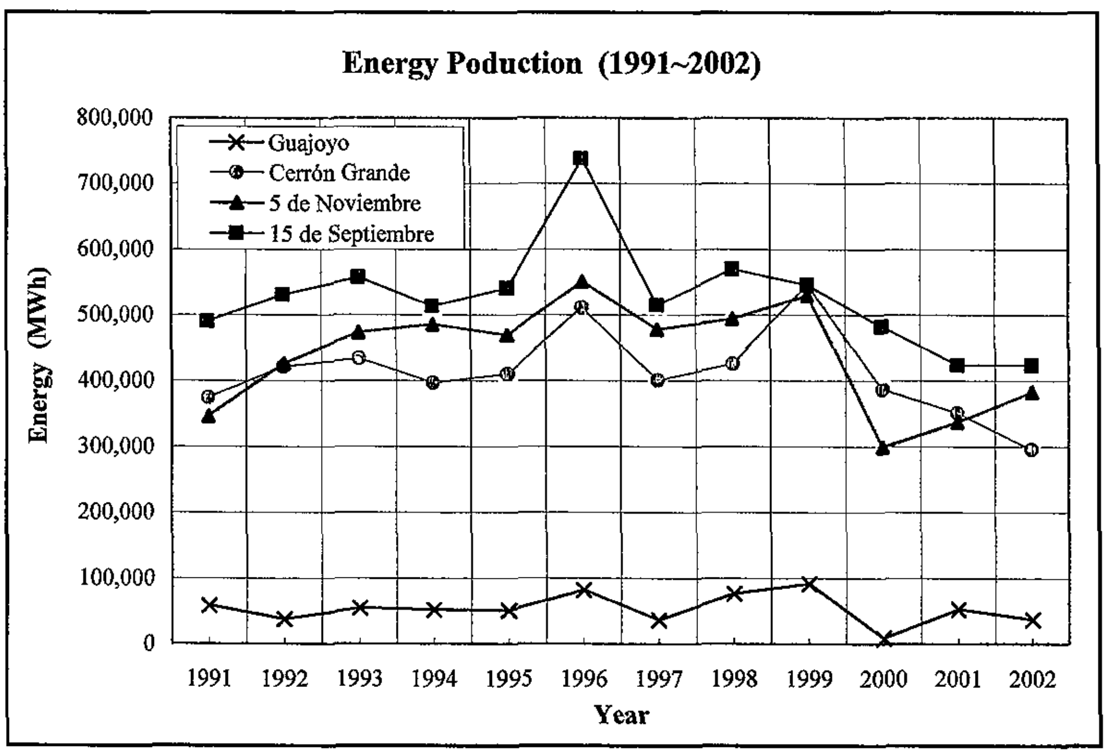

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Table 4.4 Transmission and Distribution Lines

(Unit : km)

Year	230 kV	115 kV	Middle Voltage	Low Voltage	Total
1991	15	804			819
1992	15	804			819
1993	15	804			819
1994	15	727			819
1995	15	736			819
1996	15	736			819
1997	15	743			819
1998	15	743			819
1999	15	749	12,102	11,110	23,976
2000	15	881	11,226	13,117	25,107
2001	15	941	14,379	13,653	28,988
2002	107	1,022	16,135	17,366	34,630

Note : 1) Meddle Voltage is 46, 34.5, 23, 13.2 and 4.16 kV

2) Low Voltage is 440, 220 and 110V

3) Data of Middle and Lower Voltage Lines before 1998 is not available from related Company.

Table 4.5 Transformer Capacity at Substation

(Unit : MVA)

Year (End of March)	230 / 115/46-23 kV	110 / 46 kV	110 / 34.5 kV	115 / 23 kV	43.8 / 13.2 kV	46 / 34.5 kV	44 / 22 kV	34.5 / 13.2 kV	Total
1991	313	360	77	300	150	6			1,206
1992	313	360	77	300	168	6			1,223
1993	313	405	70	350	188	6		26.125	1,358
1994	313	405	70	350	190	6		27.125	1,360
1995	313	355	70	500	250	6	24	1	1,519
1996	313	355	70	500	256	6	24	1	1,525
1997	313	355	70	500	257	6	24	1	1,525
1998	313	650	70	500					1,533
1999	313	650	70	500					1,533
2000	313	670	70	500					1,553
2001	313	640	70	450					1,473
2002	626	620	70	450					1,766

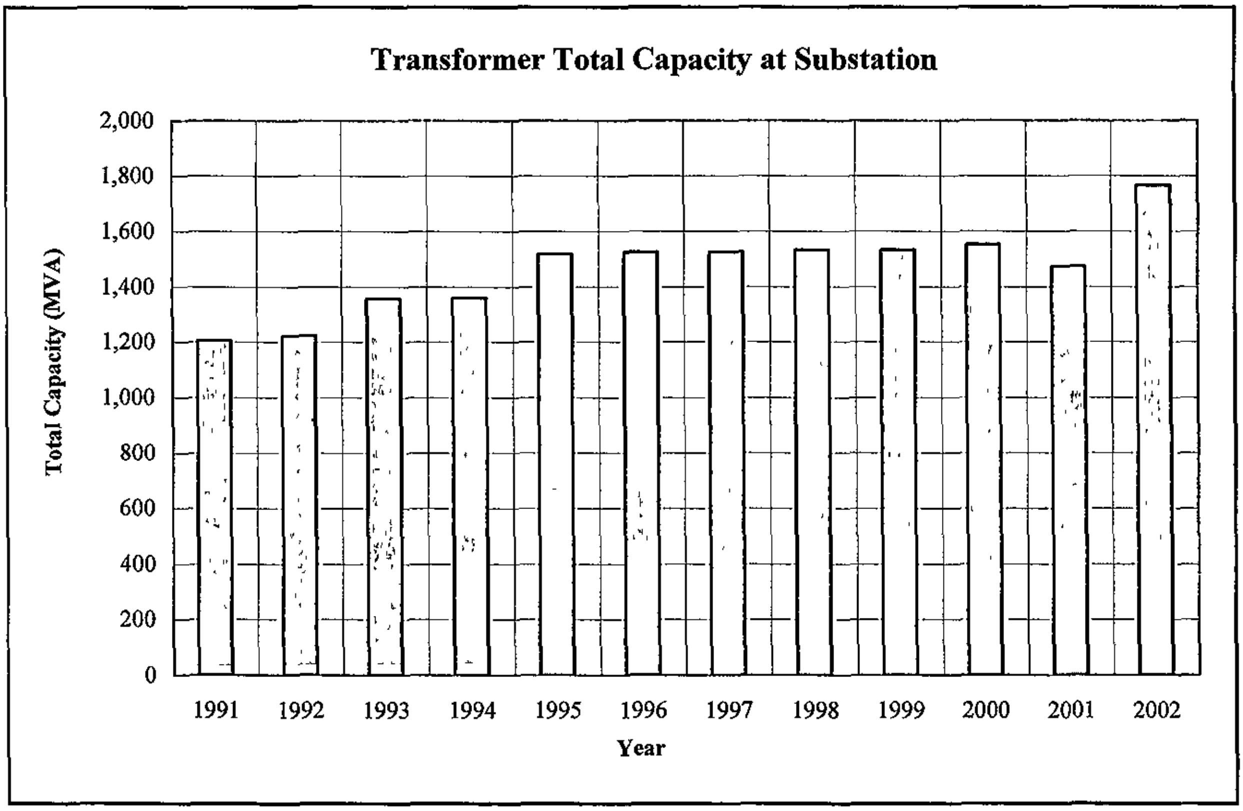

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Table 4.6 Weighted Average of Monthly Market Cost of MRS (1998～2002)

(Unit : $/MWh)

Month \ Year	1998	1999	2000	2001	2002	Ave.
Jan.	58.45	61.33	86.99	64.08	67.69	67.71
Feb.	70.61	57.87	91.84	66.35	70.75	71.48
Mar.	59.20	61.94	106.66	66.84	56.06	70.14
Apr.	54.92	61.46	173.71	72.51	64.85	85.49
May.	73.21	65.75	74.39	70.49	69.12	70.59
Jun.	59.76	76.81	65.34	70.77	53.05	65.15
Jul.	52.04	64.94	58.12	73.61	63.91	62.52
Aug.	46.67	57.21	63.97	69.88	70.01	61.55
Sep.	46.55	61.39	64.84	54.53	66.57	58.78
Oct.	52.30	56.92	58.87	58.32	67.43	58.77
Nov.	58.00	67.34	60.50	63.14	71.98	64.19
Dec.	66.45	74.42	59.58	69.83	72.79	68.61
Ave.	58.18	63.95	80.40	66.70	66.18	67.08

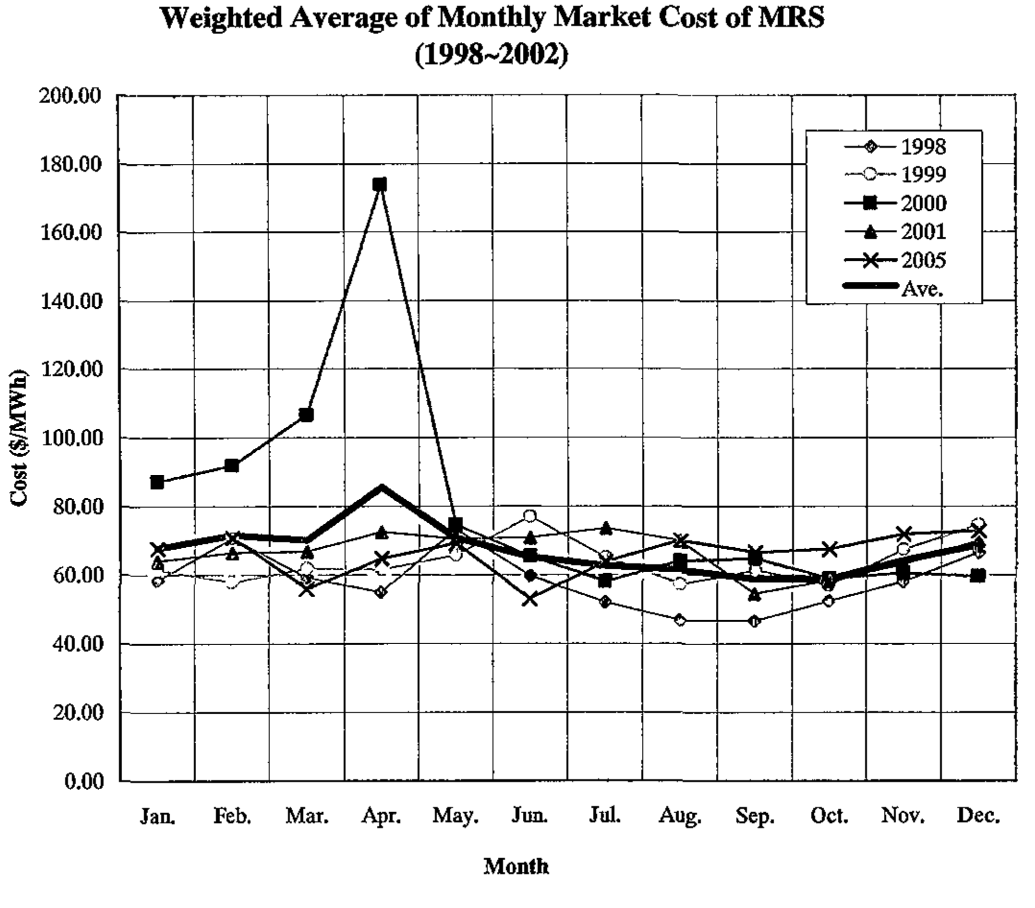

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Table 4.7 Electricity Tariff by Level of Voltage and Demand in El Salvador

in 2001

(Unit : US$/kWh)

Low Voltage					Interim Voltage	
Small Demand			Medium Demand	Large Demand	Medium Demand	Large Demand
0<kW<10			10<kW<50	>50kW	10<kW<50	>50kW
Total Residential	General Use	Public Streetlight				
0.1338	0.1322	0.1251	0.1438	0.1261	0.11431	0.11459

Fuente : Superintendencia General de Electricided y Telecomunicaciones (SIGET)

in 2002

(Unit : US$/kWh)

Low Voltage					Interim Voltage	
Small Demand			Medium Demand	Large Demand	Medium Demand	Large Demand
0<kW<10			10<kW<50	>50kW	10<kW<50	>50kW
Total Residential	General Use	Public Streetlight				
0.1332	0.1182	0.1207	0.1425	0.1473	0.10587	0.08972

Fuente : Superintendencia General de Electricided y Telecomunicaciones (SIGET)

Table 4.8 Number of Electricity Consumers

(Unit : Thousand)

Consumer	1996	1997	1998	1999	2000	2001	2002	Share of 2002 (%)
Domestic	809	852	836	889	988	1,051	1,078	93.3
Commercial	65	67	---	---	---	---	---	---
Industry HT	6	6	---	---	---	---	---	---
Medium Demand (10<kW<50)	---	---	3	4	4	4	3	0.3
Large Demand (>50kW)	---	---	2	2	2	2	2	0.2
General Use	---	---	70	70	70	70	70	6.1
Others	5	6	1	1	1	1	1	0.1
Total	885	931	912	966	1,065	1,128	1,154	100.0

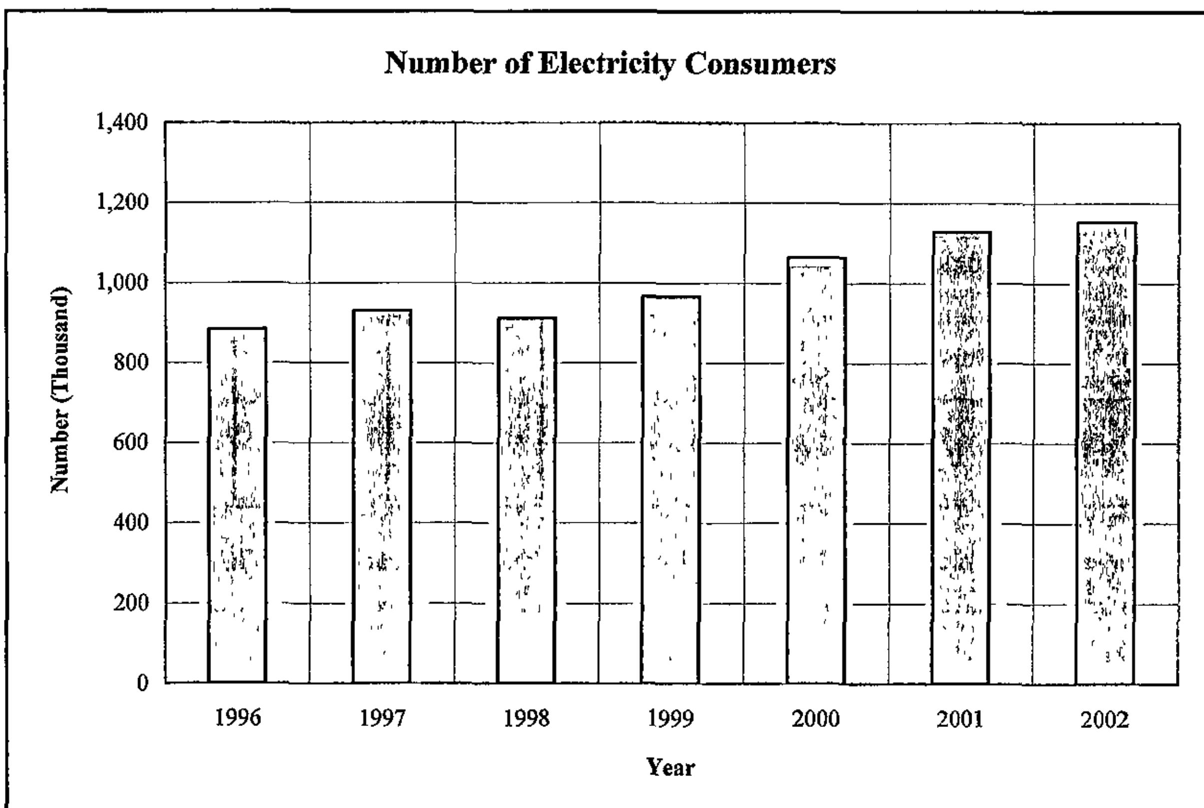

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Table 4.9 Trend of Energy Consumption in Power Market

(Unit : MWh)

Year	Domestic	Commercial	Industry	Others	Total
1991	706,939	303,659	588,045	339,204	1,937,847
1992	749,765	325,087	628,239	346,617	2,049,708
1993	839,107	383,182	730,516	413,060	2,365,865
1994	912,285	428,538	773,959	471,940	2,586,722
1995	1,001,853	495,069	829,975	502,784	2,829,681
1996	1,057,965	505,422	842,129	520,679	2,926,195
1997	1,149,240	556,246	905,020	573,963	3,184,469
1998	1,179,565	428,949	1,265,936	238,314	3,112,764
1999	1,209,890	301,652	1,626,852	67,833	3,206,227
2000	1,717,864	217,734	1,683,235	6,795	3,625,628
2001	1,684,792	234,689	1,443,455	2,888	3,365,824
2002	1,885,099	167,884	1,502,206	600	3,555,789
Share 2002 (%)	53.01	4.72	42.25	0.02	100.00

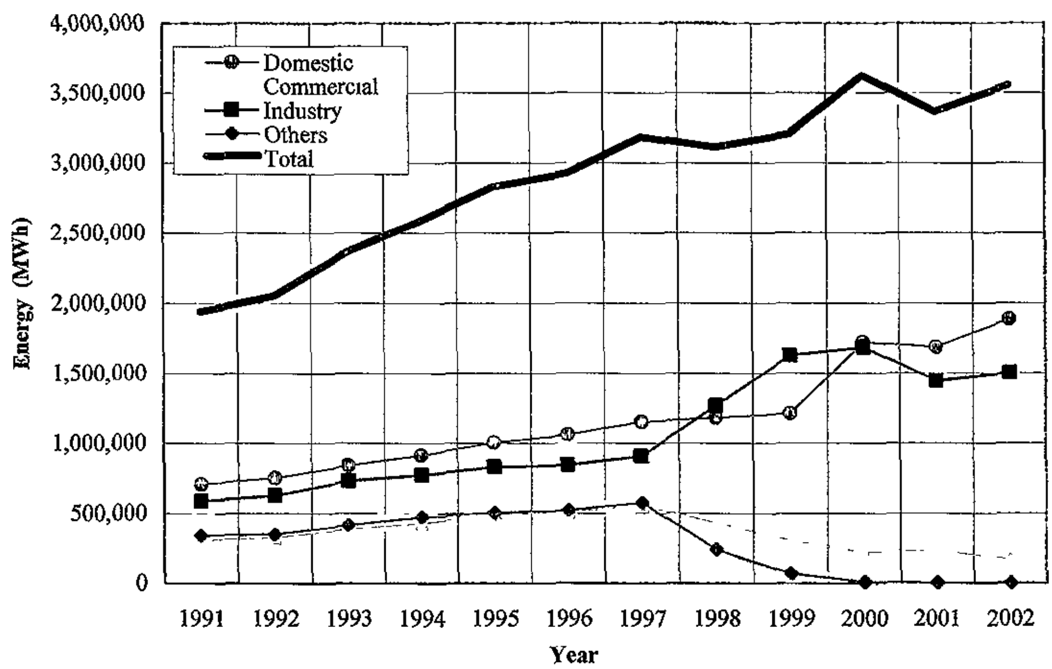

Fig. 4.4 Energy Consumption in Power Market

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Table 4.10 Electricity Generation of Past 12 Years

(Unit : GWh)

Year	Domestic Generation	Share (%)	Imported Energy	Share (%)	Sold Energy	Growth (%)	Peak Demand (MW)	Growth (%)
1991	2,297	99.8	5	0.2	2,086	---	448	---
1992	2,382	87.8	53	2.2	2,248	7.8	476	6.3
1993	2,783	97.2	79	2.8	2,627	16.9	530	11.3
1994	3,146	100.4	-11	-0.4	2,905	10.6	566	6.8
1995	3,338	101.1	-35	-1.1	3,123	7.5	592	4.6
1996	3,391	99.4	21	0.6	3,208	2.7	626	5.7
1997	3,614	97.6	88	2.4	3,538	10.3	666	6.4
1998	3,806	99.0	38	1.0	3,686	4.2	694	4.2
1999	3,702	93.7	250	6.3	3,780	2.6	718	3.5
2000	3,382	82.9	696	17.1	3,934	4.1	765	6.5
2001	3,762	92.4	309	7.6	3,849	-2.2	734	-4.1
2002	3,981	91.2	384	8.8	4,155	8.0	752	2.5
Average	3,299	95.5	156	4.5	3,262	6.6	631	4.7

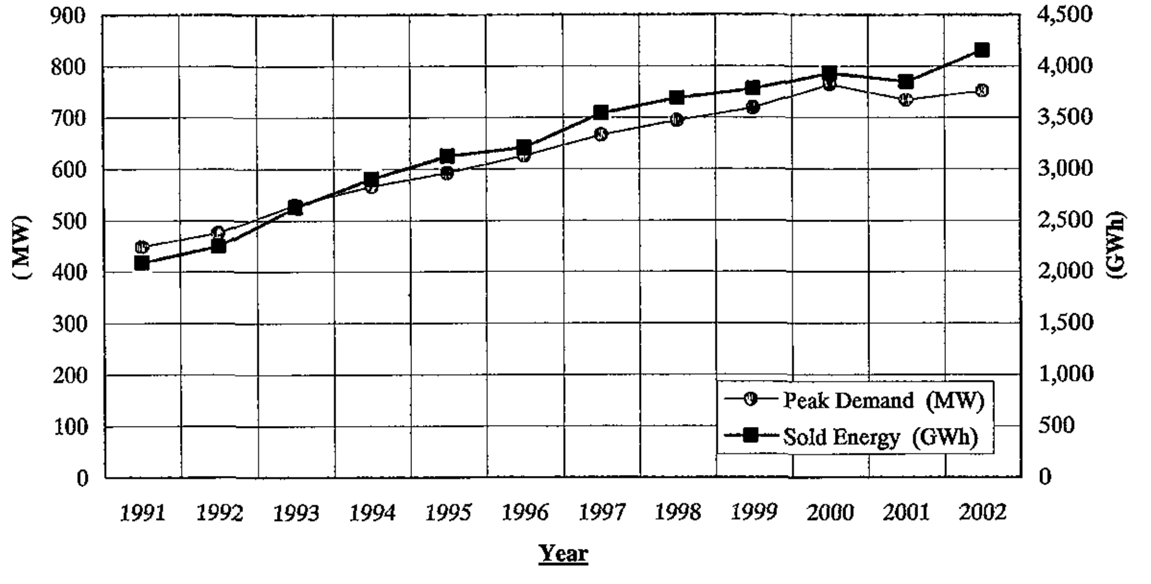

Fig.4.5 Electricity Generation of Past 12 Years

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Table 4.11 Actual Operating (Load) Pattern of Unidad de Transacciones (UT)

I. INYECCIONES

(Unit : MWh)

	Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Inyeccions	HIDRO	99	98	94	96	102	106	107	112	137	156	164	170	156	156	161	159	160	164	261	260	192	106	89	87
	GEO	63	63	63	63	63	63	63	63	63	63	63	62	62	62	61	61	62	62	62	62	62	62	62	63
	TERM	90	85	86	87	97	143	184	184	214	218	218	223	213	221	223	221	221	216	222	239	239	213	132	90
	GUAT-ES	58	58	59	59	58	60	68	103	112	125	124	128	130	125	129	125	118	98	90	89	90	95	96	83
	Total	310	305	302	305	321	372	423	462	526	561	569	583	561	563	574	566	559	540	635	650	583	477	379	323

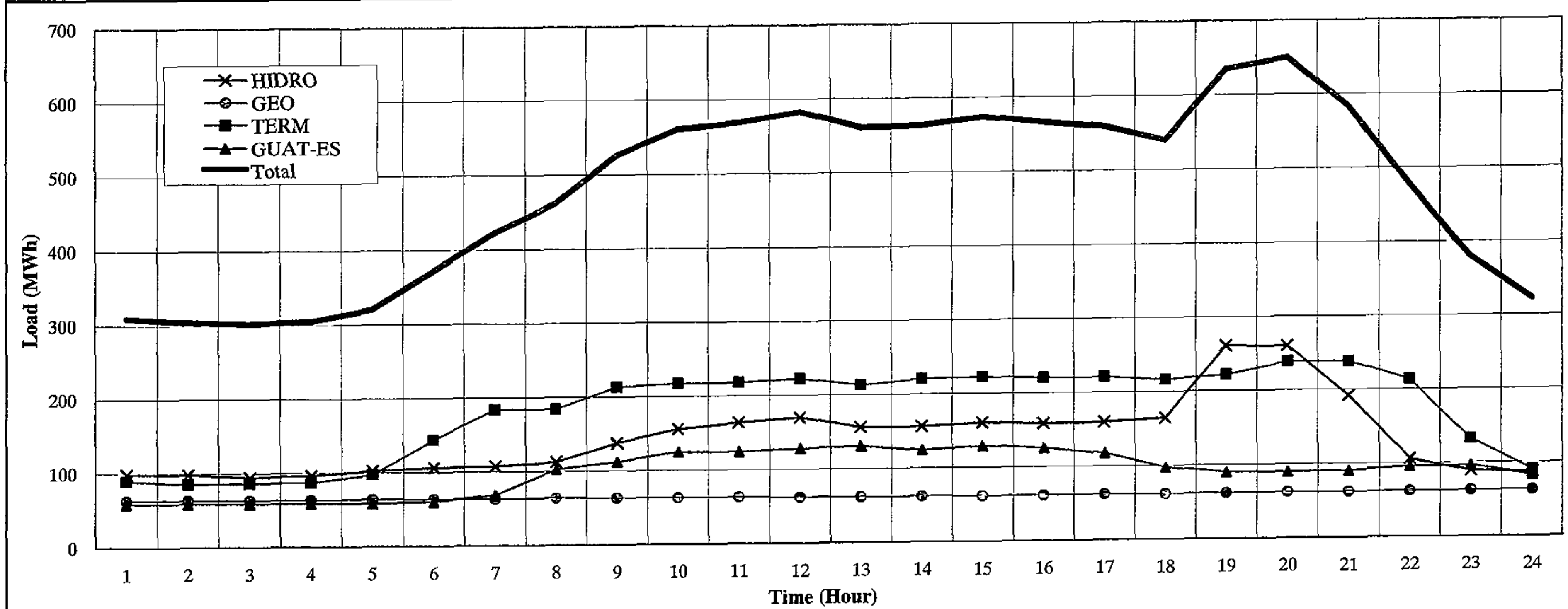

Fig.4.6 Actual Operating Pattern of UT

COMISION EJECUTIVA HIDROELECTICA DEL RIO LEMPA-CEL

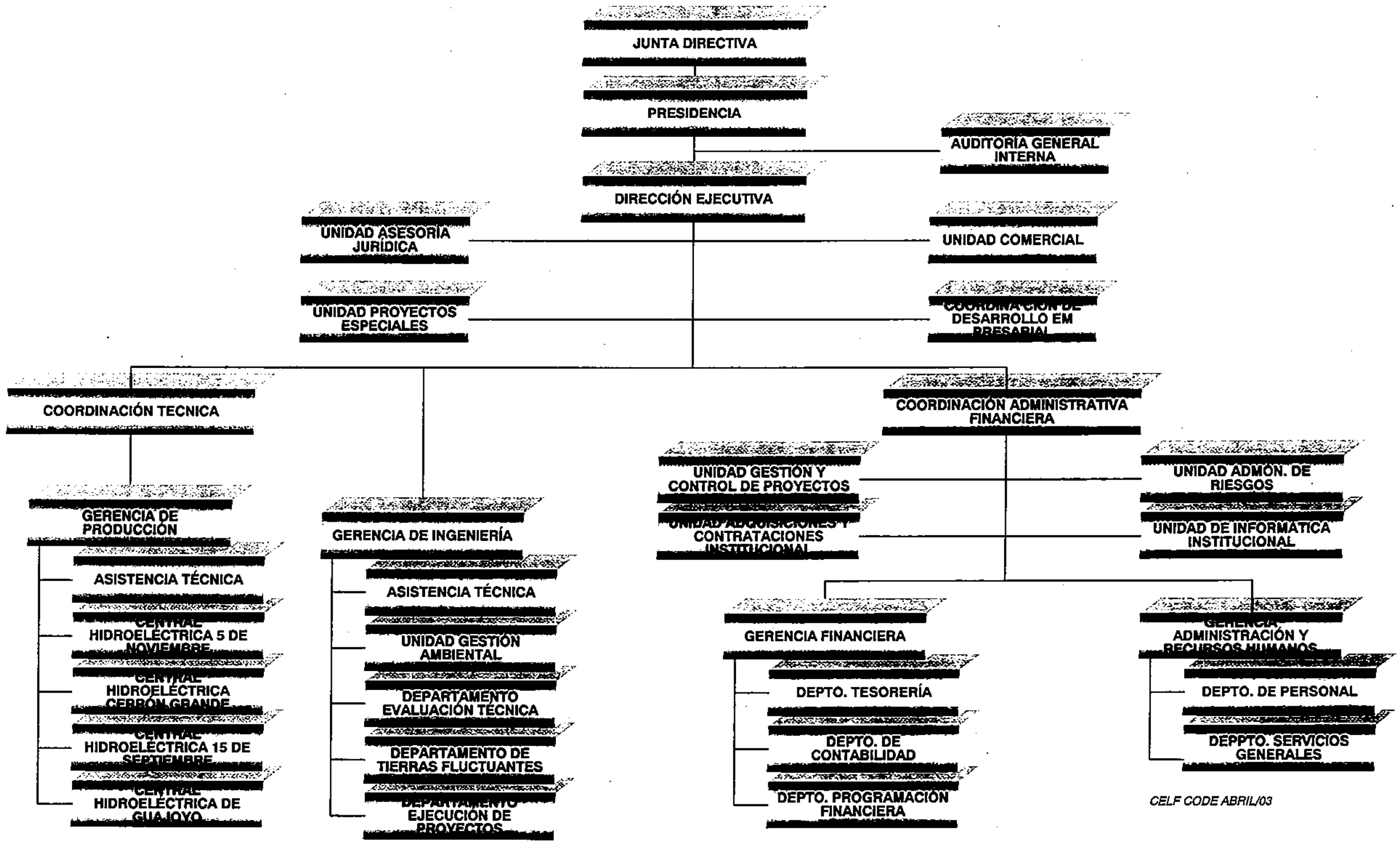

Fig. 4.1 Organization Chart of CEL

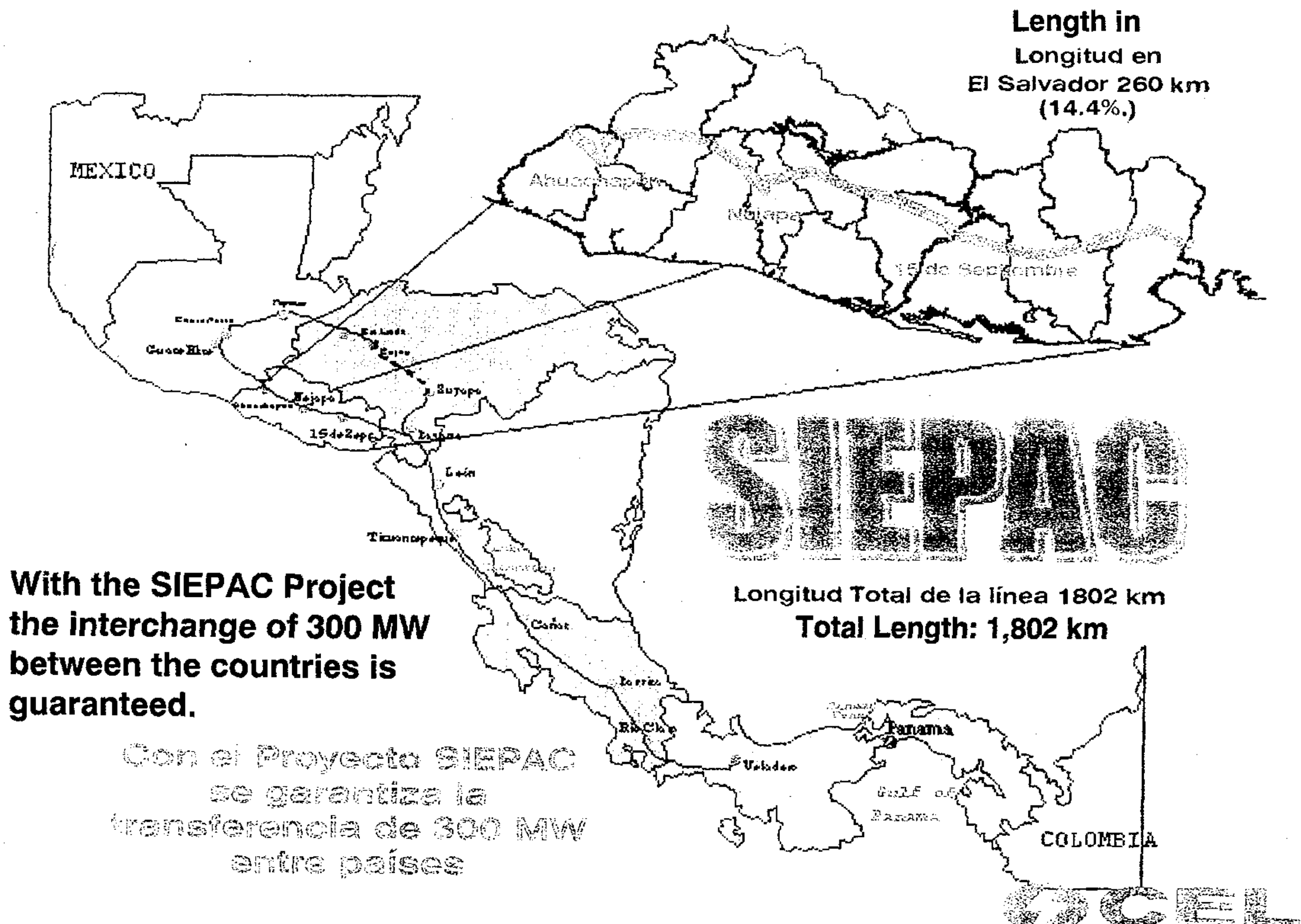

Fig. 4.2 Transmission Route

GENERAL SUPERINTENDENCE FOR ELECTRICITY AND TELECOMMUNICATIONS (SIGET)

Regulating Organization of the Electrical Sector

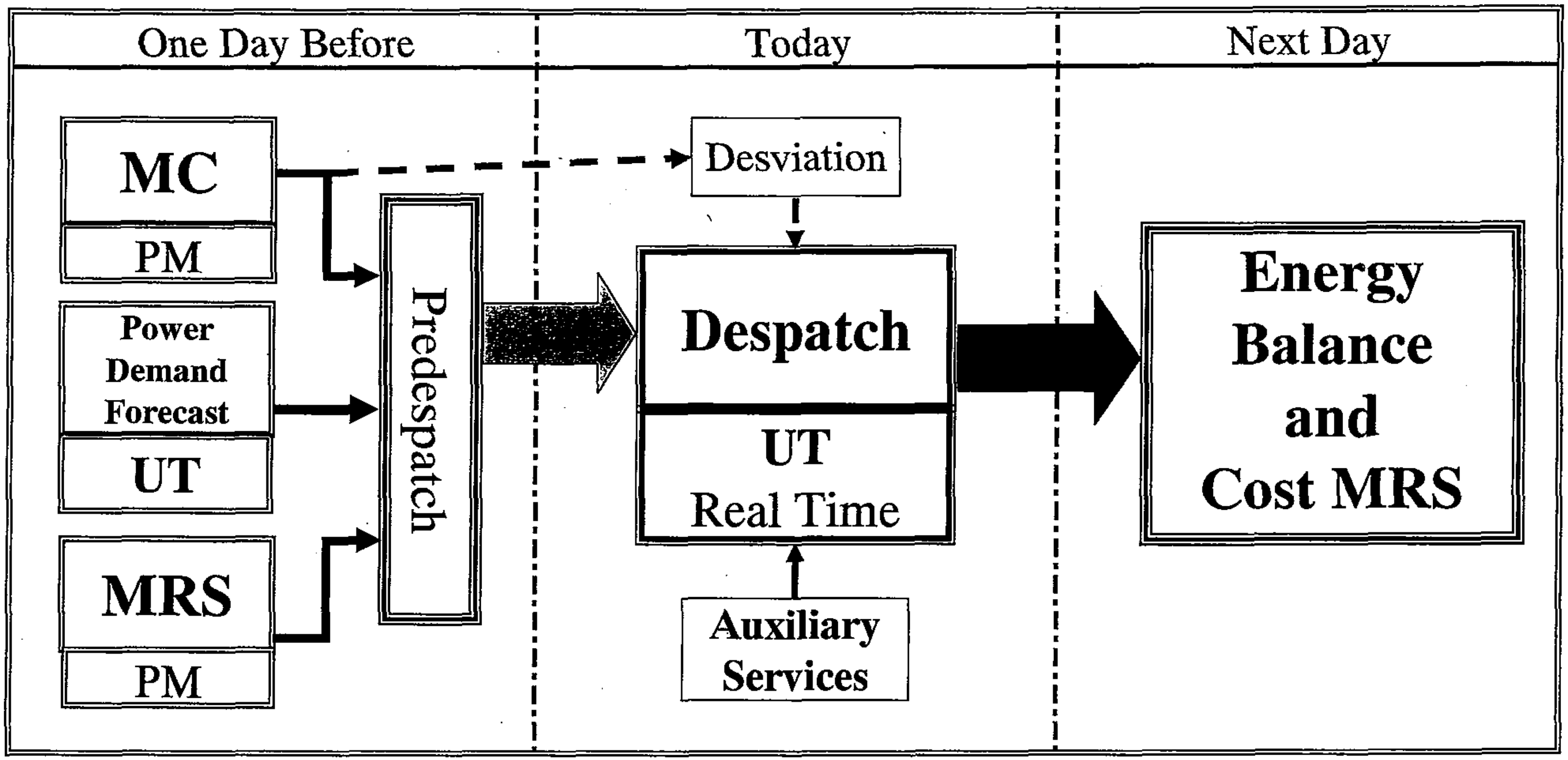

Fig. 4.3 Electric System of El Salvador (SIGET)

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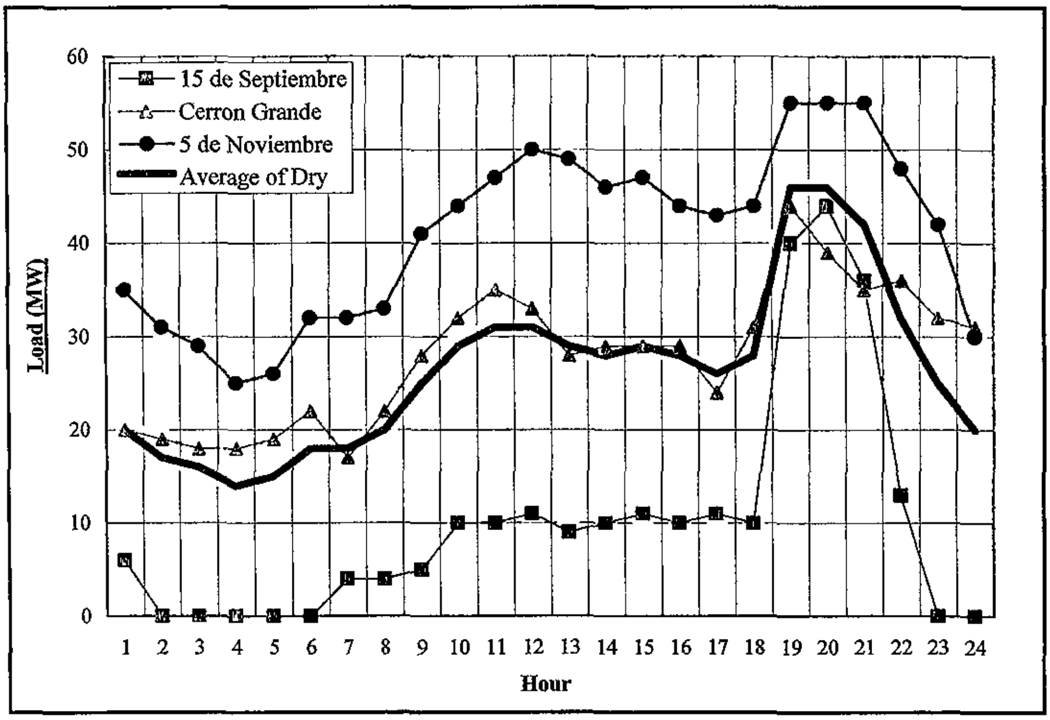
Dry Season : Nov.~Apr., 2000



Note : Guajoyo Hydro Power Station did not operated during 2000 because of renovation of Turbine-Generator.

Wet Season : May~Oct., 2000

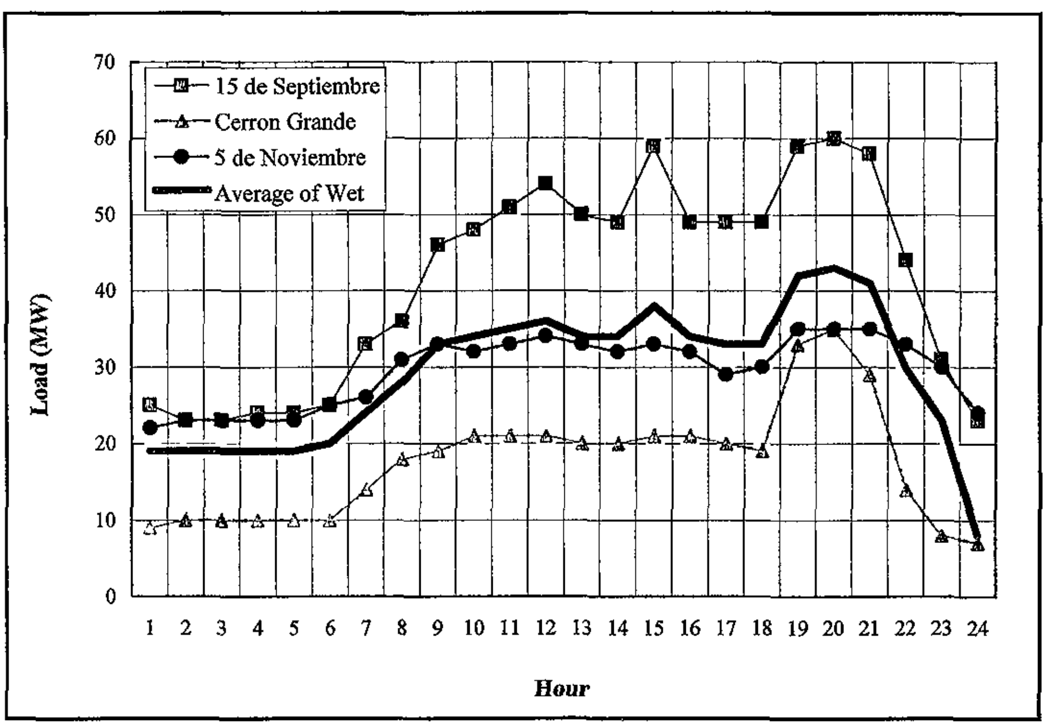


Fig. 4.7 Daily Load Curve in Hydro Power Station

5. POWER DEMAND FORECAST AND SUPPLY PLAN

CONTENTS

5. Power Demand Forecast and Supply Plan

5.1 Power Demand Forecast

5.1.1 Power Demand Forecast by CEL

CEL carried out a power demand forecast for 2003 to 2011 based on the actual power demand from 1991 to 2002. The growth rates of annual average energy and peak demand for the past twelve years were about 5.3% and 4.7%, respectively, as shown in Fig. 4.5.

According to the data on the demand forecast obtained from CEL, the annual average growth rates of the energy demand and the peak power during the ten years after 2002 are expected to grow at about 4.9% and 4.7% respectively as shown in Fig. 5.1 and Fig. 5.2. The reserve margin under the current power development plan, however, is expected to drop below the 10% level for kWh and kW in 2008. Therefore, new power development plans are necessary in light of an increasing pressure on the power demand and supply balance, which is expected after 2009.

5.1.2 Power Demand Forecast by Macroeconomic Forecast Method

(1) Method of Power Demand Forecast and Conditions

1) Method of forecast

To estimate the power demand, a macroeconomic forecast method is used with regard to the comprehensive nationwide power demand. In this method, a trend is derived from the actual demand trend of the past, and this serves as a basis for the estimation of the long-term nationwide power demand. Generally, a power demand forecast is carried out based on the premise that a strong relationship exists between an increase in power demand and an increase in income standards of customers, which is expressed in terms of GDP.

The following three approximate equations are available as effective methods in discovering the correlation between the power consumption and the economic potential.

(a) The primary regressive prediction method is used when a linear correlation has been found between the power demand and GDP.

(b) The parabolic regressive prediction method is used when a quadratic correlation has been found between the power demand and GDP.

(c) The multi-regressive prediction method is used when a linear correlation has been found among the power demand, population (i.e. the number of users), and GDP.

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Out of the above regression equations, the most suitable one for the power pattern in the target country - the primary regressive prediction method - was selected.

2) Conditions for Estimation

(a) Time series data and forecast of GDP

GDP data obtained from CEL are used as follows:

1995 ~ 2000: Actual (Average: About 3.5 %)

2001 ~ 2005: Expected (Average: About 4.2 %)

Macroeconomic Statistics

Year		1995	1996	1997	1998	1999	2000
CPI Inflation	(%)	11.40	7.40	1.90	4.20	4.25	4.30
Nominal GDP	(US$m)	9,500	10,358	11,192	11,989	12,467	13,217
Real GDP Growth	(%)	6.40	1.80	4.00	3.50	3.40	2.00
Deflector (2000 base)	(%)	84.3	89.0	92.1	95.8	96.2	100.0

Forecast Past ten (10) years

Year		2001		2002	2003	2004	2005
GDP Growth	(%)	3.00	4.00	3.80	4.30	4.80	5.10
Inflation	(%)	3.00	4.00	3.00	3.00	3.00	3.00

(b) Time series data and forecast of power demand

Data of power demand obtained from CEL are used as follows:

1991 ~ 2000: Record (Average about 5%)

2001 ~ 2011: Expected (Average about 5%)

(c) Peak power

The peak power in the system is calculated based on the forecasted energy demand, and the estimated load factor of around 63 ~ 64% is used.

(d) Estimation of GDP growth rate

The GDP growth rates, which are estimated on the long-term development outlook by the Government of El Salvador, are as follows:

Eighth 5-year Plan (2001 ~ 2005): 4.2%,

Ninth 5-year Plan (2006 ~ 2011):5.0%.

(2) The Primary Regressive Prediction Method Based on the Correlation with GDP

The above growth rates were used for the establishment of a base case (i.e. middle scenario), and a high scenario and a low scenario for sensitivity analysis were derived by adjusting the base case by ±1.0%. The results of the above study are shown in Fig. 5.3: Sensitivity Analysis of Power Demand Forecast.

The examined particulars of the primary regressive prediction method based on the correlation with GDP are shown on Appendix-5.1.

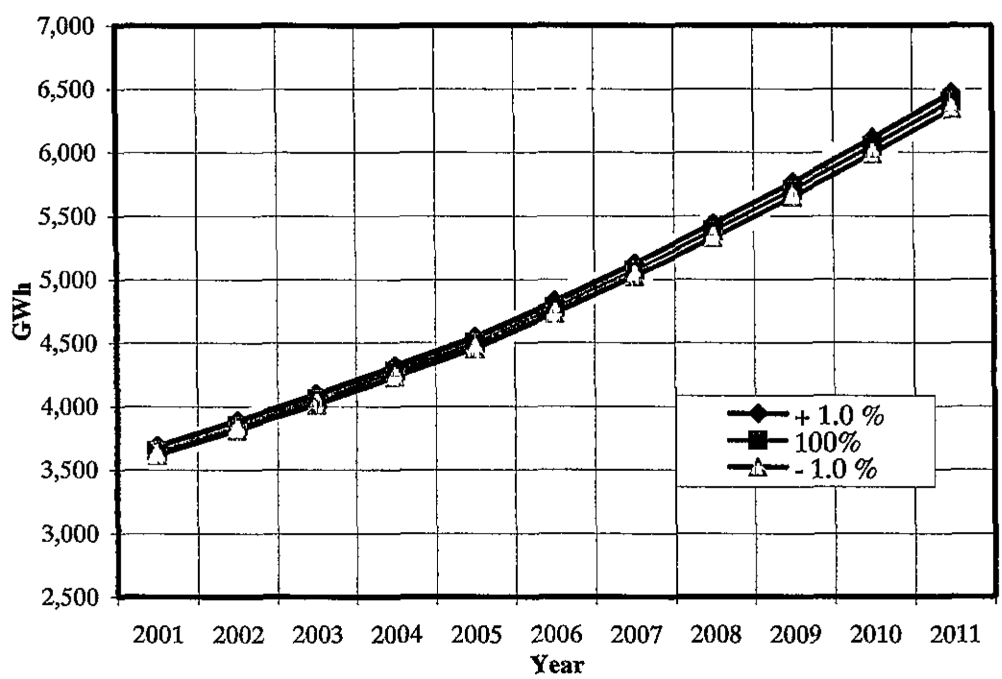

Fig. 5.3 Sensitivity Analysis of Power Demand Forecast

5.1.3 Result of Power Demand Forecast

According to the above study of the power demand forecast by CEL, annual energy is expected to increase from 4,088 GWh in 2001 to 6,629 GWh in 2011, while maximum power demand is expected to rise from 739 MW to 1,181 MW for the same period. Their annual average growth rates will be about 4.9% and 4.7% respectively.

The results of the simple regression equation for the base case (i.e. middle scenario) based on the correlation with GDP using the macroeconomic forecast technique, as shown in Fig. 5.4 and

Fig. 5.5, show an increase of about 3,652 GWh to 6,407 GWh for energy and an increase from 737 MW to 1,294 MW for the maximum power demand during the same period. And the annual average growth rate for both is about 5.8 %. Therefore, the power demand forecast by the macroeconomic forecast technique resulted in smaller numbers for energy and larger numbers for the maximum power compared to the those provided by CEL's forecast. However, it should be noted that both forecasts show the same trend pattern, and the forecast of CEL was concluded to be adequate. Therefore, the result of CEL's power demand forecast was adopted for the balance study of power demand.

5.2 Power Supply Plan

(1) Power Development Plan

The installed capacity as of the end of 2002 is 1,044.2 MW, excluding that of small power facilities (about 26 MW), as shown in Table 4.1. According to the power development plan made by CEL, the installed capacity of 2013 will be 1,629.1 MW, as shown in Table 5.3.. It is involved El Chaparral project which will be completed in 2010. The major development projects after 2001 are as follows:

1) Abolition of some facilities for Acajutla Thermal Power Station Project

   The abolition of two units of the existing thermal power plant led to a reduction in output of 74 MW (37 MW × 2 units). It was completed in 2001.

2) Renovation for 5 de Noviembre HydroPower Station Project

   By renovating the existing hydropower plant, the installed capacity rose 5 MW in one unit. It resumed its commercial operation after renovation in 2001.

3) Construction for Warsila Thermal Station Project

   Six internal-combustion engine units totaling 96 MW (each installed capacity: 16 MW) were installed at Acajutla. They were launched for commercial operation in 2001.

4) Renovation for 5 de Noviembre Hydro Power Station Project

   By renovating the existing hydropower plant, the installed capacity increased by 10 MW (5 MW × 2 units). It resumed its operation after renovation in 2002.

5) Abolition of part of facilities for Soyapago Thermal Power Station Project

   The abolition of three units at the existing thermal power plant has led to a reduction of 53.9 MW(16.7MW × 2 units + 20.5MW × 1 unit) in output. It was completed in 2002.

6) Abolition of part of facilities for San Miguel Thermal Power Station Project

The abolition of one unit at the existing thermal power plant has led a reduction in output of 25.3 MW(1 unit). It was completed in 2002.

7) Construction of additional facilities for Soyapago Thermal Power Station Project

The power output of three diesel engine units was boosted, leading to an additional output of 18 MW(6 MW × 3 units). It was completed in 2003.

8) Renovation for Cerron Grande Hydro Power Station Project

By renovating the existing hydro power plant, the installed capacity will increase 37 MW (18.5 MW × 2 units). It will put into commercial operation in 2003 and 2004, respectively.

9) Construction for Ateos Thermal Power Station Project

Installation of diesel engine units at Ateos will produce 54MW (18 MW × 3 units). They are scheduled for commercial operation in 2004.

10) Expansion for Berlin Geothermal Project

At the existing geothermal plant, one unit producing 27.5 MW will be added and put into commercial operation in 2005.

11) Renovation for 15 de Septiembre Hydro Power Station Project

By renovating the existing hydropower plant, the installed capacity will increase 11.7 MW in one unit. Their commencing year will be 2005.

12) Renovation for 15 de Septiembre Hydro Power Station Project

By renovating the existing hydropower plant, the installed capacity will increase 11.7 MW in one unit. It is scheduled for a 2006 completion.

13) Construction for El Chaparral Hydro Power Station Project

A main unit with an output of 64.4 MW and a sub unit producing 1.3 MV will be constructed at the El Chaparral Project Site. Their commercial operation is scheduled for 2010.

14) Construction for El Cimarron Hydro Power Station Project

A new hydro power station consisting of three units with an output of 81 MW each (combined capacity of 243 MW) is scheduled to commence its commercial operation in 2010.

15) Construction for San Vicente Geothermal Power Station Project

A new geothermal power plant with two units with 27.5 MW each (combined capacity of

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55 MW) is scheduled to start its commercial operation in 2013.

(2) Expansion Plan for Transmission Lines and Substations

According to the power development plan of CEL, the transmission line and substation plan related to the El Chaparral project is scheduled to be implemented in 2009. This, along with the SIEPAC plan involving six countries of Central America, serves as the core for the long-term power plan of El Salvador. The expansion plans of transmission lines and substations from 2001 to 2010 are shown in the Table 5.4 below.

Table 5.4 Expansion Plan for Transmission Lines and Substations

No.	Plan	Commercial Launch	Length (km)
1.	Honduras Interconnection		
	LT: 15 de Septiembre - Pavana, 230 kV, 2 CF/1C	Jul. 2002	93
	ST: 15 de Septiembre, 230 kV, 2 banks × 156MVA	Jul. 2002	
2.	SIEPAC Plan		
	LT: Guate-Este - Ahuachapn, 230 kV, 1 CF/1C	Feb. 2007	11
	LT: Ahuachapn - Nejapa, 230 kV, 1 CF/1C	Feb. 2007	78
	LT: Nejapa - 15 de Septiembre, 230 km, 1 CF/1C	Feb. 2007	85
	LT: 15 de Septiembre - Pavana, 230 km, 1 CF/1C	Feb. 2007	93
	ST: Nejapa, 230/115kV, 2 Banks × 156MVA	Feb. 2007	
3.	Reinforcement of Transmission Lines		
	LT: Ahuachapn - Nejapa, 230 kV, 1 CF/1C	Feb. 2007	93
	LT: Nejapa - 15 de Septiembre, 230 km, 1 CF/1C	Feb. 2007	95
4.	El Chaparral Plan		
	LT: El Chaparral - 15 de Septiembre, 115 kV, 1 CF/1C	Dec. 2009	43
	ST: El Chaparral, 115 kV	Dec .2009	
	ST: 15 de Septiembre, 115kV	Dec .2009	
5.	Voltage Compensate Condenser		
	ST: Nejapa, 115/46 kV, 1Bank × 10.8 MVAR	Sep. 2006	
	ST: Ateos, 115/46 kV, 2Banks × 10.8 MVAR	Sep. 2006	
	ST: Ozatlan, 115/46 kV, 3Banks × 10.8 MVAR	Sep. 2006	

Note: LT/ ST. Transmission / Substation 1CF/2CF. Single Line / Phase / Double Line / Phase
1C: 1 Circuit

5.3 Balance between Power Demand and Supply

The following Table 5.5 shows the balance between power demand and supply in El Salvador for the 1998-to-2002 period. It indicates that power demand is met by the electricity generated by the existing hydropower, thermal power geothermal facilities, as well as by imported power from another country. The reserve power margin of the past five years averaged 15%. The amount of imported power from another country (Guatemala) and distribution generators (IPP) are on the rise after 1999.

Table 5.1 and Figures 5.1 and 5.2 show the results of power demand and supply forecasts for the period after 2001 by CEL. According to them, the severity of the imbalance between power demand and supply is projected to grow after 2009, as the reserve margin (factor) will drop below 10% for kWh and kW in 2008. Therefore, new power development plans, including the current project plan under review should be required for the period subsequent to 2008.

Should an additional power be injected into the power system, several options are available, including the construction of a new hydropower project such as EL Chaparral by CEL, the importation of power from other countries, and new thermal power development of IPP. However, the thermal power plant development by the private sector would not be suitable for the following reasons:

- It needs to be in line with the energy policy of the country, including its measures to cope with environmental problems and initiatives for the promotion of alternative energy development replacing oil.
- Promptness and readiness are required for the operation and administration of power. In addition, a power source with adjustable load levels is needed to meet the change in the power system such as the frequency change and to administer measures when a power system accident takes place.

With regard to imported power, El Salvador will carry out the power interchange with countries other than Guatemala through the SIEPAC project. However, this option will not provide a good power supply source compared to the domestic development of hydro power, unless the following situations are cleared:

- Imported power needs to be cheap. If the cost of imported power is low, it will be used to supply a part of the base load, and domestic power will be used for the peak load, as this arrangement will result in higher reliability for power supply.
- If the cost of imported power is higher than that of the domestic power, imported power will be applied for the peak load, and, when this is the case, ways to ensure high reliability for power supply will be required.

As mentioned above, the examination of the balance between power demand and supply suggests that the development of hydro power projects should be positioned as a solid base that provides a very important power source to ensure reliability. This view is also supported by the following considerations:

- Hydro power is an alternative power source replacing oil and aids the prevention of the green heat gas effect.
- Deregulation of the electric utility industry
- Wide-range interchange of power by SIEPAC

Table 5.5 Balance between Power Demand and Supply (1998~2002)

Item	Energy (GWh)				
Year	1998	1999	2000	2001	2002
1). Power generated					
a). Hydro power stations	1,565.79	1,766.59	1,175.19	1,163.80	1,139.07
b). Thermal power stations	2,240.16	1,884.02	2,206.67	2,713.74	2961.28
Sub-total	3,805.95	3,650.61	3,381.86	3,877.54	4,100.35
2). Power consumed in station auxiliary. (%)	- 68.76 (-1.8%)	- 5.05*3 (-0.2%)	- 4.77*3 (-0.1%)	- 12.08*3 (-0.31%)	- 12.11*3 (-0.29%)
3). Power sent out (1 – 2)	3,737.19	3,645.56	3,377.09	3,865.46	4,088.24
4). Power received from distribution generators	--	--	52.10	5.60	2.10
5). Power received from other country	60.68	458.20	807.70	352.80	434.60
6). Power handled by the system (3 + 4 + 5)	3,797.87	4,103.76	4,236.89	4,223.86	4,524.94
7). Power exported to other country	- 22.72	- 207.79	- 111.70	- 43.80	- 50.70
8). Power loss in the system (%)	- 88.79 (-2.4%)*1	- 116.37 (-2.8%)*1	- 141.86 (-3.4%)*1	- 106.80 (-2.7%)*1	- 94.70 (-2.2%)*1
Total sales (6 – 7 – 8)	3,686.36*2	3,779.60*2	3,983.33*2	4,073.26*2	4,379.54*2

Note: *1: Loss of transmission only
*2: Selling energy at demand terminal
*3: *Power consumed in stations of CEL only*

5.4 Timeframe for El Chaparral Project

The year in which the El Chaparral project becomes commercially operational should be decided from a viewpoint of the balance between power demand supply, while considering the results of power supply plan and power demand forecasts for the past 10 years. Thus, it is essential for the

El Chaparral project to be fully operational by 2010. This timeframe is strongly recommended, as this will allow a more suitable power reserve margin (factor), contributing to more stable power supply.

Table 5.1 Trend of Energy & Power Demand

Year	Energy Demand (GWh)	Peak Demand (MW)	Ehergy Availability (GWh)	Peak Availability (MW)	Surplus (GWh)	Surplus (MW)
2000	3,931	712	5,434	984	1503 (38%)	272 (38%)
2001	4,088	739	5,123	926	1035 (25%)	187 (25%)
2002	4,229	763	5,252	948	1023 (24%)	185 (24%)
2003	4,397	793	5,705	1,028	1308 (30%)	236 (30%)
2004	4,597	827	5,705	1,027	1108 (24%)	199 (24%)
2005	4,823	867	5,919	1,064	1096 (23%)	197 (23%)
2006	5,083	912	5,919	1,062	836 (16%)	150 (16%)
2007	5,358	960	5,919	1,061	561 (10%)	101 (11%)
2008	5,650	1,011	6,140	1,098	490 (9%)	88 (9%)
2009	5,959	1,064	6,363	1,137	404 (7%)	72 (7%)
2010	6,285	1,121	6,363	1,135	78 (1%)	14 (1%)
2011	6,629	1,181	7,223	1,287	594 (9%)	106 (9%)
Aveage	5,086	913	5,922	1,063	836 (16%)	151 (16%)

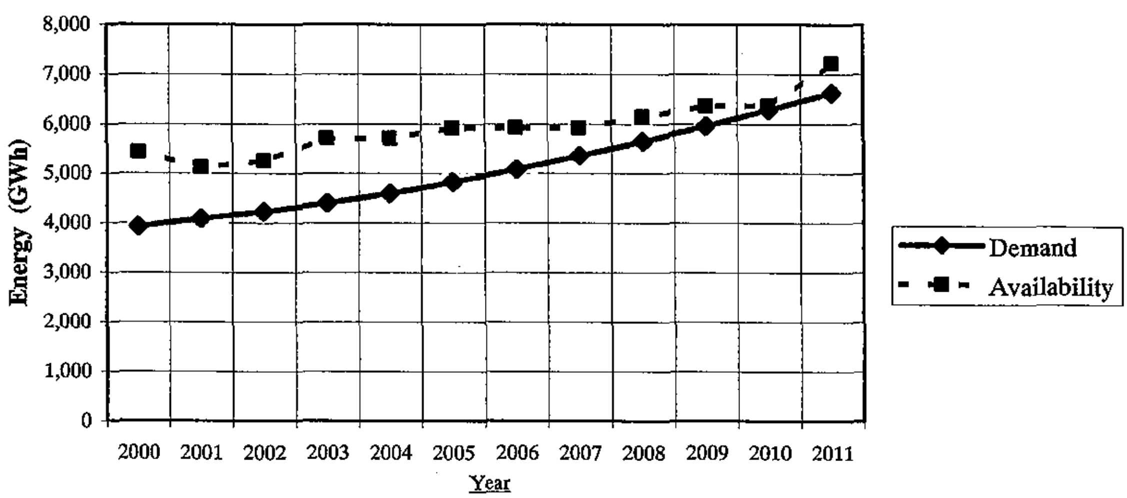

Fig.5.1 Trend of Energy Demand

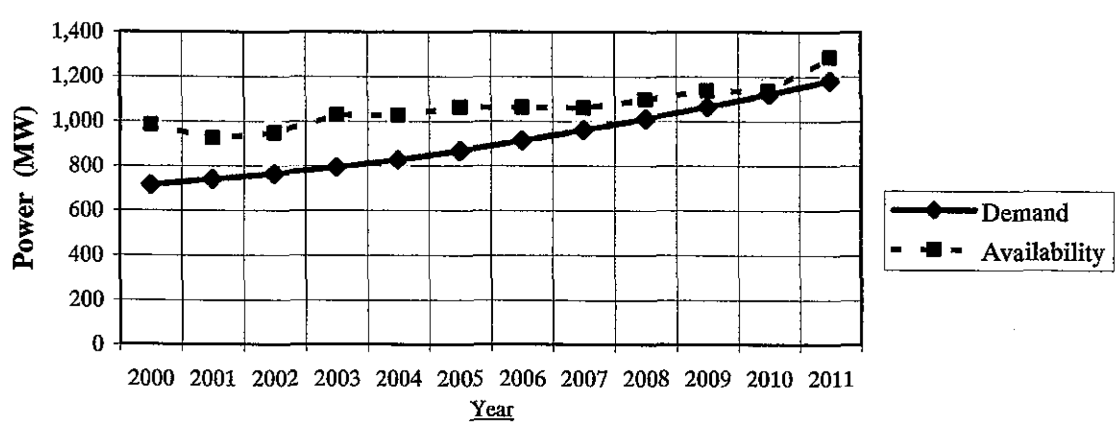

Fig.5.2 Trend of Power Demand

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Table 5.2 Trend of Energy & Power Demand (Simple Regression Equation)

Year	Energy Demand (GWh)	Peak Demand (MW)	Ehergy Availability (GWh)	Peak Availability (MW)	Surplus (GWh) (%)	Surplus (MW) (%)
2001	3,652	737	5,123	926	40	26
2002	3,851	778	5,252	948	36	22
2003	4,059	819	5,705	1,028	41	25
2004	4,276	863	5,705	1,027	33	19
2005	4,502	909	5,919	1,064	31	17
2006	4,782	965	5,919	1,062	24	10
2007	5,076	1,025	5,919	1,061	17	4
2008	5,385	1,087	6,140	1,098	14	1
2009	5,709	1,153	6,363	1,137	11	-1
2010	6,050	1,221	6,363	1,135	5	-7
2011	6,407	1,294	7,223	1,287	13	-1
Aveage	4,886	986	5,966	1,070	24	10

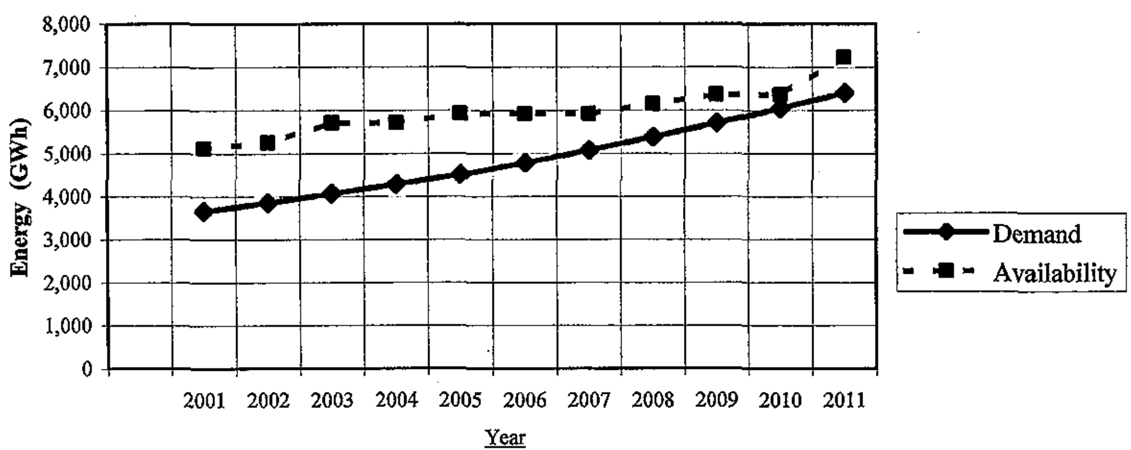

Fig.5.4 Trend of Energy Demand (Simple Regression Equation)

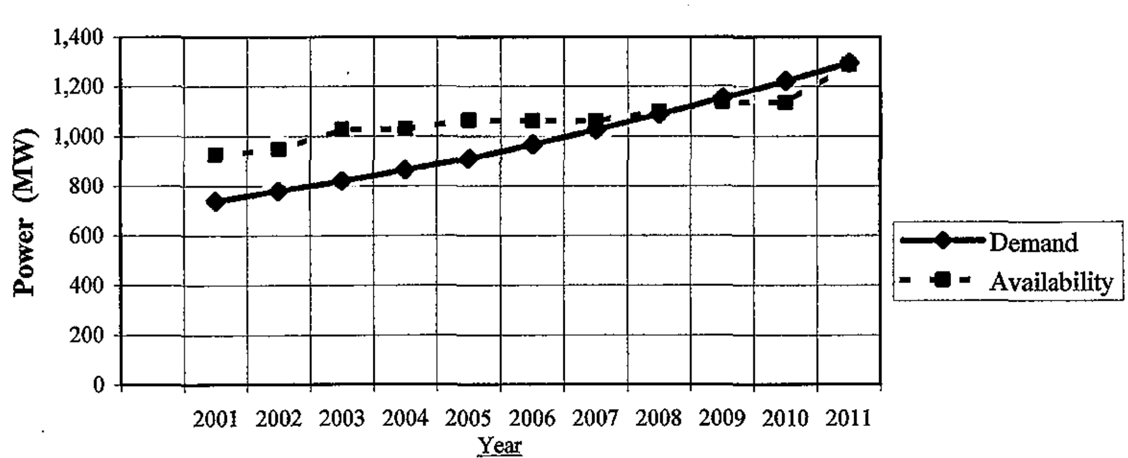

Fig.5.5 Trend of Power Demand (Simple Regression Equation)

Table 5.3 Power Development Plan

Year of Commercial Operation	Name of Projects	Unit (No.) × (MW)	Total Installed Capacity (MW)
2000	Installed Capacity	Total	1,147.7
2001	Removeal of unit 3 and 4 of Acajutla Thermal Power Plants	- 2 × 37	- 74
	Installation of 3 units Warsila DG16 MW in Acajutla.	6 × 16	96
	Renovation in 5 MW 5 de Noviembre Hydroelectric P/S	1 × 5	5
2002	Renovation in 10 MW for 5 de Noviembre Hydroelectric P/S	2 × 5	10
	Removeal of unit 1, 2 and 3 of Soyapango	- 2 × 16.7 and - 1 × 20.5	-53.9
	Removeal of unit 1 of San Miguel Thermal Power Plant	- 1 × 25.3	- 25.3
2003	Renovation in 18.5 MW Cerrón Grande Hydroelectric P/S	1 × 18.5	18.5
	Installation of 3 units Warsila DG6 MW in Soyapango	3 × 6	18
2004	Renovation in 18.5 MW Cerrón Grande Hydroelectric P/S	1 × 18.5	18.5
	Installation of 54 MW Ateos Thermal P/S Diesel Engines)	3 × 18	54
2005	Installation of 1 unit 27.5 MW in Berlin Geothermal Power Plant	1 × 27.5	27.5
	Renovation in 11.7 MW for 15 de Septiembre Hydroelectric P/S	1 × 11.7	11.7
2006	Renovation in 11.7 MW for 15 de Septiembre Hydroelectric P/S	1 × 11.7	11.7
2007			
2008			
2009			
2010	El Chaparral Hydroelectric Power Station	1 × 64.4 + 1 × 1.3	65.7
	El Cimarron Hydroelectric Power Station	3 × 81	243
2011			
2012			
2013	San Vicente Geothermal Power Plant	2 × 27.5	55
	Total		1,629.1

Source : Prepared by CEL except El Chaparral hydro electric power station

Note :
1) Honduras – El Salvador interconnection line was operated since July, 2002
2) SIEPAC interconnection line will be to operate in May, 2007.
3) Escenario de demanda media (2000 – 2004: 3.83 %, 2005 – 2009: 5.78 %,2010 – 2014: 5.32 %)

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6. METEOROLOGY AND HYDROLOGY

(25 (126R)

CONTENTS

(27 (1282)

6. Meteorology and Hydrology

6.1 Outline

6.1.1 Topography

In terms of the topography, the Torola River basin around the confluence with the Lempa River is characterized as a gentle hill region, but around the area of its peak elevation near the area where the river originates is a steep mountain region. The highest elevation point along the River is around the river source in Honduras and is about 1,900 m above sea level, while the lowest point is the confluence with the elevation of about 60 m above sea level.

Geological conditions show that volcanic rocks and volcaniclastic rocks of the Cenozoic age underlies almost all parts of the river basin; therefore, there is no significant variance from the viewpoint of the runoff of rainfalls given the geology of the basin. The same thing can also be said from the viewpoint of the vegetation of the basin, as there is no significant difference in land use based on the observation of the relatively even distribution of forests, cultivated fields and grass fields.

6.1.2 Meteorology and Hydrology

The Torola River basin, with two distinct seasons of a dry season from November to April and a rainy season from May to October, is the region noted for a heavy annual rainfall when compared with different points of El Salvador. Its rainfall in December, January and February, the season with the least amount of rains throughout the year, is almost zero. In June and September, the peak of the rainy season, the monthly rainfall reaches the level between 300 and 500 mm. Rainfalls in the rainy season are orographic rainfalls caused by trade winds from the Pacific Ocean that reaches the northern mountain slope. The annual rainfall in the basin varies from 1,200 to 2,900 mm. The past history of annual rainfalls and the isohyetal map of annual rainfalls are shown in Fig. 6.1 and Fig. 6.2 respectively.

Heavy rainfalls that cause floods in the basin are non-orographic rainfalls associated with hurricanes from the Caribbean Sea. Most hurricanes which affect El Salvador originate in the Caribbean Sea and land on Guatemala or Honduras. Since most of these hurricanes change their route directions to the north before traveling towards El Salvador, hurricanes seldom reach El Salvador. And they often scale down to the level of tropical storms when they approach El Salvador.

Temperatures fluctuate little throughout the year. The daily average temperature in the lowlands (250 m asl) generally ranges from 25°C to 30°C and the highlands (1,200 m asl) from 19°C to 23°C.

6.2 Meteorological and Hydrological Gauging

The Project site is located between the middlestream and downstream zones of the Torola River. There are several meteorological stations, along with the Osicala hydrological gauging station (Osicala GS) in and around the project basin, as shown in Fig. 6.3. Table 6.1 shows items measured and measurement periods of the main stations. The monthly rainfall has been computed for the periods for which no records are available by using the correlation among the rainfall stations. The monthly rainfall between January 1942 and December 1997 has been provided in the pre-F/S.

The riverflow measurement was carried out at Osicala GS from February 1962 to April 1980, and it started measurement again in August 1998 after it was reinstalled.

The sampling of suspended sediment has been carried out since 1969 (1969~1980, 1998~).

Historical monthly rainfall records, historical monthly mean discharge records and historical records of the sampling of suspended sediment are shown in Appendix 6.1, Appendix 6.2 and Appendix 6.3, respectively.

6.3 Riverflow at the Project Site

6.3.1 Necessity of Installation of a New Hydrological Gauging Station

As explained before, riverflow records at Osicala GS are used for the discharge estimation at the project site. Also, the applicability of the records taken at Osicala GS to the discharge estimation at the project site was verified, and the necessity of installation of a new hydrological gauging station near the project site was examined. After the examination, it was concluded that the installation of a new gauging station was not necessary. Reasons for the conclusion are as follows:

(1) Osicala GS and the project site are located in the upstream and the downstream of the same river respectively.

(2) Geological conditions and vegetation conditions in the upstream and the downstream basins are similar to each other (see Fig. 6.4 and Fig.6.5).

(3) The difference between the catchment area of Osicala GS and that of the project sites is not significant.

(4) Because conditions of (1), (2) and (3) are satisfied, it is possible to estimate the discharge at the project site based on the discharge at Osicala GS, which can be scaled up or down in proportion to the size of the catchment area of the project site.

(5) Since there are data of about 20 rainfall stations within and around the project site basin, it is possible to improve the precision of the discharge estimation mentioned above.

(6) Even if there is some difference in runoff characteristics between Osicala GS's basin and the project site's basin, the difference in the characteristics does not affect the energy output of the project, because the project is planned as a reservoir type power, which is capable of reducing seasonal discharge fluctuations.

6.3.2 Examination of Riverflow Record at Osicala GS

In the FS stage, the monthly rainfall data of nine stations (5204, U070, Z03, Z04, Z05, Z07, Z08, Z12 and Z13) between January 1942 and December 2000 were completed. In this estimation, the monthly rainfalls for which no records were available were estimated from other rainfall station data noted high correlation. Appendix 4 shows the extended monthly rainfall for each rainfall stations and monthly average rainfall over the Osicala basin. The monthly average rainfall for the Osicala basin was calculated from the data of the nine rainfall gauging stations based on the Tiessen method (Jan. 1942~Dec. 2000).

The runoff at the project site was made based on the actual riverflow records and on the correlation between the monthly rainfall and the monthly riverflow, which supplements the riverflow data. The runoff estimation was carried out as follows:

(1) Examination and Modification of Riverflow Records

1) Examination of Riverflow Records

Monthly riverflow records at Osicala GS are available for several months (February 1962~April 1980, August 1998~December 2000). An examination of these riverflow records at Osicala GS was carried out.

Fig. 6.6 shows a double mass curve that shows the relationship between monthly rainfall records and monthly riverflow records at Osicala GS between February 1962 and April 1980. The rainfall of the double mass curve is the average rainfall over Osicala GS basin estimated by the Thiessen Method based on the data of the nine rainfall stations

(5204, U070, Z03, Z04, Z05, Z07, Z08, Z12, Z13). There is a change in the slope of the curve around 1968. This means that either monthly rainfall records or monthly riverflow records are inhomogeneous and/or either records previous to 1968 or records after 1969 are inhomogeneous). In order to examine which records of the monthly rainfall or monthly riverflow are inhomogeneous, the monthly riverflow records at 0101 GS were submitted in addition to the monthly rainfall and monthly riverflow at Osicala GS. The following two additional double mass curves were graphed:

- A double mass curve depicting the relationship between the monthly rainfall and the monthly riverflow at 0101 GS (Fig. 6.7)
- A double mass curve showing the relationship between the monthly riverflow at Osicala GS and the monthly riverflow at 0101 GS (Fig. 6.8)

The riverflow gauging station of 0101 GS was selected for the following four reasons:

- It is located in Grande San Miguel near the Torola River.
- It has monthly riverflow records before and after 1968, when the change in the slope developed.
- There is no dam further up the riverflow gauging station.
- Its catchment area is 1,074 km^2, almost the same as that of Osicala GS.

It was concluded that the monthly riverflow at Osicala GS was found to be inhomogeneous, because the two double mass curves, i.e., the double mass curve showing the relationship between the monthly riverflow at Osicala GS and the monthly riverflow at 0101 GS and another depicting the relationship between the monthly riverflow at Osicala GS and the monthly rainfall, have a change in the slope of the curve around 1968 whereas no change in the slope of the curve around 1968 was observed in the double mass curve showing the relationship between the monthly riverflow at 0101 GS and the monthly rainfall.

Furthermore, in order to examine which periods of records, i.e., the records previous to 1968 or records after 1969, of the monthly riverflow at Osicala GS were inhomogeneous, the records of the monthly riverflow at Osicala GS between 1998 and 2000 were submitted in addition to the monthly riverflow between 1962 and 1980. Then a double mass curve showing the relationship between the monthly rainfall and the monthly riverflow at Osicala GS including the records between 1998 and 2000 was graphed (Fig. 6.9). Here, the rainfall of the double mass curve were based on the records of the rainfall station Z-13. In Fig. 6.9, the double mass curve was graphed only with the rainy season data because the rainfall data of the rainy season between 1998 and 2000 are the only ones available. Since it is obvious from Fig. 6.9 that a slope of the curve after 1969 is almost the same as the one after 1998, the riverflow records at Osicala GS previous to 1968 were concluded to be inhomogeneous.

2) Modification of Riverflow Data

The heterogeneity of the riverflow data was corrected as follows based on the examination of the riverflow records depicted in the double mass curves:

- Calculate the slopes before and after the change in slope in Fig. 6.6.
- Multiply the discharge data before the change by the following constant number so that the slope before the change fits to the slope after the change.

Constant number = (the slope after the change) / (the slope before the change) = 0.73

(2) Examination of Correlation between Riverflow and Rainfall

Fig. 6.10 shows a regression line showing the correlation between the monthly rainfall and the monthly riverflow at Osicala GS from 1962 to 1980. Fig. 6.11 shows a regression line between the monthly rainfall in the rainy season and the monthly riverflow in the rainy season at Osicala GS from 1962 to 1980, while Fig. 6.12 depicts a regression line between monthly rainfall in the dry season and the monthly riverflow in the dry season at Osicala GS from 1962 to 1980. The correlation factors of these regression lines are 0.697, 0.581 and 0.164, and it is considered that the monthly discharge, especially the discharge in the dry season, was not estimated accurately based on the correlations.

6.3.3 Estimation of Monthly Discharge by Tank Model Method

As mentioned above, it became clear that efforts to complement the riverflow records by correlations are not adequate from the viewpoint of accuracy. Consequently, the application of the Tank Model was studied to replace the correlation method.

(1) Rainfall-Runoff Analysis by Tank Model Method

The Tank Model Method was developed by Masami Sugawara in 1968, and it is a runoff calculation method in which the river basin is replaced by tanks equipped with several outlets on their sides and the bottom. Rainwater is put into the top tank. A part of the water in each tank flows through the side outlets. The remainder of the water travels down to the next lower tank through the bottom outlet. The total flow from the side outlet of each container is the riverflow. Fig. 6.13 shows the concept of the tank model and runoff system which represents aquifer structure. Fig. 6.14 shows procedures for the runoff analysis.

(2) Procedures for Rainfall-Runoff Analysis by Tank Model Method

1) Development of Runoff Model

The runoff model with tanks is prepared by determining the structure of tanks and the runoff coefficient of the outlets of the tanks through coinciding the monthly runoff derived from the model with the actual monthly riverflow records, including the shape of the unit hydrograph.

2) Conditions of Calculation

a) Period of Calculation

In the development of the model, the monthly discharge, monthly rainfall and monthly evapo-transpiration records between January 1970 and December 1975 were used. Data for this period was selected for the development for the following reasons:

- Successive records of the monthly rainfall and monthly discharge exist for the longest term in this period.
- A rainy year and a dry year are included in this period.

b) Mean Monthly Evapo-Transpiration

The mean monthly evapo-transpiration was estimated as follows:

- Potential evapo-transpiration was estimated by the Penman equation, and the annual potential evapo-transpiration over the Torola basin was estimated to be 1,500 mm based on "Potential evapo-transpiration in El Salvador, August 1985".
- It was assumed that the monthly potential evapo-transpiration over the Torola basin was the monthly potential evapo-transpiration at Santiago de Maria, because its annual potential evapo-transpiration of 1,457 mm is almost the same as the 1,500 mm for the Torola basin.
- Table 6.2 shows the mean monthly rainfall and the monthly potential evapo-transpiration over the Torola basin. When the mean monthly rainfall was smaller than the monthly potential evapo-transpiration, the evapo-transpiration was assumed equal to the monthly rainfall, because the monthly rainfall is the only moisture to evaporate. On the other hand, when the monthly rainfall is larger than the monthly potential evapo-transpiration, the monthly evapo-transpiration was assumed equal to the monthly potential evapo-transpiration because there is enough moisture to evaporate. Therefore,

the monthly evapo-transpiration was estimated as shown in Table 6.2, and the annual evapo-transpiration was estimated to be 873 mm.

- The mean annual evapo-transpiration between January 1962 and December 1979, which was assumed to show the difference between the annual rainfall and the annual discharge at Osicala GS, was 901 mm, and it is almost equal to the 873 mm mentioned earlier. Therefore, the estimated evapo-transpiration is considered adequate.

Table 6.2 Monthly Evapo-Transpiration (mm)

	Monthly Rainfall A	Monthly Potential Evapo-Transpiration B	Monthly Evapo-Transpiration Min (A, B)
January	3	122	3
February	3	123	3
March	24	149	24
April	70	144	70
May	272	131	131
June	374	113	113
July	220	134	134
August	272	131	131
September	419	95	95
October	287	108	108
November	56	99	56
December	5	108	5
Total	2005	1,457	873

(3) Results of Calculation

1) Suitability of the Runoff Model

Fig. 6.15 shows the actual riverflow data and the simulated runoff data by the tank model. Fig. 6.16 shows a correlation between the actual riverflow data and the simulated runoff by the tank model. The correlation factor between the two data, R2, was 0.854, indicating that the developed tank model reproduced the runoff characteristics of the basin relatively well.

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6.3.4 Estimation of Runoff at the Project Site

The monthly runoff at Osicala GS was estimated by inputting, to the developed tank model, the monthly rainfall from January 1942 to December 2000 and the mean monthly evapo-transpiration. Actual riverflow records were used when such data was available in the estimation prior to the evaluated data.

The monthly discharge at Osicala GS was transposed to the monthly discharge at the project site by taking into account the catchment area and the mean annual rainfall of the project site. The catchment areas and the annual rainfall in the basins are shown in Table 6.3.

Table 6.3 Catchment Area and Annual Rainfall for Basins

	Catchment Area (km^2)	Annual Rainfall for Basins (mm)
Osicala	862	2,005
La Honda	1,065	2,169
El Chaparral	1,233	2,145

The monthly discharges at Osicala GS and the project sites are shown in Appendix 6.5 and Appendix 6.6. Duration curves at Osicala GS and the project sites are shown in Fig. 6.17 and Fig. 6.18. Table 6.4 and Fig. 6.19 show mean monthly discharge at Osicala GS and project sites. Table 6.4 also shows 95% probable monthly discharge.

Table 6.4 Mean Monthly Discharge and 95% Probable Discharge (Unit : m^3/sec)

	Osicala	La Honda	El Chaparral
January	3.2	4.2	5.0
February	2.5	3.3	3.8
March	3.5	4.7	5.4
April	5.3	7.1	8.1
May	27.8	37.2	42.6
June	61.9	82.7	94.7
July	36.0	48.1	55.0
August	40.0	53.5	61.2
September	94.9	126.8	145.2
October	68.8	91.9	105.2
November	19.9	26.6	30.5
December	5.7	7.6	8.8
Total	30.9	41.2	47.2
Q 95%	1.4	1.8	2.0

6.4 Flood Discharge at the Project Site

6.4.1 Probable Maximum Flood (PMF)

It is reasonable to adopt PMF (Probable Maximum Flood) as the design flood discharge for the dam design from the viewpoint of the economical and social importance. PMF is defined as the maximum flood that may happen in an area. PMF is estimated by the following procedures:

(1) Probable Maximum Flood (PMF)

- Estimation of Probable Maximum Precipitation (PMP)
- Development of Unit Hydrograph
- Estimation of PMF

1) Probable Maximum Precipitation (PMP)

PMP is roughly classified into orographic PMP and non-orographic PMP. The PMP in the project basin is non-orographic PMP caused by hurricanes from the Caribbean Sea. PMP was computed based on two models.

a) Hurricane Model

The Hurricane Model was developed by the National Weather Service (NWS) in 1968. It calculates rainfall time history distribution for the time periods in which hurricanes pass over the basin by assuming a concentric circular rainfall distribution, a hurricane route and migratory speed. The National Oceanic and Atmospheric Administration (NOAA) provides some information on hurricane which approaches near El Salvador as indicated below.

- There was no record of hurricane which hits the land of El Salvador directly.
- Four hurricanes approached near El Salvador in the period between 1921 and 2001 (1934, 1935, 1988, 1998).
- Among them, Hurricane Mitch approached nearest to El Salvador, in September 1998.
- It can be anticipated that hurricanes would not approach near El Salvador, and when they come closer, the scale of hurricanes is reduced to that of tropical storms.
- The speed of hurricanes which approach near El Salvador is in the range of 10 to 25 km/hr.

A Hurricane Model for PMP in the project basin was estimated based on the following:

- For assumptions used in the Hurricane Model, the route which Hurricane Mitch traveled was adopted, but, taking into account that no Hurricane has hit El Salvador, the route was shifted towards the border area between El Salvador and Honduras. (Fig. 6.20).
- The scale of the Hurricane Model was assumed to have a center pressure of 950 hp, which is the same as Hurricane Mitch when it transformed itself into a tropical storm, based on the fact that no full-scale hurricane has approached near El Salvador except for tropical storms.
- The speed of the Hurricane Model was assumed to be 8 km/hr, taking into account the past hurricane speed records.

Conditions for computing PMP estimation by Hurricane Model were set as follows:

- 5-kilometer grids were placed in east-west and north-south directions, and calculation intervals were set at 1 hour.
- The wind adjustment factor was set at 0.6 based on the report entitled "Preliminary Memorandum HUR 7-79 and Memorandum 7-79A" by the NWS.
- The ocean temperature adjustment factor was set at 1.0, because seawater temperatures in the Caribbean Sea and the Pacific Ocean near El Salvador are almost the same from July through September when many hurricanes are generated.
- The orographic adjustment factor was set at 1.3 based on the fact that

  (mean annual rainfall over Torola basin) / (mean annual rainfall over Pacific Ocean coast of El Salvador) = 2,150 mm / 1,700 mm = 1.26≒1.3
- The overall adjustment factor was calculated as follows

  Overall adjustment factor = 0.6 x 1.0 x 1.3 = 0.78

  Fig. 6.21 shows PMP at El Chaparral. The 24-hour PMP at La Honda and El Chaparral are 502 mm and 486 mm respectively.

2) Estimation of PMP by Hershfield Method

In order to confirm the estimated PMP by the Hurricane Model, estimation of PMP by the Hershfield Method was carried out. The Hershfield Method was developed by Hershfield in 1965, and it is a method to estimate the 24-hour PMP based on the annual maximum 24-hour rainfall. A rainfall station of Z05 has 24-hour rainfall records for a comparatively long period, and PMP was estimated based on the records of this station.

As a result, 24-hour PMP by the Hershfield Method was 477 mm. The PMPs computed by the Hurricane Model and Hershfield Method are considered to be in harmony. Table 6.5 shows the calculation flow and results of the PMP estimation by the Hershfield Method.

Table.6.5 PMP calculated by Hershfield Method

Mean of annual series of maximum observed rainfall : Xn	104.2 mm
Mean of annual series of maximum observed rainfall except the largest one : Xn-m	99.8 mm
Standard deviation of annual series of maximum observed rainfall : Sn	29.45
Standard deviation of annual series of maximum observed rainfall except the largest one : Sn-m	24.07
Period of records	17 years
Xn-m/Xn	0.9578
Sn-m/Sn	0.8173
Adjustment for mean of annual series of maximum observed rainfall	1.01
Adjustment for mean of annual rainfall for period of records	1.03
Adjustment for standard deviation of annual series of maximum observed rainfall	0.973
Adjustment for standard deviation of annual rainfall for period of records	1.12
Mean of annual series of maximum observed rainfall after adjustment	103.8 mm
Standard deviation of annual series of maximum observed rainfall after adjustment	26.23
Function of rainfall duration and mean of annual series	15
PMP before adjustment	497 mm = 103.8 + 26.23 × 15
Adjustment for fixed interval rainfall amount for number of observational units within the interval	1.13
Adjustment for PMP of catchment area	0.85
PMP after adjustment	477 mm

2) Probable Maximum Flood (PMF)

a) Unit Hydrograph

In order to estimate the unit hydrograph, the hourly rainfall records and hourly discharge records at the time of floods are necessary. Hurricane FIFI in 1977 is the

(3)

only flood that can provide the data for this purpose. The hourly rainfall data is available at Z03, Z04 and Z05 and the hourly discharge data is available at Osicala GS. The lag time, effective rainfall duration time, peak discharge and other parameters were estimated by the Snyder Method based on Osicala GS records at the time of Hurricane FIFI. The shape of the unit hydrograph was expressed based on FIFI's hydrograph. The unit hydrograph at the project site basin was estimated by replacing several Snyder's parameters for Osicala GS basin, catchment area, L and Lc, to suit each basin's value.

The hourly rainfall and discharge at Osicala GS at the time of hurricane FIFI are shown in Appendix 6.8. The unit hydrograph for El Chaparral is shown in Fig. 6.22.

b) PMF

PMF at the project site was estimated based on the PMP and unit hydrograph. Maximum discharges of PMF at El Chaparral and La Honda are 6,484 m^3/sec, 6,197 m^3/sec. The PMF hydrograph for El Chaparral is shown in Fig. 6.23.

6.4.2 Probable Flood

In order to carry out a flood frequency analysis, a number of different theoretical distribution functions were examined to find the one that best suits the records of annual maximum instantaneous flood peaks. The Log-Pearson Type III distribution provided the best fit, which was therefore adopted for this study.

Osicala GS has 19 observed records of annual maximum instantaneous flood peaks between 1962 and 2000, as shown in Table 6.6. A 1966 figure of 3,248 m^3/sec was omitted, because a significant error was conceded in the estimation of the discharge. Flood peaks prior to 1968 were modified because the measured values as reported were believed to be larger than actual.

The flood discharge at Osicala GS was converted into the flood discharge for the project sites using the Creager equation. Table 6.7 shows the results of the flood frequency analysis at Osicala GS and the project sites.

Table 6.6 Annual Maximum Instantaneous Flood Peaks

Year	Annual Maximum Instantaneous Flood Peaks (m^3/sec)
1962	701 *
1963	734 *
1964	745 *
1965	1,138 *
1966	3,248 * &**
1967	1,648 *
1968	1,540 *
1969	2,409
1970	1,381
1971	1,509
1972	1,454
1973	2,121
1974	2,914 ***
1975	1,106
1978	981
1979	795
1998	3,086 ****
1999	2,802
2000	1,223

* : These data were modified from original records because the measured values as reported are considered to be larger than actual discharge.

** : This data is not used because a significant error was conceded.

*** : Hurricane FIFI

**** : Hurricane MITCHI

Table 6.7 Probable Flood Discharge (Unit : m^3/sec)

Year	Osicala	La Honda (Upstream Alternative)	La Honda	El Chaparral
1	614	678	680	728
2	1,386	1,530	1,534	1,644
5	2,105	2,325	2,331	2,498
10	2,641	2,917	2,924	3,134
20	3,199	3,533	3,543	3,796
30	3,560	3,931	3,942	4,224
40	3,790	4,186	4,197	4,498
50	3,989	4,405	4,417	4,733
100	4,634	5,117	5,131	5,498

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6.5 Sedimentation

6.5.1 Sedimentation at the Project Site

The Sampling of suspended sediment has been carried out since 1966 (1966~1980, 1998~) at Osicala GS. Fig. 6.24 shows a suspended sediment rating curve. Table 6.8 shows the results of investigations on reservoir sedimentation of Cerron Grande, 5 de Noviembre and 15 de Septiembre.

Table 6.8 Data of Bathometric Investigation

	Incremental Area (km^2)	Yearly Sediment ($10^6 m^3$/year)	Specific Sediment (m^3/km^2/year)
Cerron Grande	5,816	6.57	1,130
5 de Noviembre	1,279	0.76	594
15 de Septiembre	7,661	4.87	636

The suspended sediment was estimated by an approximate equation, which was derived using the upper expected value for the 95% probability from Fig. 6.24. This would be a conservative estimate that takes into account that the observed suspended sediment would be in the range of relatively small discharge. The annual specific suspended sediment was estimated to be 695 ton/km^2/year. Procedures for the bed load measurement have not been established, and the bed load is calculated generally in proportion to the suspended sediment load. Generally, the bed load is estimated to be 10% to 20% of the suspended sediment load, and it seldom exceeds 25% of the suspended sediment load. For conservative estimation of the bed load, the bed load was estimated to be 25% of the suspended sediment load in this study.

The trap efficiency can be obtained from Brune curves. For conservative estimation of sediment, the trap efficiency was estimated to be 100% in this study.

According to the sediment data in three existing reservoirs, i.e., Cerron Grande, 5 de Noviembre and 15 de Septiembr, the densities of the suspended load and the bed load were estimated to be 1.25 ton/m^3 and 1.5 ton/m^3 respectively.

The estimated sediment at Osicala GS and the project sites are shown in Table 6.9 and Table 6.10. The estimated specific sediment load of 700(m^3/km^2/year) was considered appropriate because, although it was estimated based on conservative assumptions, it was not particularly larger than the sediment records at the existing three reservoirs.

Table 6.9 Specific Sediment

	Weight (ton /km²/year)	Specific Gravity (ton/m³)	Volume (m³/km²/year)
Suspended Load	695	1.25	556
Bed Load	174	1.50	116
Total	-	-	672
Adopted Amount	-	-	700

Table 6.10 Annual Sediment (Unit: m³/year)

Osicala	La Honda	El Chaparral
603,400	745,500	863,100

6.5.2 Estimate of Sedimentation Shape and Backwater Calculation of Flood

(1) Estimate of Sedimentation Shape

An estimate of sedimentation shape in the reservoir by simulation was carried out. An outline of the calculation is described below.

1) Process of Calculation

a) The calculation of non-uniform flows is carried out for the initial riverbed condition.

b) The friction velocity ($u_*=(gRI)^{0.5}$) is calculated for respective sections.

c) The sediment load will be calculated for respective sections.

suspended load by Lane・Kalinske formula

bed load by Ashida・Michiue formula

d) The riverbed movement is estimated by the equation of continuity for respective sections

$$\partial z / \partial t = 1/(1-\lambda) \cdot 1/B \cdot \partial(q_B \cdot B) / \partial x)$$

Where:

z : Riverbed elevation;
λ (porosity) = 0.4;
B: Width of river section; and,
q_B : Sediment load (per unit width).

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In this case, at the most upstream section of river, it is assumed that the same amount of sediment load (suspended load + bed load) is supplied time constantly from the upstream.

e) The sediment shape 50 years from now is estimated by the reiteration of the above calculation.

2) Conditions for Calculation

a) The grading curve of the riverbed material was based on the "ANALISIS GRANULOMETRICO ASTM C=136."

b) The river discharge data was based on the daily discharge data at Osicala GS.

c) The reservoir water level was based on the operation for generation.

3) Calculation Results

Simulation results of sediment are shown in Fig. 6.25 and Appendix 6.9. The figures indicate that the front of the sediment will not reach the dam site 50 years later, but the sediment around the backwater of the resevoir will cause slight shortage in the effective volume of reservoir.

Therefore, it is necessary to shift the sediment load to the dead volume in the area near the dam site by dredging.

(2) Backwater Calculation of Flood

The backwater calculation of flood in the upstream of the dam reservoir was carried out based on the simulation results on the sedimentation shape. Conditions for calculation are shown in Table 6.11, and the water level after the dam construction was compared with the level before the dam construction.

Table 6.11 Backwater Calculation Conditions

	Flood Discharge (m^3/s)	Water level at dam site
Before dam construction	6,484	EL 150.85 m
After dam construction	6,484	EL 212.00 m

Fig.6.26 and Appendix 6.9 show the calculation results. The backwater curve after the dam construction begins to come closer to the curve before the dam construction at the distance of about

11 km from the dam, and there is no difference between the two at about 13 km. This means that 13km is the upper point that will be affected by the inundation of the reservoir.

Table 6.12 Backwater Calculation for a Flood (Qf=6,484 m^3/s)

Distance (m)	Water level after 50 yr (EL m)	Water level before dam construction (EL m)	Difference between two (m)
Dam	212.00	150.85	61.15
500	212.01	154.71	57.31
1,000	212.03	157.37	54.65
1,500	212.02	158.35	53.67
2,000	212.02	164.40	47.63
2,500	212.03	168.28	43.74
3,000	212.03	171.32	40.71
3,500	211.98	175.05	36.93
4,000	211.96	178.25	33.71
4,500	212.05	183.63	28.42
5,000	212.05	184.15	27.90
5,500	212.06	188.27	23.79
6,000	212.03	191.97	20.06
6,500	212.04	195.45	16.59
7,000	211.88	197.38	14.50
7,500	212.11	202.05	10.06
8,000	211.92	201.76	10.16
8,500	212.22	205.54	6.68
9,000	212.69	207.55	5.14
9,500	212.55	207.72	4.82
10,000	213.61	210.38	3.23
10,500	213.39	210.37	3.02
11,000	213.38	211.85	1.53
11,500	216.65	216.03	0.62
12,000	218.05	217.48	0.57
12,500	219.45	218.81	0.64
13,000	221.36	221.46	-0.09
13,500	222.06	222.08	-0.02

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Table 6.1 Items and Periods of Hydrological Measurements

Item	Station	1940										1950									
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Rainfall	Z-02																	■	■	■	■
	Z-03																				
	Z-04																				
	Z-05																				
	Z-06																				
	Z-07																				
	Z-08																				
	Z-09																				
	Z-10																				
	Z-11																				
	Z-12																				
	Z-13																				
	Z-14																				
	Z-15																				
	M-05																	■	■	■	■
	M-18																				
	M-21																				
	M-22																				
	U070												■	■	■	■	■	0	■	2	7
	5204																				
Discharge	Osicala																				
	0101																				

Item	Station	1960										1970									
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
Rainfall	Z-02	■													6	■	■	■	■	■	■
	Z-03			6		6	■	■	■	■	■	■	■	■	■	■	■	■	◆	■	■
	Z-04			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	◆	■	■
	Z-05			2	■	■	■	■	◆	■	■	■	■	■	■	■	■	◆	◆	■	■
	Z-06										◆	8	■	■	■	■	■	■	■	■	■
	Z-07										0	■	■	◆	■	0	■	■	◆	■	■
	Z-08						■	■	■	■	■	■	■	■	■	■	■	■	■	0	■
	Z-09												0	◆	■	■	■	■	◆	■	■
	Z-10													◆	◆	◆	■	■	■	■	■
	Z-11												4	■	■	■	◆	■	0	■	■
	Z-12													◆	■	◆	■	■	■	0	0
	Z-13													◆	■	■	■	■	■	9	4
	Z-14														4	■	■	■	■	■	■
	Z-15																■	8	■	■	■
	M-05	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	◆	■	■
	M-18												◆	■	■	■	■	■	◆	■	■
	M-21												3	3	0	■	■	■	■	■	■
	M-22												5	0	■	■	◆	■	■	■	■
	U070		1	■	◆								9	■	■	■	◆	◆	■	9	0
	5204														6	■	■	■	■	■	■
Discharge	Osicala			◆	◆	■	0	0	■	◆	8	■	■	■	■	■	■	9	■	■	■
	0101					5	◆	■	■	■	■	■	■	■	■	0	■	◆	◆	■	■

Item	Station	1980										1990										2000		
		0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2
Rainfall	Z-02	◆	■	◆	■	■	■	■	◆	■	■	■			6	6	5	5	6	6	6	6		
	Z-03	■	■	0											1	4					6	6		
	Z-04	■	■	0	■	4																		
	Z-05	■	■	■		■	■	8	■	■	■				4	5	5	5	6	6	3			
	Z-06			6		■																		
	Z-07	1																						
	Z-08	■	◆	0	■	■	■	0	◆	8	■	7			1	4	5	4	6	6	5	4		
	Z-09	6																						
	Z-10																							
	Z-11	9	6																					
	Z-12	4													5	2	5	5	4	5	6	5		
	Z-13														4	6	3	5	3	6	6	6		
	Z-14	■	4																					
	Z-15																							
	M-05	0	■	6	0	8												6	6	6	6	6		
	M-18	■																6	6	6	5	6		
	M-21	■	■	0																				
	M-22	6																						
	U070	◆	■	■	■	■	■	■	◆	■	■	■	■											
	5204	◆	■	◆	■	■	■	■	◆	■	■	■												
Discharge	Osicala	4																		4	■	■		
	0101	■																						

■ = Data exist for 12 months
1-9 = Data exist for numbered months
0 = Data exist for 10 months
◆ = Data exist for 11 months

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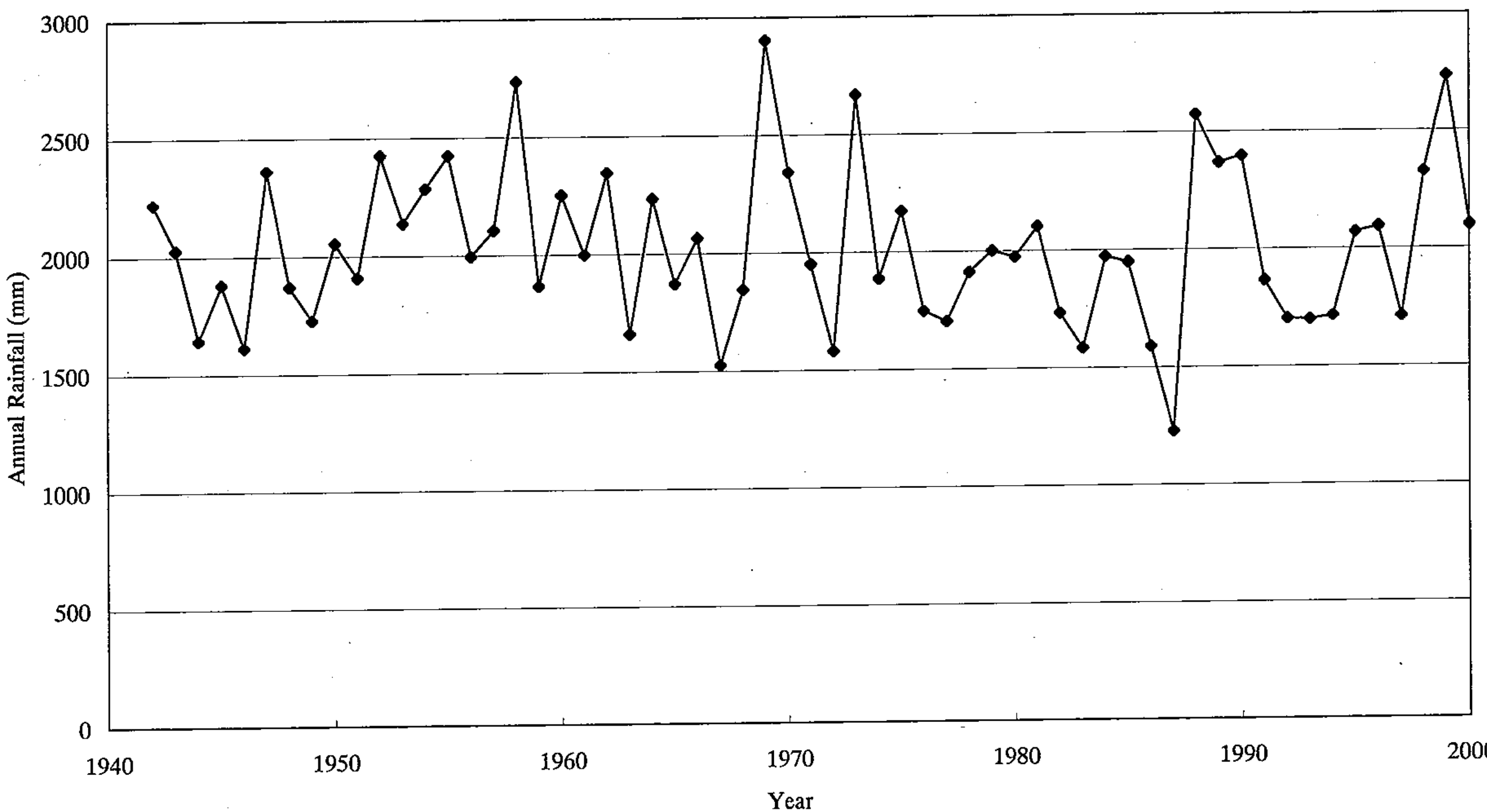

Fig. 6.1 Annual Rainfall Distribution for Osicala Basin

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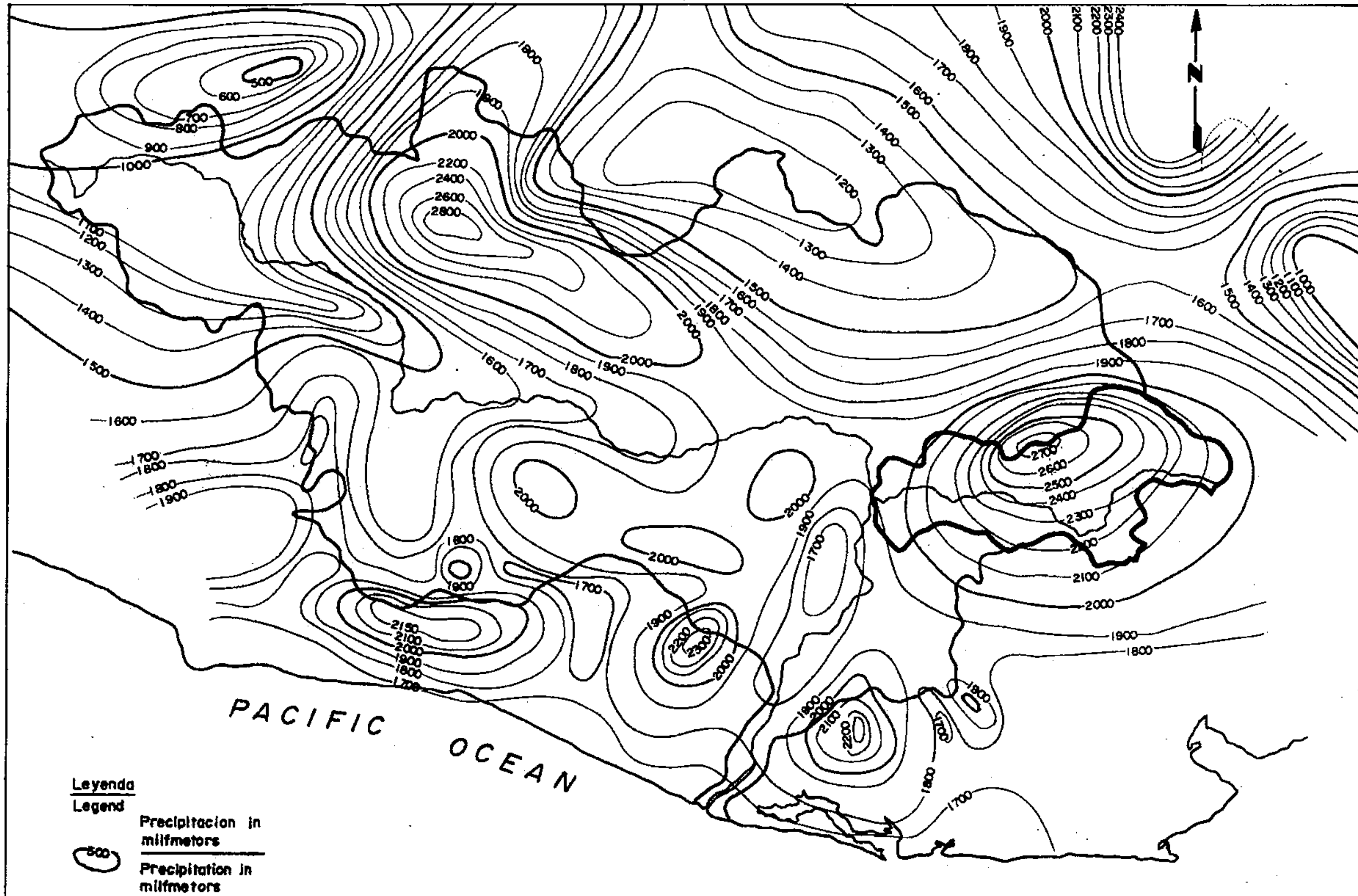

Fig.6.2 Isohyetal Map of Annual Mean Rainfall

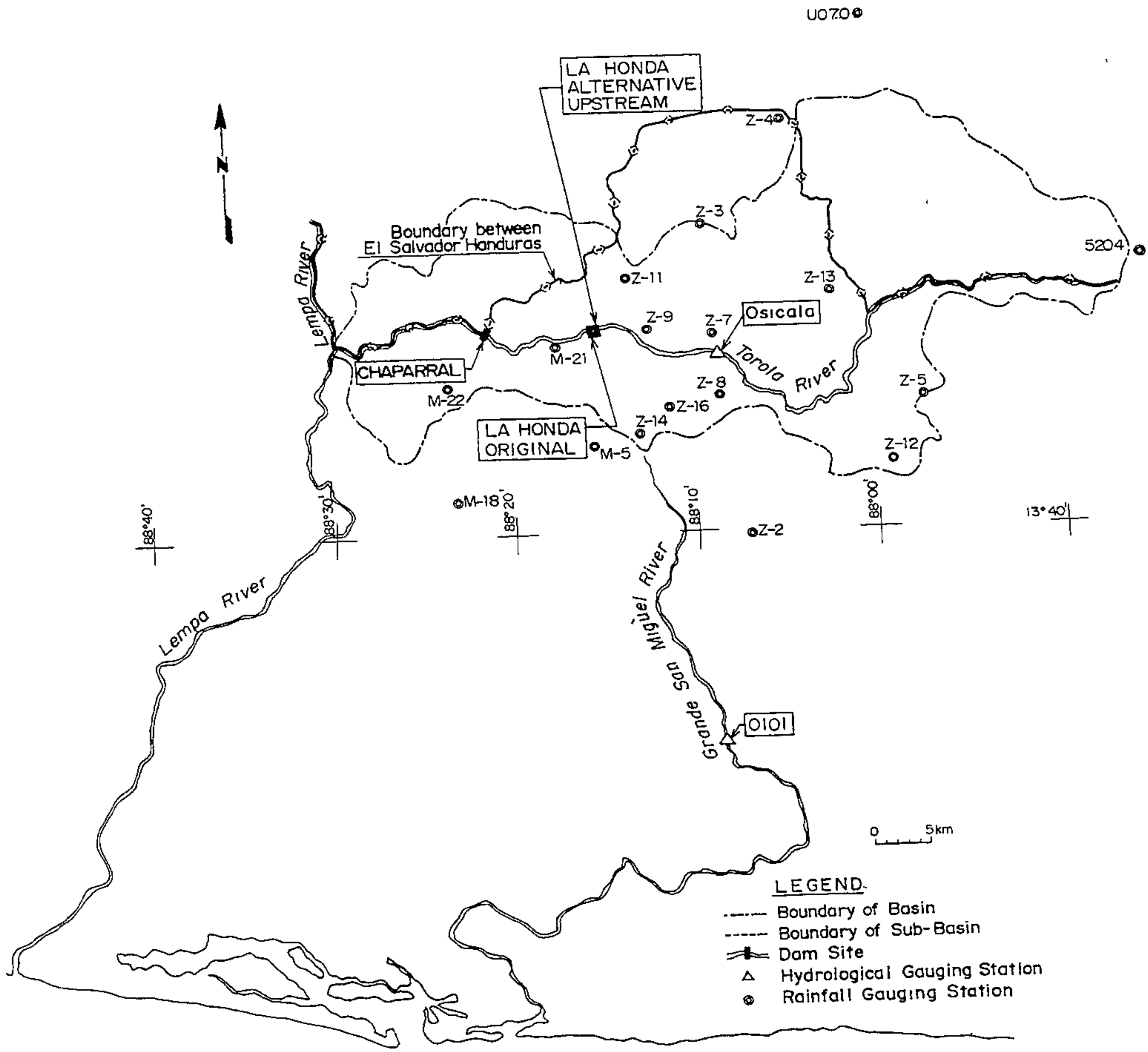

Fig.6.3 Location of Hydrological Guaging Station

149 (150|2)

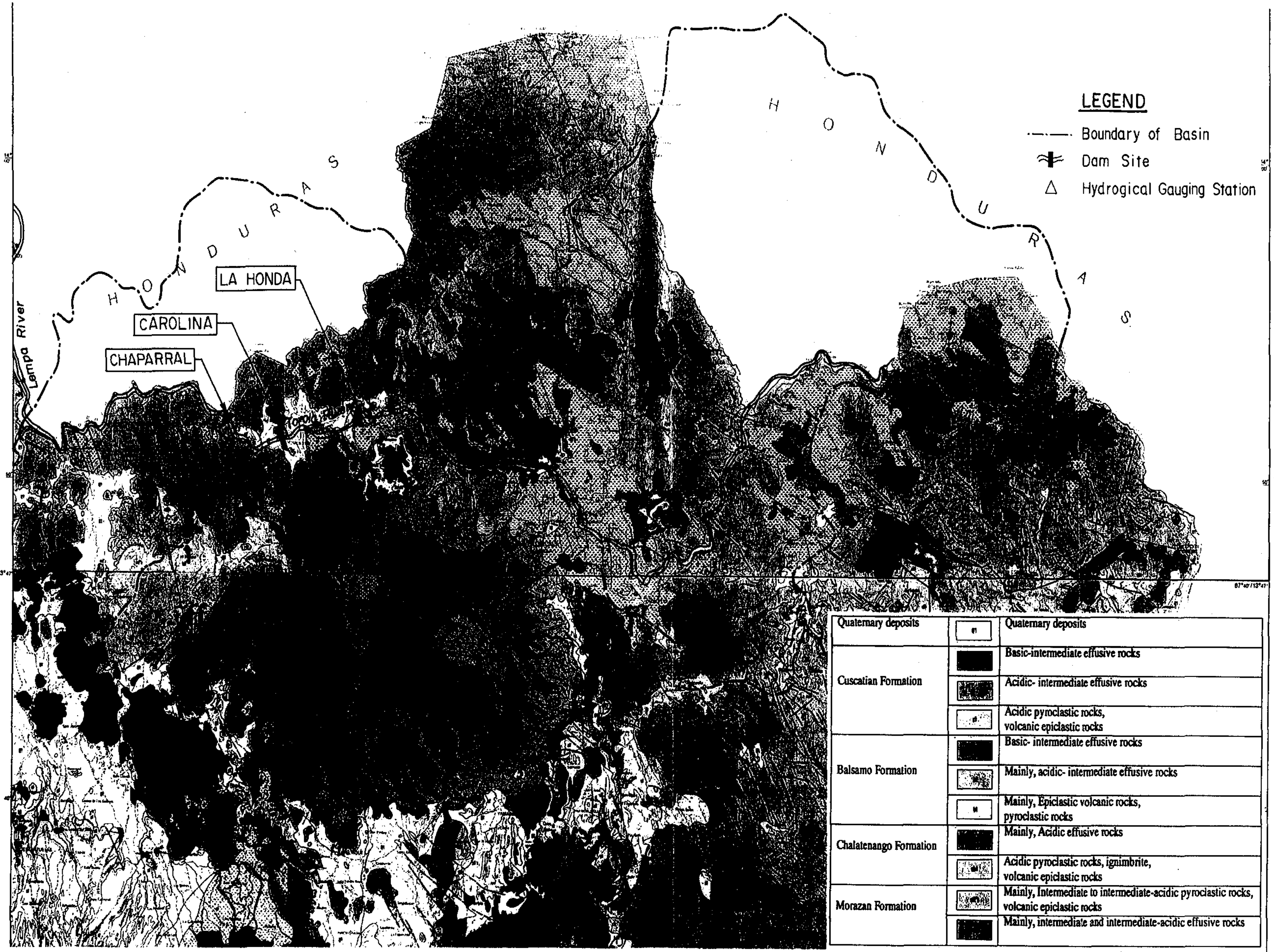

Fig.6.4 Geological Map for Torola Basin

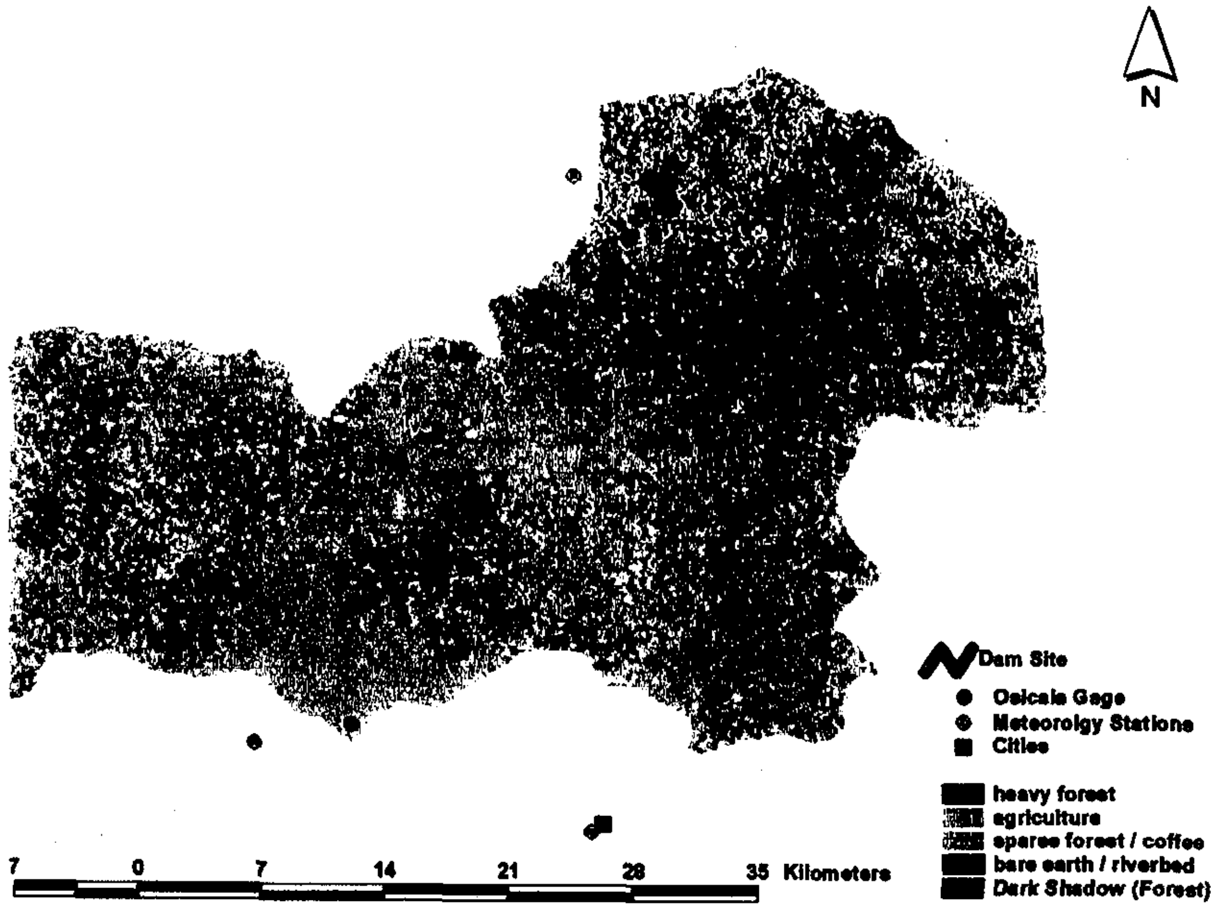

Fig.6.5 Vegetation Map for Torola Basin

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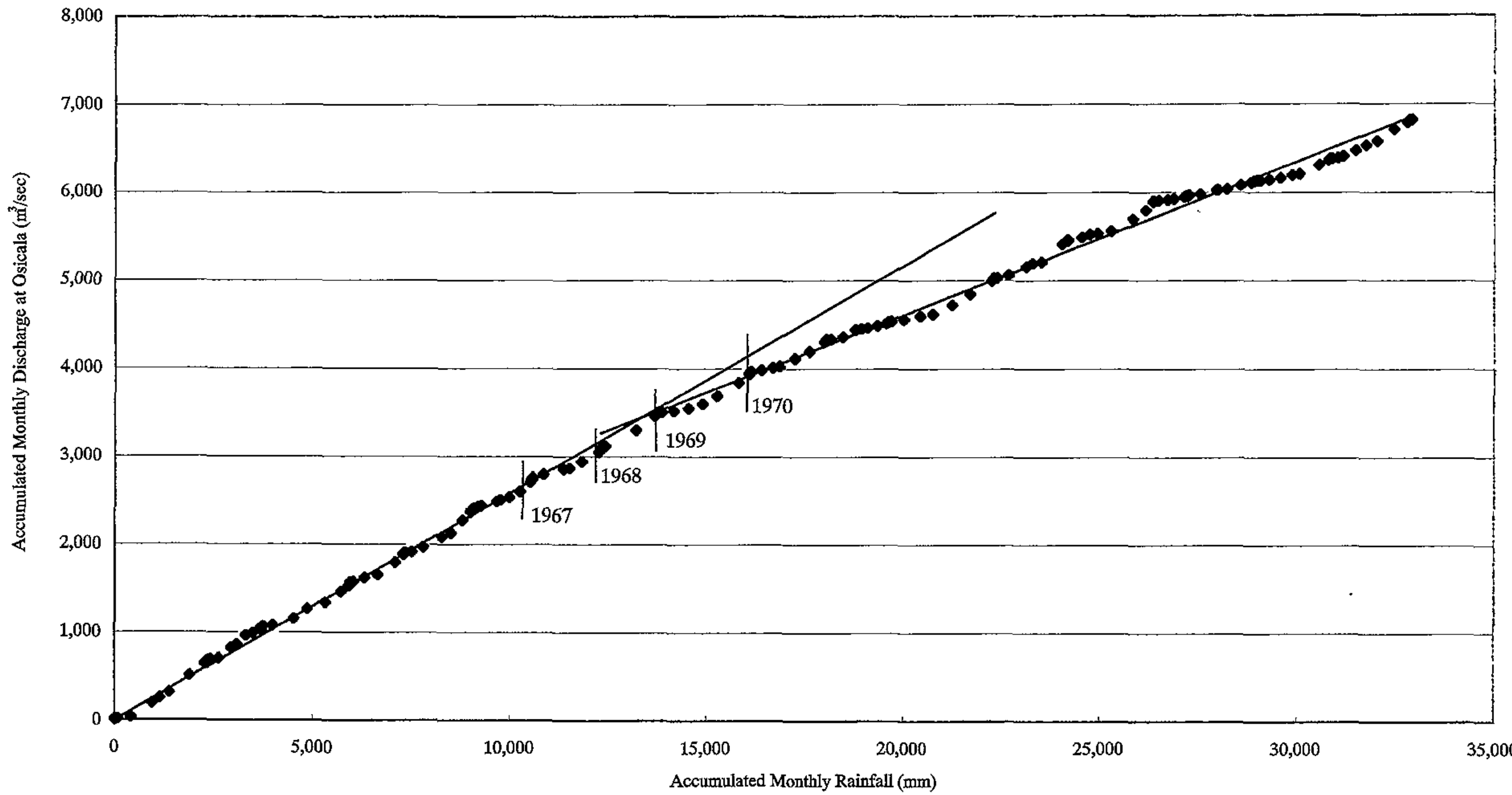

Fig. 6.6 Double Mass Curve between Rainfall and Discharge at Osicala

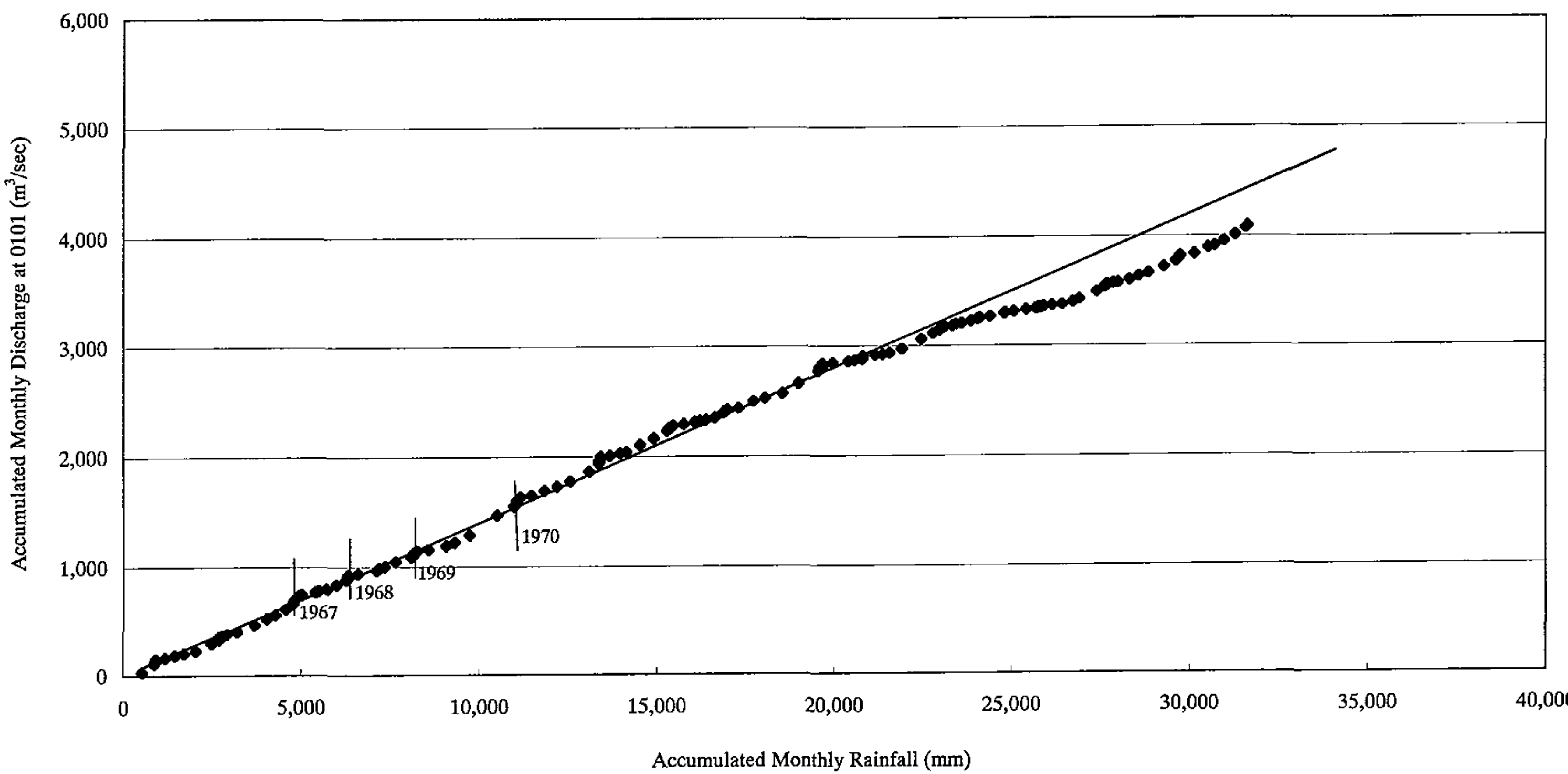

Fig. 6.7 Double Mass Curve between Rainfall and Discharge at 0101

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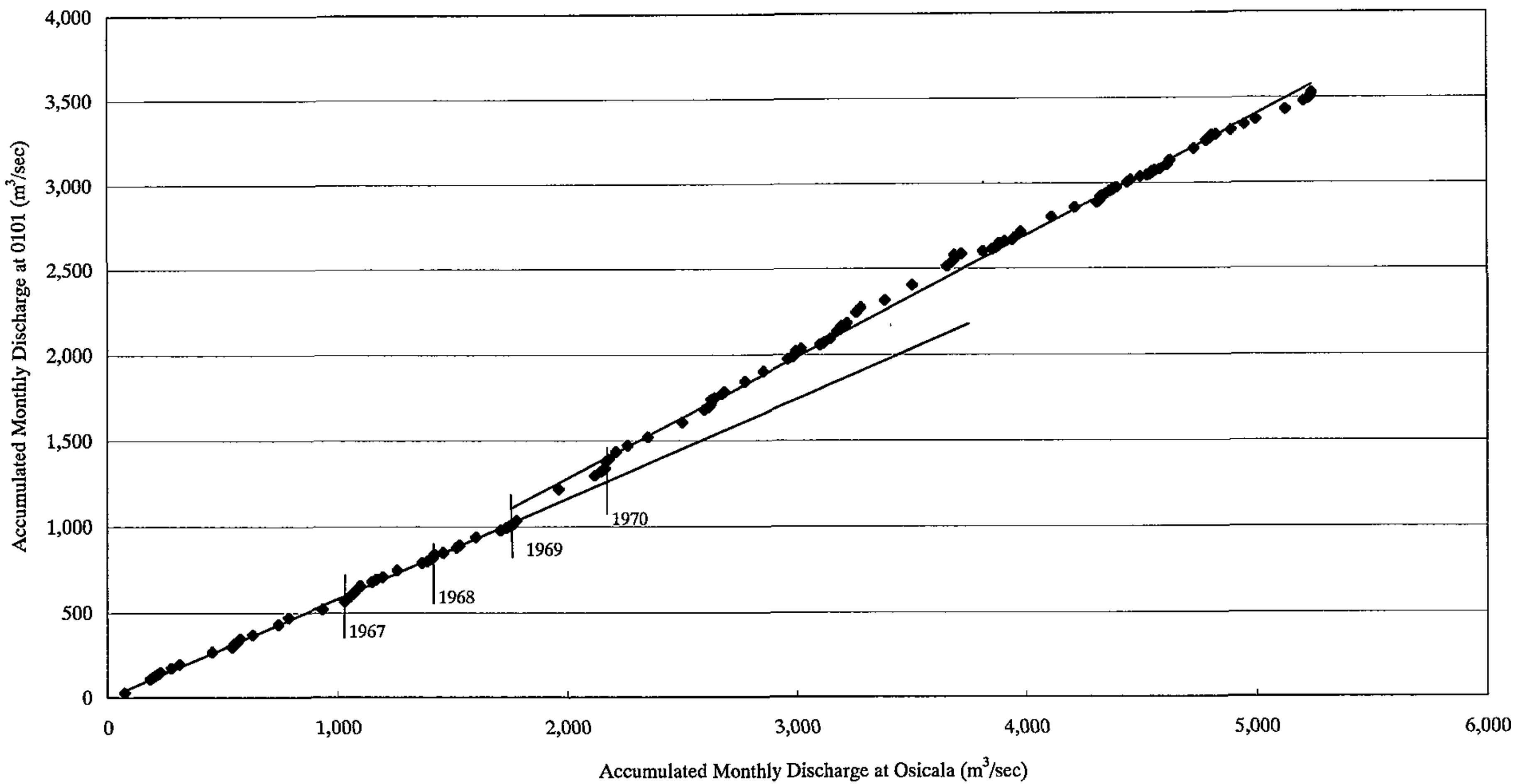

Fig. 6.8 Double Mass Curve Discharge between Osicala and 0101

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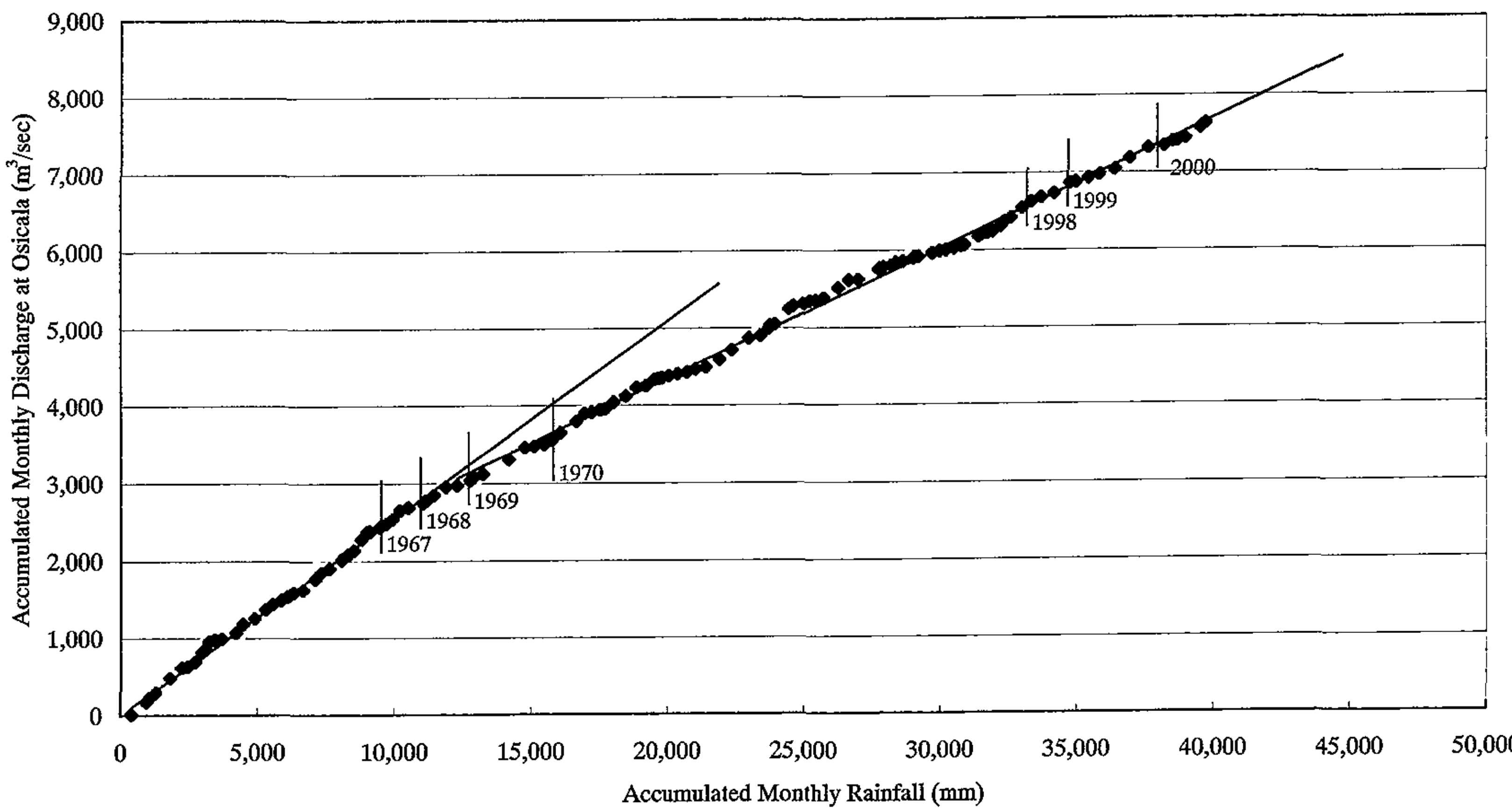

Fig. 6.9 Double Mass Curve between Rainfall and Discharge at Osicala

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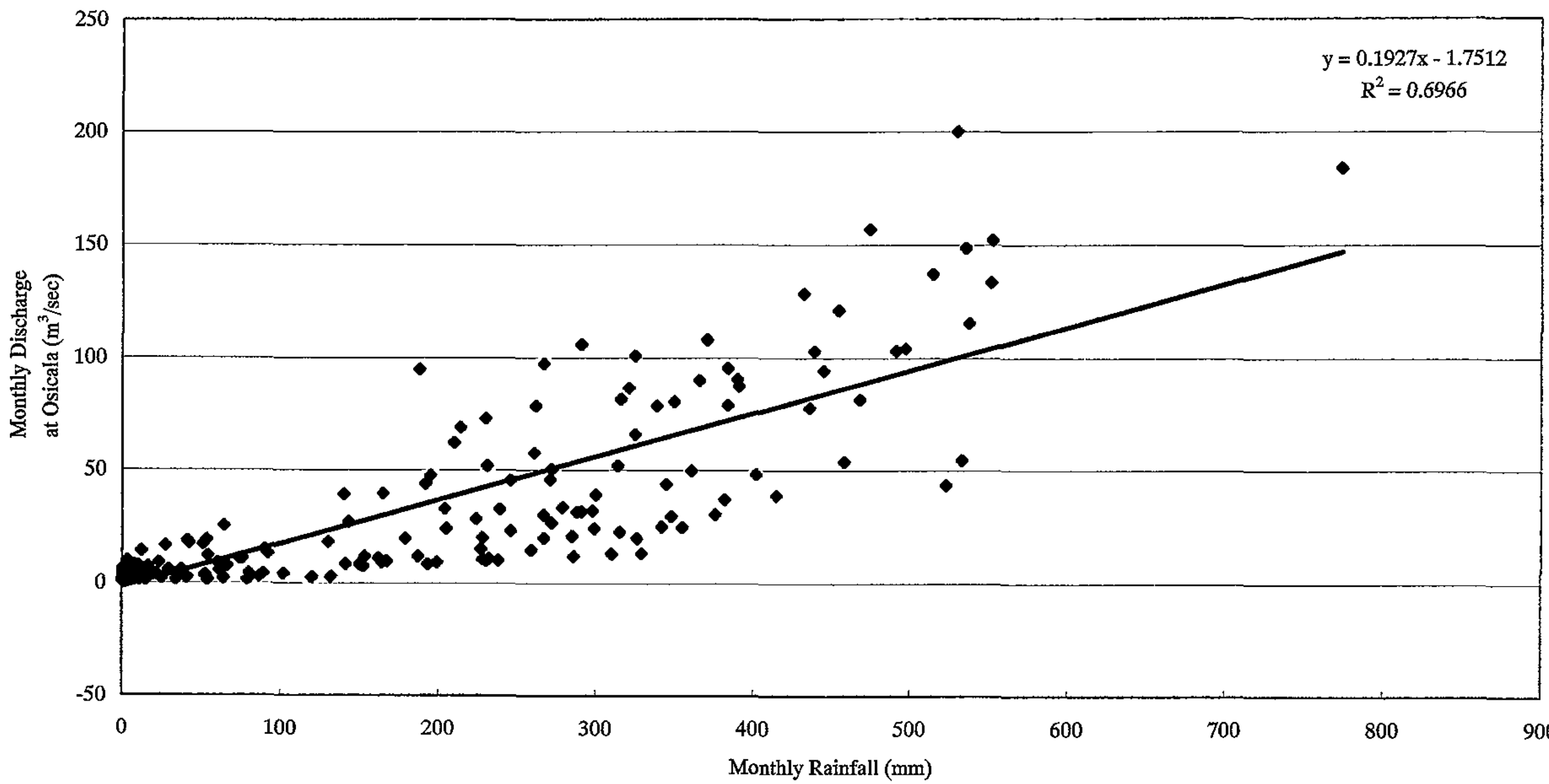

Fig. 6.10 Correlation between Rainfall and Discharge

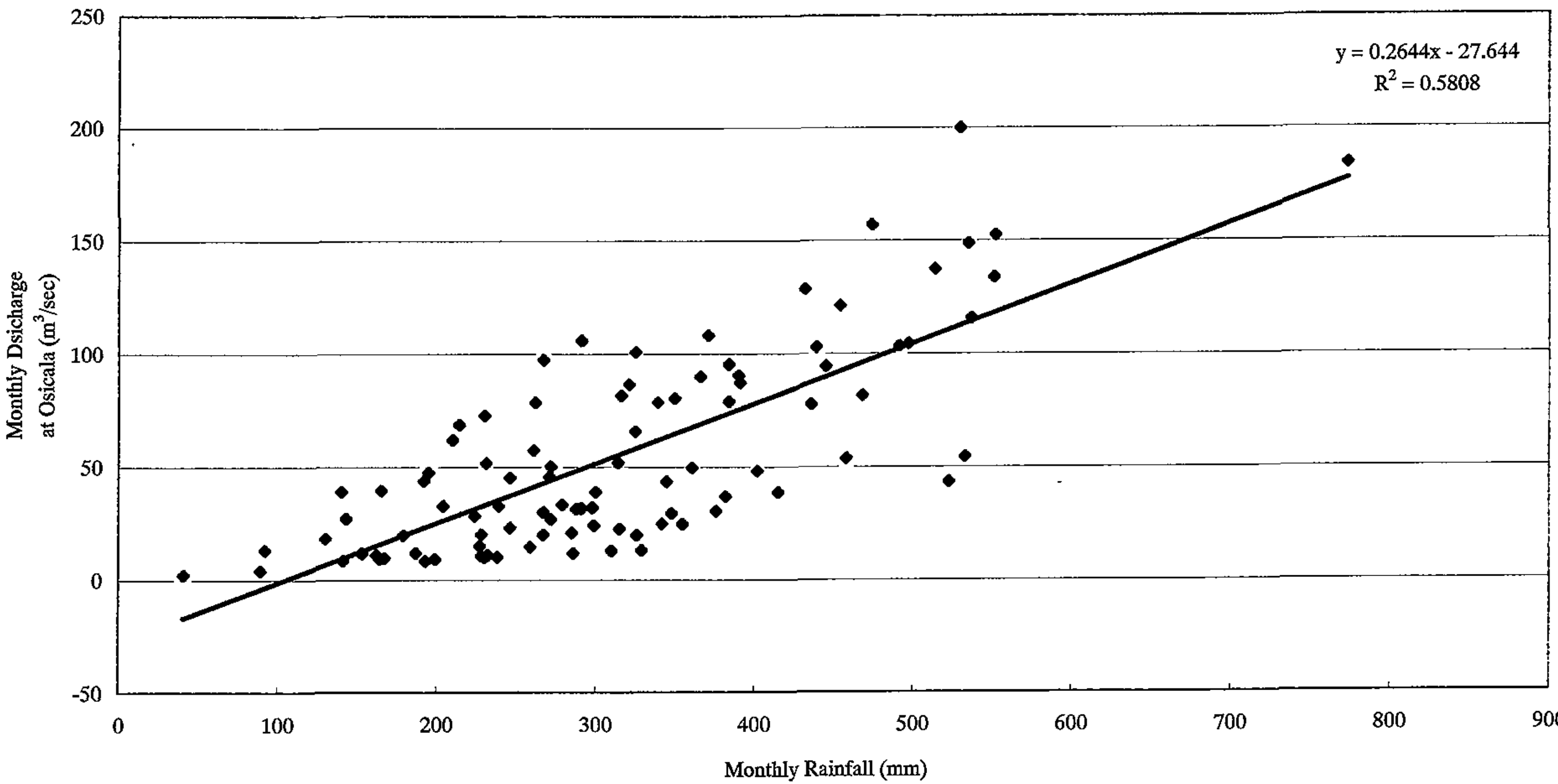

Fig. 6.11 Correlation between Rainfall and Discharge during Rainy Season

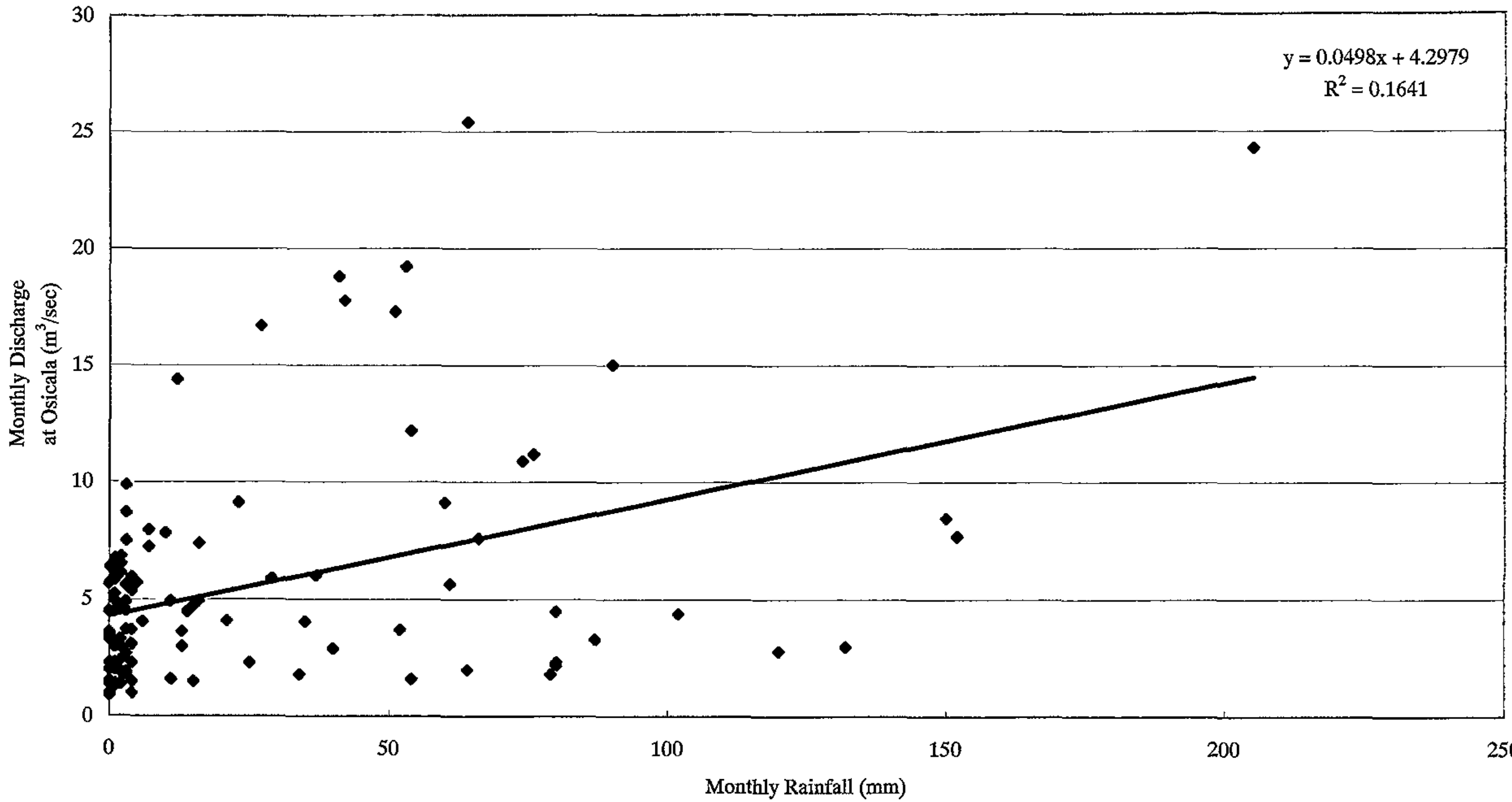

Fig. 6.12 Correlation between Rainfall and Discharge during Dry Season

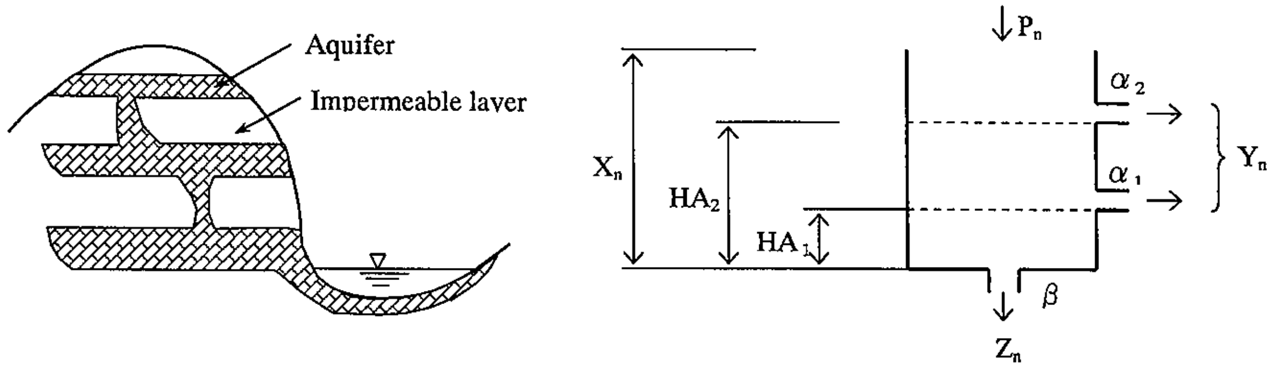

Fig. 6.13 Concept of Tank Model

The runoff amount and infiltration amount are acquired in the following equations.

$$Y_n = \begin{cases} 0 & \text{..........} \; O \le X_n \le HA_1 \\ a_1 \times (X_n - HA_1) & \text{..........} \; HA_1 < X_n \le HA_2 \\ a_1 \times (X_n - HA_1) + a_2 \times (X_n - HA_2) & \text{..........} \; HA_2 < X_n \end{cases}$$

$$Z_n = \beta \times X_n$$

$$0 < a_1, a_2$$

$$\beta < 1$$

where,

a_1, a_2,	:	runoff coefficient (parameter of side outlets)
β	:	infiltration coefficient (parameter of bottom outlet)
HA_1, HA_2	:	heights of the side outlets
P_n	:	rainfall
X_n	:	water storage volume
Y_n	:	runoff amount from the side outlet
Z_n	:	infiltration amount from the bottom outlet

Remainder X'_n in the tank is $X'_n = X_n - Y_n - Z_n$

The remaining balance of X_{n+1} at time (n + 1) is expressed in the following equation;

$$X_{n+1} = X'_n + P_{n+1}$$
$$= X_n - Y_n - Z_n + P_{n+1}$$

The calculation is repeated in time series.

Fig. 6.14 Flow of Calculation by Tank Model

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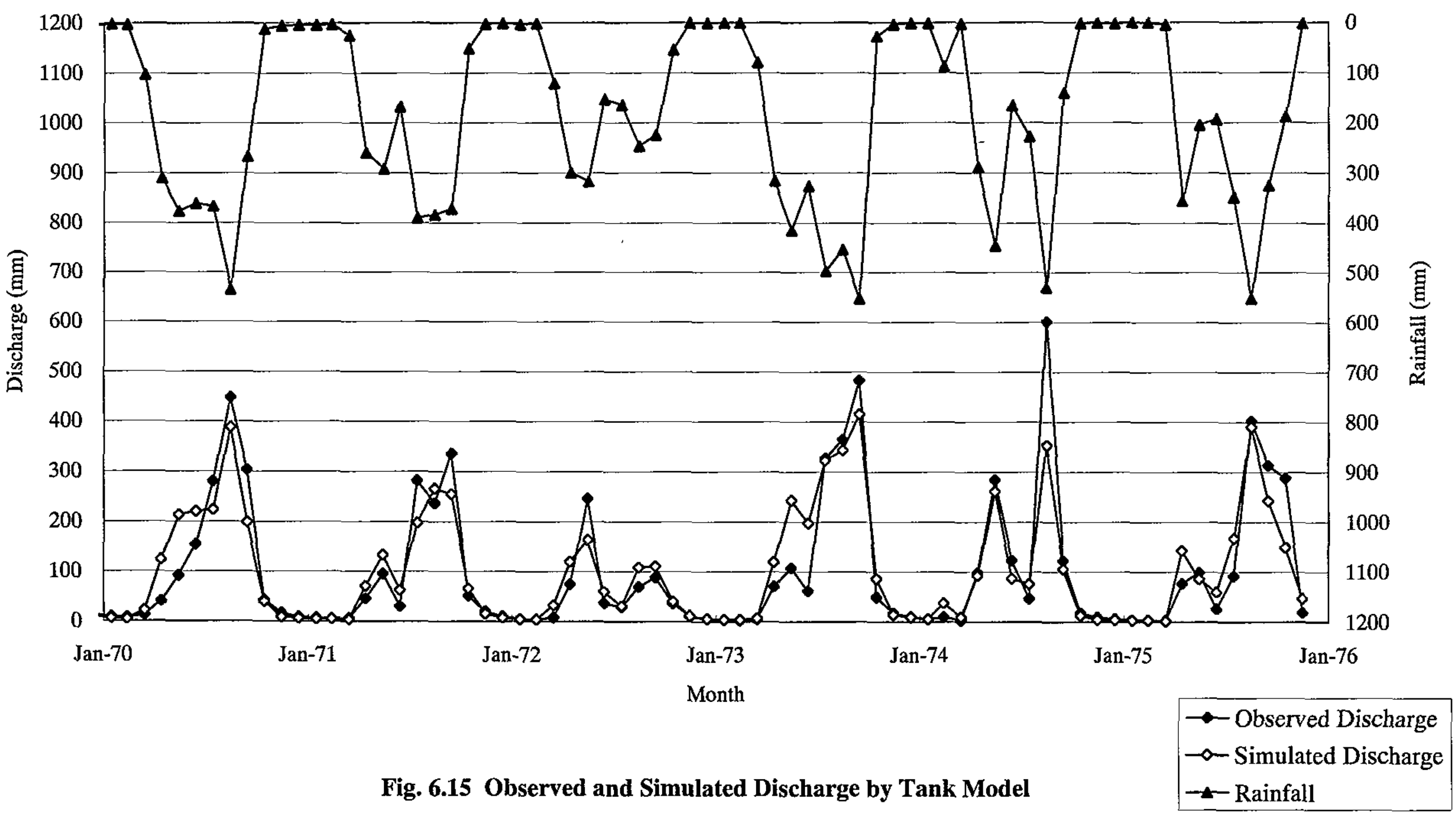

Fig. 6.15 Observed and Simulated Discharge by Tank Model

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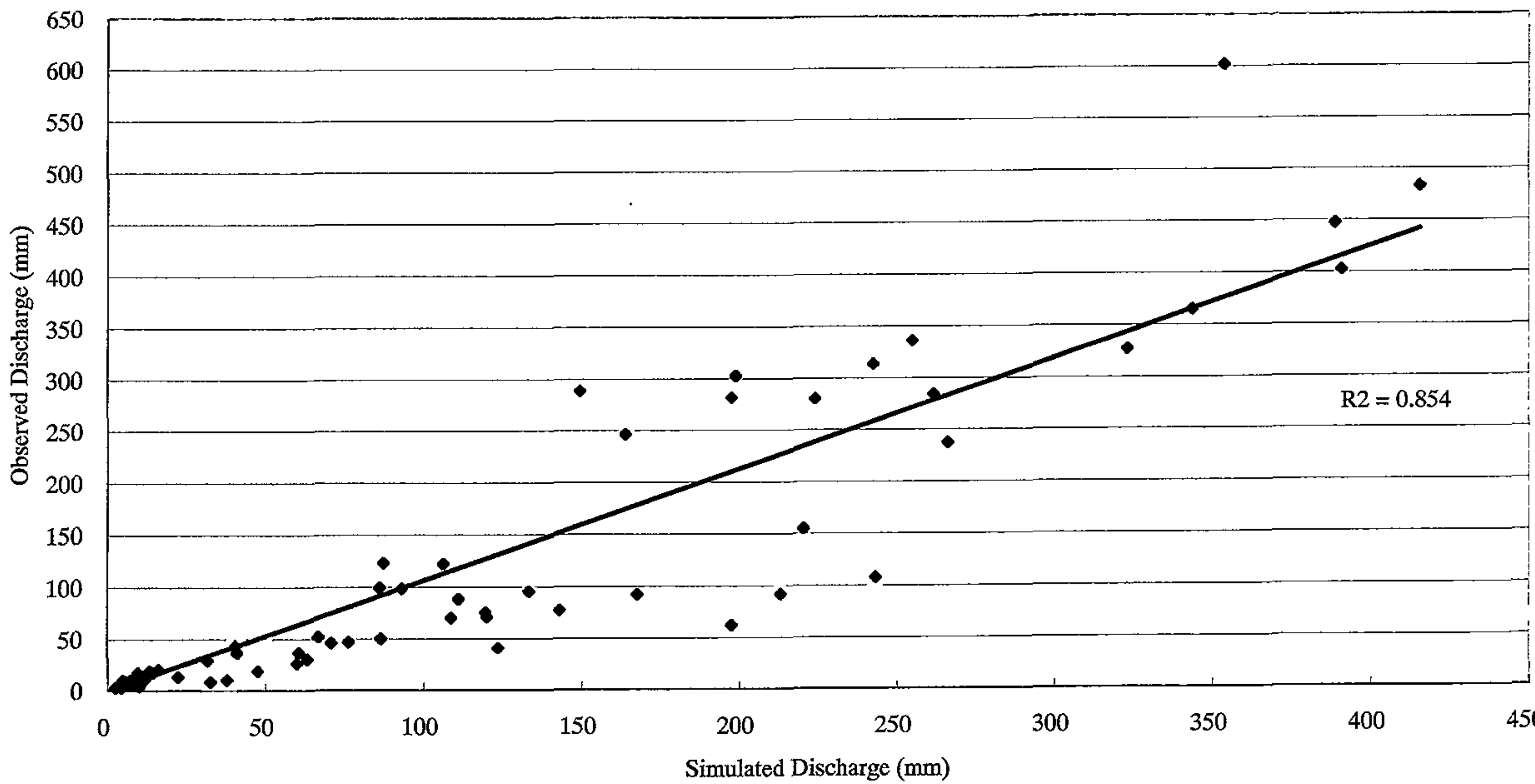

Fig. 6.16 Correlation between Observed and Simulated Discharge

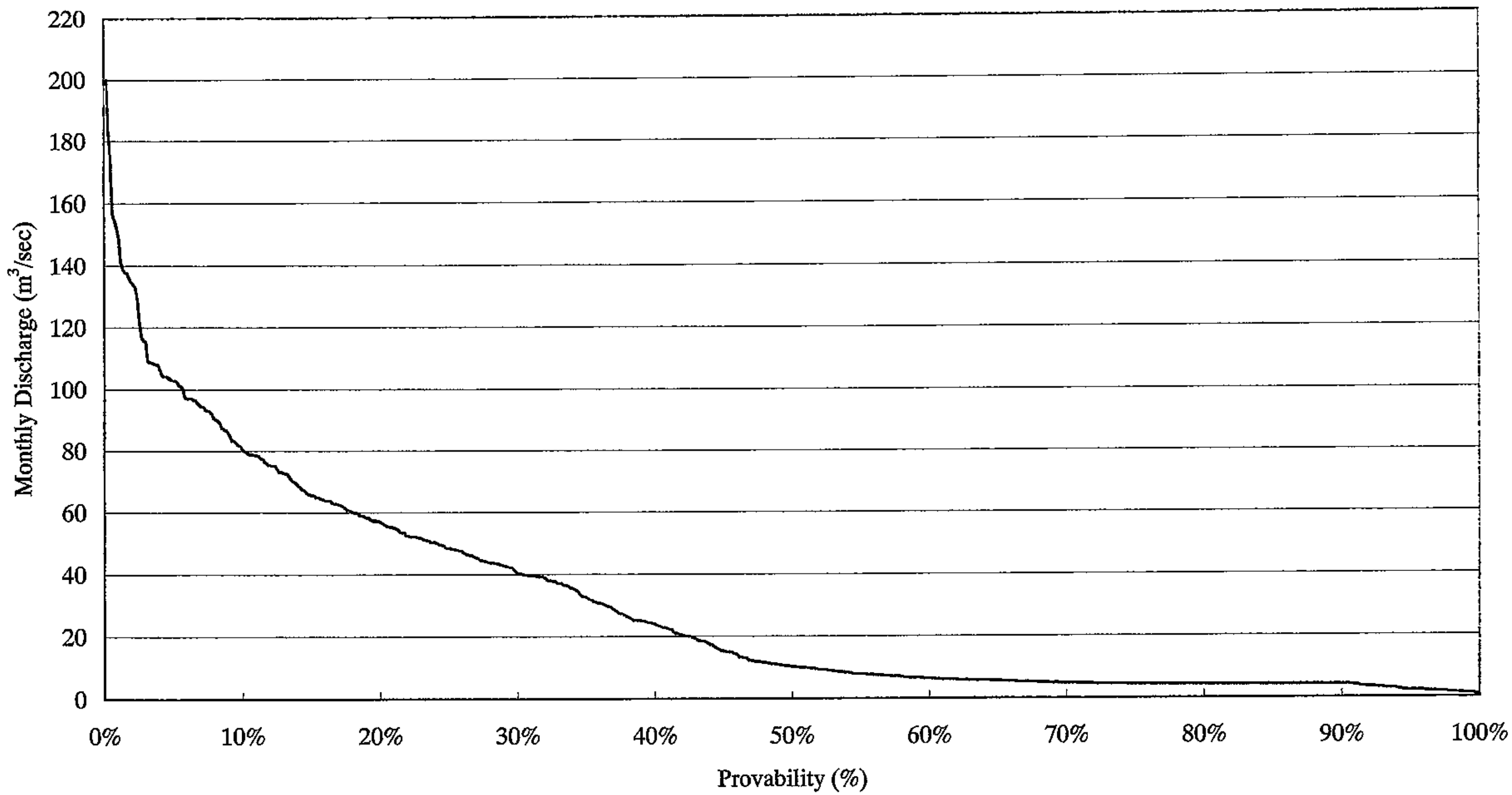

Fig. 6.17 Duration Curve at Osicala

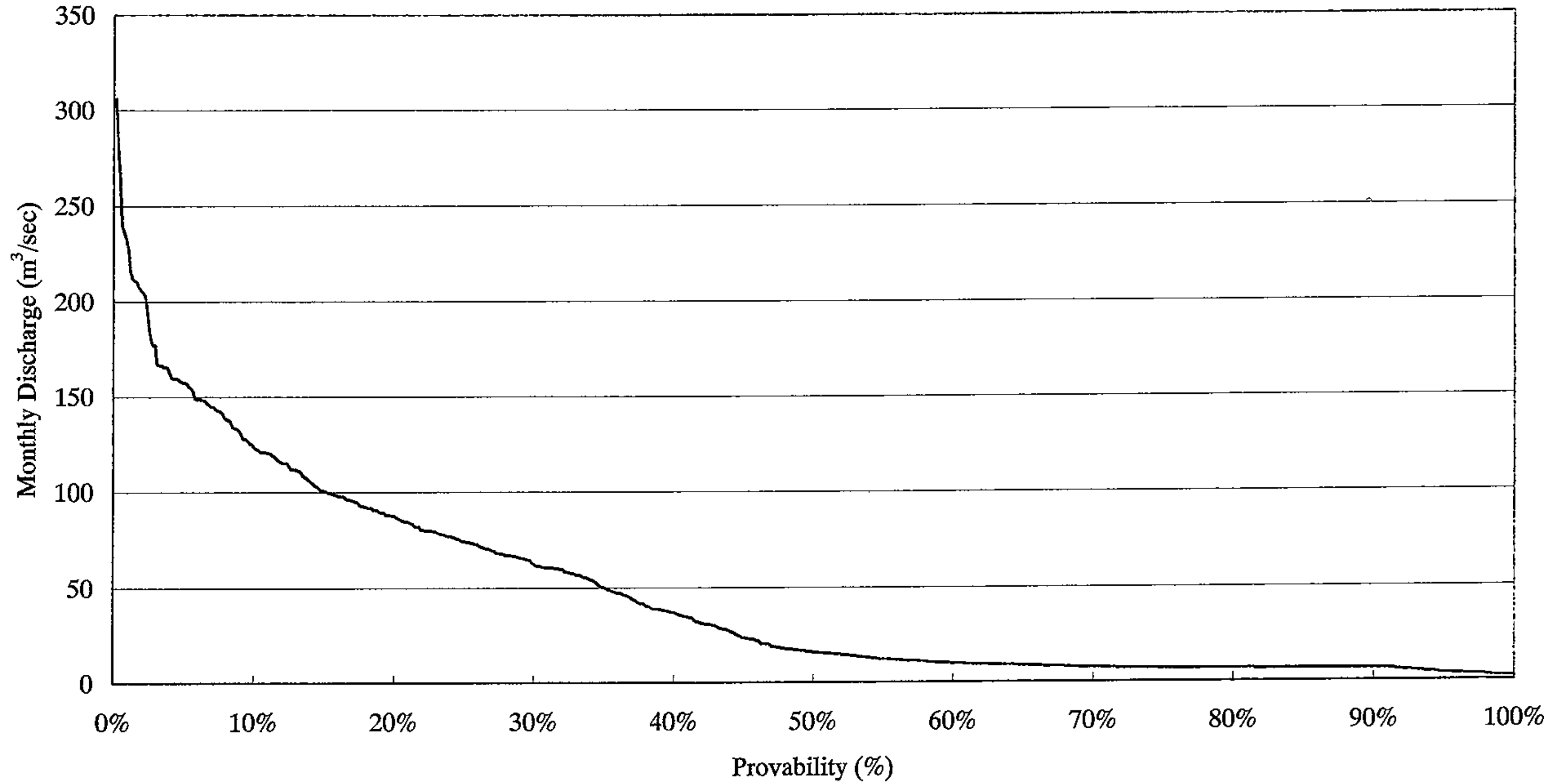

Fig. 6.18 Duration Curve at El Chaparral

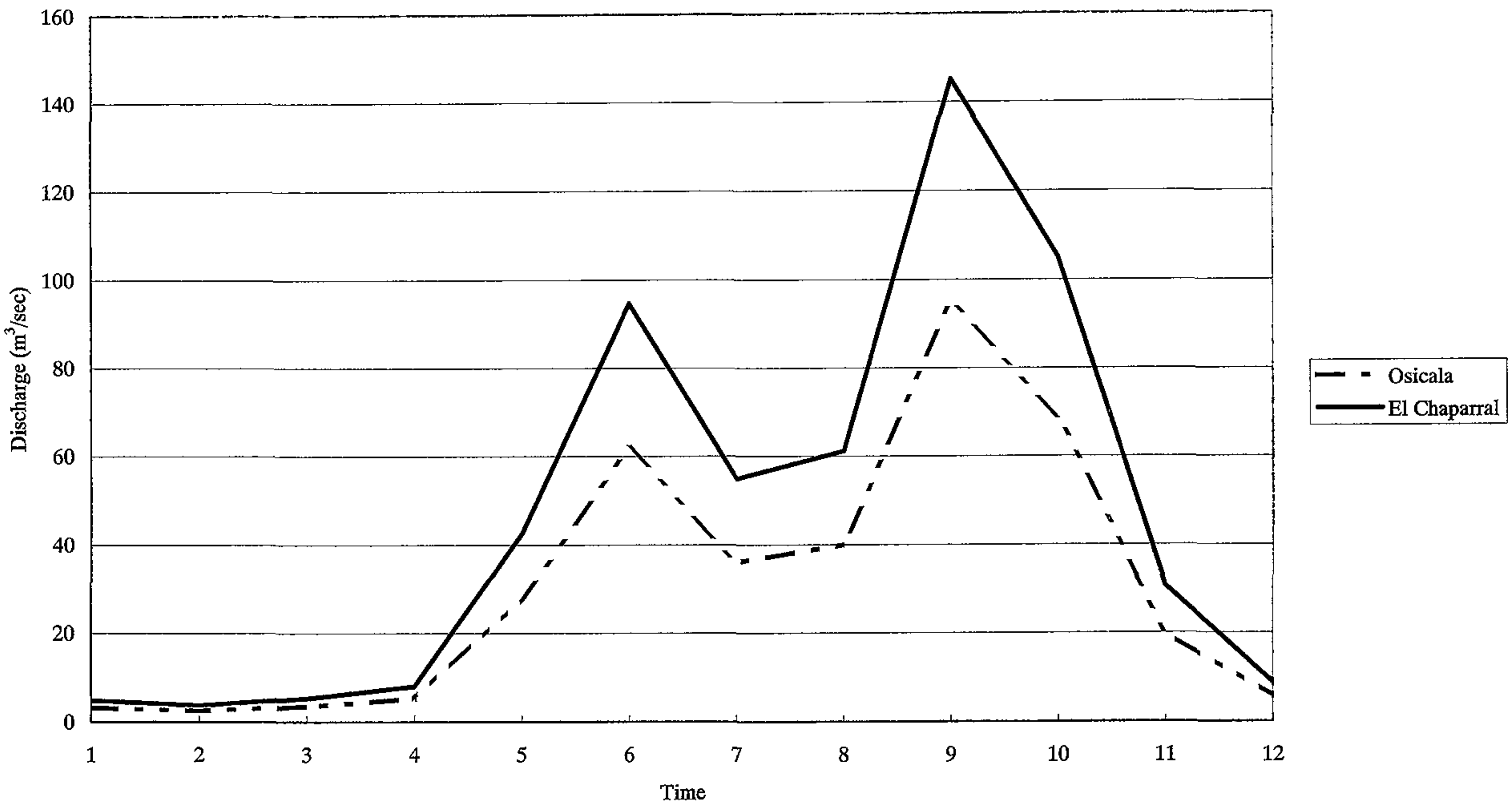

Fig.6.19 Mean Monthly Discharge

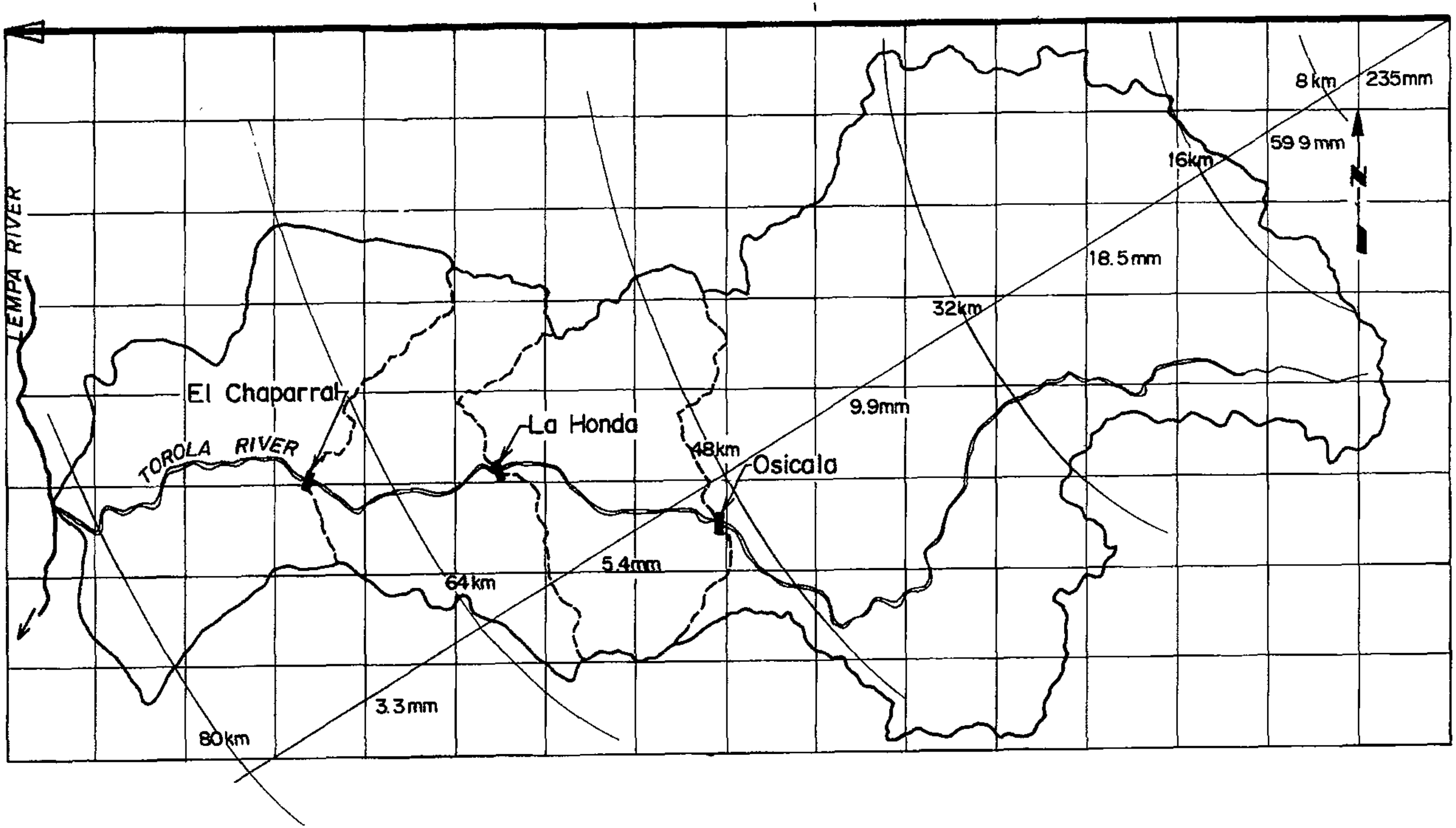

Fig. 6.20 Modeled Hurricane Route

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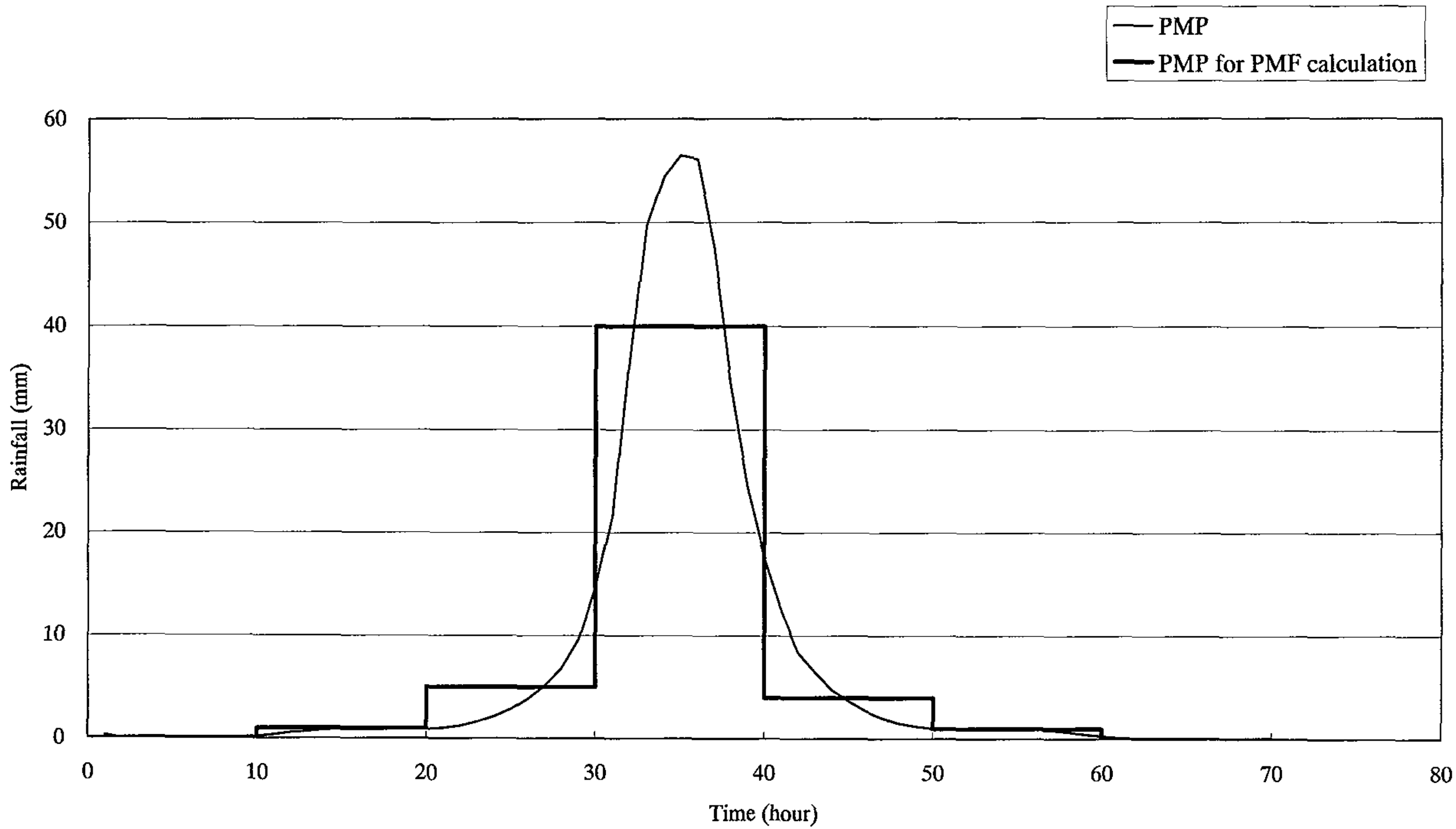

Fig. 6.21 PMP for El Chaparral

167

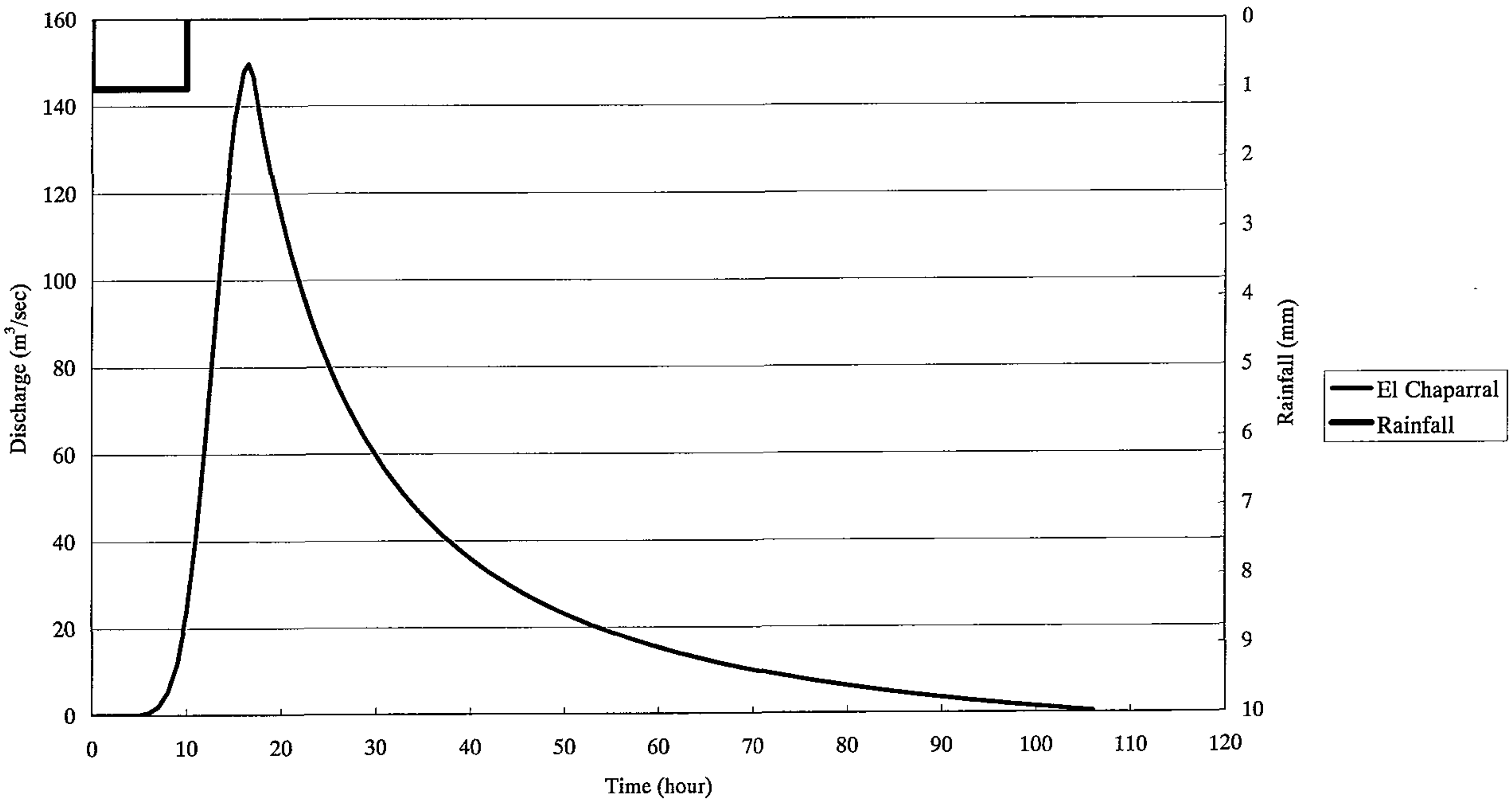

Fig. 6.22 Unit Hydrograph for El Chaparral

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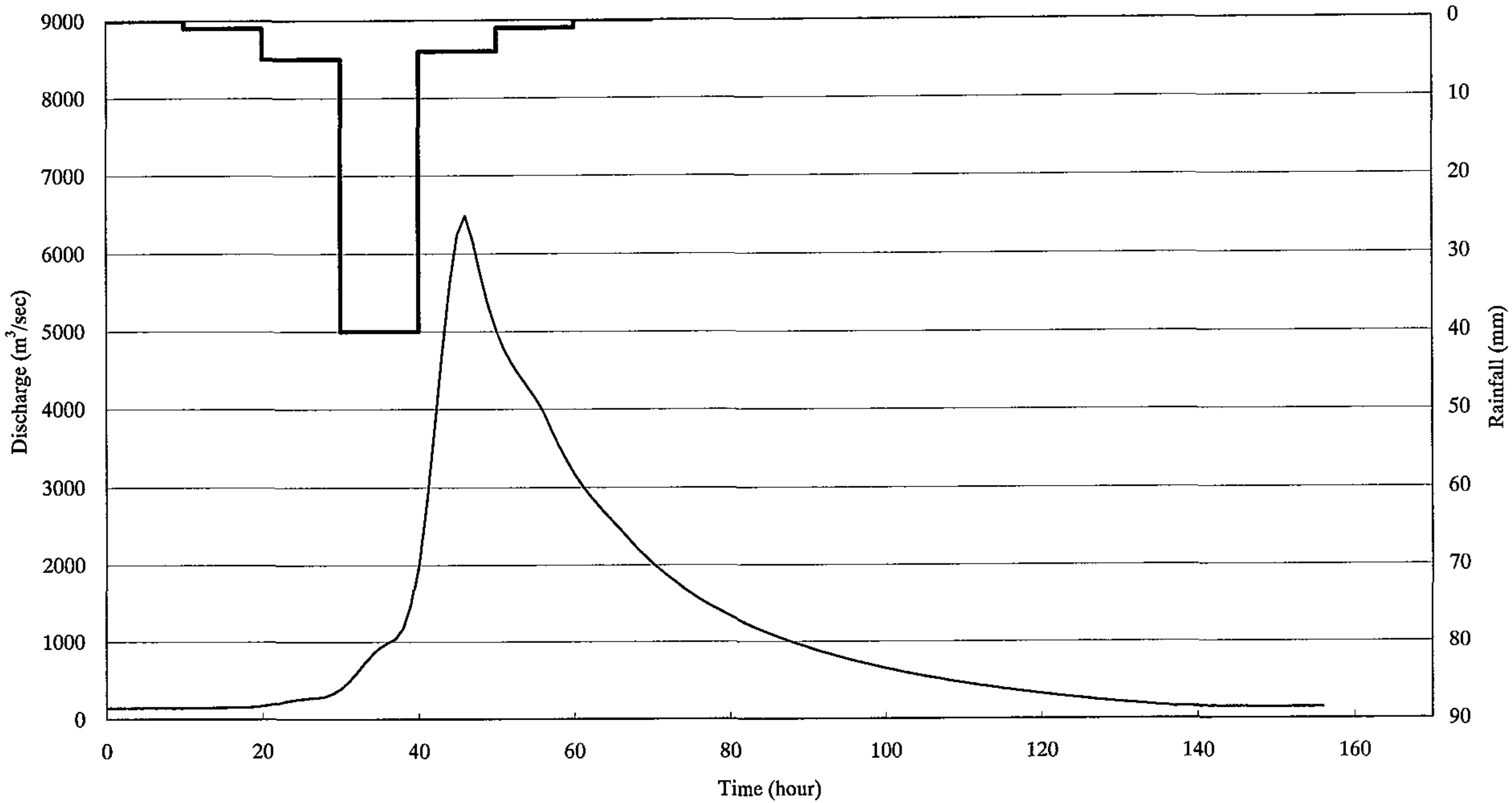

Fig. 6.23 PMP and PMF at El Chaparral

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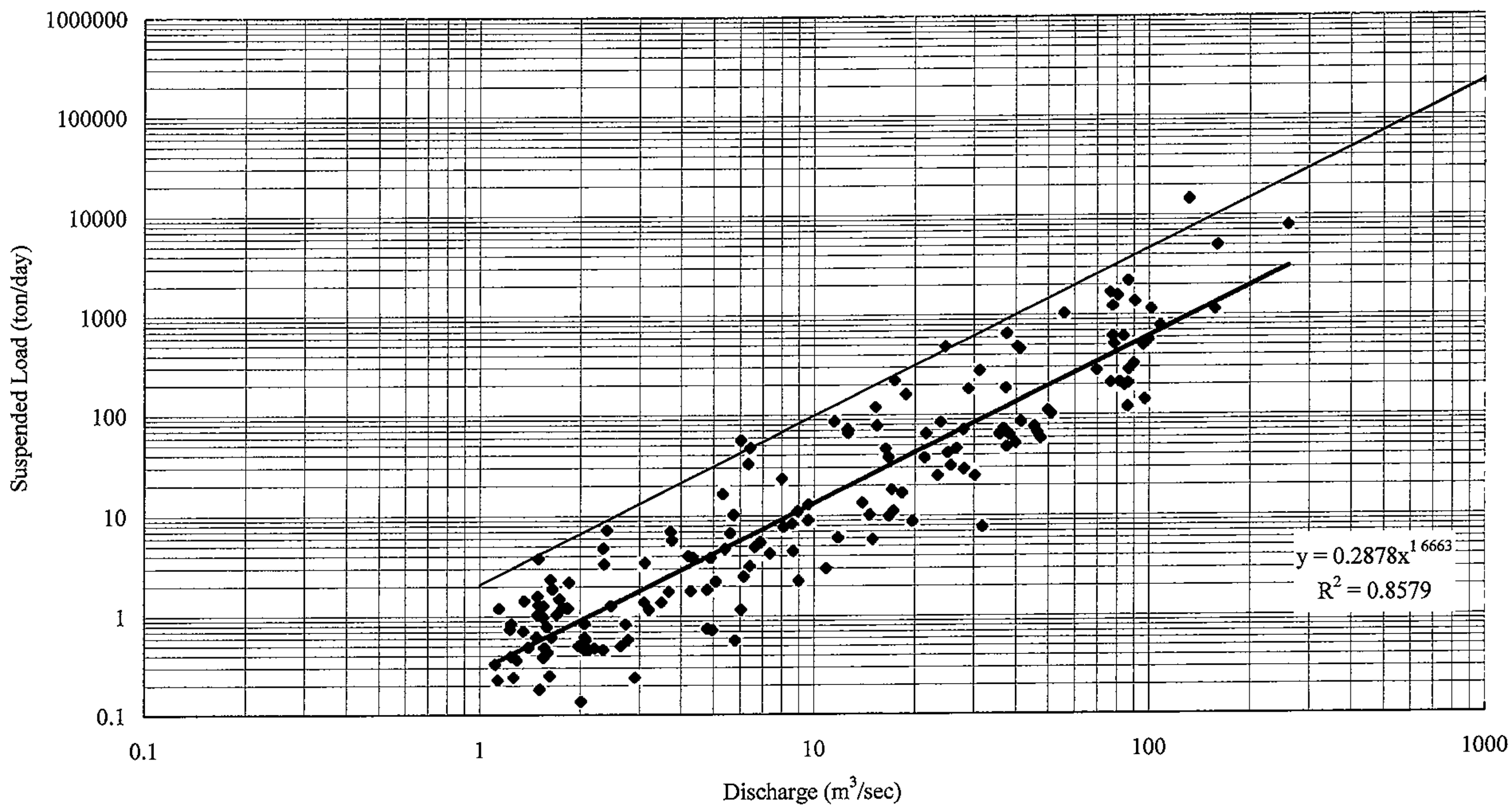

Fig. 6.24 Correlation between Suspended Load and Discharge at Osicala

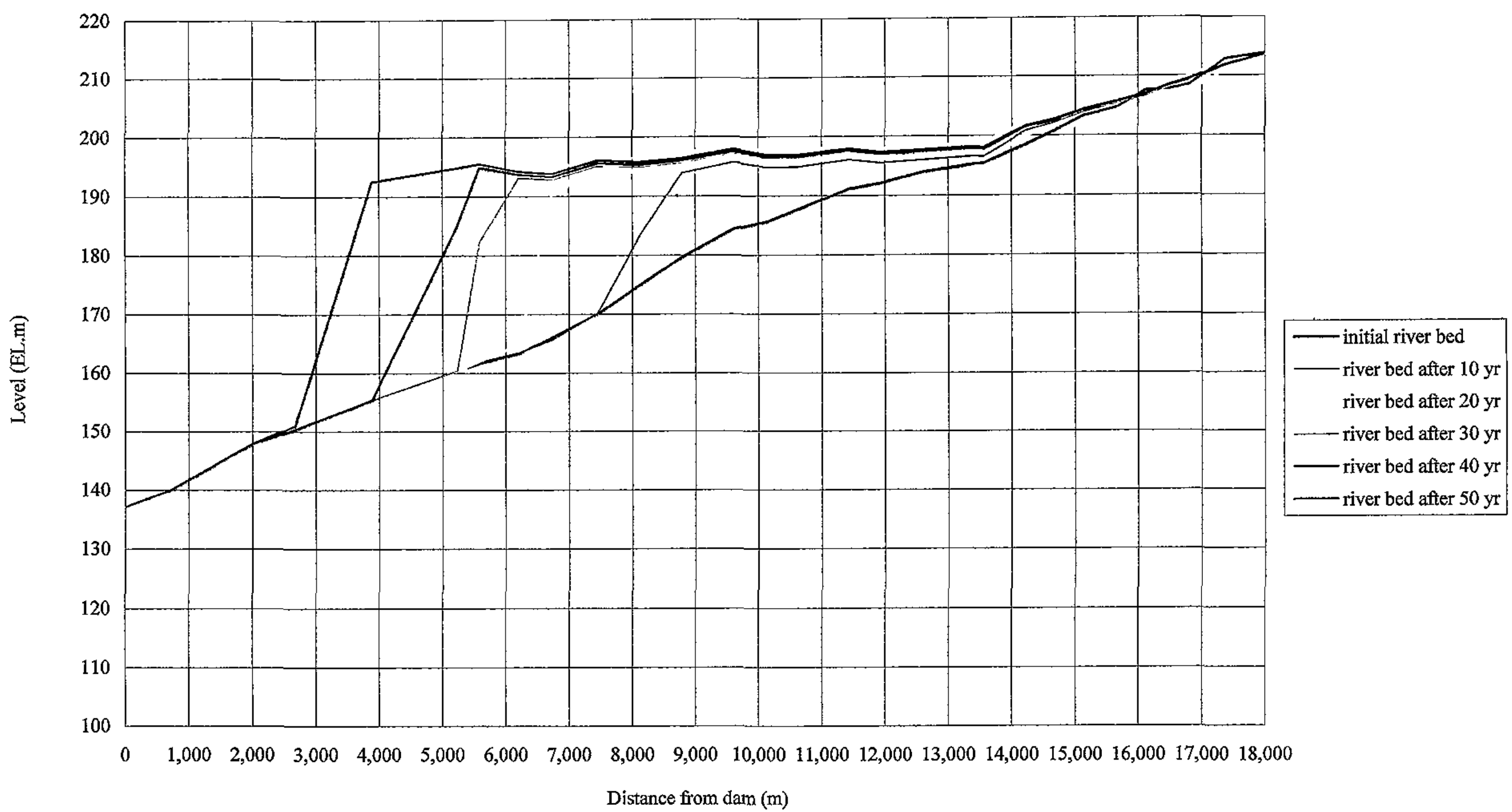

Fig. 6.25 Simulation of Sedimentation

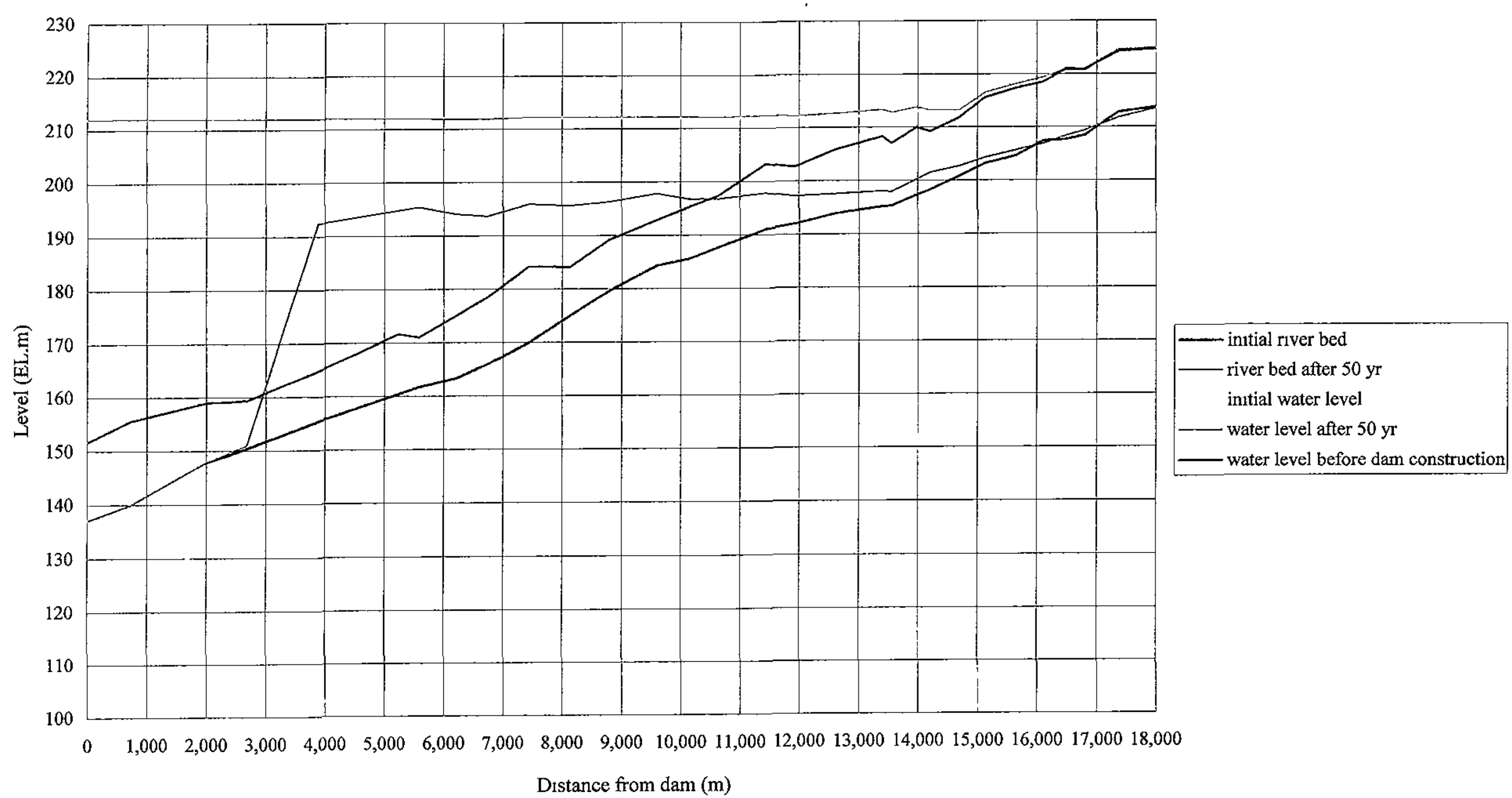

Fig. 6.26 Backwater Curve with a Flood Discharge (Q_F=6,484 m^3/s)

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