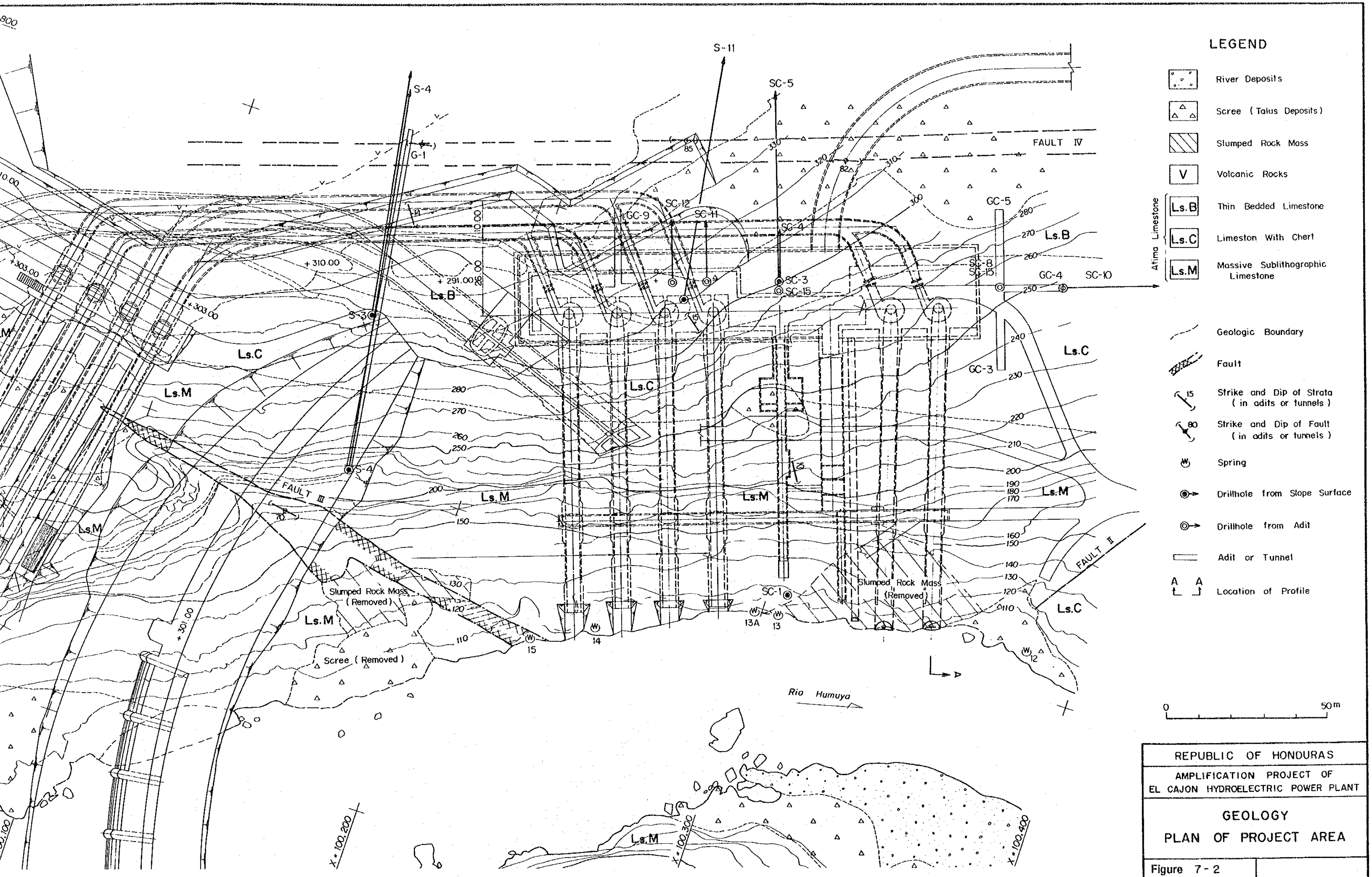
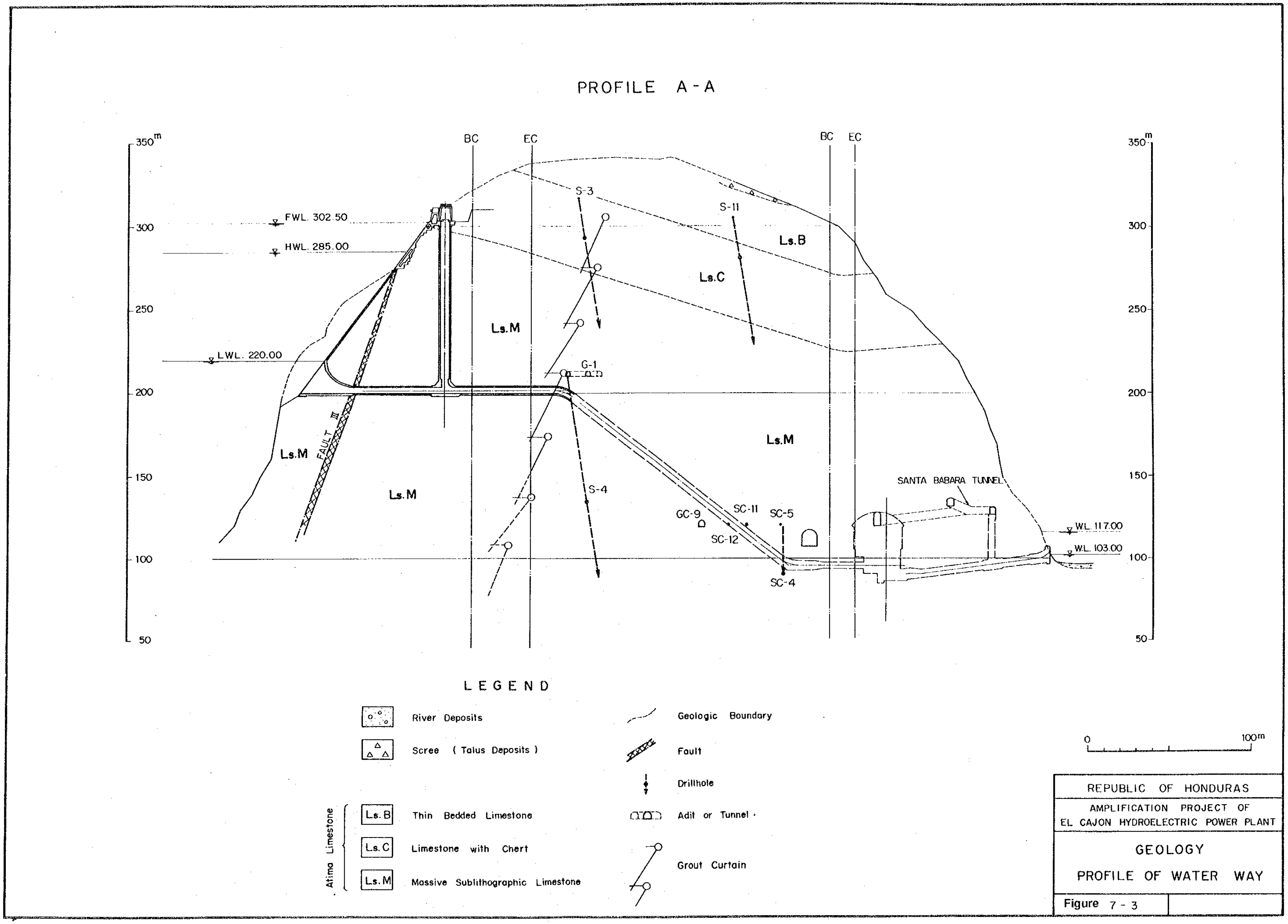

LEGEND
River Deposits
Scree (Talus Deposits)
Slumped Rock Mass
Volcanic Rocks
Atima Limestone
Ls.B Thin Bedded Limestone
Ls.C Limeston With Chert
Ls.M Massive Sublithographic Limestone
Geologic Boundary
Fault
Strike and Dip of Strata (in adits or tunnels)
Strike and Dip of Fault (in adits or tunnels)
Spring
Drillhole from Slope Surface
Drillhole from Adit
Adit or Tunnel
Location of Profile
0 50m
FAULT IV
FAULT III
FAULT II
Slumped Rock Mass (Removed)
Scree (Removed)
Rio Humuya
REPUBLIC OF HONDURAS
AMPLIFICATION PROJECT OF EL CAJON HYDROELECTRIC POWER PLANT
GEOLOGY
PLAN OF PROJECT AREA
Figure 7-2


PROFILE A-A
BC
EC
BC
EC
350m
300
250
200
150
100
50
FWL. 302.50
HWL. 285.00
LWL. 220.00
S-3
S-11
Ls.B
Ls.C
Ls.M
G-1
Ls.M
Ls.M
FAULT III
Ls.M
S-4
SANTA BABARA TUNNEL
GC-9
SC-11
SC-5
SC-12
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WL. 117.00
WL. 103.00
LEGEND
River Deposits
Scree (Talus Deposits)
Atima Limestone
Ls.B Thin Bedded Limestone
Ls.C Limestone with Chert
Ls.M Massive Sublithographic Limestone
Geologic Boundary
Fault
Drillhole
Adit or Tunnel
Grout Curtain
0
100m
REPUBLIC OF HONDURAS
AMPLIFICATION PROJECT OF
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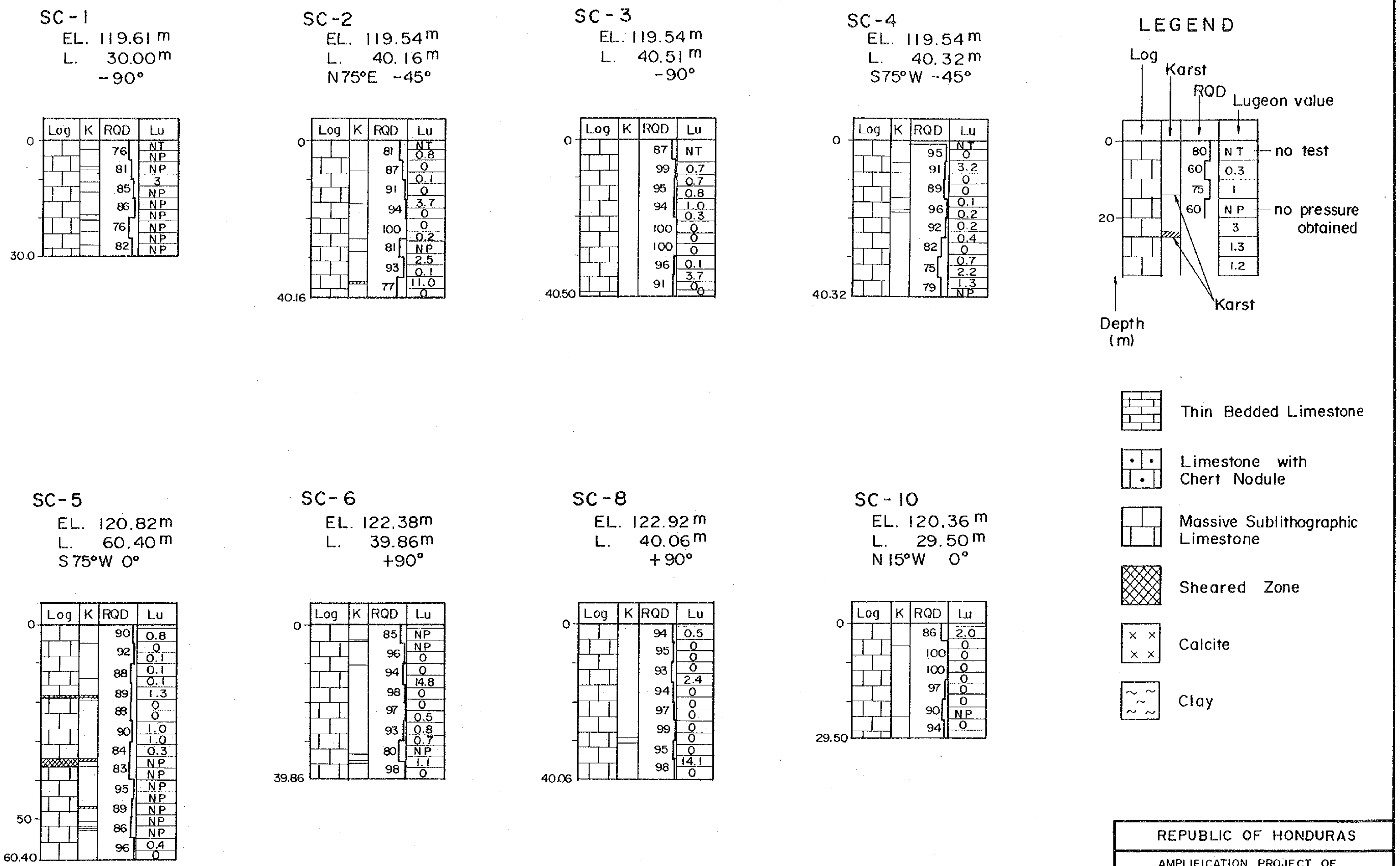
GEOLOGY
PROFILE OF WATER WAY
Figure 7 - 3



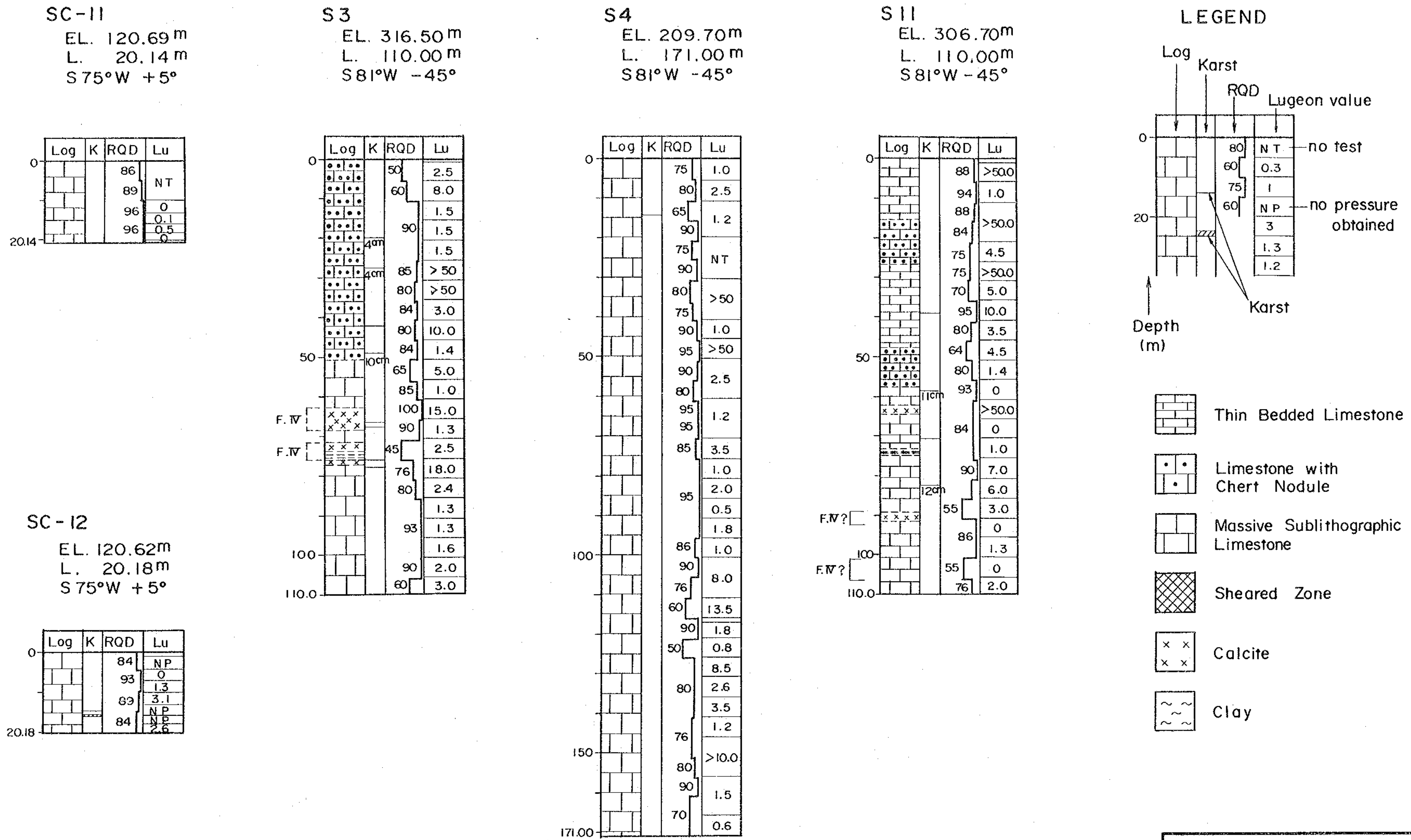
REPUBLIC OF HONDURAS

AMPLIFICATION PROJECT OF
EL CAJON HYDROELECTRIC POWER PLANT

GEOLOGY

LOG OF DRILLHOLE (1of 2)

Figure 7-4 (1)



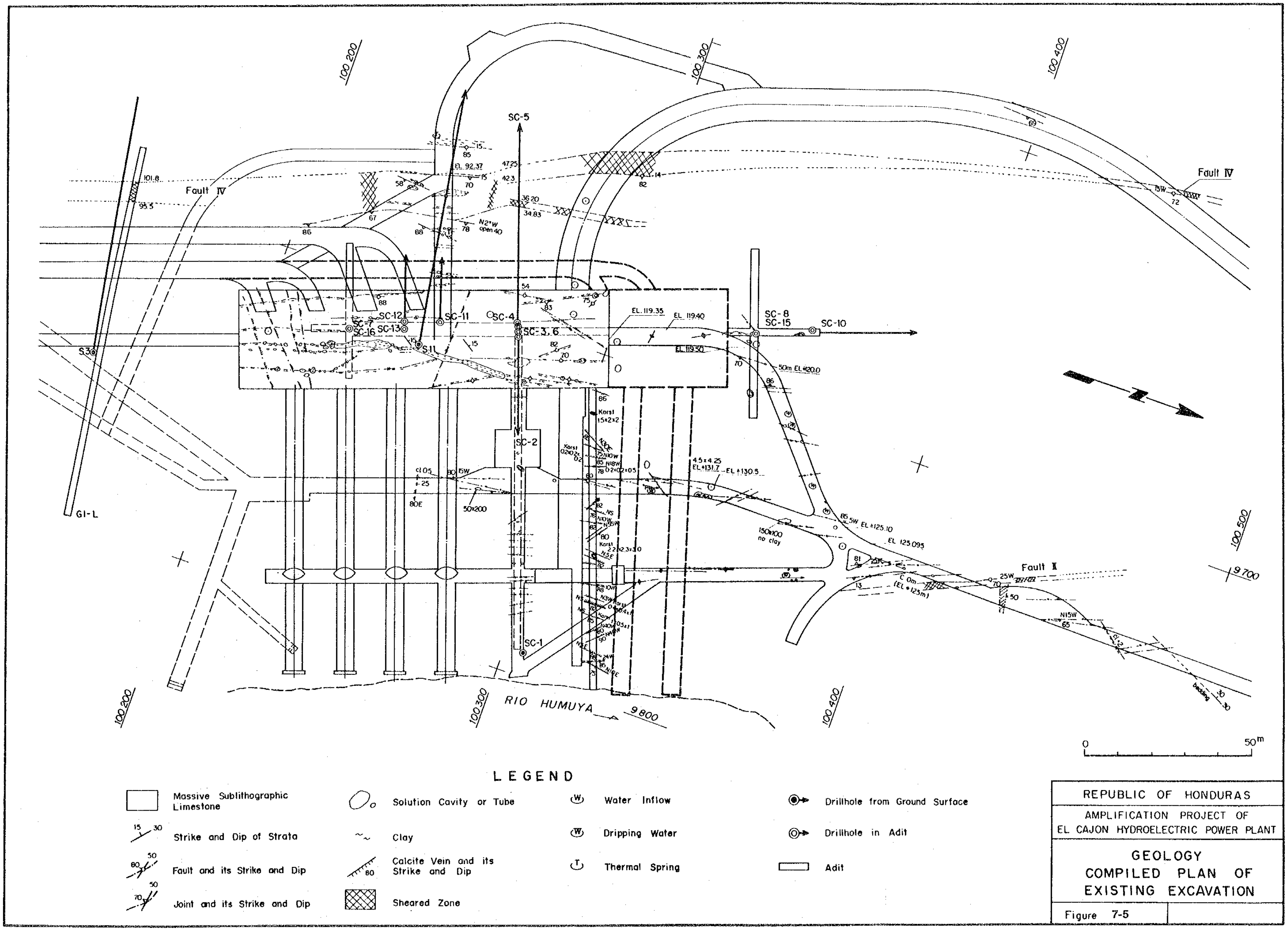
REPUBLIC OF HONDURAS

AMPLIFICATION PROJECT OF EL CAJON HYDROELECTRIC POWER PLANT

GEOLOGY

LOG OF DRILLHOLE (2 of 2)

Figure 7-4 (2)



REPUBLIC OF HONDURAS

AMPLIFICATION PROJECT OF
EL CAJON HYDROELECTRIC POWER PLANT

GEOLOGY
COMPILED PLAN OF
EXISTING EXCAVATION

Figure 7-5

Chapter 8 REMOTE TRANSMISSION SYSTEM

Chapter 8

REMOTE TRANSMISSION SYSTEM

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Chapter 8 REMOTE TRANSMISSION SYSTEM

8.1 Outline of ENEE Communications System

In the Republic of Honduras, the duty of radio wave assignment rests on HONDUTEL, which is a venture in charge of public communications.

Since the 150 MHz band and the 400 MHz band are the VHF bands assigned to ENEE for use in the remote transmission facility which is currently under planning, the proposal shall be based on the use of the unused frequencies in these frequency bands.

The communication network of ENEE consists of the power-line carrier communication sector and the wireless network sector, and the former is utilized by the telephone for load dispatching and maintenance, protection relay and the telemetering from the main power stations and substations to the Central Dispatching Office.

The wireless network sector utilizes the UHF (400 MHz band) and the VHF (150 MHz band) systems, and is mainly used for telephone and telemeter.

The communications maintenance territory of ENEE is broadly divided into the northern district and the central south district. The former includes the power stations and substations at La Ceiba, Tela, Cortés, Bermejo, Progreso, El Cajón, La Puerta, Río Lindo, Cañaveral, El Níspero, and El Mochito, and the latter, those at Piedras Azules, Santa Fe, Suyapa León and Pavana.

The UHF (400 MHz band) network used in the northern district is mainly used for the SCADA system and telephone.

The VHF (150 MHz band) is used as the telephone for transmission and distribution line maintenance in both districts.

ENEE has a plan of newly installing a 2 GHz band TDM radio communication network in the central south district in 1993, and is further scheduled to replace the UHF (400 MHz band) network by a 2 GHz band TDM radio communication network.

The present plan needs to be so advanced as to maintain compatibility with these scheduled plans.

8.1.1 Outline of Communication System in El Cajón

The communication system in El Cajón includes, besides the power-line carrier network, a local telephone exchange system consisting of a UHF (400 MHz band) and cable network.

In addition, the VHF (150 MHz band) is used in the power transmission and distribution line maintenance telephone.

8.2 Rainfall and Water Level Telemetering System

8.2.1 Outline of Rainfall and Water Level Telemetering System

(1) Concept of Rainfall and Water Level Telemetering System

The concept of the rainfall and water level telemetering system that accompanies the proposed expansion of El Cajón Power Station covers the entire system of the existing facilities of the Water Level Gauging Station and the Rainfall Gauging Station, and is outlined as follows:

The proposed telemeter network, as shown in **Fig. 8-1**, consists of several gauging stations for gauging the hydrological data (rainfall and water level) and supervisory/control stations for controlling the gauging stations and for collecting the data. The supervisory/control stations shall be established at the control building in El Cajón and the Central Dispatching Office in Suyapa. Basically, the gauging stations shall be controlled by the Control Building in El Cajón, but new facilities (case 1 and case 2) shall also be controllable by the Central Dispatching Office in Suyapa.

When the existing SCADA system is to be used (case 3), the gauging stations are to be controlled by the Control Building in El Cajón, and the Central Dispatching Office in Suyapa is to execute the data collection and monitoring only.

The supervisory/control stations shall type out the data received from the gauging stations and shall display the data on the graphic panel.

The data transmission between the gauging stations and the supervisory/control station in El Cajón shall be conducted over radio networks (150 MHz and 400 MHz), and the data transmission between the El Cajón Supervisory/Control Station and the Central Dispatching Office in Suyapa shall be executed over unused channels in the existing power-line carrier network.

For data collection, generally, two systems are available; the polling system in which the supervisory/control station calls up all the gauging stations one by one in sequence or collectively at once, requesting the sending of the gauging data, and the automatic data transmission system in which the gauging stations send in the gauging data at a regular interval or whenever certain changes occur, and in the proposed plan, the former polling system shall be employed on the following ground.

- Possibility of increasing the number of gauging station in one system
- Possibility of retrieving any data at any time.
- Possibility of shortening access time

8.2.2 Design of Rainfall and Water Level Telemetering System

(1) Radio Repeater Station (New Installation)

A repeater station shall be newly installed at the following location which is central among the existing water level gauging stations and rainfall gauging stations (including weather stations) distributed in the El Cajón watershed regions, where the whole area coverage is secured with the minimum number of repeater stations:

- W longitude 87° 31' 47"; N latitude 14° 48' 10"; 8 km west of La Libertad
  Altitude; 1,710 m (estimated)

The design conditions are as follows:

(a) Because of the difficulty in installing power supply line, the solar cell power supply system shall be used in this system.

(b) In consideration of the bad road conditions to the repeater station site, the storage battery capacity shall be sufficient to warrant load operation over one month even when insolation remains absent continuously.

(c) Because of the nearly uniform distribution bearing angle of the gauging stations, the antenna to be used shall be non-directional.

(d) Because of the larger transmission loss of the radio wave in the 150 MHz and 400 MHz bands, compared with the 60 to 70 MHz band, a high power radio wave output shall be secured with high output transmitters and high gain antennas.

(e) The steel tower heights of the repeater station and the gauging stations shall be such that an unobstructed view is secured between them.

(f) The station buildings shall be made of the standard type ENEE building.

(g) Employment of a watcher or installation of a protection fence shall be considered because of security control of radio repeater stations.

(2) Existing Repeater Station (Los Picachos)

Two cases, 1) the existing facility (400 MHz radio facility) between El Cajón and Los Picachos is usable, and 2) it is not usable, shall be taken into consideration.

The design conditions are as follows:

(a) When the existing facility (400 MHz radio facility) is not usable, a 2 GHz radio equipment shall be newly installed.

(b) In the design, the use of the power supply facility of the existing repeater station (Los Picachos) shall be assumed.

(c) In the design of the building space in the existing repeater station (Los Picachos), the increase of space shall be assumed.

(d) A new steel tower shall be installed for the repeater station (Los Picachos), on the assumption that the existing tower cannot be used.

(3) Existing El Cajón Control Building

The design conditions shall be as follows:

(a) A supervisory/control station equipment, an operating console, a typewriter and a display shall be newly installed.

(b) A new 2 GHz radio network shall be installed in place of the existing facility (400 MHz radio facility), when the latter cannot be used.

(c) Two cases shall be examined; the case of an independent telemeter system between El Cajón and Suyapa (case 1 and case 2), and the case of the use of the existing SCADA system (case 3).

(d) The existing power supplies (48 V DC and 100 V AC) are assumed to be usable in designing the facilities.

When the existing SCADA system is to be used, the I/O shall be connected to the existing RTU, and only the output up to the I/O of the supervisory/control station equipment shall be planned.

(4) Existing Central Dispatching Office in Suyapa

The design conditions shall be as follows:

(a) Only when the El Cajón to Suyapa telemeter system is to be an independent system (case 1, case 2), a supervisory/control station equipment, an operating console, a typewriter and a display shall be newly installed in the Central Dispatching Office in Suyapa.

(b) The existing power supply system (48 V DC, 100 V AC) shall be assumed to be usable in designing the system.

(5) Water Level Telemetering Gauging Station

The existing water level gauging stations (Santa Elena, Maragua, Guacamaya, El Jicaro, Los Encuentros, Siale and Marale) are generally located in the deep valleys of El Cajón, where no direct view to the repeater station is available for radio wave transmission, and for this reason, a radio wave transmission survey test is required. Especially, Siale is unfavorable in view condition, and a detailed survey test is required. The design conditions shall be as follows:

(a) The steel tower shall be sufficient to meet the antenna height requirement at the respective locations.

(b) The solar cell power supply system shall be adopted in the design.

(c) Since the existing self-recording-type water level meter does not allow the adaption to a telemetering system, and since the well for water level measuring is narrow, a telemeter-use water level meter, a well, a station building, a power supply system, gauging equipment and radio equipment shall be newly installed.

(6) Weather (Rainfall Gauging) Station

Because the existing weather stations (El Cajón, Santa Elena, Marale, San Jeronimo, and Vallecillo) and the existing Rainfall Gauging Stations (El Palmital, Sulaco, Pueblo Nuevo, Esquias and San Ignacio) are considered to be more favorable in the installation condition, than the water level gauging stations, the power supply for them is considered to be dependable on the distribution line.

However, the station in Sulaco is located where vision is blocked, a detailed radio wave transmission survey test needs to be executed.

The design conditions are as follows:

(a) Since the existing self-recording type precipitation meter is not usable for rainfall telemetering, a tipping-bucket type rain gauge shall be newly installed.

(b) Since the existing gauging stations are located not necessarily at an optimum radio wave transmission point, a new station building and a steel tower shall be erected close to the existing gauging station.

(c) Power supply systems, gauging equipment and radio equipment shall be newly installed.

8.3 Discharge Warning System

8.3.1 Outline of Discharge Warning System

(1) Concept of Discharge Warning System

The proposed discharge warning system is for warning the people in the downstream area before dam water discharging, which creates a very different artificial state in the river system through the operation of the El Cajón dam in such an emergency state as flood, in order to prevent personal and other hazards. The discharge warning system shall consist of discharge warning stations for giving warning in the downstream area of the El Cajón dam, and a supervisory/control station for controlling the discharge warning stations.

The discharge warning stations shall be installed, in consideration of the conditions including the areas' requirements for warning because of the large water level fluctuation caused by water discharge, of the sound volume setting and of the sound insensitive locality, at two locations; one in Santa Rita, and the other in El Remolino. (**Fig. 8-11**)

The warning stations shall be designed to ensure restless transmission of warning and notices through out the object area, in due consideration of the sound reach range of sirens or broadcast sound.

Between the two alternatives for supervisory/control and transmission; the wireless system and cable system, the high-reliability wireless system shall be employed in the proposed system in consideration of the absence of various shortcomings which accompany the cable system: The great cable length involving breakage and the vulnerability of cables to abnormal weather conditions such as storm.

The discharge warning network shall be composed of a supervisory/control station in El Cajón Control Building, a repeater station in Los Picachos, and two warning stations, controlled by a 150 MHz radio network, in Santa Rita and El Remolino. (**Fig. 8-15**)

8.3.2 Design of Discharge Warning System

(1) Existing Radio Repeater Station (Los Picachos)

Two cases shall be taken into consideration; one case where the existing facility (400 MHz radio equipment) between El Cajón and Los Picachos is used, and the other case where it is not used.

The design conditions are as follows:

(a) When the existing facility (400 MHz radio equipment) can not be used, and it is to be replaced by a 2 GHz radio equipment. (common use with the rainfall and water level telemetering system)

(b) The power supply facility of the existing repeater station (Los Picachos) is assumed to be usable in the design. (common use with the rainfall and water level telemetering system)

(c) The station building space in the existing repeater station (Los Picachos) is assumed to be increased in the design. (common use with the rainfall and water level telemetering system)

(d) The steel tower of the existing repeater station (Los Picachos) is considered to be hardly usable, and new tower shall be erected. (common use with the rainfall and water level telemetering system)

(2) Existing El Cajón Control Building

The design conditions are as follows:

(a) A supervisory/control station equipment, an operating console and a typewriter shall be newly installed.

(b) When the existing facility (400 MHz radio communication facility) can not be used, it is to be replaced by a 2 GHz radio communication network. (common use with the rainfall and water level telemetering system)

(c) The existing power supplies are assumed to be usable in the designing of the proposed system. (common use with the rainfall and water level telemetering system)

(3) Warning Station

Two warning stations shall be allocated at El Remolino and Santa Rita, in consideration of the overall situations including the residence conditions, topography, insensitive zone, etc. in the downstream area.

The design conditions are as follows:

(a) Steel towers shall be newly erected to secure the needed antenna height at the respective locations.

(b) The power supply through the distribution line is assumed to be available, in the design of the system.

(c) A station building, a power supply system, a siren alarm unit and a radio equipment unit shall be newly installed.

(d) The siren warning station equipment shall be capable of serving both as a speaker and as a siren.

8.4 Conclusion

8.4.1 Rainfall and Water Level Telemetering System

The following three renewal plans are considered according to renewal time of 400 MHz radio equipment between Los Picachos and El Cajón.

Case	Renewal time	Construction period	Construction cost	Installation condition
1	1997 -	3 years	US$ 4,886,000	The system between El Cajón and Suyapa shall be independent
2	1992 - 1997	3	4,501,000	The system between El Cajón and Suyapa shall be independent
3	1992 - 1997	3	3,605,000	Existing SCADA System shall be used

(1) For the detailed design of the telemetering system, a detailed survey of radio wave propagation characteristics must be conducted, and it is expected that this survey would take a half year to one year.

(2) A detailed survey has been conducted on the existing 400 MHz radio equipment between El Cajón and Los Picachos. It is possible to install additional 24 channels on these facilities. Therefore, we recommend Case 2 as the economical, optimal system, if the system is to be constructed within 5 years.

(3) If the system is to be constructed more than 5 years in future, we recommend Case 1, which is the plan of replacing the existing 400 MHz radio equipment between El Cajón and Los Picachos by taking into account the possibility of increasing the number of channels in future.

(4) Concerning Case 3, the construction cost estimated in this study is the lowest, because the existing SCADA System is utilized. However, the memory capacity of the existing CPU at Suyapa Central Load Dispatching Office is small, and it may be difficult to expand this system. Therefore, the system of Case 3 would not turn out to be a convenient system.
However, this plan is worthwhile for further consideration when the CPU is replaced in future.

As for construction period:

(1) It is recommended to divide the construction schedule into two stages; allocating 1 year for detailed survey and design, and 2 years for field construction work.

(2) The recommended schedule is to implement the construction work of the main channel from El Cajón, via Los Picachos, to the new repeater station first, and then implement the construction works of related communication systems of each rainfall gauging station, and water level gauging station. In particular, due consideration must be given on the construction work of water level gauging stations, because conditions of their sites are not favorable for construction work.

8.4.2 Discharge Warning System

The following two construction plans are considered according to renewal time of existing 400 MHz radio equipment between Los Picachos and El Cajón.

Case	Renewal time	Construction period	Construction cost
1	1997-	1.5 years	US$ 839,000 *(US$ 1,362,000)
2	1992-1997	1.5	US$ 887,000

* In case of changing radio facilities between Los Picachos and El Cajón into 2 GHz System.

(1) A separate, detailed survey of radio wave propagation characteristics and the sound propagation test will be required in developing the detailed design, and this survey will take around half a year.

(2) A detailed survey has been conducted on the existing 400 MHz radio facilities between El Cajón and Los Picachos. It is possible to install additional 24 channels on these facilities. Therefore, we recommend Case 2 as the economical, optimal system, if the system is to be constructed within 5 years.

(3) If the system is to be constructed more than 5 years in future, we recommend Case 1, which is the plan of replacing the existing 400 MHz radio facilities between El Cajón and Los Picachos by taking into account the possibility of increasing the number of channels in future.

As for construction period:

(1) It is recommended to divide the construction schedule into two stages; allocating half a year for detailed survey and design, and 1 year for field construction work.

(2) First, the construction works of the portions of communication facilities between El Cajon and Los Picachos which are commonly used by the rainfall/water level telemetering system shall be mainly implemented. Then, the construction works of communication system of each discharge warning station shall be implemented, and the output of warning equipment shall be reviewed by surveying the propagation ranges of siren sound and warning voices.

8.4.3 Conclusion

If the rainfall and water level telemetering system and the discharge warning system are constructed simultaneously, this would be more economical because the common facilities for these systems to be installed at El Cajón and Los Picachos can be manufactured more efficiently. And it is recommended to construct both systems after 1997 in case the existing radio facilities are to be changed. Construction period will be 3 years including investigation period. Total construction cost of the rainfall and water level telemetering system and the discharge warning system will be US$ 5,725,000.

Training must be provided to the maintenance personnel and operating personnel to ensure operation and maintenance of the system and appropriate consideration must be given on this matter prior to operation.

Table 8-1 The Yearly Duration of Sunshine (Tegucigalpa)

TEGUCIGALPA

MONTH / THE YEAR	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL [Hour]
1970	255	228	246	212	245	160	232	206	172	205	165	200	2,526
1980	222	250	278	238	235	152	226	206	188	178	172	194	2,539

Table 8-2 The Yearly Duration of Sunshine (Choluteca)

CHOLUTECA

MONTH / THE YEAR	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	TOTAL [Hour]
1970	292	230	295	286	275	232	280	235	202	220	236	284	3,067
1980	315	240	272	281	262	206	252	215	130	231	236	270	2,910

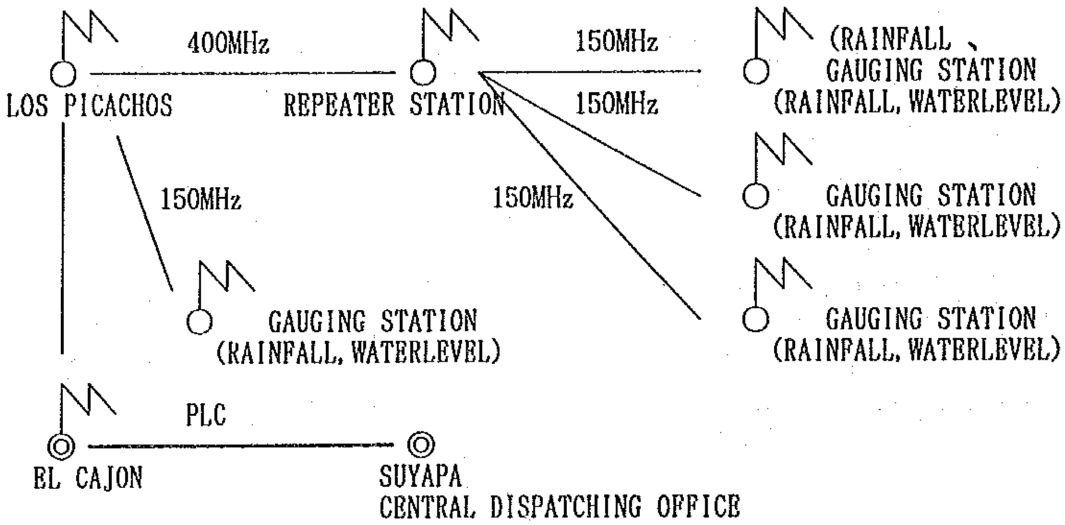
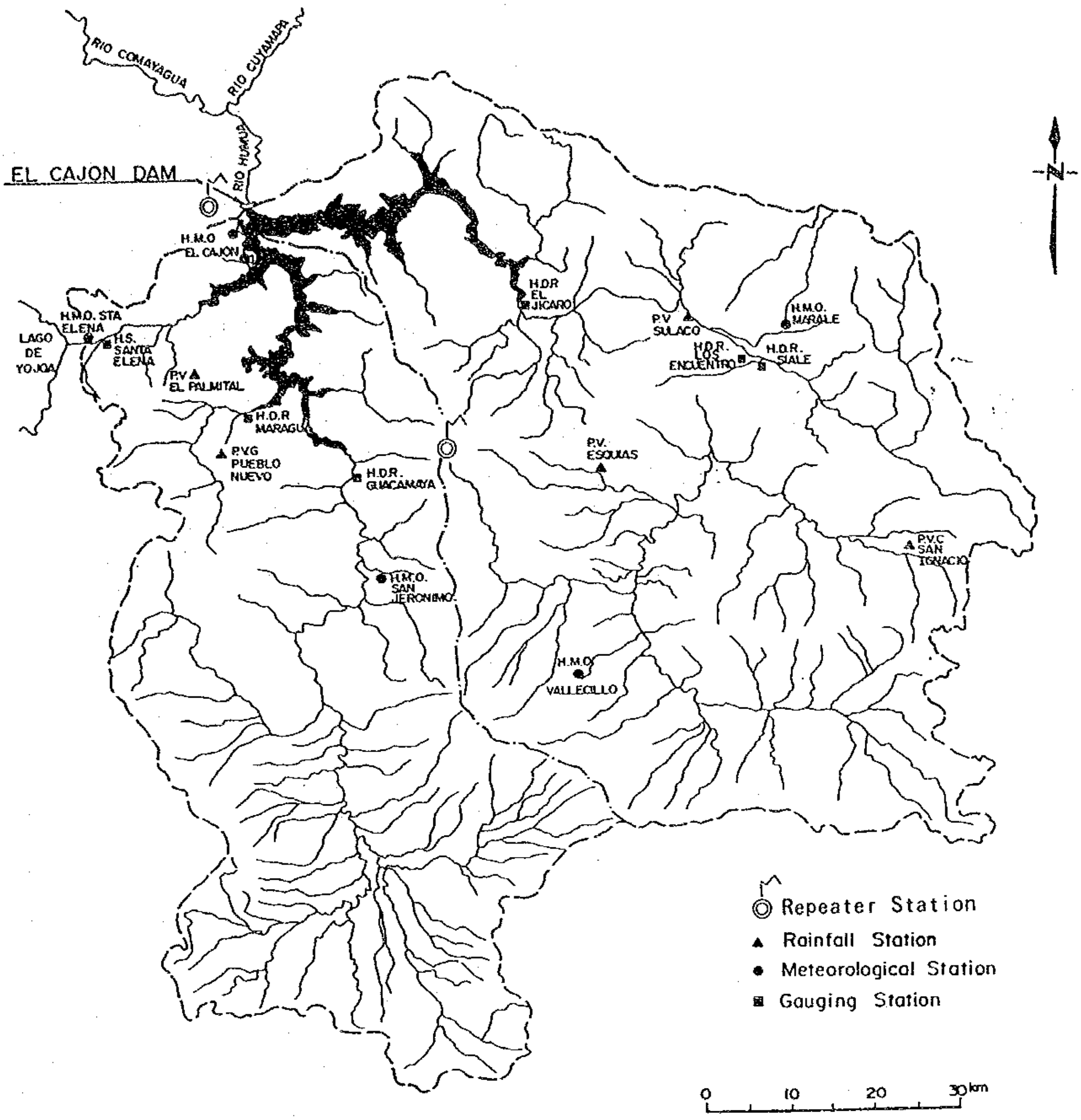


Figure 8-1 Rainfall and Water-level Telemeter System



Catchment area

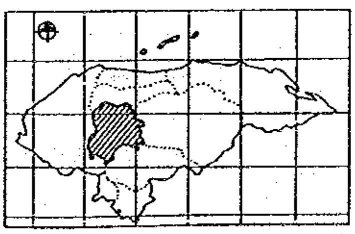


Figure 8-2 Rainfall, Meteorological and Gauging Station of EL CAJON River Basin

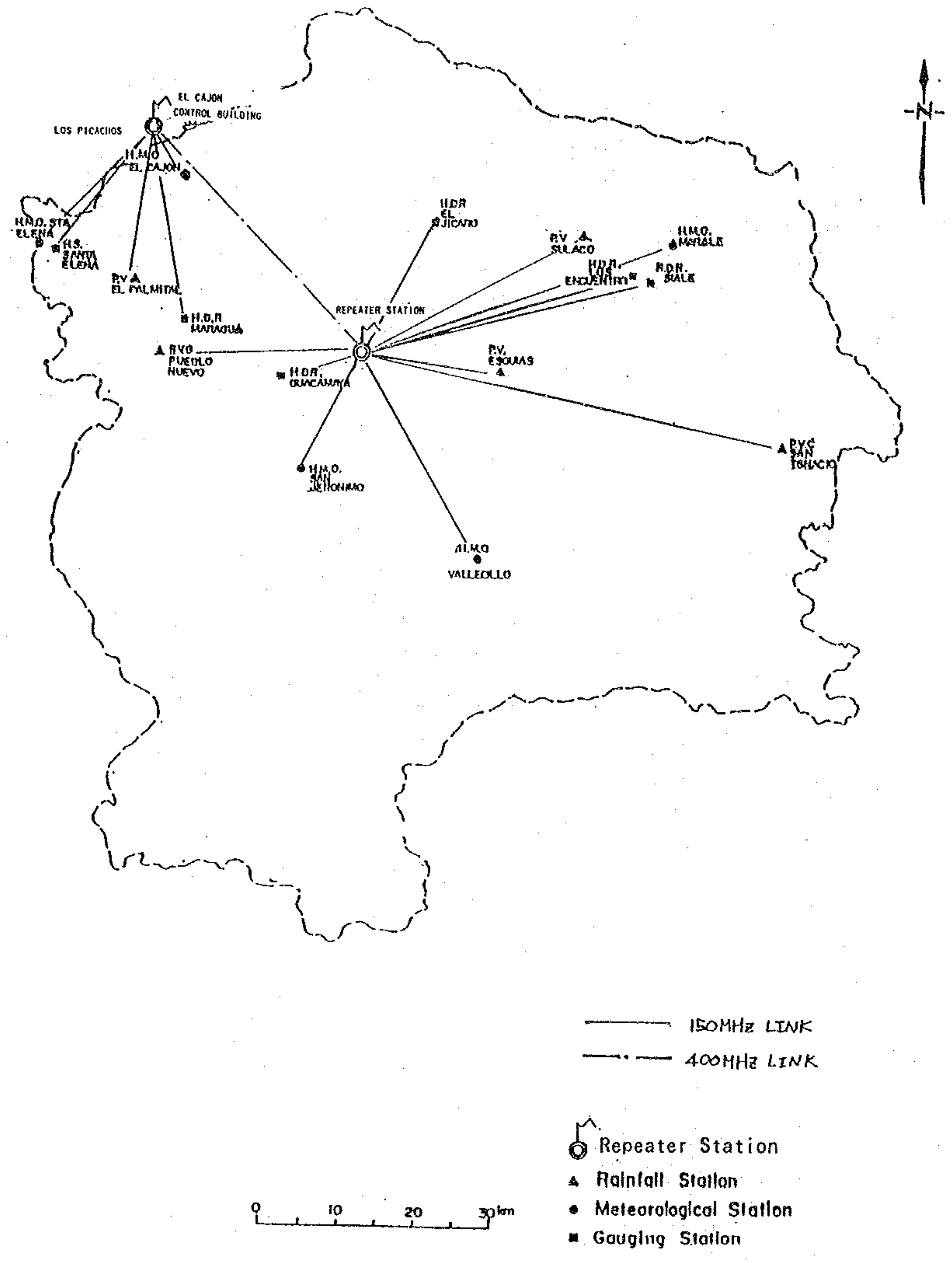


Figure 8-3   Radiowave System of Rainfall and Water-level Telemetering

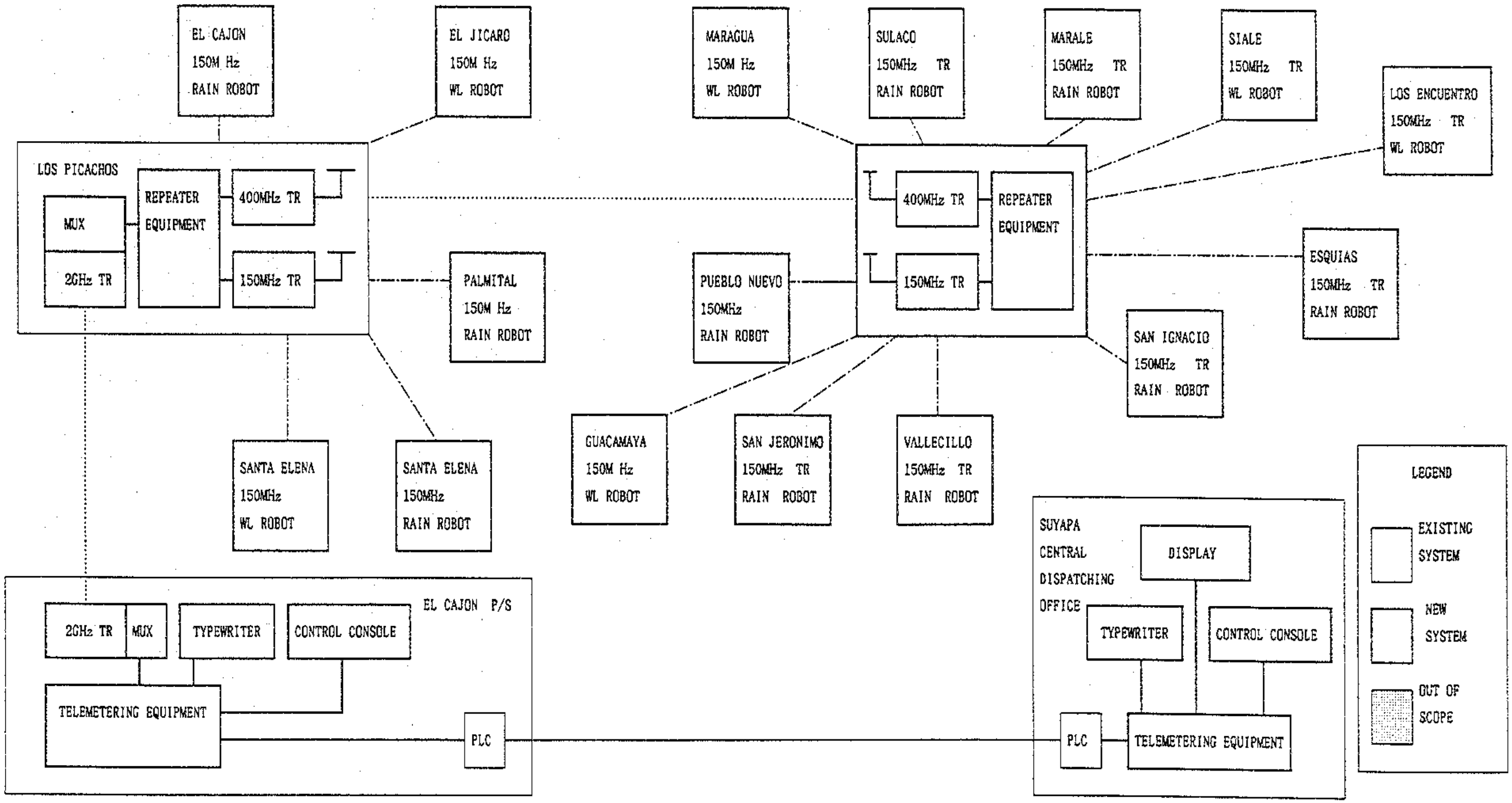


Figure 8-4 Rainfall and Water-level Telemetering System (CASE 1)

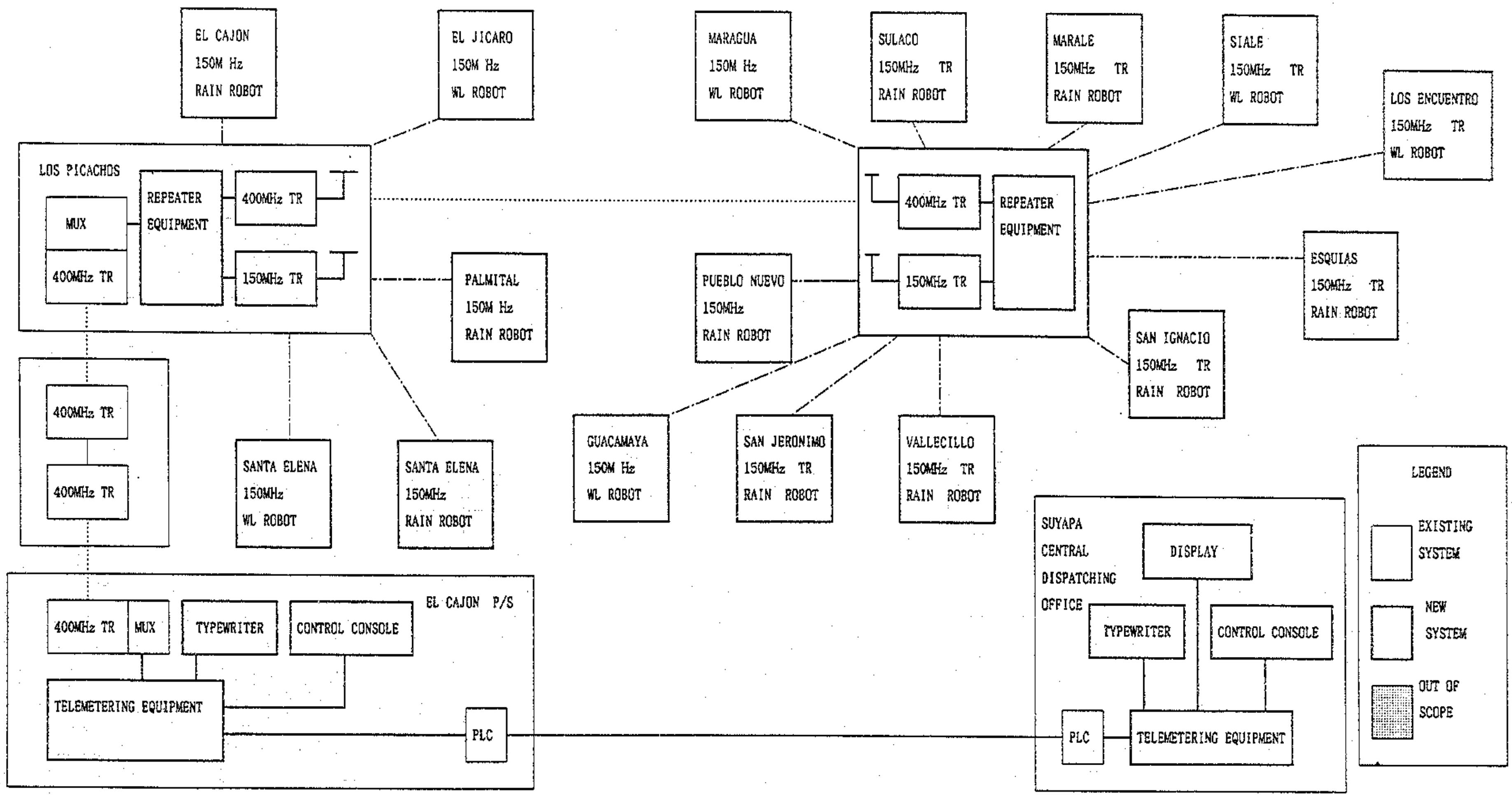


Figure 8-5 Rainfall and Water-level Telemetering System (CASE 2)

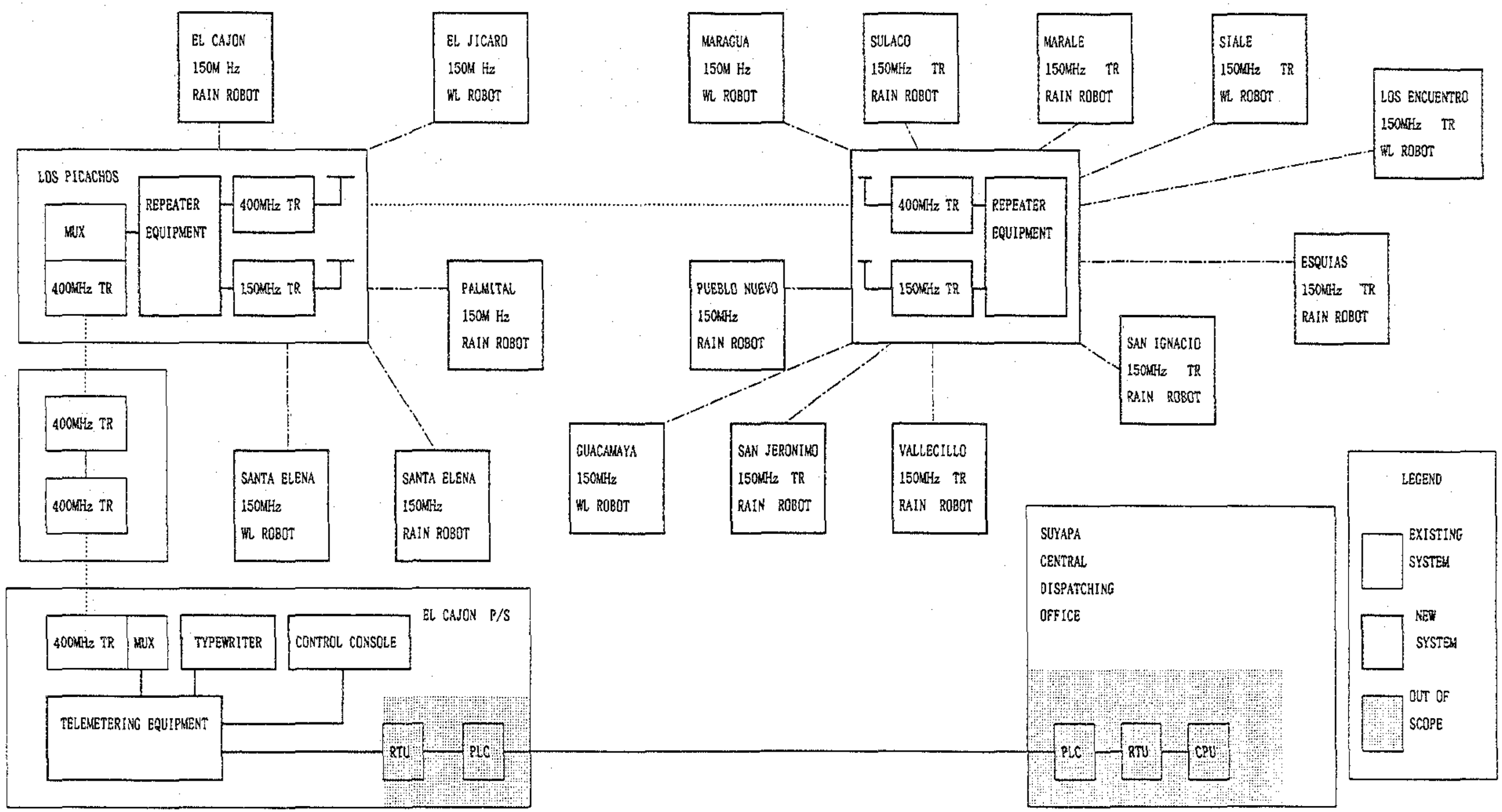


Figure 8-6 Rainfall and Water-level Telemetering System (CASE 3)

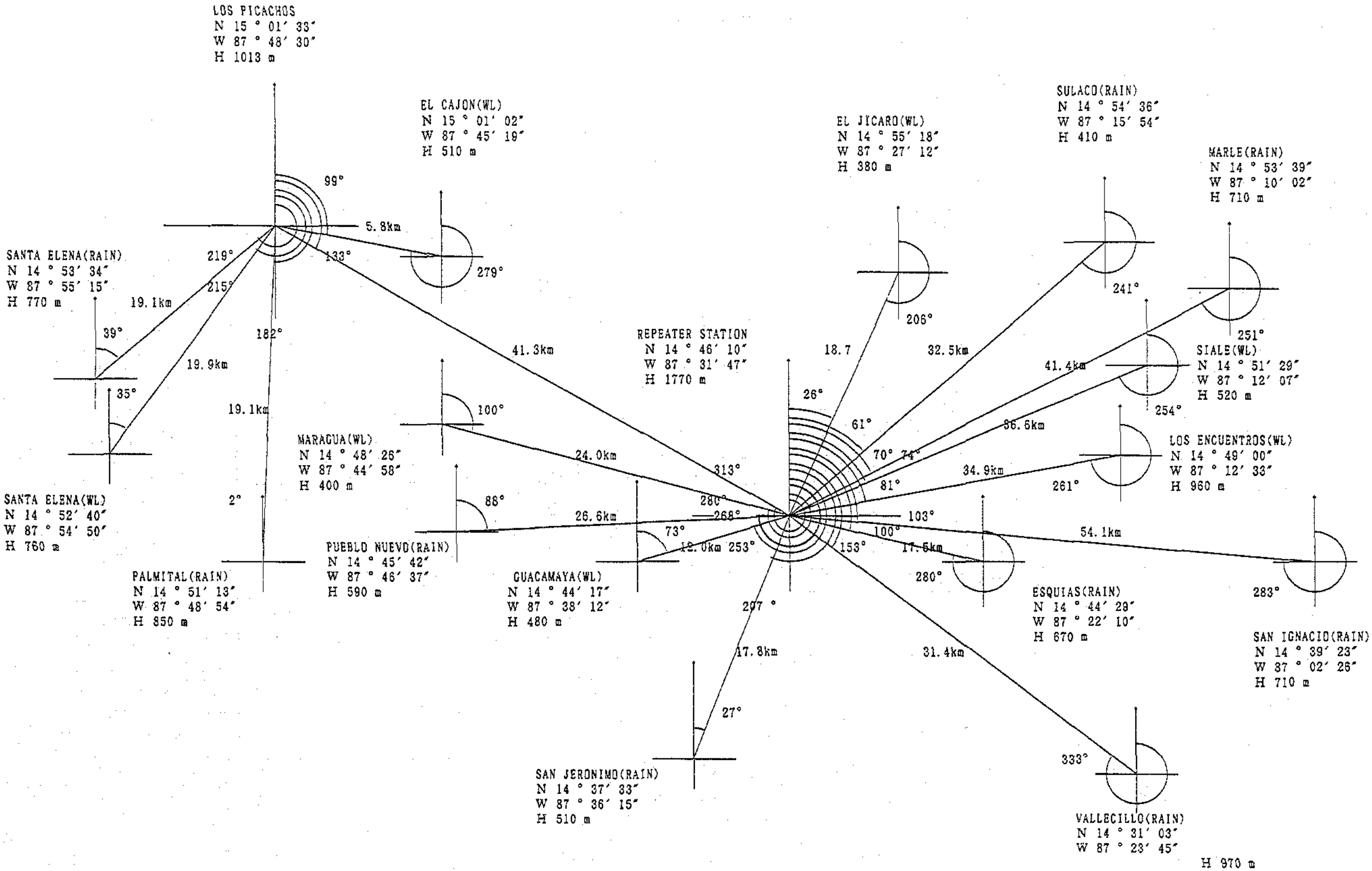
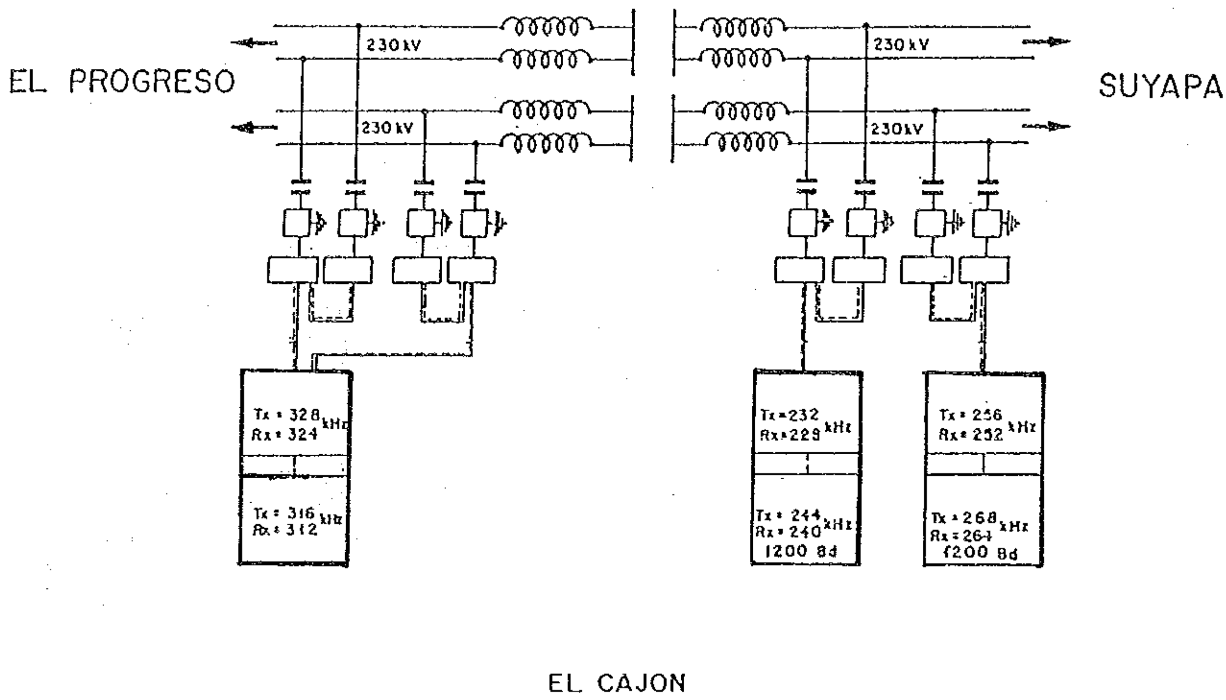


Figure 8-7 Rainfall and Water-level Tetemetering System Rout Map

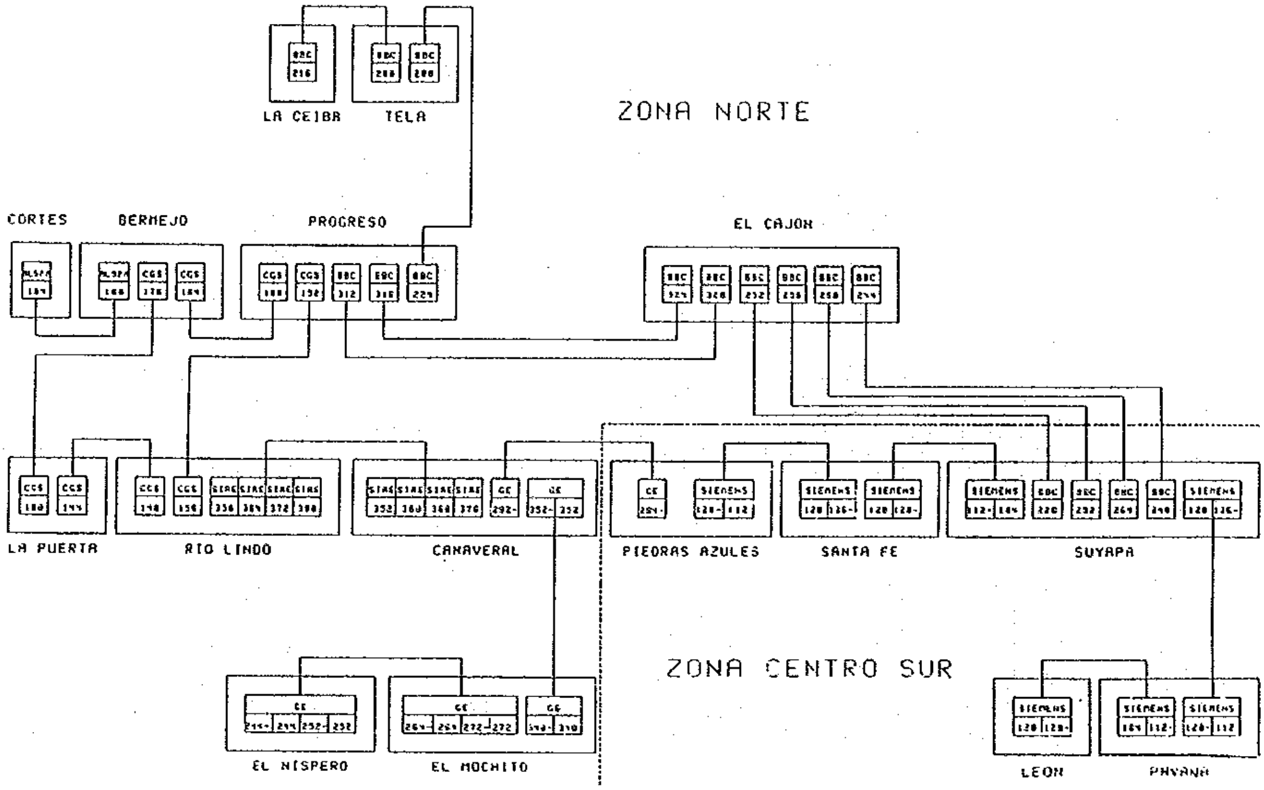


LEGEND

PLC SYS 1
TX :TRANSMISSION FREQUENCY RX :RECIEVING FREQUENCY
PLC SYS 2
TX :TRANSMISSION FREQUENCY RX :RECIEVING FREQUENCY

AVAILABLE PLC

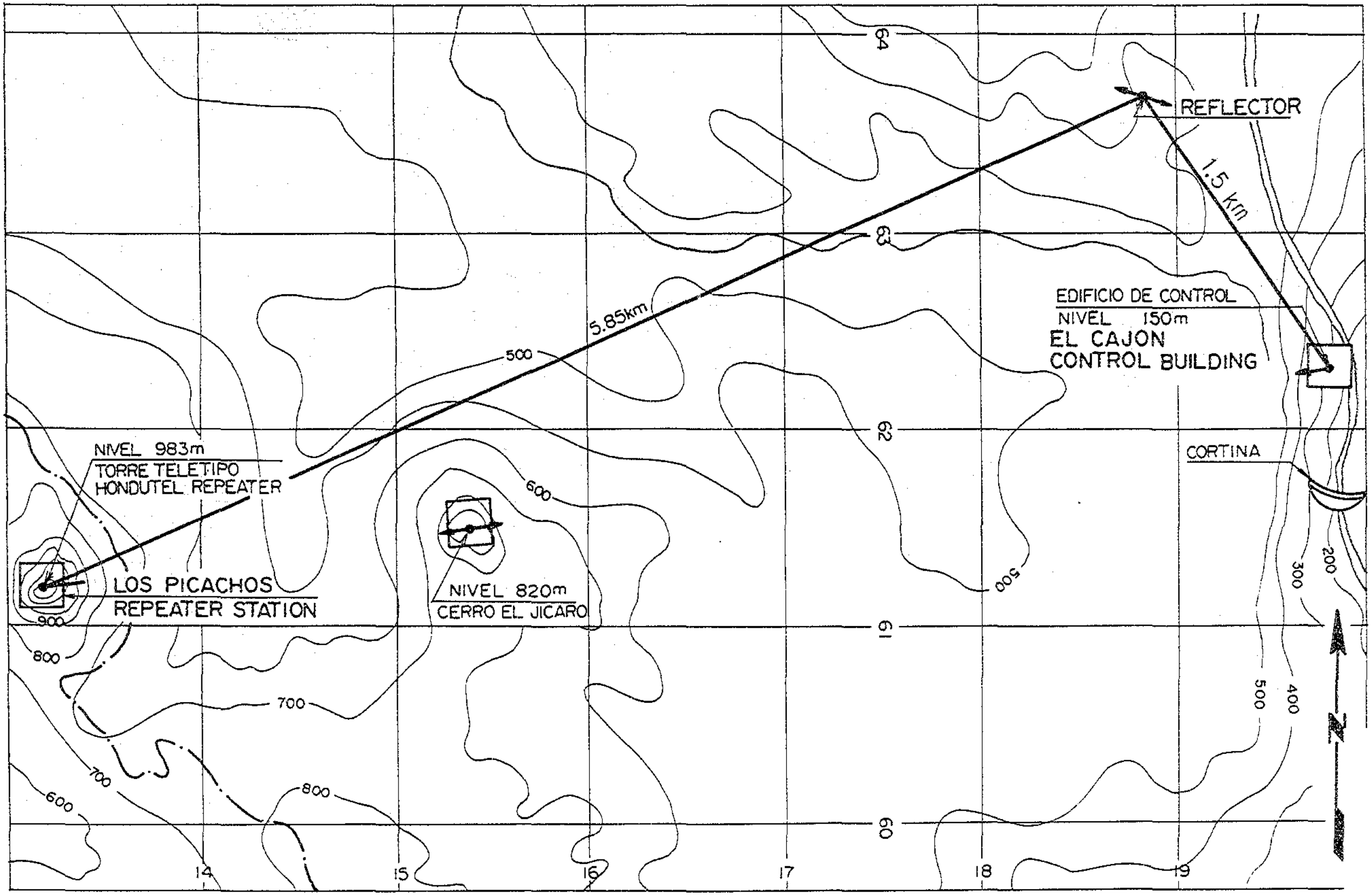
Figure 8 - 8 El Cajon Existing PLC Links



LEGEND

MANUFACTURER
TRANSMISSION FREQUENCY

Figure 8 - 9 Existing PLC Links of ENEE



SCALE 1: 25,000

Figure 8 - 10 2 GHz RADIOWAVE SYSTEM

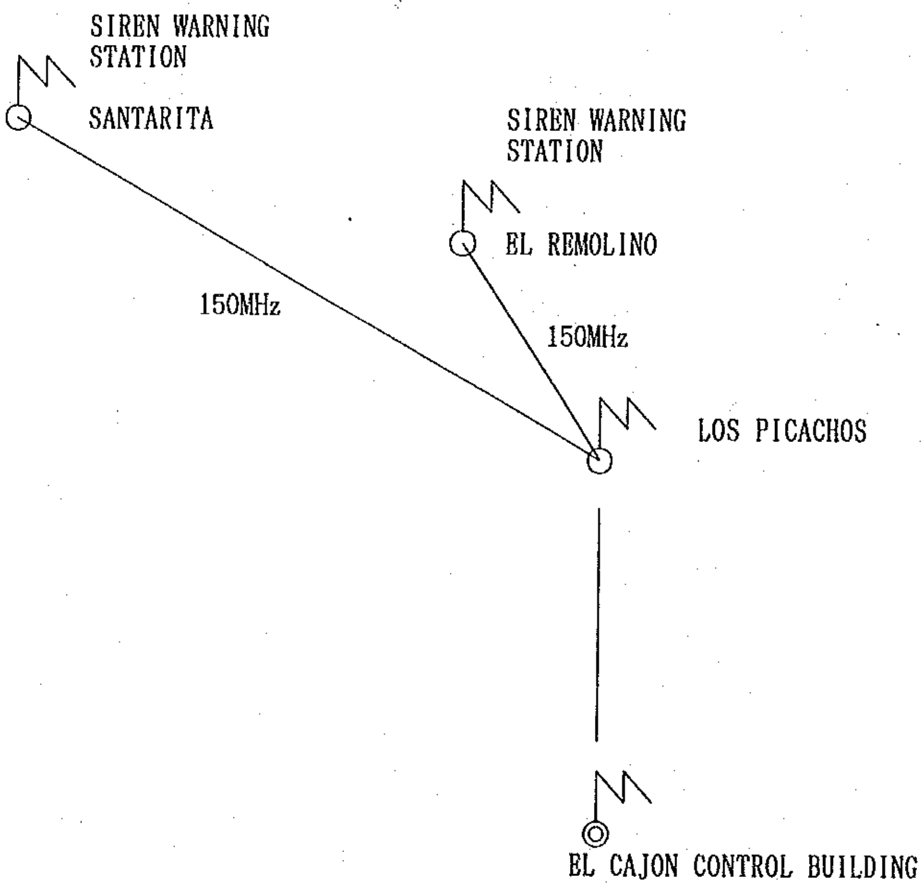


Figure 8-11 Discharge Warning System

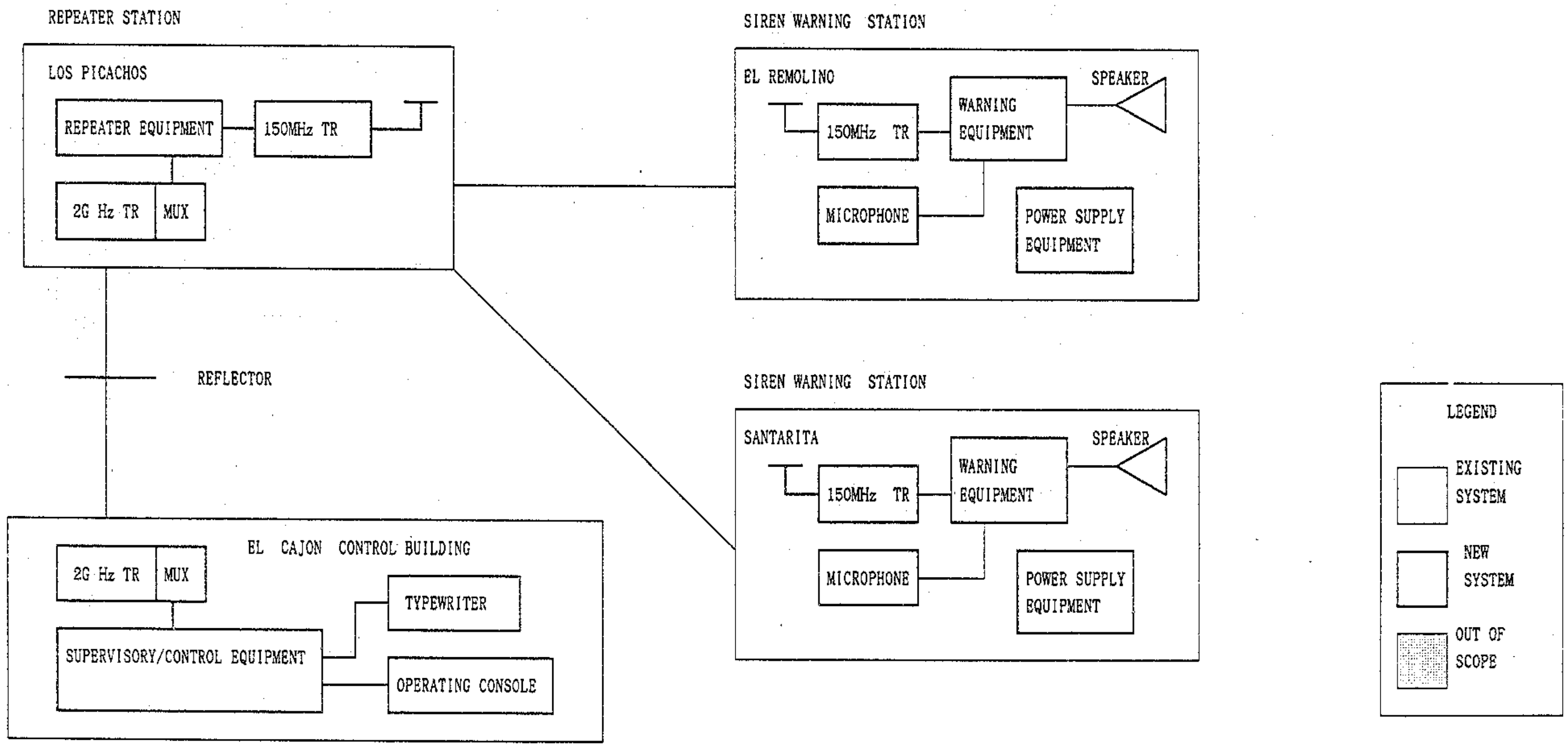


Figure 8-12 Discharge Warning System (CASE 1)

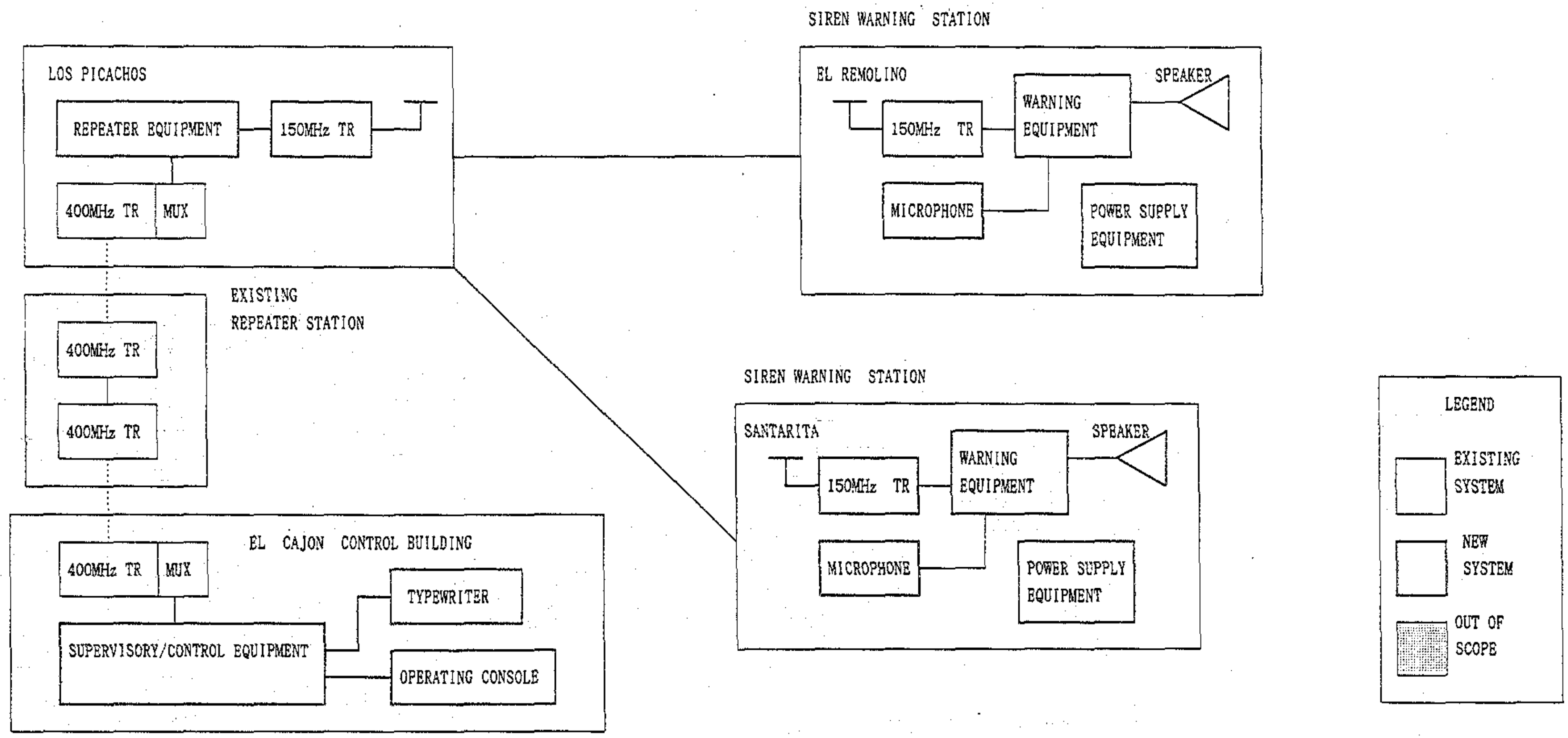


Figure 8-13 Discharge Warning System (CASE 2)

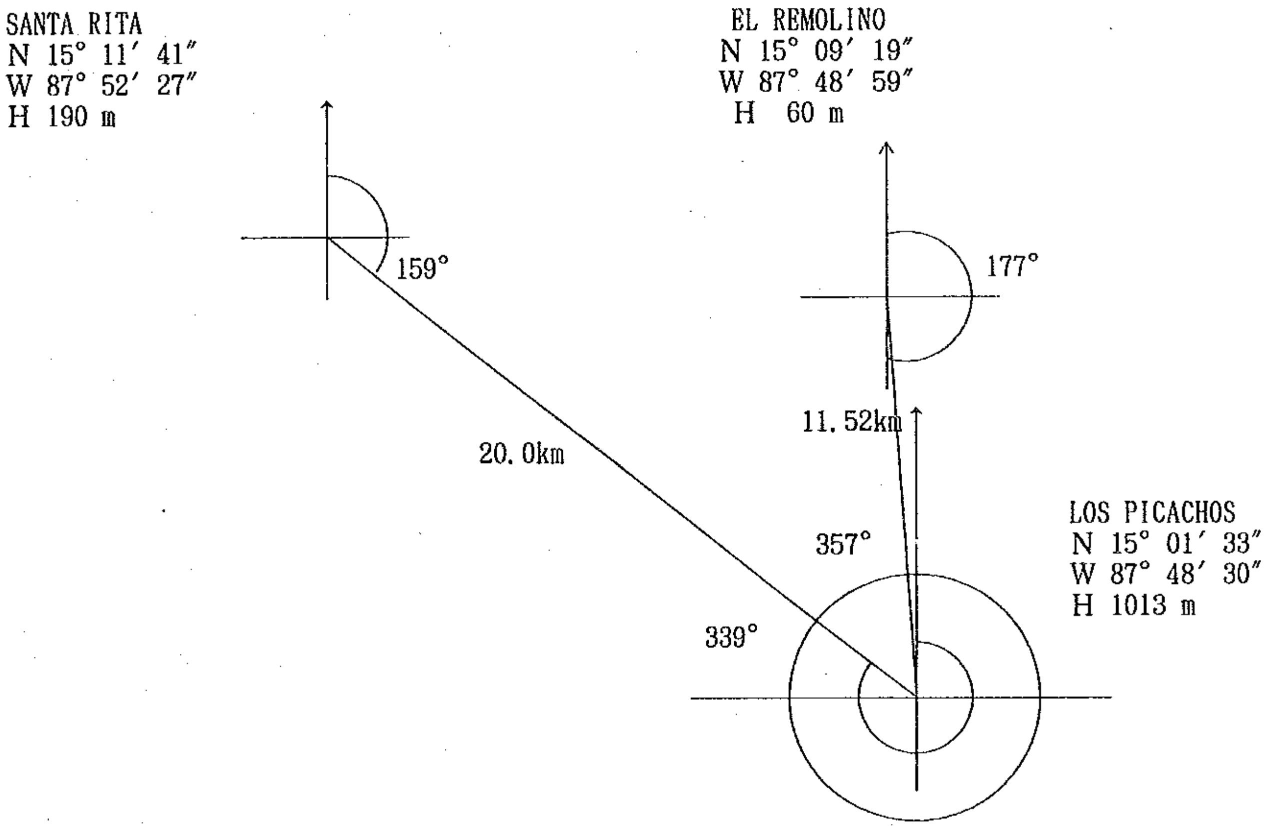


Figure 8-14 Discharge Warning System Route Map

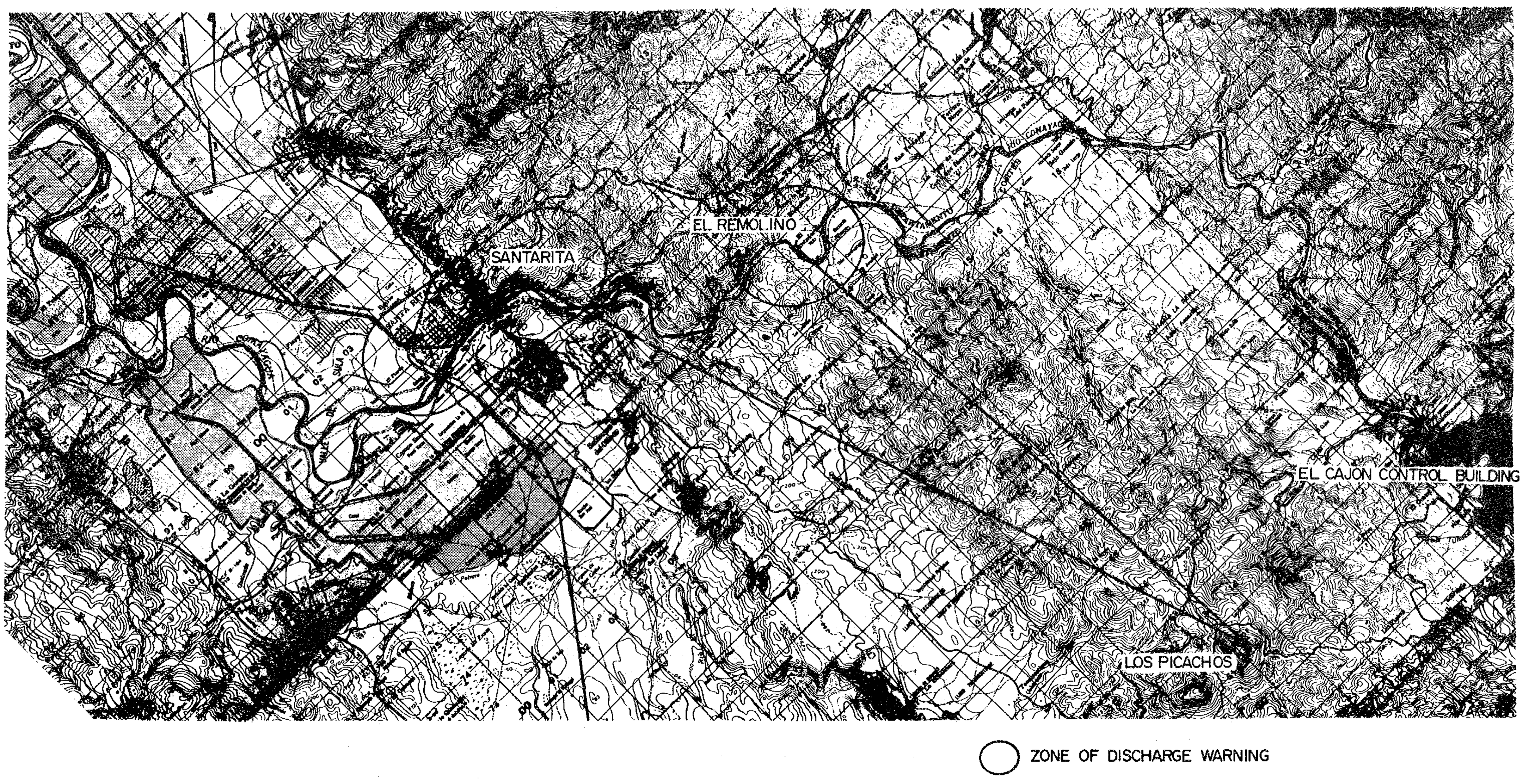


Figure 8-15 Discharge Warning Station of El Cajon River Basin

Chapter 9 STUDY ON AMPLIFICATION PROJECT

Chapter 9

STUDY ON AMPLIFICATION PROJECT

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Chapter 9 STUDY ON AMPLIFICATION PROJECT

9.1 Policy for the Study

(1) Commissioning of El Cajón Hydroelectric Power Plant was in 1985 with maximum output of 292 MW (73 MW x 4 units), and installation of additional units (final capacity: 73 MW x 8 units) has been schemed since its initial stage. For the purpose of this plant amplification, advance construction works have been done with intake, a part of penstock and powerhouse.

Additional powerhouse is laid out underground in the same way as the existing El Cajón Hydroelectric Power Plant. Since there is a fault running parallel to the river on the mountain side of penstock and underground powerhouse, the layout of penstock and underground powerhouse is limited to a narrow area sandwiched between this fault and ground surface line. Therefore, by moving inclined shaft a bit downstream, penstock route is designed to take the same route as the existing facilities, and extension of the underground powerhouse is laid out toward the downstream direction while its main building is placed parallel to the river. As shown in **Fig.9-1**, intake, vertical shaft of intake gate, and upper horizontal part of penstock have already been completed in conjunction with major civil structures.

As for underground powerhouse, access tunnel and generator assembly room of the existing El Cajón Hydroelectric Power Plant can be utilized for the amplified facilities too. And a pilot tunnel has been completed at entire portion of the crown of underground powerhouse of the amplified facilities. In addition, service tunnels which can be used for excavation of tailrace gate room and the lower part of underground powerhouse are left. Therefore, upon studying the amplified capacity, priority should be given to the utilization of such structures as have been constructed in advance from economic point of view as well. However, the cost for the existing structures such as intake and a part of penstock is not included in the cost for the amplification project.

(2) There is an altitude difference of 10 m between normal high water level and the floor level of free-flow-type dam's crest spillway, which creates a storage capacity of 820×10^6 m^3. Therefore, when normal high water level is changed upward to an elevation of 295.00 m, low water level necessary to attain the current storage capacity is an elevation of 242.00 m which is higher than the current low water level by 22.00 m. This is equivalent to an increase of 14.00 m (9%) in standard head, and 22.00 m (18%) in minimum head, which will bring about a remarkable increase of energy and output. Adequacy of amplification plan is to be enhanced by change of high water level as it does not involve any cost factor.

Therefore, when it is concluded that there is no problem with flood treatment after having examined relationship between design flood discharge, spillway capacity, and surcharge capacity of reservoir, elevated standard intake level is to be adopted as an optimum plan.

(3) Regulation ratio (Effective storage capacity/Annual inflow) of El Cajón Reservoir exceeds 100%, so El Cajón Hydroelectric Power Plant can generate averaged electricity all the year round, and most of river water is being utilized for power generation. In other words, it means that an increase of energy generation can hardly be expected from amplification even though increase of maximum discharge and increase of output is brought about as peak load station. Therefore, economy of this amplification plan cannot be evaluated properly by a criterion of construction cost per kW.

(4) Optimum amplification plan is to be carried out based on a power demand projection, power facility amplification program, and a study of generation capacity by existing and amplified facilities of El Cajón Hydroelectric Power Plant.

9.2 Conditions for the Study

Study of optimum amplified capacity is to be carried out based on the following conditions:

(1) Amplification of El Cajón Hydroelectric Power Plant is to be designed to supply peak load.

(2) After amplification, El Cajón Hydroelectric Power Plant is to increase the percentage of installed capacity of the entire country of Honduras. So, this station has to supply not only peak load but middle load and/or base load as well, once amplified.

(3) In order for El Cajón Hydroelectric Power Plant to be amplified to supply peak load, an alternative power plant becomes necessary to supply base load which has been supplied by the former station.

(4) Stage development program where generators are phased in, should be considered, with the increase of power demand and commissioning program of base load thermal plants taken into consideration.

(5) When studying amplified capacity, 292 MW is to be regarded as maximum in view of power demand supply balance, reservoir operation, and the scale of existing (already constructed) structures.

(6) Study of the scale of this amplification project should be carried out to be independent of a hydroelectric project of Agua de la Reina located downstream of the El Cajón Dam.

9.3 Reservoir Operation Plan

9.3.1 Water Level for Reservoir Operation

As shown in "**9.1 Policy for the Study** (2)" it should be discussed whether normal high water level should be raised to an elevation of 295.00 m in order to increase energy production of El Cajón Hydroelectric Power Plant. When raising normal high water level, it is a major problem whether flood treatment can be done safely. Therefore, following cases have to be studied.

Case 1: When historical largest flood discharge (3,600 m^3/sec) occurs at normal high water level

Case 2: When historical largest flood discharge (3,600 m^3/sec) occurs at the water level of 288.80 m, the highest in operation record

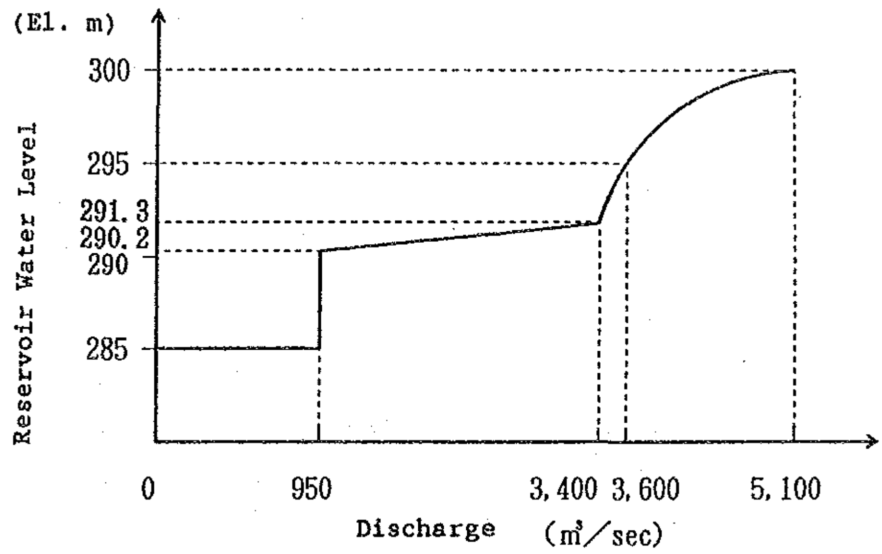
Case 3: When flood with 100-year return period occurs (8,800 m^3/sec) at normal high water level

Wave form of the historical largest flood discharge (3,600 m^3/sec) used in this study was obtained by reference to wave form of hurricane "Fifi" shown in a feasibility report prepared by Lahmeyer International GmbH.

And the capacity of discharge from outlet facilities installed in dam (bottom outlet, tunnel spillway, crest spillway) was obtained based on reservoir operating procedures prepared by ENEE.

According to the reservoir operating procedures the top limit of harmless discharge for downstream area is 950 m^3/sec. A total of 950 m^3/sec is discharged where a water level is up to 290.20 m from bottom outlet and tunnel spillways, and 3,400 m^3/sec is to be discharged where an elevation is higher than that, in accordance with an ascent of water level.

When water level exceeds a water level of 295.00 m the volume of discharge increases further because of free overflow from crest spillway. Relation between reservoir water level and discharge from bottom outlet and spillway is as shown below.



Results of Study;

(1) In the event that historical largest flood discharge of 3,600 m^3/sec flows into reservoir when its water level is at normal high water level, the water level of reservoir is raised to 288.40 m if harmless discharge of 950 m^3/sec is to be released continuously. Since maximum discharge is to be 950 m^3/sec according to the reservoir operating procedures when water level is up to 290.2 m, it will not cause any damages in the downstream area.

(2) In the event that historical largest flood discharge of 3,600 m^3/sec flows into reservoir when its water level is at the highest level of 288.80 m in operation record, the water level is raised to 290.90 m if discharge is done in accordance with operation procedures, and volume of discharge then becomes 2,460 m^3/sec which causes enormous flood damages in the entire Sula valley area downstream from dam.

Since the historical largest flood discharge corresponds to flood with 5 to 10 year return period, it is quite likely that flood damage occurs quite often in the downstream area if operation is continued with water level at an elevation of 288.80 m.

(3) In the event that 100 year return period flood discharge of 8,800 m^3/sec flows into reservoir when its water level is at normal high water level (EL. 285.00 m), the water level is raised even though gates are controlled in accordance with operating procedures. Discharge in this situation is 3,510 m^3/sec which causes enormous flood damage in the entire Sula valley area in the same way as the above (2) case.

As a conclusion normal high water level of 285.00 m of El Cajón Reservoir is judged to be adequate. Operation at high water level of El Cajón Reservoir has an advantage to bring about an increase of energy production, but on the other hand, a probability to cause flood damage in the downstream area gets larger as it diminishes storage effect of reservoir in case of flood. Therefore, it is desirable to operate at a water level that does not exceed normal high water level.

9.3.2 Calculation of Energy Generation

According to the operation record of El Cajón Hydroelectric Power Plant (See **Fig. 9-2**), only approximately 20 m drawdown (corresponding to effective storage capacity of 1,675 x 10^6 m^3) below the high water level has been utilized, while the available drawdown of the reservoir is 65 m (corresponding to effective storage capacity of 4,170 x 10^6 m^3).

If reference to the questions of whether the past operation procedure of the reservoir will also be appropriate in the future, and whether the increase of energy generation can be expected by the amplification plan, the relation between the reservoir operation plan and the energy generation has been studied for the following 2 cases.

Case 1: The reservoir is operated by fully utilizing the available drawdown of 65 m below high water level.

Case 2: The reservoir is operated by utilizing the drawdown of 20 m below high water level.

The data of river runoff used for the energy generation calculation were the 50 year flow data which were synthesized from the river flow record for the period from 1970 to 1982.

Reservoir operation plan is studied to maximize energy generation by using Dynamic Programming method (DP method).

The result of this calculation is presented in the table below. The average annual energy generation is 1,237 GWh when the available drawdown of 65 m is fully utilized (Case 1), and 1,305 GWh when a drawdown of upper 20 m is used (Case 2).

	Case 1 Available drawdown 65 m	Case 2 Available drawdown 20 m
Annual Energy Generation (GWh)	1,237	1,305
Firm Energy Generation (GWh)	952	605
Secondary Energy Generation (GWh)	285	700
Average Reservoir Water Level (m)	266.5	274.5

The firm energy generation is defined as the energy generation which is obtained by the 95% firm discharge of the river as recorded in 50 years, and the energy generation in excess of the firm energy generation is defined as the secondary energy generation. The firm energy generation is 952 GWh in Case 1 and 605 GWh in Case 2.

As the ways of effectively utilizing the secondary energy generation, the operation of the hydroelectric power plant may be operated in a coordinated manner with the thermal power plants, or the fuel cost of the thermal power plant may be reduced by decreasing the operating hours of the base load thermal power plants. However, the proportion of the thermal power plants in the power supply sources of the power system of Honduras is small, and it can not be expected at the present moment that the El Cajón Hydroelectric Power Plant and thermal power plants can be operated in a coordinated manner so that they supplement each other.

For the reason explained above, it will be difficult for some time to come to effectively utilize the secondary power generation.

Although more annual energy generation can be realized by operating the reservoir with higher water level (Case-2), the reservoir of El Cajón should be operated according to the operation schedule by which more firm energy generation is realized, and therefore, the available drawdown of the reservoir should be effectively utilized.

The reservoir water level, energy generation, inflow to the reservoir and plant discharge, as calculated by the Dynamic Programming (DP) method for Case 1 and Case 2 are presented in **Fig. 9-3** through **Fig. 9-8**. To examine the incremental energy generation realized by the amplification project, the reservoir operation has been analyzed by the DP method, and it has been confirmed that the dam overflow almost disappears in both cases. That is, since the river discharge is almost completely utilized for power generation with the existing generation capacity, no incremental energy generation can be expected by the amplification project.

9.4 Load Characteristics and Scale of Amplification Project

(1) Load Characteristics

The electric power demand in Honduras has the maximum value in a year in November or December, and the daily load curves can be broadly categorized into the weekday load curves and the weekend load curves.

To examine the daily load curves in April 7 (Tuesday) and June 21 (Monday) of 1992, the load on weekdays starts to build up at around 4 o'clock in the dawn, reaches the morning peak at 11 to 12 o'clock, then lowers to the level of 9 to 10 o'clock from noon break to around 18 o'clock, and finally starts to increase rapidly at around 18 o'clock to form the lighting peak at 18 to 19 o'clock. This general pattern is almost the same for all weekdays. Approximately 54% of the daily maximum load continues for 24 hours, and the remaining 46% forms a peak load that continues for 14 to 15 hours. A daily load curve is presented in **Fig. 9-9**. A short peaks are observed twice a day, in the morning and in the evening, and these peaks continue for 3 to 5 hours. The daily maximum load (as of April 7, Tuesday, 1992) is 410 MW, with the daily load factor being approximately 70%.

(2) Scale of Amplification Project

In examining the scale of amplification project in this study, required peak supply capability was examined based on the power demand/supply status.

For the purpose of this study, the required peak supply capability was examined based on the power demand projection prepared by ENEE. The power supply sources of ENEE mainly consist of hydroelectric power plants, and this situation will continue for some time to come, owing to the power supply plan of ENEE.

In this study, the required peak supply capability has been examined by the "difference method".

Study Conditions

In applying the "difference method", the following premises have been set down.

(a) The Amplification Project of El Cajón Hydroelectric Power Plant consists of the commissioning of one unit (73 MW) in 2002, and the commissioning of another unit (73 MW) in 2006. Based on this premise, the study has been conducted on the time cross section to 2006.

(b) The daily load curve, which has been established in reference to the load on April 7, Tuesday, 1992, has been converted to the daily load curve of 2006 in which the whole amplification units of El Cajón are commissioned.

(c) Thermal power plans are assumed to be operated for 24 hours to supply the base load (with the exception of gas turbine plants,which are operated to supply the peak load).

(d) Existing and newly built hydroelectric power plants supply the middle load.

(e) Short peak loads are supplied by gas turbine plants.

(f) El Cajón Hydroelectric Power Plant supplements the deficit of power supply capability which can not be met by the supplies of Items (c) through (e), and El Cajón also supplies the peak load when required.

(e) The electric power imported from other nations is not taken into account in this study.

(h) The Amplification Project of El Cajón Hydroelectric Power Plant consists of the additional 73 MW x 2 units = 143 MW. The total capacity of El Cajón including the existing units shall be 438 MW.

Fig. 9-10 shows a daily load curve of 2009 when 5th and 6th units (total 143 MW) are commissioned. The curve is elaborated considering the result of above item (1).

As a result as shown in **Fig. 9-10**, it is thought that power supply of El Cajón Hydroelectric Power Plant including Amplification Project (143 MW) is characterized as that of peak and middle load station.

9.5 Study of Scale of Amplification Project

Since El Cajón Hydroelectric Power Plant is a reservoir type power plant, the scale of its amplification project must be studied from two different aspects.

That is, one aspect is the optimal scale of amplification as a power plant (the supply capability) which is determined by the inflow to the reservoir and the regulating capability of the reservoir, and another aspect is the supply capacity of the additional units which is required by the daily load curve on the demand side.

As the scale of amplification project, it is most desirable if the values of supply capacity as determined by these two aspects are identical.

Generally, the economic evaluation of a hydroelectric power project is evaluated in reference to the cost of electric power and energy which are supplied by an alternative generating facility, which is regarded as the "benefit" of the project in question. This benefit is compared with the cost of the project, which is the construction cost of the hydroelectric project under study.

9.5.1 Cost

As mentioned earlier, it is common to take construction cost of hydroelectric power plant as the cost factor in economic comparison (of hydroelectric power plant).

However, in the case of this amplification project there is a special condition that increase of generated energy cannot be expected from amplification of generation facilities. Therefore, the following items have to be considered as cost factors of this amplification project:

(1) Direct expenses of amplification such as the cost of civil works, costs of electrical and hydro mechanical equipment

(2) Fuel cost of base load thermal plants which corresponds to energy generation at peak hours in amplified facilities

(3) Construction cost of base load thermal power plant

To increase output of El Cajón Hydroelectric Power Plant is to change a method of water utilization while amount of water resources is invariable.

In other words, it is an idea to store a part of firm discharge of El Cajón Reservoir and to utilize them for amplified capacity to supply peak load.

This concept is expressed by the following formula:

$$86{,}400 \text{ sec} \times q_1 = 3{,}600 \text{ sec} \times T \times q_2$$

where,

q_1	:	discharge stored for amplified capacity	11 (m^3/sec)
q_2	:	discharge by amplified capacity	53 (m^3/sec)
T	:	peak generation hours	5 (hours)

q_1 and q_2 are determined by peak generation time and amplified capacity

Mean net head of El Cajón Hydroelectric Power Plant being 160 m, necessary discharge is to be 53 m^3/sec provided that amplified capacity is 73,000 kW.

When the above formula is substituted with these figures assuming that peak generation time is 5 hours, discharge stored for amplified capacity (q_1) is to be 11 m^3/sec. Namely, amplification of El Cajón Hydroelectric Power Plant means to allocate 11 m^3/sec out of 102 m^3/sec of annual firm discharge for amplified capacity, and to supplement deficiency caused by this change with base load thermal power generation.

Therefore, fuel cost of base load thermal power plant is to be the fuel cost which can produce energy equivalent to energy produced by discharge q_1 (11 m^3/sec). In this case, it is suitable to use coal which is the most inexpensive fuel among any fuels for thermal power generation, and this thermal power plant has to have an expected capability to supplement more than 15,000 kW which can be produced by discharge of 11 m^3/sec at El Cajón Hydro Power Plant.

9.5.2 Benefit

When studying amplified capacity of this amplification project a method is adopted which is to take, as 'benefit' of the relevant project, cost and expenses of a thermal power plant which is to be constructed as an alternative generation facility in the event that this project is not carried out.

Since this project is designed as peak load generation facility, gas turbine power plant of 73,000 kW facility is to be taken up in making assessment of benefit. The total of construction cost of gas turbine power plant, operation and maintenance cost, and fuel cost for 50 years (service life of this project) is to be regarded as 'benefit'.

Assumptions used for calculating 'benefit' are shown below:

Item	Specification
Facility Output	73,000 kW
Construction Cost	US$ 720/kW
Period of Construction	2 years (1st year - 70%, 2nd year - 30%)
Service Life	15 years
Fuel Cost	US$ 0.0422/kWh
Annual Maintenance Cost	Construction cost x 4.56%
Operation Hours	5 hours/day

9.5.3 Determination of Amplification Capacity

Study of amplification capacity is to be conducted three cases from two alternatives; an alternative to develop simultaneously "C route" and "D route" of intake and penstock which were constructed in advance in 1985 (maximum 292 MW), and other alternatives to develop them in different stages (maximum 146 MW).

(1) As for simultaneous development of "C route" and "D route", cases with amplification capacity of 73 MW, 146 MW, 219 MW, and 292 MW each are studied.

(2) As for the plan to develop "D route" only, cases with amplification capacity of 73 MW and 146 MW are studied.

(3) When "C Route" is developed after "D Route" is developed, this study shall be conducted for the capacity of 73 MW and 146 MW.

As far as a development method is concerned, phased development method is adopted for both plans, where power generators are to be commissioned in accordance with load growth.

By examining daily load curve projected for the time when amplified capacity is expected to be commissioned, 5 hours is adopted as peak generation time which is an important factor to determine amplification capacity.

Table 9-2 through **9-5** show cash flow projection for construction cost of this amplification project, construction and fuel cost of base load thermal power plant, construction cost of an alternative thermal power plant, operation and maintenance cost, renovation cost, and fuel cost for energy production which is equivalent to that of this amplification project.

Energy production is calculated for each amplification capacity assuming that generation time at its maximum output is 5 hours.

Based on the above-mentioned assumptions current cost and benefit are calculated for each case in order to examine their economy. Its result is shown in **Fig. 9-11**.

Result of Analyses

(1) Simultaneous Development Plan of "C Route" and "D Route"

(a) The values of (B- C) and B/C are maximum for the amplification plan of 292 MW. However, the difference of these values for amplification plans of 146 MW and 219 MW is so small that this can not be the decisive factor in determination of the amplification capacity.

(b) For amplification plans of 219 MW and 292 MW, the additional generating facility becomes fully effective only at a time around 2020. Therefore, the validity of this analysis is deemed uncertain, because the power development plan of Honduras for the period after 2010 has not been formulated.

In other words, it is possible that the order of superiority in the economic comparison of amplification plans is reversed depending on whether priority is placed on hydroelectric power or thermal power in the power development plan of Honduras after 2010.

(2) Plan to Develop "D Route" Only

(a) (B-C) and B/C become maximum in the case of 146 MW

(b) B/C in the case of 73 MW also exceeds 1.0, but it is far less economical in comparison with the case of 146 MW

(3) Plan of Developing "C Route" after Developing "D Route"

(a) The economy of both 146 MW Plan and 73 MW Plan is inferior. This is because the economic benefit of this amplification plan is "eaten" by the development of "D Route" which precedes "C Route."

(b) This "eating" of the benefit implies that the benefit of converting El Cajón Hydroelectric Power Plant from a base load supply source to a peak load supply source is far greater than the benefit of converting this Power Plant from a middle load supply source to a peak load supply source.

Based on synthetical evaluation of the above-mentioned points, it is concluded that the case of 146 MW of "D route" development plan is to be the optimum development capacity where both (B-C) and B/C become maximum.

The case of 146 MW of simultaneous development scheme of "C route" and "D route" is deemed very economical even though it has to bear cost of an advance investment portion of civil works of "C route" and others, but necessary fund of construction including interest during construction is US$138.5 x 10^6 which is more than the "C route" development scheme by about US$30 x 10^6. This is not a good plan because an advance investment of US$30 x 10^6 is to deprive Honduras government of an opportunity to effectively invest in other projects. Therefore, 146 MW case of "D route" development plan is to be adopted as optimum development scheme.

9.5.4 Study of Number of Main Units and Unit Capacity

Though optimum development capacity is 146 MW of "D route" development plan, following comparisons are to be done in order to study optimum number of units and unit capacity.

(1) 48.7 MW x 3 units
(2) 73 MW x 2 units

Assumptions used in economic comparison are the same items as those of "**9.5.3** Determination of Amplification Capacity".

Table 9-6 to **9-10** show parameters such as cash flow projection for each case together with results of comparison.

It is generally said that a plan which produces maximum investment effect (B-C) is the optimum development scheme. Therefore, stage development plan which is to develop 73 MW x 2 units in accordance with power demand supply balance is adopted as the amplification plan of El Cajón Hydroelectric Power Plant.

Alternative Plan	*Construction Cost	(B-C)	B/C
48.7 MW x 3 units	US$112.0 x 10^6	US$15.6 x 10^6	1.10
73.0 MW x 2 units	US$95.7 x 10^6	US$30.2 x 10^6	1.21

* Construction cost does not include interest during construction.

Table 9-1 Stage Development Plan

Year	"C & D" Routes Development Plan	"D" Route Development Plan	"C" Route Development Plan	Note
2002	73 MW	73 MW		*1
3				
4				
5				
6	73 MW	73 MW		*2
7				
8				
9				
2010				
11				
12				
13				
14				
15				
16	73 MW		73 MW	
17				
18				
19				
2020	73 MW		73 MW	
21				
22				
23				
24				
25				

*1)
- As the condition of calculation, it is assumed that El Cajón Hydroelectric Power Plant functions as the generating facility to supply the base load and middle load until 2005.
- The output capacity of the thermal power plant, which supplements the energy deficit created by shifting the base portion of water discharge of El Cajón to the peak supply (73 MW), is assumed to be 15 MW.

*2)
- After year 2006, El Cajón Hydroelectric Power Plant functions as the supply source for middle and peak loads.
- Under this situation, the output capacity of the supplementary thermal power plant is assumed to be 30 MW.

<u>Characteristics of Thermal Power Plant</u>

Unit construction cost; US$1,350/kW
Construction period ; 2 years (60% in the first year)
(40% in the second year)
Service life ; 25 years
Fuel cost ; US$0.0205/kWh

Table 9-2 Economic Comparison ("C&D" Routes Plan, Installed Capacity 73MW)

EL CAJON PROJECT (4-1) (unit: 1000 US$)

No.	COST					BENEFIT				B - C
	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	
-4	13,070				13,070				0	-13,070
-3	21,895				21,895				0	-21,895
-2	47,285				47,285	36,792			36,792	-10,493
-1	30,250				30,250	15,768			15,768	-14,482
1		346	557	2,731	3,634		2,397	5,622	8,019	4,385
2		346	557	2,731	3,634		2,397	5,622	8,019	4,385
3		346	557	2,731	3,634		2,397	5,622	8,019	4,385
4		346	557	2,731	3,634		2,397	5,622	8,019	4,385
5		346	557	2,731	3,634		2,397	5,622	8,019	4,385
6		346	557	2,731	3,634		2,397	5,622	8,019	4,385
7		346	557	2,731	3,634		2,397	5,622	8,019	4,385
8		346	557	2,731	3,634		2,397	5,622	8,019	4,385
9		346	557	2,731	3,634		2,397	5,622	8,019	4,385
10		346	557	2,731	3,634		2,397	5,622	8,019	4,385
11		346	557	2,731	3,634		2,397	5,622	8,019	4,385
12		346	557	2,731	3,634		2,397	5,622	8,019	4,385
13		346	557	2,731	3,634		2,397	5,622	8,019	4,385
14		346	557	2,731	3,634	36,792	2,397	5,622	44,811	41,177
15		346	557	2,731	3,634	15,768	2,397	5,622	23,787	20,153
16		346	557	2,731	3,634		2,397	5,622	8,019	4,385
17		346	557	2,731	3,634		2,397	5,622	8,019	4,385
18		346	557	2,731	3,634		2,397	5,622	8,019	4,385
19		346	557	2,731	3,634		2,397	5,622	8,019	4,385
20		346	557	2,731	3,634		2,397	5,622	8,019	4,385
21		346	557	2,731	3,634		2,397	5,622	8,019	4,385
22		346	557	2,731	3,634		2,397	5,622	8,019	4,385
23		346	557	2,731	3,634		2,397	5,622	8,019	4,385
24	34,426	346	557	2,731	38,060		2,397	5,622	8,019	-30,041
25	22,951	346	557	2,731	26,585		2,397	5,622	8,019	-18,566
26		346	557	2,731	3,634		2,397	5,622	8,019	4,385
27		346	557	2,731	3,634		2,397	5,622	8,019	4,385
28		346	557	2,731	3,634		2,397	5,622	8,019	4,385
29		346	557	2,731	3,634	36,792	2,397	5,622	44,811	41,177
30		346	557	2,731	3,634	15,768	2,397	5,622	23,787	20,153
31		346	557	2,731	3,634		2,397	5,622	8,019	4,385
32		346	557	2,731	3,634		2,397	5,622	8,019	4,385
33		346	557	2,731	3,634		2,397	5,622	8,019	4,385
34		346	557	2,731	3,634		2,397	5,622	8,019	4,385
35		346	557	2,731	3,634		2,397	5,622	8,019	4,385
36		346	557	2,731	3,634		2,397	5,622	8,019	4,385
37		346	557	2,731	3,634		2,397	5,622	8,019	4,385
38		346	557	2,731	3,634		2,397	5,622	8,019	4,385
39		346	557	2,731	3,634		2,397	5,622	8,019	4,385
40		346	557	2,731	3,634		2,397	5,622	8,019	4,385
41		346	557	2,731	3,634		2,397	5,622	8,019	4,385
42		346	557	2,731	3,634		2,397	5,622	8,019	4,385
43		346	557	2,731	3,634		2,397	5,622	8,019	4,385
44		346	557	2,731	3,634	36,792	2,397	5,622	44,811	41,177
45		346	557	2,731	3,634	15,768	2,397	5,622	23,787	20,153
46		346	557	2,731	3,634		2,397	5,622	8,019	4,385
47		346	557	2,731	3,634		2,397	5,622	8,019	4,385
48		346	557	2,731	3,634		2,397	5,622	8,019	4,385
49		346	557	2,731	3,634		2,397	5,622	8,019	4,385
50		346	557	2,731	3,634		2,397	5,622	8,019	4,385
TOTAL	169,877	17,300	27,850	136,556	351,583	210,240	119,837	281,105	611,182	259,599
[NPV]					114,608				104,639	-9,969
									B/C	0.91

Table 9-3 Economic Comparison ("C&D" Routes Plan, Installed Capacity 73MW ×2units)

EL CAJON PROJECT (4-2) (unit: 1000 US$)

	COST					BENEFIT				
No.	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	B - C
-4	13,070				13,070				0	-13,070
-3	21,895				21,895				0	-21,895
-2	47,285				47,285	36,792			36,792	-10,493
-1	30,250				30,250	15,768			15,768	-14,482
1		346	557	2,731	3,634		2,397	5,622	8,019	4,385
2		346	557	2,731	3,634		2,397	5,622	8,019	4,385
3	42,006	346	557	2,731	45,640	36,792	2,397	5,622	44,811	-829
4	28,004	346	557	2,731	31,638	15,768	2,397	5,622	23,787	-7,851
5		348	922	2,731	4,001		2,397	5,622	8,019	4,018
6		348	922	5,462	6,732		4,793	11,244	16,038	9,305
7		348	922	5,462	6,732		4,793	11,244	16,038	9,305
8		348	922	5,462	6,732		4,793	11,244	16,038	9,305
9		348	922	5,462	6,732		4,793	11,244	16,038	9,305
10		348	922	5,462	6,732		4,793	11,244	16,038	9,305
11		348	922	5,462	6,732		4,793	11,244	16,038	9,305
12		348	922	5,462	6,732		4,793	11,244	16,038	9,305
13		348	922	5,462	6,732		4,793	11,244	16,038	9,305
14		348	922	5,462	6,732	36,792	4,793	11,244	52,830	46,097
15		348	922	5,462	6,732	15,768	4,793	11,244	31,806	25,073
16		348	922	5,462	6,732		4,793	11,244	16,038	9,305
17		348	922	5,462	6,732		4,793	11,244	16,038	9,305
18		348	922	5,462	6,732	36,792	4,793	11,244	52,830	46,097
19		348	922	5,462	6,732	15,768	4,793	11,244	31,806	25,073
20		348	922	5,462	6,732		4,793	11,244	16,038	9,305
21		348	922	5,462	6,732		4,793	11,244	16,038	9,305
22		348	922	5,462	6,732		4,793	11,244	16,038	9,305
23		348	922	5,462	6,732		4,793	11,244	16,038	9,305
24	34,426	348	922	5,462	41,158		4,793	11,244	16,038	-25,121
25	22,951	348	922	5,462	29,683		4,793	11,244	16,038	-13,646
26		348	922	5,462	6,732		4,793	11,244	16,038	9,305
27		348	922	5,462	6,732		4,793	11,244	16,038	9,305
28	38,916	348	922	5,462	45,648		4,793	11,244	16,038	-29,611
29	25,944	348	922	5,462	32,676	36,792	4,793	11,244	52,830	20,153
30		348	922	5,462	6,732	15,768	4,793	11,244	31,806	25,073
31		348	922	5,462	6,732		4,793	11,244	16,038	9,305
32		348	922	5,462	6,732		4,793	11,244	16,038	9,305
33		348	922	5,462	6,732	36,792	4,793	11,244	52,830	46,097
34		348	922	5,462	6,732	15,768	4,793	11,244	31,806	25,073
35		348	922	5,462	6,732		4,793	11,244	16,038	9,305
36		348	922	5,462	6,732		4,793	11,244	16,038	9,305
37		348	922	5,462	6,732		4,793	11,244	16,038	9,305
38		348	922	5,462	6,732		4,793	11,244	16,038	9,305
39		348	922	5,462	6,732		4,793	11,244	16,038	9,305
40		348	922	5,462	6,732		4,793	11,244	16,038	9,305
41		348	922	5,462	6,732		4,793	11,244	16,038	9,305
42		348	922	5,462	6,732		4,793	11,244	16,038	9,305
43		348	922	5,462	6,732		4,793	11,244	16,038	9,305
44		348	922	5,462	6,732	36,792	4,793	11,244	52,830	46,097
45		348	922	5,462	6,732	15,768	4,793	11,244	31,806	25,073
46		348	922	5,462	6,732		4,793	11,244	16,038	9,305
47		348	922	5,462	6,732		4,793	11,244	16,038	9,305
48		348	922	5,462	6,732		4,793	11,244	16,038	9,305
49		348	922	5,462	6,732		4,793	11,244	16,038	9,305
50		348	922	5,462	6,732		4,793	11,244	16,038	9,305
TOTAL	304,747	17,392	44,640	259,456	626,235	367,920	227,690	534,099	1,129,709	503,475
[NPV]					165,302				172,201	6,898
									B/C	1.04

Table 9-4 Economic Comparison ("C&D" Routes Plan, Installed Capacity 73MW ×3units)

EL CAJON PROJECT (4-3) (unit: 1000 US$)

	COST					BENEFIT				
No.	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	B - C
-4	13,070				13,070				0	-13,070
-3	21,895				21,895				0	-21,895
-2	47,285				47,285	36,792			36,792	-10,493
-1	30,250				30,250	15,768			15,768	-14,482
1		346	557	2,731	3,634		2,397	5,622	8,019	4,385
2		346	557	2,731	3,634		2,397	5,622	8,019	4,385
3	42,006	346	557	2,731	45,640	36,792	2,397	5,622	44,811	-829
4	28,004	346	557	2,731	31,638	15,768	2,397	5,622	23,787	-7,851
5		348	922	5,462	6,732		4,793	11,244	16,038	9,305
6		348	922	5,462	6,732		4,793	11,244	16,038	9,305
7		348	922	5,462	6,732		4,793	11,244	16,038	9,305
8		348	922	5,462	6,732		4,793	11,244	16,038	9,305
9		348	922	5,462	6,732		4,793	11,244	16,038	9,305
10		348	922	5,462	6,732		4,793	11,244	16,038	9,305
11		348	922	5,462	6,732		4,793	11,244	16,038	9,305
12		348	922	5,462	6,732		4,793	11,244	16,038	9,305
13	42,006	348	922	5,462	48,738	36,792	4,793	11,244	52,830	4,091
14	28,004	348	922	5,462	34,736	52,560	4,793	11,244	68,598	33,861
15		350	1,287	8,193	9,830	15,768	7,190	16,866	39,824	29,994
16		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
17		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
18		350	1,287	8,193	9,830	36,792	7,190	16,866	60,848	51,018
19		350	1,287	8,193	9,830	15,768	7,190	16,866	39,824	29,994
20		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
21		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
22		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
23		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
24	34,426	350	1,287	8,193	44,256		7,190	16,866	24,056	-20,200
25	22,951	350	1,287	8,193	32,781		7,190	16,866	24,056	-8,725
26		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
27		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
28	38,916	350	1,287	8,193	48,746	36,792	7,190	16,866	60,848	12,102
29	25,944	350	1,287	8,193	35,774	52,560	7,190	16,866	76,616	40,842
30		350	1,287	8,193	9,830	15,768	7,190	16,866	39,824	29,994
31		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
32		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
33		350	1,287	8,193	9,830	36,792	7,190	16,866	60,848	51,018
34		350	1,287	8,193	9,830	15,768	7,190	16,866	39,824	29,994
35		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
36		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
37		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
38	38,916	350	1,287	8,193	48,746		7,190	16,866	24,056	-24,690
39	25,944	350	1,287	8,193	35,774		7,190	16,866	24,056	-11,718
40		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
41		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
42		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
43		350	1,287	8,193	9,830	36,792	7,190	16,866	60,848	51,018
44		350	1,287	8,193	9,830	52,560	7,190	16,866	76,616	66,786
45		350	1,287	8,193	9,830	15,768	7,190	16,866	39,824	29,994
46		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
47		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
48		350	1,287	8,193	9,830	36,792	7,190	16,866	60,848	51,018
49		350	1,287	8,193	9,830	15,768	7,190	16,866	39,824	29,994
50		350	1,287	8,193	9,830		7,190	16,866	24,056	14,226
TOTAL	439,617	17,464	57,780	360,507	875,368	578,160	316,369	742,116	1,636,646	761,278
[NPV]					186,341				203,034	16,692
									B/C	1.09

Table 9-5 Economic Comparison ("C&D" Routes Plan, Installed Capacity 73MW ×4units)

EL CAJON PROJECT (4-4) (unit: 1000 US$)

	C O S T					B E N E F I T				
No.	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	B - C
-4	13,070				13,070				0	-13,070
-3	21,895				21,895				0	-21,895
-2	47,285				47,285	36,792			36,792	-10,493
-1	30,250				30,250	15,768			15,768	-14,482
1		346	557	2,731	3,634		2,397	5,622	8,019	4,385
2		346	557	2,731	3,634		2,397	5,622	8,019	4,385
3	42,006	346	557	2,731	45,640	36,792	2,397	5,622	44,811	-829
4	28,004	346	557	2,731	31,638	15,768	2,397	5,622	23,787	-7,851
5		348	922	5,462	6,732		4,794	11,244	16,038	9,306
6		348	922	5,462	6,732		4,794	11,244	16,038	9,306
7		348	922	5,462	6,732		4,794	11,244	16,038	9,306
8		348	922	5,462	6,732		4,794	11,244	16,038	9,306
9		348	922	5,462	6,732		4,794	11,244	16,038	9,306
10		348	922	5,462	6,732		4,794	11,244	16,038	9,306
11		348	922	5,462	6,732		4,794	11,244	16,038	9,306
12		348	922	5,462	6,732		4,794	11,244	16,038	9,306
13	42,006	348	922	5,462	48,738	36,792	4,794	11,244	52,830	4,092
14	28,004	348	922	5,462	34,736	52,560	4,794	11,244	68,598	33,862
15		350	1,287	8,193	9,830	15,768	7,191	16,866	39,825	29,995
16		350	1,287	8,193	9,830		7,191	16,866	24,057	14,227
17	42,006	350	1,287	8,193	51,836	36,792	7,191	16,866	60,849	9,013
18	28,004	350	1,287	8,193	37,834	52,560	7,191	16,866	76,617	38,783
19		352	1,652	10,924	12,928	15,768	9,588	22,488	47,844	34,916
20		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
21		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
22		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
23		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
24	34,426	352	1,652	10,924	47,354		9,588	22,488	32,076	-15,278
25	22,951	352	1,652	10,924	35,879		9,588	22,488	32,076	-3,803
26		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
27		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
28	38,916	352	1,652	10,924	51,844	36,792	9,588	22,488	68,868	17,024
29	25,944	352	1,652	10,924	38,872	52,560	9,588	22,488	84,636	45,764
30		352	1,652	10,924	12,928	15,768	9,588	22,488	47,844	34,916
31		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
32		352	1,652	10,924	12,928	36,792	9,588	22,488	68,868	55,940
33		352	1,652	10,924	12,928	52,560	9,588	22,488	84,636	71,708
34		352	1,652	10,924	12,928	15,768	9,588	22,488	47,844	34,916
35		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
36		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
37		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
38	38,916	352	1,652	10,924	51,844		9,588	22,488	32,076	-19,768
39	25,944	352	1,652	10,924	38,872		9,588	22,488	32,076	-6,796
40		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
41		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
42	38,916	352	1,652	10,924	51,844		9,588	22,488	32,076	-19,768
43	25,944	352	1,652	10,924	38,872	36,792	9,588	22,488	68,868	29,996
44		352	1,652	10,924	12,928	52,560	9,588	22,488	84,636	71,708
45		352	1,652	10,924	12,928	15,768	9,588	22,488	47,844	34,916
46		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
47		352	1,652	10,924	12,928	36,792	9,588	22,488	68,868	55,940
48		352	1,652	10,924	12,928	52,560	9,588	22,488	84,636	71,708
49		352	1,652	10,924	12,928	15,768	9,588	22,488	47,844	34,916
50		352	1,652	10,924	12,928		9,588	22,488	32,076	19,148
TOTAL	574,487	17,528	69,460	447,884	1,109,359	735,840	393,108	922,008	2,050,956	941,597
[NPV]					199,861				221,379	21,517
									B/C	1.11

Table 9-6 Economic Comparison ("D" Route Plan, Installed Capacity 73MW)

EL CAJON PROJECT (2-1) (unit: 1000 US$)

	COST					BENEFIT				
No.	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	B - C
-4	15,747				15,747				0	-15,747
-3	19,034				19,034				0	-19,034
-2	31,829				31,829	36,792			36,792	4,963
-1	19,792				19,792	15,768			15,768	-4,024
1		208	452	2,731	3,391		2,397	5,622	8,019	4,628
2		208	452	2,731	3,391		2,397	5,622	8,019	4,628
3		208	452	2,731	3,391		2,397	5,622	8,019	4,628
4		208	452	2,731	3,391		2,397	5,622	8,019	4,628
5		208	452	2,731	3,391		2,397	5,622	8,019	4,628
6		208	452	2,731	3,391		2,397	5,622	8,019	4,628
7		208	452	2,731	3,391		2,397	5,622	8,019	4,628
8		208	452	2,731	3,391		2,397	5,622	8,019	4,628
9		208	452	2,731	3,391		2,397	5,622	8,019	4,628
10		208	452	2,731	3,391		2,397	5,622	8,019	4,628
11		208	452	2,731	3,391		2,397	5,622	8,019	4,628
12		208	452	2,731	3,391		2,397	5,622	8,019	4,628
13		208	452	2,731	3,391		2,397	5,622	8,019	4,628
14		208	452	2,731	3,391	36,792	2,397	5,622	44,811	41,420
15		208	452	2,731	3,391	15,768	2,397	5,622	23,787	20,396
16		208	452	2,731	3,391		2,397	5,622	8,019	4,628
17		208	452	2,731	3,391		2,397	5,622	8,019	4,628
18		208	452	2,731	3,391		2,397	5,622	8,019	4,628
19		208	452	2,731	3,391		2,397	5,622	8,019	4,628
20		208	452	2,731	3,391		2,397	5,622	8,019	4,628
21		208	452	2,731	3,391		2,397	5,622	8,019	4,628
22		208	452	2,731	3,391		2,397	5,622	8,019	4,628
23		208	452	2,731	3,391		2,397	5,622	8,019	4,628
24	30,241	208	452	2,731	33,632		2,397	5,622	8,019	-25,613
25	20,160	208	452	2,731	23,551		2,397	5,622	8,019	-15,532
26		208	452	2,731	3,391		2,397	5,622	8,019	4,628
27		208	452	2,731	3,391		2,397	5,622	8,019	4,628
28		208	452	2,731	3,391		2,397	5,622	8,019	4,628
29		208	452	2,731	3,391	36,792	2,397	5,622	44,811	41,420
30		208	452	2,731	3,391	15,768	2,397	5,622	23,787	20,396
31		208	452	2,731	3,391		2,397	5,622	8,019	4,628
32		208	452	2,731	3,391		2,397	5,622	8,019	4,628
33		208	452	2,731	3,391		2,397	5,622	8,019	4,628
34		208	452	2,731	3,391		2,397	5,622	8,019	4,628
35		208	452	2,731	3,391		2,397	5,622	8,019	4,628
36		208	452	2,731	3,391		2,397	5,622	8,019	4,628
37		208	452	2,731	3,391		2,397	5,622	8,019	4,628
38		208	452	2,731	3,391		2,397	5,622	8,019	4,628
39		208	452	2,731	3,391		2,397	5,622	8,019	4,628
40		208	452	2,731	3,391		2,397	5,622	8,019	4,628
41		208	452	2,731	3,391		2,397	5,622	8,019	4,628
42		208	452	2,731	3,391		2,397	5,622	8,019	4,628
43		208	452	2,731	3,391		2,397	5,622	8,019	4,628
44		208	452	2,731	3,391	36,792	2,397	5,622	44,811	41,420
45		208	452	2,731	3,391	15,768	2,397	5,622	23,787	20,396
46		208	452	2,731	3,391		2,397	5,622	8,019	4,628
47		208	452	2,731	3,391		2,397	5,622	8,019	4,628
48		208	452	2,731	3,391		2,397	5,622	8,019	4,628
49		208	452	2,731	3,391		2,397	5,622	8,019	4,628
50		208	452	2,731	3,391		2,397	5,622	8,019	4,628
TOTAL	136,803	10,400	22,600	136,556	306,359	210,240	119,837	281,105	611,182	304,823
(NPV)					93,810				104,639	10,829
									B/C	1.12

Table 9-7 Economic Comparison ("D" Route Plan, Installed Capacity 73MW×2units)

EL CAJON PROJECT (2-2) (unit: 1000 US$)

No.	COST					BENEFIT				B - C
	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	
-4	15747				15,747				0	-15,747
-3	19,034				19,034				0	-19,034
-2	31,892				31,892	36,792			36,792	4,900
-1	19,792				19,792	15,768			15,768	-4,024
1		208	452	2,731	3,391		2,397	5,622	8,019	4,628
2		208	452	2,731	3,391		2,397	5,622	8,019	4,628
3	42,021	208	452	2,731	45,412	36,792	2,397	5,622	44,811	-601
4	28,014	208	452	2,731	31,405	15,768	2,397	5,622	23,787	-7,618
5		210	817	5,462	6,489		4,793	11,244	16,038	9,548
6		210	817	5,462	6,489		4,793	11,244	16,038	9,548
7		210	817	5,462	6,489		4,793	11,244	16,038	9,548
8		210	817	5,462	6,489		4,793	11,244	16,038	9,548
9		210	817	5,462	6,489		4,793	11,244	16,038	9,548
10		210	817	5,462	6,489		4,793	11,244	16,038	9,548
11		210	817	5,462	6,489		4,793	11,244	16,038	9,548
12		210	817	5,462	6,489		4,793	11,244	16,038	9,548
13		210	817	5,462	6,489		4,793	11,244	16,038	9,548
14		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
15		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
16		210	817	5,462	6,489		4,793	11,244	16,038	9,548
17		210	817	5,462	6,489		4,793	11,244	16,038	9,548
18		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
19		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
20		210	817	5,462	6,489		4,793	11,244	16,038	9,548
21		210	817	5,462	6,489		4,793	11,244	16,038	9,548
22		210	817	5,462	6,489		4,793	11,244	16,038	9,548
23		210	817	5,462	6,489		4,793	11,244	16,038	9,548
24	30,241	210	817	5,462	36,730		4,793	11,244	16,038	-20,693
25	20,160	210	817	5,462	26,649		4,793	11,244	16,038	-10,612
26		210	817	5,462	6,489		4,793	11,244	16,038	9,548
27		210	817	5,462	6,489		4,793	11,244	16,038	9,548
28	38,916	210	817	5,462	45,405		4,793	11,244	16,038	-29,368
29	25,944	210	817	5,462	32,433	36,792	4,793	11,244	52,830	20,396
30		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
31		210	817	5,462	6,489		4,793	11,244	16,038	9,548
32		210	817	5,462	6,489		4,793	11,244	16,038	9,548
33		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
34		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
35		210	817	5,462	6,489		4,793	11,244	16,038	9,548
36		210	817	5,462	6,489		4,793	11,244	16,038	9,548
37		210	817	5,462	6,489		4,793	11,244	16,038	9,548
38		210	817	5,462	6,489		4,793	11,244	16,038	9,548
39		210	817	5,462	6,489		4,793	11,244	16,038	9,548
40		210	817	5,462	6,489		4,793	11,244	16,038	9,548
41		210	817	5,462	6,489		4,793	11,244	16,038	9,548
42		210	817	5,462	6,489		4,793	11,244	16,038	9,548
43		210	817	5,462	6,489		4,793	11,244	16,038	9,548
44		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
45		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
46		210	817	5,462	6,489		4,793	11,244	16,038	9,548
47		210	817	5,462	6,489		4,793	11,244	16,038	9,548
48		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
49		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
50		210	817	5,462	6,489		4,793	11,244	16,038	9,548
TOTAL	271,761	10,492	39,390	262,187	583,830	420,480	230,087	539,721	1,190,288	606,458
[NPV]					145,723				175,961	30,239
									B/C	1.21

Table 9-8 Economic Comparison ("C" Route Plan, Installed Capacity 73MW)

EL CAJON PROJECT (2-1) Revised (unit: 1000 US$)

	COST					BENEFIT				
No.	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	B - C
-4										
-3										
-2										
-1										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12	15,747				15,747				0	-15,747
13	19,034				19,034				0	-19,034
14	43,979				43,979	36,792			36,792	-7,187
15	27,892				27,892	15,768			15,768	-12,124
16		208	452	2,731	3,391		2,397	5,622	8,019	4,628
17		208	452	2,731	3,391		2,397	5,622	8,019	4,628
18		208	452	2,731	3,391		2,397	5,622	8,019	4,628
19		208	452	2,731	3,391		2,397	5,622	8,019	4,628
20		208	452	2,731	3,391		2,397	5,622	8,019	4,628
21		208	452	2,731	3,391		2,397	5,622	8,019	4,628
22		208	452	2,731	3,391		2,397	5,622	8,019	4,628
23		208	452	2,731	3,391		2,397	5,622	8,019	4,628
24		208	452	2,731	3,391		2,397	5,622	8,019	4,628
25		208	452	2,731	3,391		2,397	5,622	8,019	4,628
26		208	452	2,731	3,391		2,397	5,622	8,019	4,628
27		208	452	2,731	3,391		2,397	5,622	8,019	4,628
28		208	452	2,731	3,391		2,397	5,622	8,019	4,628
29		208	452	2,731	3,391	36,792	2,397	5,622	44,811	41,420
30		208	452	2,731	3,391	15,768	2,397	5,622	23,787	20,396
31		208	452	2,731	3,391		2,397	5,622	8,019	4,628
32		208	452	2,731	3,391		2,397	5,622	8,019	4,628
33		208	452	2,731	3,391		2,397	5,622	8,019	4,628
34		208	452	2,731	3,391		2,397	5,622	8,019	4,628
35		208	452	2,731	3,391		2,397	5,622	8,019	4,628
36		208	452	2,731	3,391		2,397	5,622	8,019	4,628
37		208	452	2,731	3,391		2,397	5,622	8,019	4,628
38		208	452	2,731	3,391		2,397	5,622	8,019	4,628
39	42,391	208	452	2,731	45,782		2,397	5,622	8,019	-37,763
40	28,261	208	452	2,731	31,652		2,397	5,622	8,019	-23,633
41		208	452	2,731	3,391		2,397	5,622	8,019	4,628
42		208	452	2,731	3,391		2,397	5,622	8,019	4,628
43		208	452	2,731	3,391		2,397	5,622	8,019	4,628
44		208	452	2,731	3,391	36,792	2,397	5,622	44,811	41,420
45		208	452	2,731	3,391	15,768	2,397	5,622	23,787	20,396
46		208	452	2,731	3,391		2,397	5,622	8,019	4,628
47		208	452	2,731	3,391		2,397	5,622	8,019	4,628
48		208	452	2,731	3,391		2,397	5,622	8,019	4,628
49		208	452	2,731	3,391		2,397	5,622	8,019	4,628
50		208	452	2,731	3,391		2,397	5,622	8,019	4,628
TOTAL	177,304	7,280	15,820	95,589	295,993	157,680	83,886	196,773	438,339	142,346
[NPV]					26,141				24,569	-1,572
									B/C	0.94

Table 9-9 Economic Comparison ("C" Route Plan, Installed Capacity 73MW×2units)

EL CAJON PROJECT (2-2) Revised (unit: 1000 US$)

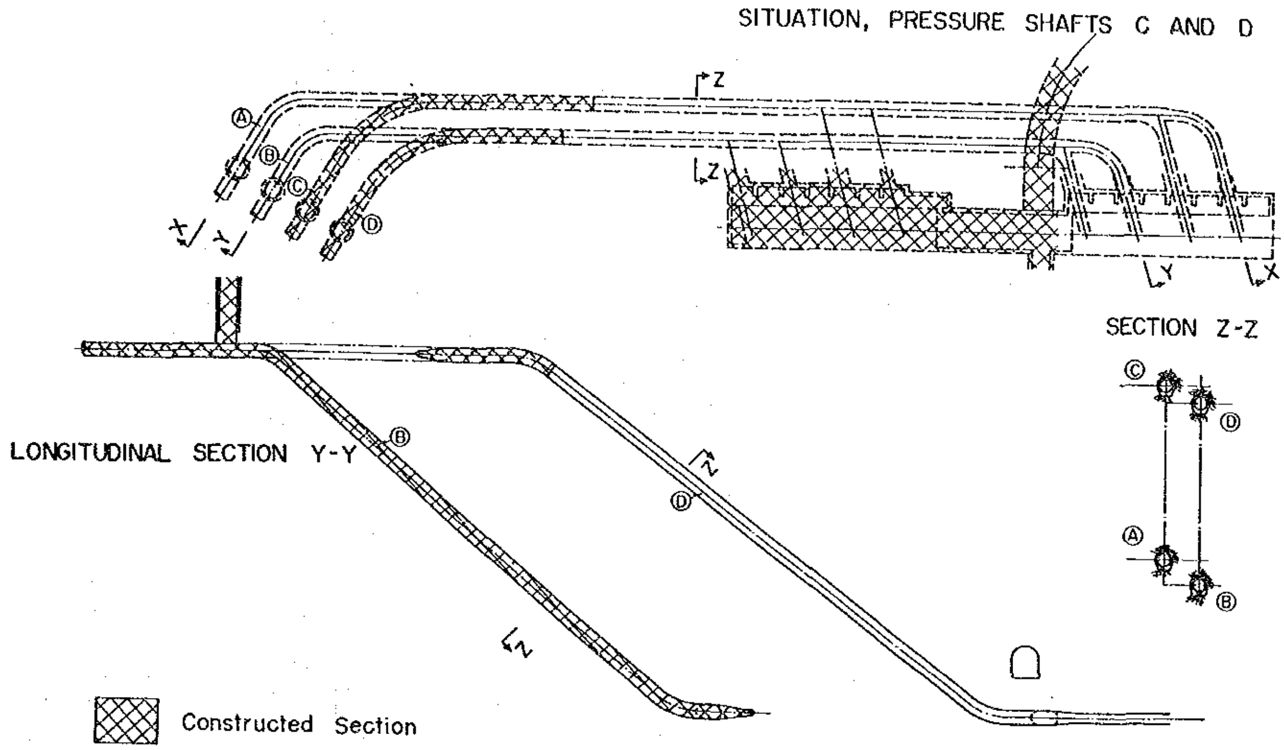
	COST					BENEFIT				
No.	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	B - C
-4										
-3										
-2										
-1										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12	15,747				15,747				0	-15,747
13	19,034				19,034				0	-19,034
14	43,979				43,979	36,792			36,792	-7,187
15	27,892				27,892	15,768			15,768	-12,124
16		208	452	2,731	3,391		2,397	5,622	8,019	4,628
17		208	452	2,731	3,391		2,397	5,622	8,019	4,628
18	42,021	208	452	2,731	45,412	36,792	2,397	5,622	44,811	-601
19	28,014	208	452	2,731	31,405	15,768	2,397	5,622	23,787	-7,618
20		210	817	5,462	6,489		4,793	11,244	16,038	9,548
21		210	817	5,462	6,489		4,793	11,244	16,038	9,548
22		210	817	5,462	6,489		4,793	11,244	16,038	9,548
23		210	817	5,462	6,489		4,793	11,244	16,038	9,548
24		210	817	5,462	6,489		4,793	11,244	16,038	9,548
25		210	817	5,462	6,489		4,793	11,244	16,038	9,548
26		210	817	5,462	6,489		4,793	11,244	16,038	9,548
27		210	817	5,462	6,489		4,793	11,244	16,038	9,548
28		210	817	5,462	6,489		4,793	11,244	16,038	9,548
29		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
30		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
31		210	817	5,462	6,489		4,793	11,244	16,038	9,548
32		210	817	5,462	6,489		4,793	11,244	16,038	9,548
33		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
34		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
35		210	817	5,462	6,489		4,793	11,244	16,038	9,548
36		210	817	5,462	6,489		4,793	11,244	16,038	9,548
37		210	817	5,462	6,489		4,793	11,244	16,038	9,548
38		210	817	5,462	6,489		4,793	11,244	16,038	9,548
39	42,391	210	817	5,462	48,880		4,793	11,244	16,038	-32,843
40	28,261	210	817	5,462	34,750		4,793	11,244	16,038	-18,713
41		210	817	5,462	6,489		4,793	11,244	16,038	9,548
42		210	817	5,462	6,489		4,793	11,244	16,038	9,548
43	38,916	210	817	5,462	45,405		4,793	11,244	16,038	-29,368
44	25,944	210	817	5,462	32,433	36,792	4,793	11,244	52,830	20,396
45		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
46		210	817	5,462	6,489		4,793	11,244	16,038	9,548
47		210	817	5,462	6,489		4,793	11,244	16,038	9,548
48		210	817	5,462	6,489	36,792	4,793	11,244	52,830	46,340
49		210	817	5,462	6,489	15,768	4,793	11,244	31,806	25,316
50		210	817	5,462	6,489		4,793	11,244	16,038	9,548
TOTAL	312,199	7,342	27,135	180,253	526,929	315,360	158,185	371,058	844,603	317,673
[NPV]					38,420				41,202	2,782
									B/C	1.07

Table 9-10 Economic Comparison ("D" Route Plan, Installed Capacity 48.7MW×3units)

EL CAJON PROJECT (3-3) (unit: 1000 US$)

	COST					BENEFIT				
No.	INVEST	CIVIL O&M	E/M O&M	FUEL	TOTAL(C)	INVEST	O & M	FUEL	TOTAL(B)	B - C
-4	18,812				18,812				0	-18,812
-3	20,863				20,863				0	-20,863
-2	26,967				26,967	24,545			24,545	-2,422
-1	14,340				14,340	10,519			10,519	-3,821
1	25,815	263	379	1,822	28,279	24,545	1,599	3,751	29,894	1,615
2	17,209	263	379	1,822	19,673	10,519	1,599	3,751	15,869	-3,804
3	29,946	265	655	3,644	34,510	24,545	3,198	7,501	35,244	734
4	19,963	265	655	3,644	24,527	10,519	3,198	7,501	21,218	-3,309
5		267	931	5,466	6,664		4,797	11,252	16,049	9,385
6		267	931	5,466	6,664		4,797	11,252	16,049	9,385
7		267	931	5,466	6,664		4,797	11,252	16,049	9,385
8		267	931	5,466	6,664		4,797	11,252	16,049	9,385
9		267	931	5,466	6,664		4,797	11,252	16,049	9,385
10		267	931	5,466	6,664		4,797	11,252	16,049	9,385
11		267	931	5,466	6,664		4,797	11,252	16,049	9,385
12		267	931	5,466	6,664		4,797	11,252	16,049	9,385
13		267	931	5,466	6,664		4,797	11,252	16,049	9,385
14		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
15		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
16		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
17		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
18		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
19		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
20		267	931	5,466	6,664		4,797	11,252	16,049	9,385
21		267	931	5,466	6,664		4,797	11,252	16,049	9,385
22		267	931	5,466	6,664		4,797	11,252	16,049	9,385
23		267	931	5,466	6,664		4,797	11,252	16,049	9,385
24	23,428	267	931	5,466	30,092		4,797	11,252	16,049	-14,043
25	15,618	267	931	5,466	22,282		4,797	11,252	16,049	-6,233
26	19,302	267	931	5,466	25,966		4,797	11,252	16,049	-9,917
27	12,868	267	931	5,466	19,532		4,797	11,252	16,049	-3,483
28	27,564	267	931	5,466	34,228		4,797	11,252	16,049	-18,179
29	18,376	267	931	5,466	25,040	24,545	4,797	11,252	40,593	15,553
30		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
31		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
32		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
33		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
34		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
35		267	931	5,466	6,664		4,797	11,252	16,049	9,385
36		267	931	5,466	6,664		4,797	11,252	16,049	9,385
37		267	931	5,466	6,664		4,797	11,252	16,049	9,385
38		267	931	5,466	6,664		4,797	11,252	16,049	9,385
39		267	931	5,466	6,664		4,797	11,252	16,049	9,385
40		267	931	5,466	6,664		4,797	11,252	16,049	9,385
41		267	931	5,466	6,664		4,797	11,252	16,049	9,385
42		267	931	5,466	6,664		4,797	11,252	16,049	9,385
43		267	931	5,466	6,664		4,797	11,252	16,049	9,385
44		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
45		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
46		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
47		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
48		267	931	5,466	6,664	24,545	4,797	11,252	40,593	33,929
49		267	931	5,466	6,664	10,519	4,797	11,252	26,568	19,904
50		267	931	5,466	6,664		4,797	11,252	16,049	9,385
TOTAL	291,071	13,338	44,894	262,366	611,669	420,768	230,244	540,091	1,191,103	579,434
[NPV]					159,397				175,026	15,629
									B/C	1.10

(Penstock)



(Underground Powerhouse)

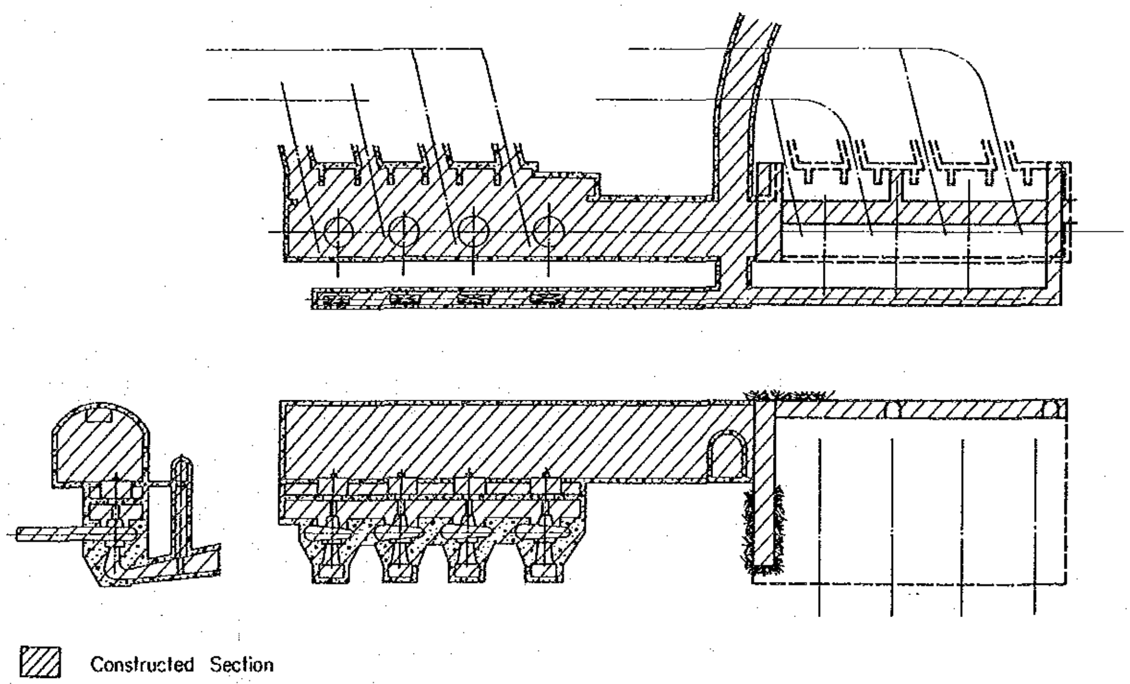


Figure 9-1 Completed Portion El Cajón Hydroelectric Power Plant

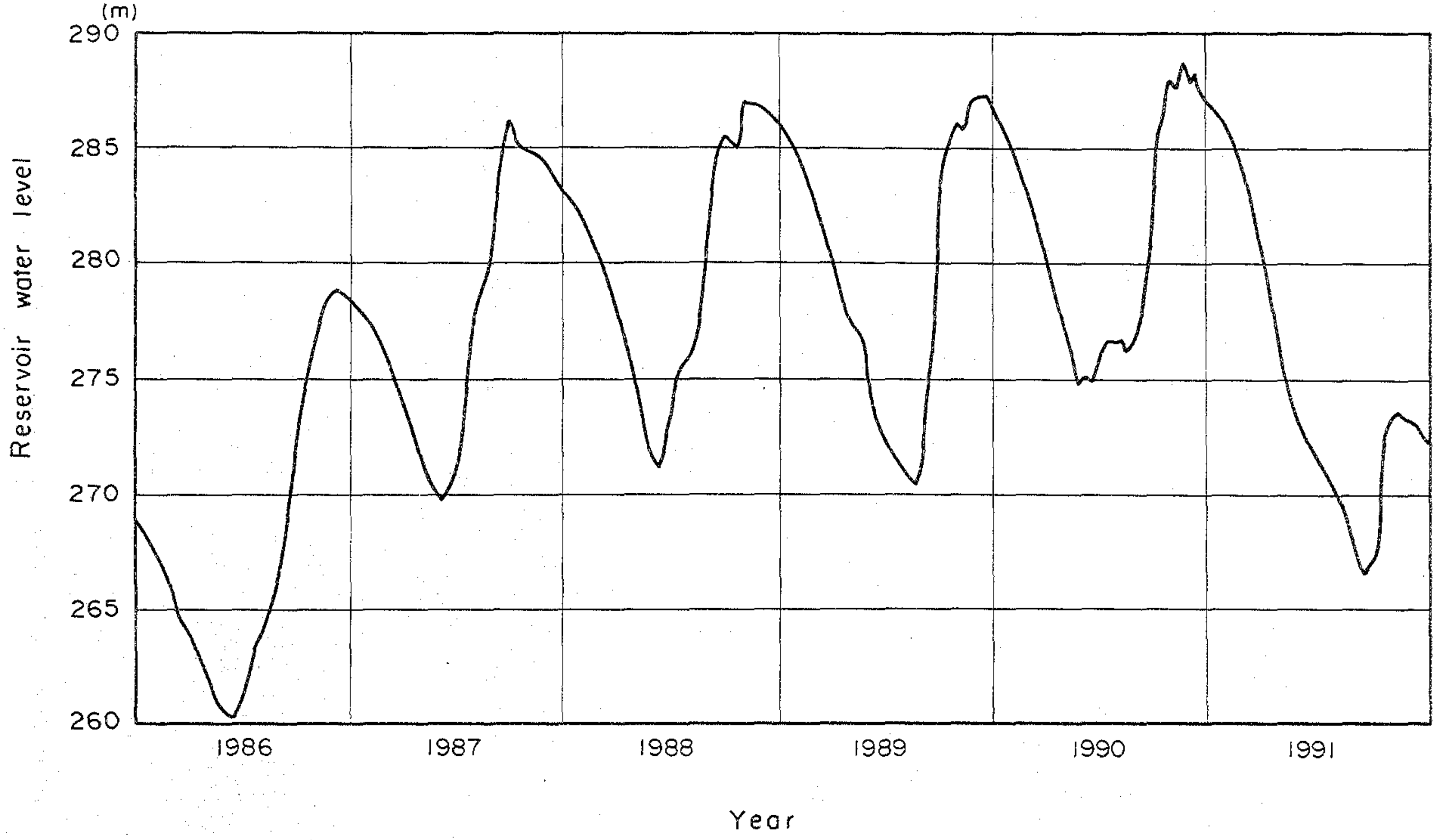


Figure 9-2 Actual Operation of El Cajon Reservoir

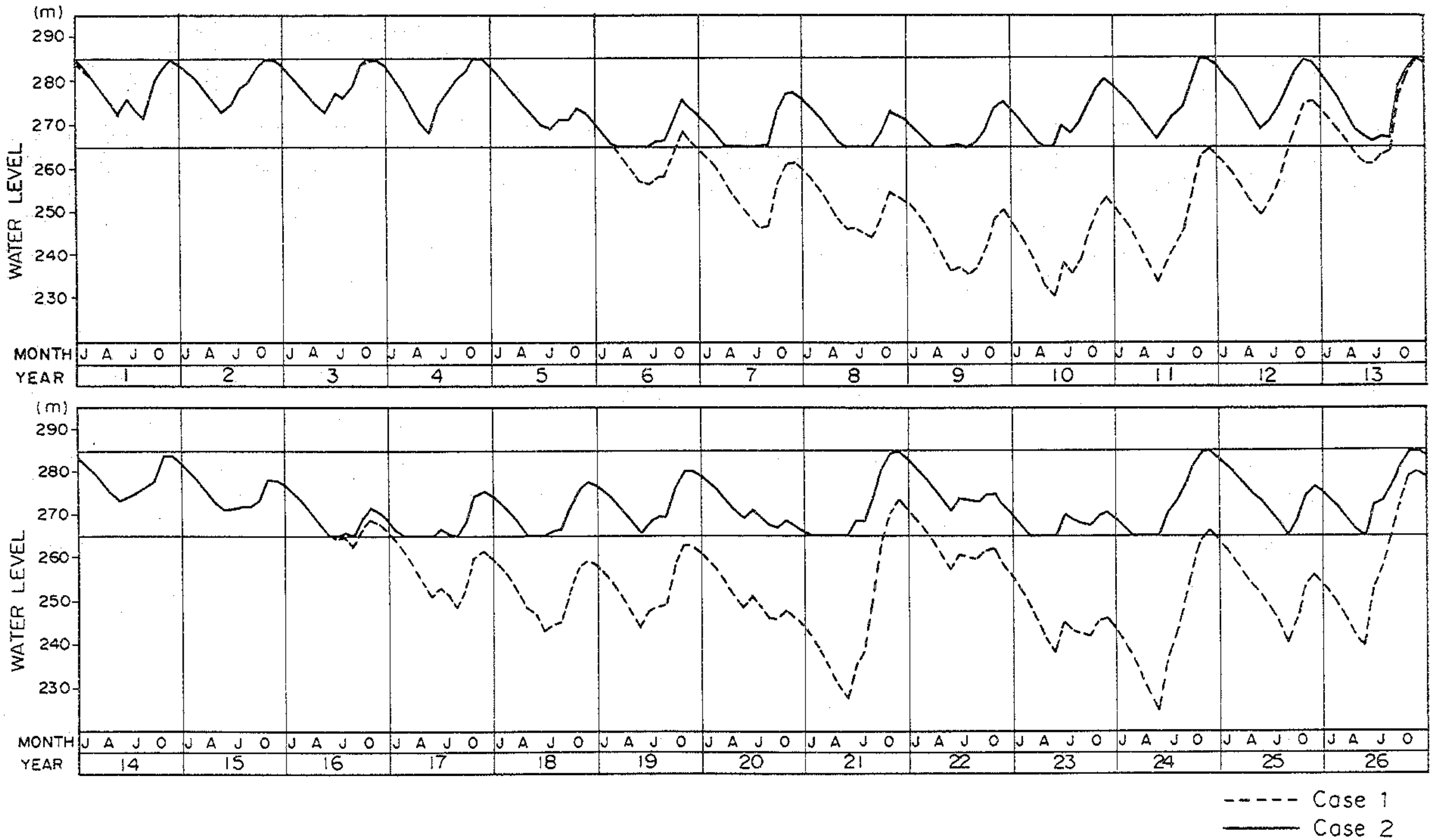


Figure 9-3 Reservoir Water Level by DP Method (1/2)

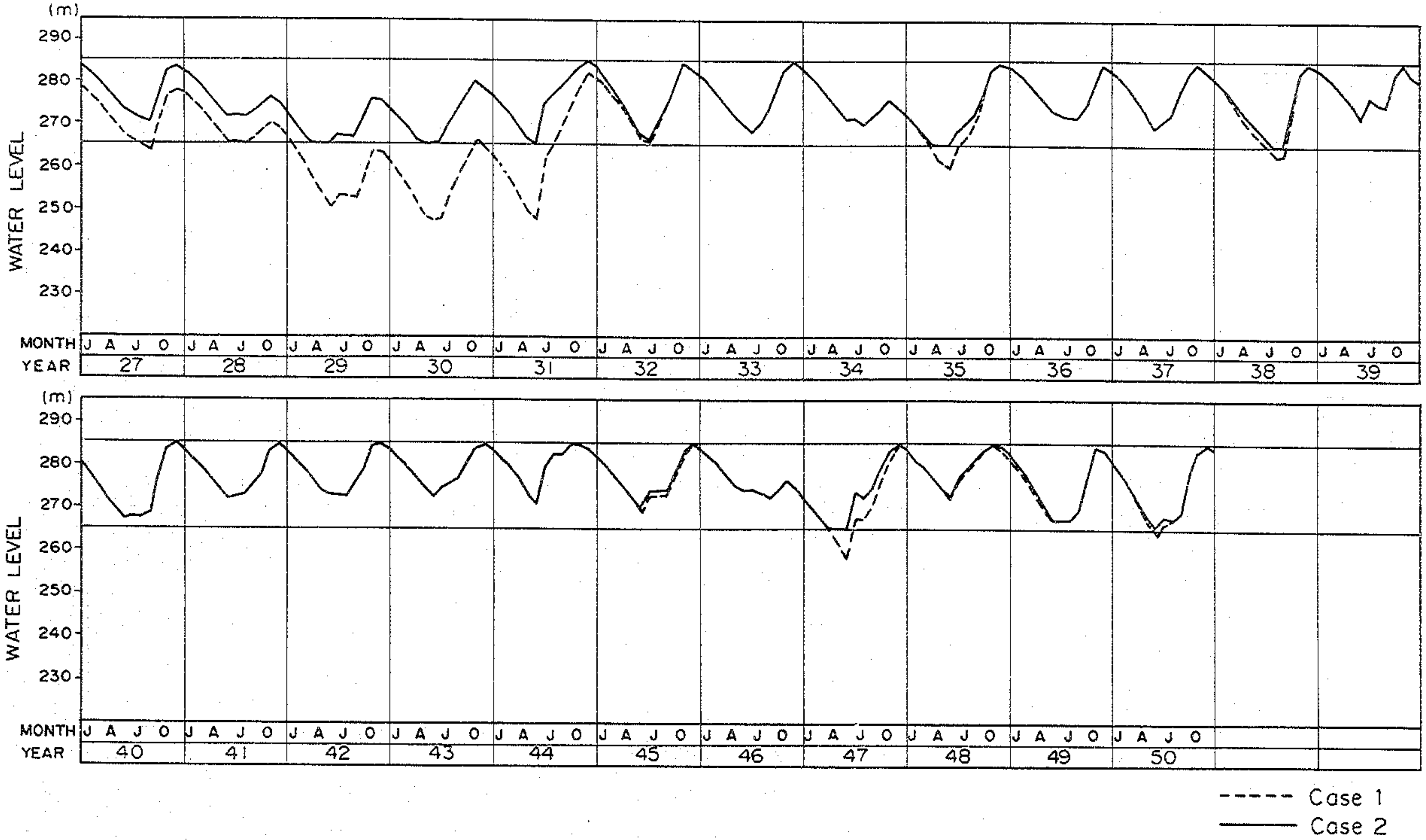


Figure 9-4 Reservoir Water Level by DP Method (2/2)

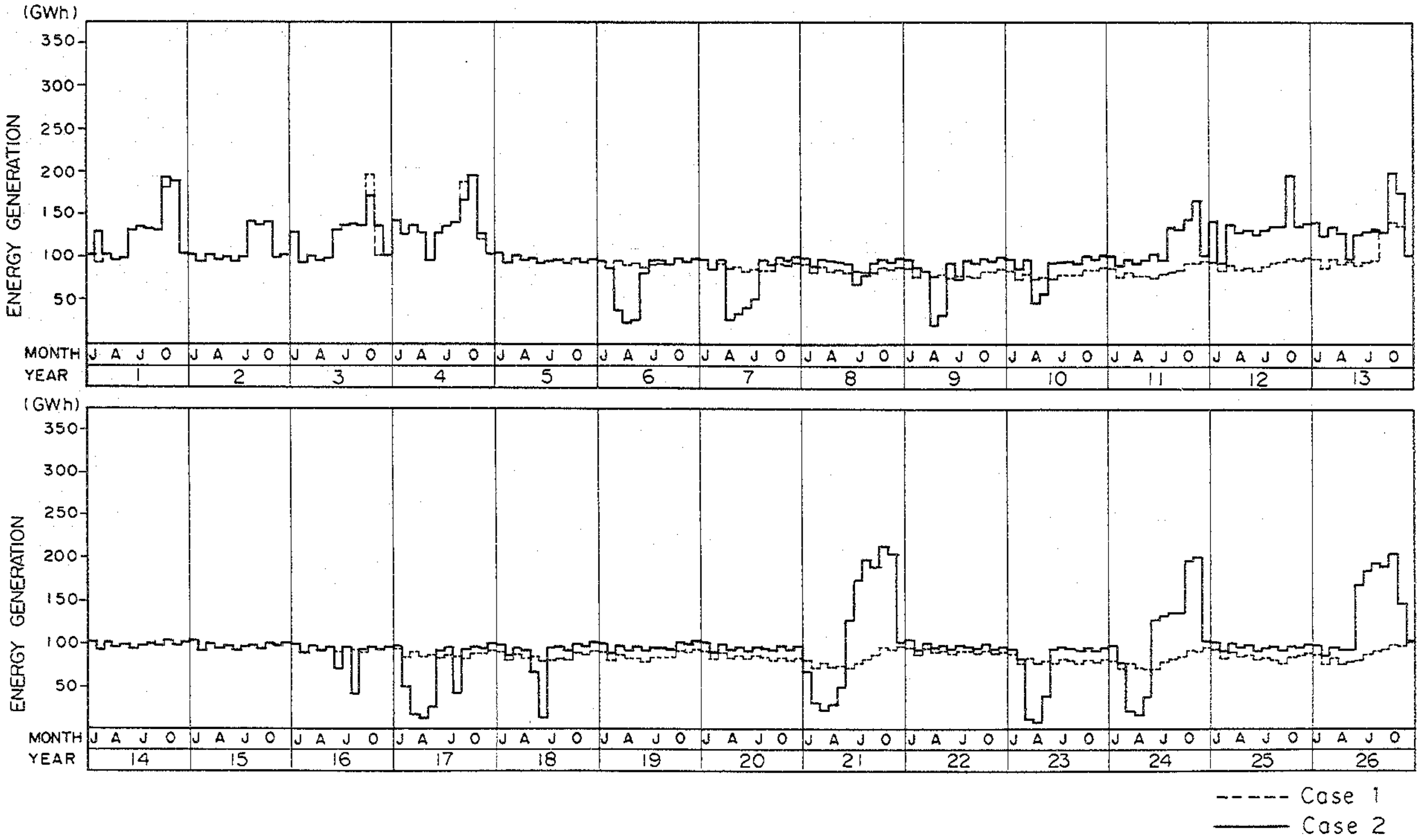


Figure 9-5 Energy Generation by DP Method (1/2)

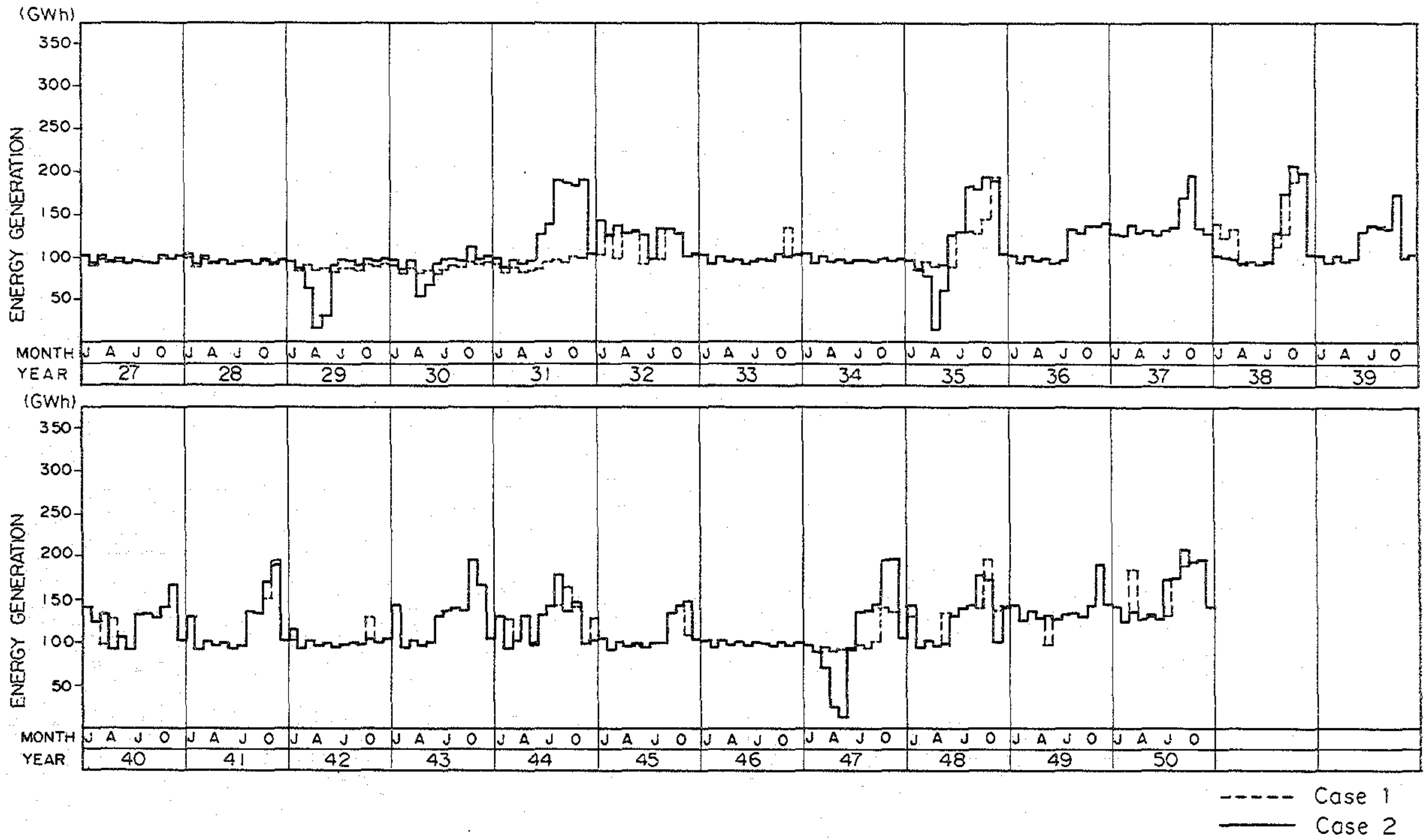


Figure 9-6 Energy Generation by DP Method (2/2)

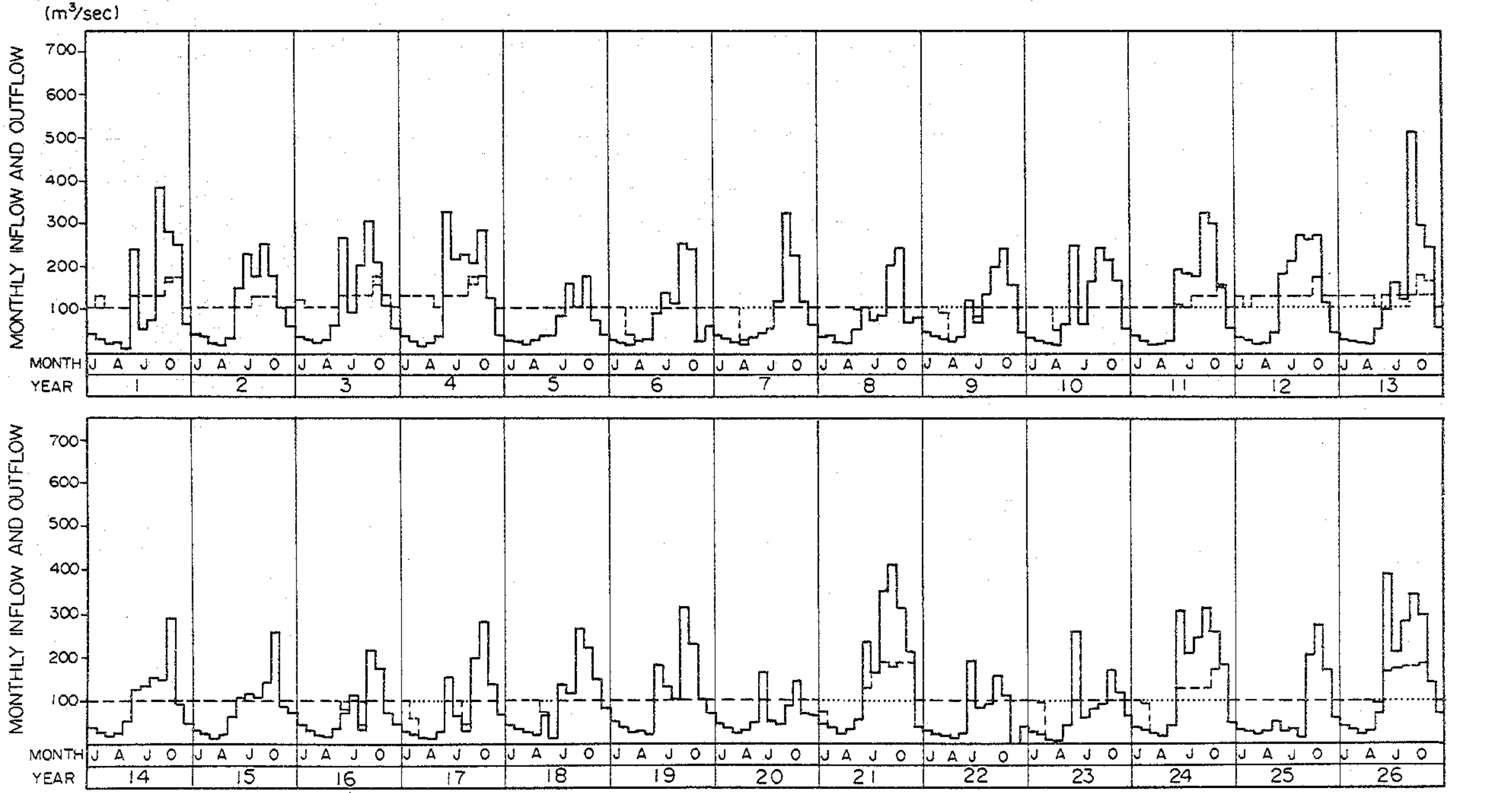


Figure 9-7 Inflow and Outflow by DP Method (1/2)

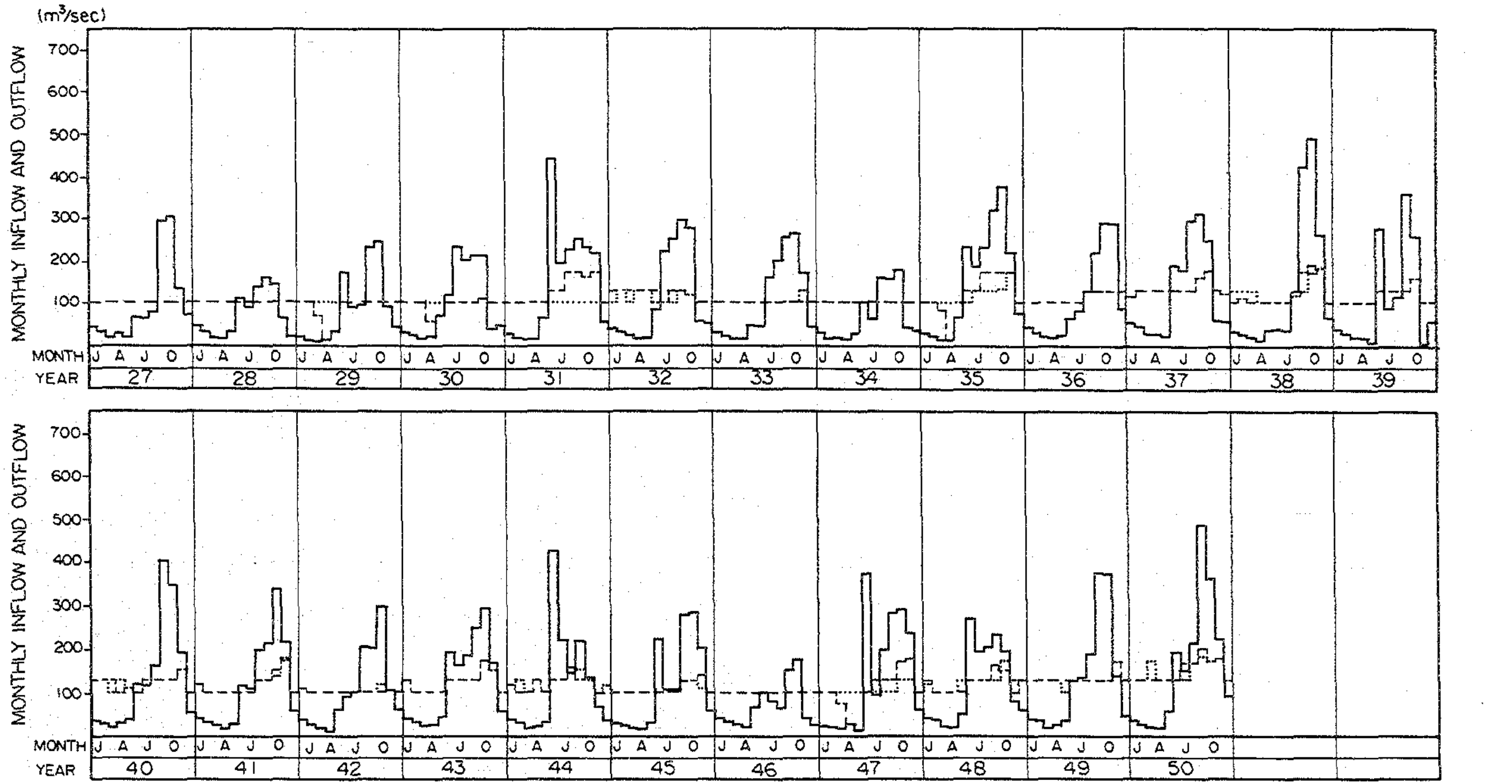


Figure 9-8 Inflow and Outflow by DP Method (2/2)

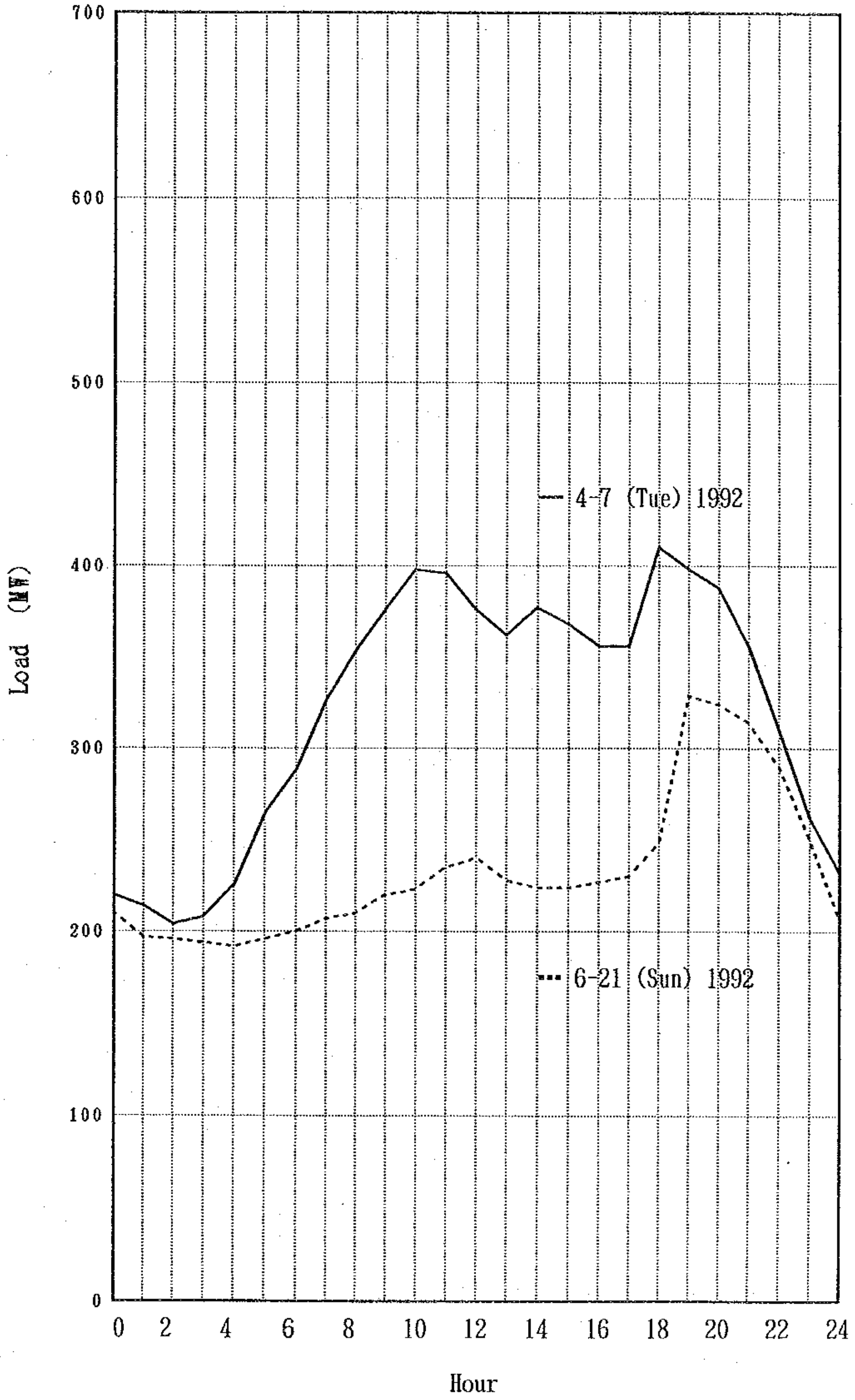


Figure 9-9 Daily Load Curve

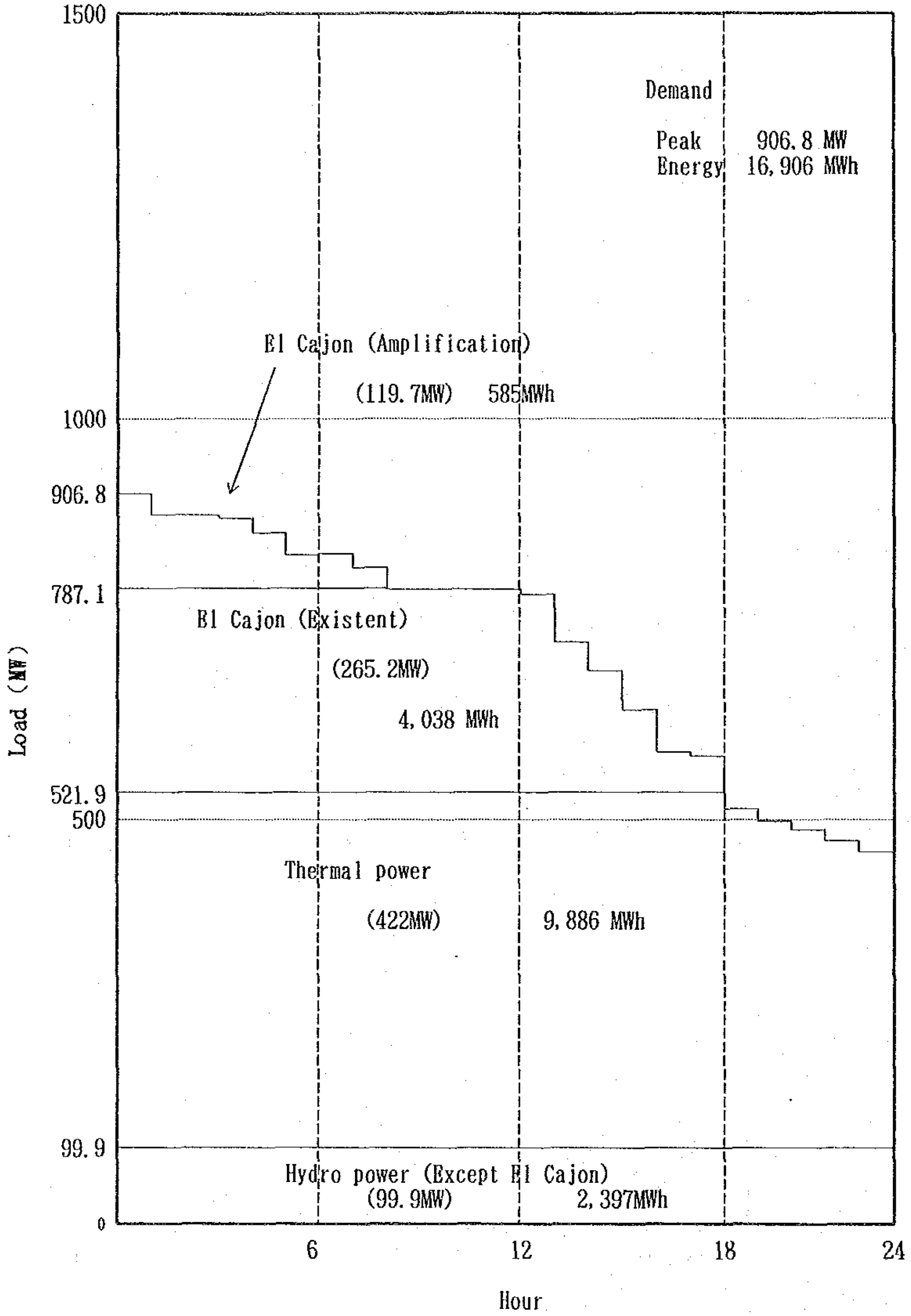


Figure 9-10 Power Demand and Supply Balance (2009)

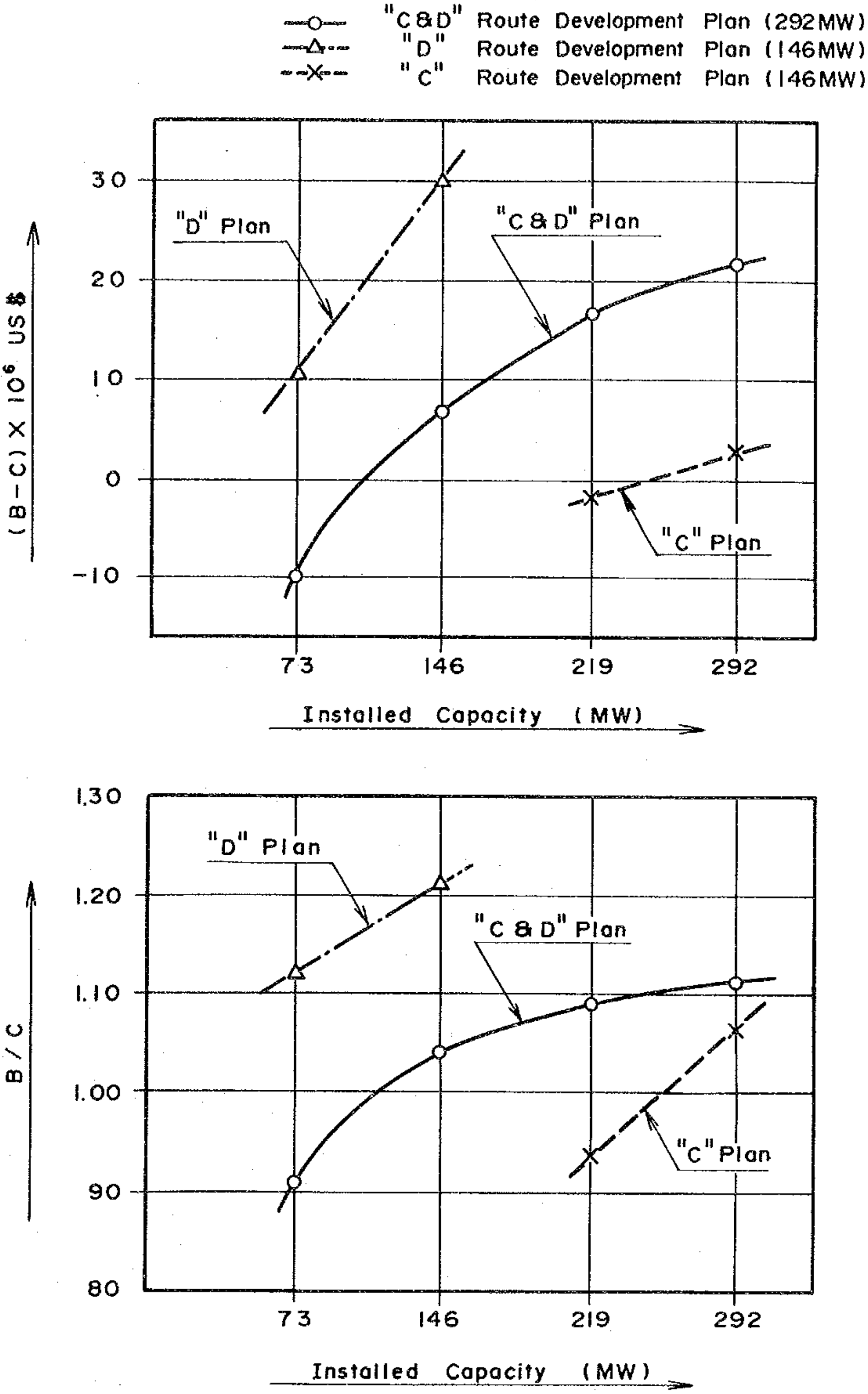


Figure 9-11 Study on Optimum Installed Capacity

Chapter 10 POWER TRANSMISSION PLAN AND POWER SYSTEM ANALYSIS

Chapter 10

POWER TRANSMISSION PLAN AND POWER SYSTEM ANALYSIS

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Chapter 10 POWER TRANSMISSION PLAN AND POWER SYSTEM ANALYSIS

10.1 Outline of Power Transmission Systems

The power transmission systems of Honduras are composed of 230 kV, 138 kV and 69 kV power transmission lines. The total length of these power transmission lines were 2,569 km as of 1988.

The 230 kV power transmission system is interconnected to the neighboring nation of Nicaragua, and this interconnection extends to Panama via Costa Rica. The surplus power of El Cajón Hydroelectric Power Plant has been exported to Costa Rica and Panama by means of this interconnection.

An interconnection to another neighboring nation, El Salvador, is being planned. The national power transmission systems of Honduras as of the time cross section of 1992 is presented in **Fig. 10-1**.

The output electric power of El Cajón Hydroelectric Power Plant is supplied to the north to San Pedro Sula City, which is an industrial city in the northern part of Honduras on the coast of Caribbean Sea, by a double circuit of 230 kV power transmission line, and to the south to Tegucigalpa, the capital city also by a double circuit of 230 kV power transmission line.

The total power transmission capacity of these lines is approximately 700 MW. Other 230 kV power transmission lines in the nation are single circuit lines, and these lines are not satisfactory in terms of supply reliability.

The supply of power to other areas is transmitted by 138 kV and 69 kV lines.

10.2 Power Transmission Plan

The power generated by El Cajón Hydroelectric Power Plant is transmitted to San Pedro Sula City in the north, which is the major industrial city of this nation by a double circuit 230 kV power transmission line that reaches Progreso Substation, and to Tegucigalpa City in the south by a double circuit 230 kV power transmission line that reaches Suyapa Substation.

The power transmission capacity of each circuit of these power transmission lines ranges from 170 MW to 190 MW. Since El Cajón Amplification Project is implemented with 73 MW x 2 units, the scale of amplification is less than the total power transmission line capacity. However, it is anticipated that shortage in power transmission line capacity could occur depending on the proportion of transmission power allotted to the north-bound line and south-bound line. The power flow simulation study has been conducted for the time cross sections of 1992, and 2006 in which year the Amplification Project will be completed. The study indicated that the power can be satisfactorily transmitted by the existing two power transmission lines. Therefore, there is no need to provide additional power transmission lines or to reinforce the existing power transmission lines.

The projected power flows in 1992 is presented in **Fig. 10-2**, and in 2006 in **Fig. 10-3**.

10.3 Power System Analysis

The thermal capacity of lines, voltage regulation, short circuit capacity and stability of the existing power systems of Honduras were analyzed.

These studies have been conducted on the time cross sections of 1992, and 2006 when the Amplification Project is completed.

10.3.1 Power Flow Calculation

(1) Study Conditions

▪ Total power demand of ENEE power system	;	410.6 MW (as of 1992), 764.1 MW (as of 2006)
▪ Voltage regulation facilities	;	postulated as **Fig. 10-3**
▪ Additional transmission lines and transformer banks	;	postulated as **Fig. 10-3**
▪ Locations of new power plants	;	postulated as **Fig. 10-3**
▪ Load power factor	;	95% lagging at substation bus.
▪ Generator output	;	All generators except those of El Cajón were assumed to supply full output. The load is regulated by El Cajón.
▪ Voltage regulation target	;	Voltage is kept within 95 - 105% at each power plant and substation.

(2) Study Result

The power flow diagram are presented in **Fig. 10-2** and **Fig. 10-3**. The study results indicate that there are slight voltage dips in the time cross section of 1992, but they do not pose a particular problem. In the time section of 2006, additional power transmission lines, tranformer banks and voltage regulating facilities are required as illustrated in **Fig. 10-3**, and the target voltage values can not be realized, being only a little too low or too high at some substations. However, there is no particular problem, with the transmission line power flows kept within the capacity limits.

10.3.2 Short Circuit Capacity

(1) Study Conditions

- Generator; All generators were synchronized to the power system, and calculation was performed by using the subtransient reactance, X"d.

(2) Study Result

The calculation indicates that the short circuit capacity at El Cajón is within 31.5 kA which is in accordance with IEC Standard, and there is no particular problem.

Therefore, there is no need to replace the circuit breakers.

10.3.3 System Stability

(1) Study conditions

- Fault condition; The fault condition is assumed as a single circuit, 3-phase to ground short circuit (3LG) occurring at the bus of El Cajón switchyard, which is cleared in 6 cycles (100 ms).

(2) Study Result

An example of the simulation study results is presented in **Fig. 10-4~6**, and the result of the stability calculations for 1992 and 2006 in the table below. The power system is stable in all study cases, and there is no particular problem.

Stability Calculation Result

Fault Point \ Year	1992	2006
El Cajón	Stable	Stable

10.4 Conclusion

In 1992, there was no need to modify the current transmission line facilities connected to El Cajón Hydroelectric Power Plant, and they can be operated satisfactorily.

In 2006, when 2 additional units (73 MW x 3) are commissioned at El Cajón, there will be no problem concerning the sound operation of the power system if the reinforcement program of transmission/substation facilities (including installation of reactive power compensation facilities in substations), illustrated in **Fig. 10-3**, is implemented.

Therefore, the existing power transmission lines connected to El Cajón Hydroelectric Power Plant can be operated without difficulty even after the two additional units are commissioned, and there is no need to add or improve the existing power transmission lines.

If the locations of new power plants and additional construction of power transmission lines are modified in future from the current plan, the power system analysis must be conducted every time such modification is made, to confirm that there is no problem in power system operation.

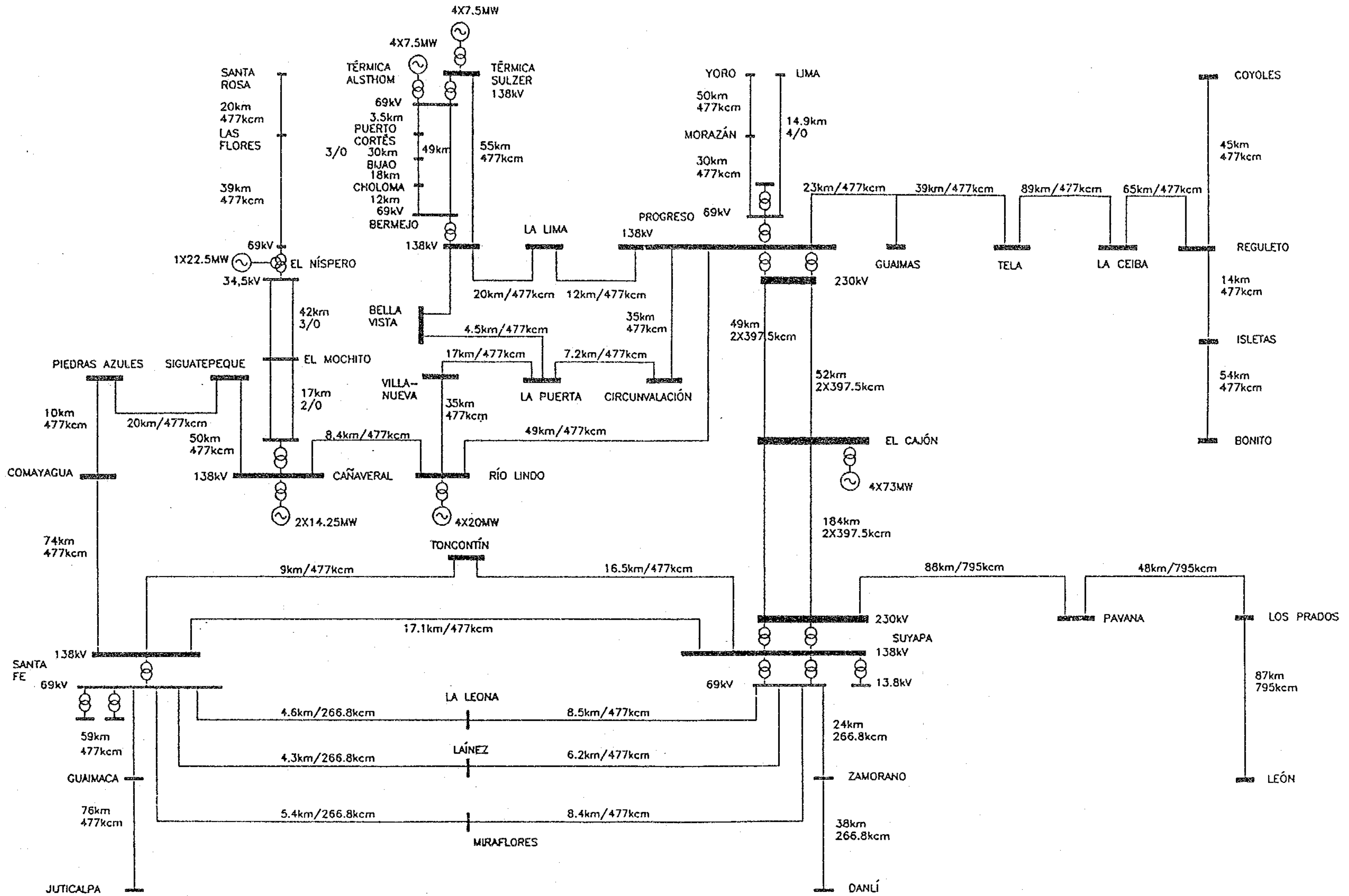

Figure 10-1 System of National Transmission Line (1992)

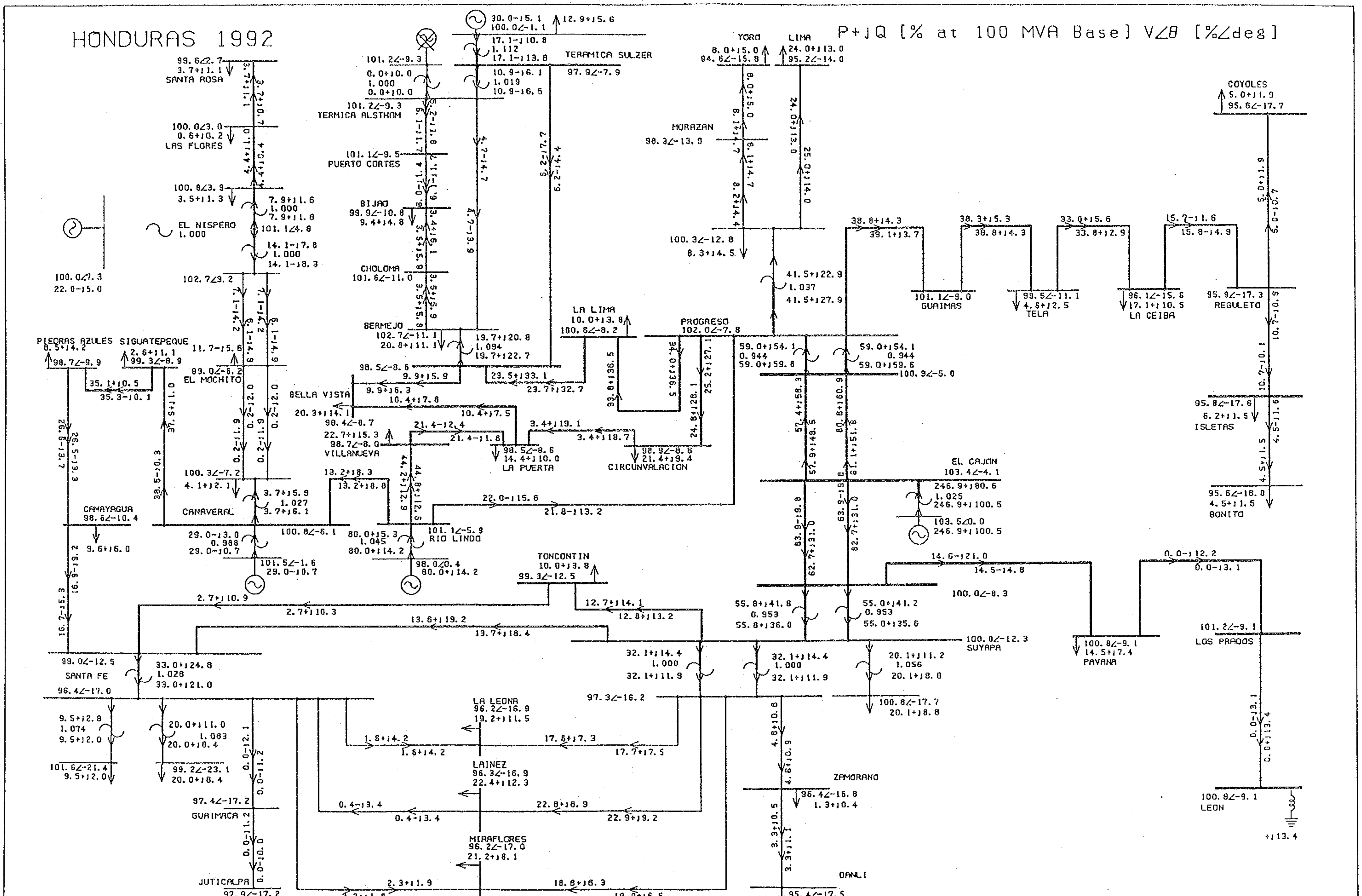

Figure 10-2 Power Flow of National Transmission Line (1992)

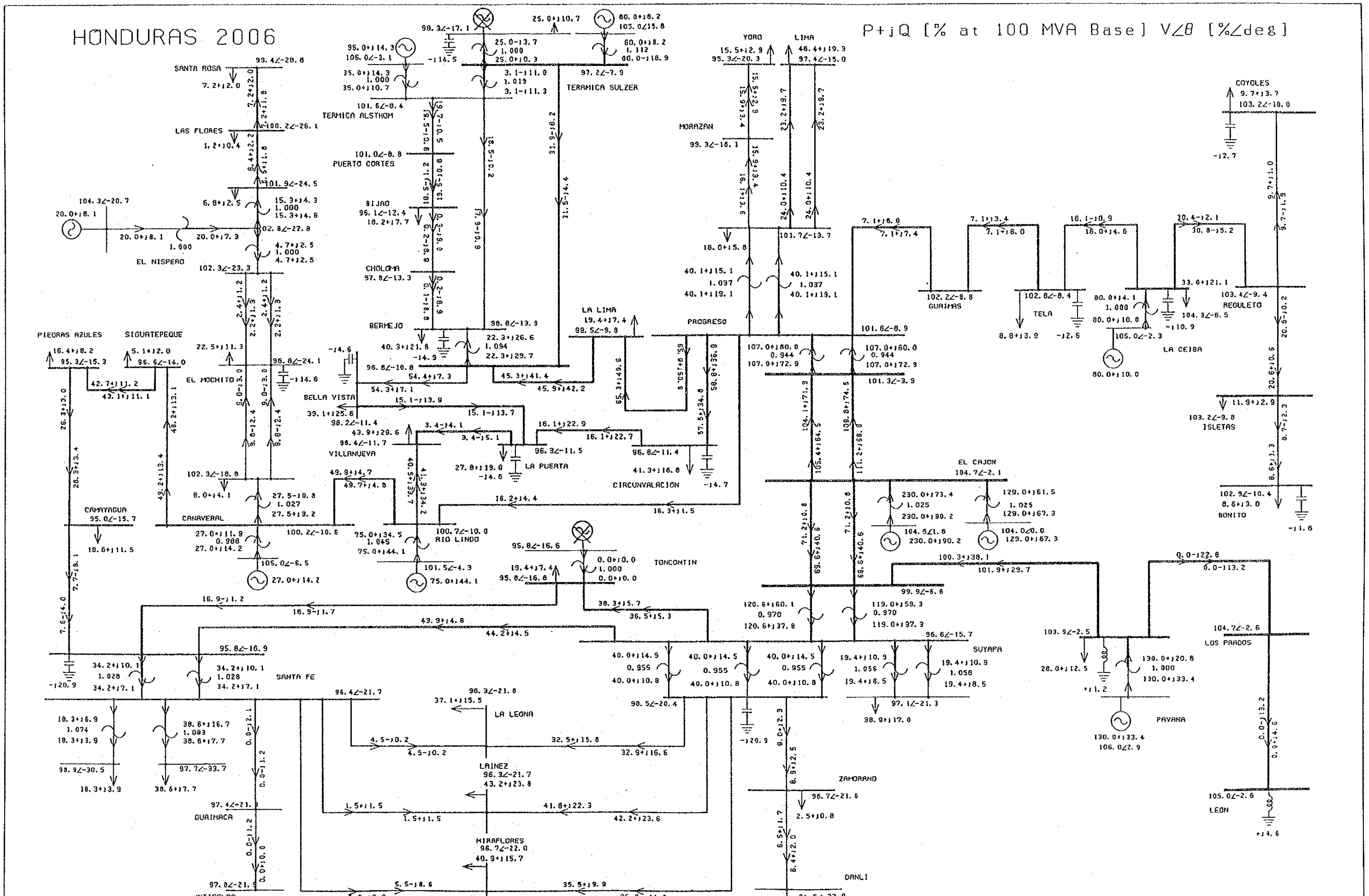

Figure 10-3 Power Flow of National Transmission Line (2006)

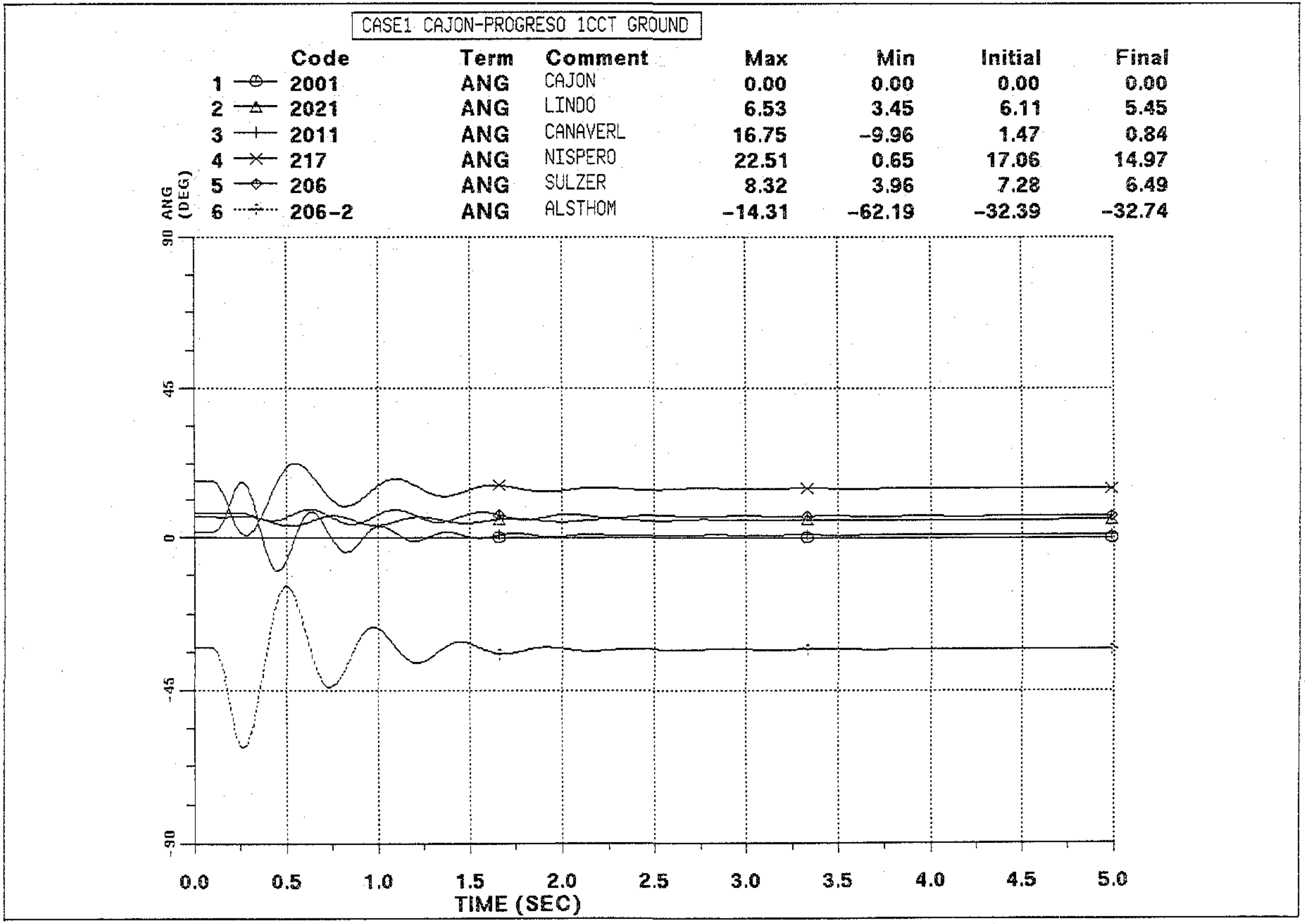

Figure 10-4 Result of Stability Study (1992)

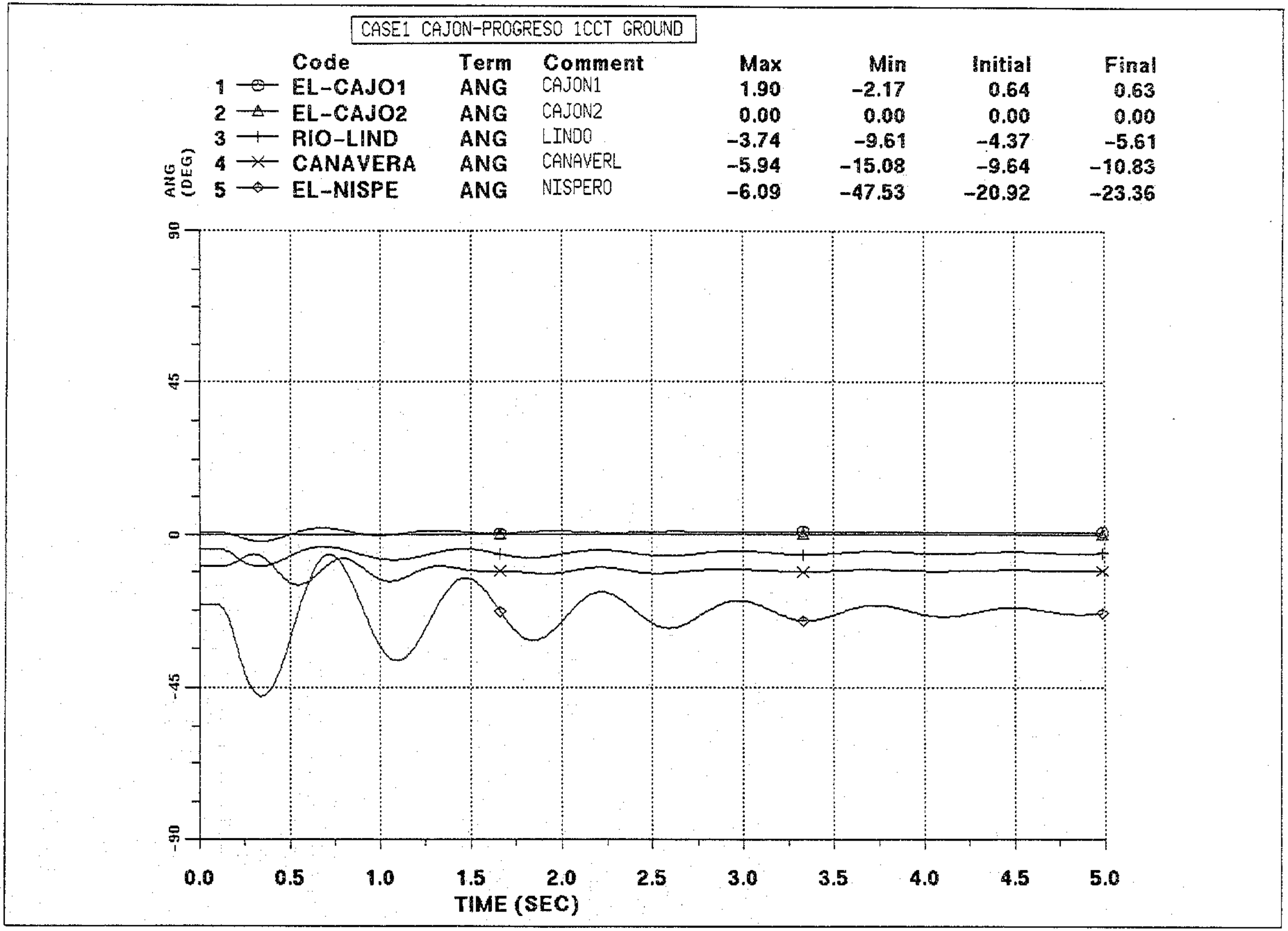

Figure 10-5 Result of Stability Study (2006) (1/2)

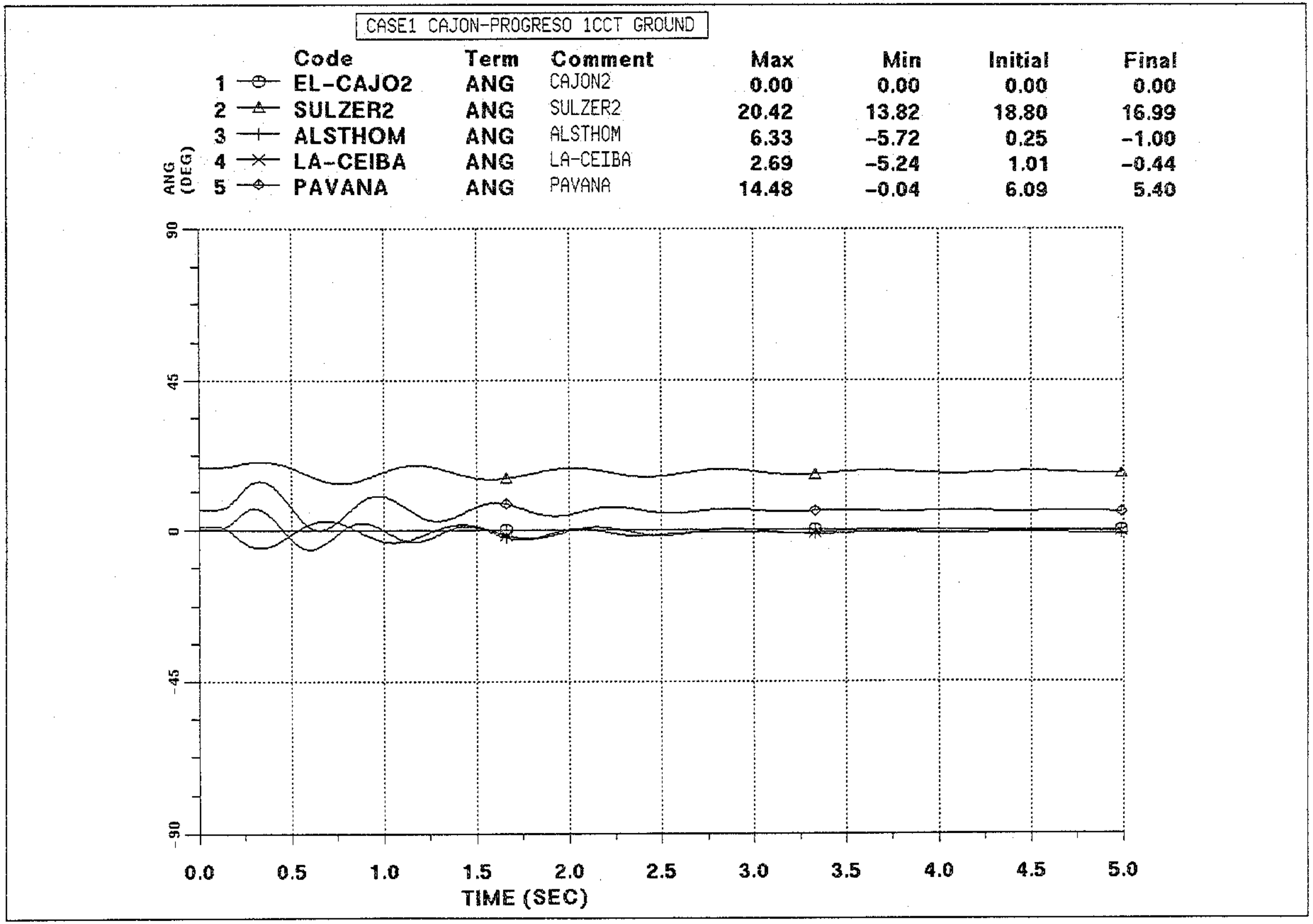

Figure 10-6 Result of Stability Study (2006) (2/2)

Chapter 11 FEASIBILITY DESIGN

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The El Cajón Hydroelectric Power Plant started operation in 1985 with the maximum output of 292 MW (73 MW x 4 units) as the first stage of the project. Considering the future amplification (292 MW : 73 MW x 4 units), the water intake, ground for the switchyard, part of the penstock and powerhouse were arranged in advance at the time of the first stage construction.

Fig. 11-1 shows general layout of structures in the project area.

The present amplification project is made for 146 MW (73 MW x 2 units) and the penstock, powerhouse and tailrace were designed using the channel route D out of routes C and D in the original amplification plan. (See **Fig. 11-2** and **11-3**.)

11.1 Civil Structures

11.1.1 Outline of Civil Structures

The outline of civil structures related to the amplification is described below. Drawings for each structure are shown in **Fig. 11-4** to **11-9**.

Intake (constructed)

Type	:	Inclined type with gate shaft
Maximum capacity	:	107.20 m^3/sec
Inside diameter	:	4.20 m (Tunnel section)

Penstock (Partly constructed)

Type	:	Underground type
Number of lines	:	One Two after branch
Maximum capacity	:	107.20 m^3/sec, 53.60 m^3/sec after branch
Diameter	:	4.20 to 3.00 m

Length	:	One line part 254.831 m (74.612 m constructed) Two lines part 27.126 m and 14.262 m
Plate thickness	:	24 to 34 mm
Branch type	:	T type branch

Powerhouse (Connected to the existing powerhouse)

Type	:	Underground type
Width	:	29.50 m
Height	:	41.40 m
Length	:	42.75 m

Tailrace

Type	:	Circular and semi-circular pressure tunnel
Number of lines	:	2
Inside diameter	:	4.20 m (circular section) (Height) 5.10 - 6.35 m x (Width) 5.10 m (semi-circular section)
Length	:	88.00 m (circular section: 81.50 m, semi-circular section: 6.50 m "without lining")
Gradient	:	1 : 7.913
Maximum capacity	:	53.60 m^3/sec

Tailrace (Service gallery)

Type	:	Semi-circular
Height	:	7.00 m
Width	:	3.00 m
Length	:	47.00 m

Tailrace (Gate shaft)

Type	:	Elliptic (vertical shaft)
Sectional dimension	:	3.70 x 6.00 m
Height	:	25.57 m