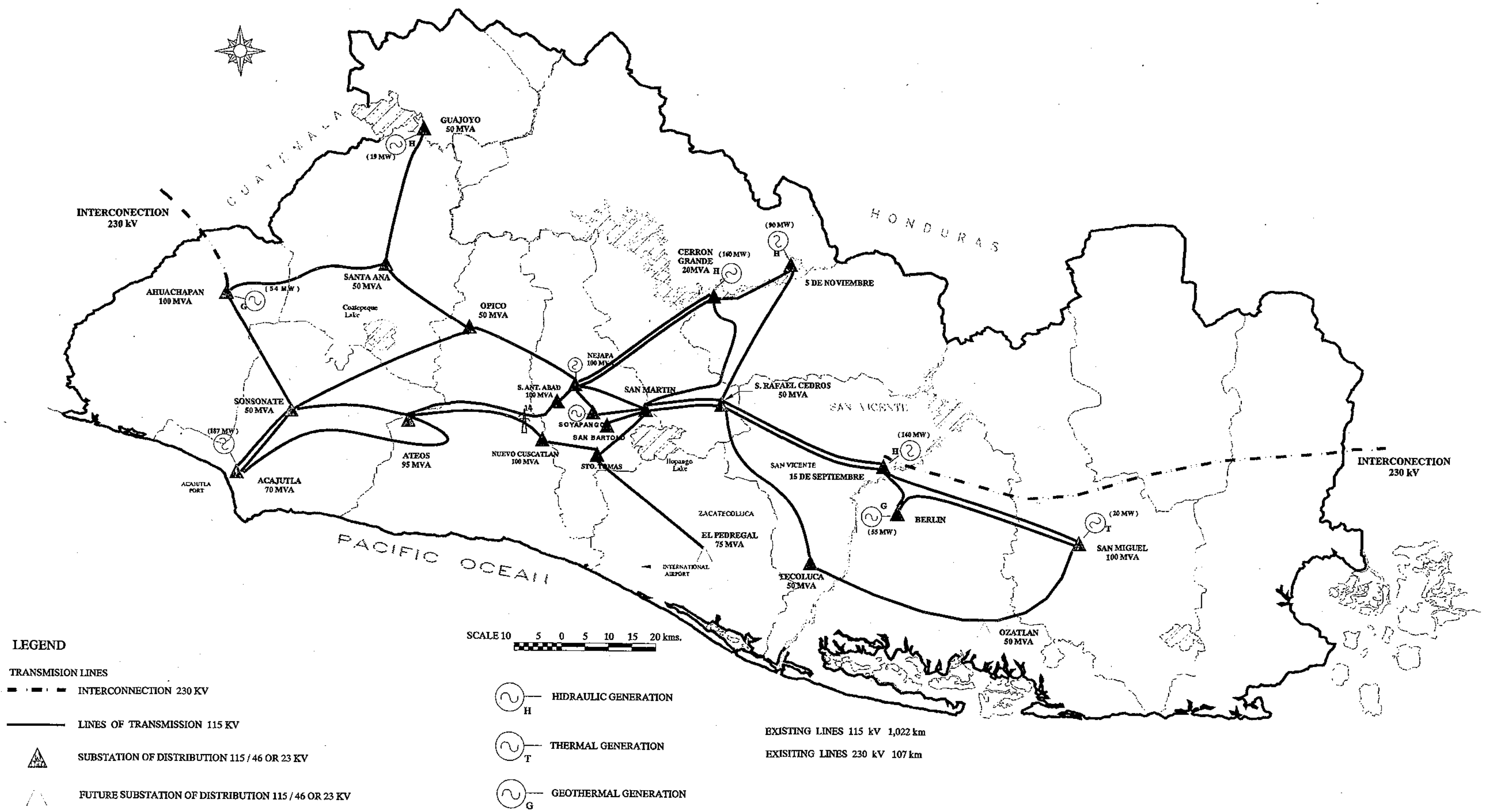

Fig. 10.1 Power System Diagram in El Salvador (2002)

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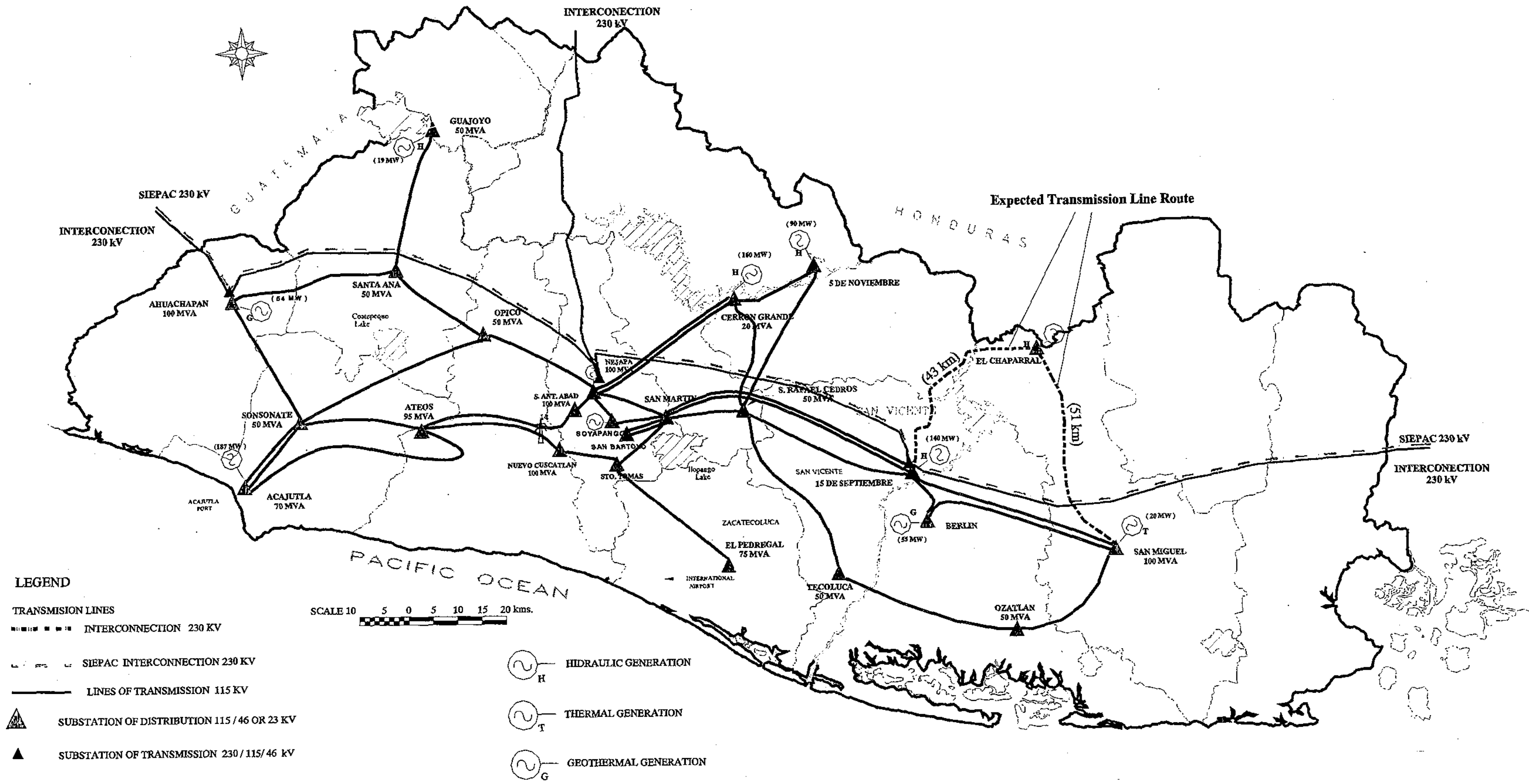


Fig. 10.2 Expected Power System Diagram in El Salvador (2010)

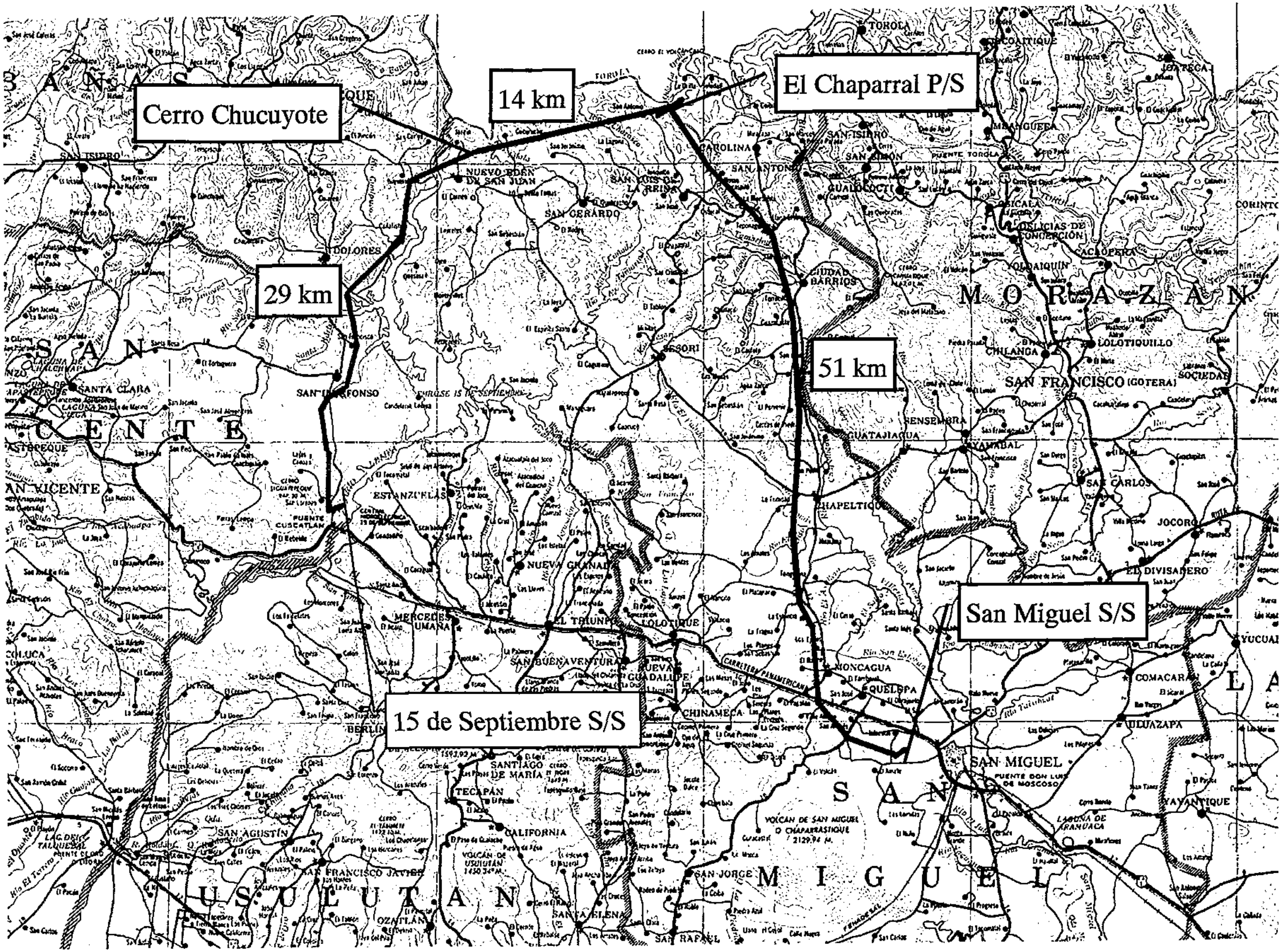


Fig.10.3 Alternatives of Transmission Line Route

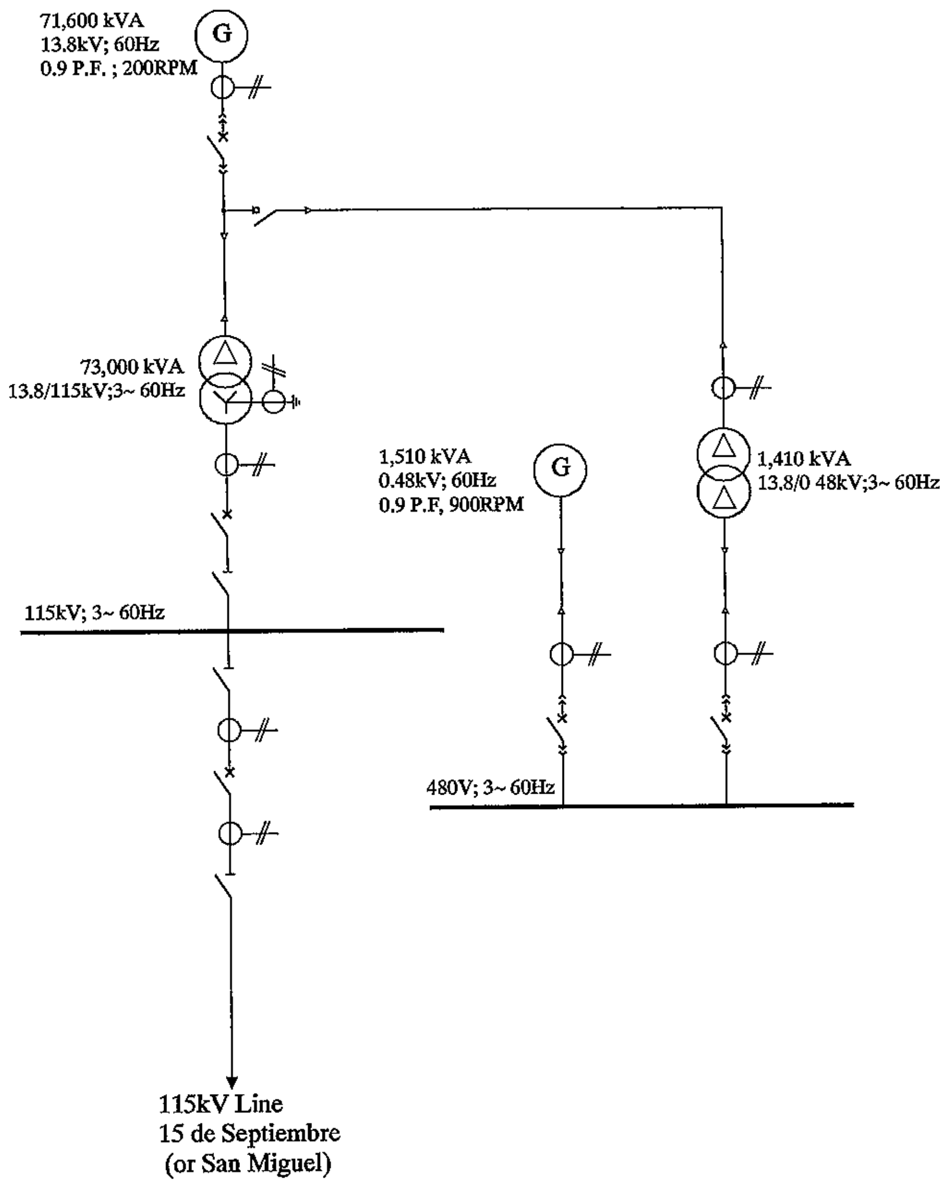


Fig. 10.4 Single Line Diagram of Single Bus System

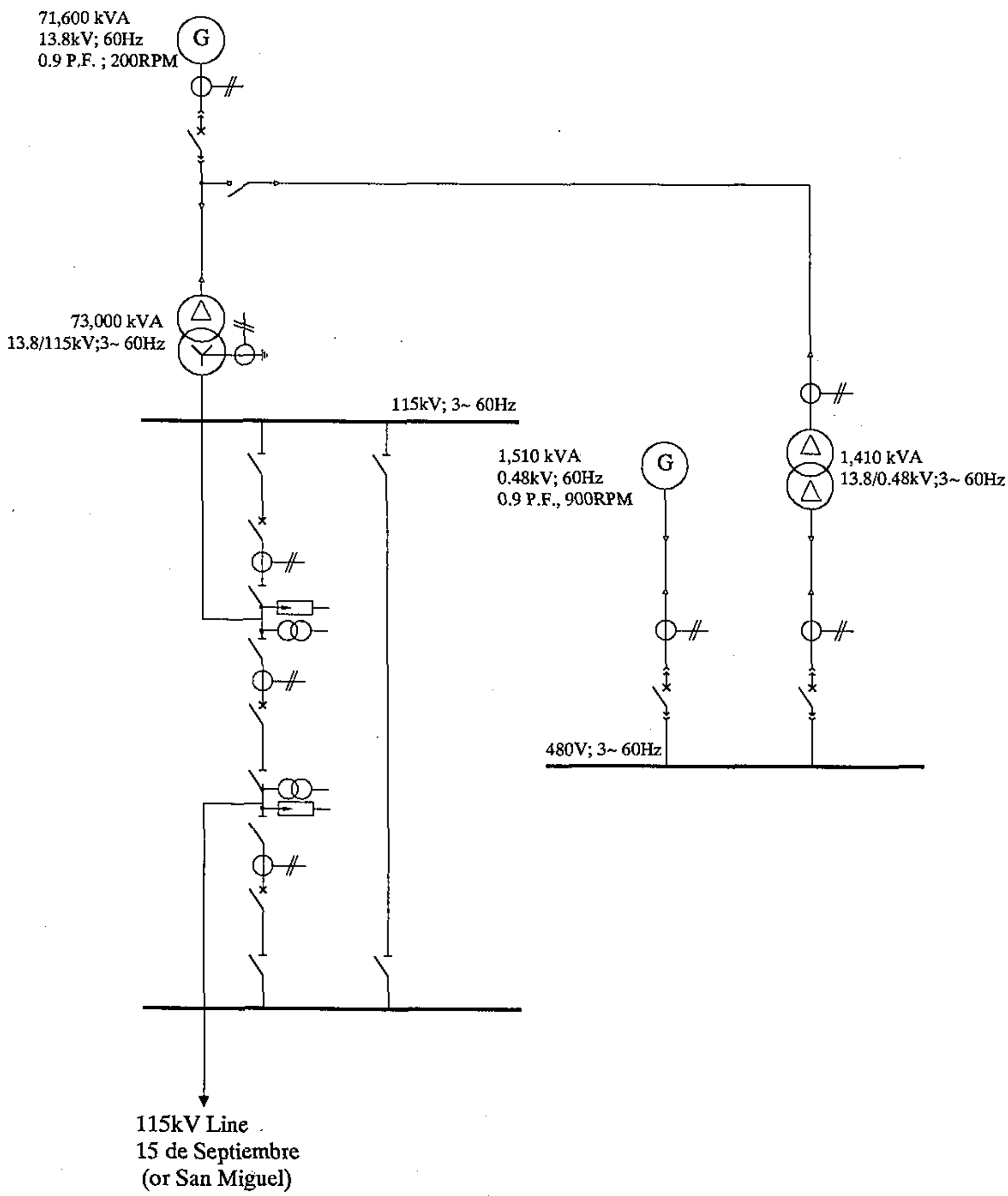
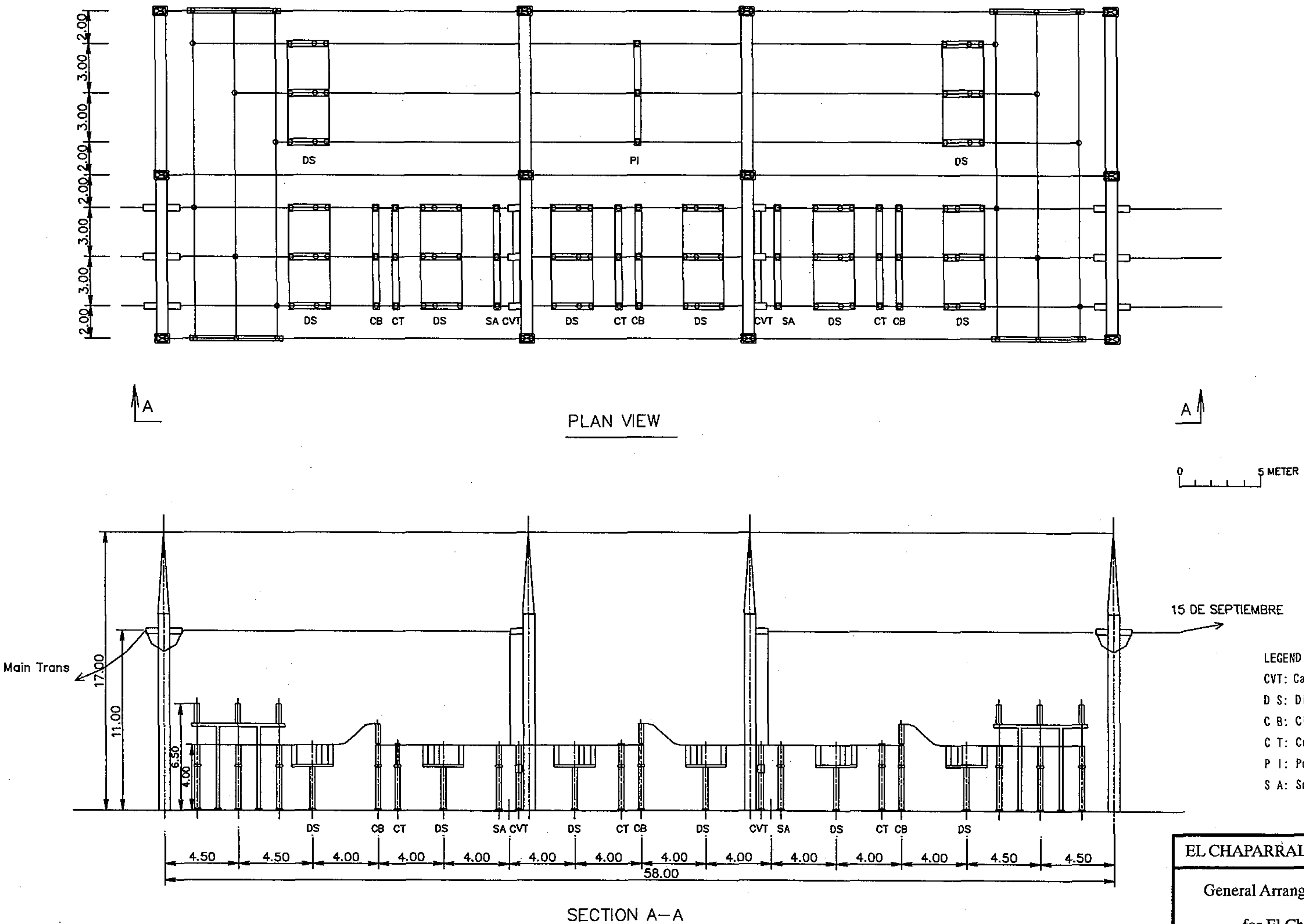


Fig. 10.5 Single Line Diagram of $1\frac{1}{2}$ CB Bus System

300 (30|2)



LEGEND

CVT: Capacitor Voltage Transformer

D S: Discnnector Switch

C B: Circuit Breaker

C T: Current Transformer

P I: Post Insulator

S A: Surge Arrester

EL CHAPARRAL HYDROPOWER PROJECT		
General Arrangement of Switching Station for El Chaparral Power Station		
Fig.10.6		

SHEET NO. 1 OF 1

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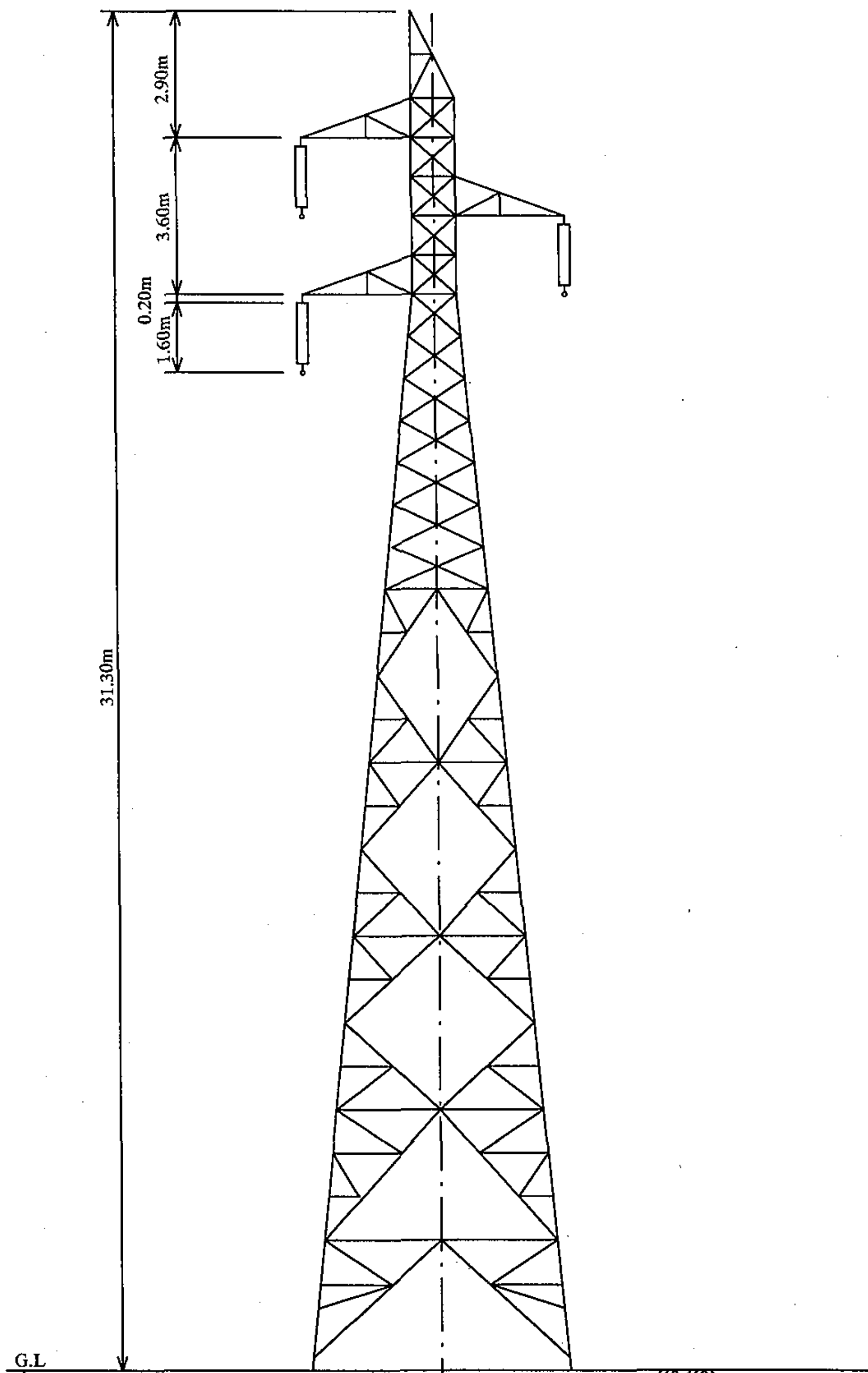

Fig. 10.7 Standard Suspension Tower for 115 kV Transmission Line

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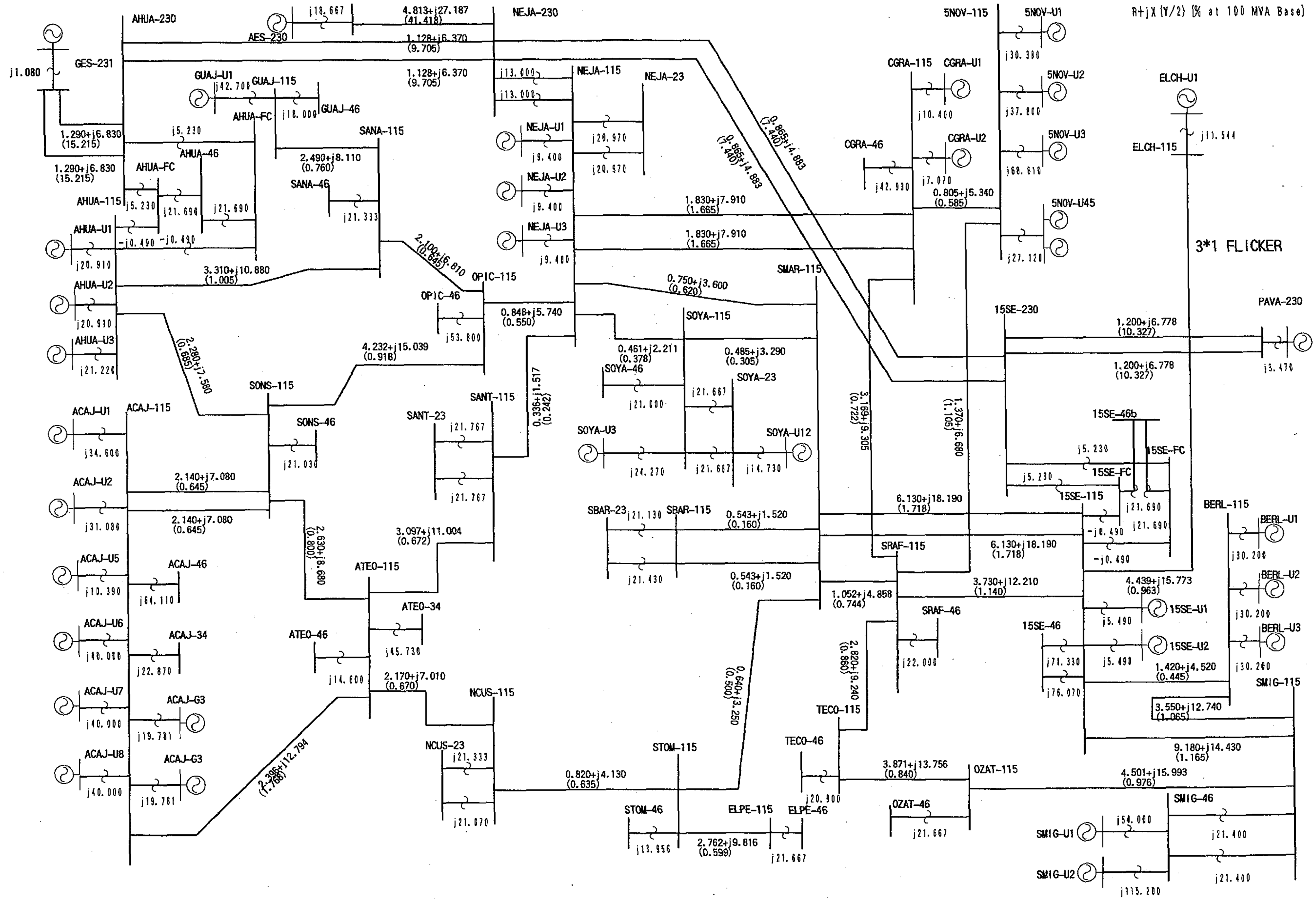

Fig. 10.8 Positive Sequence Impedance Map in 2010

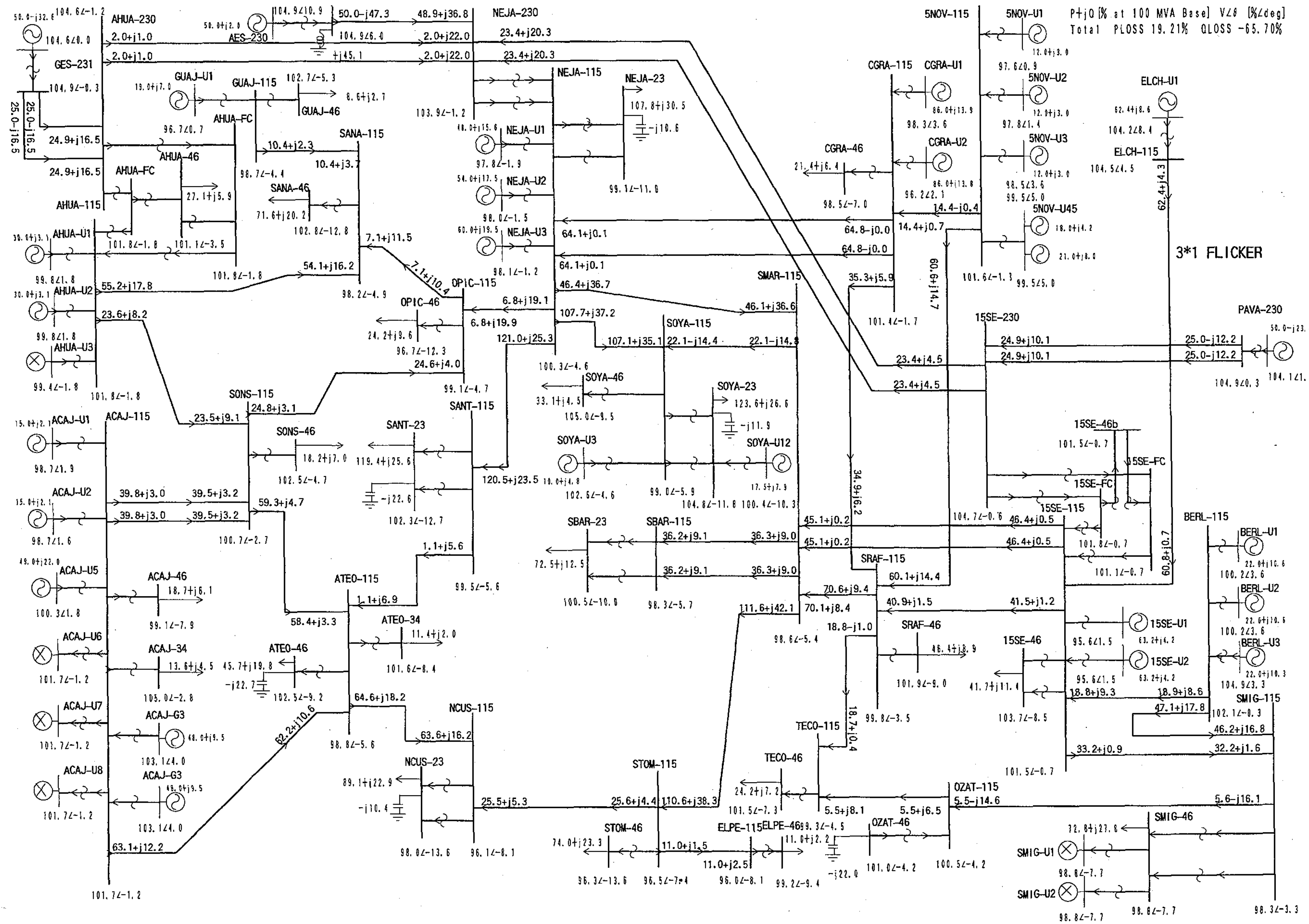

Fig. 10.9 Power Flow Calculation Result (2010 Peak)

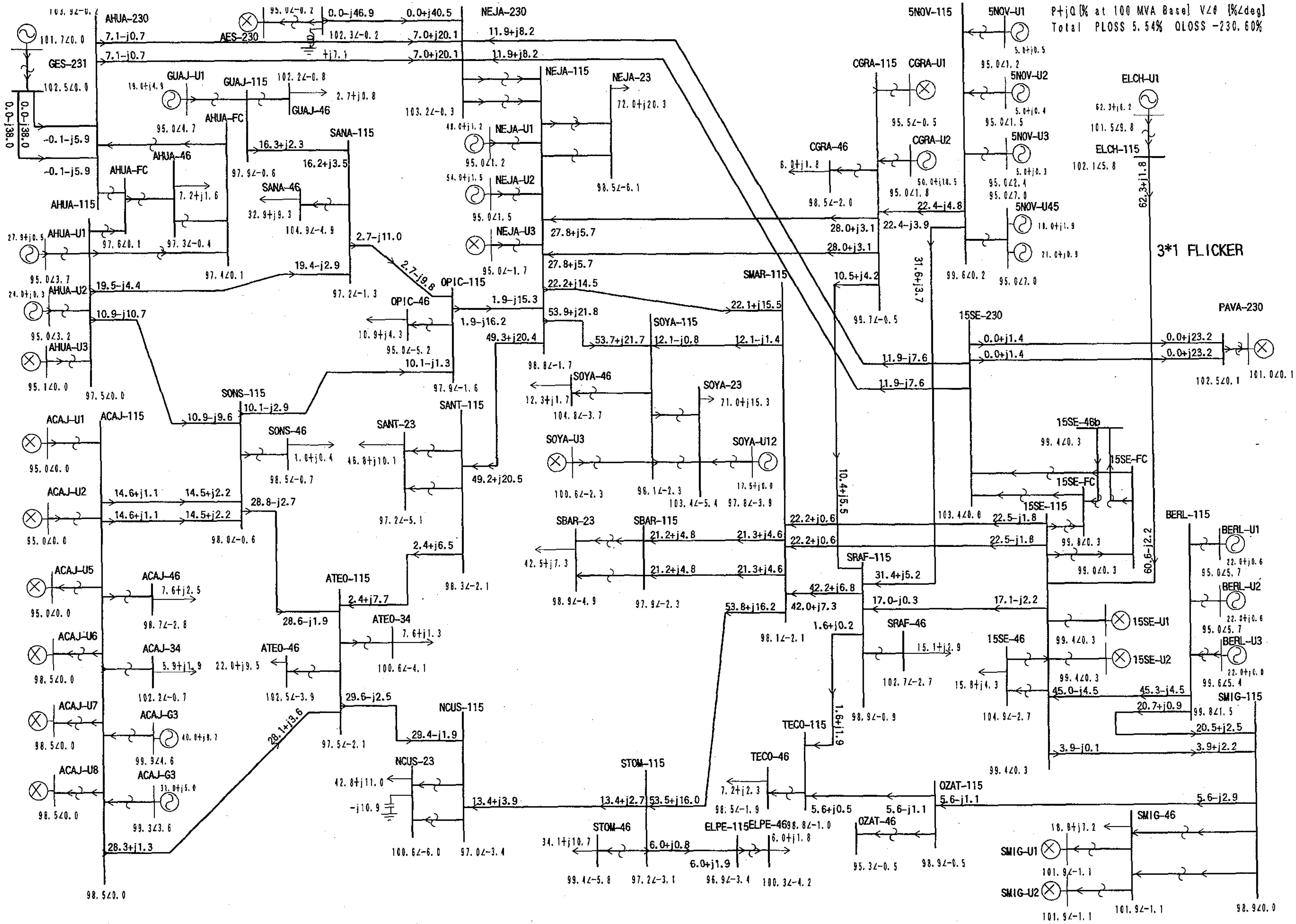

Fig. 10.10 Power Flow Calculation Result (2010 Off-peak)

		CODE	TERM	CASE	TYPE	MAX	MIN	INITIAL	FINAL
1	⊖	30042	ANG	ELCH-U1	G	72.37	7.45	35.22	35.09
6 2	△	21211	ANG	BERL-U1	G	32.95	27.73	30.64	30.30
5 3	+	21172	ANG	CGRA-U2	G	41.23	36.24	39.19	39.10
4 4	×	21371	ANG	NEJA-U1	G	29.71	26.67	28.71	28.62
3 5	◇	21161	ANG	AHUA-U1	G	53.62	51.12	52.72	52.65
2 6	↑	21136	ANG	ACAJ-G3	G	31.49	28.98	30.30	30.29

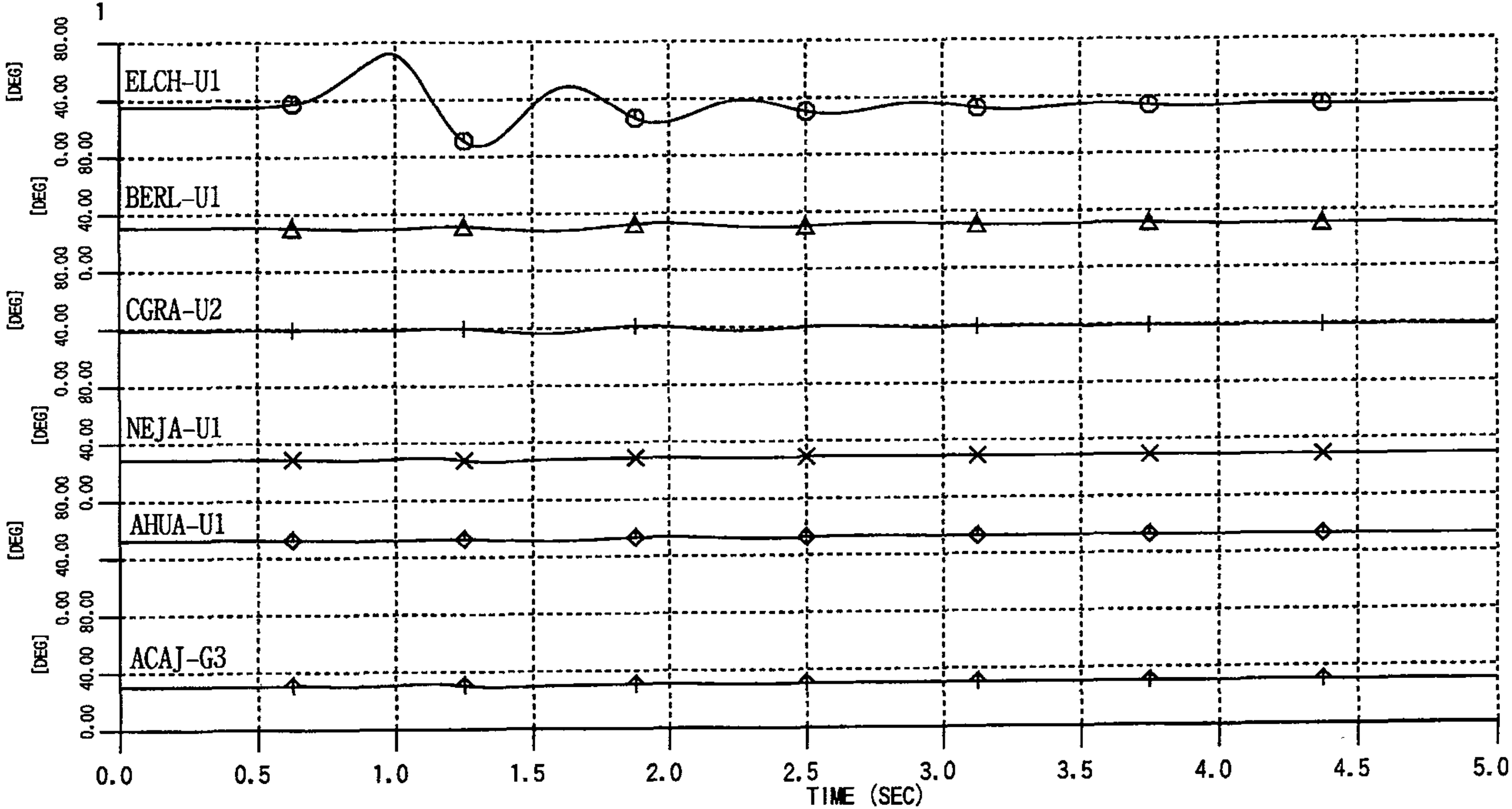

Fig. 10.11 Stability Study (1/4)

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		CODE	TERM	CASE	TYPE	MAX	MIN	INITIAL	FINAL
1	⊖	30042	ANG	ELCH-U1	G	83.17	3.59	35.22	38.15
6 2	△	21211	ANG	BERL-U1	G	63.07	-4.41	30.64	30.04
5 3	+	21172	ANG	CGRA-U2	G	68.94	3.34	39.19	38.57
4 4	×	21371	ANG	NEJA-U1	G	58.47	8.26	28.71	26.94
3 5	◇	21161	ANG	AHUA-U1	G	63.79	33.27	52.72	51.70
2 6	↑	21136	ANG	ACAJ-G3	G	54.66	15.01	30.30	30.08
1									

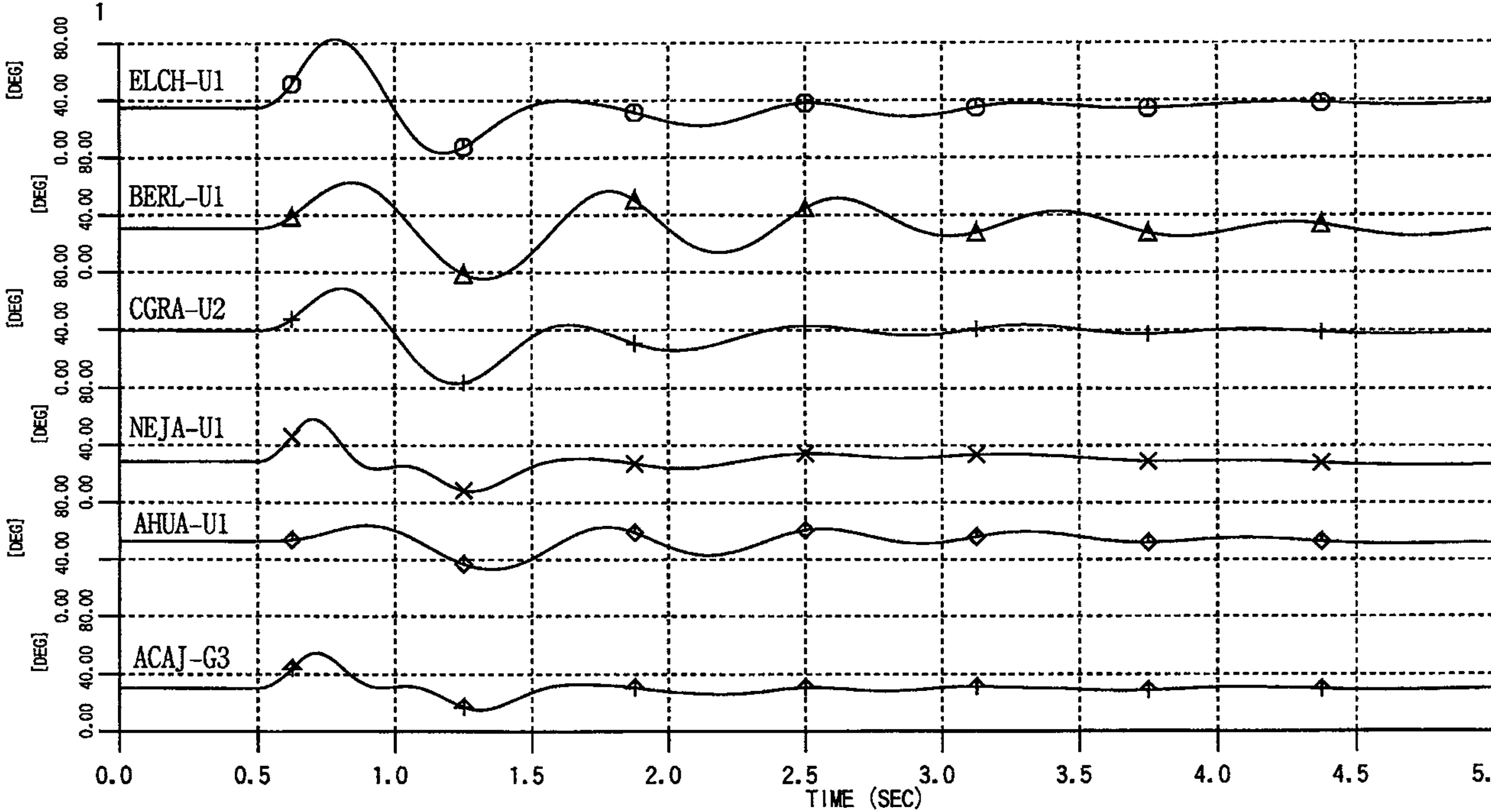

Fig. 10.12 Stability Study (2/4)

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	CODE	TERM	CASE	TYPE	MAX	MIN	INITIAL	FINAL
1	30042	ANG	ELCH-U1	G	77.79	8.25	38.32	38.40
2	21211	ANG	BERL-U1	G	44.84	38.16	42.27	42.15
3	21172	ANG	CGRA-U2	G	28.62	21.46	25.20	25.29
4	21371	ANG	NEJA-U1	G	39.63	35.07	38.49	38.64
5	21161	ANG	AHUA-U1	G	59.62	56.05	58.47	58.65
6	21136	ANG	ACAJ-G3	G	30.14	26.22	28.37	28.41

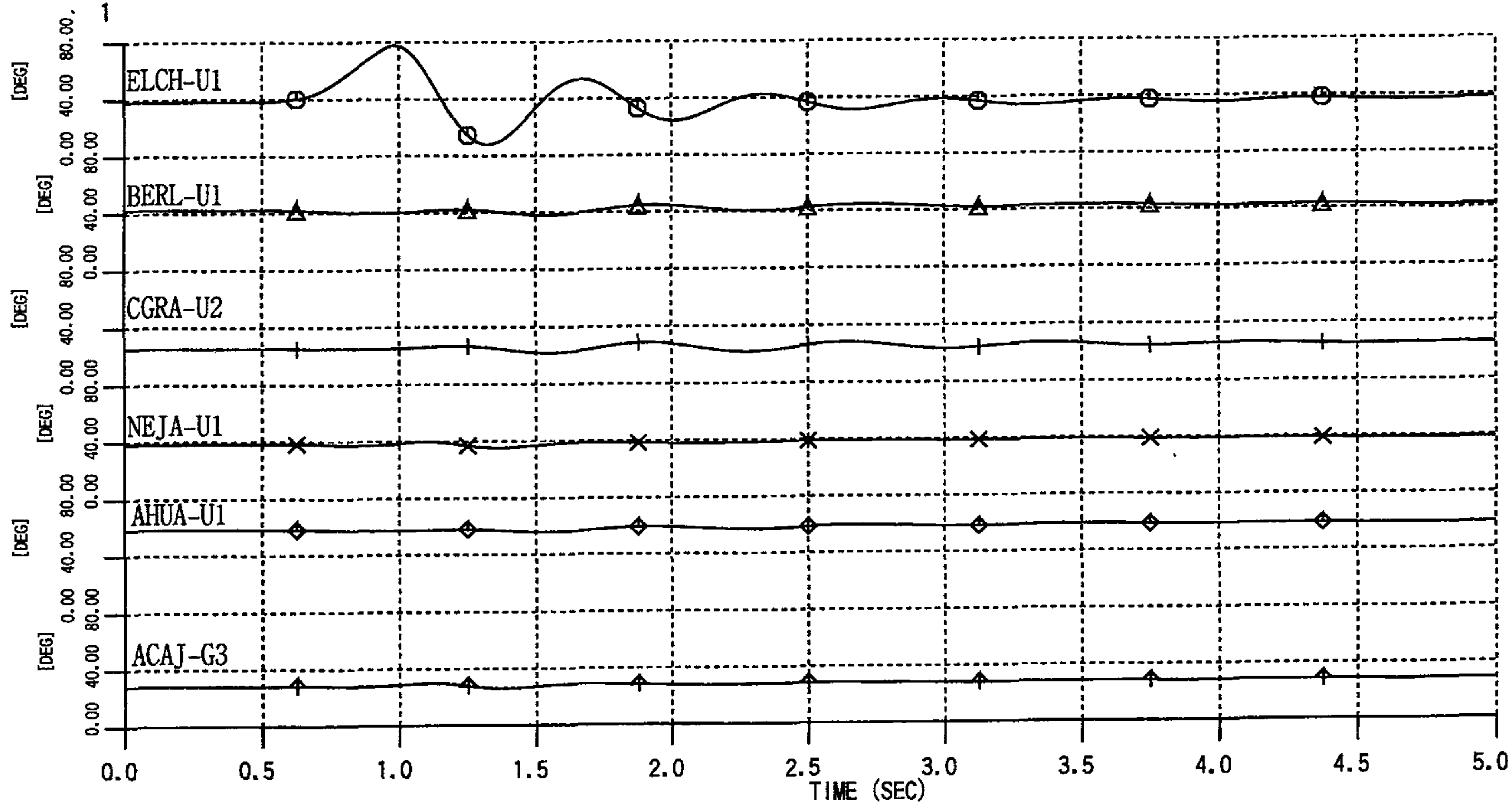

Fig. 10.13 Stability Study (3/4)

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		CODE	TERM	CASE	TYPE	MAX	MIN	INITIAL	FINAL
1	○	30042	ANG	ELCH-U1	G	85.47	3.33	38.32	38.33
2	△	21211	ANG	BERL-U1	G	72.34	10.82	42.27	43.50
3	+	21172	ANG	CGRA-U2	G	45.12	-3.18	25.20	24.46
4	×	21371	ANG	NEJA-U1	G	69.68	23.41	38.49	38.79
5	◇	21161	ANG	AHUA-U1	G	66.19	45.03	58.47	58.95
6	↑	21136	ANG	ACAJ-G3	G	50.50	22.45	28.37	27.33

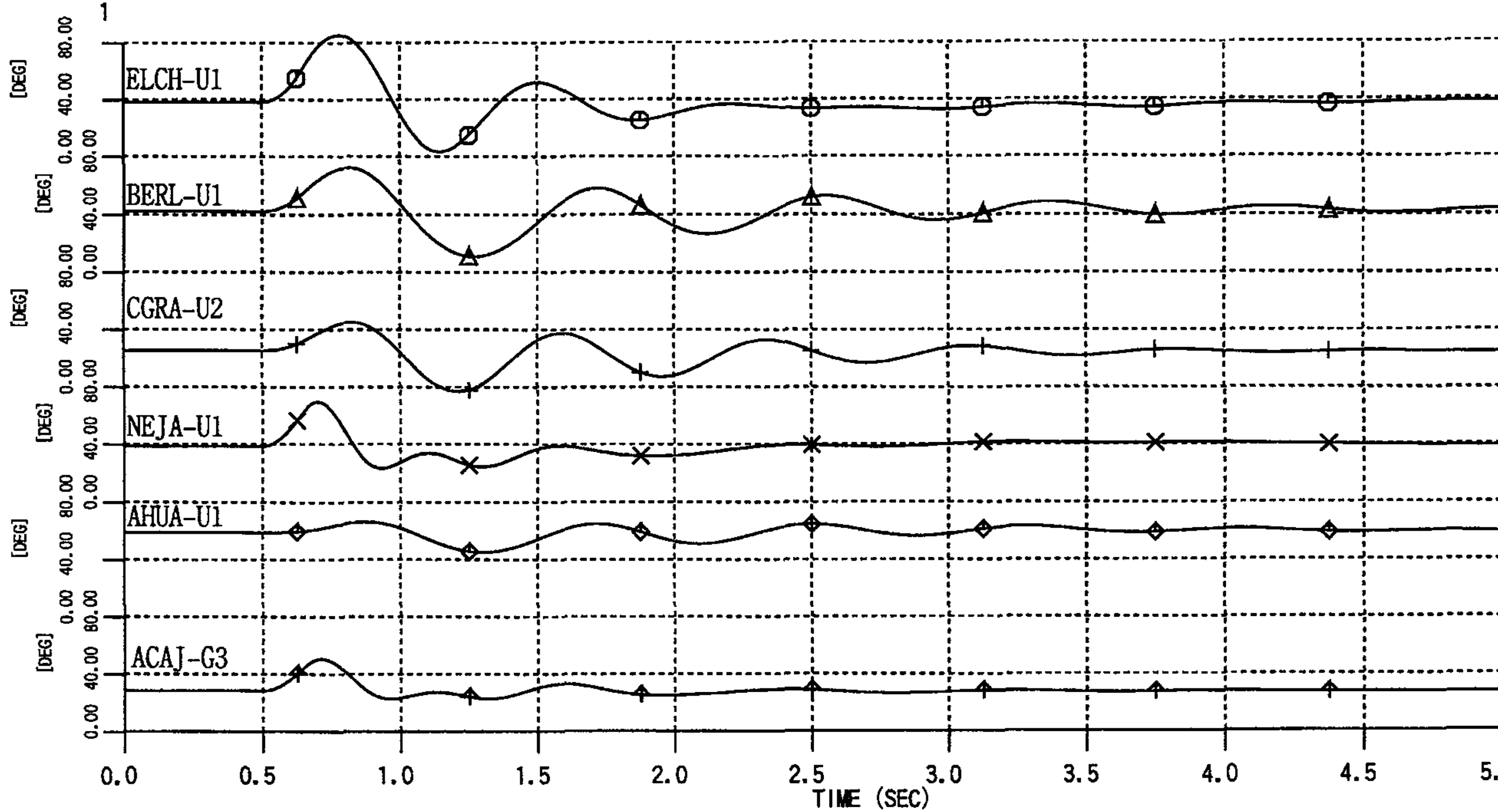

Fig. 10.14 Stability Study (4/4)

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11. FEASIBILITY STUDY

CONTENTS

11. FEASIBILITY DESIGN

11.1 Outline

The feasibility design works for the optimum development plan described in "9.3 Selection of Development Plan" will be outlined below.

The powerhouse under the development plan is located just downstream of dam and will make a daily peak operation during required peaking time by using effective reservoir capacity. The electric facilities are composed of one unit of turbine and generator and one unit of small sized turbine and generator, which uses the ecological minimum flow released from the dam. The electric power generated at the powerhouse will be transmitted to the existing 15 de Septiembre Substation. Table 11.1 shows the generation features of the development plan, and design drawings for each civil structure (including electric facilities) are shown in Fig. 11.3 ~ Fig. 11.10.

11.2 Dam and Auxiliary Structures

11.2.1 Dam Axis and Dam Type

Generally, the following items are taken into consideration for fixing the position of the dam axis.

- Desired topographical conditions call for a narrow valley and should allow the volume of the dam to be small.
- Foundation rock has enough strength for the loads from the dam body.
- Foundation rock should have the characteristics of impermeability and should facilitate water sealing measures.

In the Pre-Feasibility Study, the dam axis was set at the position about 360 m upstream from the conjunction point between the Torola river and the border of Honduras and El Salvador, where topographical condition is relatively narrow. In the Feasibility Study, a new dam axis was set at the position 60 m downstream from the previous one in view of the topographical shape of valley, the right side abutment and the layout of the diversion tunnel based on the 1/1,000 topographical map and the results of geological investigation of the subcontracted survey works.

At the selected site of the dam axis, the width of river is about 30m and the slope at the abutments on both banks is steep at lower elevations and modest at higher elevations. The width of the valley is very narrow, and there is no better axis site other than the selected point, because the valley width is gradually widened in the direction of upstream from the selected axis point.

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Generally, the dam type is selected from among various types of dams based on the natural conditions such as topography, geology and hydrology at the dam site, and the quantity and quality of construction materials for dam, as well as local environmental conditions.

The Concrete Gravity Dam, which was proposed as the type of the main dam for the project in the Pre-Feasibility Study, is reasonable and proper, in light of the technical conditions, which were confirmed in the investigations at the stage of Feasibility Study. The dam site is covered mainly with basalt, while no large-scale fault is observed there. Since the distribution of surface deposits at the dam site is generally thin except for about 30 m-thick weathered rocks at the right abutment, the foundation rock on the river bed has enough compressive and shearing strength to withstand the construction of an 80-to-90 m class concrete gravity dam.

The Rockfill Dam was also considered as an alternative for the main dam. However, this dam type is apparently inferior to the Concrete Gravity Dam type when the construction cost including care of the river and the spillway is considered. Specific reasons are provided below:

- Design flood discharge of the diversion tunnel to care for the river in the case of a Rockfill Dam (20-year probability flood: 3,796 m^3/s) is more than five times than that of a Concrete Gravity Dam (1-year probability flood: 728 m^3/s).
- The spillway chute on the right abutment, if constructed, requires massive excavation.

The Rockfill Dam, for which a large-scale quarry site for construction materials of the dam is needed, is not suitable for the project from the environmental point of view. As a result, the most suitable dam type is the Concrete Gravity Dam for the project.

11.2.2 Dam and its Auxiliary Structures

(1) Dam

1) Basic Shape

To study the basic dam shape, a stability analysis of the dam (please refer to Appendix 11.4 Dam Stability Analysis) was carried out using k (design seismic coefficient) = 0.15, which is estimated from the design seismic movement (please refer to Chapter 8 Earthquake). The dam slope gradient upstream is vertical with fillet and the downstream slope gradient is 1:0.8. Standard geotechnical parameters for the dam foundation for this analysis were estimated based on the parameters for similar foundation found in the existing literature.

The elevation at the dam crest is EL.214.5 m, determined by adding, to the normal high water level, the hydraulic freeboard such as the wave height at the time of wind and earthquakes and the height of the beam of the road at the dam crest. The maximum dam height is 87.5 m, as measured from the bedrock to the dam crest, and the dam concrete volume is approximately 370,000 m^3.

2) Concrete Aggregate

Required concrete aggregates for the dam will be provided from the river deposit located 2.0 km upstream of the dam axis. The available supply of the river deposit for concrete aggregates is estimated to be approximately 320,000 m^3. As for the quality of the concrete aggregates, the density in dry condition is relatively small and the ratio of absorption is high; therefore, they are not considered superior in terms of quality (refer to Chapter 7 Geology). However, they are usable as concrete aggregates based on the fact that no severe weather condition like frost damage need to be considered here. Consequently, the diversion of excavated materials from the dam and the powerhouse into concrete aggregates is also under review (Please refer to Chapter 12 Construction Plan and Construction Costs). Yet, it is still necessary to investigate the feasibility of the diversion including the deposit in the left bank terrace during the detailed design stage.

3) Grouting

The permeability at the dam foundation is generally high. A permeability test held at boring holes along the dam axis indicates the existence of zones showing approximately 20Lu. In particular, the high permeability zone at the right abutment reaches deep into the underground, and the permeability test results of boring hole CDB-5 at the saddle part show more than 20Lu at approximately 70 m below from the ground surface. Consequently, the ground water level is very low.

The foundation treatment is planned for the control of seepage from the reservoir in the dam foundation. Two kinds of grouting were planned. One is the curtain grouting that forms a vertical sealing zone in the dam foundation along the dam axis, and the other is the consolidation grouting designed to improve the relatively shallow zone of dam foundation horizontally for the purpose of seepage control of the contact zone of the dam foundation and of ensuring the effectiveness of curtain grouting.

a) Consolidation Grouting

As for the consolidation grouting, grouting boring holes are basically placed in a grid pattern at 5-meter intervals, while the standard boring depth is set at 5 m. The basic pattern for grouting holes is modified when needed with additional grouting boring holes depending on the crack condition of the actual dam foundation.

b) Curtain Grouting

Since the permeability of the dam foundation is relatively high and the underground water level at the right and left abutments is very low as explained above, it is necessary to make careful decision on the treatment area and the depth to be applied by curtain grouting.

For this reason, a two-dimensional water seepage analysis was executed, and the treatment area and the depth were determined. As a result of the analysis, the sealing effect by curtain grouting was confirmed. It was also confirmed that the treatment depth of H/2 (H: dam height) is adequate for the parts of the dam foundation where the path length is short and the hydro potential gradient is large. A schematic drawing of curtain grouting is shown in Fig. 11.6.

The water leakage at the right abutment, which is a cause of concern because of its high permeability, was found to be too negligible an amount to affect the power generation plan of the project, since its hydraulic gradient was small and the leakage amount was half or less than that at the dam foundation.

Because the seepage flow velocity remains at 10-4 cm/s order and is sufficiently smaller than the critical velocity, there is no concern over piping.

(2) Spillway

The type of the spillway type is the center overflow type with the gates and the direction of spillway are designed to coincide with the center of downstream river. There are two methods to determine the value of design flood discharge. One of them uses the Probable Maximum Flood (PMF: 6,484 m^3/s) for design flood discharge. The other is an adoption of a value smaller than the PMF, to factor in the surcharge effect. In the latter case, the height of the dam shall be higher because the setting up of a surcharge water level is required for the dam operation.

The design flood discharge for the design of a spillway was determined to be 6,484 m^3/s without setting up a surcharge water level. The topographical features of the project, characterized by a saddle part at the right prolongation of the dam axis and a deep valley bordered on Honduras at the right abutment of the upstream reservoir, sets limits on the determination of the high water level. It should also be noted that a higher water level results in more economic benefits.

On this account, five radial gates of 13.2 m in width and 15.2 m in height are installed on the crest of the spillway to discharge the design flood safely in the condition of a high water level. The total width of the spillway is 82.0 m. However, since the width of the river downstream is narrower, a guide wall is installed in order to conform the spillway width to the width of river.

Energy dissipation of the discharged water is to be achieved by providing a bucket at the end of the spillway chute to generate the downstream hydraulic jump.

(3) Care of River

The temporary river closing and the switching of river flows would be made by creating upstream and downstream cofferdams and bypass tunnels (2 lines, Horseshoe type D=7.8m) prior to the launch of dam and powerhouse foundation excavation works. The design discharge for the care of the river is taken as 728 m^3/s (1 year probability discharge). For this discharge amount, an optimum height of the upstream cofferdam and the optimum inside height of the bypass tunnel were examined. The optimum inside height of the tunnel can be obtained by minimizing the total of the upstream cofferdam and bypass tunnel construction costs. The following table shows the results. The combination of the cofferdam height H = 18.0m and the bypass tunnel inside height H = 8.0 m was found to be most economical.

Bypass tunnels will be lined with concrete for the entire length of the invert as well as the 40-meter segments at the entrance and the outlet. Other parts will be lined with shotcrete.

Table 11.2 Diversion Tunnel Inner Height Comparison

Dimension				Remarks
Cofferdam Height (m)	30	18	9	
Diversion Tunnel Inner Height (m)	7	8	10	
Construction Cost	Civil works quantity			Unit price
(Upstream Cofferdam)				
Common Excavation (m^3)	3,800	3,800	3,800	4 US$/$m^3$
Rock Excavation (m^3)	1,600	1,600	1,600	10 US$/$m^3$
Cofferdam Concrete (RCC : m^3)	39,800	14,400	4,000	55 US$/$m^3$
Others (1 ls)	40	40	40	10^3 US$
(Downstream Cofferdam)				
Common Excavation (m^3)	3,500	3,500	3,500	4 US$/$m^3$
Rock Excavation (m^3)	1,500	1,500	1,500	10 US$/$m^3$
Cofferdam Embankment (m^3)	3,000	3,000	3,000	7 US$/$m^3$
Others (1 ls)	40	40	40	10^3 US$
(Diversion Tunnel)				
Common Excavation (m^3)	8,200	8,200	8,200	4 US$/$m^3$
Tunnel Excavation (m^3)	18,800	24,000	37,600	150 US$/$m^3$
Tunnel Lining Concrete (m^3)	1,900	2,100	3,200	230 US$/$m^3$
Reinforced Bar (t)	54	60	91	1,500 US$/t
Others (25%)	843	1,051	1,636	10^3 US$
Total Cost	6,564	6,210	8,563	10^3 US$

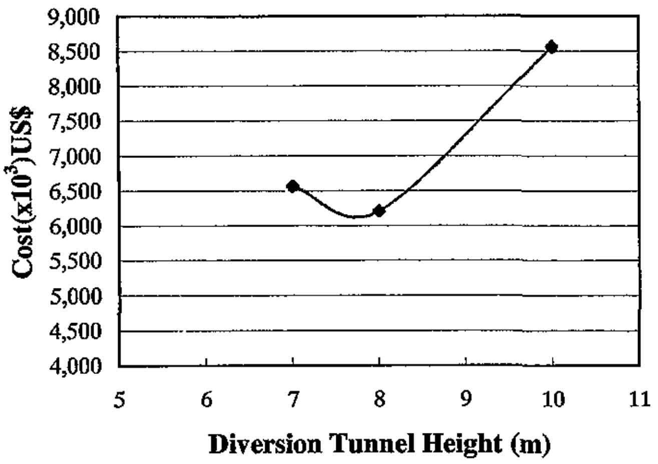


Fig. 11.1 Diversion Tunnel Inner Height

(4) Discharge Facilities

Discharge Facilities will be installed for the downstream discharge for the initial stage and a discharge in an emergency. Discharge facilities include a discharge pipe, a jet flow gate and a high pressure slide gate. A gate chamber will be installed in the dam body. The ecological minimum flow (2.0 m^3/s) will be diverted from the end of the penstock and discharged from a small turbine.

11.3 Waterway and Powerhouse

11.3.1 Intake and Penstock

(1) Intake

A power intake will be constructed at the left abutment just upstream of the dam axis. The shape of the intake is the bellmouth type. Its structure was determined based on the condition that the flow velocity at the screen would be 1m/s at the maximum discharge. The power intake is equipped with a screen at the entrance and an intake gate (roller gate) for closing.

(2) Penstock

A penstock is installed to connect the power inlet and the turbine. The penstock is installed so that it runs horizontally through the dam body from the inlet, from where it runs as an inclined shaft down to the elevation of the turbine center, eventually leading horizontally to the turbine. The length of the penstock is 144.5 m. A small-diameter penstock (D = 0.7 m) is branched at an area just upstream of the inlet valve, connecting the small turbine. The penstock's inside diameter was derived so that the total of the annual expenses obtained from the construction costs and the annual benefit loss obtained from the head loss can be minimized. The following table shows the results. The optimum diameter was found to be 5.0 m.

Table 11.3 Penstock Optimum Diameter

($Q=100\ m^3/s$)

D(m)	4.8	5.0	5.2
V (m/s)	5.5	5.1	4.7
dP = 9.8 × ηt × ηg × Qmax × hl (kW)	3	2	2
dE = 9.8 × ηt × ηgx Qmax × hl × T (kWh)	10,863	8,737	7,088
B1 = dp × 171 US$/kW (US$)	522	420	341
B2 = dE × 0.046 US$/kWh (US$)	500	402	326
B = B1 + B2 (US$)	1,022	822	667
Construction cost for Penstock (US$)	17,826	19,343	20,921
C Annual Cost (US$)	1,943	2,108	2,280
B+C (US$)	2,965	2,930	2,947

dp :	Decrease of dependable capacity for head loss (kW)
dE :	Decrease of energy for head loss (kWh)
171 US$/kW:	kW unit price of alternative thermal power plant
0.046 US$/kWh :	kWh unit price of alternative thermal power plant
B :	Annual loss of benefit for head loss (per unit length of penstock)
C :	Annual cost (per unit length of penstock)

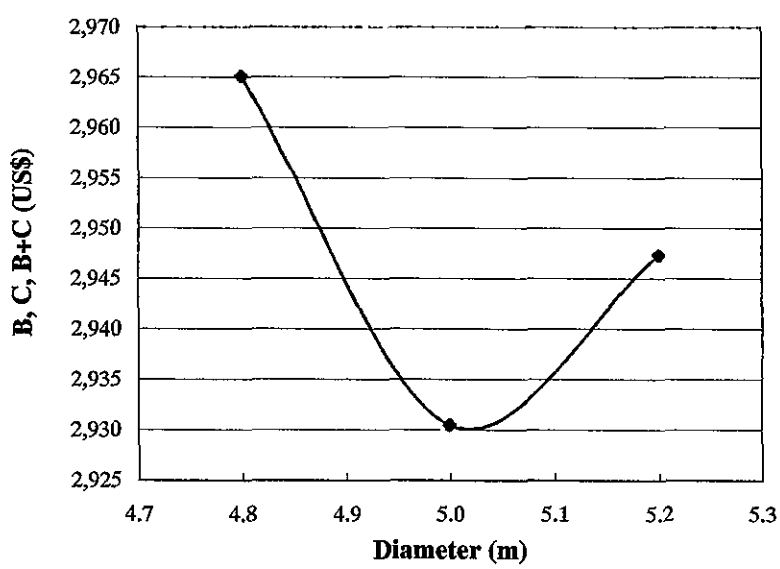


Fig. 11.2 Penstock Optimum Diameter

11.3.2 Powerhouse and Outlet

(1) Powerhouse and Outlet

The proposed powerhouse will be located in the left abutment for easy access. It also offers comparatively sound geological conditions. Although the vertical shaft type was recommended in the pre-F/S, the powerhouse is of the open excavation type in consideration of workability and economical efficiency. Consequently, the tailrace tunnel required for the vertical type shaft is eliminated. Fig. 11.11 shows the layouts of the two types of powerhouse, and the following table, comparison of construction costs.

The main transformer will be constructed outside at the mountainside adjacent to the powerhouse. The outlet will be constructed as an integral part of the powerhouse, and two slide gates will be installed there.

Table 11.4 Comparison of Power House Construction Cost

Item	Open Excavation Type	Vertical Shaft Type	Remarks
Construction Cost	Quantity		Unit Price
Civil Works			
(Penstock)			
Incline Shaft Excavation (m^3)	2,400	1,600	200 US$/$m^3$
Filling Concrete (m^3)	800	600	190 US$/$m^3$
Structural Concrete (m^3)	500	500	130 US$/$m^3$
Reinforced Bar (t)	20	20	1,500 US$/t
Others (10%)	72,700	52,900	US$
(Power House)			
Common Excavation (m^3)	35,900	14,000	4 US$/$m^3$
Rock Excavation (m^3)	143,500	56,000	10 US$/$m^3$
Shaft Excavation (m^3)	—	25,700	200 US$/$m^3$
Shaft Lining Concrete (m^3)	—	4,800	230 US$/$m^3$
Structural Concrete (m^3)	11,700	9,800	130 US$/$m^3$
Reinforced Bar (t)	740	920	1,500 US$/t
Others (20%)	841,920	1,902,800	US$
(Control Building)			
Control Building (m^3)	12,300	17,400	40 US$/$m^3$
(Outlet / Tailrace Tunnel)			
Common Excavation (m^3)	4,900	4,800	4 US$/$m^3$
Rock Excavation (m^3)	11,300	11,200	10 US$/$m^3$
Tunnel Excavation (m^3)	—	5,600	150 US$/$m^3$

Item	Open Excavation Type	Vertical Shaft Type	Remarks
Tunnel Lining Concrete (m^3)	—	2,000	230 US$/$m^3$
Reinforced Bar (t)	—	120	1,500 US$/t
Others (20%)	26,520	322,240	US$
Hydromechanical Equipment			
Penstock Tube (t)	350	290	5,000 US$/t
Total	8,252,340	16,078,140	US$

(2) Switchyard

The site for the switchyard is located in the gently sloped area on the left bank in an area just downstream of the dam. It will be excavated down to EL.175.0 m .

11.4 Electrical and Mechanical Equipment

The El Chaparral hydropower project requires the following main equipment for its main turbine.

(1) Hydraulic Turbine

(2) Generator

(3) Main Transformer

(4) Switchyard Equipment

For a sub turbine, Items (1) and (2) above will be provided for its own use, while it will share the use of the station service transformer for the station service circuits.

11.4.1 General

The El Chaparral Power Station is a directly under dam type, diurnal poundage facility to enable the variations in power requirement at the 3-to-4 hours peak power using the maximum net head of 78.05 m to produce the power of 64.4 MW from the main machine and 1.3 MW from the sub turbine-generator. The sub-type turbine is employed to maintain the river flow for the downstream of the dam. The semi-under ground powerhouse contains one vertical shaft turbine-generator with 65.9 MW (71.6 MVA of generator capacity at 0.9 power factor lagging) for the main machine. The main transformer and the switchyard for a transmission line will be installed outdoors. Additionally, a horizontal-type sub Francis turbine generator of 1.4 MW (1.5 MVA of generator capacity at 0.9 power factor lagging) will be provided in the same power station with the main machine.

The design criteria for the electro-mechanical equipment were determined by computer software "HDWiz" developed by J-Power (EPDC) based on the data of existing power stations around the world.

11.4.2 Unit Capacity and Number of Units

It has been identified that the appropriate unit size of a turbine-generator should be determined in relation to the influence of the power system, the year of the development launch and the limitations on transportation. It is a general practice to set a unit capacity as large as possible for the entire project to achieve economies of scale. However, the sub-type turbine be installed for the supporting discharge of river flow responsibility.

The design for the unit capacity is decided based on the points listed below:

a) Weight and dimension limits for transportation route

b) Level of current manufacturing technology, taking account of manufacturing cost reductions through competition among manufacturers

c) Reliability, flexibility and maintenance for plant operation

d) The ratio of unit size into the power system to the capacity of power system and its stability based on the power system study conducted in El Salvador

e) Construction cost

f) Energy cost

With respect to a) above, the above site survey revealed that the weight limitation of the roads is 100 metric tons, and dimensions need to conform to a width of 3 m, a height of 3.8 m for the mountain area. The trailer must be able to travel through the roadway with 180° hairpin bends with an apex radius 6 m.

In the following detailed design stage, a new investigation will be needed to determine whether to reinforce the existing bridges or to replace them with new ones to be in line with El Salvador's road plan, if necessary.

The heaviest equipment is the main transformer, which weighs approx. 70 metric tons without oil. This class of transformers (73 MVA, outdoor, OFAF: forced oil, air cooled type) can be transported in a unit composed of a 3-phase type transformer. No problem is expected for the transportation of the main turbine-generator, its auxiliary equipment, etc. whether the number of units to be transported is one or two.

As for b) above, all major manufacturers in the world are capable of manufacturing this capacity class in terms of manufacturing technology.

For c) above, the proposal calling for two units is superior from the perspective of reliability and flexibility for maintenance and operation. However, in terms of the unit output, one unit is sufficient for El Salvador's power system for operational and maintenance points of view, as evidenced in the power system analysis. With the two-unit plan, on the other hand, the power source for station service should experience an improvement in reliability since the sub turbine-generator to be installed uses an ecological minimum flow.

Regarding d), The employment of only one unit with a unit capacity of 70 MW, which is about 6% of the maximum power estimated at 1,120 MW at the time of commercial operation in 2010, will be acceptable in El Salvador's power system based on the power system analysis and calculation.

As for Item e), adoption of two units plan would increase by about 20% of the construction cost compared with one unit plan, that yields economies of scale is more advantageous, which are a dabble capacity of two units. Other hand, concerning civil design, the main penstock will have a single line which connect to main inlet valve. If it will be designed two units plan for main machine, the penstock will be used commonly but it will be necessary to add a branch, draft tubes and draft gates. And then, two units plan will increase a space of power station and a volume of foundation excavation. Therefore, a design of one unit plan will be profitable. Fig. 11.12 shows the layout of both plans, for comparison, and the following table, comparison of construction costs.

As for Item f), a generating cost of both one unit and two units plans are not difference because an annual net energy is same mostly due to use a same volume of the reservoir, though the stop rate for power station of the both plans is difference. Other hand, the operation & maintenance cost of two unit plans is higher than one unit. A result of them, the generating cost of one unit plan is higher than two units will be profitable and lower about 7 % than two units.

Table 11.5 Powerhouse Number of Unit Comparison

Item	1 Unit (1 × 64.4MW)	2 Units (2 × 32.2MW)
Construction Cost (US$)		
Preparatory Works	4,471,800	4,471,800
Civil Works (Care of River)	6,210,450	6,210,450
Civil Works (Dam)	44,048,400	44,048,400
Civil Works (Water Way)	1,070,300	1,157,200
Civil Works (Power house)	5,784,960	7,839,440
Hydromechanical Equipment	11,720,000	12,040,000
Electric Equipment	17,786,000	21,127,000
Transmission Equipment	2,597,000	2,597,000

Item	1 Unit (1 x 64.4MW)	2 Units (2 x 32.2MW)
Environmental Cost	7,420,000	7,420,000
Land Acquisition & Resettlement	9,823,700	9,823,700
Total Direct Cost	110,932,610	116,734,990
Contingency	7,763,750	11,951,770
Administration & Engineering Cost	16,639,900	17,510,250
Total Indirect Cost	24,403,650	29,462,020
Total Project Cost	135,336,260	146,197,010
Annual Energy (GWh)	233.2	233.2
Effective Annual Energy (GWh)	228.1	228.1
station service rate	0.3%	0.3%
transmission line loss	1.9%	1.9%
Capital recovery factor		
civil facility	10.09%	10.09%
hydromechanical equipment	10.37%	10.37%
electric equipment	10.37%	10.37%
Operation & Maintenance Cost		
civil facility	0.5%	0.5%
hydromechanical equipment	1.5%	1.5%
electric equipment	1.5%	2.25%
Annual Cost Factor	10.9%*2	11.0%*3
Energy Cost (US$/kWh)	0.065	0.070

*1: % is a value for project cost

*2: annual cost factor = (10.09+0.5)×75%+(10.37+1.5)×15%+(10.37+1.5)×10%=10.9%

*3: annual cost factor = (10.09+0.5)×75%+(10.37+1.5)×15%+(10.37+2.25)×10%=11.0%

From the above-mentioned examination results, it has been decided that the one-unit plan is selected for this project. For the sub-turbine using the ecological minimum flow, a small penstock is branched from the main penstock before the main inlet valve.

11.4.3 Hydraulic Turbine and Generator

(1) Hydraulic Turbine

1) Turbine Output

The turbine output will be designed for a full-gate output of not less than 65.9 MW operating under a rated effective head of 72.8 m. For more than the rated effective head, one turbine runs at a constant output.

Output is determined by:

$$Pt = 9.8 \times Hn \times Qt \times \eta t$$
$$= 9.8 \times 72.8 \times 100 \times 0.923$$
$$\fallingdotseq 65{,}900 \text{ kW}$$

where:

	Pt:	Rated output (kW)
	Hn:	Rated effective head (m)
	Qt:	Rated water discharge per unit (m^3/s)
	ηt:	Turbine efficiency (%)

2) Turbine type

The turbine will be of the vertical-shaft, single-runner Francis type with steel spiral case and elbow type draft tube according to our practice.

3) Materials Used in the Runner and Spares

Specifications for the Francis runner components should call for 13-4 Cr. Ni stainless steel. In addition, soft or hard coating should be applied on the runner surfaces and wear ring, wicket gates, etc. of the Francis type turbine. The coating method shall be specified during the detailed design stage.

4) Turbine Setting Level

The centerline of the turbine runner, i.e., the draft head (Hs) below the minimum tail water level of 133.00 m, will be set at El. 130.00 m above mean sea level. Hs (- 3 m) was obtained by computer calculation. This setting provides a reasonable margin above the critical sigma to provide a conservative plant cavitation coefficient. This coefficient is related to the optimum turbine specific speed (Ns).

5) Effective Head

The effective head is determined by the friction head loss, because, for low flow, the head loss is significantly reduced, thus increasing the net head. Estimated friction head loss by computer calculation is to be 1.2 m, then effective head will be 74.0 – 1.2 m = 72.8 m.

6) Principal Runner Size

The runner size needs to be designed for the purposes of understanding the principal dimension of the turbine and plant layout for computer calculation. According to analysis results, the dimension of the runner is approximately 2.7 m in diameter at the entrance of the runnerand it weighs about 26 metric tons. However, actual turbine dimensions will depend on the proposal received from the manufacturer of turbine equipment.

7) Revolving Speeds and Runaway Speeds

The specific speed of the Francis type turbine, generally, is between Ns: 70 and 300 m-kW. We have derived a speed of Ns: 241 m-kW in relation to an "effective head-specific speed curve" by computer calculation and our practice. A turbine rated speed of 200 rpm was then obtained as the rate corresponding to the specific speed of Ns: 241 m-kW units at the rated effective head of 72.8 m.

(For reference, the runaway speeds to be specified will be less than 1.94 times of the rated speed.)

8) Turbine Aeration System

Whether the pipe system for aerating the turbine runner, draft tube, etc. is required will be determined later during the detailed study.

9) Penstock and Inlet Valves for Turbine

There is one penstock in the civil design. The penstock is connected to the main inlet valve (through-flow valve) with a diameter of approximately 4.3 m. The branch pipe for the sub-turbine is connected to the iron tube of the main inlet valve.

(2) Generator

The generator will be of the vertical shaft, synchronous type, with a rated continuous output of 71.6 MVA, three-phases, 0.9 lagging power factor. The generator stator and rotor windings will be provided with epoxy insulation of Class F type. The generator ventilation will be of the enclosed hood, air cooled type with a rim-duct fan system.

The required characteristics of the generator are as follows.

Direction of rotation: Clockwise view from above

Rated speed:	200 rpm
Rated out put:	71.6 MVA
Rated current:	3,000 A
Power factor:	0.9 lag
Rated voltage:	13.8 kV
Rated frequency:	60 Hz

Generator Capacity:

$$Pg = Pt \times \eta g / p.f \text{ (kVA)}$$
$$= 65{,}900 \times 0.977 / 0.9$$
$$\fallingdotseq 71{,}600 \text{ kVA}$$

where: Pt : Rated out put of turbine (kW)

ηg: Generator efficiency (%)

p.f: Power factor (%)

(3) Sub Turbine-Generator

The sub turbine-generator is a horizontal Francis turbine, and a small size penstock will be branched from the main penstock before the main inlet valve, connecting the inlet valve for the sub-turbine.

1) Turbine Specifications

The turbine output will be designed for a full-gate output of not less than 1.42 MW operating at a fixed rated ecological minimum flow 2 (m^3/s) and maximum effective head 78.13 m.

Out put is determined Pt $= 9.8 \times Hh \times Qt \times \eta t$

$= 9.8 \times 78.13 \times 2.0 \times 0.925$

$\fallingdotseq$ 1,420 kW

where, Pt : Rated out put (kW)

Hh: Maximum effective head (m)

Qt : Rated water discharge per unit (m^3/s)

ηt : Turbine efficiency (%)

2) Generator

The generator is of the horizontal shaft, synchronous type with a rated continuous output of 1.51 MVA, three-phases, 0.9 lagging power factor. The generator stator and rotor windings will be provided with epoxy insulation of Class F type. The generator ventilation will be of the free air cooled type with the rim-duct fan system.

The required characteristics of the generator are as follows.

Direction of rotation: Clockwise view from above

Rated speed:	900 rpm
Rated out put:	1.51 MVA
Rated current:	1,820 A
Power factor:	0.9 lag
Rated voltage:	0.48 kV
Rated frequency:	60 Hz

Generator capacity: $Pg = Pt \times \eta g / p.f$ (kVA)

$= 1{,}420 \times 0.958 / 0.9$

$\fallingdotseq 1{,}510$ kVA

Where: Pt: Rated out put of turbine (kW)

ηg: Generator efficiency (%)

p.f : Power factor (%)

11.4.4 Main Transformer

One power transformer unit will be installed outdoors near the downstream of the powerhouse. The power transformer type will be designed as three-phases type to consider the transportation limitation regarding the weight, as well as efficiency and installed spaces, etc. The existing and proposed roads to the project site allow a maximum load of 100 tons (inclusive of weight of the trailer). In other words, the three-phase type used for this project meets the transportation limitations.

The required characteristics of the power transformer are as follows:

Rated capacity: 73 MVA

Rated voltage:	primary	13.8 kV
	Secondary	115 kV
Rated current:	primary	3,063 A
	Secondary	368 A

Rated frequency: 60 Hz

Cooling system: outdoor, OFAF (forced oil, air cooled type)

The power transmission line of 115 kV, ACSR type from a secondary terminal of the main transformer will be connected to the outdoor switchyard, which should be, installed about 100 m away from the main transformer. A fire extinguisher system will be of the water sprinkler type using the spray nozzles installed around the transformer.

11.4.5 Information Transmission System

Information transmission system is a system designed for the transmission of necessary data to ensure stability in the supply of electric power. For the protection and operation of the 115 kV transmission line (about 43 km) and the maintenance of each electric facility installed in the power

33/

station, a microwave multiplex radio or a power line carrier relay system is installed for El Chaparral power station. To facilitate various works involved in carrying out the electric utility business, the information of each electric facility is transmitted by the microwave multiplex radio to CEL's head office and to a UT center though an existing relay station installed near the 15 de Septiembre substation. A detailed examination of matters to be transmitted will be carried out during the subsequent detailed design (D/D) stage.

11.4.6 Ports and Inland Transport Routes

For the investigation on transport routes for the electrical equipment and others, the route from La Union Port and the route from Acajutla Port were reviewed. The same roads will be taken by the two plans for the segment between San Miguel and the project site. The roads from El Triunfo of Pan American Highway to the Chaparral point though intermediate villages of Sesori and San Luis de la Reina have recently undergone improvement for the most part. According to the results of the investigation, the route can be taken after an improvement of a few concrete bridges and the widening of the roads that lead to the point near the project site are made. Additional investigations will be required at the time of the detailed design.

(1) La Union Port Route

La Union Port, which is located about 50 km east of San Miguel, is a fishing port, and it will be transformed with a financial aid from Japan in the near future. Although a more detailed study examining details of the port project is due, the route has an advantage in view of transportation hours, costs and security after its completion, because the distance to be covered by the inland transport is only about 100 km.

The road conditions of the route do not appear to pose any problem, though there are five bridges (the longest one being 15 m in length) en route between San Miguel and La Union except the central area of La Union town. The route between San Miguel and the Project Site is also taken if the Acajutla Port Route is selected. It also seems that no problem exists in terms of road conditions between San Miguel and Osicala near the Torola river based on detailed inspections on several small bridges at 12 ~13 locations (the longest being 10m in length).

(2) Acajutla Port Route

Acajutla Port is located in Sonsonate Prefecture, about 85 km west of San Salvador and about 103 km by railway. It is the only international port in El Salvador at present. There are three wharves, A, B and C. Both A and C are served as breakwaters also. Wharf A is for boats and normal sized ships while Wharf C is for vessels. Wharf B has unloading facilities such as an unloader and a belt comber of 350 tons per hour for small materials and grain. The port is equipped with one set of 30-, 45- and 60-ton cranes, four 40-ton container cranes, 90 fork lifts, six trainers for container and small baggie, 41 freight cars, a storage space of 4,500 m^2 for Wharf A, a container yard of 30,000 m^2 and an outdoor space of 24,000 m^2 between the storehouses.

According to past records, the largest cargo the port has unloaded is 235 metric tons. CEL also used this port to unload a power transformer (about 112 tons) for 15 de Septiembre power station and transported it about 250 km inland.

In terms of road conditions, the road between Acajutla and San Salvador is American Highway, which is serviced completely. There are three bridges on the route but heavy-duty trucks can pass these bridges. There are two routes between San Salvador and San Miguel. CEL used the seaside route to transport the main transformer mentioned the above. The reason is that the road conditions of the seaside route are superior to the mountain side route of American Highway.

Concerning the inland transport route from Acajutla to the project site, four routes were examined with the following conditions. The major cities served by each route are shown in Fig.11.15.

1) Maximum dimensions (m): (width) 3.0 × (height) 3.8 × (length) 30.43 – 34.43

2) Maximum tolerant weight (ton): 100 tons

Notes:

Route No.1 (Approx. Distance: 360 km) < Recommended by CEL>

Acajutla ~ Sonsonate ~ San Salvador ~ Comalapa ~ Delirio ~ San Miguel ~ El Triunfo ~ San Simon ~ San Luis de La Reina ~ El Chaparral.

Route No.2 (Approx. Distance: 345 km)

Acajutla ~ Sonsonate ~ San Salvador ~ Comalapa ~ Zacatecoluca ~ San Vicente ~ El Triunfo ~ San Simon ~ San Luis de La Reina ~ El Chaparral.

Route No.3 (Approx. Distance: 335 km)

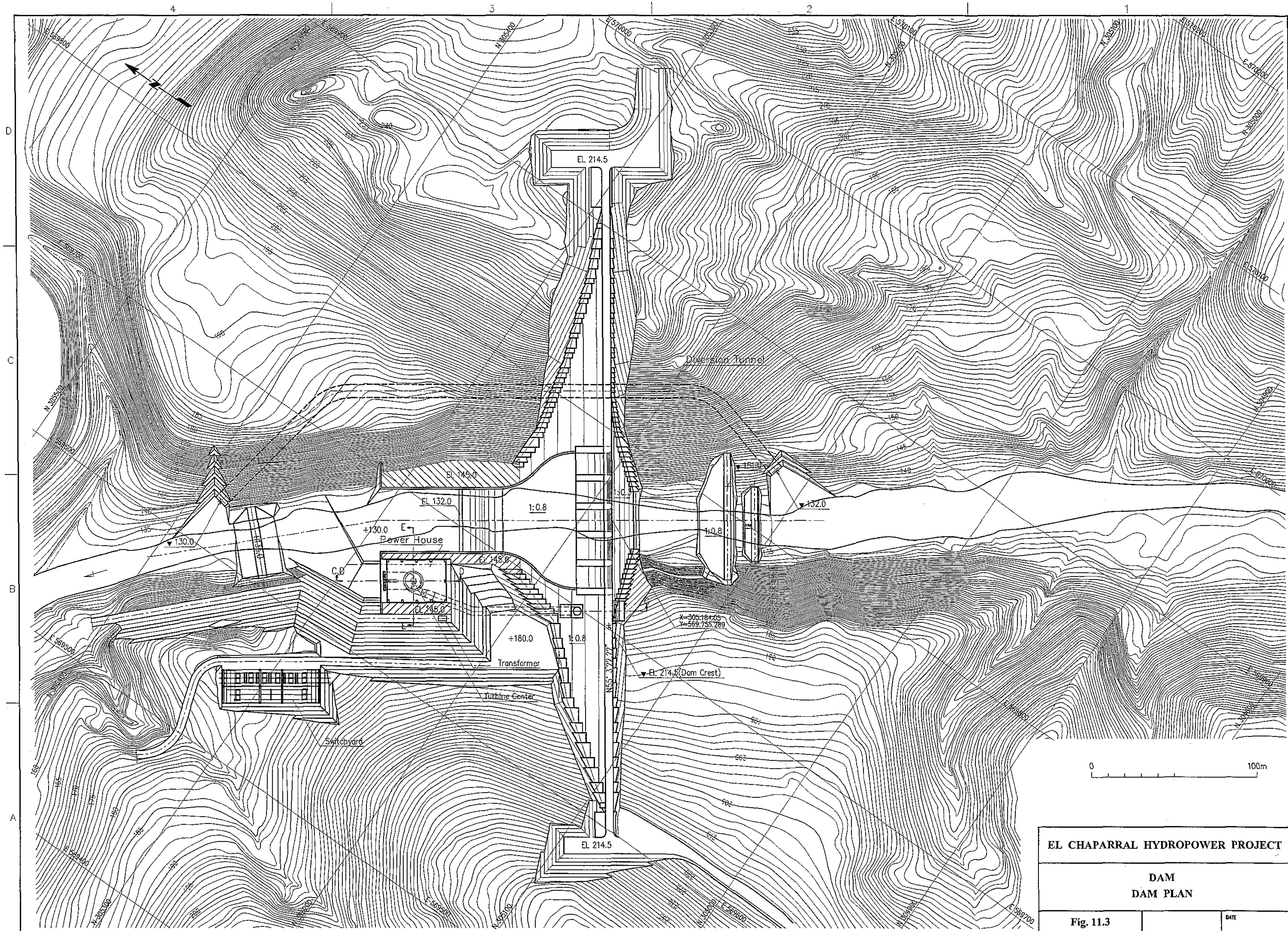
Acajutla ~ Comalapa ~ Usulutan ~ San Miguel ~ El Triunfo ~ San Simon ~ San Luis de La Reina ~ El Chaparral.

Route No.4 (Approx. Distance: 320 km)

Acajutla ~ Sonsonate ~ San Salvador ~ Puente Cuscatlan ~ El Triunfo ~ San Simon ~ San Luis de La Reina ~ El Chaparral.

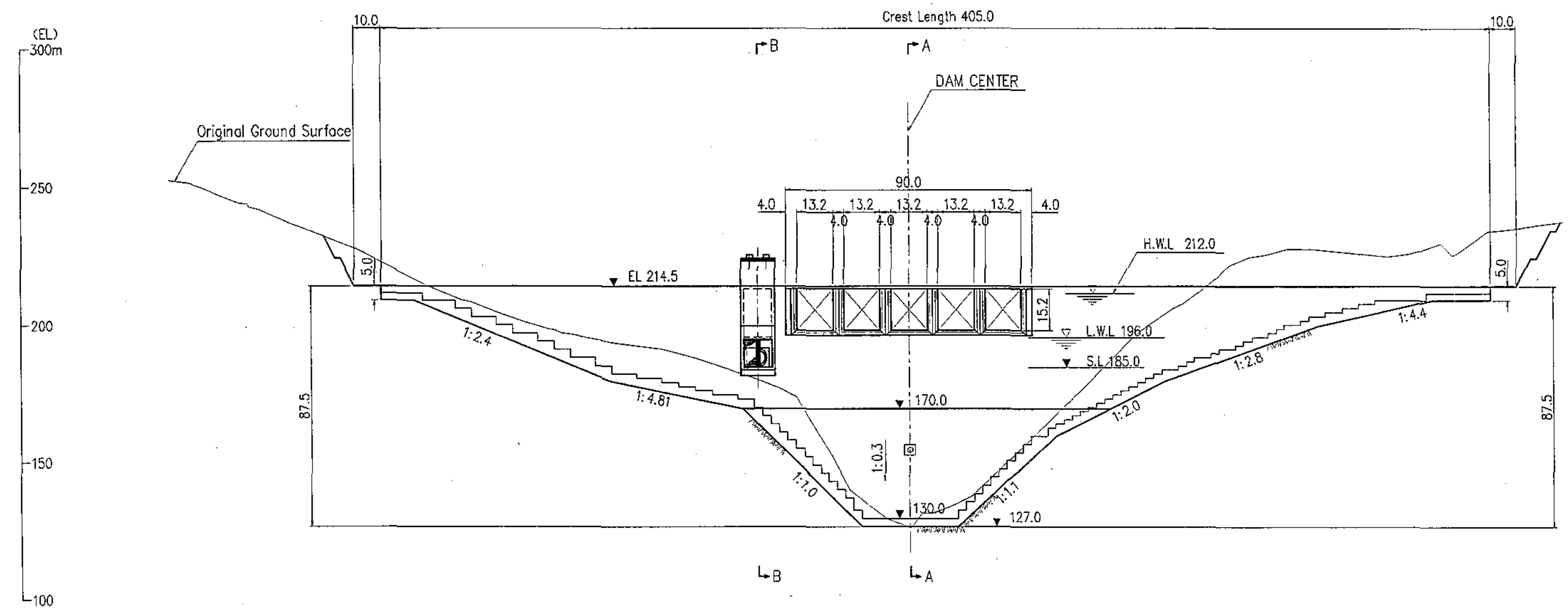
Table 11.1 Salient Features of El Chaparral Development Plan

Generation Type	Dam Type (P/S is located just downstream of dam)		
		Main Unit	Sub Unit
Installed Capacity	kW	64,400	1,300
Maximum Discharge	m^3/s	100.0	2.0
Effective Head	m	72.8	78.1
Annual Average Energy	GWh	220.6	10.6
Reservoir			
Catchment Area	km^2	1,233	
Gross Storage Capacity	m^3	189×10^6	
Effective Storage Capacity	m^3	106×10^6	
Available Draw-down	m	16.0	
Reservoir Area (at HWL)	km^2	8.6	
Design Flood Discharge	m^3/s	6,484 (PMF)	
Dam			
Dam	-	Concrete Gravity Dam (RCC)	
Crest Length L × Height H	m	L 405.0 × H 87.5	
Concrete Volume V	m^3	370,000	
Spillway			
Spillway Gate	W × H	Radial Gate W 13.2 × H 15.2, 5 Gates	
Water way			
Intake	-	Incorporated in dam	
Intake Gate	W × H	Roller Gate W 7.0 × H 7.0 1 Gate	
Penstock			
Length L	m	144.5 (1 Line)	
Inner Diameter D	m	5.0	
Powerhouse			
Power house	-	Semi Underground Type	
Outlet			
Outlet Gate	W × H	Slide Gate W 5.8 × H:5.2	

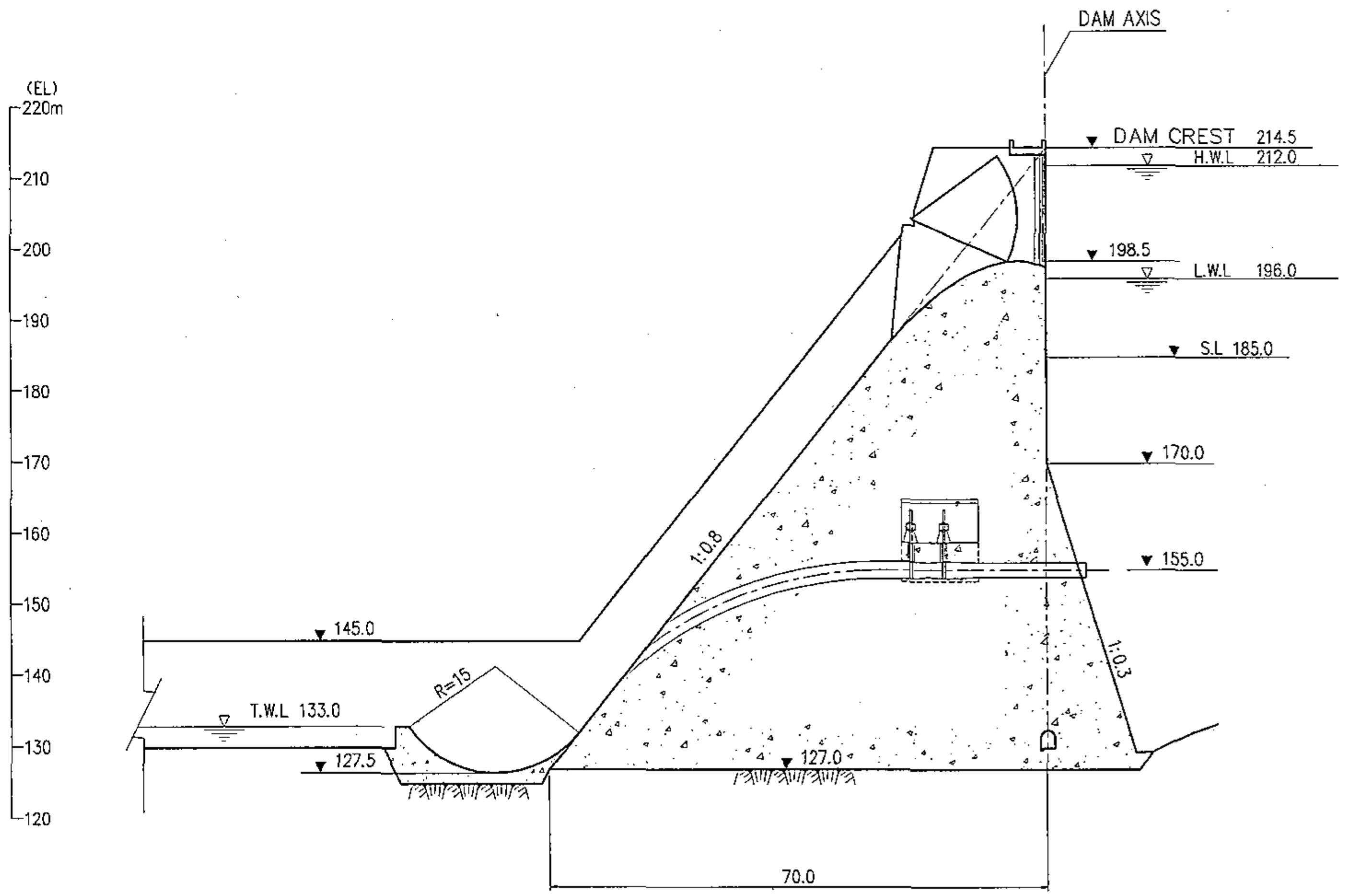


F-1 SHEET NO. OF

DAM ELEVATION



TYPICAL SECTION A



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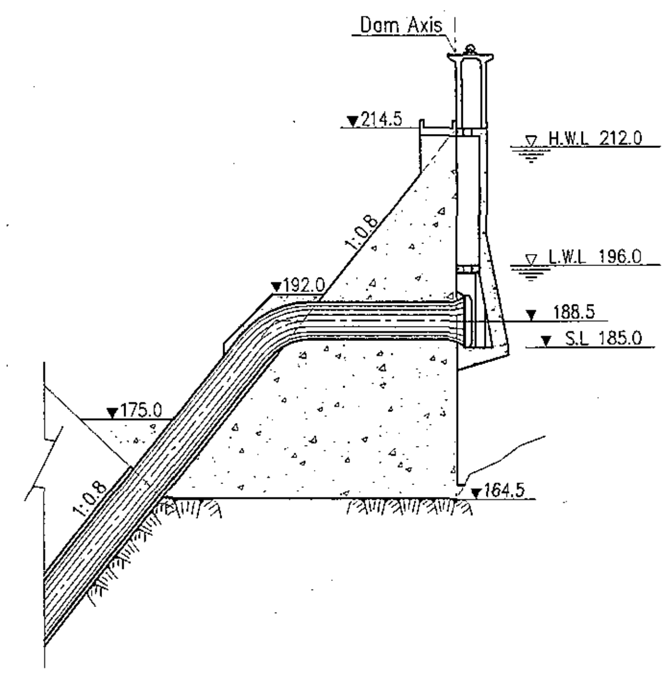

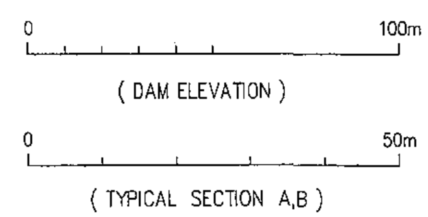

EL CHAPARRAL HYDROPOWER PROJECT

DAM
DAM ELEVATION AND TYPICALSECTION

Fig. 11.4		DATE

F - 2 SHEET NO. OF

EL CHAPARRAL HYDROPOWER PROJECT

DIVERSION TUNNEL
PLAN AND SECTION

Fig. 11.5

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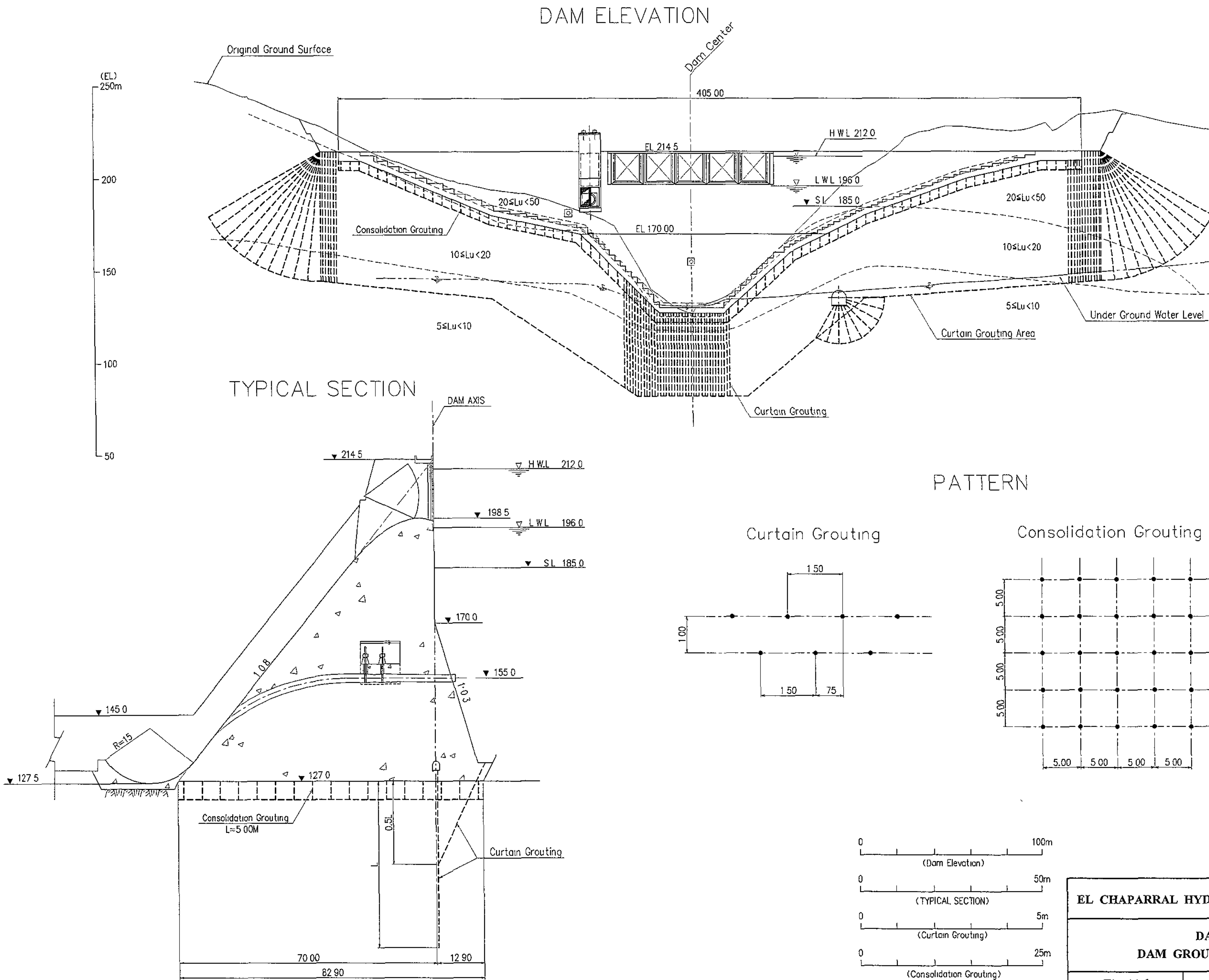


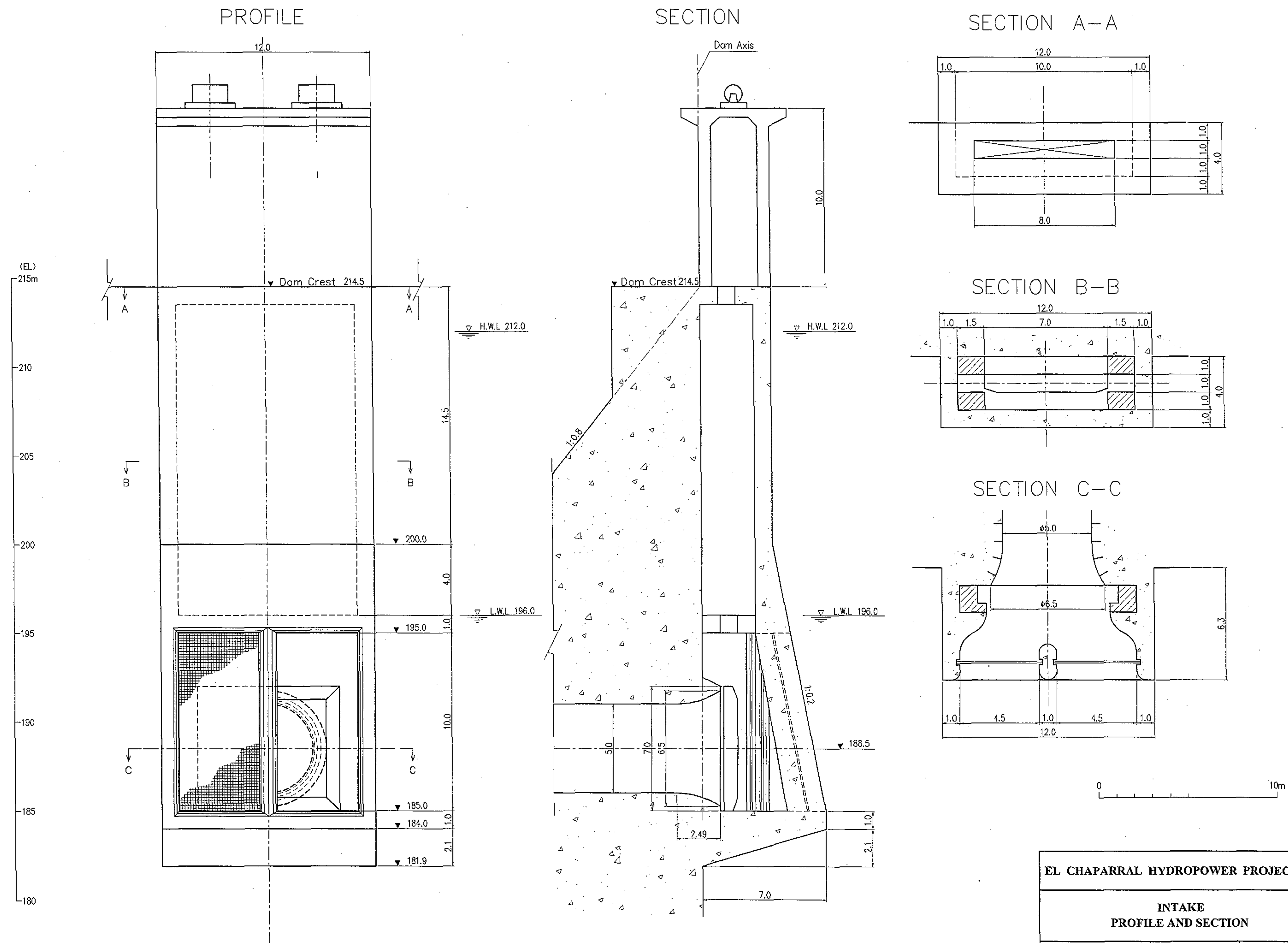
EL CHAPARRAL HYDROPOWER PROJECT

DAM
DAM GROUTING PLAN

Fig. 11.6 | DATE

F-4 SHEET NO. 1 OF

339



EL CHAPARRAL HYDROPOWER PROJECT

INTAKE
PROFILE AND SECTION

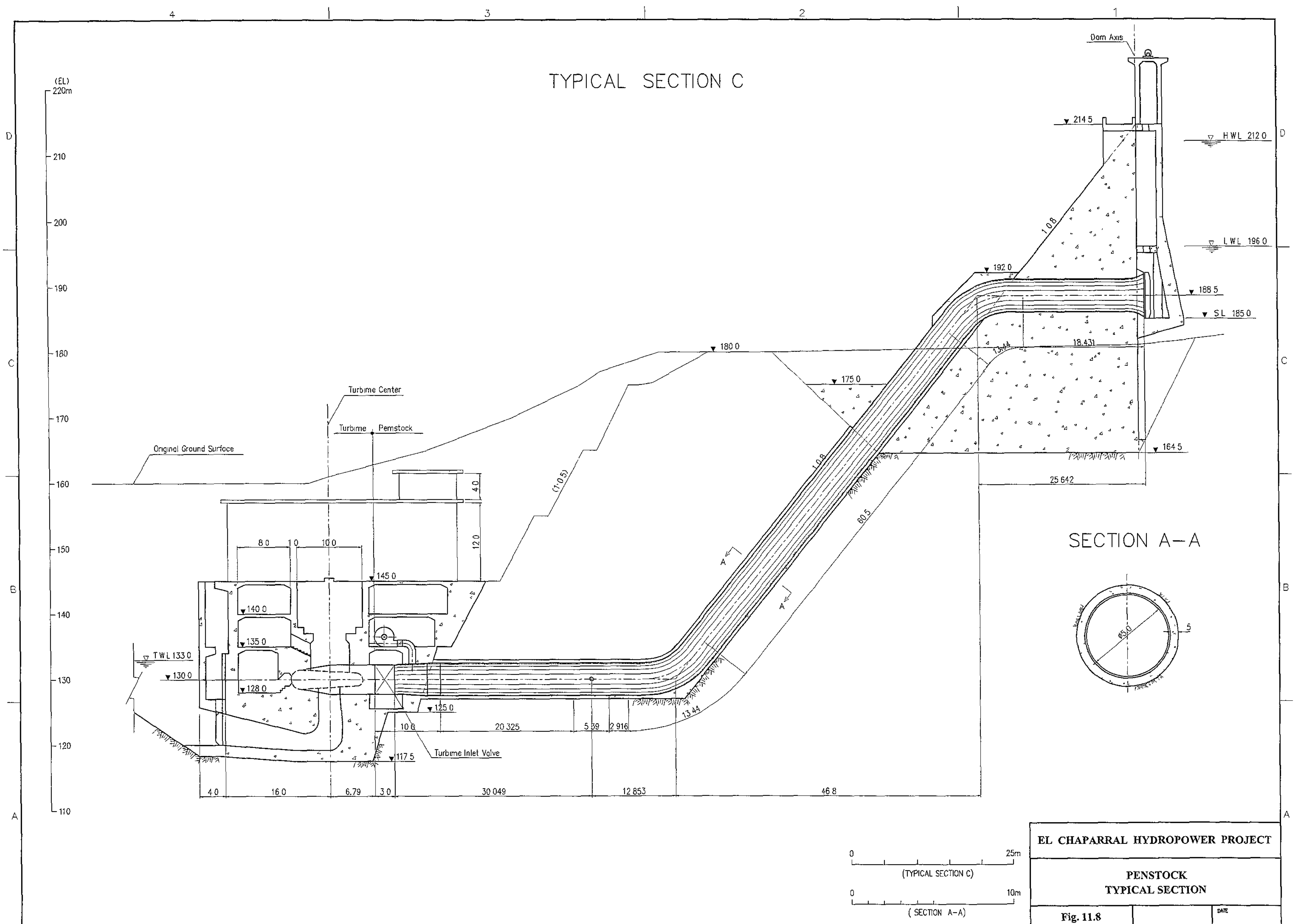
Fig.11.7

DATE

SHEET NO. OF

F - 5

340



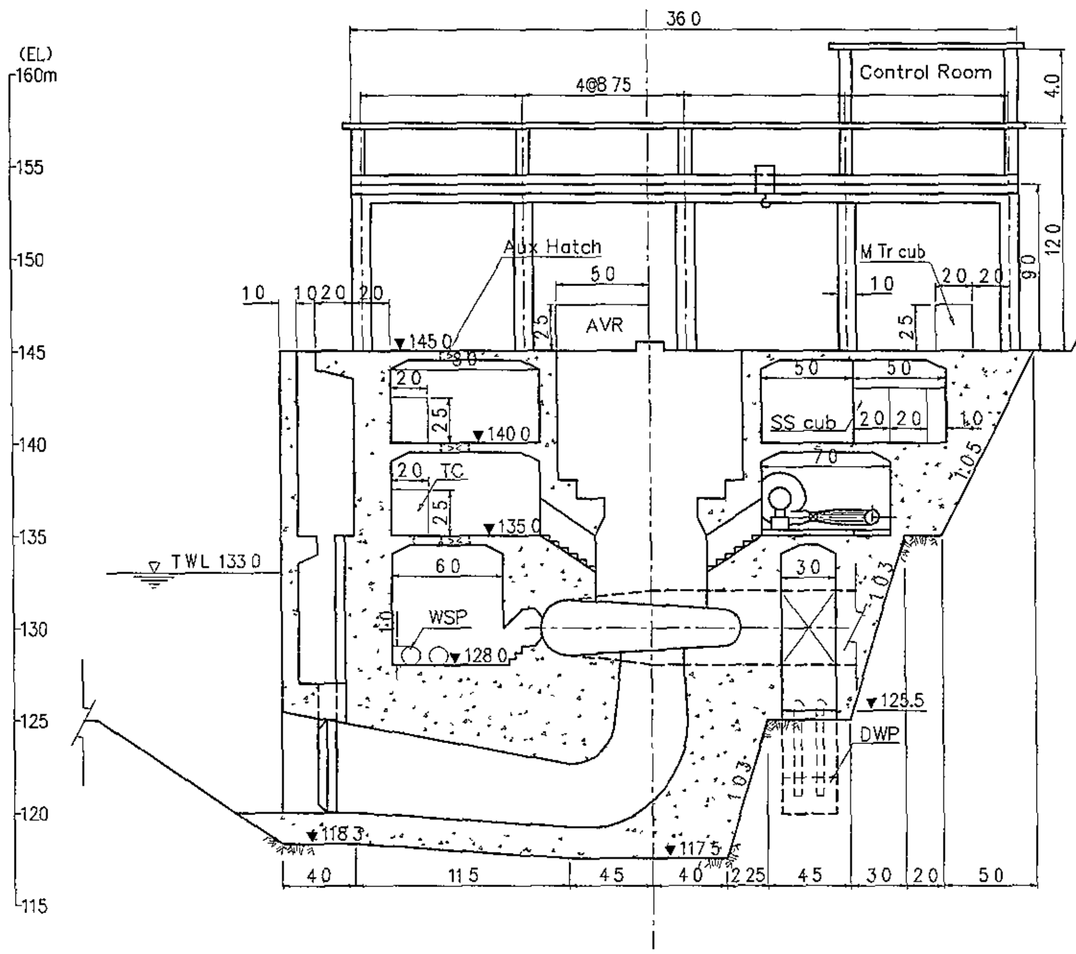
EL CHAPARRAL HYDROPOWER PROJECT

PENSTOCK
TYPICAL SECTION

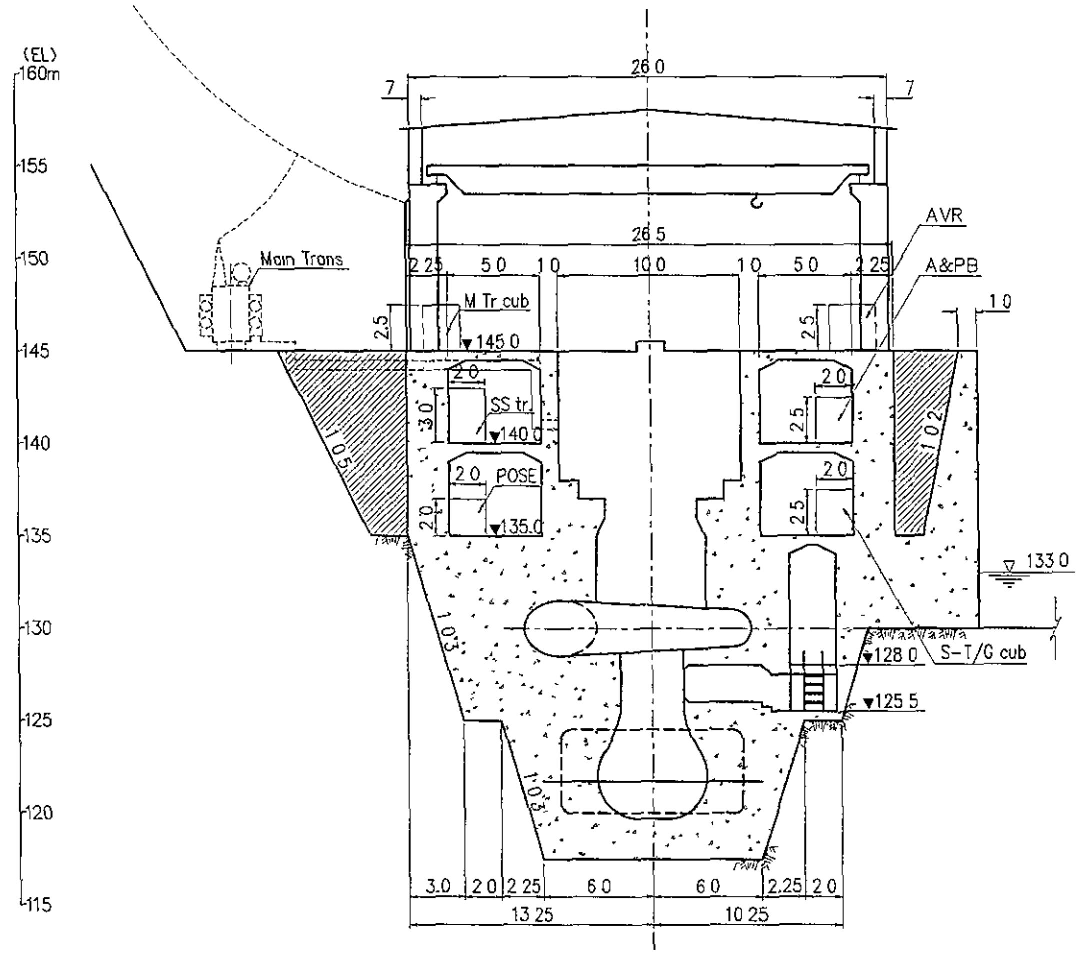
Fig. 11.8 | DATE

F-6 SHEET NO. OF

TYPICAL SECTION D



TYPICAL SECTION E



Legend

(Typical section D)
M Tr cub Main Transformer Control Cubicle
AVR Exciter regulation (with AVR) Cubicle
SS cub Station Service Cubicle
TC Turbine Control Board
WSP Water Supply Pump
DWP Drainage Water Pit

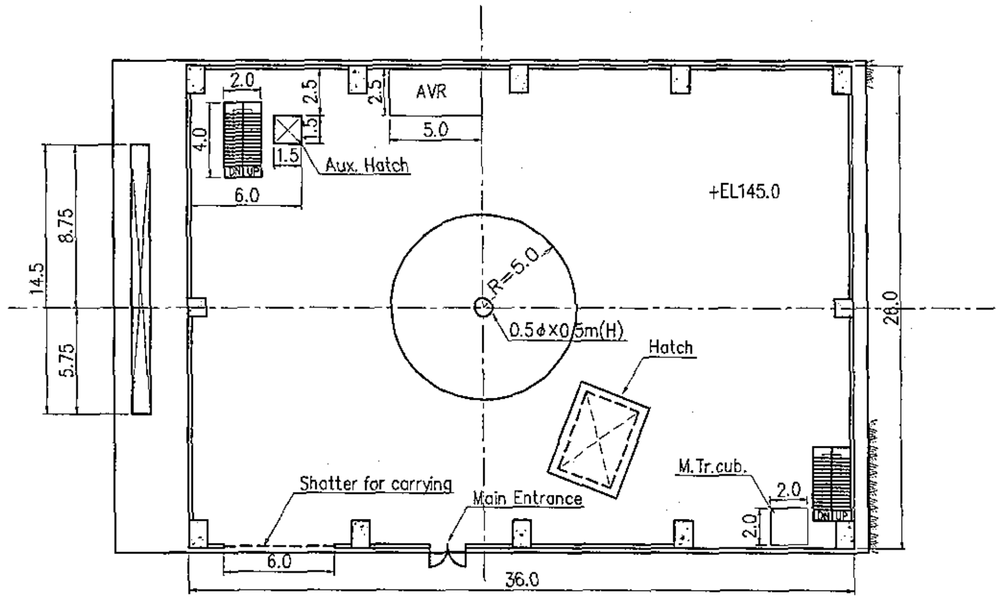
(Typical Section E)
M Tr cub Main Transformer Control Cubicle
AVR Exciter Regulation (with AVR) Cubicle
SS Tr Station Service transformer
A&PB Automatic Control & Protection Relay Board
POSE · Pressure Oil Supply Equipment
S-T/G cub Sub-Turbine/Generator Control Cubicle

0 20m

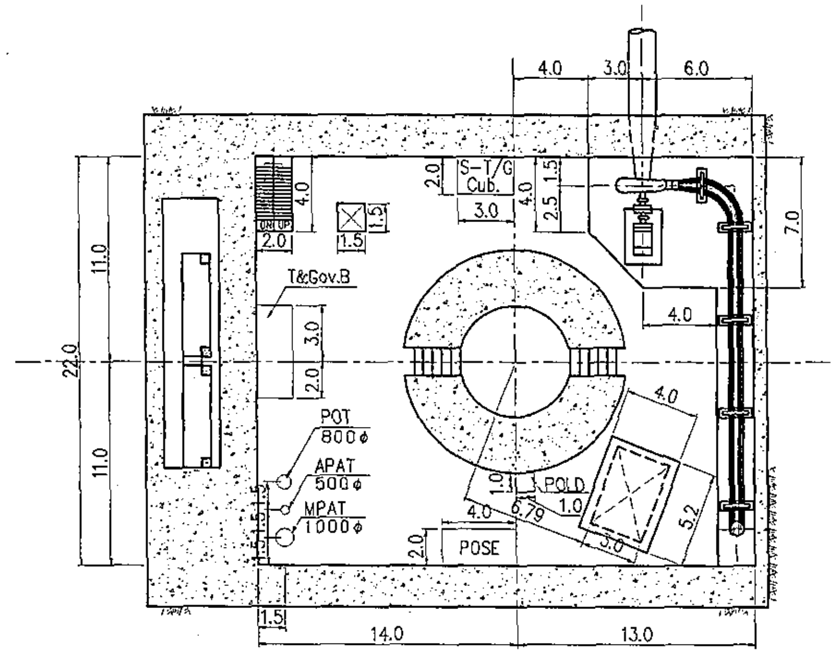
EL CHAPARRAL HYDROPOWER PROJECT	
POWER HOUSE TYPICAL SECTION	
Fig.11.9	DATE

SHEET NO. OF

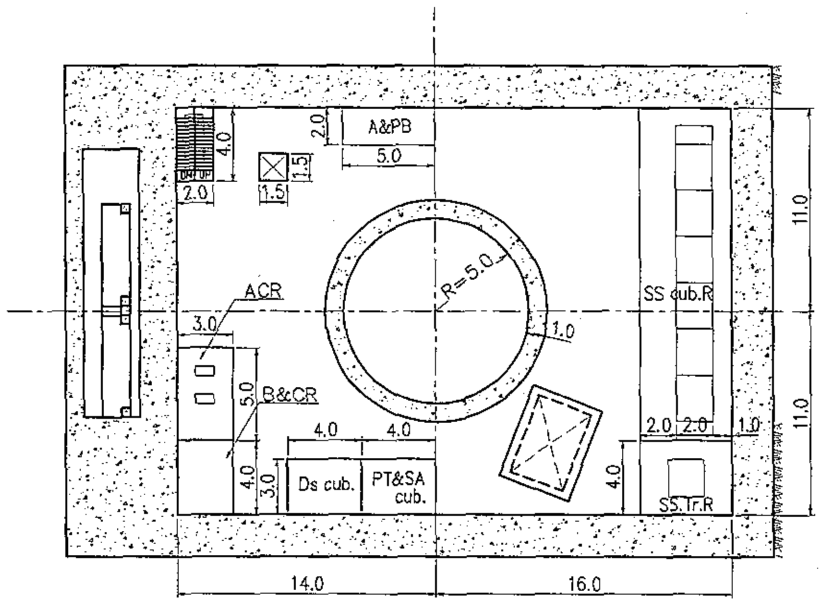
EL145.0



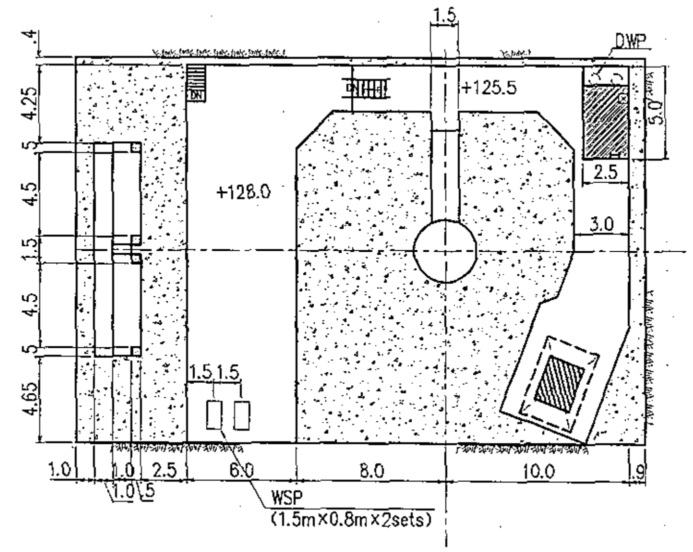
EL135.0



EL140.0



EL125.5



Legend :

(EL145.0)
M.Tr.cub. : Main Transformer Control Cubicle
AVR : Exciter Regulation (with AVR) Cubicle

(EL140.0)
SS.Tr.R : Station Service Transformer Room
A&PB : Automatic Control & Protection Relay Board
SS cub.R : Station Service Cubicle Room
ACR : Air Compressor Room
B&CR : Battery & Charger Room
DS cub. : Disconecting switch Cubicle
PT&SA cub. : Potential Transformer & Serge Absorber Cubicle

(EL135.0)
S-T/G cub. : Sub-Turbine/Generator Control Cubicle
T&Gov.B : Turbine & Governor Control Board
POT : Pressure Oil Tank
APAT : Auxiliary Pressure Air Tank
MPAT : Main Pressure Air Tank
POSE : Pressure Oil Supply Equipment
POLD : Pressure Oil Lifting Device

(EL125.0)
WSP : Water Supply Pump
DWP : Drainage Water Pit

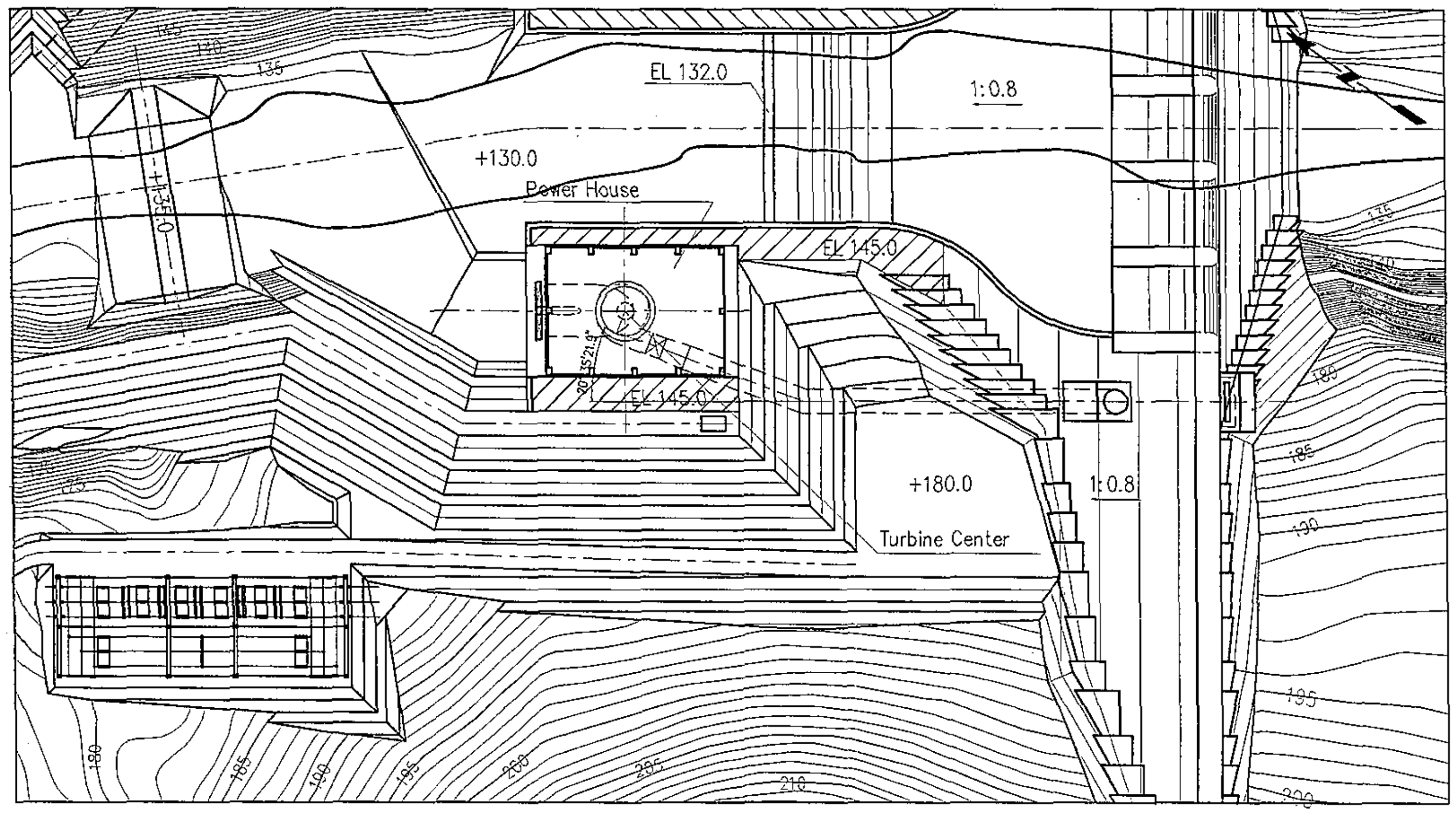
0 20m

EL CHAPARRAL HYDROPOWER PROJECT

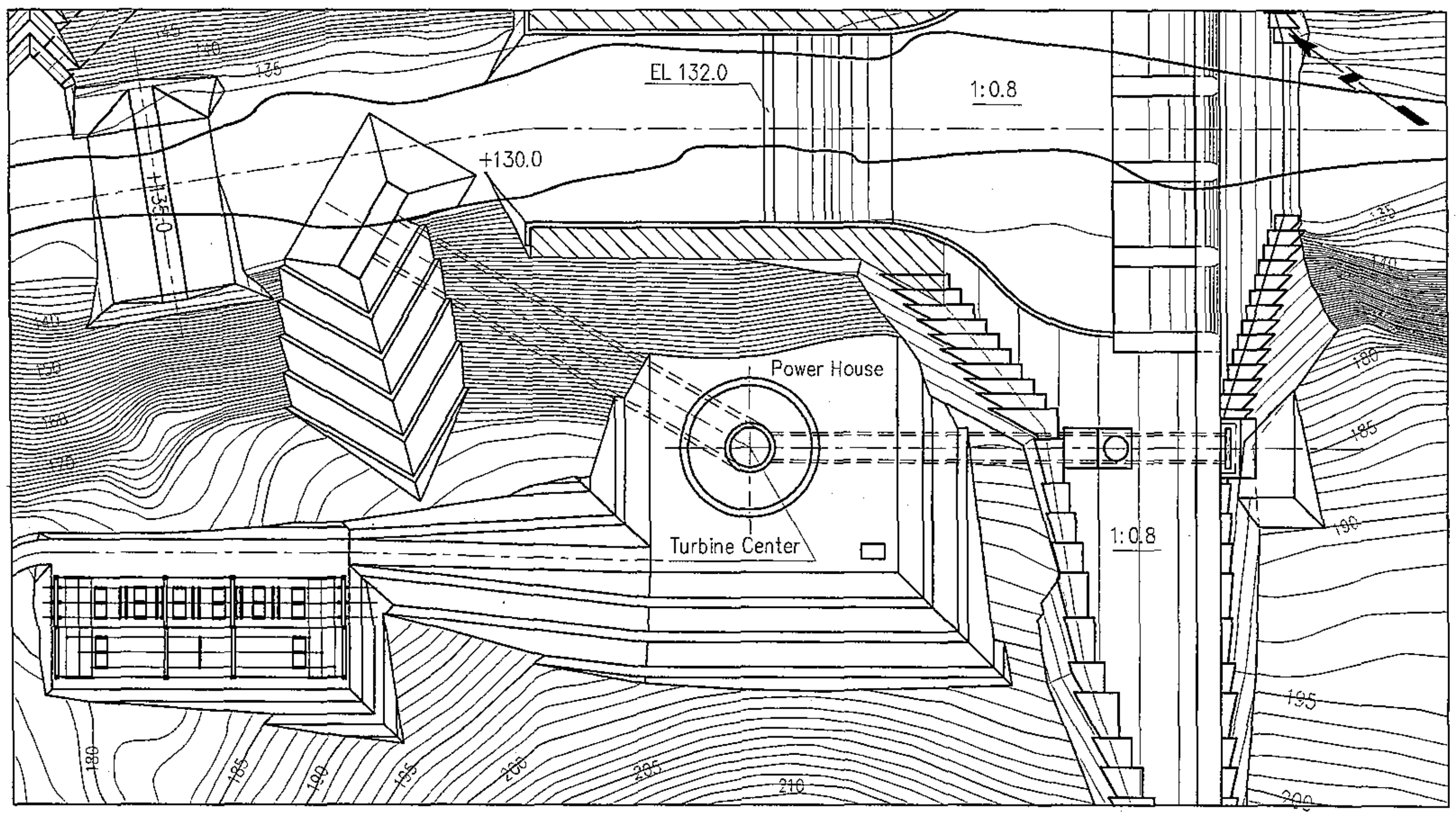
POWER HOUSE
PLAN

Fig.11.10 DATE

Proposed Plan (Open Excavation Type)



Alternative Plan (Vertical Shaft Type)



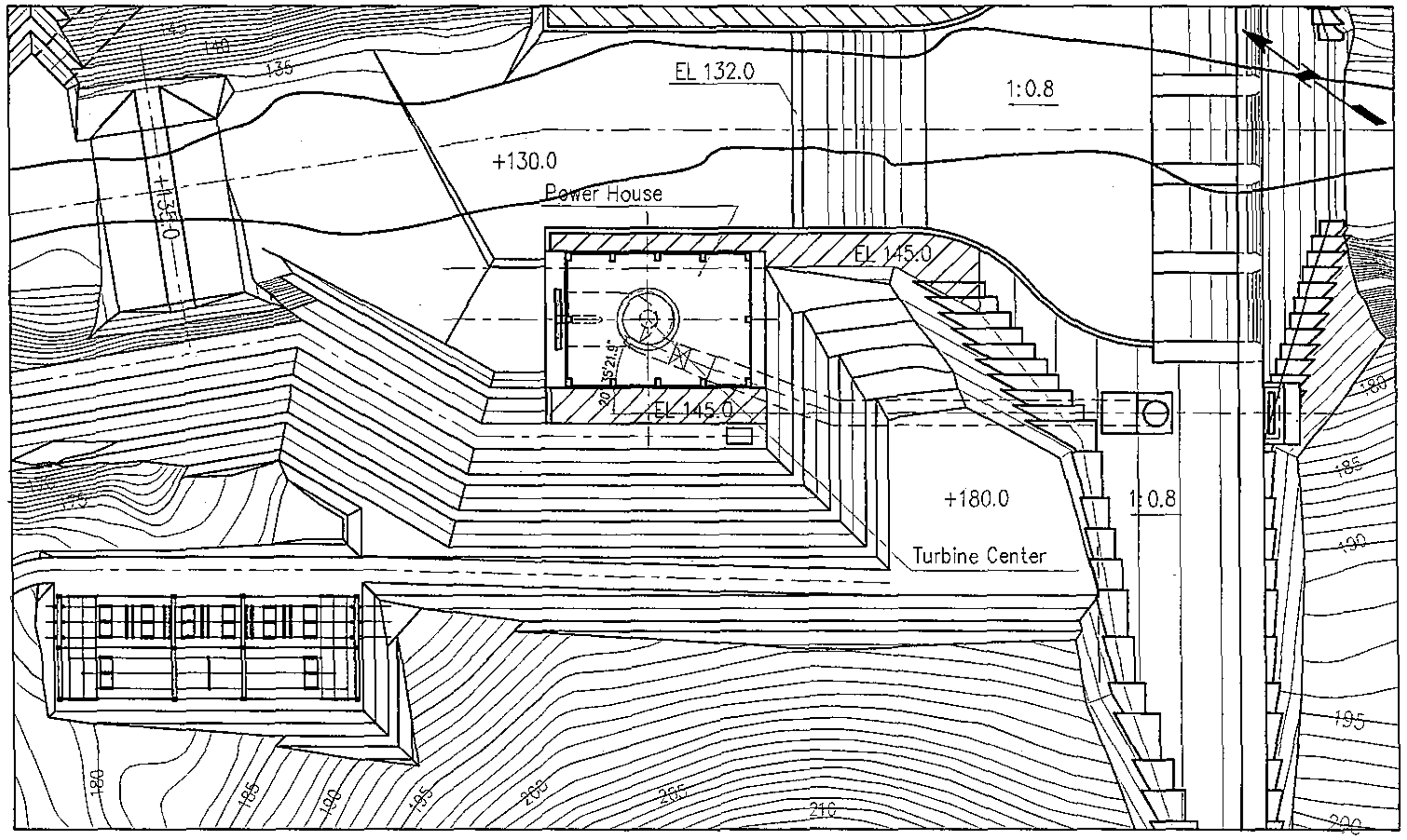
0 50m

EL CHAPARRAL HYDROPOWER PROJECT

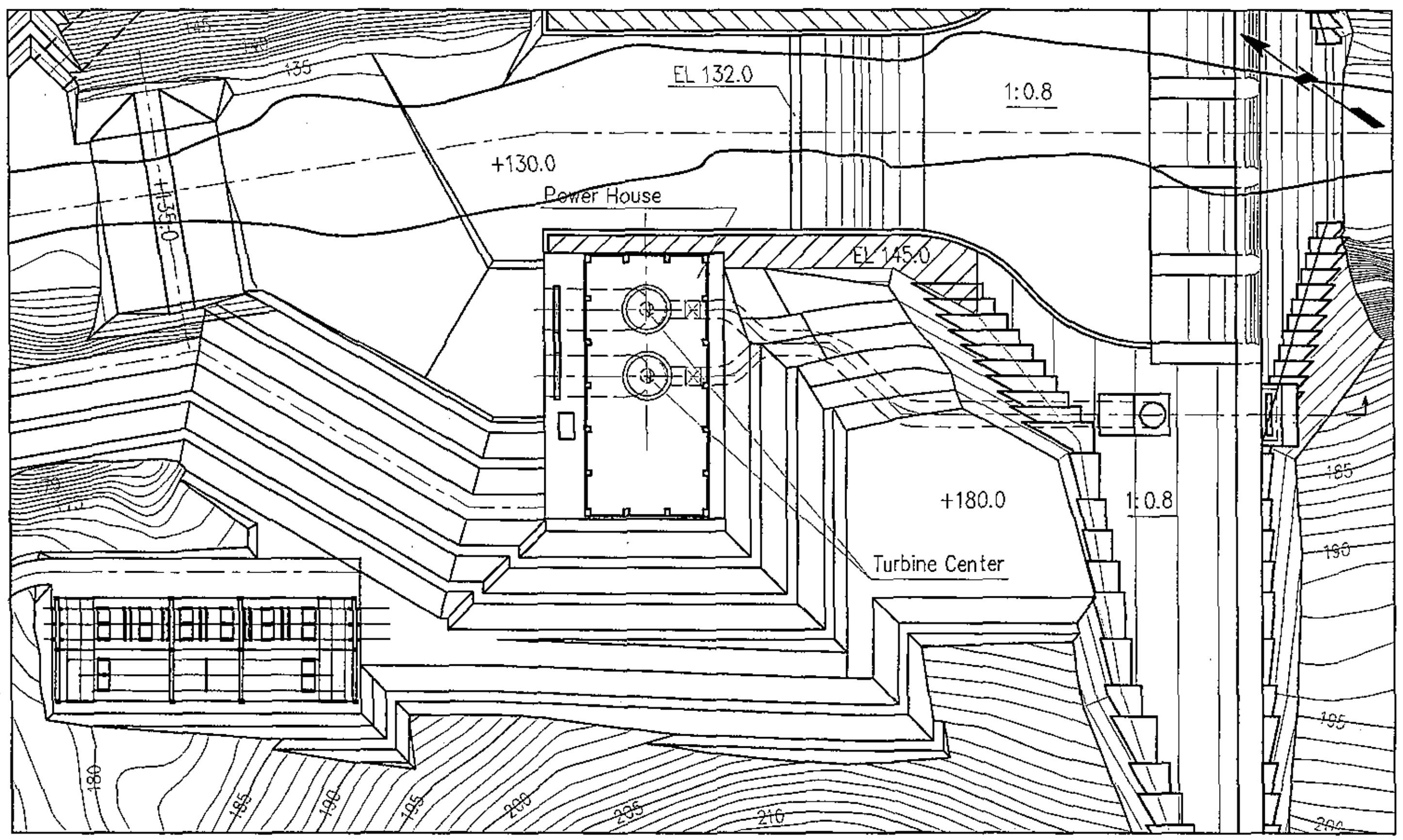
POWER HOUSE
ALTERNATIVE PLAN 1

Fig. 11.11		DATE

Proposed Plan (1 unit)

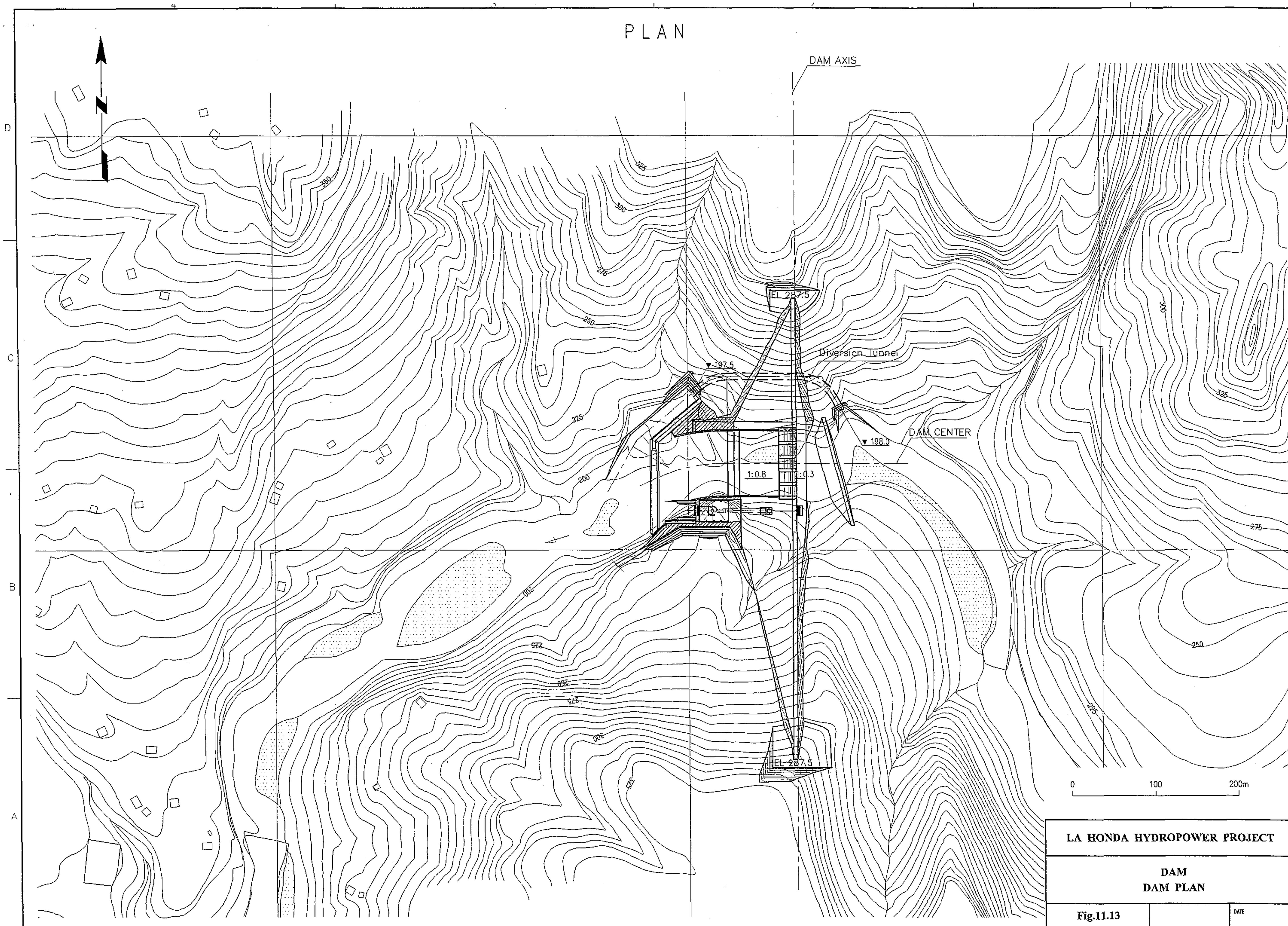


Alternative Plan (2 units)



0 50m

EL CHAPARRAL HYDROPOWER PROJECT	
POWER HOUSE ALTERNATIVE PLAN 2	
Fig. 11.12	DATE



LA HONDA HYDROPOWER PROJECT

DAM
DAM PLAN

Fig.11.13

DATE

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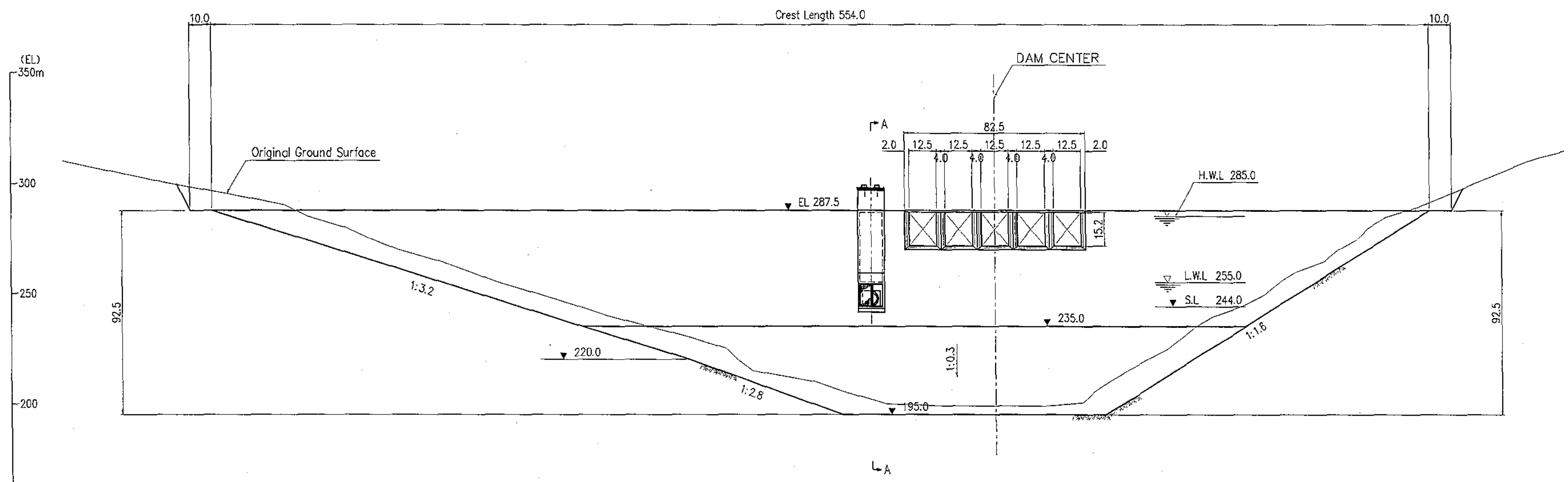
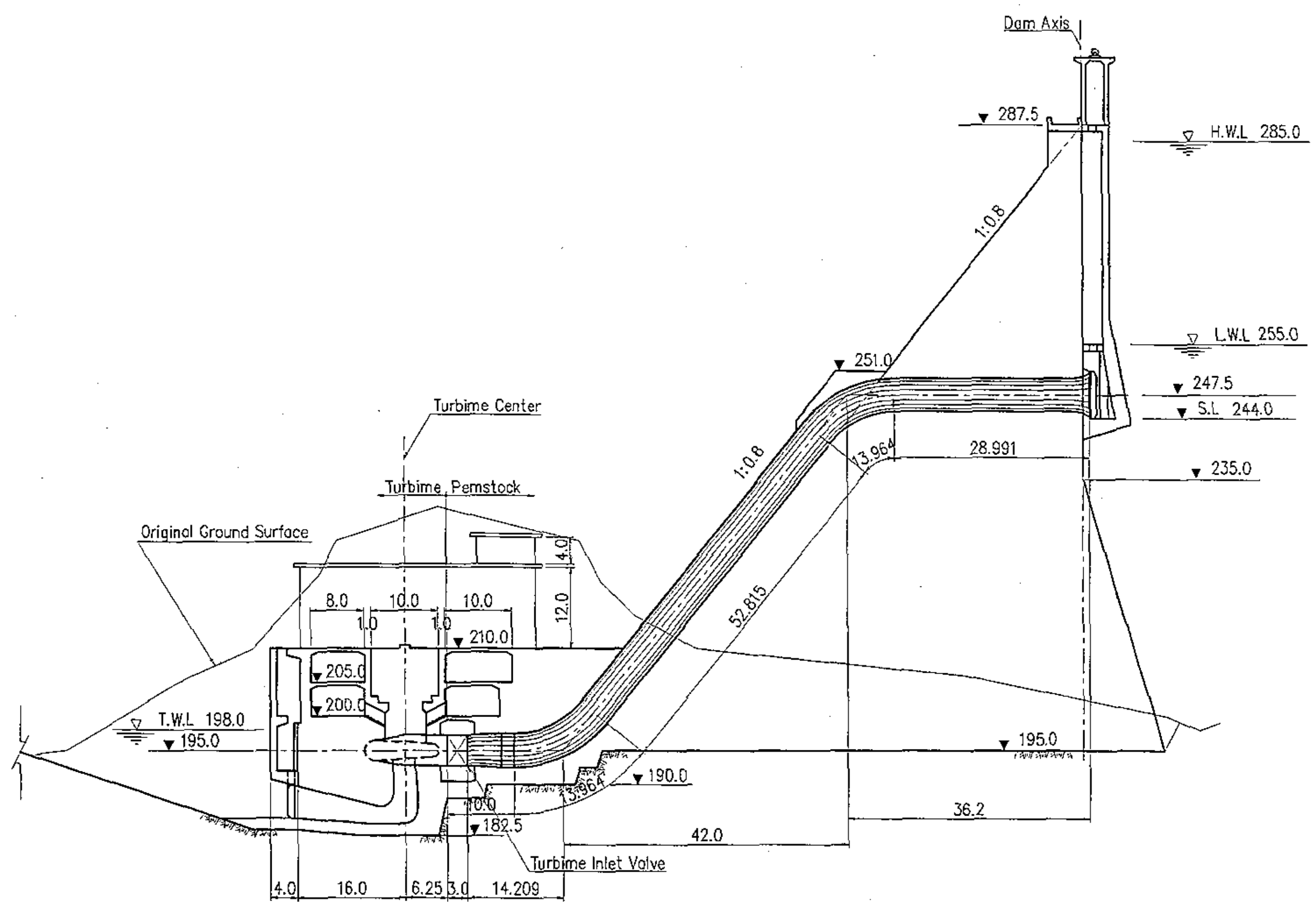
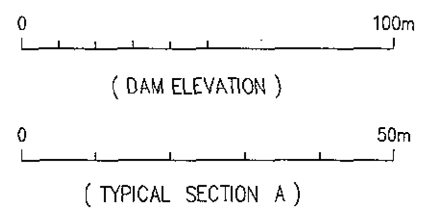
DAM ELEVATION



TYPICAL SECTION A





LA HONDA HYDROPOWER PROJECT

DAM

DAM ELEVATION AND TYPICAL SECTION

Fig.11.14

DATE

SHEET NO. 1 OF

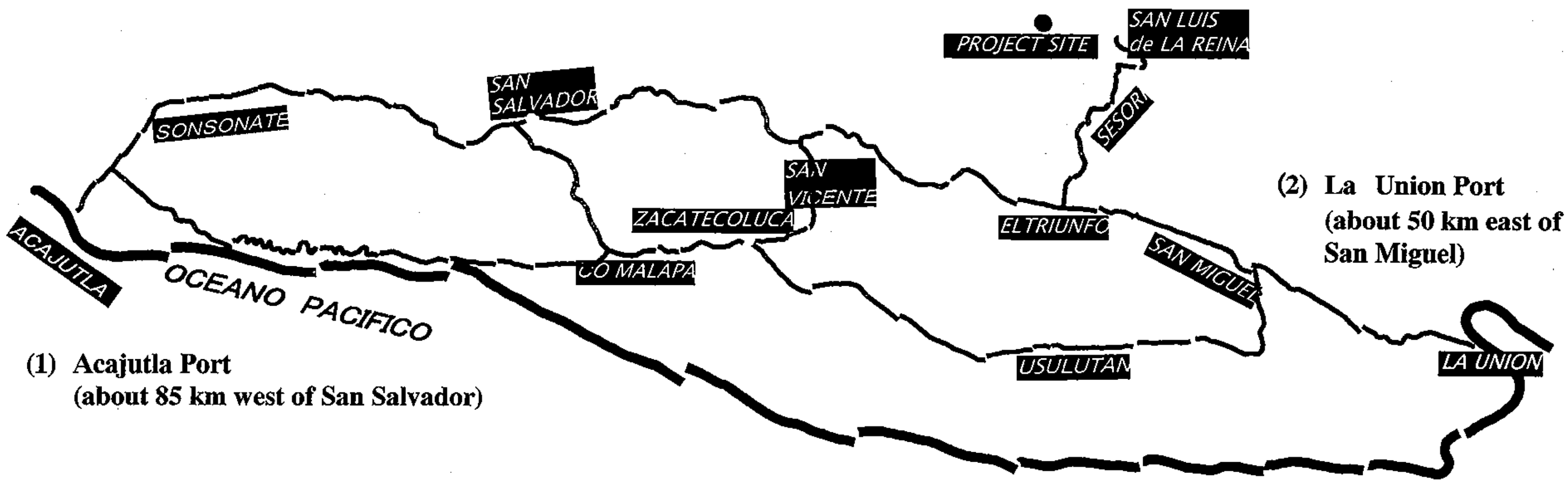


Fig.11.15 Ports & Inland Transport Route

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