Outdoor switchyard site (Constructed)

Width	:	42.35 m
Length	:	148.50 m

11.1.2 Outline of Design

(1) Penstock

The horizontal and vertical routes for the amplification project were set out at the time of the first stage construction and the intake gate shaft joint to the curved pipe part at the start end of the inclined shaft was already constructed in the first stage work. In designing the amplification, the route, inside diameter, concrete thickness, geology, etc. were studied and the original design was adopted with no change in consideration of economy and workability.

That is, the route D is used as the penstock route in relation to two amplification turbines to be installed and is the inclined shaft from the end of the constructed part (from the intake gate shaft joint to the curved pipe part at the start end of the inclined shaft) to the lower horizontal shaft (EL. 961.00 m). It is connected to two turbines by providing the branch pipe in the horizontal shaft part at the end of the penstock. The inclined shaft is 38 degrees in relation to the branch pipe and T type branch pipe is used because the penstock and powerhouse shaft are parallel. As for length of the penstock, one line part is 254.831 m (74.162 m constructed) and two lines part is 14.269 m and 27.126 m. As for the inside diameter of the penstock, the one line part is 4.20 m and two line part is 3.00 m. The penstock is installed underground and a void space between penstock and ground is filled with concrete.

The pipe shell material uses SM41 (JIS standards) and pipe thickness was decided by calculating the water hammer pressure.

The result is shown in Fig. 11-5. The water hammer pressure at the inlet of the turbine is 37.7% of hydrostatic pressure.

(2) Powerhouse

The intake and part of the penstock were constructed in the first stage work to make installation of a maximum of four amplification turbines possible. Excavation of the joint to the existing powerhouse (7.50 m) was completed in the first stage work.

The amplification planned now proposes two turbines and generators and the position of the turbine axis, shape of the cavity, etc. were studied in designing the amplification. As a result, they will be united with the first stage work (73 MW x 4 turbines) as planned originally and will be installed in a column on the downstream side of the existing powerhouse. The cavern section dimension (width 29.50 m, height 41.40 m), turbine center elevation (EL. 96.00 m) and distance of turbine axis (15.00 m) are the same as the first stage work. The length of the amplification of cavern is 42.75 m.

Two Francis turbines with vertical shaft, generators, main transformer room, control board room, cable processing room, overhead crane supports are provided in the cavern.

Because the amplification powerhouse uses the same cavity as the first stage work and the assembly room, overhead crane, drain pit and access tunnel (serving also as cable tunnel) are shared. (See Fig. 11-6.)

(3) Tailrace tunnel

One tailrace tunnel is constructed for one turbine in the same way as the first stage work. The route is at a right angle to the powerhouse center in the first stage work but amplification routes (two lines) are set 4°30' upstream from the normal direction in consideration of topography of the outlet. The elevation of the starting point is EL.88.20 m the same as the first stage work. The gradient of the tunnel rises toward the outlet by 1:7.913. The tunnel length is 88.00 m for two lines respectively. (See Fig. 11-8)

The circular cross section (with inside diameter of 4.20 m, concrete lined) has been selected for the section of the tailrace tunnel down to 81.50 m from the powerhouse, similarly to the first stage work. The 6.50 m length from the outlet has the cross section of which the upper half is circular and lower half rectangular. The reason is that, while it is customary to construct the tailrace by providing the cofferdam, the tailrace in this project is planned to be constructed by starting from the power plant all the way, because the coffering is difficult in this case, and the operation of the existing power plant will have to be shut down for a long period if cofferdam is provided. (The details are shown in Construction Planning)

(4) Service Gallery

The service gallery is provided for the maintenance work management of the tailrace tunnel and gates, and it will be provided by expanding the existing Santa Barbara Horizontal Shaft (the access tunnel to the service gallery of the first stage work) for the 45.00 m section from the joint made in the first stage work. The cross sectional geometry and dimensions are similar to those of first stage work, and the service gallery will have the cross section of which the upper part is a circular arch and the lower part rectangular, being 3.00 m wide and 7.00 m high.

(5) Service Shaft

The service shaft is a vertical shaft used for opening and closing of the tailrace gate, and it is directly connected to the service gallery. The position of the service shaft was selected at a point which is 53.24 m from the starting point of the tailrace tunnel, in view of the relative position of the service gallery. The cross sectional geometry is an ellipse (3.00 m x 7.00 m), similar to the first stage work and the height is 24.28 m.

(6) Outdoor Switchyard Site

The amplification site (for two turbines) was arranged in the first stage work. The size of the site is 42.35 m wide and 148.50 m long. (See **Fig. 11-9**.)

11.2 Electrical Equipment

Electrical equipment for the amplification will have the same specifications as the existing equipment, because of advantage for economy, operation and maintenance. The salient features of the main equipment are shown below.

(1) Turbine

Number of unit	:	1 or 2
Type	:	Vertical shaft Francis type
Output	:	93 MW at maximum head 180 m
		75 MW at rated head 157 m
Speed	:	300 rpm

(2) Generator

Number of unit	:	1 or 2
Type	:	Vertical shaft, 3 phases, rotating field
Rated output	:	91,250 kVA
Rated power factor	:	0.8 lag. to 0 lead
Rated voltage	:	13.8 kV
Overload output	:	100,000 kVA
Overload power factor	:	0.91 lag. to 0.65 lead

Speed	:	300 rpm
Frequency	:	60 Hz

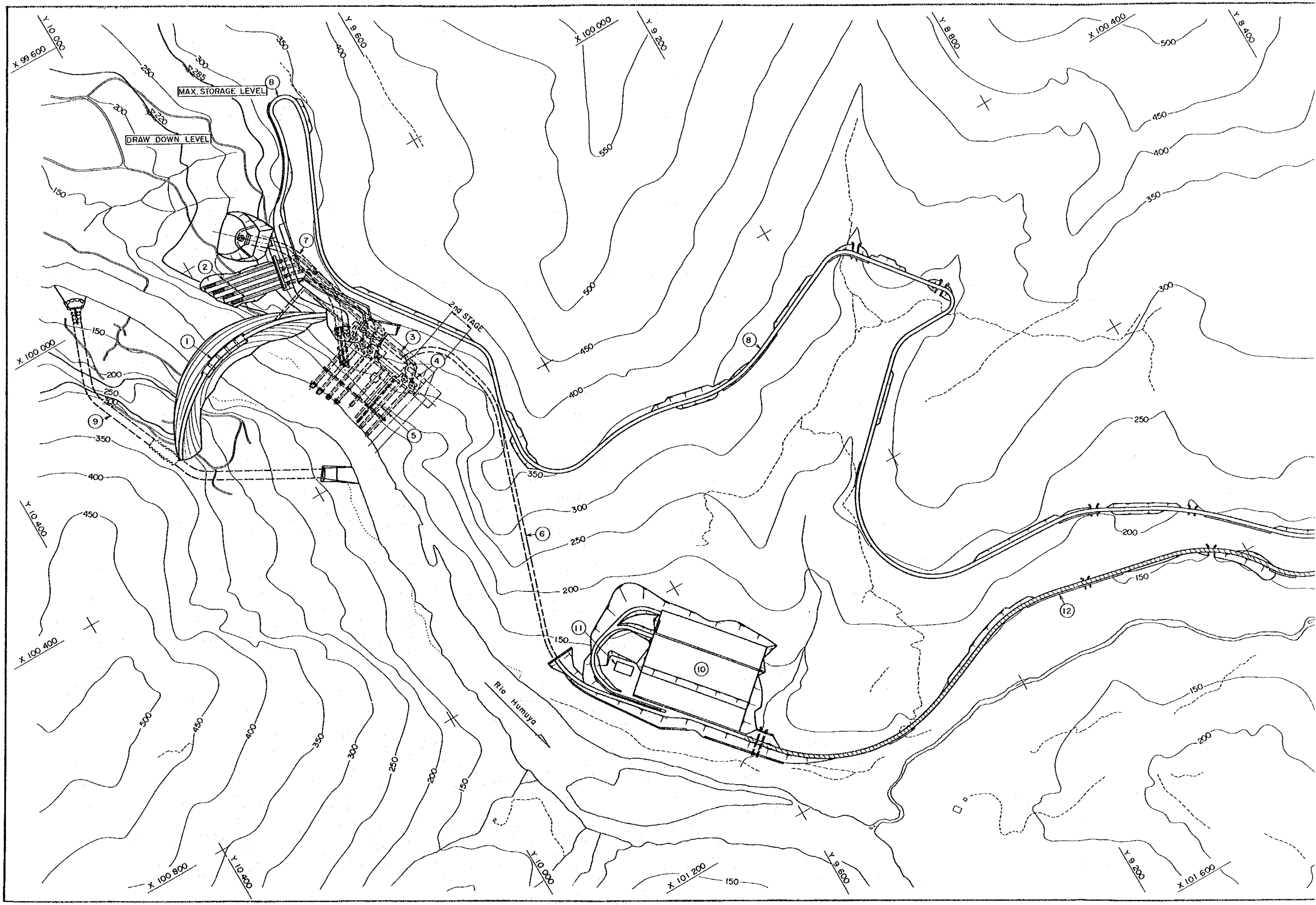
(3) Main Transformer

Rated capacity	:	100,000 kVA
Rated voltage	:	13.8 kV/230 kV
Frequency	:	60 Hz

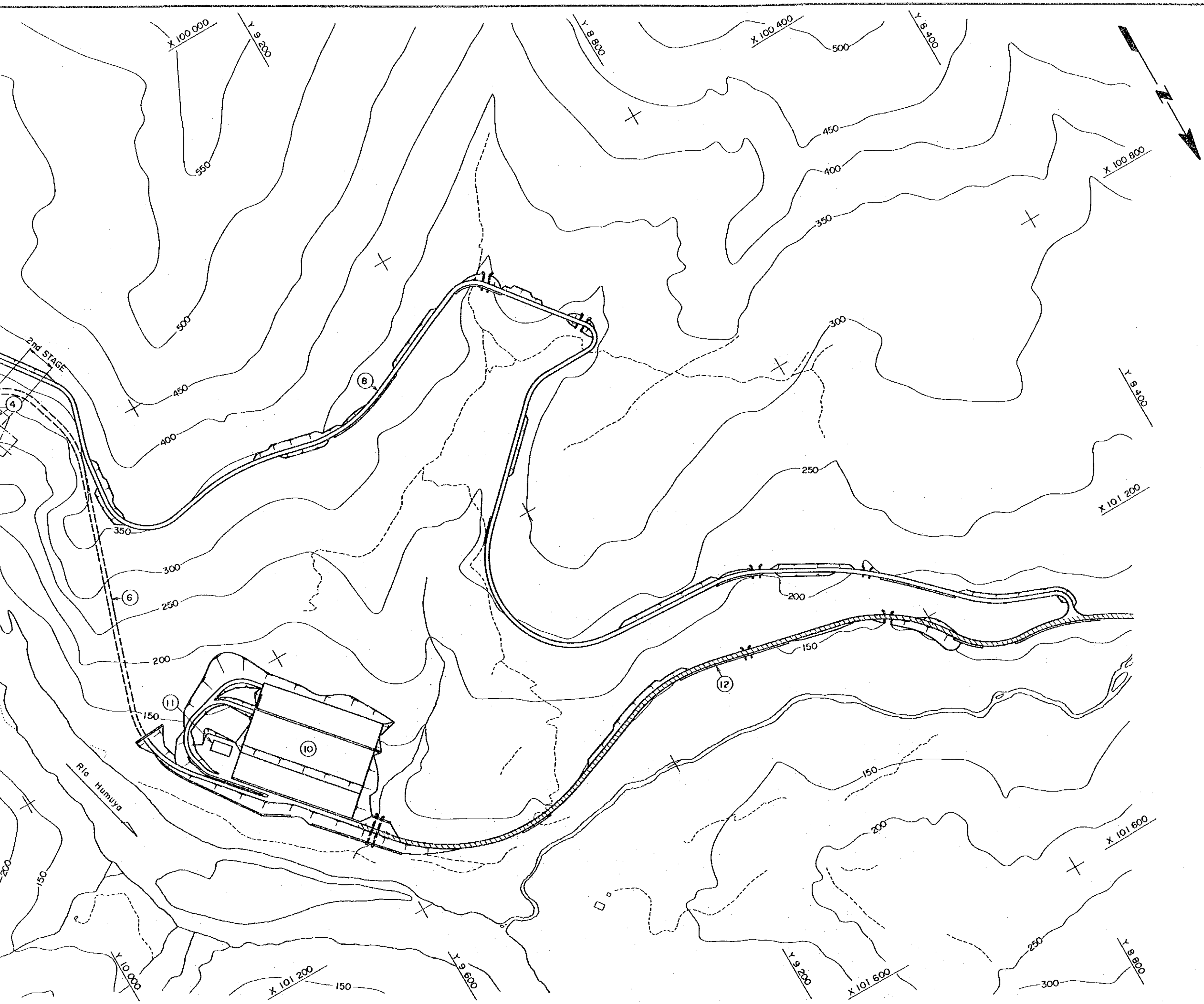
(4) Outdoor Switchyard

The generator voltage is stepped up to 230 kV by the main transformer in the underground transformer cavern and the power is connected to the outdoor switchyard 230 kV bus-line with OF cable by 1-1/2 CB scheme.

Necessity of amplification of transmission line will be determined by the result of the system analysis.



MAX. STORAGE LEVEL
DRAW DOWN LEVEL
2nd STAGE
Rio Humuya
X 99 600
Y 10 000
Y 9 600
X 100 000
Y 9 200
Y 8 800
X 100 400
Y 8 400
X 100 000
Y 10 400
X 100 400
X 100 800
Y 10 400
Y 10 000
X 101 200
Y 9 600
Y 9 200
X 101 600



LEGEND

1. ARCH DAM
2. INTAKES
3. PENSTOCK
4. UNDERGROUND POWER STATION
5. TAILRACE STRUCTURES
6. ACCESS TUNNEL
7. SPILLWAY
8. ACCESS ROAD TO DAM CREST
9. DIVERSION TUNNEL
10. SWITCHYARD
11. CONTROL BUILDING
12. ACCESS ROAD TO POWER STATION AND SWITCHYARD

(hatched) ACCESS ROAD FROM STA. CRUZ DE YOJOA BUILT BY ENEE

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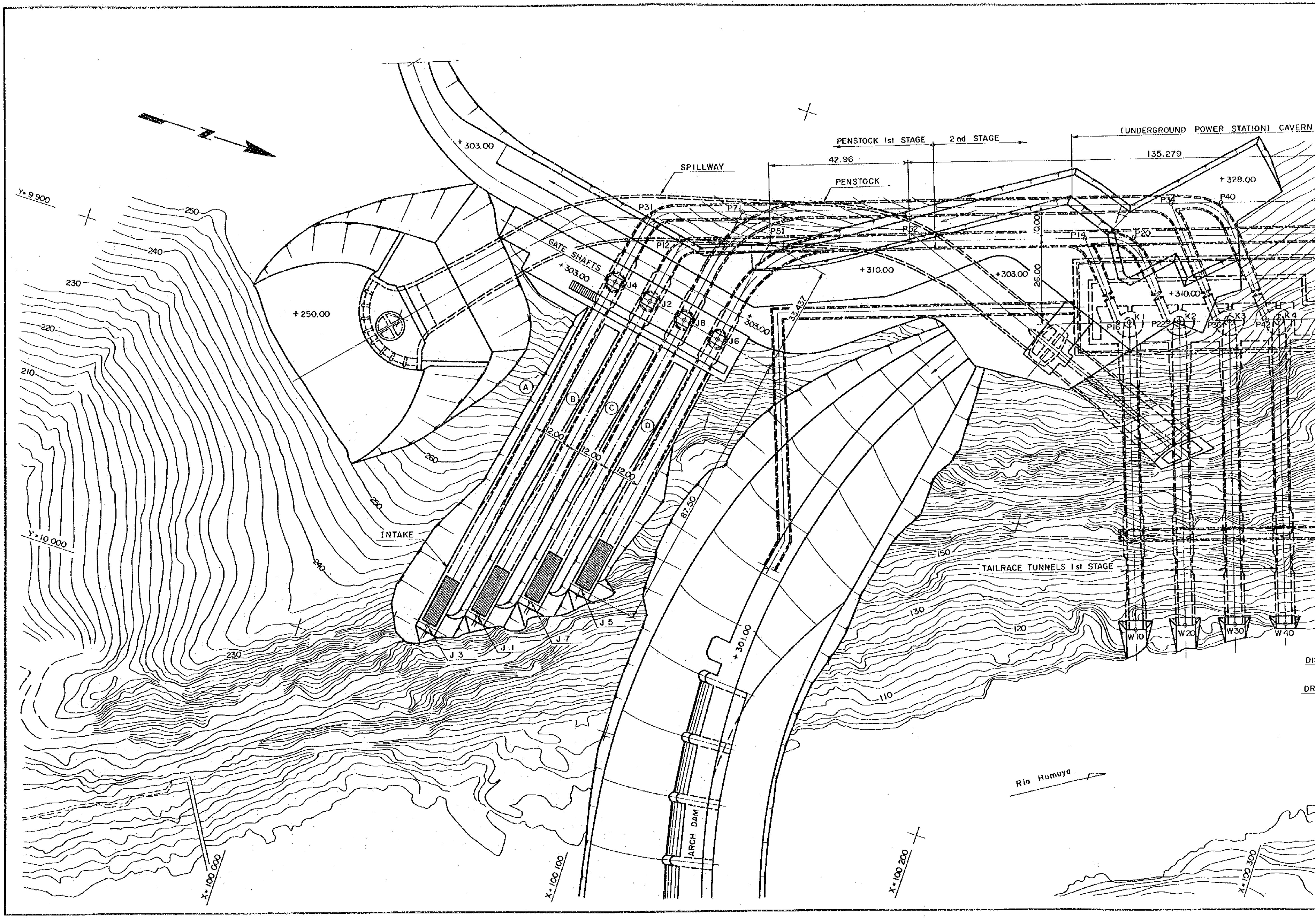
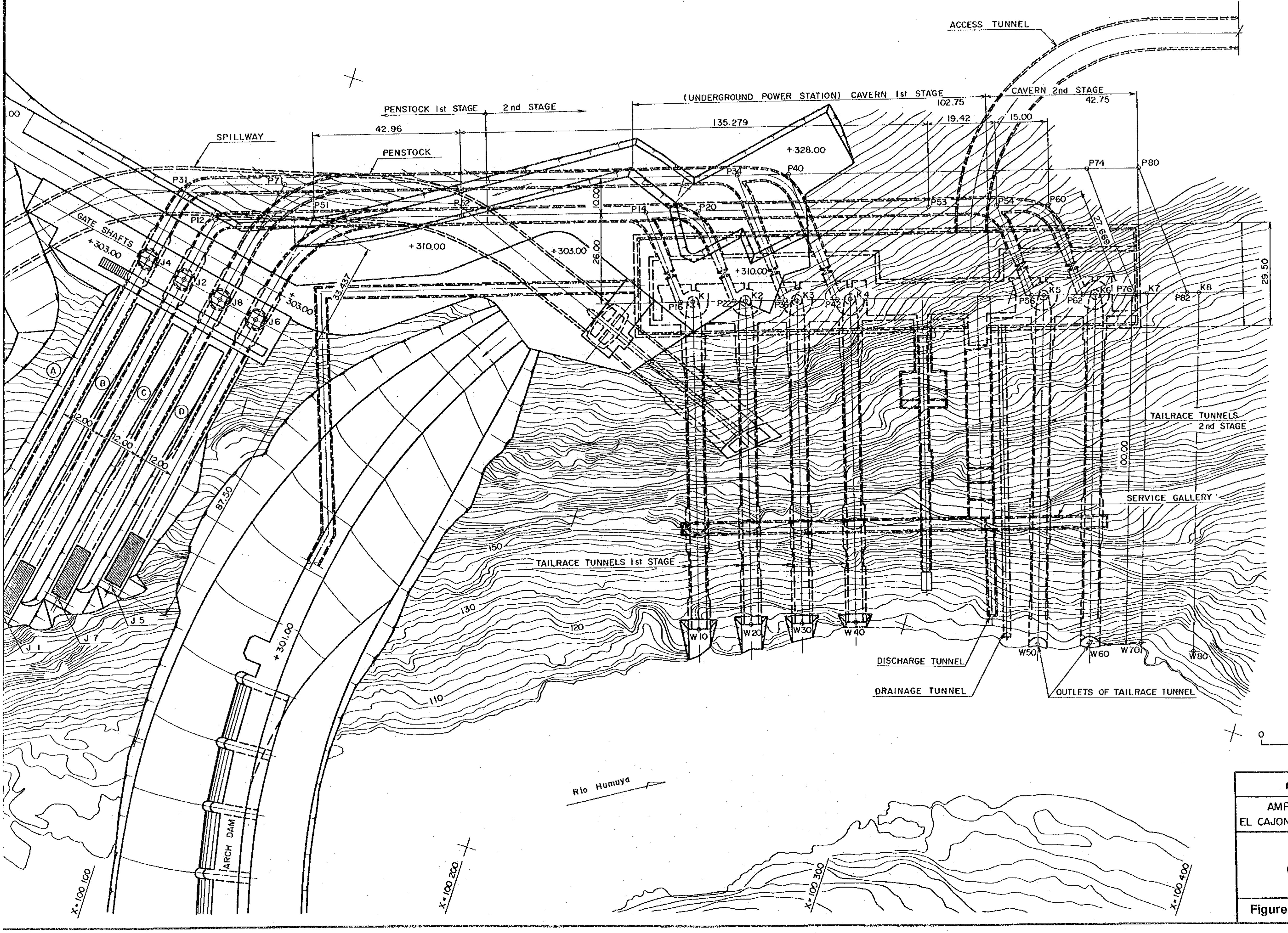
AMPLIFICATION PROJECT OF EL CAJON HYDROELECTRIC POWER PLANT

GENERAL LAYOUT

Figure 11-1


N
(UNDERGROUND POWER STATION) CAVERN
PENSTOCK 1st STAGE
2nd STAGE
42.96
135.279
SPILLWAY
PENSTOCK
+303.00
+328.00
+310.00
+303.00
+310.00
+250.00
GATE SHAFTS
+303.00
INTAKE
TAILRACE TUNNELS 1st STAGE
ARCH DAM
+301.00
87.50
33.437
12.00
26.00
10.00
Rio Humuya
Y=9 900
Y=10 000
X=100 000
X=100 100
X=100 200
X=100 300
J1
J2
J3
J4
J5
J6
J7
J8
P7
P12
P14
P18
P20
P22
P31
P33
P40
P51
P52
K1
K2
K3
K4
W10
W20
W30
W40
A
B
C
D



COORDINATES

POINT	X	Y
J 5	100 079.289	9 961.080
J 6	100 095.461	9 875.087
J 7	100 065.462	9 969.673
J 8	100 083.667	9 872.869
P51	100 101.641	9 842.226
P52	100 142.174	9 827.991
P53	100 269.811	9 783.168
P54	100 288.134	9 776.733
P56	100 305.677	9 798.128
P60	100 302.287	9 771.763
P62	100 319.830	9 793.158
P71	100 090.701	9 835.469
P74	100 309.692	9 758.564
P76	100 333.982	9 788.188
P80	100 323.845	9 753.594
P82	100 348.135	9 783.218
K5	100 309.030	9 796.951
K6	100 323.183	9 791.981
K7	100 337.335	9 787.010
K8	100 351.488	9 782.040
W50	100 338.852	9 892.401
W60	100 353.005	9 887.431
W70	100 367.157	9 882.460
W80	100 382.205	9 880.353

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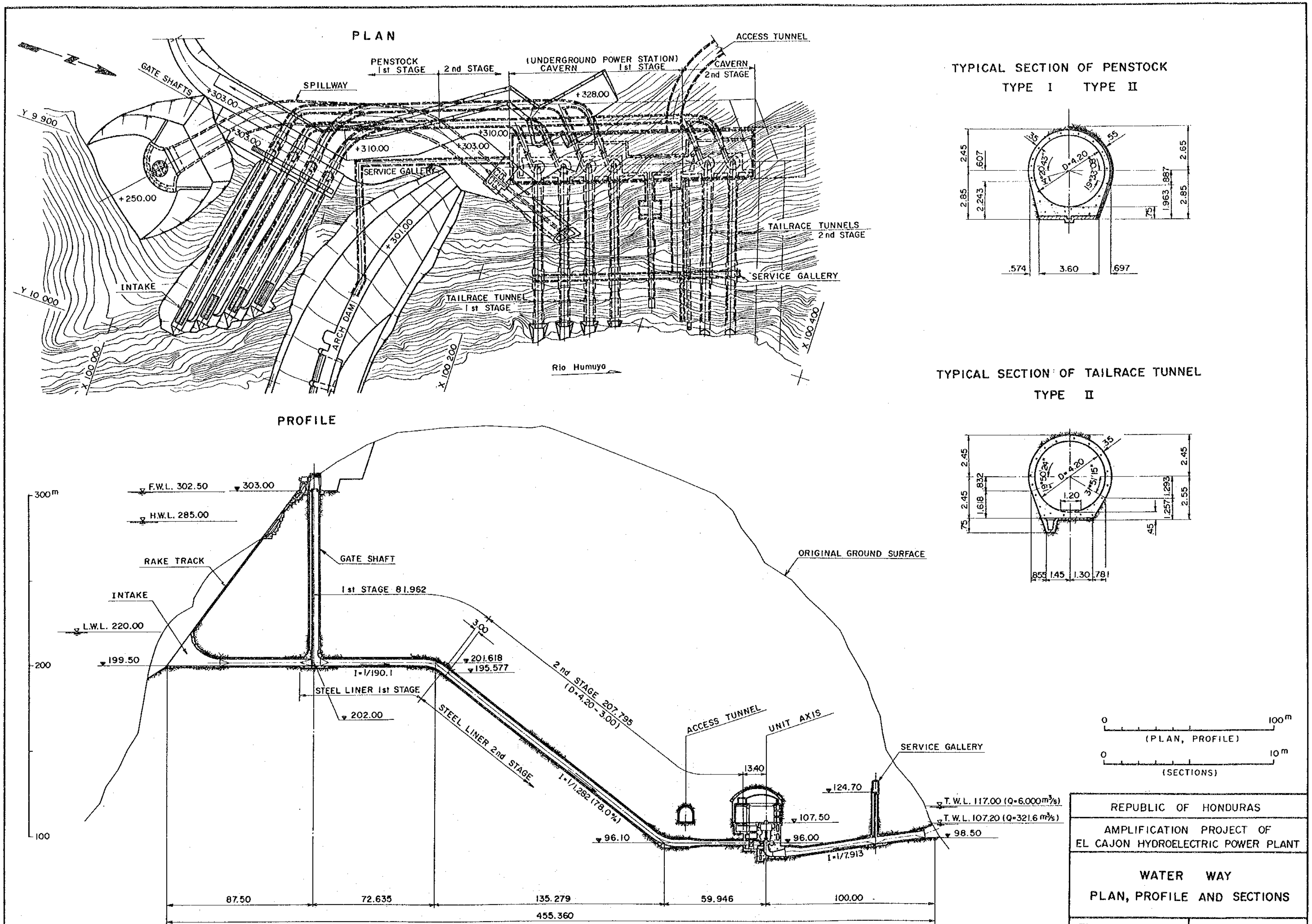
AMPLIFICATION PROJECT OF
EL CAJON HYDROELECTRIC POWER PLANT

GENERAL PLAN

Figure 11-2



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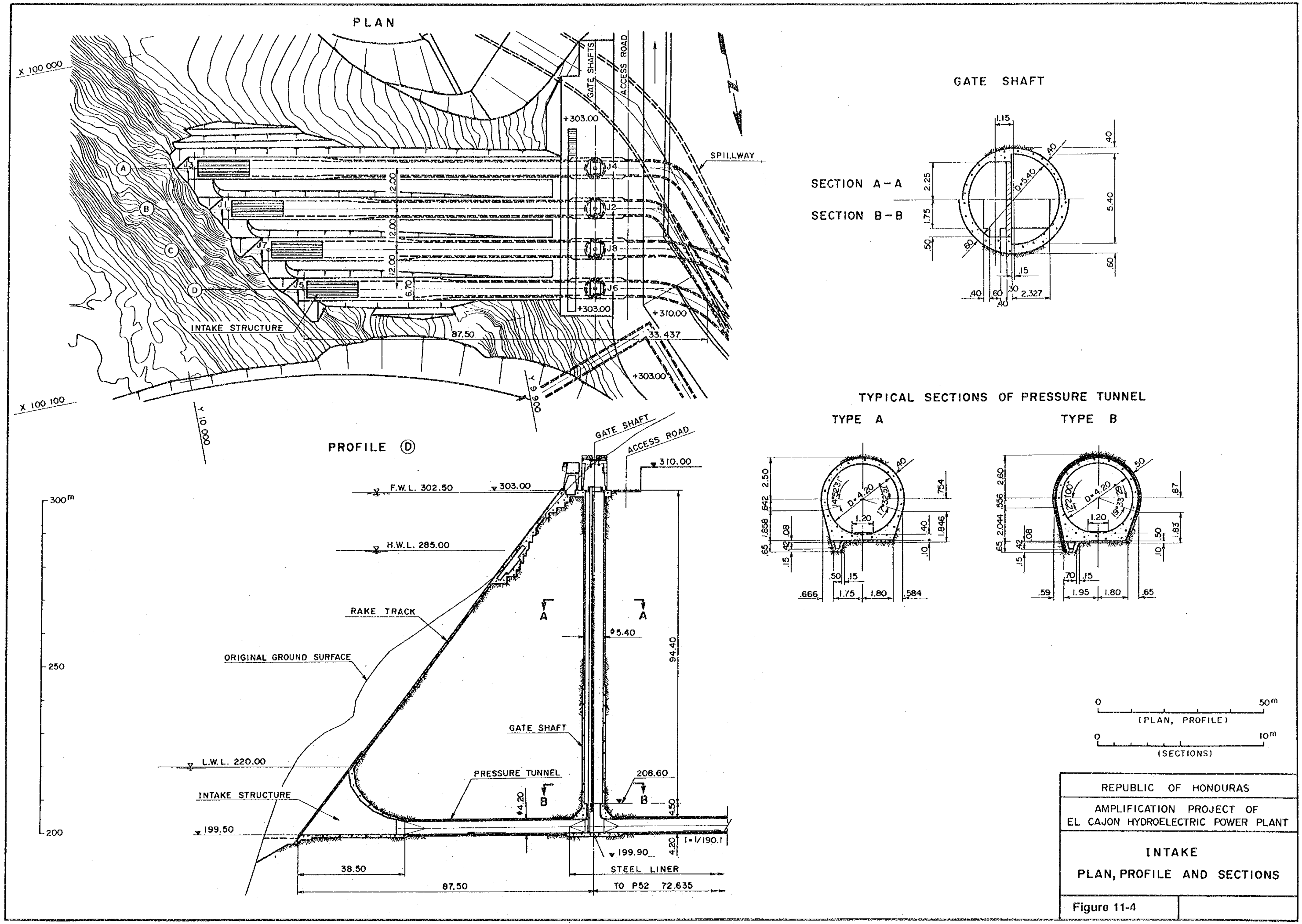
WATER WAY
PLAN, PROFILE AND SECTIONS

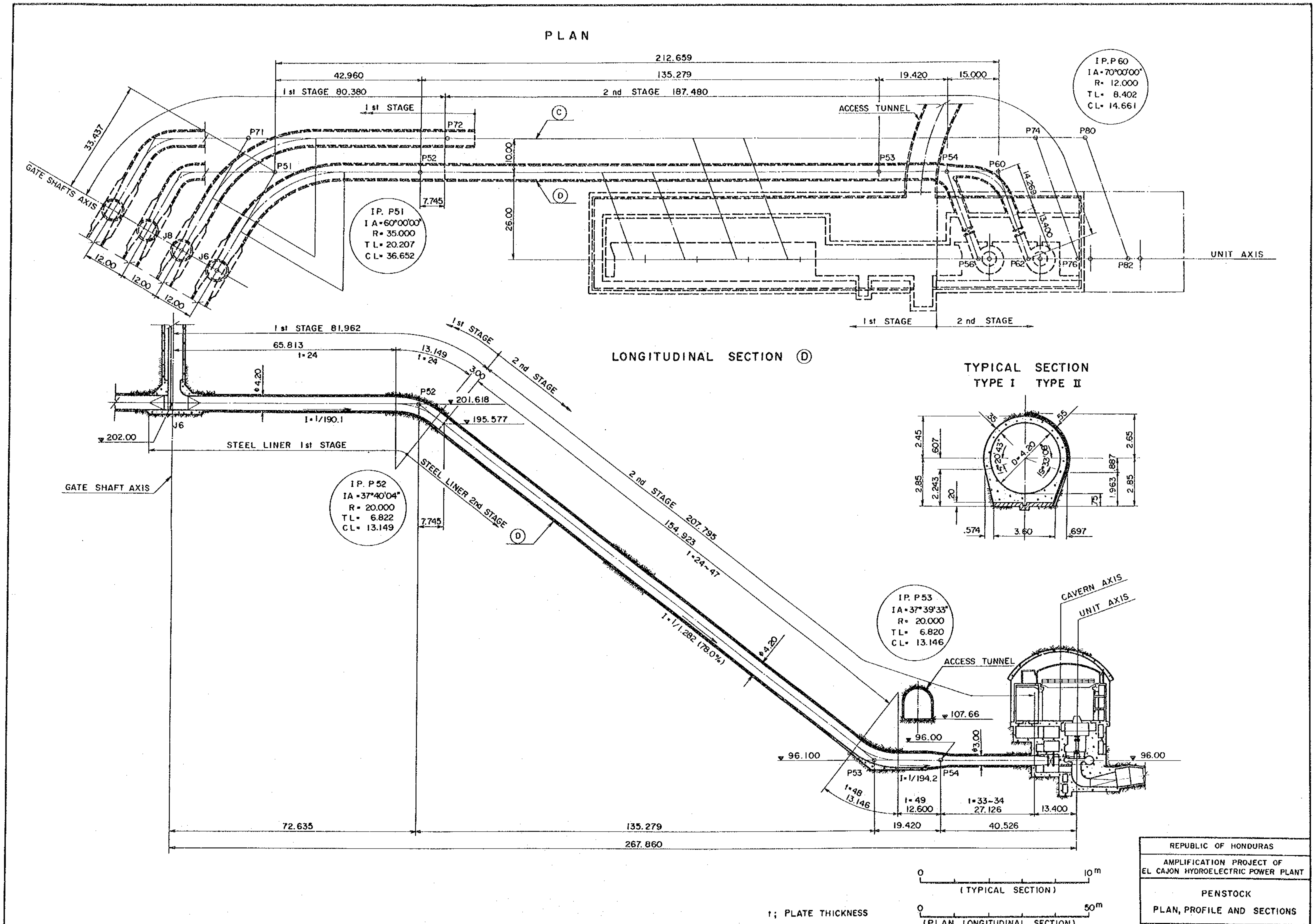
Figure 11-3



INTAKE

PLAN, PROFILE AND SECTIONS

Figure 11-4


PLAN
212.659
42.960
135.279
19.420
15.000
1st STAGE 80.380
2nd STAGE 187.480
1st STAGE
ACCESS TUNNEL
I.P. P60
IA = 70°00'00"
R = 12.000
TL = 8.402
CL = 14.661
33.437
GATE SHAFTS AXIS
P71
P72
P51
P52
P53
P54
P60
P74
P80
P56
P62
P76
P82
J8
J6
12.00
12.00
12.00
7.745
10.00
26.00
14.269
13.400
I.P. P51
IA = 60°00'00"
R = 35.000
TL = 20.207
CL = 36.652
UNIT AXIS
1st STAGE
2nd STAGE
LONGITUDINAL SECTION (D)
1st STAGE 81.962
65.813
t = 24
13.149
t = 24
3.00
1st STAGE
2nd STAGE
ϕ4.20
P52
201.618
195.577
J6
i = 1/190.1
202.00
STEEL LINER 1st STAGE
GATE SHAFT AXIS
I.P. P52
IA = 37°40'04"
R = 20.000
TL = 6.822
CL = 13.149
7.745
STEEL LINER 2nd STAGE
2nd STAGE 207.795
154.923
t = 24~47
i = 1/1.282 (78.0%)
ϕ4.20
I.P. P53
IA = 37°39'33"
R = 20.000
TL = 6.820
CL = 13.146
ACCESS TUNNEL
CAVERN AXIS
UNIT AXIS
107.66
96.00
ϕ3.00
96.100
96.00
P53
P54
i = 1/194.2
t = 48
13.146
t = 49
12.600
t = 33~34
27.126
13.400
72.635
135.279
19.420
40.526
267.860
TYPICAL SECTION
TYPE I TYPE II
35
55
2.45
.607
2.85
2.243
.20
2.65
.887
2.85
1.963
.75
D = 4.20
.574
3.60
.697
0 10m
(TYPICAL SECTION)
0 50m
(PLAN, LONGITUDINAL SECTION)
t; PLATE THICKNESS
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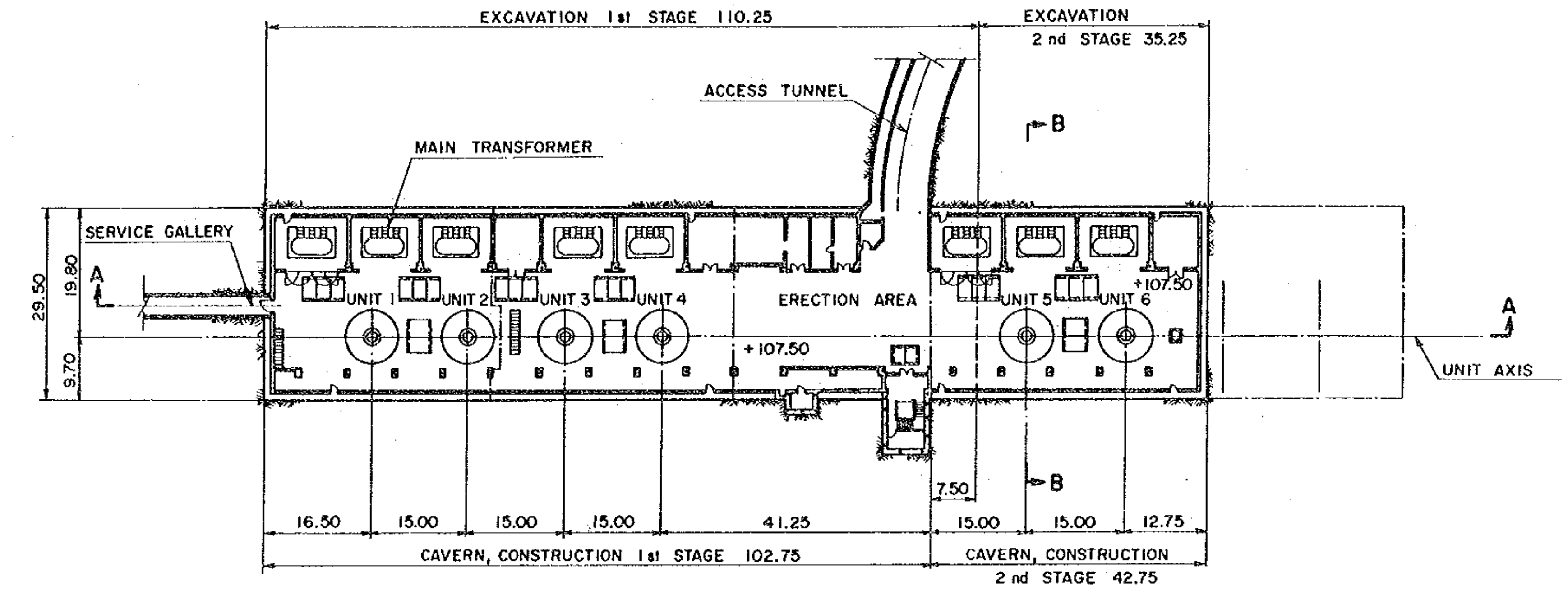
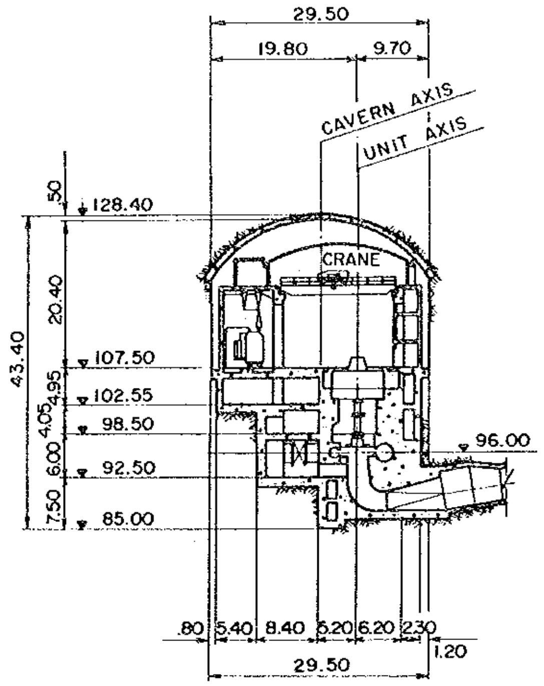
PENSTOCK
PLAN, PROFILE AND SECTIONS

Figure 11-5

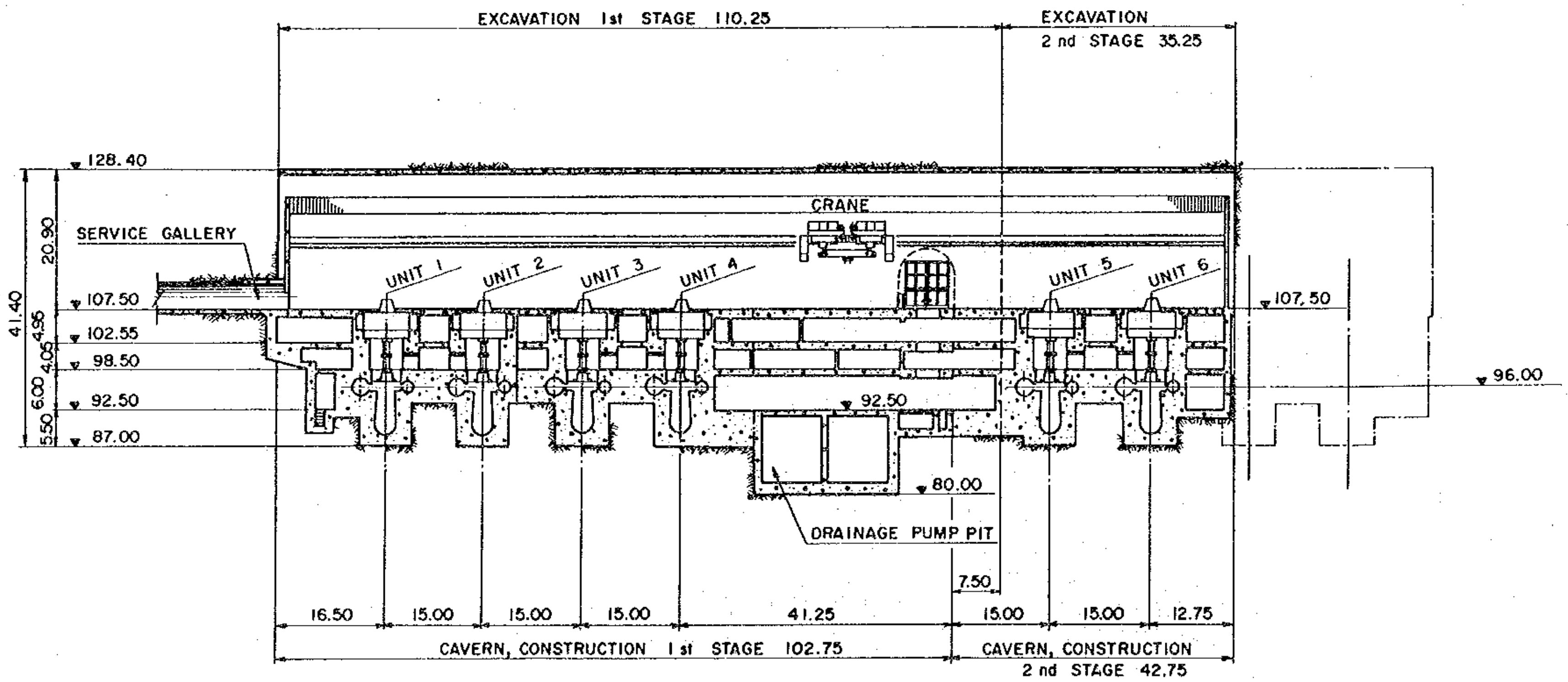
PLAN AT EL. 107.50



B — B



A — A



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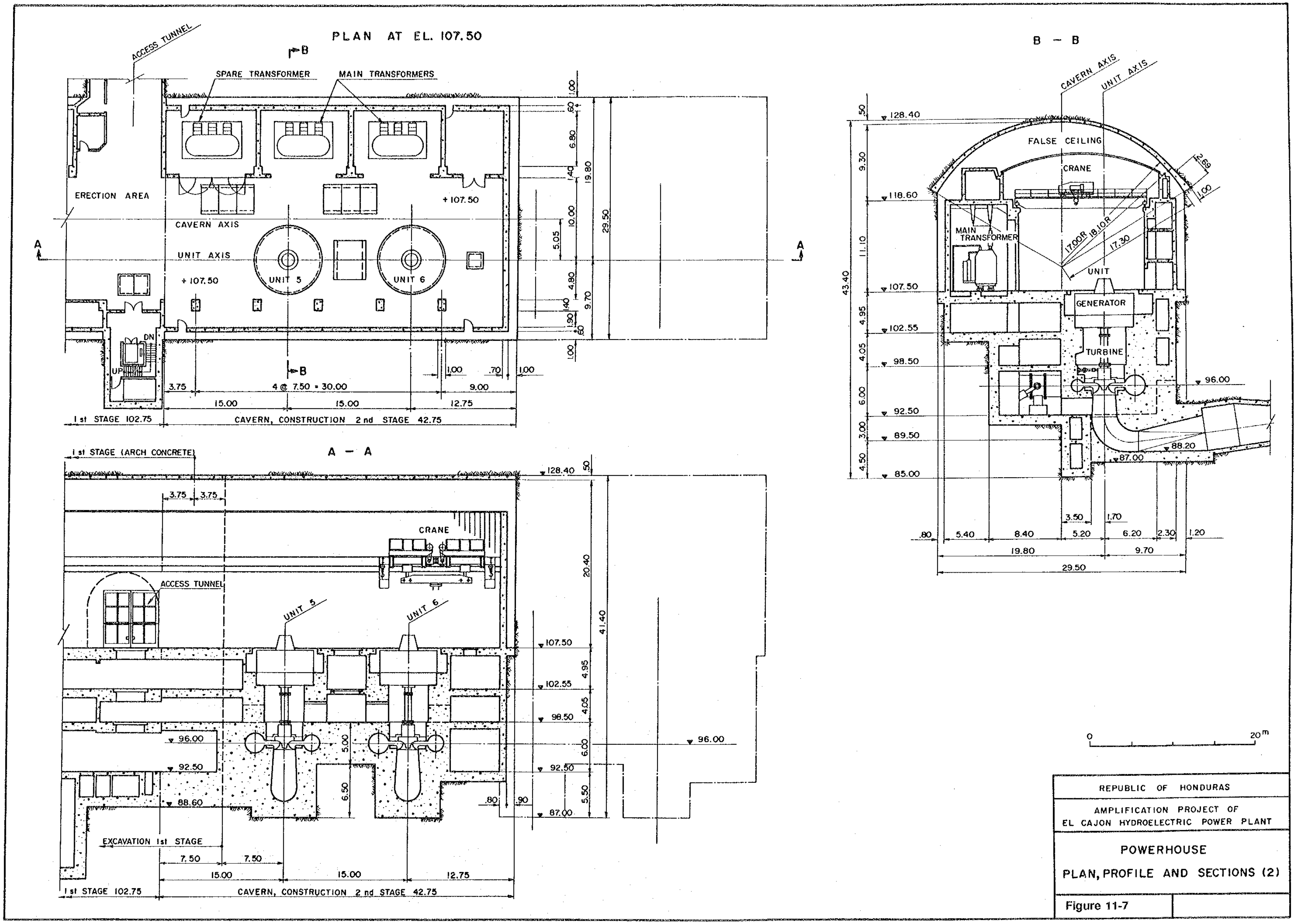
AMPLIFICATION PROJECT OF
EL CAJON HYDROELECTRIC POWER PLANT

POWERHOUSE

PLAN, PROFILE AND SECTIONS (I)

Figure 11-6



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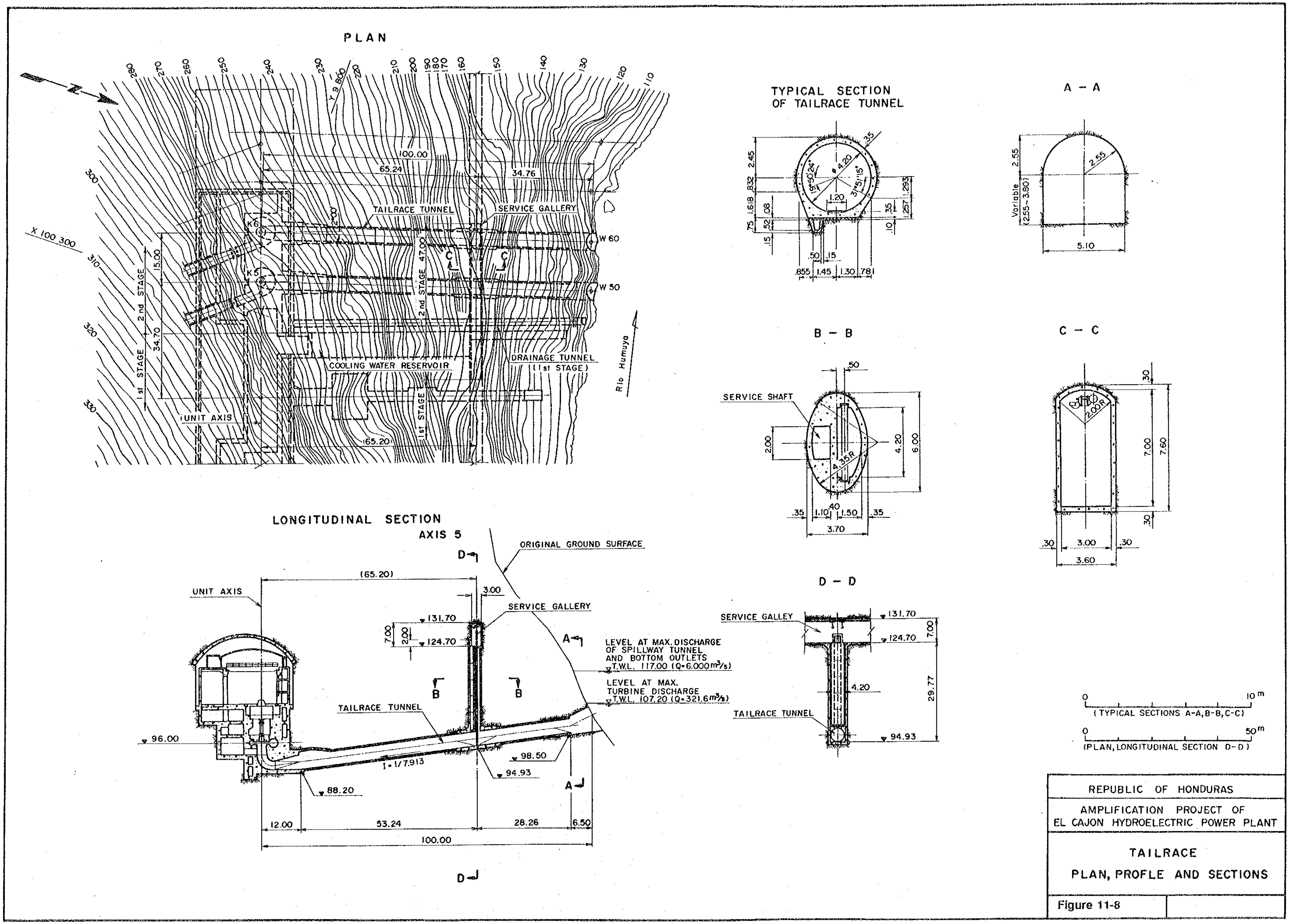
POWERHOUSE

PLAN, PROFILE AND SECTIONS (2)

Figure 11-7



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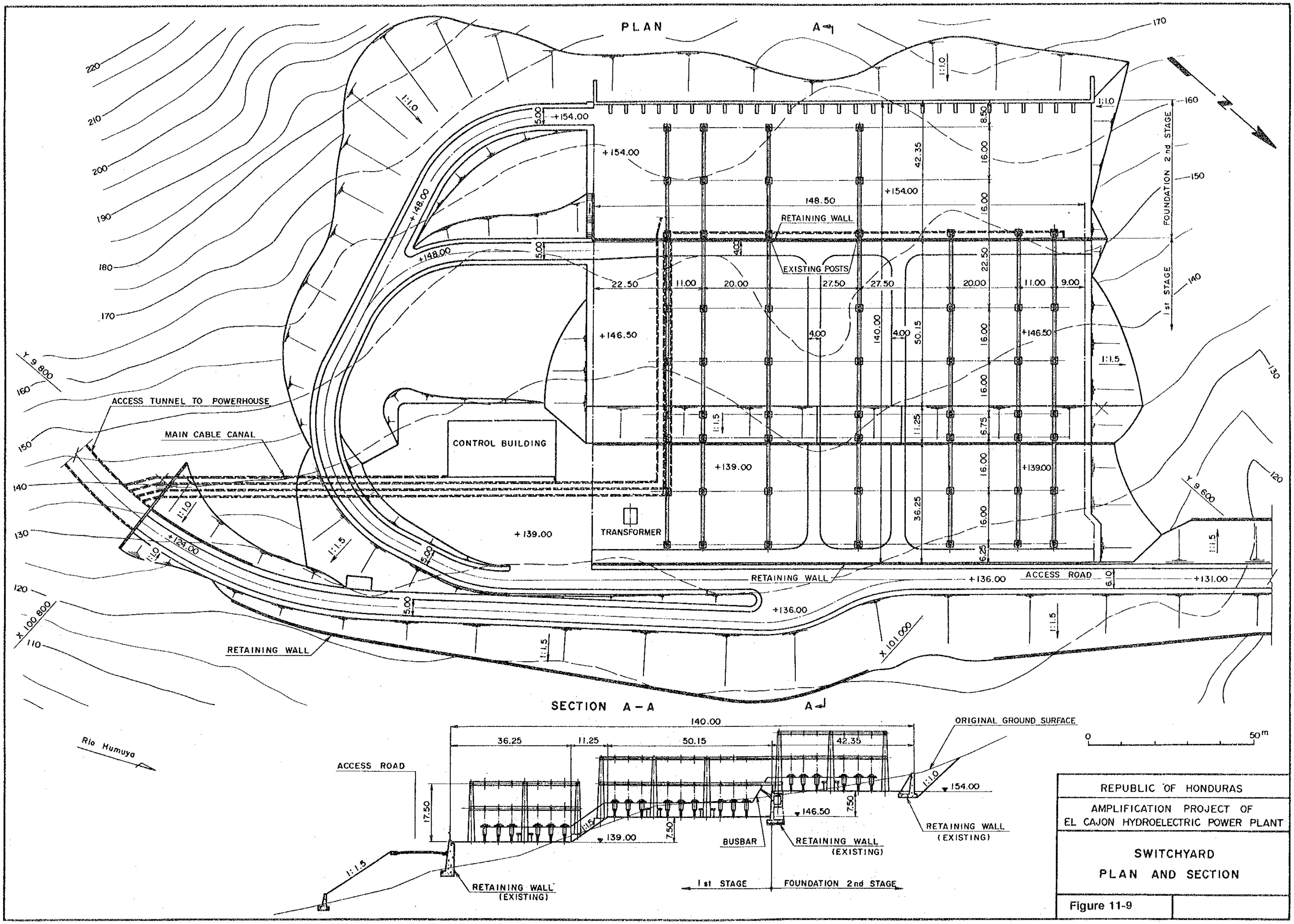
AMPLIFICATION PROJECT OF EL CAJON HYDROELECTRIC POWER PLANT

TAILRACE

PLAN, PROFLE AND SECTIONS

Figure 11-8


PLAN
A
SECTION A – A
ACCESS TUNNEL TO POWERHOUSE
MAIN CABLE CANAL
CONTROL BUILDING
TRANSFORMER
RETAINING WALL
EXISTING POSTS
ACCESS ROAD
FOUNDATION 2nd STAGE
1st STAGE
+154.00
+148.00
+146.50
+139.00
+136.00
+131.00
+124.00
Y 9 800
Y 9 600
X 100 800
X 101 000
Rio Humuya
ORIGINAL GROUND SURFACE
BUSBAR
RETAINING WALL (EXISTING)
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EL CAJON HYDROELECTRIC POWER PLANT
SWITCHYARD
PLAN AND SECTION
Figure 11-9

Chapter 12 CONSTRUCTION SCHEDULE AND CONSTRUCTION COST

Chapter 12

Construction Schedule and Construction Cost

Contents

List of Tables

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Chapter 12 Construction Schedule and Construction Cost

12.1 Construction Planning and Construction Schedule

12.1.1 Basic Conditions

The basic conditions of the studies conducted in formulating the construction planning and construction schedule of the Amplification Project are described below.

(1) Meteorology

The meteorological conditions of this Project Site have been described in Chapter 6. The construction schedule has been formulated based on the assumption that the construction works can be implemented throughout a year.

(2) Transportation Route

The major materials/equipment, hydraulic equipment and electromechanical equipment that were used for the construction of the existing El Cajón Hydroelectric Power Plant were landed at Puerto Cortes Port, facing the Caribbean Sea, and transported by land to the Project Site.

In this Amplification Project, the same route is deemed to be most appropriate, based on the evaluation of the unloading facilities of the harbor and the transportation road, and because the unit capacity of the generator units has not been changed from that of existing units.

The transportation route is shown in **Fig.12-1**.

(3) Construction Materials and Equipment

(a) Cement

In Honduras, cement is being produced in factories near San Pedro Sula and Comayagua. As the amount of the cement required for this Amplification Project is estimated to be approximately 4,800 tons, it is deemed that there will be no problem in the cement supply.

(b) Concrete Aggregate

For the supply of the concrete aggregate, there exist appropriate natural aggregates in the basin of Humuya River, and it is planned to purchase these aggregates.

12.1.2 Construction Planning

(1) General

The excavation works must be conducted with sufficient care so that the existing structures are not affected. For this reason, the excavation works are mainly implemented by the controlled blasting. For certain locations which are near the existing structures, the low speed explosives will be used for excavation works.

Since the blasting operations will be generally conducted near the powerhouse which is being operated, the induction by the leakage current from the powerhouse may pose a problem. To deal with this problem, it is required to adopt the system which is designed to prevent the explosion induced by the leakage current.

(2) Work adits

Santa Barbara Tunnel is one of the work adits that have been constructed for the first stage construction work. This adit has a cross section of 4.50 m in width and 4.25 m in height. The adit approaches the powerhouse from the downstream site, and it branches to two directions inside the adit.

One branch reaches the service gallery which was used in the first stage construction work, and this branch will be used for the construction of the service gallery and work shaft for the Amplification Project. Another branch reaches to the arch of the powerhouse cavern, and this adit will be used for the construction work of the arch of the Amplification Project.

In addition, there is a work adit which branches from the access tunnel and was used for the construction of powerhouse, tailrace and penstock in the first stage construction work.

This work adit will also be used in Amplification Project. The adit will be extended to the points at EL 106.30 m, EL 93.50 m and EL 85.50 m on the middle stage of the powerhouse, and used for construction of the powerhouse, tailrace and penstock. The existing access tunnel will be used for the excavation of the main powerhouse and transportation of construction materials and equipment including the concrete. The inside cross section of this access tunnel is currently 8.70 m in width and 9.2 m in height. However, as this access tunnel is currently being used as the cable tunnel, the cross section which can be utilized as a transportation tunnel has a width of 6.70 m (including the side-walk, 1.70 m wide), and the traffic of both directions is impossible.

Therefore, it is required to expand the width of the access tunnel at several locations to provide the turnouts, to enable the traffic of both directions.

In addition, in order to use the tunnels branching out of the access tunnel as work adits, the tunnel width must be expanded at the branching points, and the existing low voltage cables must be moved during the construction work.

To let in the penstock segments and other materials/equipment, a work shaft, having a 5.20 m in diameter, will be constructed from the ground at EL 310.00 m on the left bank of the dam to the point near EL 185.00 m on the inclined shaft. In addition, a horizontal work shaft will be constructed from a point near EL 200.00 m on this vertical shaft to the terminal of the inclined shaft.

The vertical work shaft for construction of the penstock is shown in **Fig.12-2**, and the layout of the work shafts for construction of the powerhouse and tailrace is shown in **Fig.12-3**.

(3) Penstock

(a) Excavation

The total length of the inclined shaft is 230.00 m, and the average excavation diameter of the shaft is 5.45 m.

For the excavation work, the pilot shaft will be completed by excavating it from the bottom, and this pilot shaft will be expanded to the specified diameter from the upper end, by using the pilot shaft as the muck chute.

For excavation of the pilot shaft, the lower work shaft that branches from the access tunnel is used, and the pilot shaft will be excavated by using an Alimak raise climber from the lower end of the inclined shaft. The pilot shaft will be a bottom heading type, with its cross section being a 2.00 m x 2.00 m square.

When the excavation of the pilot shaft by Alimak climber is completed, the vertical work shaft for transportation of penstock components will be excavated from the middle of the inclined shaft by using Alimak climber. Then, the expansion of the vertical work shaft from the ground at EL 310.00 m on the left bank of the dam will be started, and next the inclined shaft will be expanded by excavation.

For the expansion work of the inclined shaft, the pilot shaft which is already completed will be used as the muck chute, and the excavation work will be performed from the upper end by using the machine drill mounted on a drill jumbo. After the muck is treated, steel meshes will be placed on the necessary parts of the rock beds, shotcrete will be shot, rock bolt holes will be drilled and rock bolts will be inserted. Steel supports will be used in locations where the rock bed quality is particularly poor.

The transportation of construction materials/equipment from the ground surface will be performed through the vertical shaft which is excavated from the ground at EL 310.00 m for the purpose of taking in the penstock segments. The muck will be disposed of from the lower end of the inclined shaft via the existing access tunnel by a combined use of tractor shovels and 4-ton class dump trucks.

The excavation method of the penstock shaft is shown in **Fig.12-4.**

(b) Concrete

The filling concrete will be filled to the gaps between the penstock and natural ground, starting from the lower end of the inclined shaft, step by step in synchronism with the installation of the penstock. The section to be filled in a single concrete placement operation will be for 2 segments of the penstock (12.00 m in length) as the standard procedure.

For concrete placement operation, a hopper will be installed at the mouth of the vertical shaft at EL 310.00 m, and the concrete will be supplied by the pipe chute connected to the hopper. That is, the concrete transported by truck mixers are first charged into the hopper, and then dropped to the work shaft via the pipe chute. In this concrete placement operation, a special consideration is required to prevent the segregation of the concrete.

(c) Installation of Penstock

The penstock segments are transported to the mouth of the vertical shaft at EL 310.00 m on trailer trucks, hung by a 30-ton class gantry crane here, lowered through the vertical shaft, and then lowered through the inclined shaft by means of an incline. The standard length of a single penstock segment is 6.00 m. The transportation and installation procedure are shown as below.

- Shop assembly
- Transportation (by trailer truck)
- Hanging on the vertical shaft (by crane)
- Lowering through inclined shaft (by incline)
- Installation

The installation procedure of the penstock is shown in Fig.12-5.

(4) Powerhouse

(a) Excavation

The excavation of the powerhouse cavern is performed in 3 phases. Excavation phase-1 is the excavation down to EL 119.00 m which is performed by utilizing Santa Barbara Tunnel, and excavation phase-2 is the excavation down to EL 106.30 m which is performed by utilizing the horizontal shaft, for the purpose of excluding the muck, and which is to be constructed by branching out from the existing access tunnel. Excavation phase-3 is the excavation below EL 106.30 m, which is also to be performed by utilizing the horizontal shaft, for the purpose of excluding the muck, and which is to be constructed by branching out from the existing access tunnel.

Although the natural ground around the powerhouse cavern consists of hard rock, a collapse accident was experienced when the arch was being excavated in the first stage construction work, and it will be required to carefully study the excavation method in implementing this construction work.

The arch excavation will be performed down to EL 119.00 m by utilizing the existing Santa Barbara Tunnel. The excavation will be performed by means of the 2-boom, hydraulic crawler jumbo. The muck will be disposed of by means of the combination of tractor shovels and 4-ton class dump trucks by utilizing the existing Santa Barbara Tunnel.

The supporting work of the rock in arch will be implemented without using steel supports but by means of rock bolts and shotcrete.

Excavation phase-2 for the excavation of the main section of the powerhouse cavern will be proceeded by the construction of the horizontal shaft, for muck disposal, which will be constructed at EL 106.30 m by branching out from the existing access tunnel, and a glory hole (3.00 m x 3.00 m) will be constructed upward by means of the crater cut method. This method is an excavation method which is described below. First, the long-reaching drilling machine (such as a crawler drill) is set to drill the required blast holes, until the hole reaches the bottom of the horizontal shaft. When the hole is pierced, the first stage from the lower end (approximately 3 m) is blasted by securing a sufficient hole length. The securing of hole length and the charging of the explosive are performed from the upper end. As soon as the blasting of the first stage is completed, another hole length is secured to perform the second stage blasting. Repeating this procedure, excavation is performed from the lower end to the upper end of the hole.

The excavation muck is pushed into the muck disposal horizontal shaft by a bulldozer by utilizing this glory hole. The muck is then transported out via muck disposal horizontal shaft and access tunnel by means of the combination of tractor shovels and 8-ton class dump trucks.

The excavation of the powerhouse cavern is performed by the bench cut method, with the standard bench height of 3.00 m. The 2-boom hydraulic crawler jumbo will be used for this operation.

After excavation and muck disposal are completed, steel meshes will be placed on necessary parts, shotcrete will be shot on it, rock bolt holes will be drilled, and rock bolts will be inserted.

The standard procedure of this excavation operation is described by the following steps.

- Drilling and blasting
- Muck disposal
- Shotcreting
- Rock bolt hole drilling
- Mortar injection
- Rock bolt insertion

The excavation procedure of the main part of the powerhouse cavern is shown in **Fig. 12-6**.

In performing excavation phase-3 for the main part of the powerhouse cavern, a muck disposal horizontal tunnel will be constructed by branching the existing access tunnel at EL 93.50 m prior to the excavation. (This tunnel is also used to dispose of the excavation muck from the penstock inclined shaft.) Similarly to the excavation phase-2, the glory hole (3.00 m x 3.00 m) that is excavated by the crater cut method is utilized to dump the excavation muck to this muck disposal horizontal shaft, and the muck is transported out from here via the muck disposal horizontal shaft and the access tunnel by means of tractor shovels and 8-ton class dump trucks.

After the excavation muck is disposed of, steel meshes will be placed on necessary parts, shotcrete will be shot on it, rock bolt holes will be drilled, and rock bolts will be inserted.

The excavation at level below EL 93.50 m will be performed by cutting down the floor toward the horizontal work shaft (EL 85.50 m) which is constructed for excavation of the tailrace tunnel.

(b) Concrete

At the stage where the excavation of the arch has proceeded half way, the placement of arch concrete will be started by using a 29.50 m wide, 5.00 m long slide form. The concrete will be brought in by 2 m^3-class truck mixers via Santa Barbara Tunnel, supplied to the concrete pump and placed.

When the arch concrete placement is completed, mortar grouting will be implemented to prevent the expansion of the loose rock zone in the arch and the weathering of the rock bed.

The concrete of foundations, slabs, piers, casings and barrels will be placed by concrete pumps. The concrete will be delivered by 3 m^3-class truck mixers via the access tunnel and the work adits constructed toward EL 106.30 m or EL 93.50 m, supplied to concrete pumps and placed. As for the forms, the slide forms and assemble forms are used as appropriate.

The concrete is placed up to the level of EL 94.00 m after the draft tubes will be installed. At this stage, however, it will not be possible to use the overhead crane, and it will be required to use a mobile crane or so for installation of draft tubes.

Then, the concrete of side walls, piers, slabs, etc. will be placed up to EL 107.50 m. Following this stage, the crane post concrete and the crane beam concrete will be placed, and the crane rails will be installed in order to make the overhead crane available. At this stage, it will become possible to use the overhead crane.

After installing the casing by using the overhead traveling crane, the barrel concrete will be placed.

Then, the concrete of side walls and slabs will be placed in sequence.

(4) Tailrace Tunnel and Tailrace Outlet

(a) Excavation

The tailrace tunnel extends for 88.00 m and its inside diameter is 4.20 m. The excavation will be performed in two stages. The first stage is the excavation of the tailrace tunnel up to the point which is several meters inside from the tailrace outlet. The second stage is the excavation of the tailrace outlet section which remains after the tailrace gates are installed.

In the excavation of the tailrace tunnel in the first stage, the excavation work will be performed by the full face cutting method by utilizing the muck disposal horizontal tunnel which branches out from the existing access tunnel toward EL 85.50 m. The tunnel support will be provided by rock bolts and shotcrete, but steel supports may be used where the rock bed quality is poor. The first stage excavation will be implemented for the whole tailrace tunnel except the plug rock which will be excavated in the second stage (by one blasting operation). Since a maximum water pressure of around 8.00 m will be applied to this plug rock while the power plant is operating, the last excavation operation in the first stage must be performed with sufficient care. Although the thinner the plug rock the better, the actual thickness must be decided with due consideration on the rock bed conditions.

The method of excavating the plug rock of the tailrace outlet is shown in **Fig. 12-7**.

The excavation will be implemented by a 2-beam hydraulic crawler jumbo, and the muck disposal will be implemented by tractor shovels and 8-ton class dump trucks.

The second stage excavation will be implemented by almost one blasting operation at the stage where the concrete lining of the tailrace tunnel and the installation of the tailrace gates are completed. In this blasting operation, the impact of explosion must be suppressed to the minimum by employing the low speed explosive or other appropriate means. The excavation muck will be dumped into the river. For this blasting operation, the existing power plant operation will have to be shut down to lower the tailwater level. As it may be necessary to shape the tailrace outlet section and its upstream section, it will have to be necessary to shut down power generation for this operation, too.

(b) Concrete

The concrete lining will be started when the first stage excavation is completed and the excavation of the service shaft is finished.

The concrete is delivered by means of 2 m^3 class truck mixers via the access tunnel and the lower work shaft, and the concrete will be placed by concrete pumps around the whole cross section of the tailrace by means of the 5-meter length slide form.

(6) Service Gallery and Service Shaft

(a) Excavation

The service gallery will be constructed by expanding the existing Santa Barbara Tunnel.

The muck disposal will be implemented by the combination of rocker shovels or tractor shovels and 4-ton class dump trucks, through the existing Santa Barbara Tunnel.

The excavation of the service shaft will be implemented after the tunnel expansion for the service gallery is completed by the crater cut method, excavating the shaft from this gallery toward the lower tailrace tunnel. The excavation muck will be dumped to the tailrace tunnel, and disposed of to the outside of the tunnel via tailrace tunnel, lower work shaft and access tunnel.

(b) Concrete

The concrete will be delivered via Santa Barbara Tunnel by means of 2 m^3 class truck mixers, and placed by concrete pumps.

The slide form will be used for the service shaft, and concrete will be placed from bottom toward ceiling.

(7) Temporary Facilities

(a) Construction Road

It is not required to particularly construct a new construction road for this Project. Basically, the roads constructed for the first stage work can be used as such, and improvement works will be conducted if there are places that have to be implemented.

(b) Electric Power for Construction

The electric power needed for the construction works will be received from El Cajón Substation, and delivered to the project site by a 13.8 kV power line.

(c) Concrete Facilities

The total volume of the concrete needed will be approximately 15,000 m^3. The concrete aggregates will be purchased.

The concrete plant will be installed on the site located downstream from the dam, on the right bank of Humuya River, where the concrete plant for the first stage work was once installed.

The capacity of the concrete plant will be a 50 m^3/hour class.

(d) Compressed Air Supply Facility

The compressed air needed for the construction work will be supplied by fixed type facilities in principle, which will be installed at the entrances of Santa Barbara Tunnel, access tunnel and the inclined shaft.

(e) Water Supply Facility

To provide the utility water for the construction work, the water of Humuya River will be conducted and stored in a storage tank. The stored water will be supplied to the work sites and the concrete plant.

(f) Camp Facilities

The camp facilities required will be, in addition to the construction office building of ENEE, the contractors' office buildings, material warehouses, repair shops, the temporary shop for the penstock, etc. The lands and buildings that were used in the first stage construction work will be basically utilized (as much as possible).

12.1.3 Construction Schedule

The construction period required for this Amplification Project is approximately 4 years for Stage I (for Unit-5, commissioned in 2002), and approximately 2 years for Stage II (for Unit-6, commissioned in 2006).

The major amounts of civil work and the construction schedule are presented in **Table 12-1** and **Fig. 12-8**.

12.2 Construction Cost

12.2.1 Cost Estimation Items

(1) Preparation Works

- Construction office, lodging facilities, etc.

(2) Environmental Mitigation

- Measures against effect of power plant discharge to the downstream regions

(3) Civil Works

- Work adit
- Penstock
- Powerhouse
- Tailrace and tailrace outlet
- Service gallery and service shaft
- Temporary facilities (concrete plant, etc.)

(4) Hydraulic Equipment

- Penstock
- Tailrace gate

(5) Electrical Equipment

- Water turbines, generators and auxiliary equipment
- Outdoor switchyard equipment

(6) Transmission Power Line

- All costs incurred by the construction of the transmission power line

(7) Administration and Engineering Service

- Project management fee
- Engineering fee

(8) Contingency

(9) Interest during Construction

12.2.2 Cost Estimation Criteria

(1) Basic Conditions

(a) Time Point of Cost Estimation and Currency Exchange Rate

The time point for cost estimation is October, 1992. The currency exchange rate is US$1 = 5.8 Lempira. The construction costs are given in terms of US dollars.

(b) Labor Cost and Material Unit Price

The domestic unit prices in Honduras are adopted in determining the labor costs and material unit prices. Major labor/material unit prices are shown in **Table 12-2** and **Table 12-3**.

(c) Construction Machinery

All major construction machines, such as Alimak climbers, crawler drills, dump trucks, large truck cranes, batcher plant, and boring machines are imported. The prices of these construction machines are estimated based on their market prices in Japan and converted to the CIF prices at Puerto Cortes harbor.

(2) Preparation Works

The cost of the preparation works is calculated as 15% of the total civil work cost.

(3) Environmental Mitigation

The environmental mitigation cost is not taken into account, because, as discussed in Chapter 13, no serious environmental impact is produced by the Amplification Project.

(4) Civil Works

The cost of civil works is estimated based on the labor costs and material equipment costs as of October, 1992, and then comparing these calculated costs with the construction costs of projects in Honduras which are being studied or under construction, and which are similar to this Amplification Project, and at the same time by referring to the construction costs of similar projects in Japan.

(5) Hydraulic Equipment

All hydraulic equipment including the tailrace gates and penstock is assumed to be imported. The unit costs of this hydraulic equipment are estimated by referring to the costs in similar projects under construction in Honduras, and the actual costs incurred in similar projects in Japan.

(6) Electromechanical Equipment

All electromechanical equipment is assumed to be imported. The unit costs were estimated by referring to the actual international costs.

(7) Transmission Power Line

The transmission power line cost is not counted, because, as discussed in Chapter 10, the capacity of the existing transmission power line is sufficient even after this Amplification Project is implemented.

(8) Administration and Engineering Service

The administration and engineering fees are estimated as 10% of the direct construction cost.

(9) Contingency

15% of the preparation work costs and civil work costs, and 10% of the costs of hydraulic equipment and electromechanical equipment are estimated as the contingency.

(10) Interest During Construction

The interests during construction are set at 12.0% for domestic currency portion and 8.0% for foreign currency portion.

12.2.3 Classification of Domestic and Foreign Currency Portions

(1) Civil Works

Only cement, timber and fuels such as gasoline are procured in the domestic market, and costs of these items are estimated by the domestic currency. All other items are imported, which are estimated by foreign currencies.

(2) Hydraulic Equipment

All hydraulic equipment is paid by foreign currencies, but the transportation costs from the landing port to the construction site, and the installation costs are paid by the domestic currency.

(3) Electromechanical Equipment and Transmission Power Line

Electromechanical equipment costs are paid by foreign currency. Their inland transportation costs and installation costs are paid by the domestic currency.

(4) Administration and Engineering Service

The administration and engineering fees are paid by the domestic currency for the 35% portion and by the foreign currency for the remaining 65% portion.

12.2.4 Construction Cost

The construction costs, and their domestic currency and foreign currency are shown in **Table 12-4**.

Table 12-1 Principal Civil Works (1/2)

Item		Unit	Quantity
1.	Civil Works		
(1)	Work adit		
	Excavation in tunnel	m^3	9,500
	Excavation in shaft	m^3	2,600
(2)	Pressure shaft		
	Excavation in inclined tunnel (normal blasting)	m^3	1,210
	Excavation in inclined tunnel (controlled blasting)	m^3	2,580
	Excavation in horizontal tunnel (controlled blasting)	m^3	980
	Concrete in filling	m^3	1,840
	Concrete in base	m^3	180
	Mortar grouting	m^3	20
(3)	Powerhouse		
	Excavation in arch	m^3	7,560
	Excavation in main body	m^3	29,130
	Concrete in arch	m^3	830
	Concrete in wall	m^3	2,900
	Concrete in casing and barrel	m^3	2,930
	Concrete in pier and slab	m^3	3,310
	Concrete in base	m^3	1,190
	Mortar grouting	m^3	80
	Shotcrete in wall (t=15cm)	m^2	1,560
	Shotcrete in arch (t=15cm)	m^2	1,390
	Rockbolt in wall (ℓ=4m)	PC	320
	Rockbolt in wall (ℓ=6m)	PC	40
	Rockbolt in wall (ℓ=8m)	PC	70
	Rockbolt in arch (ℓ=4m)	PC	1,390
	Reinforcement bar	t	1,010

Table 12-1 Principal Civil Works (2/2)

Item		Unit	Quantity
(4)	Tailrace tunnel		
	Excavation in tunnel	m^3	4,150
	Excavation in outlet	m^3	180
	Concrete in lining	m^3	1,380
	Concrete in base	m^3	100
	Mortar grouting	m^3	50
	Reinforcement bar	t	70
(5)	Service gallery shaft		
	Excavation in shaft	m^3	850
	Concrete in lining	m^3	470
	Reinforcement bar	t	10
(6)	Service gallery		
	Excavation in tunnel	m^3	1,010
	Concrete in lining	m^3	240
	Reinforcement bar	t	10
2.	Hydraulic equipment		
	Penstock	t	900
	Tailrace gate	t	14

Table 12-2 Labor Cost

Unit: Lempira/day

Item	Labor Cost
Driver	80
Carpenter	60
Mason	50
Plumber	70

Table 12-3 Material Unit Price

Unit: Lempira

Item	Unit	Price
Cement	ton	252
Shape Steel	ton	17,400
Reinforcing Bar (deformed)	ton	2,650
Gasoline	gallon	9.5
Light Oil	gallon	7.2
Timber	m^3	1,100

Table 12 - 4 Project Cost

Unit: Thousand US$

Item		Stage I + Stage II			Stage I			1998			1999			2000			2001			Stage II			2004			2005		
		LC	FC	Total	LC	FC	Total	LC	FC	Total	LC	FC	Total	LC	FC	Total	LC	FC	Total	LC	FC	Total	LC	FC	Total	LC	FC	Total
1. Temporary Works		948	2,211	3,159	758	1,769	2,527	758	1,769	2,527	0	0	0	0	0	0	0	0	0	190	432	632	190	442	632	0	0	0
2. Environmental Mitigation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Civil Works	Item 3.(1)+3.(2)+3.(3) 3.(4)+3.(5)+3.(6)	6,318	14,742	21,060	6,245	14,572	27,817	717	1,674	2,391	4,566	10,653	15,219	913	2,132	3,045	49	113	162	73	170	243	24	57	81	49	113	162
(1) Work adit				4,782			4,782			2,391			2,391			0			0			0			0			0
(2) Pressure shaft				2,780			2,780			0			2,780			0			0			0			0			0
(3) Powerhouse				10,932			10,689			0			7,482			3,045			162			243			81			162
(4) Tailrace tunnel				1,938			1,938			0			1,938			0			0			0			0			0
(5) Service gallery shaft				291			291			0			291			0			0			0			0			0
(6) Service gallery				387			337			0			337			0			0			0			0			0
4. Hydraulic Equipment	Item 4.(1)+4.(2)	290	5,501	5,791	290	5,501	5,791	47	889	936	243	4,612	4,855	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(1) Penstock				5,616			5,616			936			4,680															
(2) Tailrace gate				175			175			0			175															
5. Electro-mechanical Equipment		2,436	46,284	48,720	1,218	23,142	24,360	0	0	0	244	4,628	4,872	487	9,257	9,744	487	9,257	9,744	1,218	23,142	24,360	731	13,885	14,616	487	9,257	9,744
6. Power Transmission Line		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Sub-total	Item 1.+2.+3.+4.+5.+6.	9,992	68,738	78,730	8,511	44,984	53,495	1,522	4,332	5,854	5,053	19,893	24,946	1,400	11,389	12,789	536	9,370	9,906	1,481	23,754	25,235	945	14,384	15,329	536	9,370	9,906
8. Administration & Engineering Service	Item 7.x10%	2,757	5,117	7,874	1,873	3,477	5,350	205	380	585	873	1,622	2,495	448	831	1,279	347	644	991	884	1,640	2,524	537	996	1,533	347	644	991
9. Physical Contingency	[Item 1.+3.]x15%+ [Item 4.+5.+6.]x10%	1,362	7,722	9,084	1,201	5,316	6,517	226	605	831	734	2,522	3,256	185	1,246	1,431	56	943	999	161	2,406	2,567	106	1,463	1,569	55	943	998
10. Total	Item 7.+8.+9.	14,111	81,577	95,688	11,585	53,777	65,362	1,953	5,317	7,270	6,660	24,037	30,697	2,033	13,466	15,499	939	10,957	11,896	2,526	27,800	30,326	1,588	16,843	18,431	938	10,957	11,895
11. Interest During Construction	Rate LC: 12.0%/year FC: 8.0%/year	3,581	10,808	14,389	3,239	8,349	11,588	117	213	330	634	1,386	2,020	1,155	2,887	4,042	1,333	3,863	5,196	342	2,459	2,801	95	674	769	247	1,785	2,032
12. Project Cost	Item 10.+11.	17,692	92,385	110,077	14,824	62,126	76,950	2,070	5,530	7,600	7,294	25,423	32,717	3,188	16,353	19,541	2,272	14,820	17,092	2,868	30,259	33,127	1,683	17,517	19,200	1,185	12,742	13,927

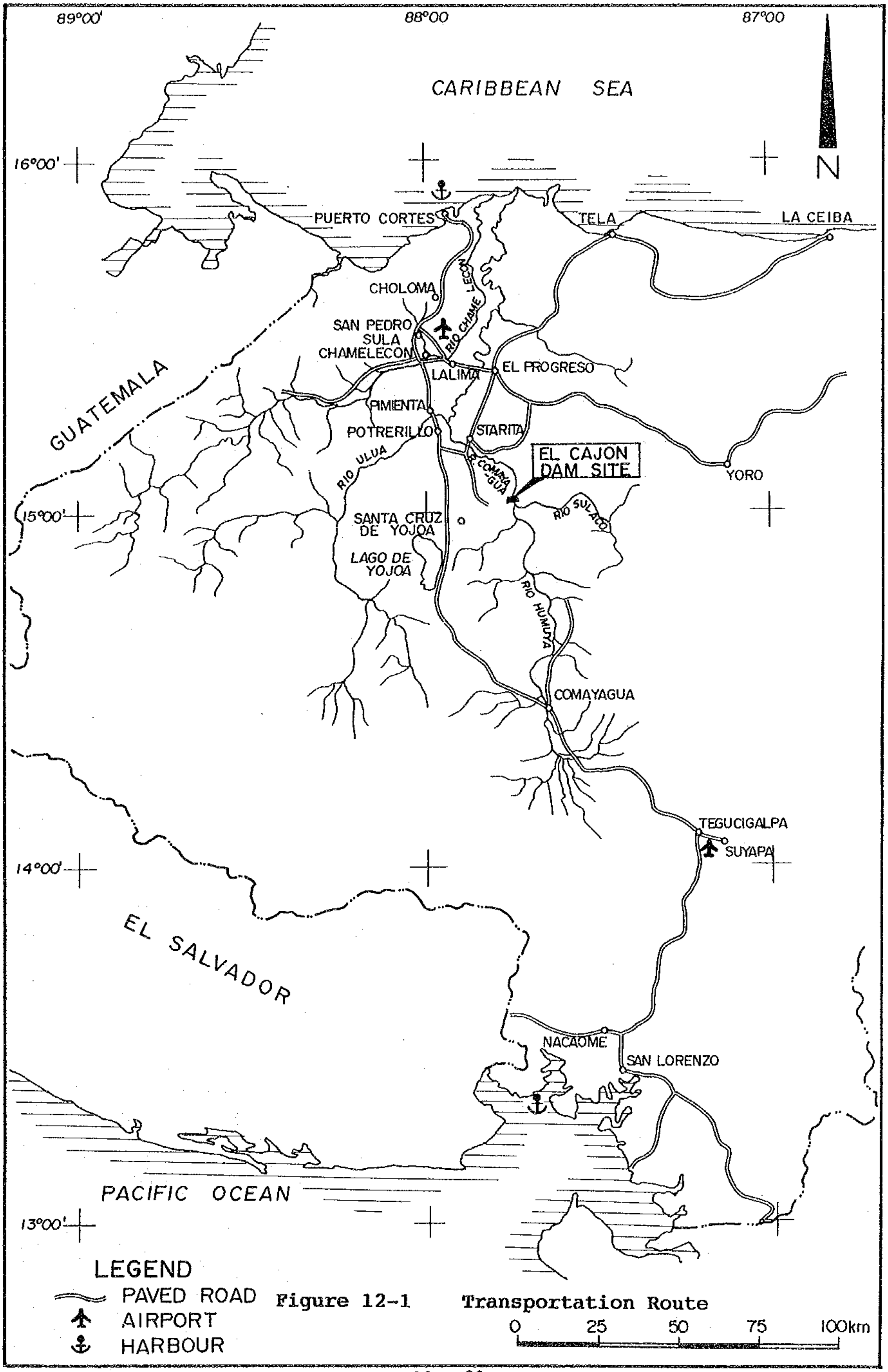
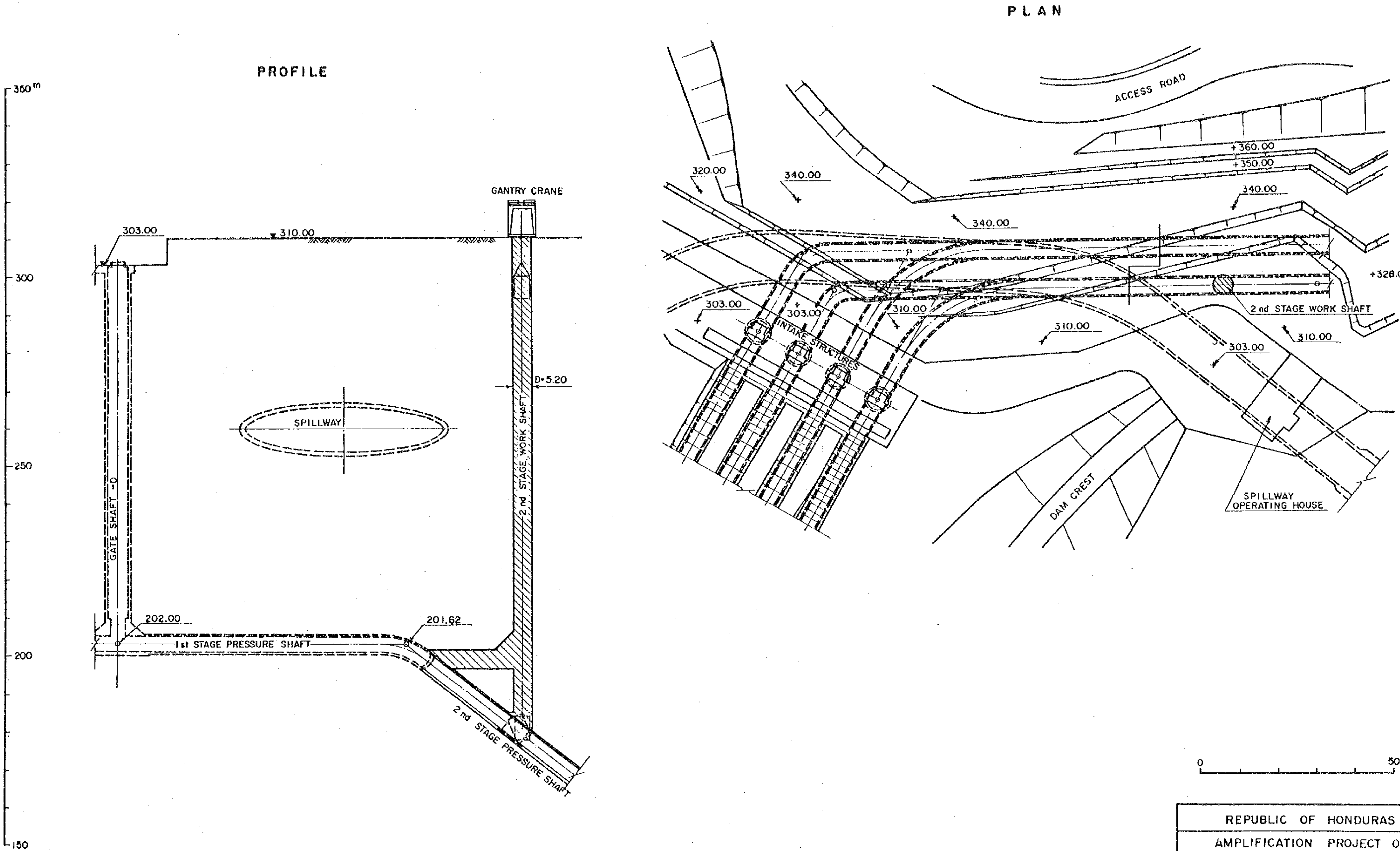


Figure 12-1 Transportation Route



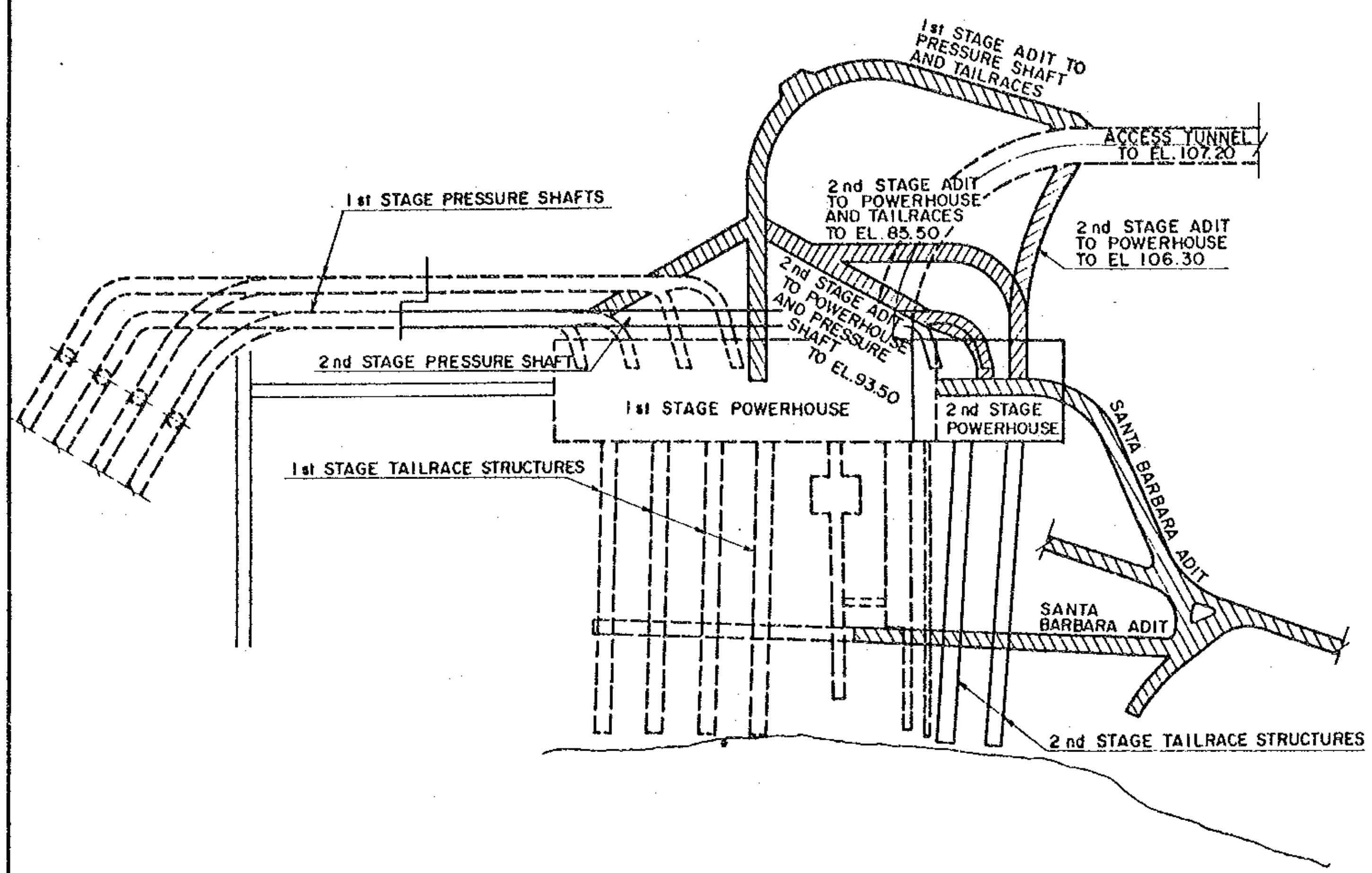
REPUBLIC OF HONDURAS

AMPLIFICATION PROJECT OF EL CAJON HYDROELECTRIC POWER PLANT

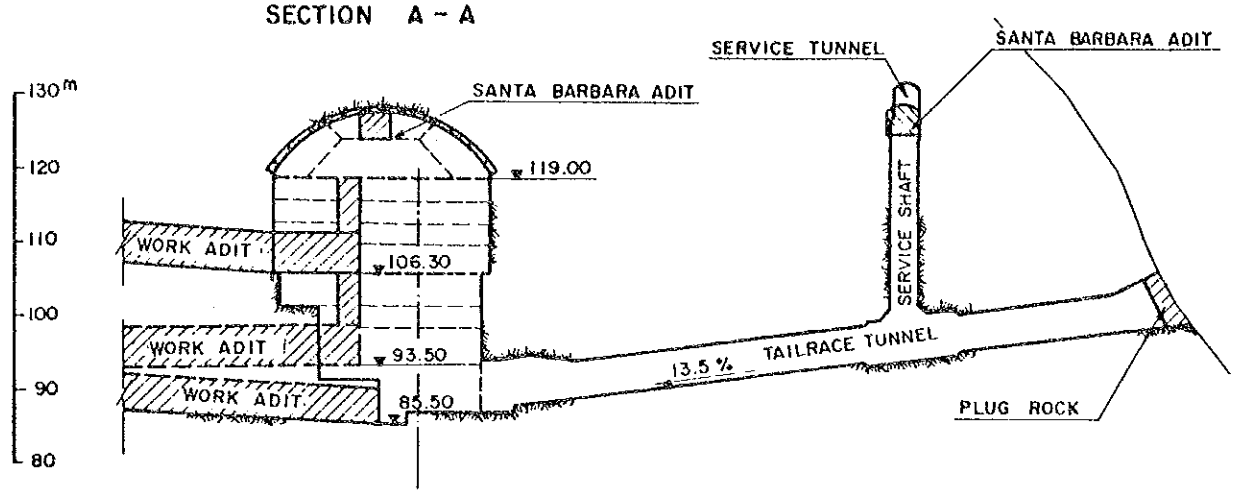
PRESSURE SHAFT
VERTICAL WORK SHAFT

Figure 12-2

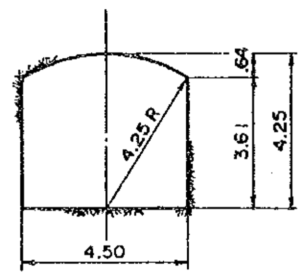
PLAN



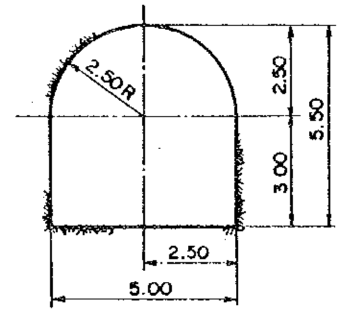
SECTION A – A



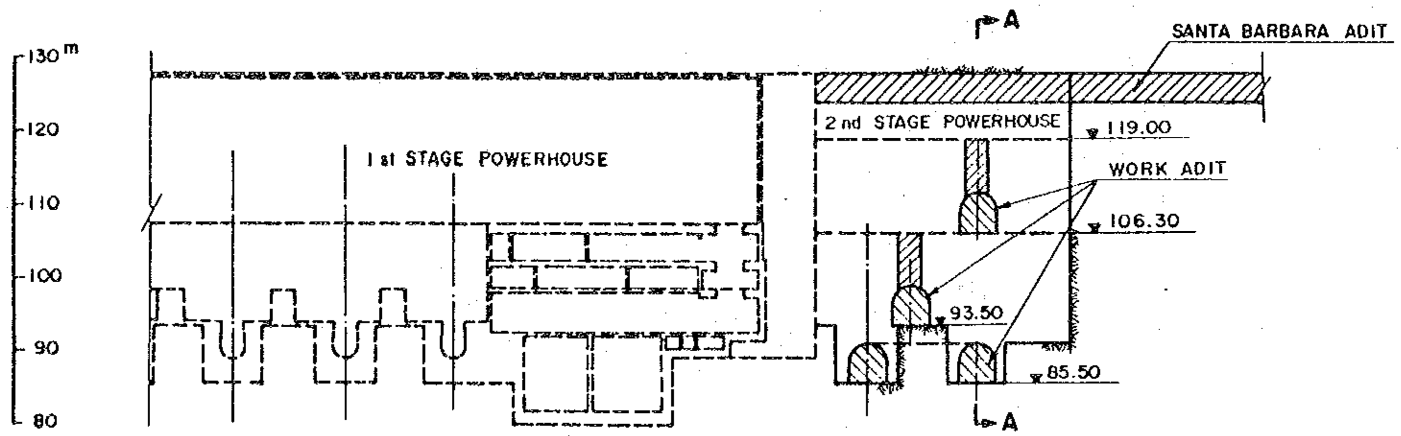
TYPICAL CROSS SECTION OF SANTA BARBARA ADIT



TYPICAL CROSS SECTION OF WORK ADIT



LONGITUDINAL SECTION



0 — 100 m (PLAN)

0 — 50 m (SECTION)

0 — 10 m (TYPICAL SECTION)

REPUBLIC OF HONDURAS

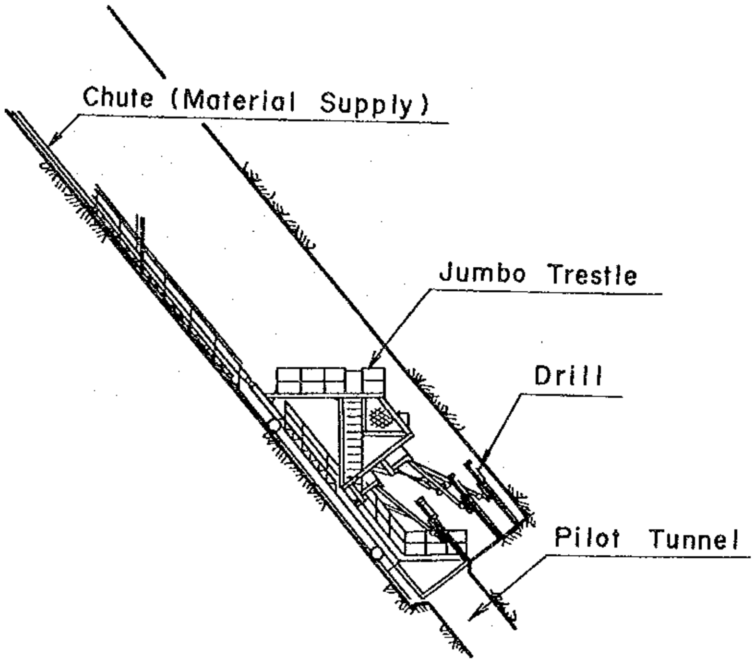
AMPLIFICATION PROJECT OF
EL CAJON HYDROELECTRIC POWER PLANT

POWERHOUSE & TAILRACE
WORK ADIT

Figure 12-3

Figure 12-4   Pressure Tunnel, Excavation

ENLARGEMENT OF PILOT TUNNEL



PILOT TUNNEL EXCAVATION

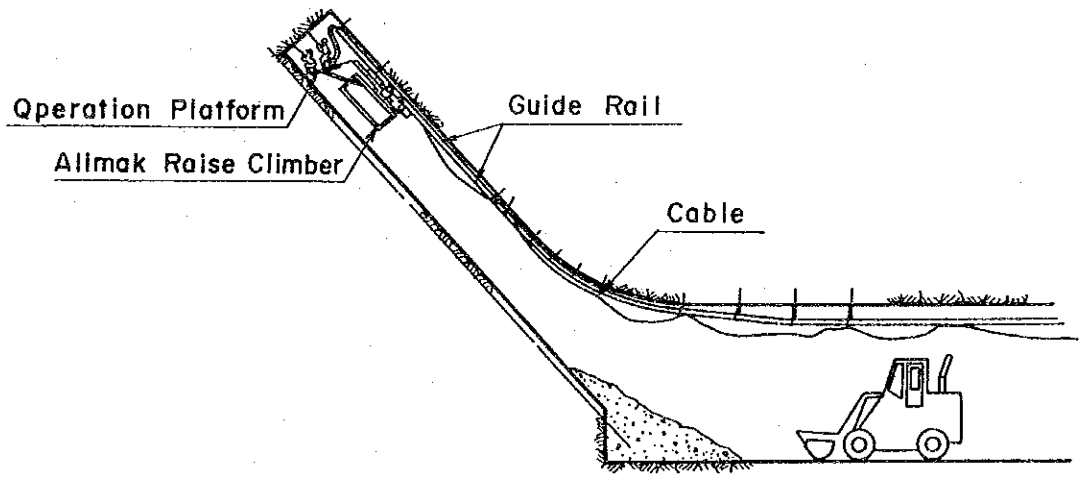
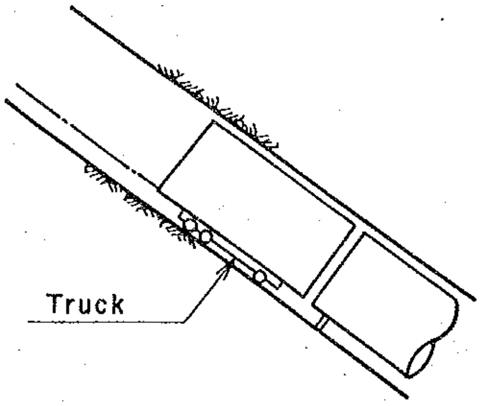
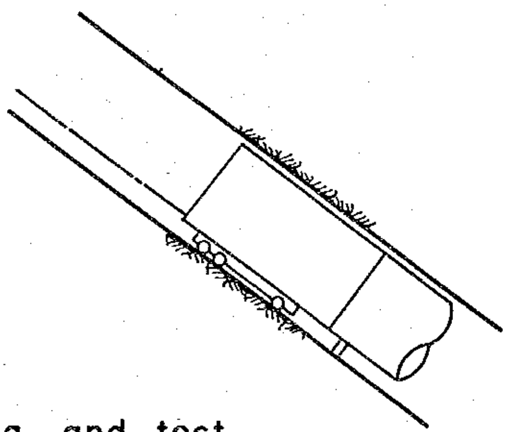


Figure 12-5 Pressure Tunnel, Erection Procedure of Steel Liner

(1) Lowering of the tube and positioning



(2) Alignement, survey check and temporaly welding



(3) Welding and test

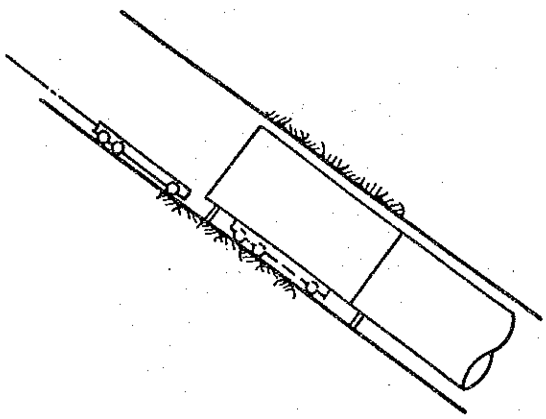


Figure 12-6   Powerhouse, Stage Blasting

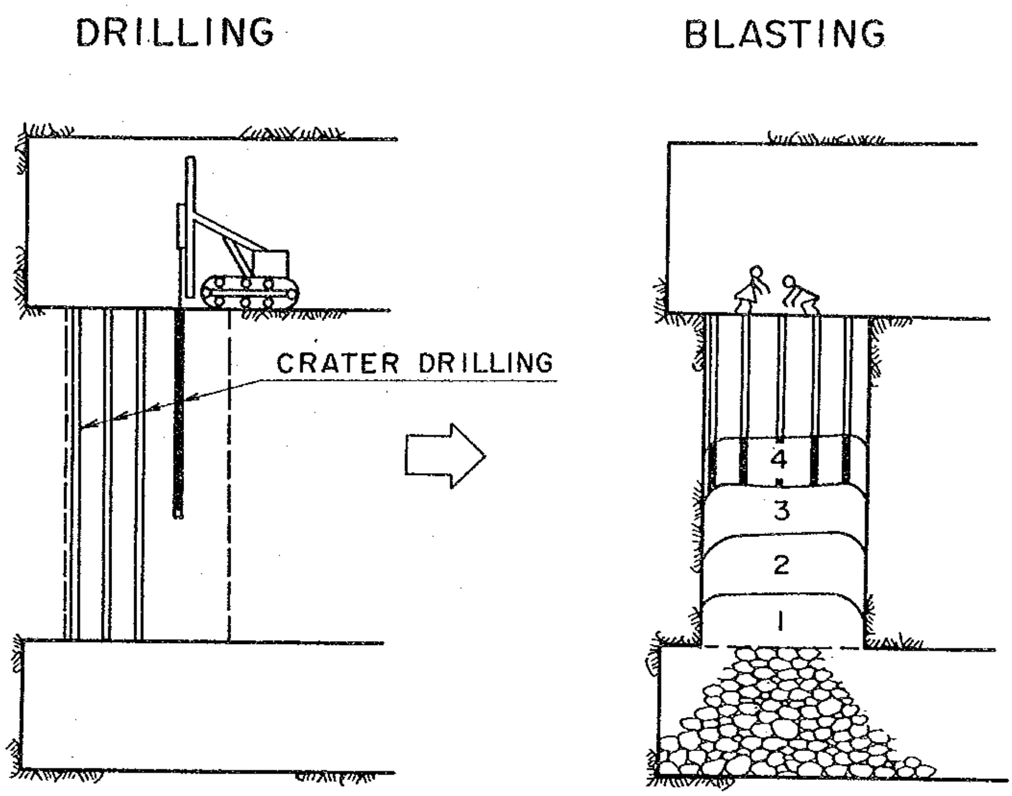
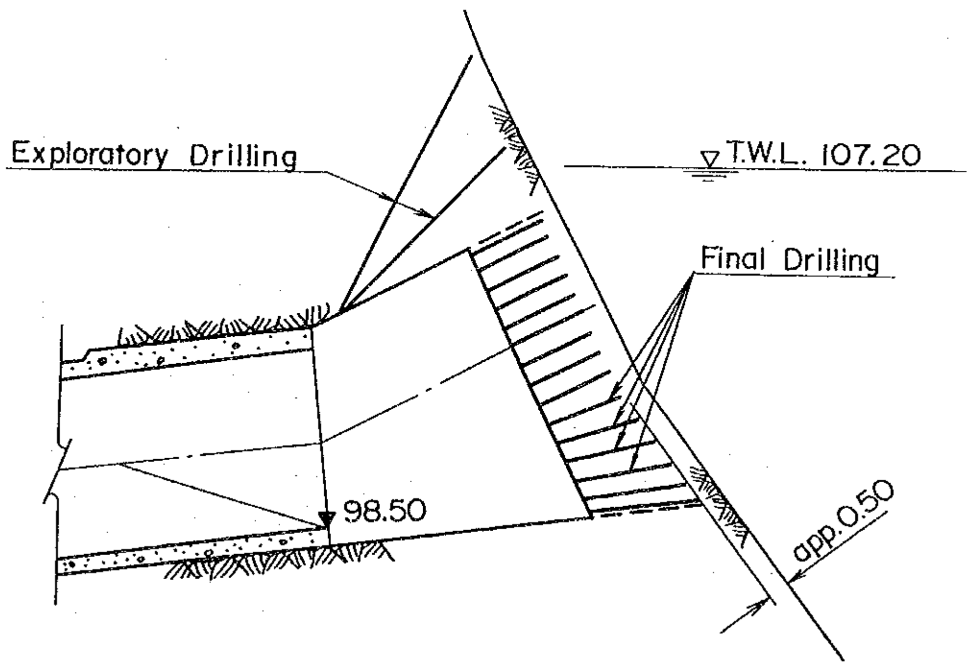


Figure 12-7   Tailrace Tunnel, Plug Rock



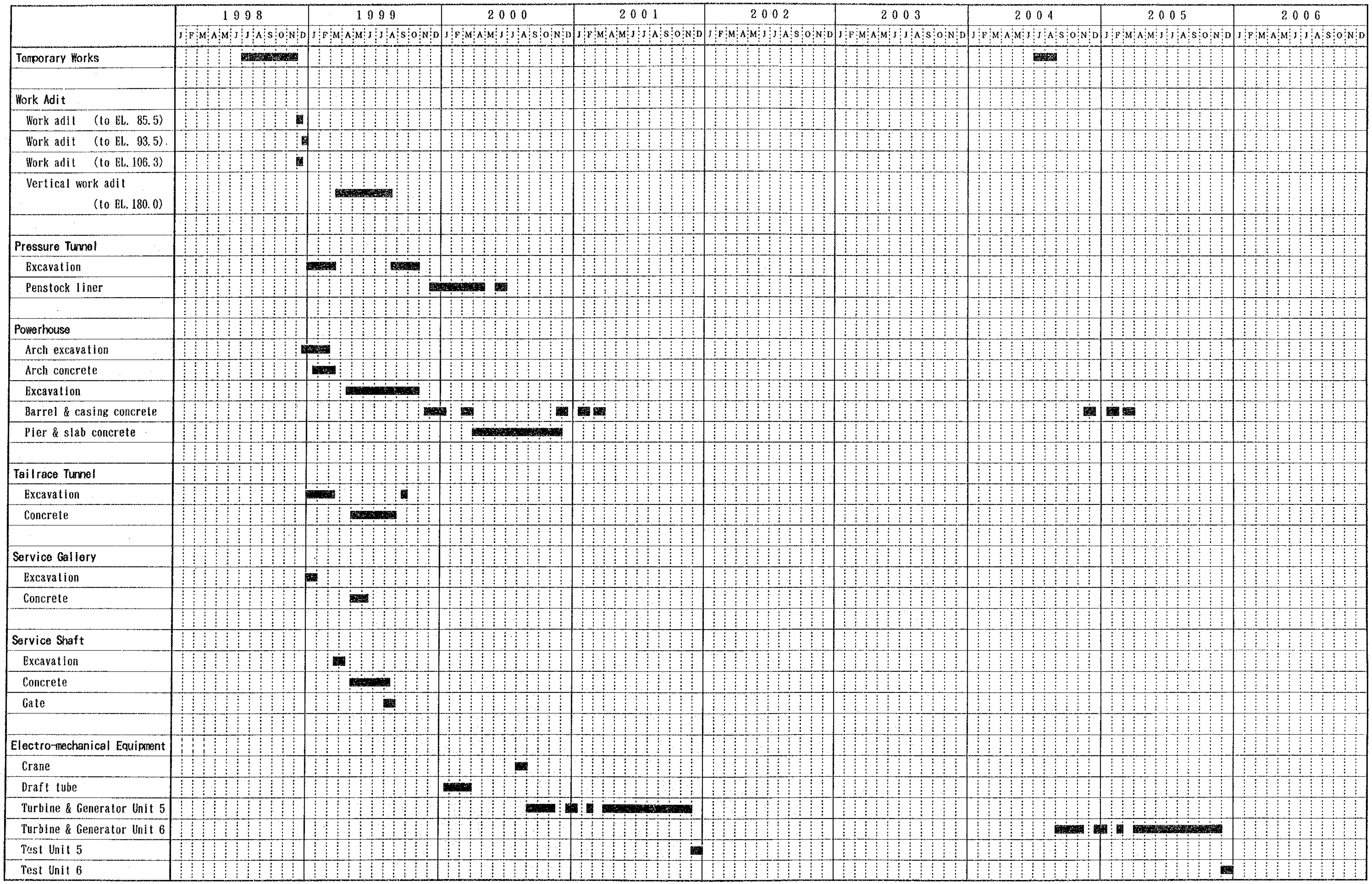


Figure 12-8 Construction Schedule

Chapter 13 IMPACTS ON ENVIRONMENT

Chapter 13

IMPACTS ON ENVIRONMENT

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Chapter 13 IMPACTS ON ENVIRONMENT

13.1 General

Large scale hydro-power development in developing countries promotes progress of their economy and makes a great contribution for improvement of energy demand, living standard, etc. However, there have been not a few instances where some countries cared for development and its economic effect only to give a vicious influence on the environment in the area.

The El Cajón Hydroelectric Power Plant is one of the big hydro-power development projects and its reservoir area is as large as 94 km^2. The dam can compare with the Yojoa lake, the biggest natural freshwater lake in Honduras in area.

Therefore, careful evaluation and monitoring have been made on impacts on environment since construction stage and no serious environmental problems have been reported.

A new power plant amplification project is now studied and this chapter describes study results of impacts of the amplification project on environment in the reservoir and downstream area.

Section 13.2 describes the present state of environment at the project site by field investigation and philological survey.

Section 13.3 gives expected impacts of the amplification project on environment in the project site. **Section 13.4** shows steps to be taken for environmental protection. **Table 13-1** shows general items of environmental impact due to dam construction. This project is an amplification project and the main cause to change the present state of environment is increased discharge for power generation. Such being the case, emphasis is placed on the above point in discussion of impacts on environment and their countermeasures.

13.2 Present State of Environment

13.2.1 El Cajón Reservoir

Construction of this dam, which is as high as 226 m, and is the highest arch dam in the American Continent, was started in 1980. The diversion tunnel was closed in 1984 to store water in the reservoir. Water in the reservoir rose to the high water level for power generation in 1987.

The maximum depth of water of the reservoir is 185 m and the mean depth is 60 m, and the impoundment area is dendritic-shaped. Trees around the reservoir are mainly pine forest. The forest is classified as a thin wood, and has been burned repeatedly and artificially for agriculture and cattle-breeding. According to the feasibility study result of the El Cajón Project, tree density was 25 trees per one hectare and tree diameter was 10 to 90 cm. They seem to be so at present. The rainfall storing capacity of forests may be low due to poor tree crowns.

The reservoir bank in the range of drawdown (EL. 285 m or less) is sparsely covered with grass and bedrocks, and soils are exposed due to water level fluctuation that occurred after trees were cut during construction.

The color of reservoir water was bluish green in June and October when we conducted a field reconnaissance. At the uppermost stream, where water flows into the reservoir, the water assumed a yellowish brown color due to mixing of muddy water, and the yellowish brown range spreads due to inflow in the rainy season with much rain. Groups of trees dying due to sinking were seen scattered in the upper stream part of the reservoir.

13.2.2 Present Situation from Right Below the Dam to Santa Rita

This area is the basin of the Comayagua River which finds its way into Valle de Sula through the narrow valley of semitropical forests, collecting streams of its tributaries. High areas are covered with such pine forests as seen around the El Cajón Reservoir. This area has been used for farming and cattle breeding. Therefore, only small woods and isolated trees are left along rivers at present and a greater part is used as grazing and farming land. Farm products are mainly corn, rice and other cereals.

Houses are scattered in hilly ground and level ground along hill slopes along the Comayagua River, Cuyamapa River and their tributaries where there seems to be no danger of submergence, and all inhabitants engage in farming and cattle breeding.

In the area where rivers pass a narrow valley and flow into Valle de Sula with flat topography, a local city called Santa Rita has grown up, to function as the center of commodity storage and marketing for this basin.

13.2.3 Valle de Sula

This area is an alluvium area formed by sedimentation of sand and silt transported by two rivers including the Comayagua River, and the Ulúa River over a long period of time. The water surface slope is nearly zero and rivers meander.

The confluence of the Ulúa River and the Comayagua River is 50 km downstream from the El Cajón Dam. Banana, sugar sorghum and other farms using rich level ground are seen in the upper and lower reaches.

Because the water level rises in the rainy season there, low land is not used as farming land and is a shrubbery zone or grass-grown swampy ground.

13.3 Impacts of Power Plant Amplification on Environment

13.3.1 Flow-duration Change in Downstream

As described in **Chapter 5**, the scale of the amplification project of El Cajón Hydroelectric Power Plant is proposed to install two additional generators, having total output of 14.6 MW, in 2001 to 2006. Accordingly, the maximum discharge of power generation increases to 321.6 m^3/sec from 214.4 m^3/sec (existing). According to the present generation operating rules, about 100 MW is generated at the night time when power consumption is small and the generation is increased in the daytime to meet increased power consumption.

This section describes the changes in river conditions in the downstream area including the water level fluctuation etc. due to the discharge changes.

(1) Water Level Fluctuation Range

Non uniform flow calculation was made concerning the dam discharge rate and water level rise rate in the downstream.

Fig. 13-1 shows the plan positions of the cross sections of the river used for calculation. The dam discharge is set at 100 m^3/sec to 500 m^3/sec at increments of 100 m^3/sec and the water level rise of each cross section per 100 m^3/sec is shown in **Table 13-2.** Calculation was made by referring to the ENEE report "PROYECTO: ZONAS INUNDADAS" for the cross section shape and the coefficient of roughness and by setting that the water level at the junction of the Comayagua River and the Ulúa River is 40 m above the sea level.

The dam discharge increases by approximately 100 m^3/sec as a result of the extension and the calculation shows that the water level rises by about 0.4 to 0.6 m in each cross section except particular points. The preliminary report by the JICA preliminary survey group indicates that the present water level fluctuation due to discharge for generation is 40 to 50 cm at 12 km downstream from the dam (corresponds to the cross section No. 2969) according to the questionnaire to nearby residents. The calculation result does not show a big difference from above mentioned fact and the questionnaire by this investigation group.

The water level fluctuation range over an overall length of the water system is estimated at about 1 plus or minus alpha meter, including the present fluctuation and fluctuation due to the plant amplification. Impacts on nearby residents can be eased by making them known to every resident without exception. However, in the rainy reason or a flood, the downstream water level rises higher and even the above rise may affect banana and other farms near Santa Rita and downstream.

(2) Water Level Rise Rate

At present, the El Cajón Hydroelectric Power Plant is operated to increase generated output from 5:00 in the morning and decrease it from 20:00 to 24:00 generally on weekdays. Generated output in the evening increases remarkably from 17:00 on weekends, however, the increase is little compared to that on weekdays. About 50 cm water level fluctuation in the downstream occurs within three hours and no problem has been encountered.

If the plant is operated after the expansion to reach the peak output within three hours in the morning in accordance with the existing operation rules, the water level rise rate will be (About 1 m)/3 hrs = About 33 cm/hr. The Japanese standards may be a guide to the limit of the discharge change which does not cause any river disasters nor any accident resulting injury, death and damage downstream. The judgment standard in "Dam Operation Rules" stipulated by the Ministry of Construction provides that safety can be secured if the fluctuation in 30 minutes is 50 cm or less and that about 30 cm/30 minutes is the standard.

Even if compared with the above standard, the water level rise rate indicated may give no problem.

13.3.2 Water Quality

The El Cajón Reservoir has the character of a subtropical lake and a remarkable thermal stratification of 10 m in thickness is formed on the epilimnion of the reservoir from April to late October or early November. When winter comes, mixing occurs with the lower layer down to the depth of 70 m and the thermal stratification becomes not remarkable. The thermal stratification grows up again in March. Temperature of the epilimnion is 26° to 30°C and temperature of the hypolimnion is stable at 25°C throughout the year.

5 to 10 ppm of dissolved oxygen is seen in the thermal stratification on the epilimnion and oxygen is hardly found in the under-layer.

A sulfide problem is mentioned as a characteristic of this reservoir. When generation was started, corrosion and other problems occurred in electric facilities. The cause was traced as isolation of H_2S contained in the turbine cooling water taken from the penstock of the power plant. Therefore, the turbine cooling water intake part was moved to a higher position.

Fig.13-2 shows seasonal variation of water temperature, dissolved oxygen, and sulfide concentration at the point about 2.5 km in the dam upstream (See **Fig. 13-3.**) in 1986. Judging from the vertical distribution of water quality of the reservoir, quality of discharge water may remain unchanged even if the discharge rate increases. In the rapid stream part extending over several km downstream right below the dam, dissolved oxygen may increase and sulfide concentration may decrease but some impacts may be given to aquatic life before a big branch joins the stream.

13.3.3 Items During Construction Work

As for details of the expansion project, civil construction works consist mainly of tunnel works and the only ground surface work is the construction of tailrace. Electric works include transportation and installation of turbines, generators and other equipment. Switchyard modification work is required for power transmission. Due to the size of the additional plant output in relation to the existing transmission line capacity, construction of a new power transmission line is not necessary.

The following items can be considered as impacts of the plant amplification work.

- Noise and vibration by operation of heavy machines and blasting during work.
- Inflow of earth and sand into rivers for processing of excavated earth, sand and rocks, and topographical change by preparation of spoil banks.
- Arising of traffic and noise due to transportation of materials.

According to the field investigation, private houses are hardly seen in the dam site and its vicinity and existence of scarce animals and plants is not reported. Existing roads to the dam site are kept in good condition for transportation of construction materials and power generation equipment. Impacts on the vicinity of work may not cause a serious problem except that due care must be paid to proper processing of excavated earth and sand by construction work.

13.4 Environmental Protection Measures

13.4.1 Items after Plant Amplification

Impacts on environment after the plant amplification are outlined in 13.3.1 to 2. The following items are considered as environmental protection measures against the above.

- Residents downstream from the dam live in full recognition of the present water level variation by discharge for generation. We think they will show some understanding of the water level rise by the plant amplification and all possible measures will be implemented to make the changes of the present situation known to every resident.
- It is seen that a small boat is used to get across the river as the current traffic means. Other river-crossing means are arranged depending on the request of residents having boats.
- Gravel collection as industry and fishing as food hunting are seen in small scale in the downstream areas. Compensation for them is considered as possibility.

Next, the question of flood must be mentioned. Since start of operation of the power plant, dam flood discharge has been done five times including experimental one, but every discharge was less than 200 m^3/sec (see **Fig. 13-4**). However, it is not sure that no flood possibility exists in future. It is proposed to install discharge warning means to secure safety of downstream residents. As one of the means, the discharge alarm equipment used in Japan is considered. Details are shown in **Chapter 8**.

13.4.2 Items During Construction Work

The following items are considered as environmental protection measures.

- Excavated earth and sand produced by construction work, switchyard work, etc. are estimated at about 40,000 - 50,000 m^3. Spoil banks are prepared to process the above earth and sand. Attention is paid in this work not to impair the nearby scenery and to prevent outflow of earth and sand from spoil banks.

Table 13-1 Items of Environmental Impact due to Dam Construction

Main Items		Importance*
1. NATURAL ENVIRONMENTAL IMPACT		
(1) Surrounding of Reservoir	Lake Water Evaporation	
	Change of Micro Climate	
	Water Leakage	
	Induced Earthquake	
	Land Collapse	
(2) Inside of Reservoir	Turbidity of Reservoir	
	Eutrophication	
	Sedimentation	
	Change of Water Temperature	
(3) Downstream	River-bed Degradation	
	River-bank Erosion	
	Accumulation of Fertility in Delta	
	Seawater Intrusion	
	Coastal Erosion	
(4) Others	Effects on Fishes	C
	Preservation of Wild Life	
2. SOCIAL ENVIRONMENTAL IMPACT		
(1) Underconstruction	Economical Condition	
	Health and Sanitation	
	Security	
	Noise and Vibration	
	Preservation of Wild Life	
(2) General	Resettlement	
	Preservation of Aethetics	
	Recreation	
	Protection of Relics	
	Effects to Fish Productivity	
	Water-related Diseases	
(3) Post Construction	Change of Flow-duration	A
	Security	B

(* ; Case of El Cajón Amplification Project)

Table 13-2 Rise of River Water Level

Cross Section Number	Distance from No.2660 (km)	Rise of the Water Level Every 100m³/sec Increase of Discharge (m)			
		Q= 100m³/sec →200 m³/sec	Q= 200m³/sec →300 m³/sec	Q= 300m³/sec →400 m³/sec	Q= 400m³/sec →500 m³/sec
No.2660	–	(*) –	–	–	–
2670	0.96	0.25	0.26	0.32	0.38
2680	2.18	0.39	0.31	0.29	0.33
2690	3.76	0.60	0.37	0.31	0.29
2700	4.87	0.65	0.39	0.34	0.31
2710	6.52	0.76	0.32	0.32	0.29
2720	8.28	1.03	0.39	0.72	0.31
2730	9.81	0.80	0.57	0.81	0.23
2740	11.14	0.67	0.57	0.75	0.24
2750	11.97	0.77	0.58	0.70	0.28
2770	12.94	0.69	0.51	0.36	0.32
2780	14.75	0.57	0.62	0.31	0.28
2785	15.46	0.50	0.49	0.35	0.32
2790	16.72	0.33	0.29	0.28	0.27
2800	17.39	0.38	0.31	0.27	0.26
2810	18.89	0.56	0.44	0.37	0.33
2820	19.83	0.72	0.51	0.37	0.31
2830	21.04	0.96	0.64	0.46	0.36
2840	22.09	0.75	0.47	0.40	0.35
2850	23.24	0.73	0.41	0.34	0.30
2860	23.95	0.81	0.53	0.41	0.36
2870	25.02	0.77	0.56	0.46	0.38
2880	25.87	0.66	0.54	0.46	0.39
2890	26.41	0.39	0.33	0.31	0.29
2910	27.93	0.58	0.48	0.41	0.37
2930	31.32	0.69	0.55	0.74	0.31
2940	32.15	0.42	0.36	0.41	0.40
2950	33.57	0.37	0.31	0.26	0.24
2960	33.94	0.43	0.33	0.29	0.26
2965	36.47	0.61	0.42	0.33	0.28
2969	38.38	0.56	0.42	0.35	0.32
2970	41.28	0.48	0.46	0.33	0.27
2971	42.34	0.60	0.50	0.37	0.30
2980	42.92	0.32	0.26	0.23	0.19
2990	44.04	0.61	0.46	0.39	0.34
2993	44.77	0.75	0.57	0.47	0.42
2994	46.39	0.52	0.40	0.35	0.30
2995	47.52	0.59	0.47	0.40	0.33
3000	48.61	0.61	0.39	0.40	0.34
3005	49.15	0.81	0.61	0.51	0.45

(*) Initial Water Level of No.2660=40.00m

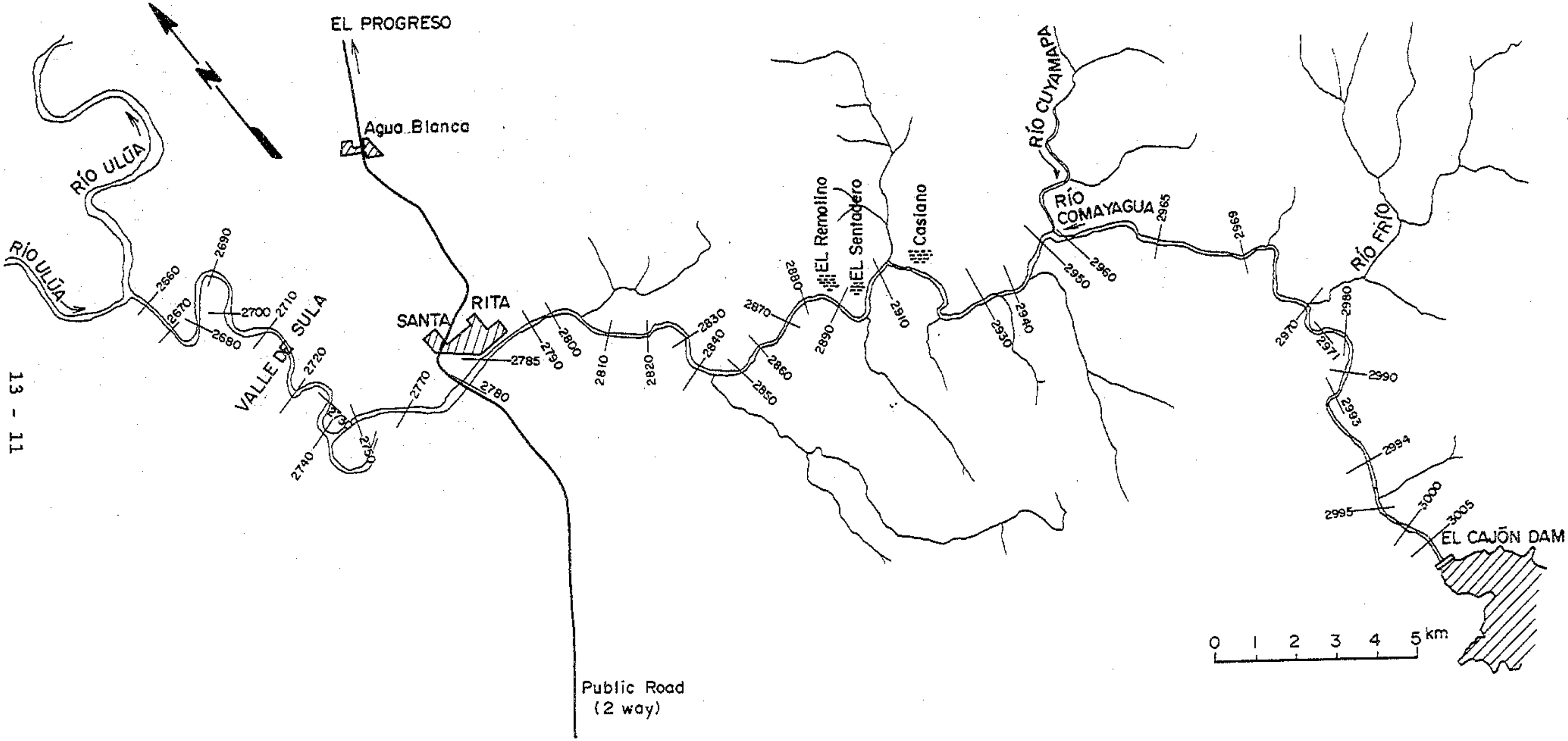

Fig. 13-1 Map of location of cross sections

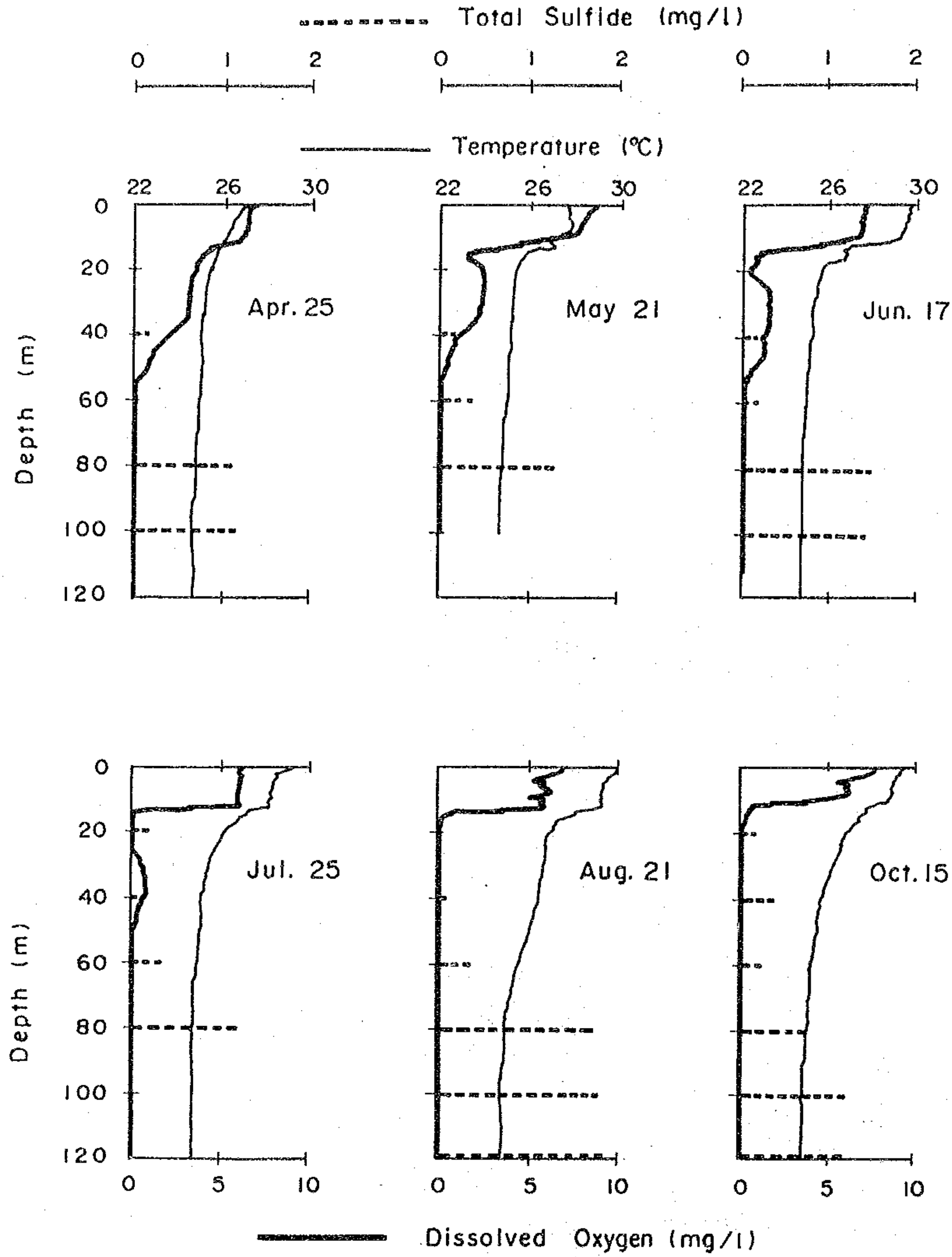

Figure 13-2 Seasonal variation in temperature, dissolved oxygen and sulfide concentrations at the index station of Lake El Cajón in 1986

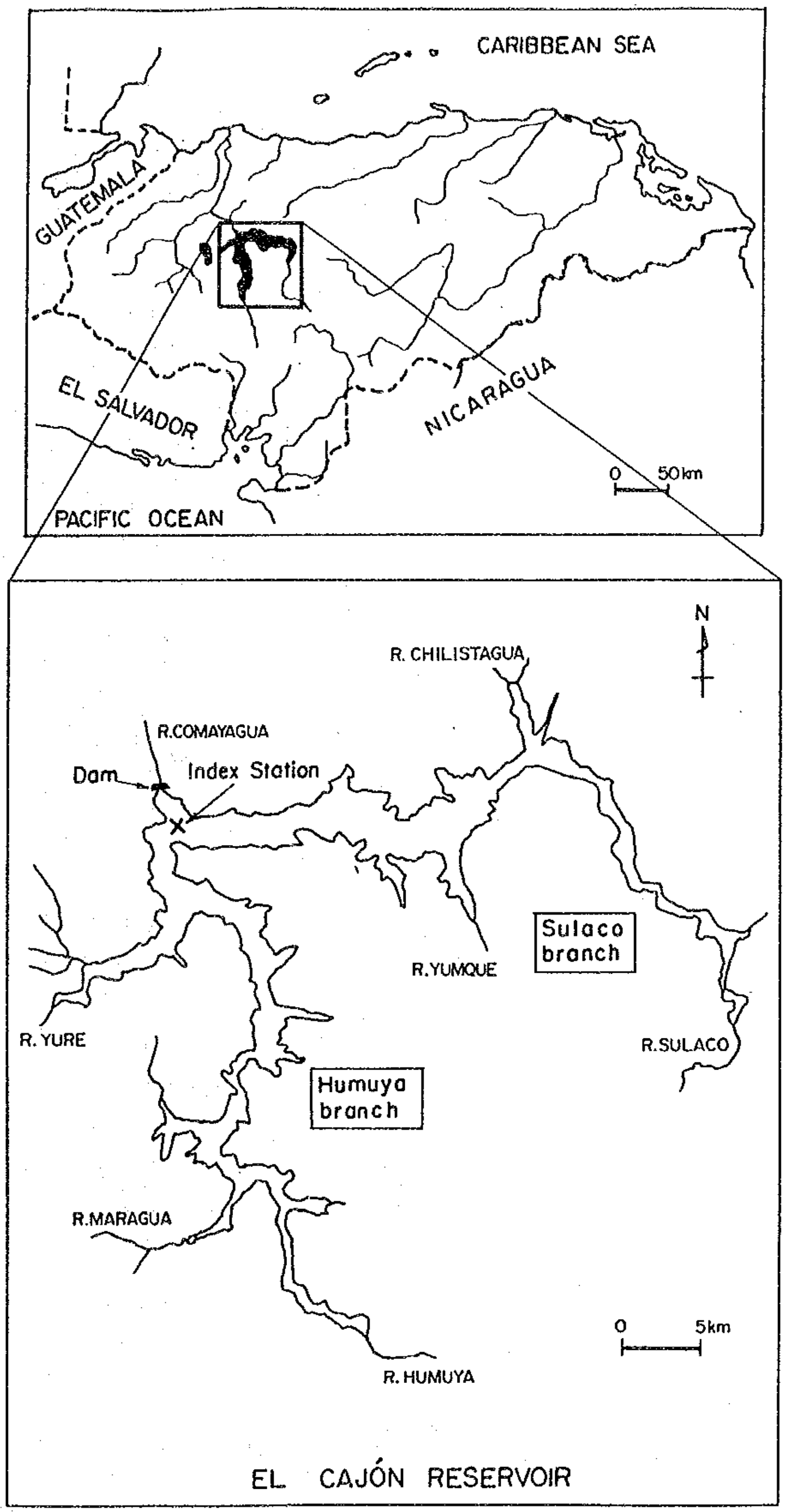

Figure 13-3 Map of the El Cajón Reservoir, central Honduras

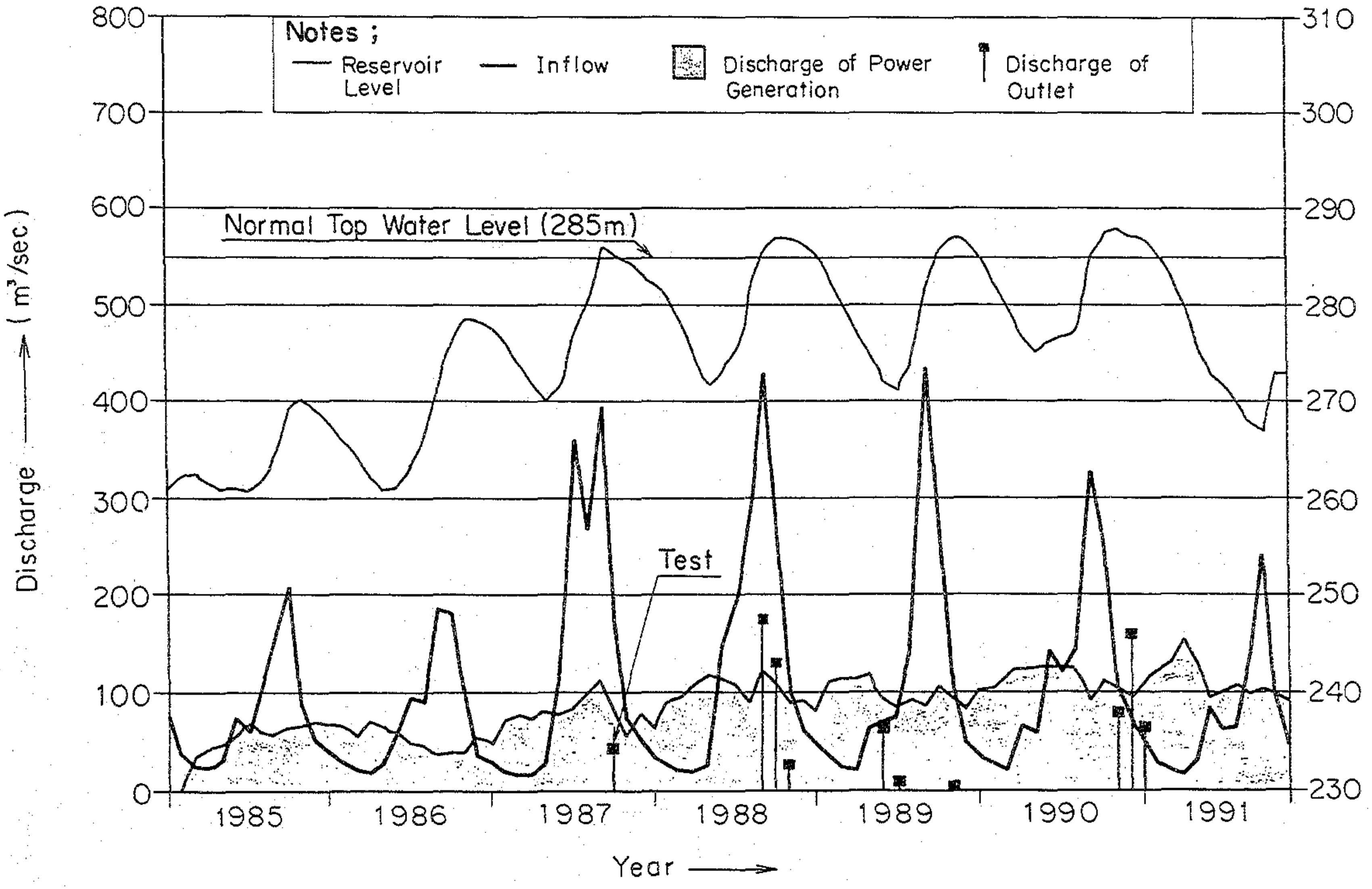

Figure 13-4 Reservoir Operation History (by ENEE)

Chapter 14 ECONOMIC AND FINANCIAL EVALUATION

Chapter 14

Economic and Financial Analysis

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CHAPTER 14 ECONOMIC AND FINANCIAL ANALYSIS

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14.1.1 Method of Economic Evaluation

(1) Basic Approach

In general, economic evaluation of a development project aims to measure how much of impact to be given to the entire social economy of the relevant country by comparing two cases; with the project and without the project. It is a general practice to use such indexes as Net Present Value, Benefit/Cost Ratio, and Economic Internal Rate of Return, etc., calculating the benefit produced by and cost incurred from the project itself, applying the "discount cash flow method".

When measuring the benefit and the cost which are used for economic evaluation, it is necessary to use economic values which have eliminated price adjusting factors derived from the necessity of economic administration of the country. Namely, usual market prices have distortions due to effects of political involvement such as taxes, subsidies, import/export restrictions, tariffs, public utility charges, minimum wage, etc. as well as monopoly prices. Therefore, it is intended to obtain figures closer to the prices of goods and services which are valid in the international market (international market prices) by eliminating these distortions in principle.

A method to calculate benefits and costs using international market prices (border prices) has been widely adopted by international financing organizations such as the World Bank, based on an understanding that these prices are formed within free competitions, though which might not be perfect.

Economic evaluation adopted by international financing organizations including the World Bank is generally carried out following the procedures shown below.

Phase 1: To eliminate, from market prices, items which are transferred to domestic income.

Phase 2: To convert market prices into border prices, item by item such as tradable goods, non-tradable goods, skilled labor, non-skilled labor, etc.

Phase 3: To calculate internal rate of return based on border prices, and to compare the rate with the opportunity cost of capital of the country.

Phase 4: To make socio-economic evaluation in consideration of national savings and income distribution.

Economic evaluation of El Cajón Amplification Project (hereinafter called "the Project") will be carried out up to the Phase 3.

(2) Method of Evaluation

In an economic evaluation of a power development project, it is a common practice to measure the benefit which belongs to the project itself, using long term marginal cost method and a tariff system whenever possible. However, when it is difficult to calculate the benefit this way, another method is commonly adopted: to calculate the saving of cost/expenses of an alternative project which has the equivalent effect as the said project, assuming the saving to be the benefit of the relevant project. This "alternative facility approach method" is also adopted in the Project. A thermal power generation facility is assumed to be an alternative project, since the Project is designed to be a peak load power generation plant. Thus, a gas turbine power generation facility which has an output capacity equivalent to the Project is assumed to be its alternative project.

Construction cost, operation and maintenance cost, etc. are to be calculated as the cost, while these costs for the alternative project are taken as the benefit of the Project, and economic evaluation is to be made, as described above in the section (1), by calculating Net Present Value (B-C), Benefit/Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR).

(3) Conversion Factors for Economic Pricing

When evaluating the benefit and the cost of a project, it is necessary to convert market prices of goods and services into border prices. Simply speaking, border prices of imported goods are to be CIF price at the port of unloading, while those of exported goods are to be FOB prices at the port of shipment.

Conversion factors are used in order to obtain border prices of non-tradable goods. While these factors are obtained from the proportion of weighted average of the amount of major export/import goods and import tariff, export subsidy, and import restriction, the standard conversion factor obtained from the total amount of major export/import goods is used as a general index to show the distortion between border prices and market prices. Aside from the standard conversion factor, in some cases, different coefficients are used for consumer goods, intermediate goods, and capital goods respectively, and a shadow wage rate is used for labor cost. However, as it is thought that omission of these factors would not cause a major effect, only the standard conversion factor is used in the economic evaluation of the Project when calculating border prices. The standard conversion factor now in use in Honduras is 1.0 for foreign currency portion and 0.8 for domestic currency portion.

(4) Discount Rate

The discount rate used for economic evaluation is to be 12%. This figure is the one also used for other projects and has been adopted based on a discussion with ENEE.

14.1.2 Economic Cost of the Project

In Chapter 9 (Section 9.5) economic comparison is discussed in order to determine the scale of amplification. In that section, the project costs were appropriated in consideration of the project's characteristics that an increase of energy production cannot be expected from the amplification of power generating facilities. Namely, they are:

- construction cost of the power plant's amplification
- construction cost of a base-load, coal-fired power plant to be required with the amplification
- operation and maintenance cost of the above power stations (including fuel cost)

In this economic evaluation, the above three items are also reckoned to be the cost factors of the Project.

(1) Cost for Amplification

Table 14-1 shows the project cost (at financial cost) reckoned by using market prices described in Chapter 12 "Construction Plan and Construction Cost" (12.2 Construction Cost). Economic cost has been obtained applying the standard conversion factor which is described in 14.1.1 (3) to this financial cost. (See **Table 14-2**)

Operation and maintenance cost is obtained by multiplying the following ratios by construction cost (at economic price).

(Unit: 1,000 US$)

Item	Rate	Stage I	Stage II
Civil structures	0.5%	137	142
Hydraulic equipment	1.5%	103	103
Electro-mechanical equipment	1.5%	432	864
Total		672	1,109

It should be noted that the following amplification works have already been undertaken for possible future amplification at the initial construction stage: intake, outside switchyard site, a part of penstock and powerhouse. As a result of a deliberation with ENEE, the cost of such preceding construction works is not to be reckoned as the cost of the Project.

(2) Cost for Coal-fired Thermal Power Plant

The specifications for the base load, coal-fired thermal power plant to be required with the amplification are stated below. Considered herein are the costs which correspond to the operation time of the Project, i.e. 5 hours a day.

- Installed capacity	73,000 kW
- Unit construction cost	US$ 1,350/kW (FC 80%, LC 20%)
- Construction period	2 years (1st 60%, 2nd 40%)
- Service life	25 years
- Operation hours	5 hours a day
- O & M cost	Construction cost x 4.56%

(a) Construction cost

The initial investment for the construction of a coal-fired thermal power plant will be as follows:

1) Market Price

(Unit: 1,000 US$)

Item	1st	2nd	Total
LC	2,464	1,642	4,106
FC	9,855	6,570	16,425
Total	12,319	8,212	20,531

2) Economic Price

(Unit: 1,000 US$)

Item	1st	2nd	Total
LC	1,971	1,314	3,285
FC	9,855	6,570	16,425
Total	11,826	7,884	19,710

(b) Operation and Maintenance Cost

- US$ 19,710 x 10^3 x 4.56% = 899 x 10^3 US$/year

(c) Fuel Cost (Coal)

- Unit fuel cost: 0.0205 US$/kWh
- Annual fuel cost: 0.0205x133,225x10^3kWh=2,731x10^3 US$/year

14.1.3 Economic Benefit of the Project

As has been described above, "alternative facility approach" method is adopted in the Project and a gas turbine power generation plant with an installed capacity equivalent to the Project is assumed to be the benefit. Evaluation is to be made at the sending end, without considering the transmission line and transmission loss.

(1) Specifications of the Alternative Thermal Power Plant

The specifications of the alternative thermal power plant which is assumed to be the benefit of the Project are stated hereunder.

- Installed capacity: 73,000 kW per unit (73,000 kW x 2=146,000 kW)
- Construction cost: US$ 720/kW (FC 80%, LC 20%)
- Construction period: 2 years (1st 70%, 2nd 30%)
- Service life: 15 years
- Operation hours: 5 hours/day

(2) Construction Cost of the Alternative Thermal Power Plant

The initial investment for the construction of the alternative thermal power plant will be as follows:

(a) Market Price

(Unit: 1,000 US$)

Item	1st	2nd	Total
FC	29,434	12,614	42,048
LC	7,358	3,154	10,512
Total	36,792	15,768	52,560

(b) Economic Price

(Unit: 1,000 US$)

Item	1st	2nd	Total
FC	29,434	12,614	42,048
LC	5,886	2,523	8,409
Total	35,320	15,137	50,457

(3) Operation and Maintenance Cost

Annual operation and maintenance cost is obtained by multiplying a cost ratio by the construction cost of the alternative thermal power plant.

- US$ 50,457 x 10^3 x 4.56% = 2,301 x 10^3 US$/year

(4) Fuel Cost

Diesel oil is to be used for the alternative thermal power plant.

- Unit Fuel Cost: US$ 0.0422/kWh
- Annual Fuel Cost: 0.042 x 133,225 x 10^3 kWh = 5,622 x 10^3 US$/year

14.1.4 Economic Evaluation of the Project

As has been described above, economic evaluation of the Project is to be made using such indices as Net Present Value (B-C), Benefit/Cost Ratio (B/C) and Economic Internal Rate of Return (EIRR) applying the "cash discount flow method".

In calculating each index, a cash flow sheet is to be prepared to develop project benefit and cost by year over the period of the project life. Construction cost of the Project, operation and maintenance cost after the commissioning, and fuel cost are to be reckoned in this cash flow projection. Such costs incurred from the invested capital as interest and depreciation are excluded.

As a result of evaluation, it has been revealed that the Project is feasible with any index. (See **Table 14-3**)

(1) Net Present Value (B-C) and Benefit/Cost Ratio (B/C)

The total present value of the Project's economic cost (C) in the initial year of the Project is calculated to be US$ 122,564 x 10^3. Likewise, the total present value of the Project's economic benefit (B) is calculated to be US$ 137,640 x 10^3. Therefore, Net Present Value (B-C) is US$ 15,076 x 10^3, and Benefit/Cost ratio (B/C) is 1.12. As both these indexes show, to construct and operate the Project is regarded to be superior, because of its smaller cost, to installing an alternative thermal power plant which can provide an equivalent service.

(2) Economic Internal Rate of Return (EIRR)

A discount rate which equalizes the present value of the invested cost in the initial year of the Project with that of the alternative thermal power plant is 16%. Therefore, it is concluded to be advantageous to carry out the Project until the discount rate is arrived at 16%. This figure is larger than the opportunity cost of capital of 12% in Honduras. Thus the Project is deemed to be worthwhile enough for investment from an economic point of view.

14.1.5 Sensitivity Analysis

As sensitivity analysis for the Project, effects are calculated for the following cases:

- when discount rate is changed to be 8%, 10%, and 12%
- when construction cost is increased by 5 to 20%

The results are shown below.

Item	i	Original	5% up	10% up	15% up	20% up
B-C (1,000 US$)	8%	48,907	44,683	40,460	36,236	32,012
	10%	28,358	24,609	20,860	17,111	13,361
	12%	15,076	11,681	8,286	4,890	1,495
B-C	8%	1.29	1.25	1.23	1.20	1.17
	10%	1.20	1.17	1.14	1.11	1.08
	12%	1.12	1.09	1.06	1.04	1.01
EIRR	--	16%	15%	14%	13%	12%

14.2 Financial Evaluation

14.2.1 Method of Financial Evaluation

In a financial evaluation of an electric power project, it is usual to obtain Financial Internal Rate of Return (FIRR) by "discount cash flow method" reckoning construction cost, operation and maintenance cost, renovation cost etc. as cost factors, while sale of electric energy produced by the project is to be reckoned as benefit. However, in the case of the Project as described in Chapter 9 (Section 9.5), it is not appropriate to apply usual method of financial evaluation, because an increase of energy production cannot be expected from installation of additional generators. Therefore, in place of a usual financial evaluation, a study is to be made as to how much of internal reserve will enable the realization of the Project, in other words, how much of incremental income from electric power sale will make the Project viable financially. Fund repayment plan is also prepared based on the above income of the electric sale.

14.2.2 Financial Cost and Benefit of the Project

(1) Financial Cost

Financial costs of the Project are the initial investment at market prices, renovation cost, and operation and maintenance cost. Among them, the initial investment and renovation cost have been obtained in Chapter 12, and taxes are added. (See **Table 14-4**)

As for taxation, tariffs of 0 to 20% are imposed on import items according to "Decree No. 54", "Decree No. 85-84", etc. in Honduras. A sales tax of 7% is also imposed. In the Project, based on a discussion with ENEE, the following taxation ratios are to be applied to import goods.

	Tariff	Sales Tax
Civil works	10%	7%
Electric/Hydraulic Equipment	30%	7%

As for operation and maintenance cost, annual amount is obtained by applying following ratios for each type of equipment.

(Unit: 1,000 US$)

Item	Rate	Stage I	Stage II
Civil structures	0.5%	1,495	1,514
Hydraulic equipment	1.5%	104	104
Electro-mechanical equipment	1.5%	438	877
Total		2,002	2,495

(2) Financial Benefit

Financial benefit of the Project is to be the incremental income of selling electric power by ENEE as a whole. The amount of incremental income is estimated using an incremental unit price of electricity which is made available by price increase of 3 to 6% from the current level, and power demand forecast by ENEE (low case). The electricity tariffs are designed to reach the final level in January 1993 repeating small-scale price hikes for the duration of 19 months since June 1991. Therefore, in the Project, the final average unit price of US$ 0.088/kWh is to be used as the unit electricity price, calculated from average tariff and energy sales as of September 1992. (See **Table 14-5** and **Table 14-6**).

14.2.3 Financial Evaluation of the Project

Financial Internal Rate of Return (FIRR) has been calculated based on the financial benefit (=income from the sale of electric power) shown in **Table 14-6**.

Rate of Increase	3%	4%	5%	10%
FIRR	6.3%	9.6%	12.4%	14.9%

From this table, it is concluded that some 5% of price increase is necessary to make the Project viable financially, or to obtain an FIRR which exceeds the expected borrowing rate of interest in terms of domestic fund (12%). (See **Table 14-7**)

14.2.4 Loan Repayment Schedule

In general, when constructing electric power facilities, a huge amount of preinvestment is needed during the initial investment period, and an income becomes available only after the construction has been completed. The period of capital recovery is considerably long in comparison with general consumers' durables. Therefore, investment fund in many cases has loan conditions of low interest rate with a long term of deferment as well as a long term of repayment.

Considerable portion of the fund necessary to realize the Project is to be procured from international financing institutions with the rest of it from domestic financial institutions. Since it is difficult to forecast the allotment at this time, as a result of a discussion with ENEE, a loan repayment schedule is prepared based on the following financing conditions.