Chapter 7. Preliminary Design

7.1 General Conditions

The preliminary designs below mentioned of civil engineering side and electric-mechanic engineering side are performed in accordance with development scales described in Chapter 6.

As for civil engineering side, São Lourenco Reversible Power Station including the upper and lower reservoirs, the pondage type upper reservoir, pump station of EE-8A, pipe line type pump station and Cubatão Compounded Reversible Power Station including the lower reservoir, are only selected and designed based on the given development scales to improve the technical capabilities of the counterparts.

As for electric-mechanic engineering side, outline selections of main units, specifications of electric machineries, main circuits and transmission lines, and layout of electric machineries in accordance with the given development scales of São Lourenco Reversible Power Station, Cubatão Compounded Reversible Power Station, and several pump stations, and the field investigations of road bridge conditions for heavy equipment transportations are only selected and studied to improve the technical capabilities of electric and mechanic engineers.

7.2 Preliminary Design of Civil Works

7.2.1 São Lourenco Reversible Power Station

(1) Upper Reservoir

Locations of structures to develop the upper reservoir are followed at the nearly same locations selected beforehand by DAAE because lots of studying times are judged to be needed, and furthermore effectiveness of technical cooperation during staying here is also judged to be prevented if selection studies of each structure are started from the beginning stage.

Dams named GD-6 and LH-3, 40 dikes and 4.5 km of canal are necessary to develop the upper reservoir with 19 km^2 of area, and furthermore almost of all reservoir area is notable to be consisted of marshy place and jungle.

(1) Dam of GD-6

This dam is located at Ribeirao Grande, which is one tributary of Juquia River and is situated at a little upstream of the confluence with the upstream reach of Juquia River.

Dam axis is selected at the most narrow river portion along the river near by there. As for dam type, the semi-rockfill type is selected considering embankment materials utilizable from borrow area.

The crest length and the height of dam are 486m and 48m respectively, of which values are determined by freeboard study from high water level the slopes of up and downstreams of dam with 1:2.3 and 1:2.1, respectively, are determined by means of simplified circle sliding method with safety factor of 1.8 of which value is judged to be a little conservative even if this is preliminary design stage so that smaller safety factor has to be adopted after development of detailed calculation computer program and investigation of embankment material characteristics. Foundation of dam is selected at the weathered rock line which is determined by means of seismic sounding procedure, but some foundation treatment by routing is consdiered to be necessary though rock characteristics are not enoughly confirmed yet.

Free-flow type spillway with tunnel type shoot is adopted because peak design flood of 580 m^3/s is small comparing with reservoir area so that high water level by means of reservoir regulation study is 709,7m of which water level difference from the normal water level is 1.70m, and because outflow discharge is calculated as $40m^3/s$, the normal open type spillway is judged to be more costful and unreasonable than the adopted type considering the remained soil being too deep and the good layout being not designed. In case of tunnel type spillway, careful water flow condition study is essential subject to that detailed study is recommendable at the definite study stage.

As described in Chapter 3, as CBA has the river utilization right of Juquia River upstream of confluence with Acungui River, the intake facility with gate of inflow is devised in the center pier of spillway in consideration of compensation cost by the hydroelectric energy production decrease at CBA's Power Station, and releasing facility planned to use the same tunnel of spillway.

The upper and lower cofferdams, of which heights are determined by the economical comparison with diversion capacity, are arranged at the inside of the main dam to make economized.

The diversion is layouted at the right bank with 3.0 m diameter which is determined by minimizing total cost of diversion tunnel and cofferdams as mentioned above.

The design capacity of diversion is calculated by 25 years return return period hydrograph with peak capacity of 88.4 m^3/s.

The deversion tunnel is planned to use for the outlet works with 2.0 m diameters after completion of construction.

The relevant preliminary designs of this dam are attached in this report.

(2) Dam of LH-3

This damsite is located at the most upstream reach with the drainage area and altitude of 5.4 km^2 and 670 m respectively of Sao Lourenco River to develop the upper reservoir.

There is not tapographically any good damsite along the river so that the complex dam type with semi-rockfill type is selected by the nearly same consideration as Dam of GD-6, but the longitudinal section along the river is a little steep, accordingly careful design is to be executed to make the dam stable at the definite study stage.

The crest length and height of 345m and 40m respectively are designed for this complex dam and the up and downstream slopes are determined as 1:2.2 and 1:2.0 respectively by means of the same procedure as the case of GD-6 after making assumption of embankment material characteristics through the field investigations.

Though rock conditions as for dam foundation is not enoughly investigated, foundation line is selected along the weathered rock with seismic sounding velocity of 1.2 km/sec of which value is judged to be enough for this kind of dam height.

According to the field investigations, and some tested results, the foundation rock is found to be a little cracky and permeability is high at some portions along the dam axis so that not only further foundation investigations are necessary but also the foundation treatments with grouting including the saddle portion are recommendable to keep water tightness of foundation.

As this dam is constructed for development of the upper reservoir, the design flood is planned to be controlled at Dam of GD-6 so that any spillway facility is not provided at this dam.

The heights of cofferdams are determined considering that estimated 25 years return period hydrograph with peak discharge of 12,6 m^3/s is not big, accordingly, the diameter of diversion tunnel is better to be minimum construction limit such as 2.0 m and they are designed at a little outside of the main dam to make the dam stable because of steep river gradient.

The diversion is located at the right bank of dam to make it economize and it is clear that there is not any other layout considering topographical conditions.

This diversion tunnel is planned to be utilized for the outlet works with diameter of 1.0 m to make the reservoir water empty at the case of emergency. Access tunnel to the outlet works is provided for operation because of providing it being difficult in the diversion tunnel.

The preliminary design of this dam is provided in this report.

(3) Dikes

As the reservoir area topographically consists of complicated plain and marshy place with lots of small hills of which geography is understood to be characteristic of advanced aged one, the little more increases the water level, the more dikes become unavoidable to keep reservoir water level.

The numbers of dike are estimated as 40 sites around the reservoir of which selection criteria are as followings;

> Dike has to be provided in case that:(1) ground level is less than 715 m and (2) section length higher than 712m of altitude along the dike is less than 100 m, of which criteria are determined considering necessary seepage length and 3 m of organic materials being deposited on the ground surface.

And designs of dike are preliminarily performed such as slope stability in connection with dike height, sliding stability at foundation and bearing stress and deformation of foundation considering the relation between consolidating deformations and times after assuming actual soil mechanic characteristics of dike itself and its foundation by means of field investigations and tested data.

According to these studies, slopes of reservoir side and opposite side are found to be stable in case of 1:3.0 and 1:2.5 respectively when excavation depth is assumed to be 6 m and 10 m for dike heights of less than 15 m and more than 15 m respectively.

The results of preliminary design are shown that total length of dike is 5 km, excavation volume $3.6 \times 10^6 m^3$ and embankment volume $4.0 \times 10^6 m^3$ severally.

(4) Canal

Connection beteen Ribeirao Grande and Sao Lourenco River with canal in case of low water level is necessary to connect the intake with the main reservoir even if great dead water depth is adopted.

According to the preliminary design, canal length of 4.5 km with 60m of invert width and excavation volume of $6.3 \times 10^6 m^3$ are necessitated and excavation slope is adopted as 1:1.5 for soil portion.

As passing area of canal is almost consisted of marshy place according to field investigations, construction procedures and protection devices for slope sliding such as stone pitching covered with mesh are important subjects for this canal so that careful design has to be performed.

(II) Pondage Type Upper Reservoir

As described already, that the upper reservoir is consisted of marshy place and jungle, cleaning of all reservoir area is that most important matter to keep the water clean and compensation is, what is worse still, to be payed for hydroelectric energy production decrease at CBA's Power Stations when the water is supplyed from the upper basin.

In case of the former subject, cleaning unit price including cutting down and removing their roots at the marshy place and the dense jungle is estimated as US\$ $3.5/m^2$, and furthermore surface excavation is necessary because of organic materials being deposited.

When pondage type upper reservoir is considered for this re reversible power station and the water is directly supplyed through pump station and pipeline from the lower basin, the construction cost of upper reservoir is judged to be competitable so that the pondage type reservoir is planned as alternative, but this idea and the adopted plan and or other many plans of upper basin have to be compared taking several factors such as construction cost, hydro-electric loss, ecological view points, and so on into considerations, and then the best solution must be selected.

The pondage type reservoir is consisted of concrete facing with transition at the all around slope of 1:2.0 which is constructed by excavation and or embankment, and concrete anchor having drainage system is provided at the basement of concrete facing.

To secure the necessary reservoir capacity, excavation at bottom of the pondage is executed at least until weathered rock being exposed in accordance with topographical and geological conditions, and excavated surface is planned to provide soil-cement spraying to decrease the leakage because exposed weathered rock is somewhat cracky considering the field investigations and investigated data at Damsite of LH-3. Also utilizable excavated material is used for embankment of the surrounding bank.

Two intakes for the reversible power station and the pump station of pipe line are installed as shown in the attached preliminary designs in this report.

Finally, this pondage type reservoir is earnestly recommendable to be studied further to get the most economical solution.

(III) Power Structures

As for selection of the best route for the waterway of this power station, four alternatives with 4 units-1 tunnel system are preliminary studies as shown in Appendix-B and the alternative-2 is finally selected for more detailed studies after many kinds of considerations.

In parallel with the above mentioned studies, demand and supply plan studies of electricity and water supply sectors are carried out and the 3 units-1 tunnel totally 9 units with 2,835 MW output capacity system is selected for the training of counterparts, of which scale is determined taking into considerations of peak generation hours in the end of economical years, necessary pumping up discharge in the same year, construction procedures in accordance with construction schedule, reliabilities of operation and maintenance viewpoints and so on.

Accordingly the following system is consisted, namely; 3 lines o of headrace tunnel with 3 surge tanks, 3 and 9 lines of penstock with branch at the middle step portion, power house of 3 main units with 1 erection bay system, transformer room of 1 transformer for 3 main units with 9 draft gate rooms, 9 lines of steel lining draft tunnel, 3 lines of tailrace tunnel with 3 surge tanks, access tunnel, open type switchyard, cable tunnel with ventilation duct, elevator shaft for mainly maintenance and operation and other facilities. As for the determination of layout on the power structures, three alternatives are selected for the economical comparison and preliminary comparisons studies are carried out assuming that construction costs of intake, power house, transformer room, draft tunnel, tailrace surge tank, outlet, switchyard, and other additional facilities are not changeable.

Main dimentions and construction costs of each alternative are as follows:

Table - III.7.1 Main Dimensions of Alternatives

Item	Unit	Alternative - I	Alternative - II	Alternative - III
Headrace Tunnel				
Diameter x Length	m x m	3(6.90 x 840)	3(6.90 x 840)	3(6.90 x 865)
Headrace Surge Tank				
Shaft Diameter x Hight	m x m	3(7.5 x 85.0)	3(7.5 x 85.0)	-
Chamber Diameter x Hight	m x m	3(10.0 x 37.5)	3(10.0 x 37.5)	-
Penstock				
Diameter x Length	m x m	(3x6.20-9x280)x1080	(3x6.20-9x2.80)x1770	(3x6.20-9x2.80)x880
Tailrace Tunnel				
Diameter x Length	m x m	3(6.90 x 2,280)	3(6.90 x 1,590)	3(6.90 x 2,360)
Access Tunnel				
Diameter x Length	m x m	1(6.7 x 1,210)	1(6.7 x 810)	1(6.7 x 1,240)
Cable Tunnel				
Diameter x Length	m x m	1(7.0 x 930)	1(7.0 x 550)	1(7.0 x 960)
Direct Construction Cost	$10^3$$	250,157	271,564	251,136

Typically, alternative - I is as same as the final layout which is described hereinunder, alternative - II is that power house is moved to dowstream side so that middle step length of penstock is long as 700 m and alternative - III is that power house is extremely moved to upstream side, therefore middle step of penstock and headrace surge tank are neglected. And it is to be remembered that calculation procedures of each structure are unified.

Finally, alternative - I is judged to be most reasonable for this power structures considering geological condition, construction procedures, easiness of maintenance and operation and so on including estimated construction cost and oil-filled cable cost.

(1) Intake

Horizontal type intake for normal upper reservoir is designed considering topographical conditions and the fore-bay of intake is connected with canal which is described already. In case of pondage type reservoir, morning glory type with 55 m shaft is designed aiming at descreasing dead water volume and considering structural and hydraulic conditions.

Intake gate is provided at a little downstream from the intake for maintenance of headrace tunnel and penstock, as for the gate type, roller gate with gate shaft is installed for the former case and bonnet type gate with access tunnel for the latter as results of economical comparison study.

(2) Headrace Tunnel

Diameter of headrace tunnel is determined by means of economical diameter estination procedure for reversible power station. Headrace tunnel with reinforcement is necessary to be grouted because foundation rock along the tunnel is supposed to be cracky according to the field investigations.

(3) Headrace Surge Tank

At the end of headrace tunnel, chamber type surge tank with port is designed, of which type is usually economical and stable for surging oscillation. The access tunnel is provided at a little downstream of surge tank for constructions of headrace tunnel, surge tank and penstock, maintenance and inspection and drainage system of headrace tunnel and surge tank and drain system with valve and steel pipe is in stalled to make the water of headrace tunnel empty when necessary.

(4) Penstock

Embedded type penstock starts from the above mentioned surge tank and ends at the main valve of pump-turbine. Economical diameter distributions of penstock are estimated utilizing the same procedures described in term of headrace tunnel and considering construction procedures.

The lower branch location is usually benefitial but its location is selected at the middle step of penstock considering the limit of steel thickness. Qualities of steel pipe of HT-60kg/mm^2 (high tension steel) and HF - 80 kg/mm^2 classes are adopted and the maximum thickness of the former is limited as 36 mm accounting welding capability. For designing of penstock steel, transfering rate to the rock of internal pressure including water hammer is, as a matter of course, considered to make economized because rock characteristics are judged to be enough to execute so, elastic modulus coefficient of plastic deformation and design criteria of rock are assumed as followings:

Elastic Modulus 50,000 kg/cm^2 at the upper part
75,000 kg/cm^2 at the lower part

Coefficient of Plastic Deformation
0.3 for the normal case
0.5 for the critical case

Safety Factor of Elastic Modulus
2.5 for the normal case
7.5 for the critical case

(Note) For the normal case, allowable stress is adopted but for the critical case, elastic yield point is allowed and bigger thickness between two cases are adopted as design thickness. Also, minimum and surplus thickness of 2 mm are considered for designing.

At a little upstream of branch portion, the access tunnel is planned for construction and drainage system, and also drainage system along the penstock line is considered to decrease the external water pressure.

Stress analysis by the external water pressure is to be studied from now on.

(5) Underground Power house and Transformer and Draft Gate Room

The dimensions of power house are determined after arranging with electric-mechanic side. According to the field investigations, RQD (rock quality definition) is assumed to be more than 75% because of 470 m underground, but concentrated crack direction and some fault zones with same direction are presupposed along the waterway so that side wall with rock bolting system is designed, though this idea may be a little conservative.

In the power house, one erection bay for 3 main unit, totally, 3 erection bays are designed taking accounts of construction procedures of step by step and maintenance viewpoints.

As for the transformer room with draft gate room, three units of main transformer, starting convertor and starting transformer and 9 units of draft gate are provided in it and three lines of buss tunnel are constructed to connect with the main transformers.

There is not any information on the rock conditions around these structures so that geological and rock mechanical investigations are quite important to determine these structures in detail.

(6) Draft Tunnel

Steel lining draft tunnel with 9 lines are designed to provide the draft gate, which is utilized for maintenance and inspection of pump-turbine and relevant mechanic equipment, and to keep water tightness of draft tunnel.

(7) Tailrace Surge Tank

Tailrace surge tank is provided at the branch location, of which surge tank is designed as the same idea of headrace surge tank excepting differences of surge chamber type and installation of air-vent. The former is consisted of upper and lower chambers of tunnel type considering differences of normal and lower water levels, economical and stable structures, relation of three tailrace tunnels and construction procedures. The latter is connected with the cable tunnel because very rare type surge tank namely, air cushion type surge tank has to be designed if the air-vent is not provided.

(8) Tailrace Tunnel

The tailrace tunnel is designed just as the same procedures with headrace tunnel.

(9) Outlet

Structure of outlet is designed as horizontal type and roller type gate with gate shaft is installed.

The fore-bay has to be excavated to keep necessary reservoir depth and hydraulic phenomena are also considered, of which fore-bay is connected with canal.

As this outlet is located at the end of back water of lower reservoir, so called sabo-dam is provided just at the upstream from the outlet location for fear that sedimented materials is deposited during operation periods. The sedimentable capacity by sabo-dam is 0.9×10^6 m^3 of which amount is corresponding to 50 years life.

(10) Switchyard and Cable Tunnel

The switchyard is selected as open type with dimension of 130m x 210m at altitude of 415m in which the main building for operation, office and so on is provided and also some space for recreation and or sports is constructed nexting to the switchyard by means of utilization of somehow flat place.

The inclined cable tunnel is designed to connect the OF-cable between transformer and switchyard, of which tunnel is planned to be also used for air ventilation.

(11) Access Tunnel, Elevator Shaft and Road

Two kinds of access route are designed, namely, the former is mainly used for transportation of many kinds of equipment and materials, the latter is designed as the elevator shaft for maintenance, operation and emergency exit and also air ventilation using the spare space is planned.

The main access road is to be constructed from the federal road of BR-116 to the access tunnel along Sao Lourenco River.

Many other access roads are planned by means of mainly inprovement of the existing forest roads from 600 m downstream of the outlet. These roads are connected to the switchyard, the elevator shaft, the construction tunnels and the upper reservoir.

The preliminary designs of power structures are attached in this report.

(IV) Lower Reservoir

Damsite of LH-2A to develop the lower reservoir is located at 9 km downstream of the power station.

Several damsites are selected to make preliminary comparison of the construction costs of dams including concrete type dams and other related main structures and the damsite is finally determined.

Dam axis is located at the narrow valley of both banks being protruded just downstream of wide valley which is necessary to secure the necessitated reservoir capacity.

This reservoir is consisted of gross capacity being 173 x $10^6 m^3$ in which effective capacity is only 99 x $10^6 m^3$.

The pump station called EE-8A with capacity of 134 MW is provided at the left bank neighbouring to the dam.

The preliminary designs of the dam, relevent structures and pump station are shown in this report.

(1) Dam

As for dam type, curved rock fill type dam is selected considering topographical and geological conditions. Crest length and dam height are 570m and 100m respectively, the slopes of both sides are deteermined as 1:2.3 and 1:2.1 for up and downstreams respectively using the same calculation criteria described already after assuming the characteristics of embankment materials by means of the field investigations.

Though any geological investigation is not executed at this damsite, rock is exposed at river - bed but remained soil depth is anticipated to be deeper in accordance with altitude being higher, so that the excavation limit for dam is assumed to be 1.2 km/sec of seismic speed. According to exposed rock conditions composed of quartz-schist, rock characteristics is judged to be fairly good but some foundation treatment with grouting may be necessitated to improve the watertightness of foundation.

Furthermore, as the water depth from the foundation is 25m at the downstream, careful study on the dam and foundation stabilities is quite recommendable. For one of this purpose, weighting zone with concrete wall at the downstream of dam is provided and this space is planned to utilize for the switchyard of pump station.

(2) Spillway

Spillway with 2 radial gates is designed at the right bank neighbouring to the edge of dam. Dimension of gate is determined to be the same water level as the normal water level of reservoir by the gate operation, and reservoir regulation for the given 1,000 years return period flood hydrograph and finally the water level is kept at the normal water level after passing the flood by means of gate operation.

Roller type dissipator is adopted as of which type is considered to be the most effective type, taking account of deep water depth at the downstream and relation among other structures.

(3) Cofferdams

Height of the upper cofferdam is decided by means of the dconomical comparisons with diversion tunnel as already mentioned procedures. Axis of the upper cofferdam is determined aiming at reinforcement of dam by supplying the weighting zone.

The lower cofferdam is consisted of concrete wall with embankment of which location is selected at 600m downstream from the dam axis, because structures rel ted to the intake of pump station, the dam and the spillway are necessary to be constructed as shown in the preliminary designs. The concrete wall after removing the embankment is planned and designed to be used for the intrusion protection of sedimented materials to the intake from the downstream during pump operation.

(4) Diversion Tunnel

The diversion tunnel is layouted at the right band, of which diameter is determined by the already mentioned procedures. After the function of diversion tunnel, almost of all the tunnel is used for the below mentioned outlet works.

(5) Outlet Works

Morning glory type is designed for intake of outlet works near the intake of diversion tunnel. The valve and pipe line of 1.5m are adopted for the outlet works the former with operation chamber if provided at the end of diversion tunnel considering the easiness of operation.

Main dimensions of São Lourenco Reversible Power Station are shown in Table III-7.2.

TABLE III-7.2: MAIN DIMENSIONS OF SÃO LOURENCO REVERSIBLE POWER STATION

Description	Unit	Dimensions
1. DRAINAGE AREA		
. GD-6	km^2	58.0
. LH-3	km^2	5.7
. LH-2A	km^2	142.0
. Average inflow at GD-6	m^3/s	2.26
. Average inflow at LH-3	m^3/s	0.34
. Average inflow at LH-2A	m^3/s	4.38
2. RESERVOIRS		
. Upper Reservoir (LH-3/GD-6)		
- High water level	m	709.70
- Normal water level	m	708.00
- Design water level	m	706.00
- Low water level	m	702.00
- Effective volume	10^6m^3	89.2
. Lower Reservoir (LH-2A)		
- High water level	m	153.00
- Normal water level	m	153.00
- Design water level	m	145.00
- Low water level	m	130.00
- Effective volume	10^6m^3	99.2

TABLE III-7.2 (cont.)

Description	Unit	Dimensions
3. PUMPING AND GENERATION PLAN		
. Gross head	m	561.00
. Effective head	m	525.00
. Number of units	1	9
. Output capacity per unit	MW	315
. Maximum output	MW	2,835
. Unit discharge	m^3/s	70.0
. Maximum discharge	m^3/s	630.0
4. STRUCTURES		
. Dam of GD-6		
- Type	-	semi-rockfill
- Crest length	m	486
- Height	m	47
. Dam of LH-3		
- Type	-	semi-rockfill
- Crest length	m	335
- Height	m	40
. Dam of LH-2A		
- Type	-	semi-rockfill
- Crest length	m	570
- Height	m	101
. Intake		
- Type	-	Horizontal type
- Gate type	-	Roller type with stop-log
- Gate quantity	-	3
. Outlet	-	
- Type	-	Horizontal type
- Gate type	-	Roller type with stop-log
- Gate quantity	-	3
. Headrace tunnel		
- Type	-	pressure type
- Length	m	840

TABLE III-7.2 (cont.)

Description	Unit	Dimensions
- Diameter	m	3 x 6.90
. Penstock		
- Type	-	embedded type
- Length	m	1,080
- Diameter	m	3 x 6.20 9 x 2.80
. Draft tunnel		
- Type	-	Steel lining type
- Length	m	163
- Diameter	m	9 x 4.8 9 x 4.0
. Tailrace tunnel		
- Type	-	pressure type
- Length	m	2,280
- Diameter	m	3 x 6.90
. Headrace Surge Tank		
- Type	-	port type with chamber
. Tailrace Surge Tank		
- Type	-	port type with chamber
. Power house		
- Type	-	underground
- H X B X L	m	41 x 25 x 290
. Transformer room		
- Type	-	underground
- H X B X L	m	16 x 18 x 285
. Switchyard		
- Type	-	normal open type
- Area	m^2	25,000

7.2.2 Pump Station of EE-8A

Pump station with pumping-up capacity of 4 units x 33,5 MW = 134 MW and necessary maximum pumping-up discharge of 126 m^3/s in year 2040 is provided at the left bank neighbouring to Dam of LH-2A.

Intake is located just downstream of dam which is connected with 2-lines pressure tunnel.

Pressure tunnel is divided into 2 lines each for steel lining draft tunnel with branch and the draft gates with draft gate room are provided on the way to the pump house.

The pump house is designed as underground type with relation to the topographical condition, of which dimensions are determined under discussions with electric and mechanic side.

The pumped up water is conducted to the upper reservoir through 4 lines at first and 2 lines of embedded of penstock pipe. At the end of penstock, outlet with gate is provided.

Access to the pump house and draft gate room is tunnel type which is planned also to be used for power cable lines. In front of the portal of access tunnel, the switchyard is designed on the weighting zone of the dam.

For the ventilation, vertical shaft by means of drilling is planned at the mountain side of pump house.

The preliminary designs are attached in this report.

The main dimensions of Pump Station of EE-8A are shown Table III-7.3.

TABLE III-7.3 - MAIN DIMENSIONS OF PUMPING STATION OF EE-8A

Description	Unit	Dimensions
1. DRAINAGE AREA		
. LH-1 (lower reservoir)	km^2	363.0
. LH-2A (upper reservoir)	km^2	142.0
2. RESERVOIR		
. Upper Reservoir (LH-2A)		
- High water level	m	153.00
- Normal water level	m	153.00
- Design water level	m	145.00
- Low water level	m	130.00
- Effective volume	$10^6 m^3$	99.2
. Lower Reservoir (LH-1)		
- High water level	m	
- Normal water level	m	78.00

TABLE III-7.3 (cont.)

Description	Unit	Dimensions
- Design water level	m	71.00
- Low water level	m	58.00
- Effective volume	$10^6 m^3$	300
3. PUMPING PLAN		
. Gross head	m	74.00
. Effective head	m	77.00
. Number of units	-	4
. Installed capacity per unit	MW	36.5
. Total installed capacity	MW	146.0
. Unit pumping capacity	m^3/s	40.0
. Maximum pumping capacity	m^3/s	160.0
4. STRUCTURES		
. Intake		
- Type	-	Horizontal type
- Gate type	-	Roller type with stop log
- Gate quantity	-	2
. Outlet		
- Type	-	Horizontal type
- Gate type	-	Roller type with stop log
- Gate quantity	-	2
. Tailrace tunnel		
- Type	-	pressure type
- Length	m	450
- Diameter	m	2 x 5.30
. Draft tunnel		
- Type	-	steel lining type
- Length	m	50
- Diameter	m	4 x 3.8
. Penstock		
- Type	-	embedded type

TABLE III-7.3 (cont.)

Description	Unit	Dimensions
- Length	m	173
- Diameter	m	2 x 4.50
. Pumping house		
- Type	-	underground
- H X B X L	m	32 x 16 x 84
. Switchyard		
- Type	-	Normal oepn type
- Area	m^2	3,600

7.2.3 Pump Station of Pipe Line

This pump station is planned as other alternative using the pondage type upper reservoir as described already.

The layout of pump station is attached in this report but that of pipe line is under designing.

Total head including loss head and water head differences for 29 km pipe line is estimated as 190 m so that 6 units of pump with 55.8 MW each are planned under the ground in connection with topographical condition and geological condition which is supposed to be weathered until deep part near the pump structures. Accordingly, geological investigations are quite required.

Three morning glory type intakes with 35 m vertical shaft waterway are designed in the pondage type reservoir.

Other structures of this pump station are more less as the same as the pump station of EE-8A in ideas and or design procedures. The different structures are as follows; access tunnel to pump house and power cable tunnel are separately designed in consideration of ventilation system and making shorten the power cable tunnel.

Drainage gallery system around pump house, draft gate room is also used for this purpose, is planned because the ground water level is supposed to be high according to the field investigations.

The most economical diameters and line numbers of the pipeline are studied considering operation commencement years, energy consuption year by year, construction cost of pipe line including foundation and annual equalized rate, and the results of study are shown that 3 lines with 3.90 m diameters case is judged to be most economical.

According to the pipe lines, the foundation conditions of the selected route are supposed to be almost covered with soft soil and to be deep to the sound and or rock foundations so that soil mechanic investigations are recommendable to be carried out for selection of support types of pipe line.

The main dimensions of pipe line type pump station are indicated in Table III-7.4.

TABLE III-7.4 - MAIN DIMENSIONS OF PIPE LINE TYPE PUMP STATION

Description	Unit	Dimensions
1. RESERVOIR		
. Lower Reservoir (pondage type)		
- Area of pondage	km^2	3.2
- High water level	m	717.5
- Design water level	m	710.0
- Low water level	m	695.0
- Effective volume	10^6m^3	73.0
2. PUMPING PLAN		
. Gross head	m	90
. Effective head	m	190
. Number of units	-	6
. Installed capacity per unit	MW	60
. Total installed capacity	MW	360
. Unit pumping capacity	m^3/s	27
. Maximum pumping	m^3/s	162
3. STRUCTURES		
. Intake		
- Type	-	morning glory type
. Tailrace tunnel		
- Type	-	pressure type
- Length	m	180
- Diameter	m	3 x 4.0

TABLE III-7.4 (cont.)

Description	Unit	Dimensions
. Draft Gate		
- Gate type	-	Bonnet type
- Gate quantity	-	6
. Draft Tunnel		
- Type	-	steel lining type
- Length	m	45
- Diameter	m	6 x 3.0
. Penstock		
- Type	-	embedded type
- Length	m	160
- Diameter	m	3 x 3.9
. Pipe line		
- Type	-	steel pipe line
- Length	km	29
- Diameter	m	3 x 3.9
. Pumping House		
- Type	-	underground
- H X B X L	m	36 x 18 x 125
. Switchyard		
- Type	m	normal open type
- Area	m^2	4,900

7.2.4 Cubatão Compounded Reversible Power Station

(I) Upper Reservoir

As for the upper reservoir of this power station, the existing reservoirs of Billing and Pedras of which reservoirs are connected by Summit Control with the gate are planned to be utilized. The above mentioned effective reservoir capacities are $1080 \times 10^6 m^3$ and $16,5 \times 10^6 m^3$ respectively and these reservoirs are simultaneously used for Cubatão Power Stations I and II of which generation capacities are 460 MW and 420 MW respectively.

(II) Power Structures

As for the layout selection of the power structures, the locations of intake and outlet structures are limited, namely, the former is to be selected considering the shape of Pedras Reservoir, the relation with the intake of Cubatão Power Station - II and the topographical conditions, and for the latter, the location of lower dam site is limited by means of the topographical conditions and other existing structures such as the intake dam for the water supply owned by SABESP (Companhia de Saneamento Basico do Estado de São Paulo) and the highway bridge of State Road - Rodovia dos Imigrantes - SP-160, accordingly, the route of water-way and the location of power house have to be selected taking into considerations of the geological contions and the relations of each structure. But there is not enough geological data excepting those of Cubatao Power Station - II so that the layout of power structures selected considering only the relations of each structure. Therefore, the layout of power structures is recommendable to be reconsidered referring the results of geological investigations.

The generation capacity is selected as 2,400 MW with 8 main units, considering the reservoir capacity of Pedras. Accordingly, the following system is planned, namely, 2, 4 and 8 lines of penstock with the branches at the middle and lower step portions, the powerhouse of 4 main units with 1 erection bay each, the transformer room of 1 transformer for 2 main units each with 8 draft gate rooms, 8 and 4 lines of steel lining draft tunnel with 2 surge tanks, 2 lines of tailrace tunnel, access tunnel, open type switchyard, cable tunnel with ventilation duct, elevator shaft and tunnel for mainly maintenance and operation, and other facilities.

(1) Intake

The horizontal type intake with the fore-bay is designed considering the topographical and reservoir conditions, and the roller type gate with vertical shaft is installed at a little downstream of intake for the maintenance of penstock.

(2) Penstock

The embedded type penstock is designed between the intake and the main-valve of pump-turbine. The economical diameter distribution study of penstock is performed in accordance with the same procedures mentioned already. The location of branch portion is adopted as the same idea as the normal designing, but the detailed designing of penstock is to be performed considering the same procedures as mentioned in the power structures of Sao Lourenco Reversible Power Station.

(3) Underground Powerhouse and Transformer Room with Draft Gate Room.

The dimensions of power house and transformer room are determined after arranging with electric-mechanic works. Considering the geological conditions of Cubatão Power Station - II, the geological conditions are judged to be fairly excellent, but the special considerations are not performed because of the time shortage for study.

In the power house, one erection bay for 4 main units, totally 2 erection bays are designed accounting the step by step construction procedures and maintenance view points. As for the transformer room with draft gate room, 4 units of main transformer, starting converter and starting transformer and 8 units of draft gate are provided in it, and 4 lines of buss tunnel are designed to connect with the main unit.

(4) Draft Tunnel

The steel lining draft tunnel of 8 and 4 lines with 2 branch portions are designed to install the draft gate which is used for maintenance and inspection of pump-turbine and so on and to keep watertightness of the draft tunnel.

(5) Tailrace Surge Tank

The railrace surge tank is designed as the same idea as that of São Lourenco Reversible Power Station.

(6) Tailrace Tunnel

The diameter of tailrace tunnel is designed in accordance with the same procedures mentioned already.

(7) Outlet

The horizontal type outlet structure with the roller gate accompanying with the vertical shaft at a little upstream is provided considering the necessiation, of fore-bay structure.

(8) Switchyard and Cable Tunnel

The switchyard is selected as the open type with the dimension of 90 m x 220 m at the altitude of 225 m, where the main building for operation, office and so on is provided.

The inclined cable tunnel is designed for the OF-cable and also air ventilation.

(9) Access Tunnels to Power house

The approach to the project site is very convenient because of the existing roads being already provided.

Two kinds of access route are planned to the power house that the one is mainly for transportation of equipment and materials and the other is the combination route of tunnel and elevator shaft for maintenance, operation and emergency refuge.

The preliminary designs of power structures are attached in this report.

(III) Lower Reservoir

The dam site to develop the lower reservoir is located at 4 km upstream of Cubatao River from Cubatao City.

The dam axis is selected considering the layout of dam and the relevant and existing structures.

The preliminary designs of lower reservoir are shown in this report.

(1) Dam

As for the dam type, the curved semirockfill dam with blanket is selected considering the dam foundation condition of which depth of alluvial deposits is assumed to be more than 40 m and the crest length and height of dam are 610 m and 38 m respectively.

(2) Spillway

The spillway with gate is designed at the right bank neighbouring to the dam. The dimension of gate is determined taking account that the design flood of 1,000 years return period is to be safely overflowed and the released discharge on the 200 years hydrograph is to be less than 650 m^3/s by means of gate operation for the downstream flood control.

The horizontal stilling basin type of dissipator is adopted considering the downstream river condition, of which design capacity is 650 m^3/s as mentioned above.

(3) Temporary Diversion Conduit

According to the temporary diversion conduit system during the construction of the dam and the relevant structures, the so-called half river diversion procedure is judged to be reasonable because of the long dam crest length, the fairly flat river bed and the big designed discharge such as 527 m^3/s which is corres-ponded to the peak discharge of the 25 years return period hydrograph.

On the construction procedures, the righ bank side structures are constructed diverting the flow discharge to the left side by means of the excavated canal and the cofferdam, and at the second stage, the flow discharge is diverted to two conduits constructed under the spillway, the one of which is plugged and the other utilized for the installation of outlet works, and then the left side embankment of dam is executed.

(4) Outlet Works

The outlet works with the valve of 1.0 m is planned to be installed at the conduit as mentioned above.

TABLE III-7.5: MAIN DIMENSIONS OF CUBATAO COMPOUNDED REVERSIBLE POWER STATION

Description	Unit	Dimensions
1. DRAINAGE AREA		
. Billings Reservoir	km^2	377.00
. Pedras Reservoir	km^2	30.00
. Cubatão Reservoir	km^2	128.00
. Average inflor at Billings		
- Natural inflow	m^3/s	11.47
- Pumping up	m^3/s	58.80
. Average inflow at Pedras	m^3/s	1.30
. Average inflow at Cubatão	m^3/s	9.38
2. Reservoirs		
. Upper Reservoir of Billings		
- High water level	m	747.00
- Normal water level	m	746.50
- Design water level	m	-
- Low water level	m	728.00
- Effective volume	$10^6 m^3$	1,080.00
. Upper Reservoir of Pedras		
- High water level	m	728.50
- Normal water level	m	728.00
- Design water level	m	727.50
- Low water level	m	726.50
- Effective volume	$10^6 m^3$	10.00
. Lower Reservoir of Cubatao		
- High water level	m	35.00
- Normal water level	m	33.00
- Design water level	m	31.50
- Low water level	m	29.00
- Effective volume	$10^6 m^3$	9.20

TABLE III-7.5 (Cont.)

Description	Unit	Dimensions
3. GENERATION PLAN		
. Gross head	m	696.00
. Effective head	m	671.00
. Number of units	-	8
. Output capacity per unit	MW	300
. Maximum output	MW	2,400
. Unit discharge	m^3/s	53.00
. Maximum discharge	m^3/s	424.00
4. STRUCTURES		
. Intake		
- type	-	Horizontal type
- Gate type	-	Roller type with stop-log
- Gate quantity	-	2
. Penstock		
- Type	-	Embedded type
- Length	m	1,420
- Diameter	m	2x6.00, 4x3.50, 8x2.40
. Draft tunnel		
- Type	-	Steel lining type
- Length	m	180.00
- Diameter	m	8 x 4.00, 4 x 5.20
. Tailrace tunnel		
- Type	-	Pressure type
- Length	m	1,665
- Diameter	m	2 x 7.00
. Tailrace Surge Tank		
- Type	-	Port type with chamber
. Power house		
- Type	-	Underground
- H X B X L	m	42.80 x 25.00 x255.00
. Transformer Room		
- Type	-	Underground
- H X B X L	m	16.00 x 18.00 x 215.00

TABLE III-7.5 (Cont.)

Description	Unit	Dimensions
. Switchyard		
- Type	-	Normal open type
- Area	m^2	19,800

7.3 Preliminary Design of Electric and Mechanic Works

7.3.1 Electric Machinery

(I) São Lourenco Reversible Power Station

(1) Selection of Main Unit

São Lourenco Reversible Power Station consisting of main point of Juquia System is planned as normal effective head of 525 m with available discharge of 630 m^3/s at the same condition. Output 2,835 MW of power station is judged to be reasonable including efficiencies of pump-turbine and generator-motor, in case of that technical innovations in the ages of 1990 when this power station is being taken into construction.

Adequate unit numbers matching to this output capacity are necessary to be selected. Generally speaking, in case that the bigger unit capacity is adopted, whole construction cost including both of electric-mechanic and civil engineering costs has tendence to be more economical, so that the unit capacity is advisable to be determined as the most benefitable one, considering the above mentioned economy, equipment manufacturing limit, installation results, limitation of transportation and harmony with power system and so on.

In case of this power station, 8 - 12 units plan is most adequate in view of equipment manufacturing limit and whichever units plan being to be developed within the limits of the above mentioned unit numbers. On the other hand, development procedures of 3 or 4 units system with 1 tunnel are most advisable considering viewpoints of civil works.

According to forecast result of electric demand and supply, 3 units operation commencement each year, (3 units operation commencement in 2 years at the first stage), namely, step by step operation commencement in case of this power system is found out to be most advisable.

From the above mentioned viewpoints, unit numbers of 9 are selected under whole considerations that the above mentioned unit numbers are not unreasonable from view of manufacturing, limitation of transportation, installation results and so on, and furthermore these numbers are economically benefitable. Accordingly, each unit capacity is selected as 315 MW and total output of this power station is 2,835 MW. Each unit consists of the compositions with 324 MW vertical shaft, Francis type reversible pump-turbine, 350 MVA synchronous generator-motor and 1,050 MVA main transformer.

The compositions of main units are indicated in Table III-7.6

TABLE III-7.6 - Compositions of Main Units of São Lourenco Reversible Power Station.

Item	Unit	Description
1. PUMP TURBINE		
. RYPW		Vertical shaft. Francis type reversible pump-turbine
. Number	unit	9
. Turbine Rating		
- Gross head		
Maximum	m	578
Normal	m	561
Minimum	m	549
- Effective head		
Maximum	m	558
Normal	m	525
Minimum	m	516
- Discharge	m^3/s	70 at normal effective head
- Output	MW	324 at normal effective head
- Revolving speed	rpm	450
. Pump Rating		
- Pump head		
Maximum	m	595

TABLE III-7.6 (Cont.)

Item	Unit	Description
Minimum	m	562
- Pumping discharge		
Maximum	m^3/s	54 at minimum pumping head
Minimum	m^3/s	48 at miximum pumping head
- Maximum pump input	MW	340 at minimum pumping head and maximum pumping discharge
- Revolving speed	rpm	450
2. GENERATOR MOTOR		
. Type		vertical shaft, reversible synchronous generator motor of totally enclosed cooling air circiut with surface air coolers. Forced air cooled using motor driven fans.
. Number	unit	9
. Generator Rating		
- Output	MVA	350
- Voltage	KV	18
- Power factor	%	90 (lagging)
- Frequency	Hz	60
- Revolving speed	rpm	450
. Motor Rating		
- Output	MW	340
- Voltage	KV	18
- Power factor	%	100
- Frequency	Hz	60
- Revolving Speed	rpm	450
3. MAIN TRANSFORMER		
. Type		split type, 3-phase, indoor
. Number	unit	3
. Capacity	MVA	1,050
. Voltage	KV	18/460
. Frequency	Hz	60

TABLE III-7.6 (Cont.)

Item	Unit	Description
4. PUMP STATION TRANSFORMER (include pipe line station)		
. Type		1 - phase
. Number	unit	4 (1... reserve)
. Capacity	MVA	230
. Voltage	KV	460/138
. Frequency	Hz	60

(2) Power House

The power house is located under the ground, and is consisted of machine hall and transformer room which is commonly used for draft gate room. 9 units of pump-turbine, generator-motor, other auxiliary equipment and circuit breakers of power system parallel for generator main circuit and so on are installed in the power house with width of 25 m and length of 270 m, and furthermore 2 units of 300 ton overhead travelling cranes are also installed in it.

Concerning the assembly hall, 1 assembly hall for 3 units is planned to be set up considering operation commencement of 3 units each year being planned, namely, more less 3 units being installed as equipment installation schedule, maintenance safety in accordance with crane operation and so on.

The transformer room being commonly utilized for draft gate room is designed as width of 18 m and length of 250 m taking into consideration of transportation, assembly, maintenance space and so on.

3 units of main transformer, 3 pairs of starting equipment (starting transformer and starting static thyristor converter) are distributed in this transformer and draft gate room.

(3) Main Circuit and 460 KV Switchyard

(a) The main single line diagram for this power station is shown in Figure III-7.26

(b) As this reversible power station is underground type and also high speed and large capacity machine, the following considerations are payed considering economy and reliability.

(b1) Pump starting method is adopted as low voltage synchronous parallel by thyristor starting. Thyristor equipment is distributed with 3 pairs totally 1 pair to 3 units and is aimed at the improvement of reliability by connecting each other. Accordingly, combination system with synchronous starting method is not especially adopted because of being accompanied with complication of control.

(b2) As for circuit breaker of power system parallel being followed by low voltage synchronous parallel method, circuit breaker of SF_6 gas with the excellent interruption ability of large currents is utilized. This SF_6 gas type is utilized for change disconnecting switch of generator and pumping. Utilization of these SF_6 gas type is accompanied with reduction of equipment.

(b3) As main transformer has its high reliability, 1 pair transformer to 3 generator-motor units is arranged to reduce the installing space.

(b4) From the results of mentioned above (b2):

a. 18 KV low voltage starting transformers are installed in exchange for 460 KV extra high voltage starting transformer, so that space is reduced and also reliability is improved.

b. Main transformer is cut off at the time of speed up of generator, so that over excitation of transformer is no feared.

(c) As distance between the underground main transformer room and switchyard of 460 KV is 1 km in relation with topographical condition, oil filled cable between them is planned as cable to reduce the cable tunnel section area.

(d) 460 KV switchgears is planned as GIS type (Gas Insulated Substation) of which type is that whole switchgear equipment including main bus is insulated by SF_6 gas and other whole ones, excepting charge part being only exposed at the connection with transmission line terminals, are installed in the earthed metal vessel. This GIS type can be not only greatly compacted comparing with usual equipment but also construction cost including that of civil works is devoted to be decreased. Furthermore mechanically all of the equipment such as conducting, insulated and contact parts are closed up in the gas so that they are not brittled for a long period and high reliability can be maintained. Equipment assembled and tested at factory are transported and installed being divided into maximum parts so that installation period can be shorten and maintenance is become to be easy.

(e) Bus of switchyard is planned to be method of double bus considering many units numbers.

(f) As this switchyard is utilized for substation of each pump station and pipe line pump station, one tie transformer of 460 KV/138 KV is installed. Single phase transformers of 4 units (230 MVA x 4) including reserve of one unit, are equipped as supply of power is transmitted to each pump station via this transformer.

(g) Main office is consisted of control, protective relay, cable connect, station service cubicle, repairing, office rooms, warehouse and so on. Main units of 9 in the power house and switchgears in the switchyard are planned to be remotely controlled in the control room.

(h) Outline of switchyard layout is shown in Figure III-7.27. As GIS type is adopted, space of switchyard is become very small as 200 m x 120 m.

(4) Transmission line

As for study of transmission design, numbers of circuit and conductor type of transmission line are planned from the view points of steady state stability limit and safety current on temperature rise on the conditions that output of generator operation at São Lourenco Reversible Power Station is 2,835 MW input of motor operation including MW of pump stations is 3,690 MW and transmission line is connected with the existing Embu-Guacu Substation.

Necessary transmission design and related to "Juquia-São Lourenco Project" is as following;

. Transmission line voltage : 460 KW

- Numbers of Circuit : 2 cct
- Size, Number of conductor : $410mm^2 \times 4$
- Kind of conductor : ACSR
- Line Length : 50 km

Embu-Guacu Substation is owned by CESP which is influential electric company in the State of São Paulo. Transmission line from Itaipu Power Station is not directly connected with the above mentioned substation, but is indirectly connected. This substation is consisted of 460 KV and 345 KV and corresponded to so called the outline rings of São Paulo. This substation has enough space and electric capacity necessary to be connected with São Lourenco Reversible Power Station and CESP has also idea to utilize this substation.

Design of 2 cct at transmission line is estimated by general calculation procedures and considering the distance of line being short. This line has enough capacity in the normal condition. Though, operation of some main units is restricted by relation with transmission capacity in case of one line being stopped. This kind of accident is judged to be no problem because of being considered to be rare case.

Anyway, when several conditions of power system is fully established, that is, when the definite study is executed, detailed study on power system conditions including transient stability by means of computer is necessary to be performed in cooperation with CESP.

(II) Cubatão Reversible Power Station

(1) Selection of Main Unit

This power station is planned as normal effective head of 670 m with available discharge of 424 m^3/s at the same condition. Especially, head of pumping is about 697 - 712 m and is very high class.

At present, this power station is the class of the highest head, but at the ages of this power station being taken into construction and moreover in case of considering popularization of this kind of high head and large capacity reversible power station, this power station is presumed not to be corresponded to the most highest head class in the world.

At the present technical development stage taking consideration of fatigue limit of runner material, single reversible pump-turbine is considered that pumping head of about 900 m is limit.

Accordingly, in case of class of 700 m, this kind of machine is not problem from view of manufacturing and reliability. In case of generator-motor, capacity of about 400 MW at 600 rpm is possible by air cooling method of existing type. If water cooling method is adopted, furthermore, manufacturing limit capacity of generator-motor can be increased. On the other hand, development procedures of 3 or 4 units system with 1 tunnel are most advisable considering civil works operation and maintenance view points.

According to forecast result of electric demand and supply, about 4 units operation commencement each year is found out to be most advisable. (4 units operation commencement in 2 year at the first stage).

From the view points of the above mentioned and the same way as São Lourenco Power Station, unit numbers of 8 are selected under whole considerations that the above mentioned units numbers are not unreasonable from views of civil works and electric mechanic works. Accordingly, each unit capacity is selected as 300 MW and total output of this power station is 2,400 MW. Each unit consists of the compositions of 310 MW vertical shaft, Francis type reversible pump-turbine, 335 MVA synchronous generator-motor and 660 MVA main transformer. The compositions of main units are indicated in Table III-7.7.

(2) Power house

This power station is planned in the same considerations as São Lourenco Power Station basically.

(a) The power house is located under the ground, and is consisted of machine hall and transformer room which is commonly used for draft gate room.

(b) 8 units of pump-turbine, generator-motor, other auxiliary equipment and circuit breakers of power system parallel for generator main circuit and so on are installed in the power house with width of 25 m and length of 255 m, and furthermore 2 units of 280 ton overhead travelling cranes are also installed in it.

TABLE III-7.7 - Compositions of Main Units of Cubatão Reversible Power Station.

Item	Unit	Description
1. PUMP TURBINE		
. Type	-	Vertical shaft Francis type reversible pump-turbine
. Number	unit	8
. Turbine Rating		
- Gross head		
Maximum	m	699
Normal	m	696
Minimum	m	693,5
- Effective head		
Maximum	m	693
Normal	m	670
Minimum	m	668
- Discharge	m^3/s	53 at normal effective head
- Output	MW	310 at normal effective head
- Revolving speed	rpm	514
. Pump Rating		
- Pumping head		
Maximum	m	712
Minimum	m	697,5
- Pumping Discharge		
Maximum	m^3/s	40,5 at minimum pumping head
Minimum	m^3/s	38,5 at maximum pumping head
- Maximum pump Input	MW	320 at minimum pumping head and maximum pumping discharge
- Revolving speed	rpm	514
2. GENERATOR MOTOR		
. Type	-	Vertical shaft reversible, synchronous generator motor of totally enclosed cooling air circuit with surface air coolers. Forced air cooled using motor driven fans.

TABLE III-7.7 (Cont.)

Item	Unit	Description
. Number	unit	8
. Generator Rating		
- Output	MVA	335
- Voltage	KV	18
- Power factor	%	90 (lagging)
- Frequency	Hz	60
- Revolving speed	rpm	514
. Motor Rating		
- Output	MW	320
- Voltage	KV	18
- Power factor	%	100
- Frequency	Hz	60
- Revolving speed	rpm	514
3. MAIN TRANSFORMER		
. Type	-	split type, 3 - phase
. Number	unit	4
. Capacity	MVA	670
. Voltage	KV	18,0/500
. Frequency	Hz	60

(Note) 18 KV of Generator voltage is necessary to be studied including stability of shaft in accordance with the study of revolving speed.

(c) Concerning the assembly hall, 1 assembly hall for 4 units is planned to be set up considering 4 units each year operation commencement being planned and maintenance safety in accordance with crane operation and so on.

(d) The transformer room being commonly utilized for draft gate room is designed as width of 18 m and length of 225 m taking into consideration of transportation, assembly, maintenance space and so on. 4 units of main transformer, and 2 pairs of starting equipment are distributed in this room.

(3) Main Circuit and 500 KV switchyard

This circuit and switchyard is planned in the same consideration as São Lourenco Power Station.

Accordingly, outlines of these designs are as followings;

(a) The main single line diagram for this power station is shown in Figure - III.7.28

(b) As this reversible power station is underground type, and high speed-large capacity machine, the following plans are adopted.

(b1) Adoption of pump starting method as low voltage synchronous parallel by thyristor starting. Thyristor equipment is distributed with 2 pairs totally 1 pair to 4 main units.

(b2) Adoption of SF_6 gas type as circuit breaker of power system parallel and charge disconnecting switch of generator-pumping.

(b3) Adoption of 1 pair transformer to 2 generator-motor units.

(c) Adoption of oil filled able to connect the main transformer with an outdoor switchyard.

(d) Adoption of GIS method as 500 KV switchgears.

(e) Adoption of double bus method as bus of switchyard considering many unit numbers.

(f) Main office is consisted of control, protective relay cable connect, station service cubicle, repairing, office rooms, warehouse and so on.

Main units of 8 in the power house and switchgears in the switchyard are planned to be remotely controlled in the control room.

(g) Outline of switchyard layout is shown Figure III-7.29
As GIS type is adopted, space of switchyard is become very small as 220 m x 90 m.

(4) Transmission line

As for study of transmission design, numbers of circuit and conductor type of transmission line are planned from the view points of steady state stability limit and safety current on temperature rise on the conditions that output of generator operation at Cubatão Compounded Reversible Power Station is 2,400 MW, input of motor operation is 3,690 MW and transmsision line is connected with the existing Tijuco Preto Substation.
Results of study are as followings;

- Transmission line voltage : 500 KV
- Number of Circuit : 2 cct
- Size, Number of conductor : 300 mm^2 x 3
- Kind of conductor : ACSR
- Line length : 50 km

Tijuco Preto Substation is owned by Furnas. Transmission line from Itaipu Power Station is directly connected with the above substation. This substation is consisted of 750 KV, 500 KV, 345 KV and corresponded to so called the outline rings of São Paulo. As same as São Lourenco Power Station, this transmission line has enough capacity in the normal condition. Though, operation of some main units is restricted by relation with transmission capacity in case of one line being stopped. This kind of accident is judged to be no problem because of being considered to be rare case.

Anyway, as same as São Lourenco Power Station, detailed study on power system conditions is necessary to be performed in co-operation with CESP and Furnas.

(III) Pump Station

Centering São Lourenco Reversible Power Station, the following each pump station is planned.

Related to the lower basin:

3 pump stations of EE-4, EE-3, EE-8A

Related to the upper basin:

2 pump stations of EE-2, EE-1

Outlines of electrical machinery designings at these pump stations are described as follows;

(1) Selection of Main Unit

Each pump station has low head (about 15 - 80 m) and large pumping discharge (37 - 42 m^3/s) and pumping up head is not so variable.

As for the type of pump, Francis type and Deriaz type are considerable but each pump station is uniformly adopted as Francis type considering that comparatively the head variation is small, the pumping discharge is large, and further, installation results and so on.

Type of main units is necessary to be selected for every each pump station from now on considering several factors such as efficiency, easinesses of maintenance and operation, economy and so on. As for input capacity of each pump station, motor output is calculated based on effective normal head and its discharge, and then, input is calculated considering 5% margin (including station service load) and 95% rating power factor. Also, the number of main units is calculated at the base of pumping discharge of about 40 m^3/s per unit.

The compositions of main units are indicated in Table III-7.8.

TABLE III-7.8 COMPOSITIONS OF MAIN UNITS OF PUMP STATIONS

Pump Station / Item	Unit	Related to Lower Basin Reservoir			Related to Upper Basin reservoir		
		EE-4	EE-3	EE-8A	EE-2	EE-1	
P.S. output	MW	44	80	146	30	114	μ_P=0.9
P.S. input	MVA	46	84	154	32	120	μ_M=0.97 Pf=0.95
1. Pump Rating							
Type	-	Vertical shaft, Francis type					
Number	Unit	4	4	4	4	4	
Effective head	m	25	45	77	15	57	normal
Discharge	m^3/s	37.5	37.5	40	41.25	42.5	at Hp nor.
P output	MW	10.7	19.3	35.2	27.7	7	
Revolving speed	rpm	150	180	225	120	200	
2. Motor Rating							
Type	-	Vertical shaft, synchronous motor					
Number	Unit	4	4	4	4	4	
M output	MW	11	20	36.5	7.5	28.5	
M input	MWA	11.5	21	38.5	8.0	30	Pf=0.95
Voltage	KV	13.8	13.8	13.8	13.8	13.8	
Power factor	%	95	95	95	95	95	
Frequency	Hz	60	60	60	60	60	
Revolving speed speed	rpm	150	180	225	120	200	
3. Main Transformer							
Type	-	3 - phase, outdoor					
Number	Unit	2	2	2	2	2	
Capacity	KVA	23	42	77	16	60	
Voltage	KV	13.8/138	13.8/138	13.8/138	13.8/138	13.8/138	
Frequency	Hz	60	60	60	60	60	

(2) Pump house

Dimension of pump house at each pump station excluding EE-8A Pump Station is designed considering mechanical dimension and assembly hall.

Main units, auxiliary equipment, control equipment, overhead travelling cranes and control room and so on are installed in each pump house with width of 14 - 16 m, length of 65 - 80 m and height of 18 - 25 m from pump center. But, main transformer and switchgears of GIS type for transmission are installed at the outdoor. On the other hand, as EE-8A Pump Station is located under the ground, as same as the next mentioned pipe line pump station, 4 units of pump-motor and circuit breakers of power system parallel for motor breakers and so on are installed in the pump house with width of 16 m, and length of 84 m. This assembly hall is 16 m x 24 m, installed at the one side of the pump house.

(3) Main circuit and 138 KV switchyard

(a) The main single line diagram for this pump station is shown in Figure III-7.30.

(b) Pump machine of each pump station has large discharge and capacity, accordingly, adoption of full voltage starting method for pumpstarting is problem because voltage change to power system is large. Therefore, half voltage starting method is planned, of which method is usually adopted in case of this kind scale of pump station and is also adopted as the actual result in Brazil. This half voltage starting method is to take out half voltage by means of installing medium tap in the main transformer and starting circuit breaker is necessary also at lower voltage side of main circuit.

(c) 1 pair transformer to 2 - motor units is adopted to reduce the equipment space and the cost of construction.

(d) Transmission voltage of 138 KV being generally adopted for this class of scale in Brazil is planned.

(e) Switchgears for transmission (138 KV) is planned as GIS method of SF_6 gas, and its equipment is installed on the housetop because the necessary space is small and the weight is not particularly high and this method is effective to reduce the cost of construction.

(f) Main transformers are installed at the outside of pump house.

(g) The main transformers and switchgears for transmission are installed in the switchyard of outdoor.

(h) Outline of switchyard layout is shown in Figure III-7.31 and III-7.32.

(4) Transmission line

The load to each pump station is transmitted via one tie transformer of São Lourenco Reversible Power Station.

(a) The load to 3 pump stations of EE-4, EE-3, EE-8A is transmitted by nucleus transmission of 2 circuit and the load of 3 pump station is supplied on branching from its nucleus transmission.
Accordingly, at the end of the pump station, the load capacity is more smaller than other pump station so that the load capacity is calculated considering conductor size and number of transmission.

(b) Pipe line pump station is planned instead of 2 pump stations of EE-1 and EE-2. Outline of pipe line pump station is described in (IV).
As the load capacity of this pipe line power station is more larger than the above mentioned 2 pump stations, transmission capacity is calculated by capacity (= 360 MW) for this pipe line station. The circuit-numbers are 2 circuit, too.

(c) Distance, capacity, conductor and so on of transmission line is indicated in Table III-7.9.

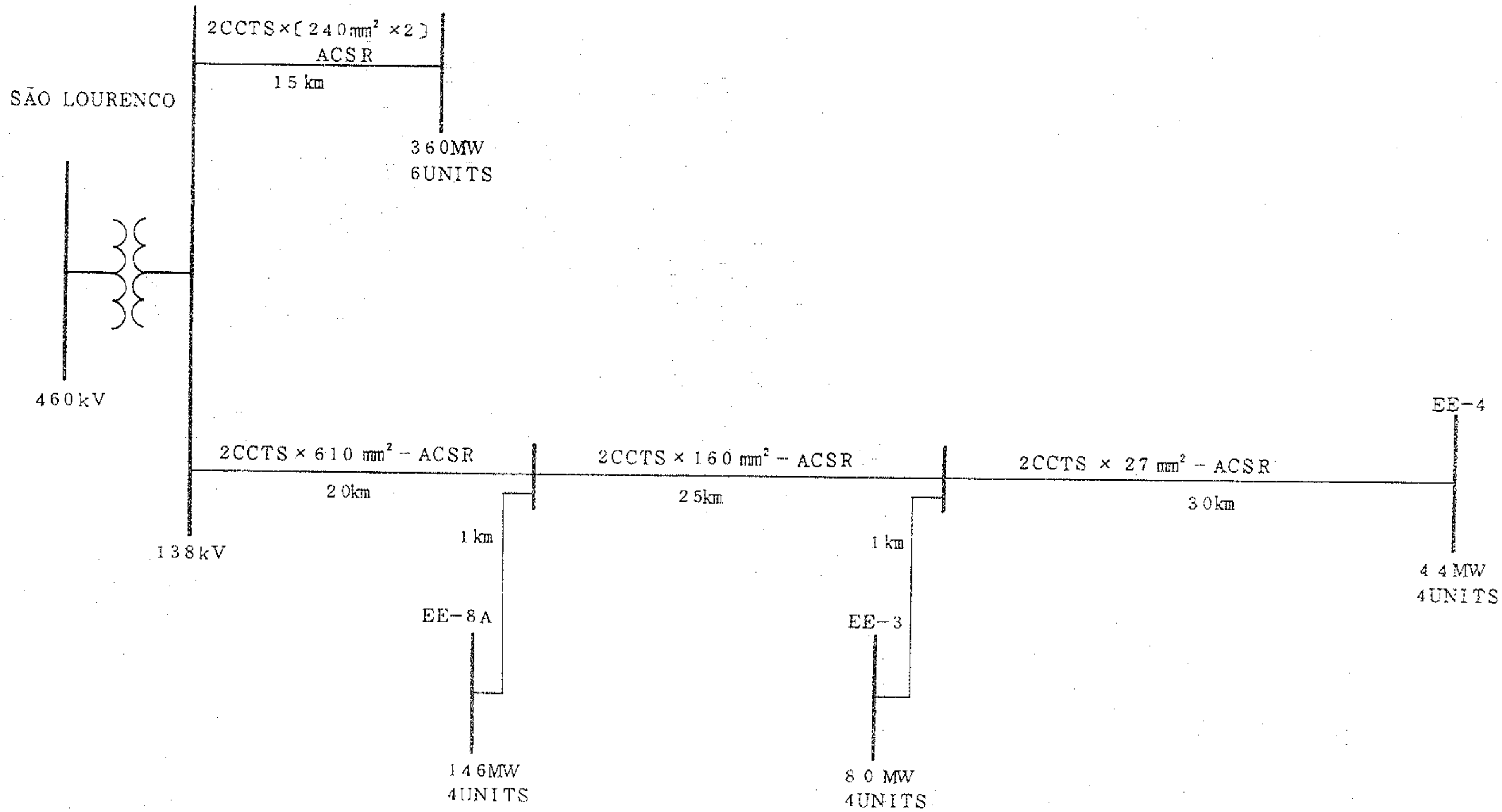


TABLE III−7.9 SINGLE LINE DIAGRAM OF TRANSMISSION LINE

(IV) Pipe Line Pump Station.

Pipe line pump station is planned instead of each pump station (EE-2, EE-1 station) at the upper basin.

Outline of electrical machinery of this pipe line pump station is described below:

(1) Selection of Main Unit

(a) This pump station is planned as normal effective head of 190 m with pumping discharge of 162 m^3/s at the same condition.

(b) Francis pump type is planned as same as other pump station.

(c) Input capacity of motor is calculated from output of motor considering 5% margin and 95% rating power factor.

(d) Numbers of main unit are 6 coinciding water way plan.

(e) The compositions of main units are indicated in Table III-7.10.

(2) Pump house.

(a) The pump house is located under the ground.

(b) 6 units of pump-motor, and circuit breakers of power system parallel for motor breakers and so on are installed in the pump house with width of 18 m and length of 125 m.

(c) Assembly hall is 18 m x 25 m, installed at one side of the pump house.

(3) Main circuit and switchyard.

(a) The main single line diagram for this pump station is shown in Figure III-7.33.

(b) Half voltage starting method is adopted as pump starting method which is the same design as the above mentioned pump stations.

(c) Main circuit is planned by 1 pair transformer to 2 main units.

(d) Voltage of 138 KV is adopted as transmission line voltage.

(e) Main transformer and switchgears for transmission are installed in the switchyard, and GIS method is adopted as switchgears for transmission.

(f) Distance between pump house and switchyard is 200m and is connected with power cable.

(g) Outline of switchyard layout is shown in Figure III-7.34.

(4) Transmission line.

(a) Transmission line is connected with São Lourenco Reversible Power Station.

(b) Distance, capacity, conductor and so on of transmission line are indicated in Table III-7.9.

TABLE III-7.10 COMPOSITION OF MAIN UNITS OF PIPE LINE PUMP STATION

Item	Unit	Description	
P.L. Station output	MW	360	
P.L. Station input	MVA	380	
1. Pump Rating			
. Type	-	Vertical shaft Francis type	
. Number	unit	6	
. Effective head	m	190	normal
. Discharge	m^3/s	27	at Hp nor.
. P output	MW	58.2	
• Revolving speed		300	
2. Motor Rating			
. Type	-	Vertical shaft synchronous motor	
. Number	unit	6	
. M output	MW	60	
. M input	MVA	64	
. Voltage	KV	13.8	

. Power factor	%	95
. Frequency	HZ	60
. Revolving speed	rpm	300
3. Main Transformer		
. Type	-	3-phase, outdoor
. Number	unit	3
. Capacity	KVA	130
. Voltage	KV	13,8/138
. Frequency	HZ	60

7.3.2. Design and Analysis of Power System.

The power systems in Brazil, especially in the region of São Paulo are fairly complicated. Furthermore, connection procedures with any power system and at what locations of them for São Lourenco and Cubatão Reversible Power Station are very difficult at the pre-FS stage of this project to require the analysis studies of power system to the related electric power companies after discussion between DAEE and the related electric power companies.

Accordingly, execution of enough power system analysis will not be possible during the period of preparation of this report.

On the other hand, conditions of power system including output of São Lourenco Reversible Power Station (315 MW x 12 units=3780 MW) at 1990 years is studied by CESP.

The studied result is judged to be feasible for São Lourenco Reversible Power Station on transmission system if Embu-Guacu Substation and so on are reconstructed. But Cubatão Compounded Reversible Power Station is not included in that report.

Anyway, detailled power system including São Lourenco and Cubatão Reversible Power Station and each pump station have to be planned and analized. According to that analysis, the most steady electric power system and economic method have to be selected. As the studied result, the voltage, number, and size of detailed transmission line and the reconstruction of the related existing substation will be planned.

The scheme of the transmission line system in the region of São Paulo is shown in Figure III-7.35. and a conceptual passing route of the transmission line is shown in Figure III-7.36.

7.3.3. Field Investigation of Road and Bridge Conditions for Heavy Equipment Transportation.

(1) São Lourenco and Cubatão Reversible Power Stations are the large scale ones and are consisted of many heavy equipment. Especially, pump-turbine runners have to be manufactured as one body runner at factory because of the high head power stations. Furthermore, the main transformers are necessary to be manufactured to the utmost at factory to maintain their reliability and to decrease their processing at the site. Maximum weights and dimensions of the both power stations for transportation are as followings;

Name of Power Station	Maximum Weight	Maximum Size
São Lourenco	Transformer; 65t	Pump-Turbine
Cubatão		runner; 5,5 m (diameter)

(Note) No including trailer weight.

(2) Transportation routes are planned to pass through the following ways; from Santos Harbor to Cubatao site (SP-150), after to São Lourenco site by State Road (SP-055) and Federal Road (BR-116).

(3) Field Investigations of road, bridge and port facilities are executed based on the above mentioned plan.

(4) Out line of field investigation results are described herein under;

(a) Bridge.

(a1) Route to São Lourenco Reversible Power Station.

a. Number of bridges: 12 (length 28m - 240m).
b. Bridge necessary checking foundation part, Bridge.
c. Bridge necessary reinforcing; 5 Bridges.

(a2) Route to Cubatão Reversible Power Station.

a. Number of bridge; 4 (length 6m - 500m).

b. Bridge necessary reinforcing; 1 Bridge.

c. Utilization of detour because of unbearable even if reinforced; 1 Bridge.

(Note) The both routes have no problem as effective bridge width of 6 - 10 m.

(b) Roads and others (including routes to the both power stations).

(b1) Road foundation and effective width no problem.

(b2) No tunnel, road curves, clearance from road to electric-distribution lines crossing road no problem.

(b3) One bridge crossing railway necessary reinforcing.

(b4) On the way to São Lourenco Power Station, there is one place necessary to pass under viaduct with 6 m width and 4 m clearance so that by passing through other road is necessary stopping temporarily general traffic by means of consulting with the related organizations.

(b5) Some old bridges are generally necessary to be reinforced.

(b6) Special item giving restriction to equipment manufacturing from view point of transportation condition, at this present, is judged not to be existing.

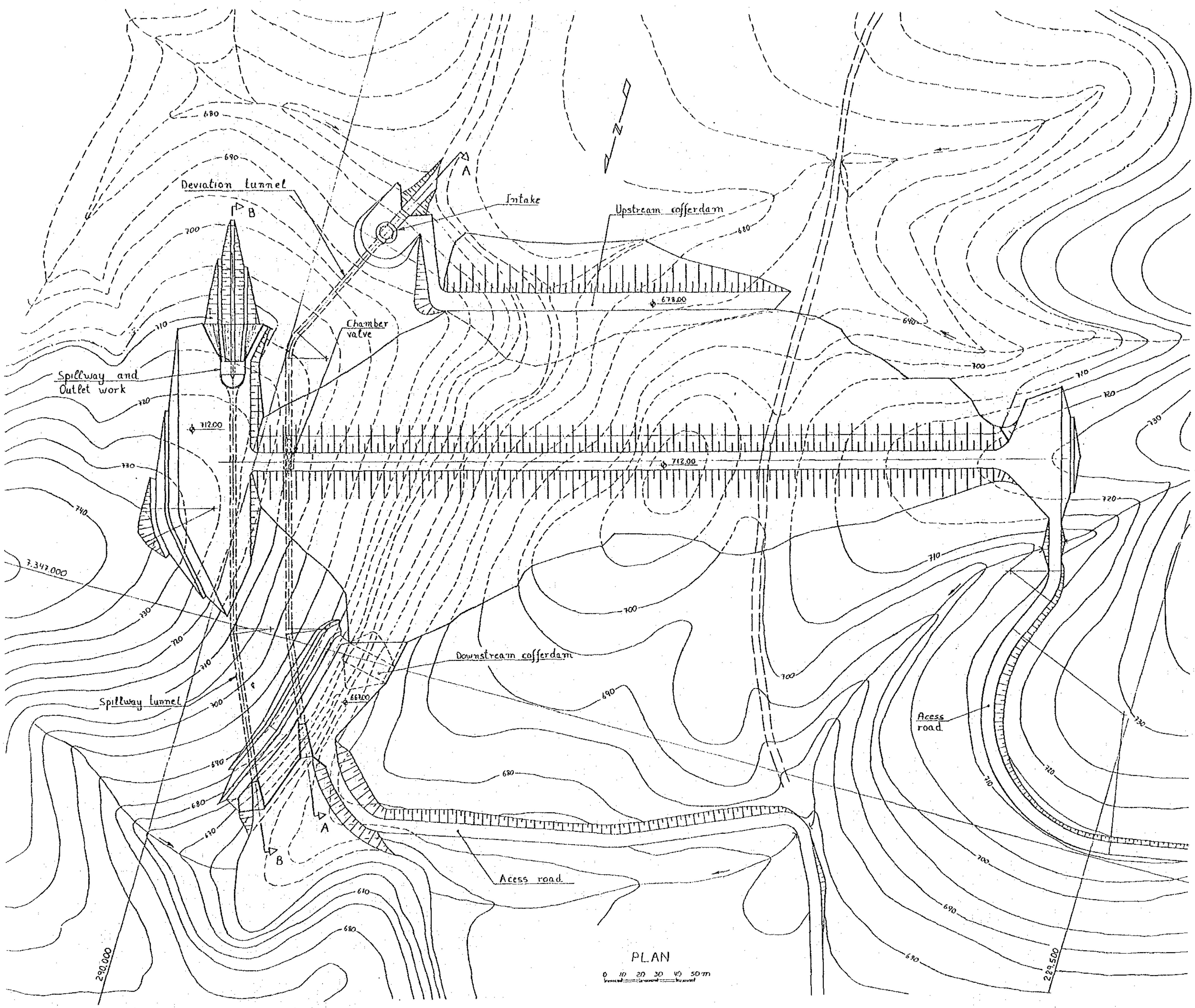
(b7) At the time of definite study, existences of some interruptions giving weight and dimension of equipment are necessary to be checked again by means of detailed field investigation of bridge conditions.

(b8) Field investigation results of road conditions for São Lourenco and Cubatão Reversible Power Stations are shown in Appendix - C.

(c) Santos Harbor

Conditions of harbor have enough equipment and have not problem.

Berth depth	:	36.5 ft = 11 m
Maximum tonnage of ship	:	25.000 ton
Travelling unloader	:	6 - 16 ton
Crane ship unloader	:	150 ton



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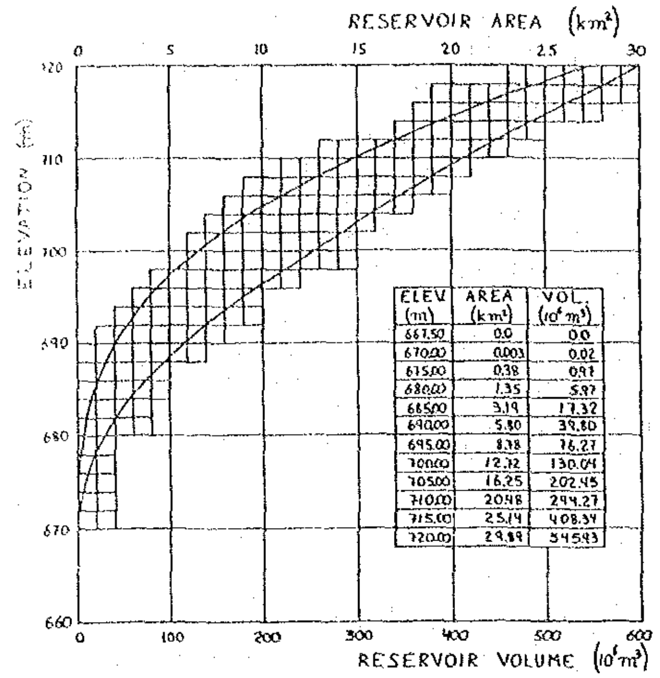
TÍTULO
JUQUIÁ - SÃO LOURENÇO PROJECT

DAM OF GD-6

PLAN

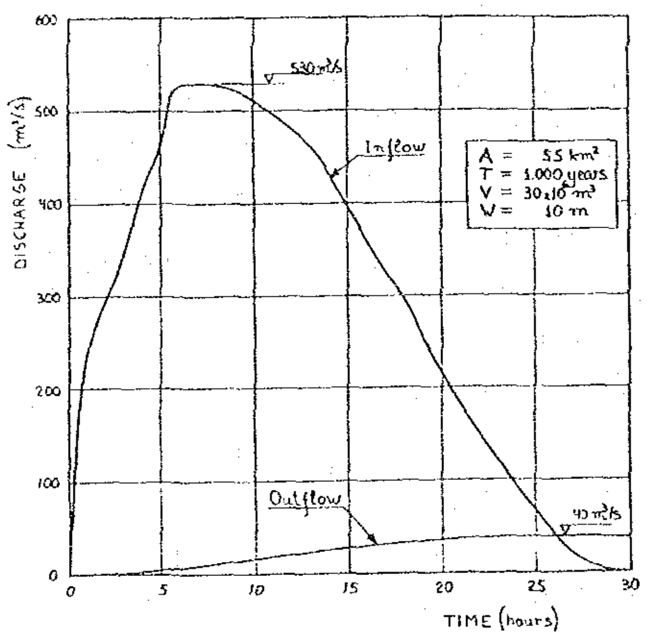
ESCALA

NÚMERO DO DESENHO
FIGURE III-7.1

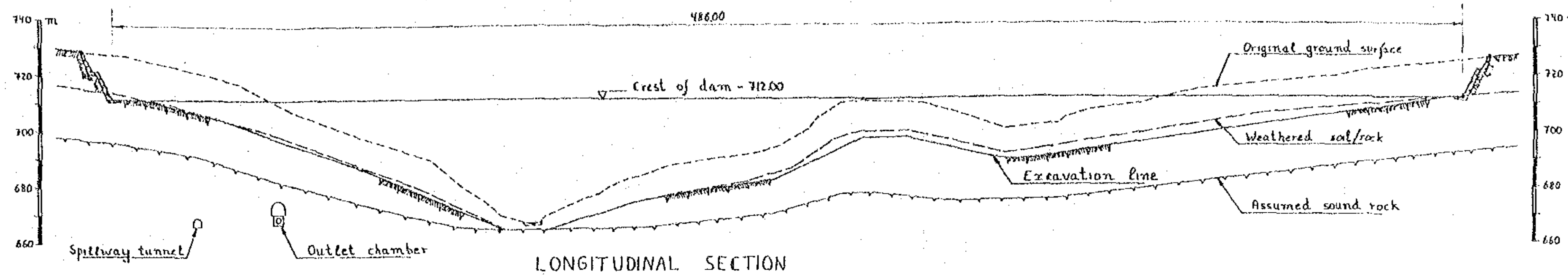


ELEV (m)	AREA (km²)	VOL. ($10^6 m^3$)
667.50	0.0	0.0
670.00	0.003	0.02
675.00	0.38	0.97
680.00	1.35	5.97
685.00	3.19	17.32
690.00	5.80	39.80
695.00	8.78	76.27
700.00	12.72	130.04
705.00	16.25	202.45
710.00	20.48	294.27
715.00	25.14	408.34
720.00	29.89	545.93

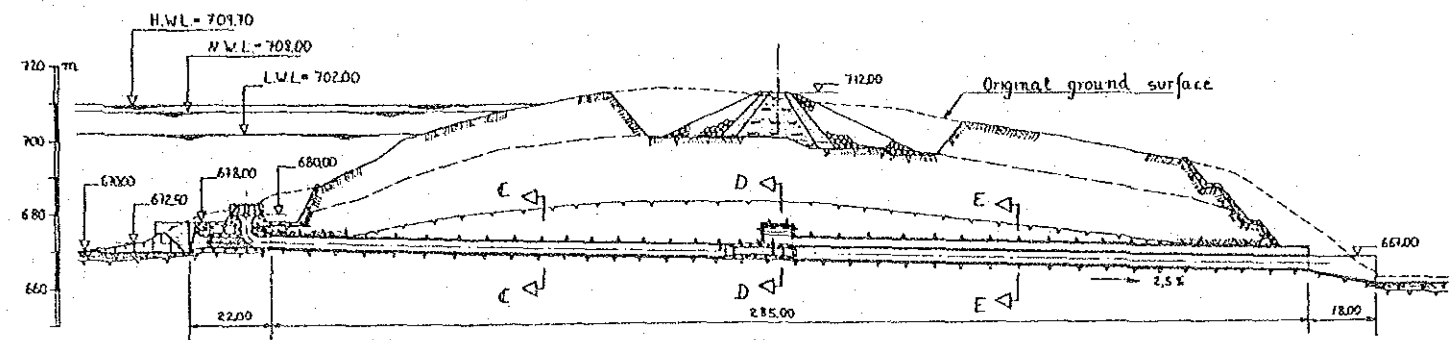
RESERVOIR AREA AND VOLUME CURVES



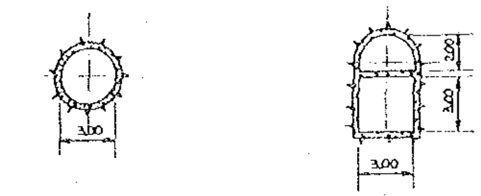
DESIGN INFLOW AND OUTFLOW HYDROGRAPHS



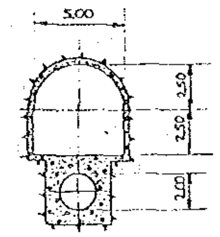
LONGITUDINAL SECTION



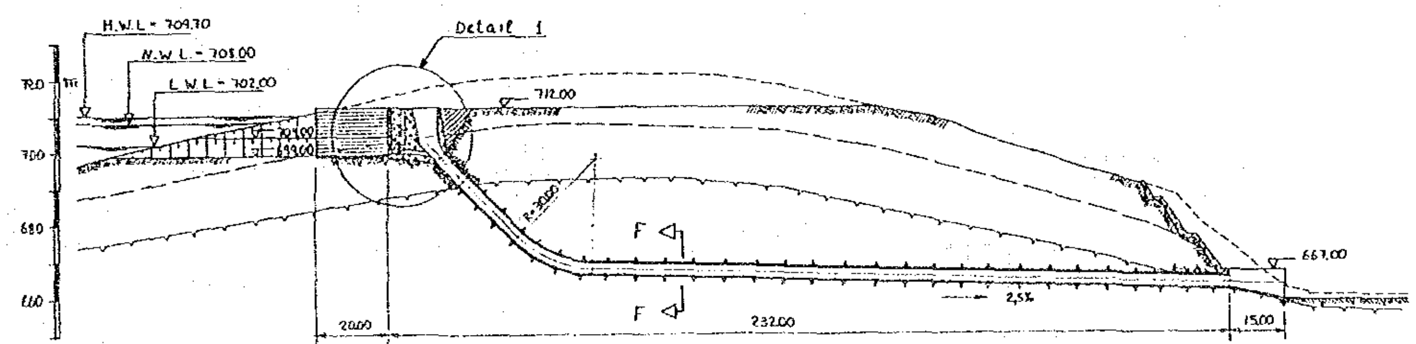
SECTION A-A



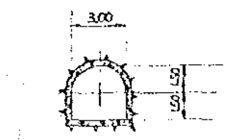
SECTION C-C   SECTION E-E



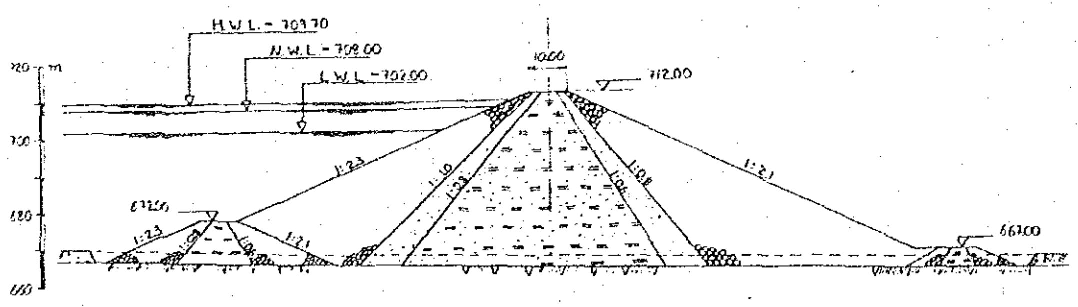
SECTION D-D



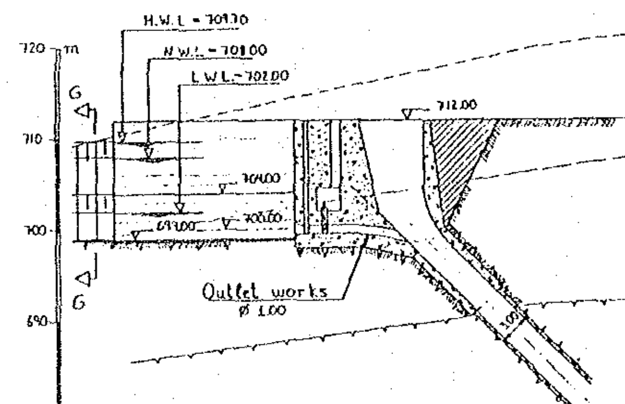
SECTION B-B



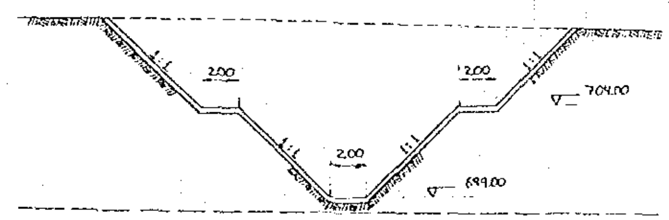
SECTION F-F



TYPICAL SECTION



DETAIL 1



SECTION G-G

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DAM OF GD-6

PLAN AND SECTION

ESCALA
NÚMERO DO DESENHO
FIGURE III - 7.2

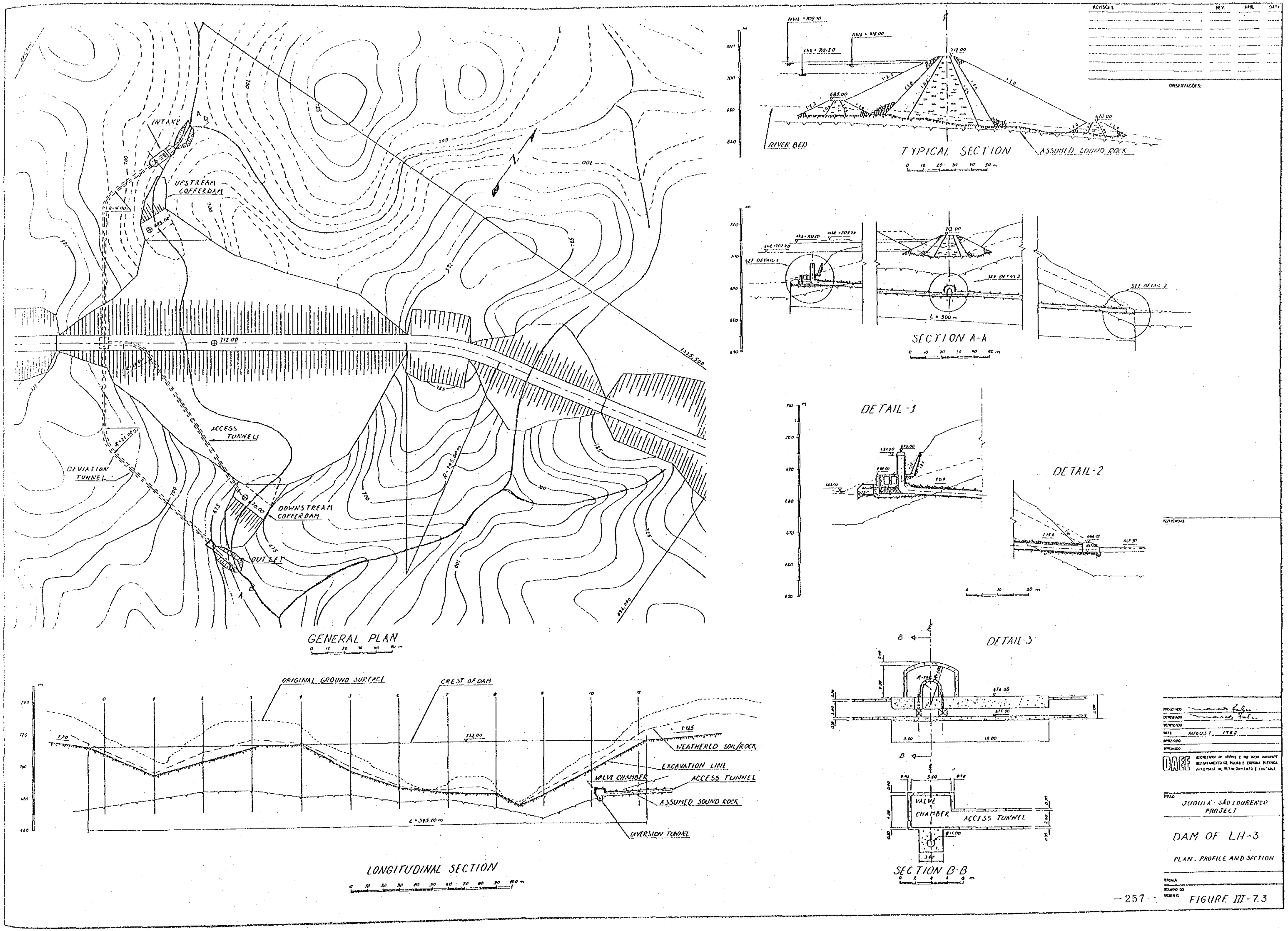
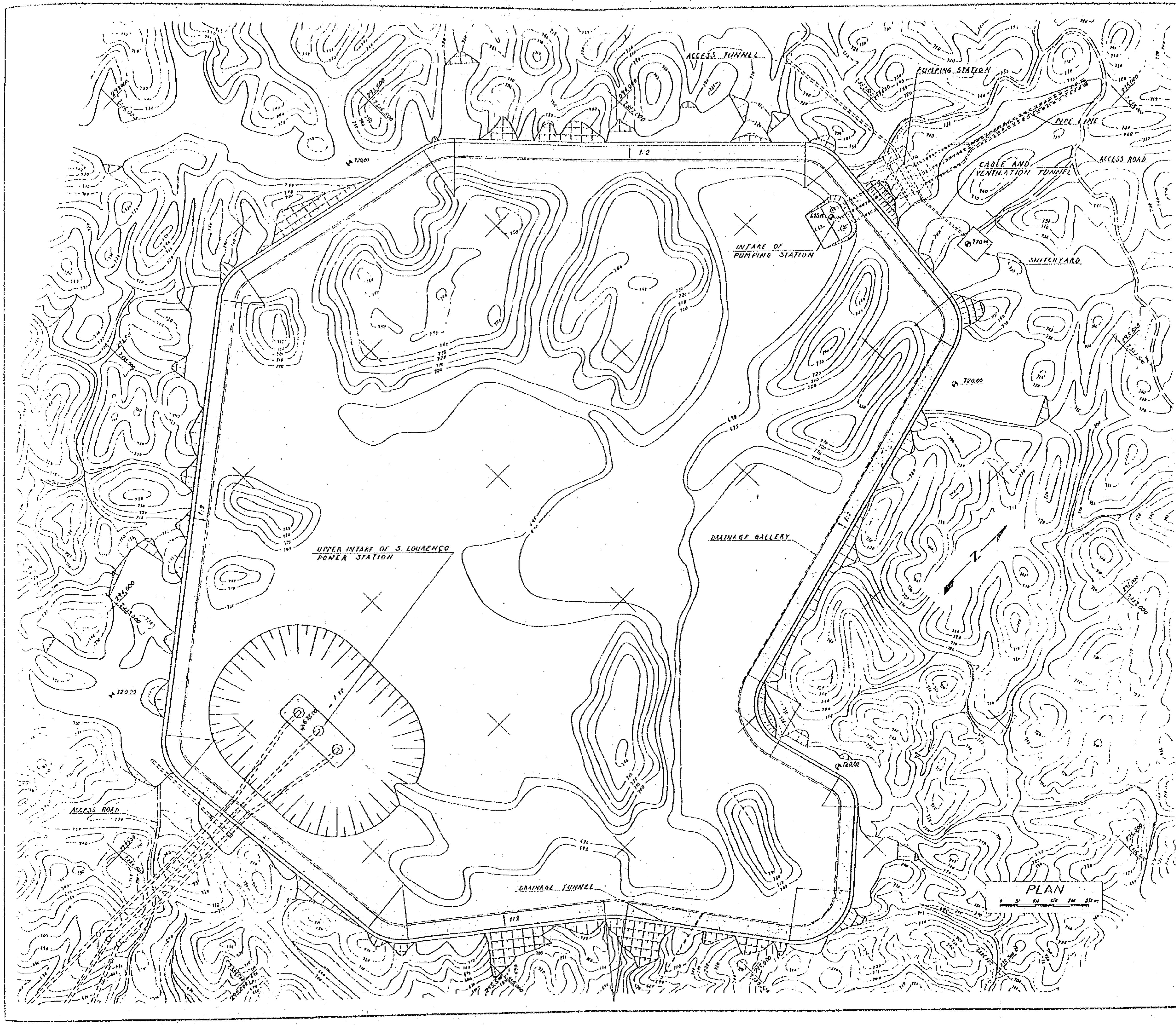


FIGURE III-7.3



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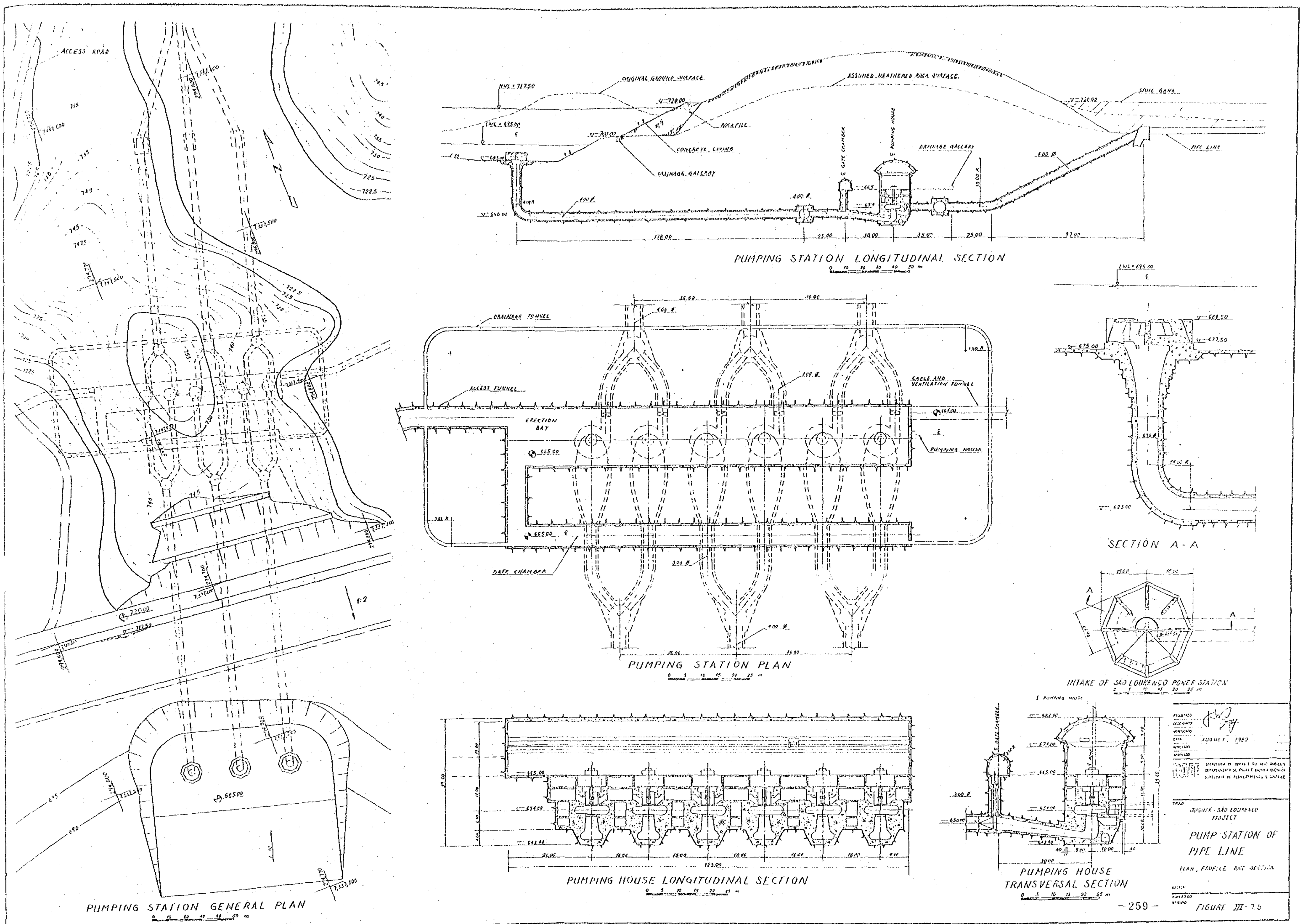
JUQUIÁ - SÃO LOURENÇO PROJECT

PONDAGE TYPE UPPER RESERVOIR

PLAN

AUGUST, 1982

FIGURE III - 7.1


ACCESS ROAD
PUMPING STATION GENERAL PLAN
ORIGINAL GROUND SURFACE
ASSUMED WEATHERED ROCK SURFACE
NWL = 717.50
LWL = 695.00
ROCKFILL
CONCRETE LINING
DRAINAGE GALLERY
GATE CHAMBER
PUMPING HOUSE
SPOIL BANK
PIPE LINE
178.00
25.00
30.00
35.00
25.00
97.00
PUMPING STATION LONGITUDINAL SECTION
DRAINAGE TUNNEL
ACCESS TUNNEL
CABLE AND VENTILATION TUNNEL
ERECTION BAY
GATE CHAMBER
PUMPING STATION PLAN
SECTION A-A
INTAKE OF SÃO LOURENÇO POWER STATION
PUMPING HOUSE LONGITUDINAL SECTION
PUMPING HOUSE TRANSVERSAL SECTION
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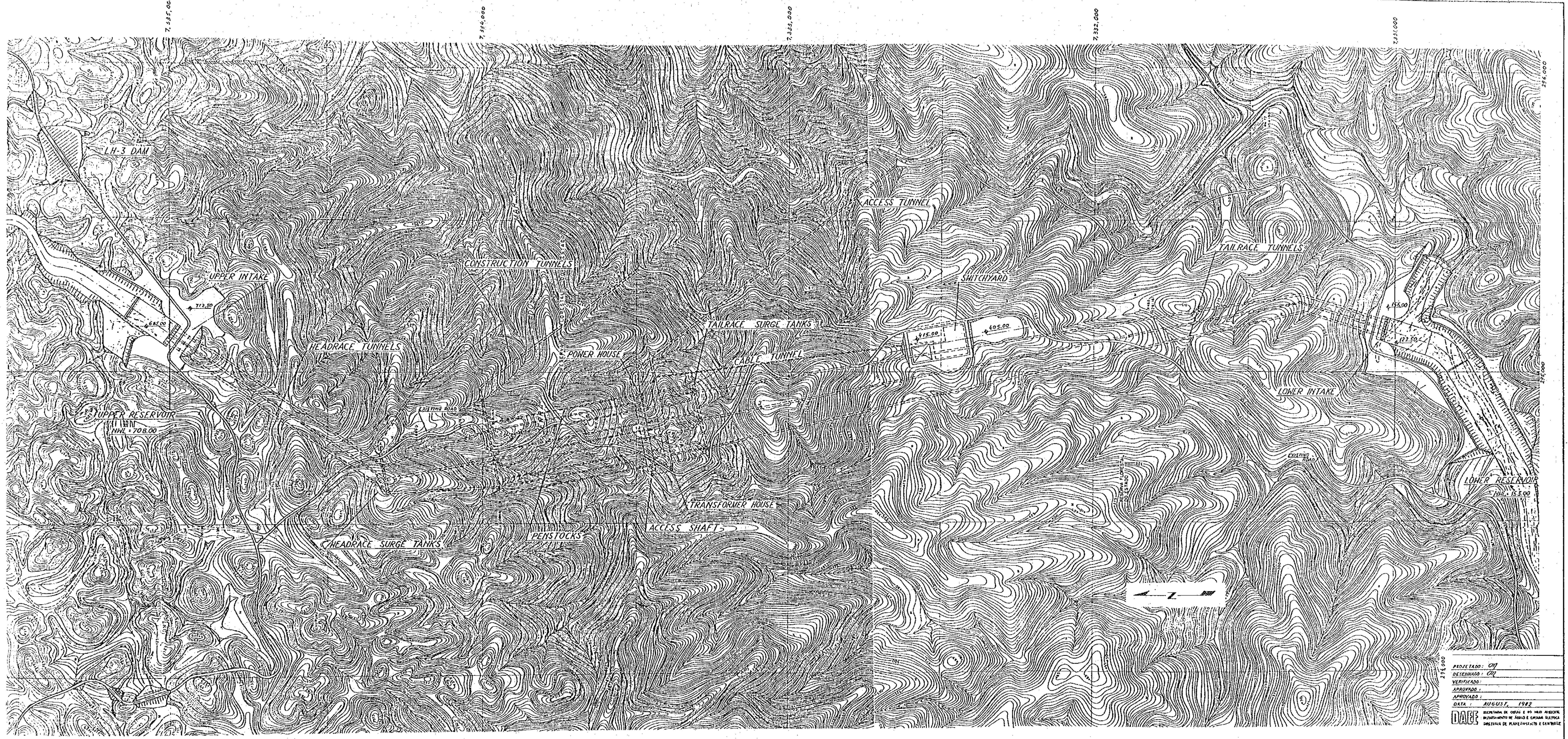
JUQUIÁ - SÃO LOURENÇO PROJECT
PUMP STATION OF PIPE LINE
PLAN, PROFILE AND SECTION
FIGURE III-7.5



GENERAL PLAN

0 — 300 m

CARTOGRAPHICAL REFERENCE :

- TOPOGRAPHICAL MAP, SCALED 1:5000, BY TERRAFOTO S.A. - 1981.

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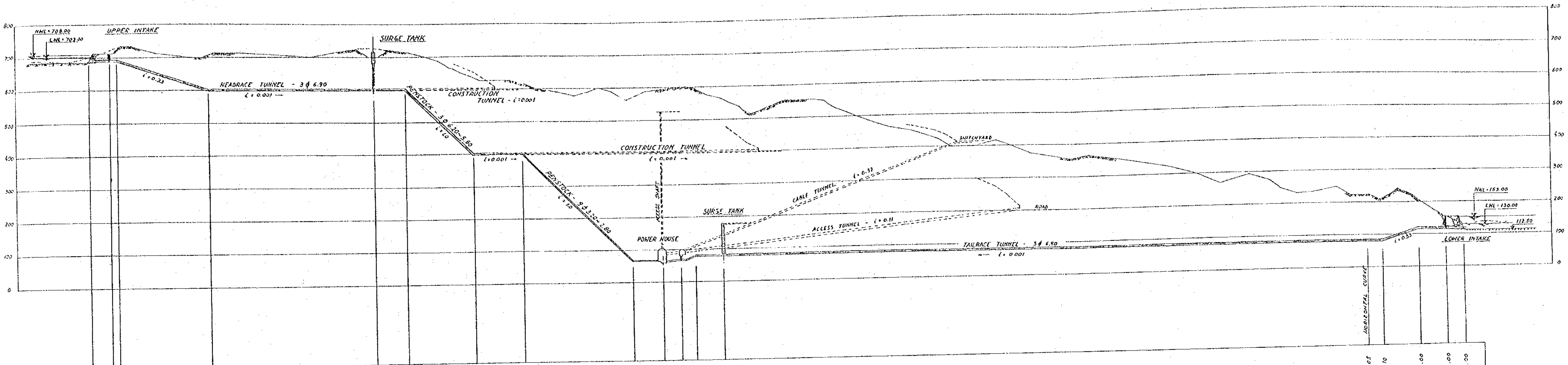
SÃO LOURENÇO REVERSIBLE POWER STATION

PLAN

ESCALA:

NUMERO DO DESENHO: FIGURE III - 7.6



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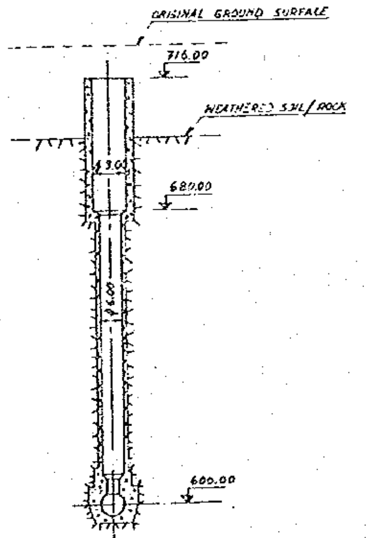
2	66.00	66.00	690.00
3	22.00	88.00	690.00
4	270.00	358.00	600.00
5	500.00	858.00	599.50
6	95.00	953.00	599.40
7	199.00	1152.00	400.00
8	150.00	1302.00	399.85
9	333.00	1635.00	67.00
10	93.00	1728.00	67.00
11	55.00	1783.00	68.50
12	48.50	1831.50	80.00
13	81.50	1913.00	80.10
14	1990.00	3903.00	82.05
15	50.00	3953.00	82.10
16	115.00	4068.00	118.00
17	90.00	4158.00	118.00
18	60.00	4218.00	118.00

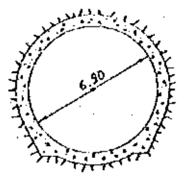
WATERWAY LONGITUDINAL SECTION

0 500 m



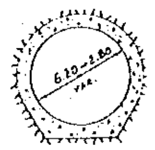
HEADRACE SURGE TANK SECTION

0 30 m



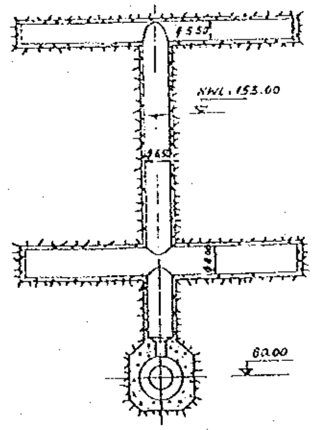
HEADRACE AND TAILRACE TUNNEL CROSS SECTION

0 5 m



PENSTOCK CROSS SECTION

0 5 m



TAILRACE SURGE TANK SECTION

0 30 m

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SÃO LOURENÇO REVERSIBLE POWER STATION

PROFILE

ESCALA:
NÚMERO DO DESENHO: FIGURE III-7.7

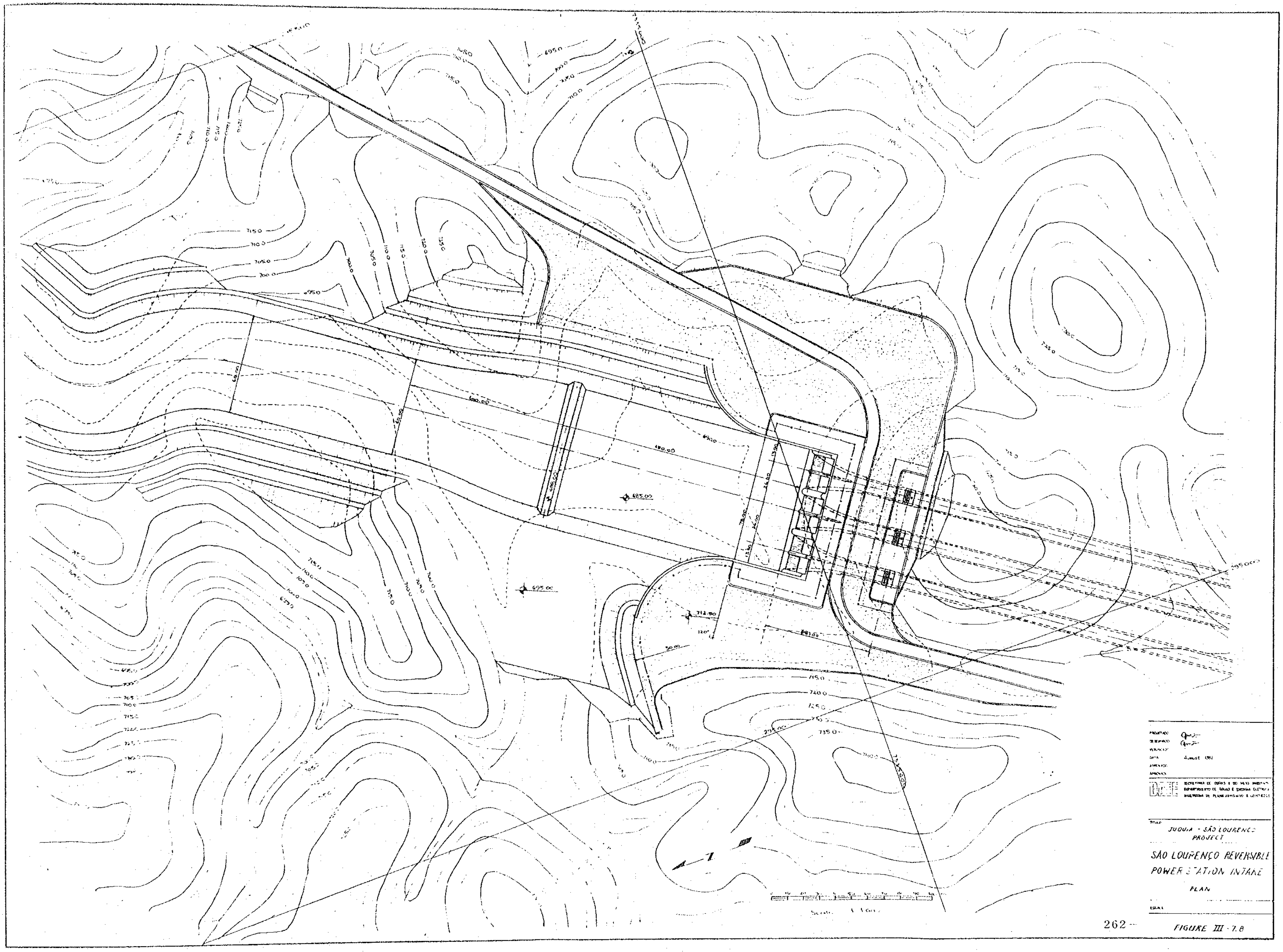
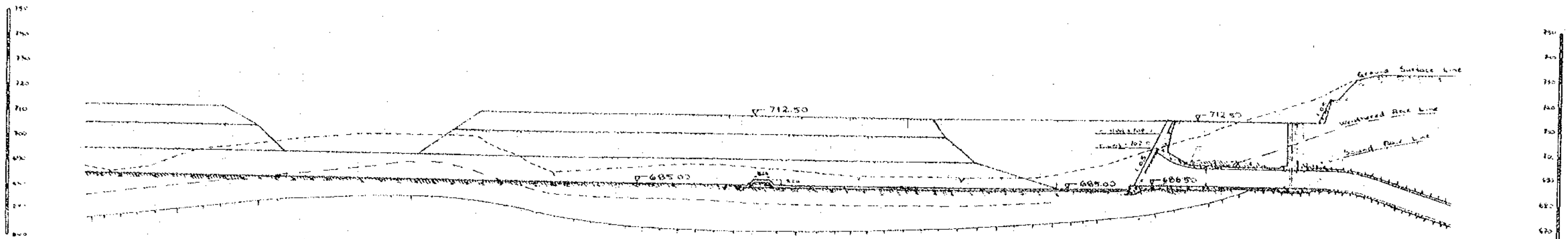
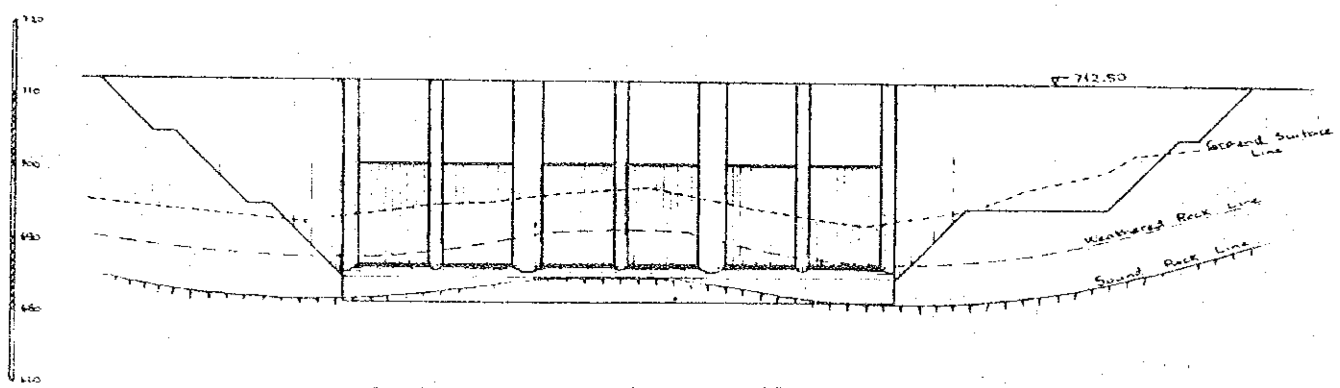


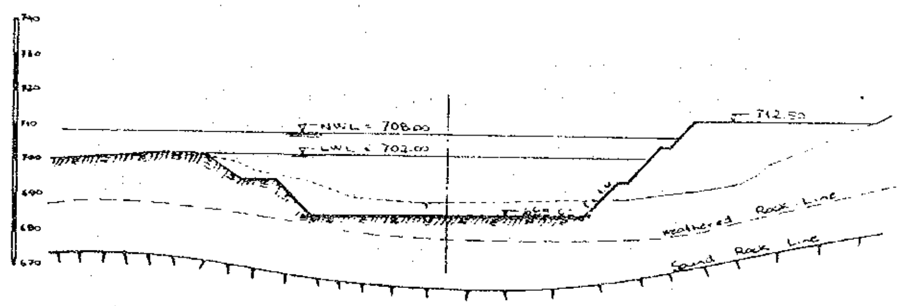
FIGURE III - 7.8



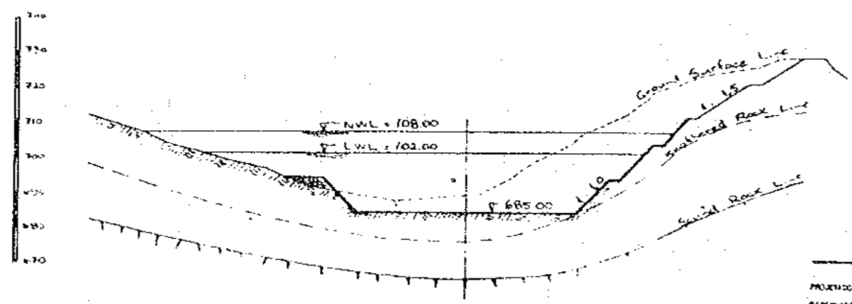
LONGITUDINAL SECTION OF INTAKE AND CANAL



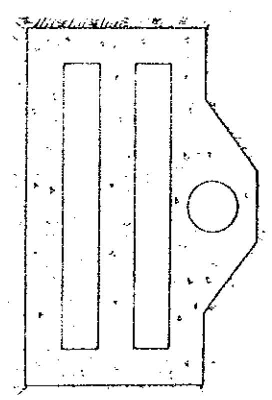
FRONTAL VIEW OF INTAKE



STANDARD SECTION OF FOREBAY



STANDARD SECTION OF CANAL



SECTION OF GATE SHAFT

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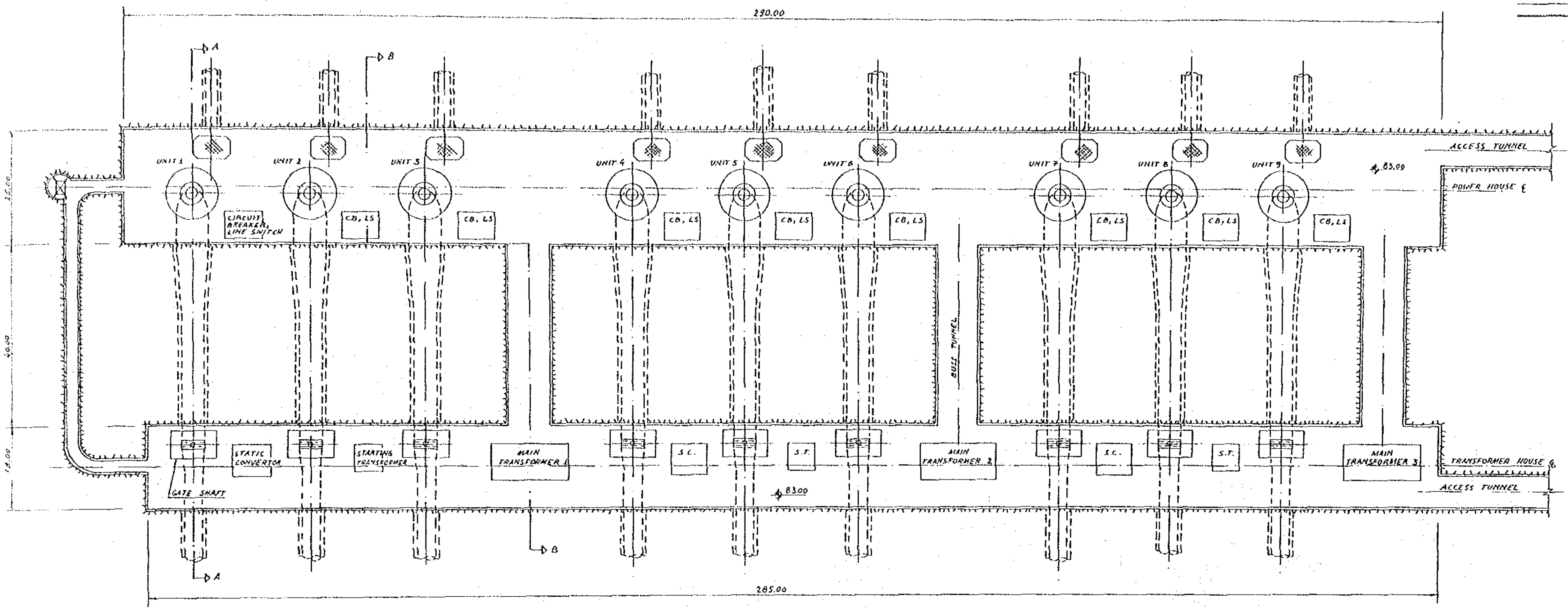
SÃO LOURENÇO REVERSIBLE POWER STATION INTAKE

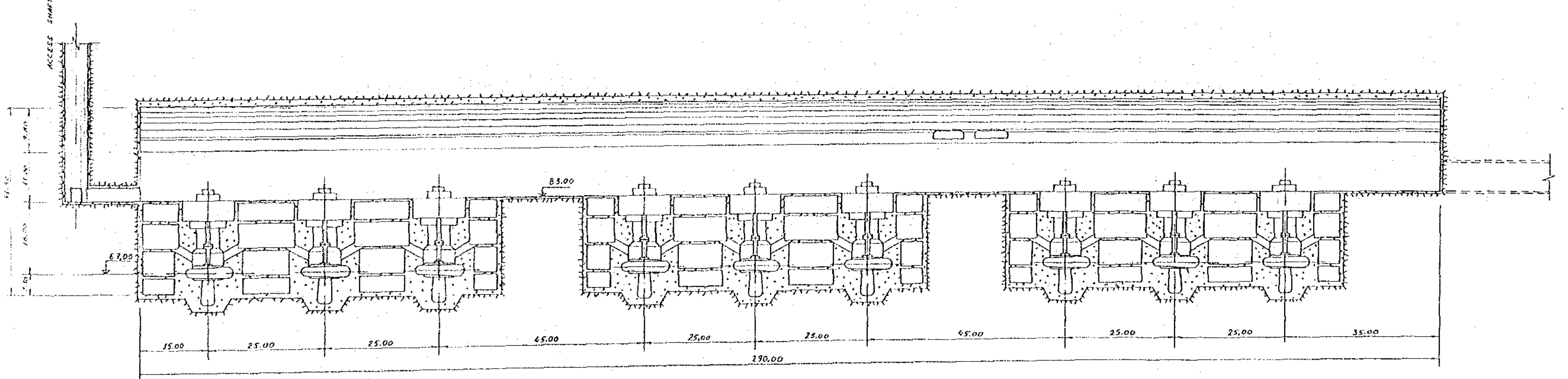
PROFILE AND SECTION

FIGURE III - 7.9



POWER STATION GENERAL PLAN

0 30 m



POWER HOUSE LONGITUDINAL SECTION

0 30 m

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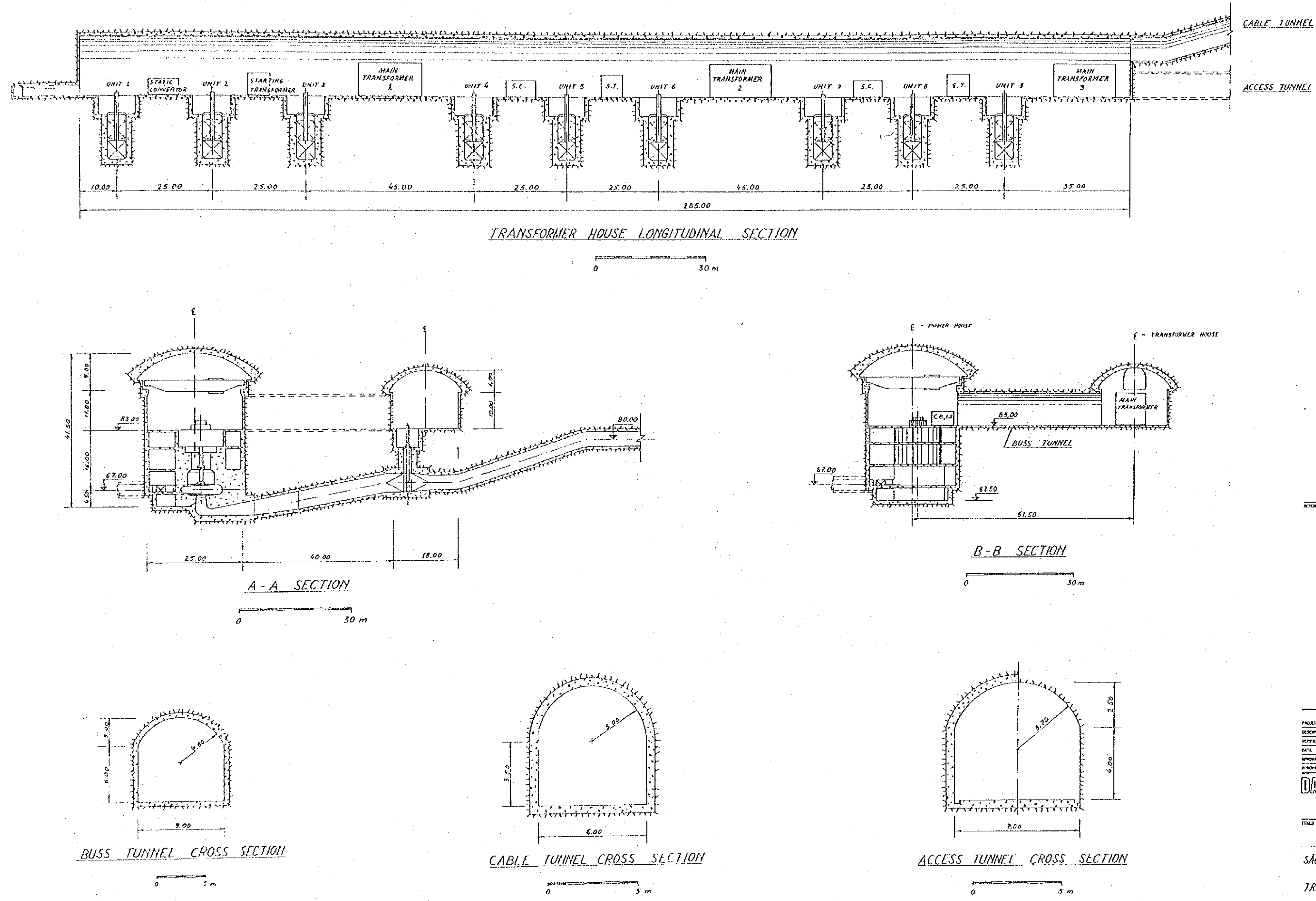
TÍTULO
JUQUIÁ - SÃO LOURENÇO PROJECT

SÃO LOURENÇO REVERSIBLE POWER STATION POWER HOUSE

PLAN AND PROFILE

ESCALA

NÚMERO DO DESENHO: FIGURE III - 7.10



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SÃO LOURENÇO REVERSIBLE POWER STATION TRANSFORMER HOUSE

PROFILE AND SECTION

ESCALA

NÚMERO DO DESENHO

FIGURE III-7.11