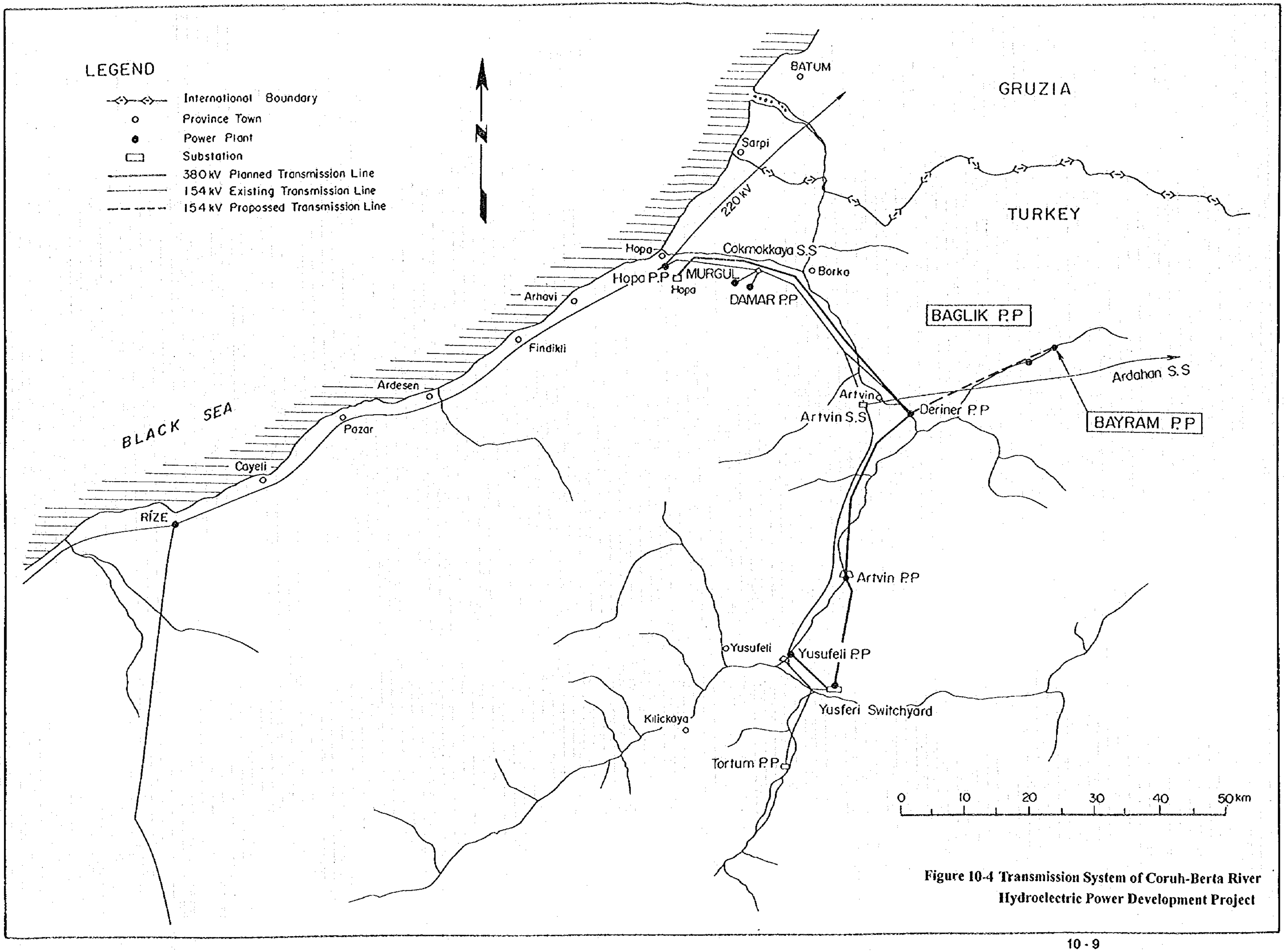
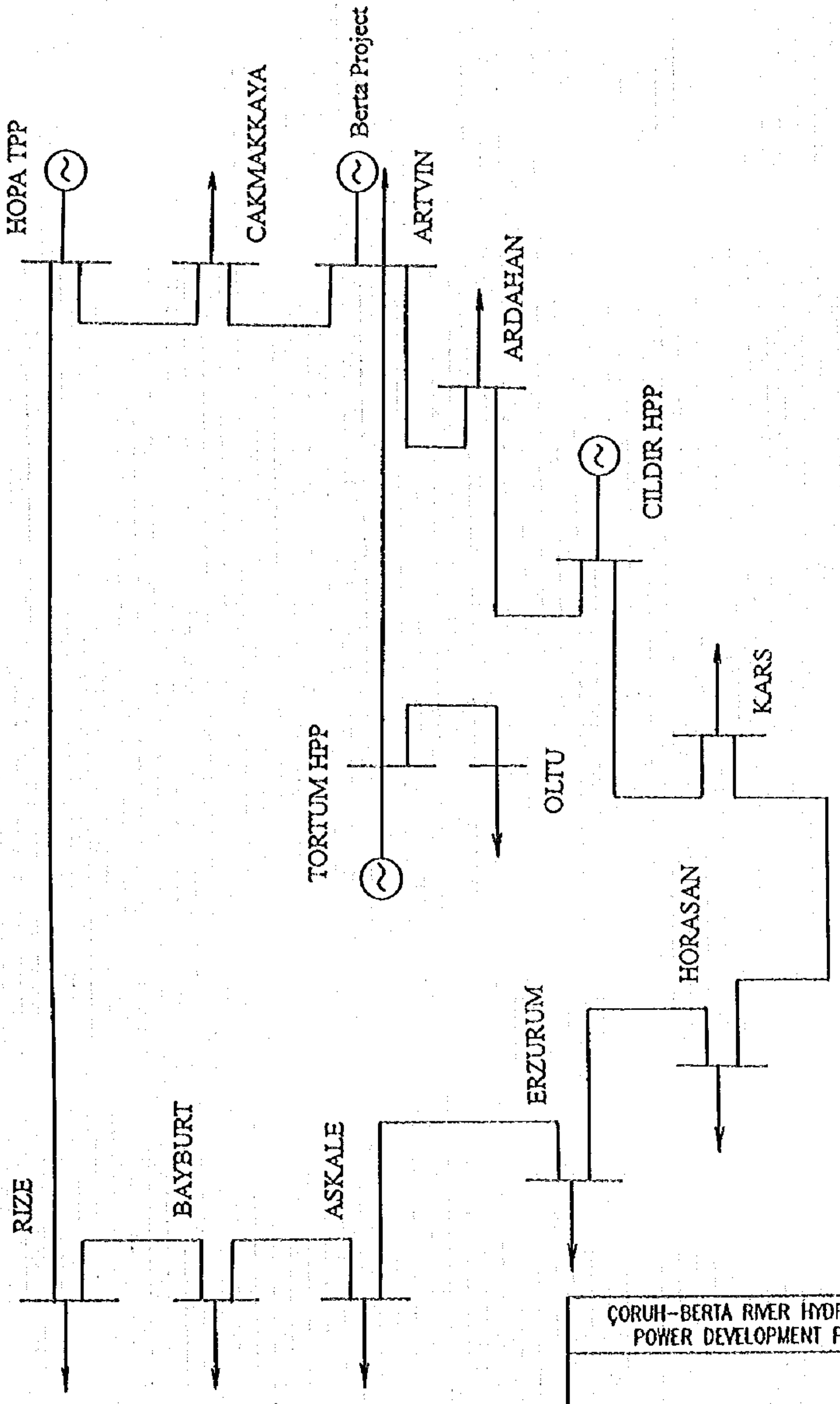


Figure 10-4 Transmission System of Coruh-Berta River Hydroelectric Power Development Project



ÇORUH–BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

SCOPE OF POWER SYSTEM
ANALYSIS

Figure 10-5

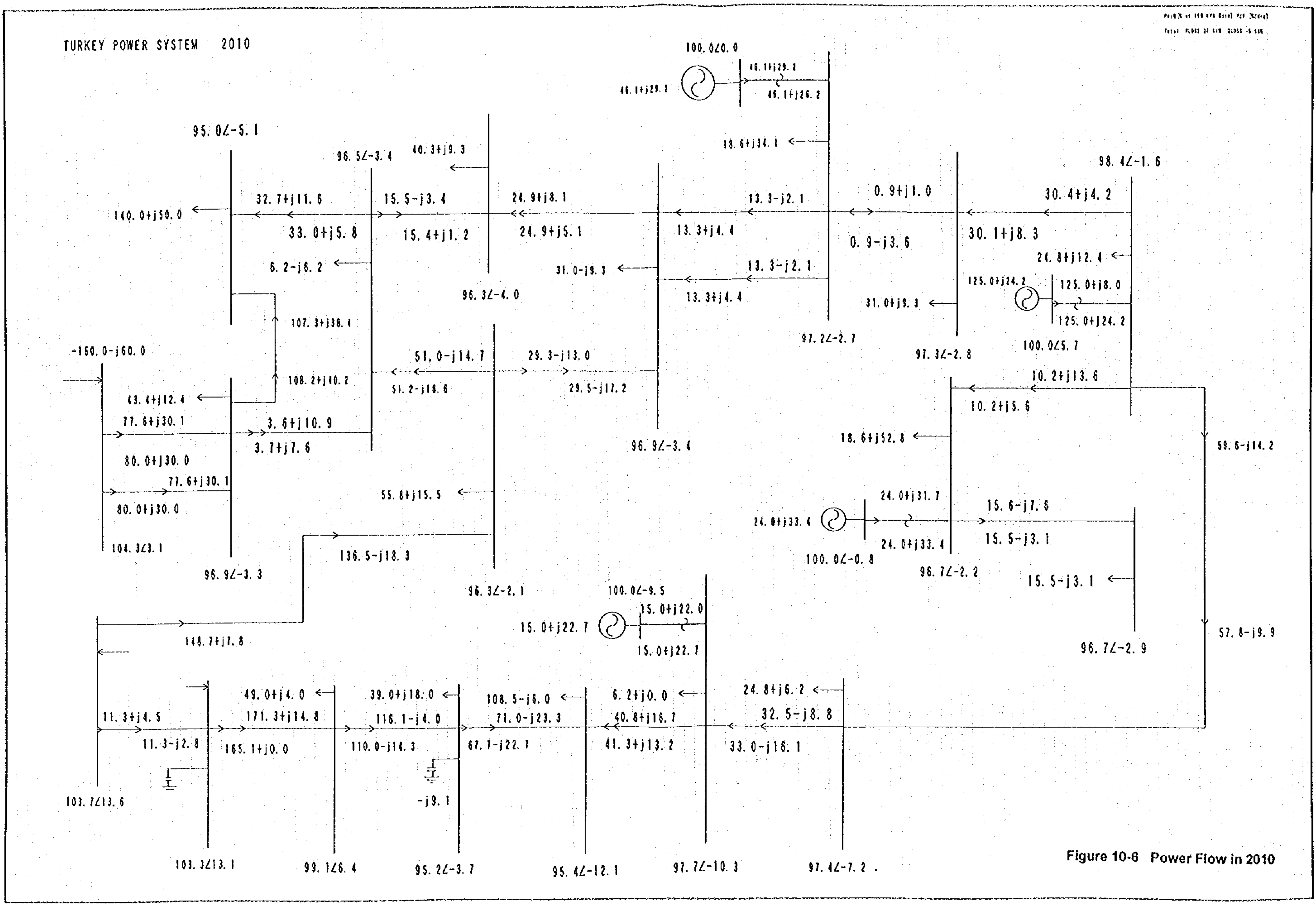
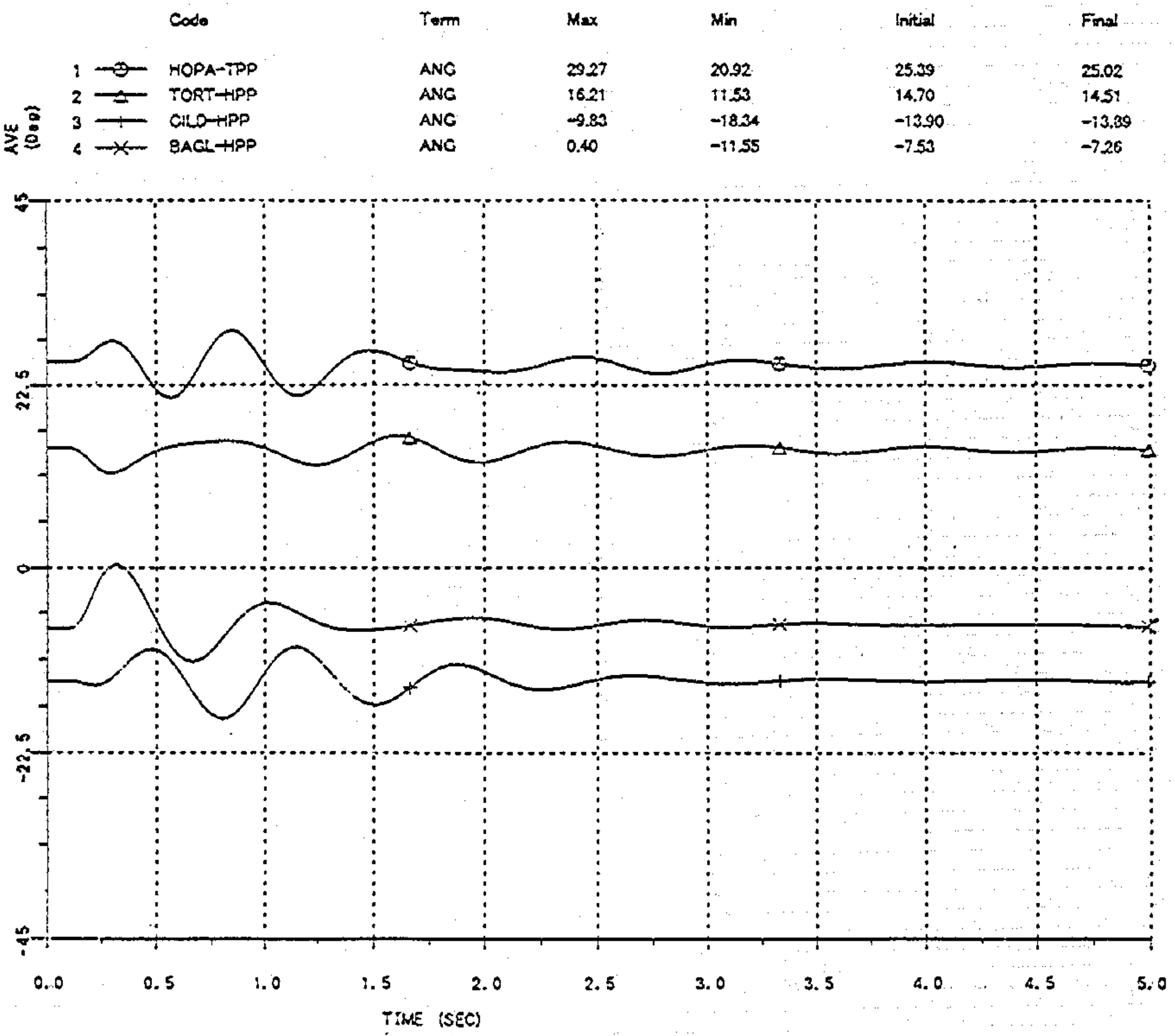


Figure 10-6 Power Flow in 2010



Chapter 11 FEASIBILITY DESIGN

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CHAPTER 11 FEASIBILITY DESIGN

Outline

The feasibility design of civil structures, electro-mechanical equipment, transmission line, and temporary facilities for construction will be described in this chapter for the Bayram project and the Bağlık project, respectively.

For principal structures such as dam and appurtenant structures, waterway and powerhouse, comparative designs will be included, and the results of studies described.

11.1 Bayram Project

11.1.1 Dam and Appurtenant Structures

(1) Outline and Selection of Dam Axis

The candidate dam site is located approximately 2.5 km downstream from the confluence of two tributaries (Meydancık, Şavşat) of the Berta river, the location being identical to the one proposed in the master plan report. The left-bank slope at the dam site has a comparatively gentle gradient of approximately 40 degree, while the right-bank slope is approximately 50 degree close to the river-bed and approximately 30 degree at parts of high elevation, the riverbed configuration being symmetrical on the whole.

The valley width at the dam site is approximately 80 m at the river bed and approximately 380 m at the crest (HWL 740 m). The embankment volume of the dam on this dam axis is a smaller volume than for other sites in the neighborhood, and since there will be no obstacles to the layout of the spillway and other appurtenant structures, the dam axis in the original proposal will be adopted.

The thickness of river-bed sediment is approximately 33 m, the deposits overlying hard basement rock belonging to the Berta Formation and having been comparatively densely compacted. At the ground surfaces, there is almost no growth and weathered rock are exposed over the entire surfaces. The depths of weathering of basement rock at the two banks are thought to be about 1 to 2 m. The basement rocks at the two banks and the river bed are composed of basalt (lava, intrusive rock), volcanic breccia, and tuff of the Berta Formation, and although the surface layer portion down to 70-80 m has development of cracks and permeability is comparatively high, the rocks are hard and large faults have not been confirmed to exist.

(2) Selection of Dam Type

Considering the topographical and geological conditions of the dam site proposed for the project, it is judged possible from an engineering standpoint for either of two dam types, a rockfill dam and a concrete gravity dam, to be constructed. From the standpoint of conditions concerning materials, embankment materials such as core material, filter material, and rock material can be collected within a range of several kilometers from the dam site and transported. As for a concrete gravity dam, use of the abundant river-bed sand-gravel as concrete aggregate can be considered, so that there will be no problem. Consequently, the comparison of the two dam types would be an economic one based on construction costs, but because the valley width is large and there are thick river-bed deposits, in case of a concrete gravity dam, not only will there be the volume of excavation to be coped with, but the volume of concrete will also be huge. The comparison of construction cost was made of the dams proper with care of river, spillways included, and the rockfill dam was shown to be more economical. Consequently, a rockfill dam was selected as the dam type.

Table 11-1 shows the comparison of dam type.

(3) Design of Dam and Appurtenant Structures

(a) Dam

The topography and geology of the dam site will not be a problem in particular as previously mentioned, and it was decided that a zoned rockfill dam having an impervious core at the center with filter and rock zones at upstream and downstream sides, respectively, would be applied. Regarding the type of the impervious core, a central impervious core type was adopted since a smaller quantity of low-strength core material would suffice. Further, since the core material planned to be used would contain a large proportion of fine-grained soil, fine-particled filter zones and coarse-particled filter zones were provided at both upstream and downstream sides of the core with the purposes of preventing loss of particles from the impervious zone and safely draining infiltration water.

The crest elevation of the dam was selected to be at EL. 745 m giving consideration to design flood water level, freeboard for waves due to wind and earthquake, and gate operation. The dam height is 145 m at maximum from foundation rock to the crest.

The basic configuration of the dam was set for upstream and downstream slope gradients of 1:2.3 and 1:2.0, respectively, upon carrying out stability analyses (circular slip method) of the dam faces assuming the design earthquake motion (design horizontal seismic coefficient 0.15) estimated for the dam site and assuming the physical property values of embankment materials. The thickness of the core at the crest is to be 8 m and that at the foundation about 65 m (B/H=0.45) and together with the consideration that the coefficient of permeability of material to be used is low (order of 10^{-7}), it is thought watertightness of the dam would be amply secured. However, at the detailed design stage, it will be preferable for the final cross-sectional configuration of the dam to be decided upon carrying out not only stability analysis based on the physical property values from materials tests to be conducted hereafter but also dynamic stability analysis by input of earthquake motion. The embankment volume of the dam will be approximately 6.2×10^6 m^3 (HWL. 740 m) with rock materials ($4,367 \times 10^3$ m^3) planned to be transported from a quarry at the right bank located 3 or 4 km upstream of the dam site. On the other hand, for filter materials (802×10^3 m^3), river-bed sand-gravel near dam site and for core material ($868 \times 10^3 m^3$), talus deposits collected from a borrow area planned at the left bank immediately downstream of the dam are planned to be used.

Further, the gully stream running in from the right-bank side at the toe of the dam slope is of comparatively large scale, and the deposits confirmed to exist in the vicinity of the junction with the mainstream are thought to have been brought down from the gully during floods, and it is thought that several small dams would be necessary to construct along this gully in order to the main dam to be safely protected. Consequently, at the time of detailed design, it will be necessary for the flow conditions of the gully to be ascertained and some protective works against sediment outflow should be contemplated.

(b) Spillway

The spillway, from the standpoint of topography, is to be provided at the left-bank side taking into consideration the existence of the comparatively large gully at the right-bank side near the toe of the dam.

The design flood discharge is the probable maximum flood discharge of 1,660 m^3/s, and the structure is to be such that this can be safely discharged downstream at the high water level of the reservoir. For this purpose, the spillway intake is to be of a structure having a total width of 23.0 m with two radial gates each of width 10.0 m and height 12.5 m. The waterway is to be a chute type of width 23.0 m, with energy dissipation to be by a hydraulic jump-type, horizontal-apron stilling basin at the end of the chute.

(c) Care of River

Cofferdams at upstream and downstream sides and a diversion tunnel are to be provided prior to excavation of the dam foundation at the river bed, and the flow is to be diverted.

Care of river is planned based on a 50-year return period flood (Qf = 317 m^3/s) in accordance with the views of EIE and the optimum combination of upstream cofferdam height and diversion tunnel inside diameter was determined. The upstream cofferdam was positioned to be inside the cross section of the main dam, while the diversion tunnel was made a single line taking flood discharge into consideration.

As a result of examination, it was found that crest elevation of the upstream cofferdam at 659 m and inside diameter of the diversion tunnel of 5.70 m would be the most economical.

As for the downstream cofferdam, the dam crest elevation was set at a height at which the downstream water level in the flood season would not overflow the dam, and similarly to the upstream side, it was located to be positioned inside the cross section of the main dam. The spillway stilling basin would be located below the downstream cofferdam, and a separate simplified cofferdam is to be provided in the dry season to carry out construction.

(d) Dam Foundation Treatment

The dam foundation rock, at both banks and also the river bed, will have parts of high permeability over a comparatively wide area, and bedrock of high permeability of 30 Lu and over has been confirmed at parts. At the left-bank side, the range of high permeability of 30 Lu and over reaches down to around 70-80 m from the ground surface, the permeability becoming abruptly lower deeper inside. At the other side, the right bank, bedrock indicating high permeability in the same range has been confirmed, while locally, values higher than 30 Lu have been confirmed in deep bedrock (100 m) also.

The groundwater level is fundamentally low. At both banks near the river bed it is only about that of the river-bed elevation. Although it rises somewhat according to the slope of the natural ground, from close to high water level, groundwater level is confirmed at approximately 60 m from the ground surface on the left-bank side and at approximately 90 m on the right-bank side.

As the foundation treatment plan for the dam, with the purpose of suppressing infiltration of stored water through the foundation rock, curtain grouting to form an impervious zone in the foundation rock along the dam axis, and blanket grouting to improve the imperviousness of the foundation rock contacting the core zone and to assure the effect of curtain grouting were planned.

In case of a rockfill dam, the range of execution of curtain grouting is normally considered with the target of improvement as about 5 Lu, but as mentioned above, since the zone indicating high permeability is around 70-80 m from the ground surface with the exception of a small part, this was made the principal zone of work execution, and giving consideration to the fact that the groundwater level was low, the range of grouting was extended to both wings of the dam crest (grout hole layout: two rows at 2-m intervals). Since the range of grouting extends to a great depth, a grouting gallery is to be provided from the standpoint of the work execution plan.

The range of blanket grouting is to be the core bed and the depth of grouting is to be 10 m (grout hole layout: 5-m grid).

(e) Discharge Facilities

Discharge facilities are to be provided for discharge downstream during initial water impoundment and for emergency discharge. The diversion tunnel is to be utilized for the discharge waterway with a valve chamber provided, but since only one diversion tunnel is planned, the structure is to be made such that when the diversion tunnel is plugged, a branch remains at the discharge waterway section. The discharge facilities would consist of a discharge conduit, discharge valve, and a high-pressure slide gate for emergency use.

The intake structure is to be of reinforced concrete provided at the intake section of the diversion tunnel, the elevation being around the design sediment level of the reservoir.

Besides the emergency discharge facilities for the dam, a simple discharge facility (less than 0.7 m^3/s) for discharge of water for downstream river maintenance is also to be provided.

11.1.2 Waterway and Powerhouse

(1) Location and Outline

The Bayram Project consists of a rockfill dam of height 145 m to be constructed at a point approximately 2.5 km downstream from the confluence of the Meydancık and Şavşat rivers, a connecting underground powerhouse immediately downstream of the dam, and a tailrace tunnel approximately 8 km in length for discharge of water after power generation to a planned location at the end of the downstream Bağlık reservoir backwater, for a dam and conduit type power generation project (tailrace type) having a maximum gross head of 192 m.

The waterway route of the project was planned at the right bank of the Berta river, in consideration of the river regime alignment being bent toward the left-bank side, the thick deposited layer on the left bank downstream of the dam(Savail Slope), and the existence of the tributary Çakar river. Further, the tailrace tunnel was planned with a layout connecting the underground powerhouse and the outlet by a straight line so that it will cross the Berta river at around approximately 3,600 m downstream on the tailrace. (covered ground depth approximately 40 m)

(2) Design of Structure

(a) Intake

The intake is to be provided at a dale on the right-bank side approximately 200 m upstream of the dam axis taking into consideration the topography, geology, etc. of the waterway route and its surroundings. This dale presents a comparatively gentle inclination, and the ridge next to the dale are covered densely with talus deposits. And the intake was planned to put on the dale part escaping the existence of these deposits. As the type of the intake, another type (Inclined type) of intake were compared. And in case of the inclined type, excavation volume is large, if open excavation for the foundation were to be carried out excessively, it would be disadvantageous from the aspect of economics and slope stability considering the big reservoir drawdown (H=54 m). So, the intake structure was made a type separating the inlet part and the gate shaft.

Selection of the intake bed elevation was done taking into consideration reservoir sedimentation, and it was set at EL. 676 m, 10 m deeper than the low water level, so that harmful flow conditions such as vortex would not occur even at times of low water in the reservoir.

(b) Penstock

After the intake gate shaft, water is to be conducted via intake tunnel of length 65 m and a embedded penstock (1 line) to an underground powerhouse turbine. The penstock is to have an inclined shaft gradient of 1:1.0, length of approximately 321 m, inside diameter 3.3 m (average flow velocity 5 m/s), and the diameter is to be gradually reduced to ultimately be 2.5 m at the end of the line.

The design maximum head of the penstock, taking into account pressure at the time of turbine load rejection, was set at approximately 259 m at the turbine center, with the design for the entire head to be loaded by the penstock alone. However, if it were to be succeeded in determining the strength characteristics of the surrounding bedrock in a rational manner, an economical design making the surrounding rock to bear some part of the design head could become possible, and it will be necessary to confirm this at the stage of detailed design.

With regard to buckling from groundwater pressure when the penstock has been dewatered, basically, this is to be dealt with by stiffeners, and the weight of steel pipes against internal pressure was increased by the weight of stiffeners.

Furthermore, it was decided to make the cross section of excavation for the penstock as small as possible within limits that installation of penstock pipe and welding operations would not be hindered, and the clearance was made 60 cm.

(c) Underground Powerhouse

The underground powerhouse is to be located approximately 250 m deep underground in a rock body at the right bank approximately 50~60 m downstream from the dam axis. According to the results of surface reconnaissances and exploratory boring carried out in this area, there is no large-scale fault in the vicinity, while the rock character is hard with RQD values 80 to 100%, and there is no problem recognized to exist in particular. However, the foundation rock for the underground powerhouse requires strength to amply withstand excavation of a large-scale underground cavern, and it is necessary for this to be confirmed hereafter by a means such as an exploratory boring.

The underground powerhouse is to be composed of the powerhouse proper, a powerhouse access tunnel for delivery of main equipment, and a cable tunnel for leading out a power cable from the powerhouse to switchyard. These tunnels can be used as mucking tunnels during excavation for the underground powerhouse.

The powerhouse access tunnel is planned from a point on an existing road approximately 1,000 m downstream of the dam to the powerhouse at a gradient of 1:10 and with a length of 901 m and inside diameter of 5 m, while the cable tunnel is also to be an inclined shaft with a length of 369 m and inside diameter 4 m (gradient 1:4.02) from an existing road approximately 400 m downstream of the dam.

The cross-sectional shape of the main cavern of height 41 m and width 19 m, at the present stage of design, is to be a mushroom type provided with a main equipment hall (1 unit), main transformer hall, etc., with the ceiling arch and side walls to be lined with concrete. In addition to the shotcrete-rock bolts comprising the excavation support for NATM, bedrock strengthening with prestressed rock anchors is to be done aiming for stabilization of the surrounding bedrock from during construction up to and including operating stage, while further, because of the proximity to the dam and reservoir, drainage tunnels are to be arranged in the surroundings of the underground powerhouse

The elevation of the turbine center is to be 533 m in relation to the tail water level (530 m: Bağlık reservoir HWL) considering the necessary turbine static draft head.

(d) Tailrace

The tailrace is to be a standard horseshoe-shape non-pressure tunnel of length 7,930 m and inside diameter 4.6 m for maximum generation discharge of 43 m^3/s. Since this tailrace tunnel will be crossing the Berta river at around 3,600 m from the powerhouse, it is to be provided at that section to have original ground overburden of a minimum of 40 m.

The gradient of the tailrace tunnel was selected to be 1:1,400, the optimum gradient as determined as the gradient at which the sum of annual expense obtained from construction cost and annual benefit loss obtained from the head (see Figure 11-1) would be minimum.

Lining of the tailrace tunnel was classified according to standard section (concrete lining thickness 40 cm:35%), good geology section (shotcrete:50%), and poor geology section (concrete lining thickness 60 cm:15%)and each length was decided on the base of the proportion ratio against the total length considering the geological conditions.

Construction of the tunnel of total length 7,930 m is to be done providing two work adits along the way for excavation from maximum of 6 faces including excavation from the powerhouse side. These work adits are to be plugged after completion of construction.

To deal with load rejection or sudden load increase at the powerhouse, a surge chamber of height 16.2 m and length 30 m is to be provided at the starting point of the tailrace tunnel, along with which a draft gate at the end of the draft tunnel connecting to the surge chamber and an outlet gate (stop logs) at the end of the tailrace tunnel are to be respectively installed.

11.1.3 Electro-Mechanical Equipment

(1) Selection of Number of Units

Generally, if capacity of turbine-generator is bigger, the efficiency is better and cost per unit output is smaller.

The installed capacity of Bayram project and Bağlık project are 68 MW and 59 MW respectively. In the case of Berta project, if number of unit is one, there is no problem for power system.

On the other hand, when operating at low load, efficiency of turbine-generator decreases, and under the influence of accident of equipment, it is impossible to operate the power plant.

Berta project has reservoirs and this project can operate at peak load. This means if number of unit is one, there is no problem for above mentioned.

To confirm one unit is optimum choice, comparison of number was carried out. Shown as Table 11-2, one unit is more profitable than two units. There is no other restriction, so one unit has been selected.

(2) Type and Ratings of Major Equipment

From the maximum discharge and the effective head, a vertical shaft Francis type is judged as appropriate for this project.

The generator is directly coupled to the turbine shaft and is a vertical shaft, three phases, alternating current, synchronous generator.

The type of main transformer will be of three phases, oil-immersed. As the underground powerhouse is relatively far from outdoor switchyard, the main transformer is installed in the powerhouse to reduce the cost of power cables connecting between the underground powerhouse and the outdoor switchyard.

The voltage of main circuit is 13.2 kV. A parallel-in circuit breaker is equipped at the low voltage side of the main transformer and is used for synchronizing generator to the power system.

For connection between the main transformer and the outdoor switchyard 154 kV XLPE power cable will be adopted.

One circuit of 154 kV transmission lines will be connected to the single bus plus transfer bus system in the outdoor switchyard. It is the TEAS's standard to provide a transfer bus to enable an inspection of the circuit breaker for the transmission line keeping the line alive.

To secure station service power in any failures on the transmission line or the switchyard equipment, a diesel engine-generator set will be installed in this power station.

Power line carrier system (earth return) is provided for composing telecommunication circuits for power generation and dam operation.

Table 11-3 shows the ratings of major equipment and Figure 11-11 indicates the single line diagram of the power station and Figure 11-12 indicates the outdoor switchyard plan.

11.2 Bağlık Project

11.2.1 Dam and Appurtenant Structures

(1) Outline and Selection of Dam Axis

The candidate site for the dam is located at immediately downstream of the confluence with the Sungu river, where the slopes at both banks of the river form a steep V-shaped valley which has hardly any topsoil or timber growth, with weathered rock exposed throughout. Geologically, there is a geological boundary at a point approximately 250 m downstream from the confluence, with the upstream side of this boundary consisting of the Yusufeli Formation and the downstream side being a rock body of granite.

The Yusufeli Formation part has a somewhat broader valley width and it may be expected that the dam volume would be increased to some extent, but geologically, it is mainly hornfels, for a rock body which is hard, dense, and stable.

On the other hand, the granite part is of a rugged gorge topography, has complex contour lines from rough ground surfaces, and although the basement rock is extremely hard, joints are distinct and, moreover, densely developed.

Studies for selection of the dam axis were made for both the Yusufeli Formation and the granite rock body. Firstly, for the granite rock body, a study was made on a location (Original Dam Site) proposed in the master plan, while in the Yusufeli Formation, a site (Selected Dam Site) further upstream by approximately 150 m was examined.

The comparison study was made applying concrete gravity dams which were considered definitely possible to construct at the two dam sites from a technical viewpoint. In the case of Original Dam Site (in the granite rock body), it was judged necessary for a considerable amount of excavation to be done to remove the unstable bedrock block due to development of distinct joints in order to secure a foundation for a concrete dam, while to prevent infiltration of reservoir water, curtain grouting to great depth would be required and the range for grouting would be greatly enlarged.

So, Selected Dam Site (in the Yusufeli Formation) would be clearly appropriate and it was finally adopted. Table 11-4 shows the comparison of dam axis.

(2) Selection of Dam Type

As previously mentioned, the dam type in the study to select the dam axis was limited to a concrete gravity dam, but when the topographical and geological conditions of the dam site proposed for this project are considered, from technical aspects it is judged possible for a rockfill dam, a concrete gravity dam, or a concrete arch dam to be constructed. Of these, with regard to a rockfill dam, material for an impervious core is not available in the vicinity so that a concrete facing rockfill dam was made the object of comparison.

The comparisons were made with care of river, spillways, stilling basin included with the dams proper. In the cases of concrete dams, the spillways were center overflow types for both proposals, with stilling works being bucket type for the gravity dam, and free-fall type for the arch dam.

After comparison, the gravity dam was shown to be more economical. As for the concrete facing type rockfill dam, open excavation for the spillway would be of an enormous volume, and it would clearly be uneconomical.

Based on the above, a concrete gravity dam is to be adopted as the dam type.

Table 11-5 shows the comparison of dam type.

(3) Design of Dam and Appurtenant Structures

(a) Dam

The dam site has slope gradients of approximately 40-50 degree at both right and left banks with a roughly symmetrical transverse configuration. The valley width at the river bed is approximately 30-40 m and narrow, while at the dam crest it is approximately 170 m (HWL EL. 530 m). The thickness of river-bed deposits is approximately 6 m and small, while at both right and left banks there is hardly any topsoil, and the thickness of weathered rock is estimated to be about approximately 10 m.

The basement rock at both banks and the river bed is composed of hornfels. The rock body is of C_M-C_H class, and although joints are somewhat numerous, it is hard and dense, while large faults have not been confirmed to exist. The RQD values are 30 to 80%, and it may be said that the bedrock condition is that ample shear strength is possessed for construction of a concrete gravity dam.

The crest elevation of the dam was selected to be at EL. 533 m giving consideration to design flood water level, freeboard for waves due to wind and earthquake and gate operation. The dam height is 74 m at maximum from foundation rock to the crest. The basic configuration of the dam was made a standard triangular cross section with the upstream dam face 1:0.1 and the downstream face 1:0.8 upon stability analysis of the dam with the design earthquake motion (design horizontal seismic coefficient 0.15) estimated for the dam site and assuming shear strength of the foundation rock. However, at the detailed design stage, it will be preferable to decide the ultimate cross-sectional configuration on carrying out not only stability analysis based on detailed physical property values of the foundation rock such as by in-site rock tests to be performed but also dynamic stability analysis by input of earthquake motion.

The concrete volume of the dam is approximately 195 x 10^3 m^3, while alluvium available from the surroundings of the Bayram dam site is planned to be used as concrete aggregate.

(b) Spillway

The spillway is to be provided at roughly the middle of the dam and its direction is to be made to agree more or less with the direction of the flow axis on the downstream side. The type of the spillway is to be center overflow type equipped with gates.

The design flood discharge is probable maximum flood of 1,830 m^3/s, and the construction is to be such that this amount can be safely discharged downstream at reservoir high water level. For this purpose, the structure of the intake part is to be for a total width of 31.0 m with two radial gates of width 14.0 m and height 11.0 m. Energy dissipation of the discharged water is to be achieved by providing a bucket at the end of the spillway chute for the water stream to be made to fall in the stilling basin formed by a downstream auxiliary dam in a manner not to damage the dam proper and the ground.

(c) Care of River

Care of river is to be done by partial river closing method. This will consist of partitioning off a part of the river by means such as a retaining wall, carrying out foundation excavation and concrete placement of that part, and when the dam body has risen to a certain extent, diverting the river to a diversion channel provided in the dam body, continue carrying out excavation and concrete placement of the remaining part.

It will be necessary for the diversion channel in the dam body to be plugged before water impoundment in order for it to function as a part of the dam body.

(d) Dam Foundation Treatment

At both right and left banks of the dam foundation rock, there are parts of high permeability of Lu = 30 or higher in the section of 50 to 60 m from the ground surface, with parts deeper indicating low permeability as a whole. On the other hand, the basement rock under the river bed is fresh and permeability is estimated to be extremely low.

As for the groundwater level, it is basically low, and although it rises somewhat along the natural ground at both banks, groundwater levels have been confirmed at approximately 35 m below the ground surface on the left bank side and approximately 45 m on the right bank side.

The foundation treatment plan for the dam has the purpose of suppressing infiltration of stored water through the foundation rock. This is to consist of curtain grouting which forms an impervious zone along the dam axis in the foundation rock to improve the imperviousness of the foundation rock contacting the dam bottom, and consolidation grouting to improve the foundation rock under the bottom of dam body to make the effect of curtain grouting positive.

In case of a concrete gravity dam, the zone of curtain grouting is usually contemplated aiming for improvement of about 2 Lu, but since the range of high permeability extends to about 50 to 60 m from the ground surface except in certain parts as mentioned above, that range was made the main zone of treatment (grout hole layout, 2 rows, 2-m intervals).

The range of consolidation grouting was made the bottom surface of the dam with depth of grouting to be 10 m (grout hole layout, 3 m grid).

(e) Discharge Facilities

Discharge facilities are to be provided with the purposes of downstream discharge during initial water impoundment and of emergency discharge. The discharge waterway is to be provided by branching off part way along the penstock to be installed at the downstream back surface of the dam, and this is to be merged with the spillway chute. The discharge facilities consist of discharge conduit, discharge valve, and high-pressure slide gate.

Further, besides the emergency discharge facilities for the dam, a simple discharge facility (less than 0.7 m^3/s) for discharge of water for downstream river maintenance is also to be provided.

11.2.2 Waterway and Powerhouse

(1) Location and Outline

The Bağlık Project consists of a concrete gravity dam of height 74 m to be constructed immediately downstream of the confluence with the Sungu river, an underground powerhouse that follows immediately downstream of the dam, and a tailrace tunnel of length approximately 4.5 km for discharge of water after power generation to the planned end of the downstream Deriner reservoir backwater, for a dam and conduit type power generation project of maximum gross head of 136.5 m.

The waterway route of the project, in consideration of the river regime alignment of the Berta River being bent toward the right-bank side, was set on the left-bank side of the river. The tailrace tunnel is of a layout with a bend at the vicinity of approximately 2,100 m downstream along the tailrace for reasons of providing a work adit part way down for carrying out excavation.

(2) Design of Structures

(a) Intake

The intake is to be a type accessory to the dam and provided in a block placed at the left-bank side of the dam body. Selection of the intake bed elevation was done considering reservoir sedimentation, and was made EL. 517 m, 10 m deeper than low water level, in order that harmful conditions such as vortex would not be produced even during low water of the reservoir.

(b) Penstock

After the intake, water is to be conducted by a penstock (1 line) embedded inside the dam body to the downstream back face of the dam, and then go underground by a vertical shaft provided at the downstream toe of the dam. The layout of the penstock to the underground powerhouse turbine was made for the penstock length to be as short as possible through the combination of vertical shaft and horizontal tunnel.

The penstock has a length of approximately 213 m and inside diameter of 3.6 m (average flow velocity 5 m/s), and is gradually reduced along the way to become 3.0 m in diameter at the end of the penstock. The design maximum head of the penstock was made approximately 165 m at the turbine center taking into account pressure rise at load rejection at the turbine, with the design for the total head to be loaded by the penstock alone. However, if the strength characteristics of the surrounding rock can be rationally determined, it will be possible for an economical design making some part of the design head to be borne by the surrounding rock, and it will be necessary for this to be ascertained at the stage of detailed design.

With regard to buckling under groundwater pressure at time of dewatering of the penstock, this is to be basically coped with by stiffeners, and the penstock weight required against internal pressure was increased by the amount of stiffeners.

As for the cross section of excavation for the penstock, it is to be made as small as possible within limits that installation of penstock pipe and welding operations will not be hindered, and the clearance is to be 60 cm.

(c) Underground Powerhouse

The underground powerhouse will be located at a depth of approximately 120 m underground in a rock body at the left bank approximately 100 m downstream of the dam axis. From the results of surface reconnaissances carried out in this area and exploratory boring in the vicinity of the dam site, there are no large-scale faults in the vicinity, the rock quality is massive and hard with RQD values 60-80% and there is no problem in particular. However, the foundation rock of the underground powerhouse requires strength to amply withstand excavation of a large-scale underground cavern, and it is necessary for confirmations to be made regarding these hereafter by means of exploratory boring.

The powerhouse is composed of the powerhouse proper, an access tunnel for delivery of main equipment, and a cable tunnel for leading out a power cable from the powerhouse to the transmission line. These tunnels can be used as mucking tunnels during underground powerhouse excavation at the initial stage of the project.

The access tunnel is planned from an existing road approximately 620 m downstream of the dam to the underground powerhouse at a gradient of 1:10, length of 560 m, and inside diameter of 5 m, while the cable tunnel is also to be from the existing road approximately 320 m downstream of the dam in the form of an inclined shaft of length 264 m and inside diameter 4 m (gradient, 1:5.73).

The cross-sectional configuration of the main cavern of height 41.5 m and width 21 m is to be a mushroom type according to the present design with a layout consisting of a main equipment hall (1 unit), main transformer hall, switching equipment room, etc., with the structure being that of concrete lining for the ceiling arch and side walls. In addition to excavation support for NATM consisting of shotcrete and rock bolts, bedrock strengthening is to be done with prestressed rock anchors aiming for stabilization of the surrounding rock from during construction to the operating stage, while further, because of the proximity to the dam and reservoir, drainage tunnels are to be arranged in the surroundings of the underground powerhouse.

The turbine center elevation is to be 394 m considering the necessary static draft head of turbine in relation to the tail water level (392 m: Deriner reservoir HWL).

(d) Tailrace

The tailrace is for discharge of the maximum available water of 52 m^3/s to the downstream Deriner reservoir by a standard horseshoe-shape non-pressure tunnel of length 4,454 m and inside diameter 4.9 m.

The gradient of the tailrace tunnel was selected to be 1:1,400 with the gradient at which the sum of annual expense determined from construction cost and annual benefit loss obtained from head will be minimum as the optimum gradient (see Figure 11-13).

Lining of the tailrace tunnel was divided into standard section (concrete lining thickness 40 cm: 10%), good geology section (shotcrete: 80%), and poor geology section (concrete lining thickness 60 cm:10%) and each length was decided on the base of the proportion ratio against the total length considering the geological condition.

Construction of the tunnel of total length 4,454 m is to be done providing a work adit along the way for excavation from maximum of 4 faces including excavation from the powerhouse side. This work adit is to be plugged after completion of construction.

To deal with load rejection or sudden load increase at the powerhouse, a surge chamber of height 15.1 m and length 30 m is to be provided at the starting point of the tailrace tunnel, along with which a draft gate at the end of the draft tunnel connecting to the surge chamber and an outlet gate (stop logs) at the end of the tailrace tunnel are to be respectively installed.

11.2.3 Electro-Mechanical Equipment

(1) Selection of Number of Units

From same reason as Bayram project, number of units is selected to one.

(2) Type and Ratings of Major Equipment

From the maximum discharge and the effective head, a vertical shaft Francis type is judged as appropriate for this project.

The generator is directly coupled to the turbine shaft and is a vertical shaft, three phases, alternating current, synchronous generator.

There is no place to install main transformer and switchyard equipment. These equipment will be installed in powerhouse and GIS (Gas Insulated Switchgear) will be adopted.

The voltage of main circuit is 11 kV. A parallel-in circuit breaker is equipped at the low voltage side of the main transformer and is used for synchronizing generator to the power system. Generator is connected with GIS by IPB (Isolated Phase Bus).

For connection between GIS and outside structure, 154 kV XLPE power cable will be adopted.

To secure station service power in any failures on the transmission line or the switchyard equipment, a diesel engine-generator set will be installed in this power station.

Power line carrier system (earth return) is provided for composing telecommunication circuits for power generation and dam operation.

Table 11-6 shows the ratings of major equipment and Figure 11-21 indicates the single line diagram of the power station.

11.3 Transmission Line

11.3.1 Transmission Line Route

From power development plan, Deriner power plant will be built before Berta project. From this, existing roads will be under water and new roads will be necessary. So, transmission line route for Berta project should be avoided from under water area and should be near and parallel with construction road. For construction work, whether existing road can be used or not to transport construction materials is very important for construction cost.

Transmission line route should be along right bank from upstream.

11.3.2 Conductor Size and Tower

(1) Transmission Line Voltage and Number of Circuits

Transmission line voltage is 154 kV. Number of circuits is as shown below:

Bayram - Bağlık	1 cct
Bağlık - Deriner	2 cct

(2) Conductor

Taking into account current capacity adopted this project, mechanical strength, insulation coordination and condition of existing 154 kV transmission line as well as TEAS's plan, type of conductor is shown as follows:

(a) Bayram - Bağlık : 6 km

154 kV, ACSR 477 MCM, 1 conductor 1 cct

(b) Bağlık - Deriner : 20 km

154 kV, ACSR 477 MCM, 1 conductor 2 cct

The ambient conditions for the transmission line are as follows:

Snow deposit: Max. 214 cm
Rainfall: Annual total 624 mm
Temperature: Annual average 9.9°C, Max. 38.8°C, Minimum -19.9°C
Wind velocity: Average 24.2m/sec

(3) Ground-wire

In order to reduce lightning strokes as less as possible and to enhance the stability of the system, an overhead ground-wire 70 mm^2 GSW, 2 lines) is fitted.

(4) Insulator

Taking into account the results of electrical and mechanical studies and insulation coordination with the existing 154 kV transmission line, the number of insulators per one string and type are taken for 12 units of suspension insulators with 250 mm in diameter.

(5) Supporting Structure

In view of the geographical features and meteorological conditions, steel towers which are provided with higher mechanical strength are adopted. As a design condition for these steel towers, the following loads due to wind pressure were considered.

Conductor: 68 kgf/m^2
Steel tower: 90 kgf/m^2

Figure 11-22 (two-circuit design) and 11-23 (one-circuit design) show typical tower types to be adopted into the design of this transmission line.

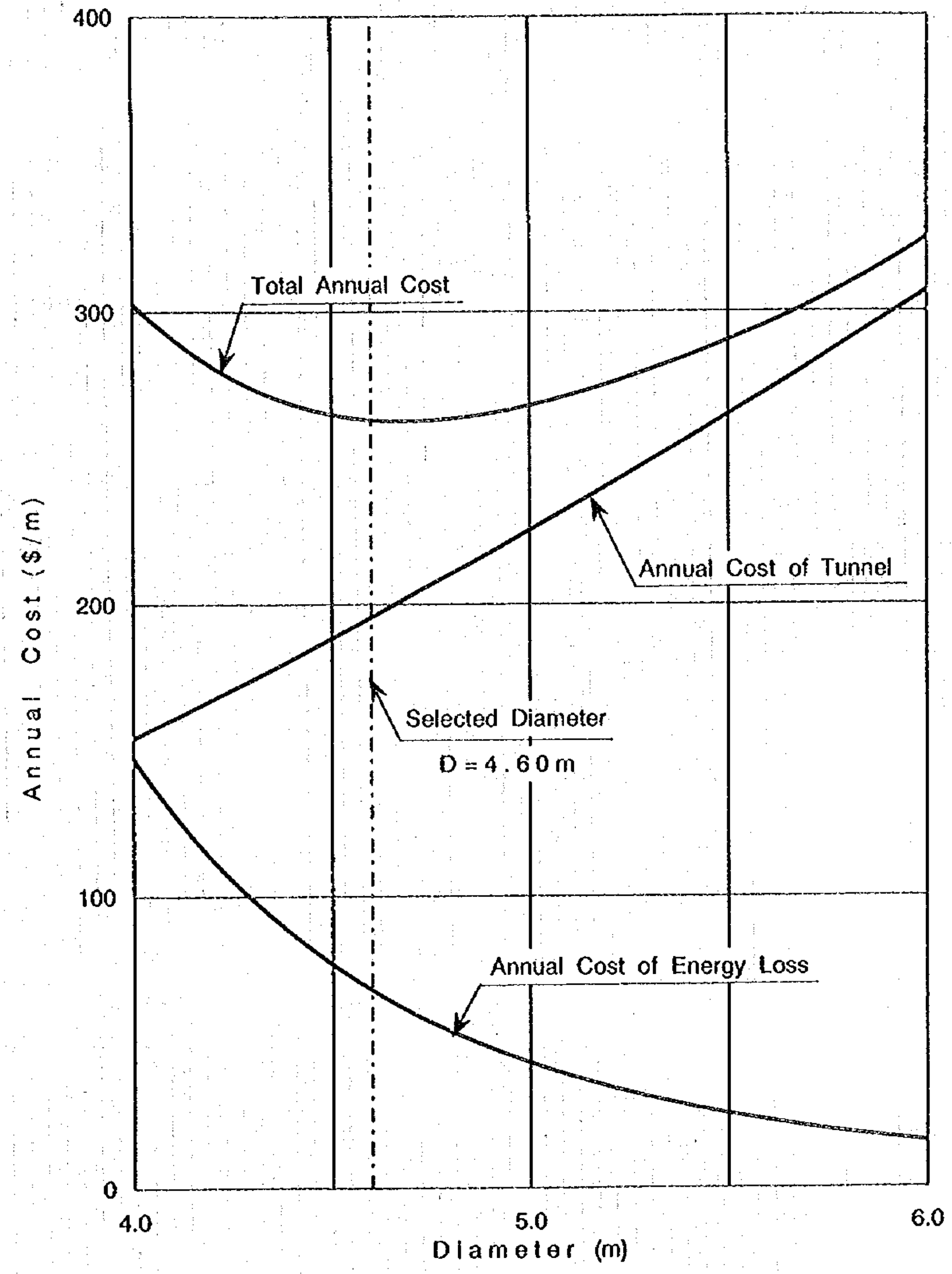
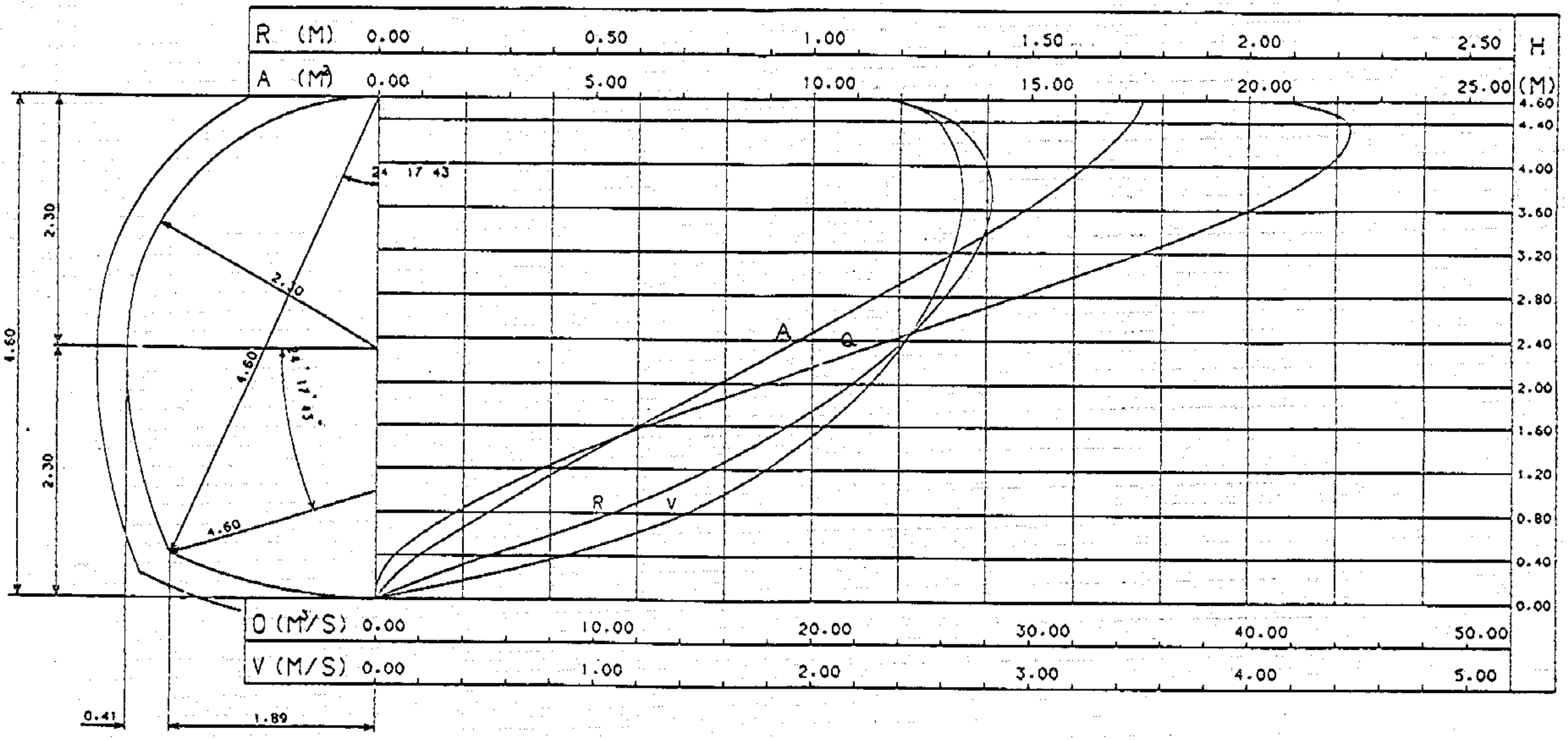


Figure 11-1 Estimation of Optimum Diameter of Tailrace Tunnel Bayram Project



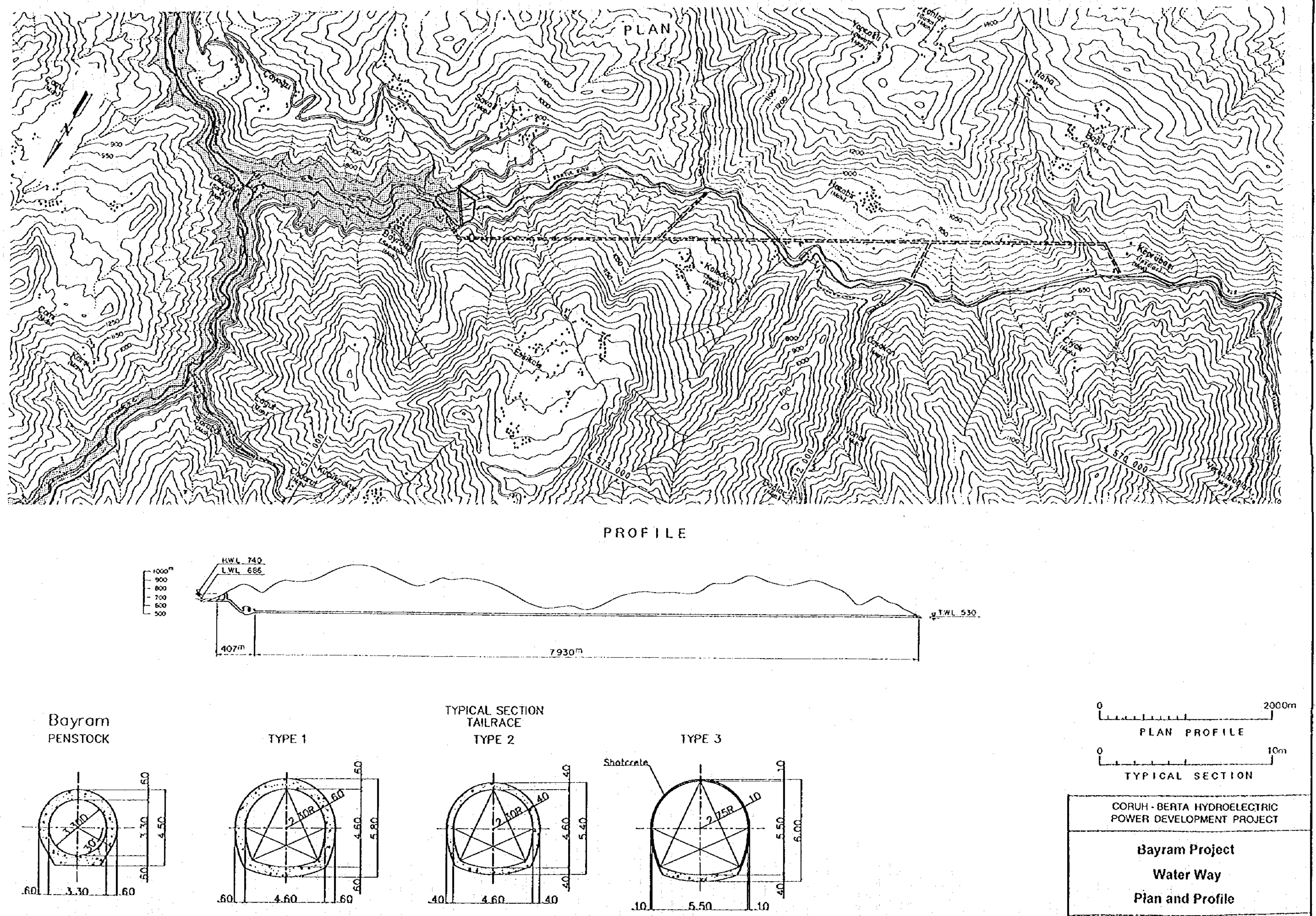
FORMULA

$Q = A \cdot V$

$= A \cdot R^{\frac{2}{3}} \cdot I^{\frac{1}{2}} / N$

V ;VELOCITY (M/S)
Q ;DISCHARGE (M³/S)
A ;CROSS-SECTIONAL AREA OF FLOW (M²)
R ;HYDRAULIC RADIUS (M)
N ;COEFFCIENT OF ROUGHNESS (NC=0.0125)
I ;CHANNEL GRADE (1:1400)
H ;WATER LEVEL (M)

Figure 11-2 Rating Curve of Tailrace Tunnel Bayram Project

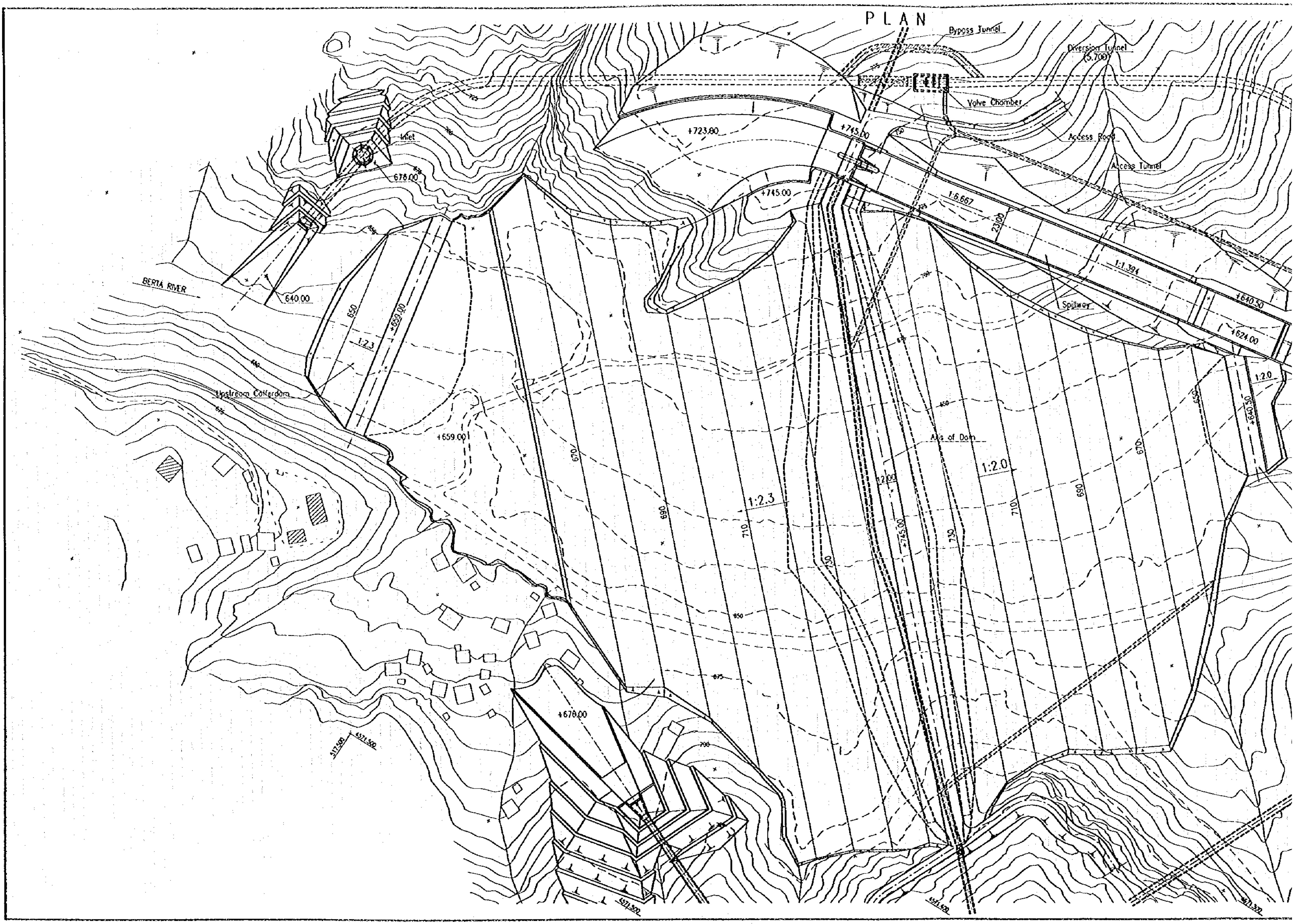


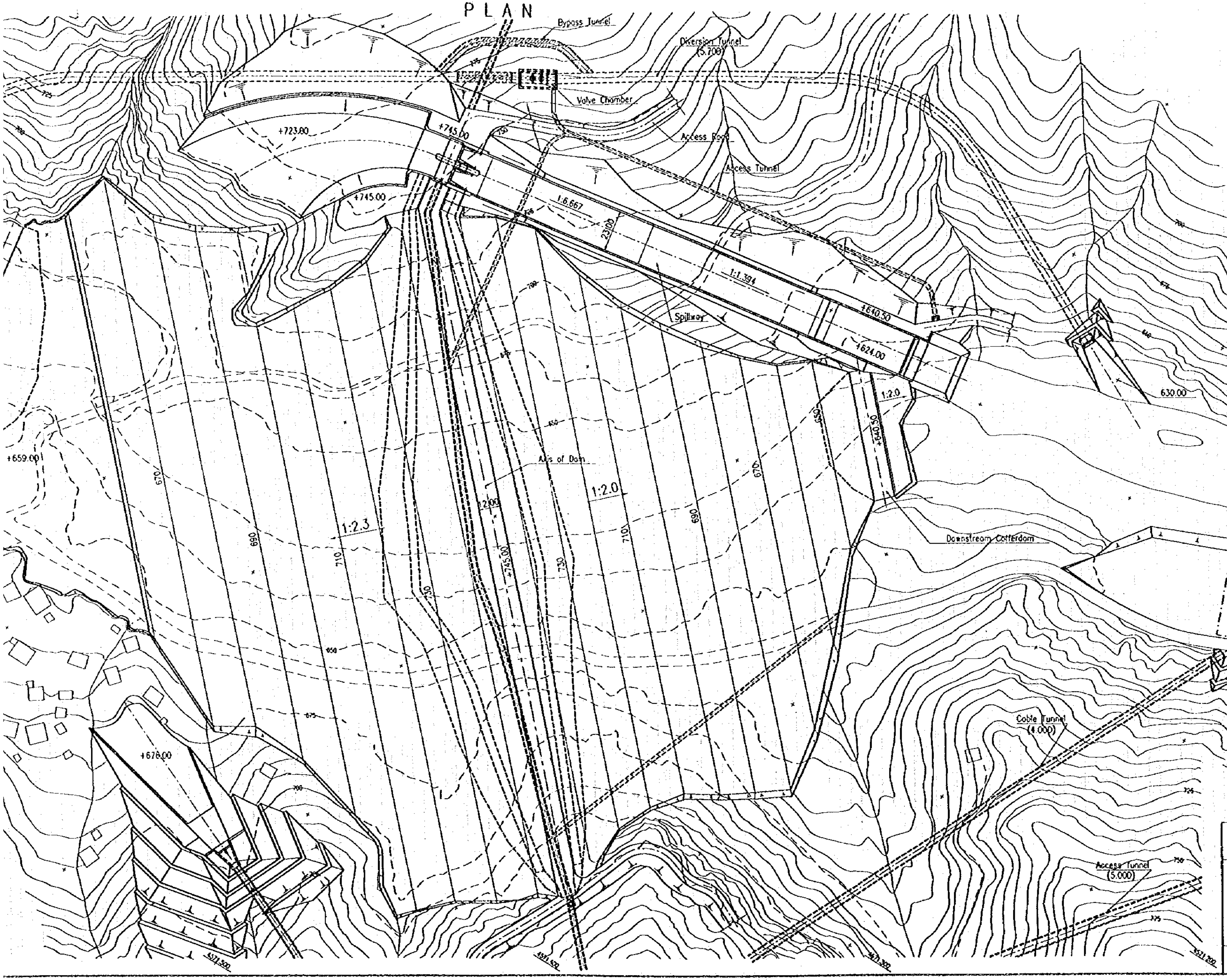
CORUH - BERTA HYDROELECTRIC
POWER DEVELOPMENT PROJECT

Bayram Project
Water Way
Plan and Profile

Figure 11-3

英本文

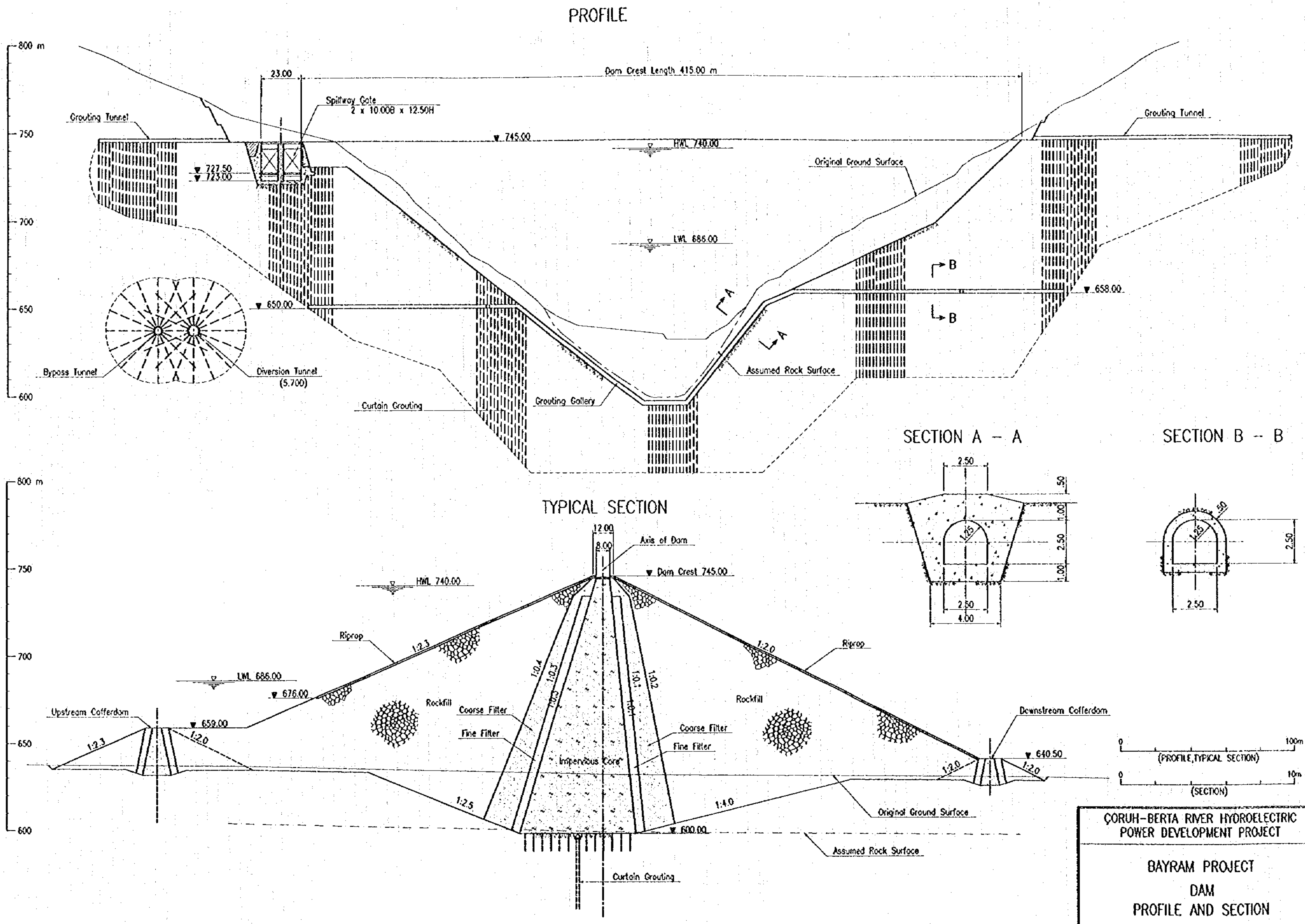

PLAN
Bypass Tunnel
Diversion Tunnel
(5.700)
Valve Chamber
Access Road
Access Tunnel
Inlet
678.00
+723.00
+745.00
+745.00
1:6.667
23.00
1:1.394
Spillway
+640.50
+624.00
1:2.0
+640.50
650
BERTA RIVER
640.00
650
1:2.3
+659.00
Upstream Cofferdam
+659.00
670
690
710
730
1:2.3
12.00
+745.00
730
Axis of Dam
1:2.0
710
690
670
650
+678.00
517.500
4571.500
4571.300
4571.400
4571.300



ÇORUH-BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAYRAM PROJECT
DAM
GENERAL PLAN

Figure 11-4

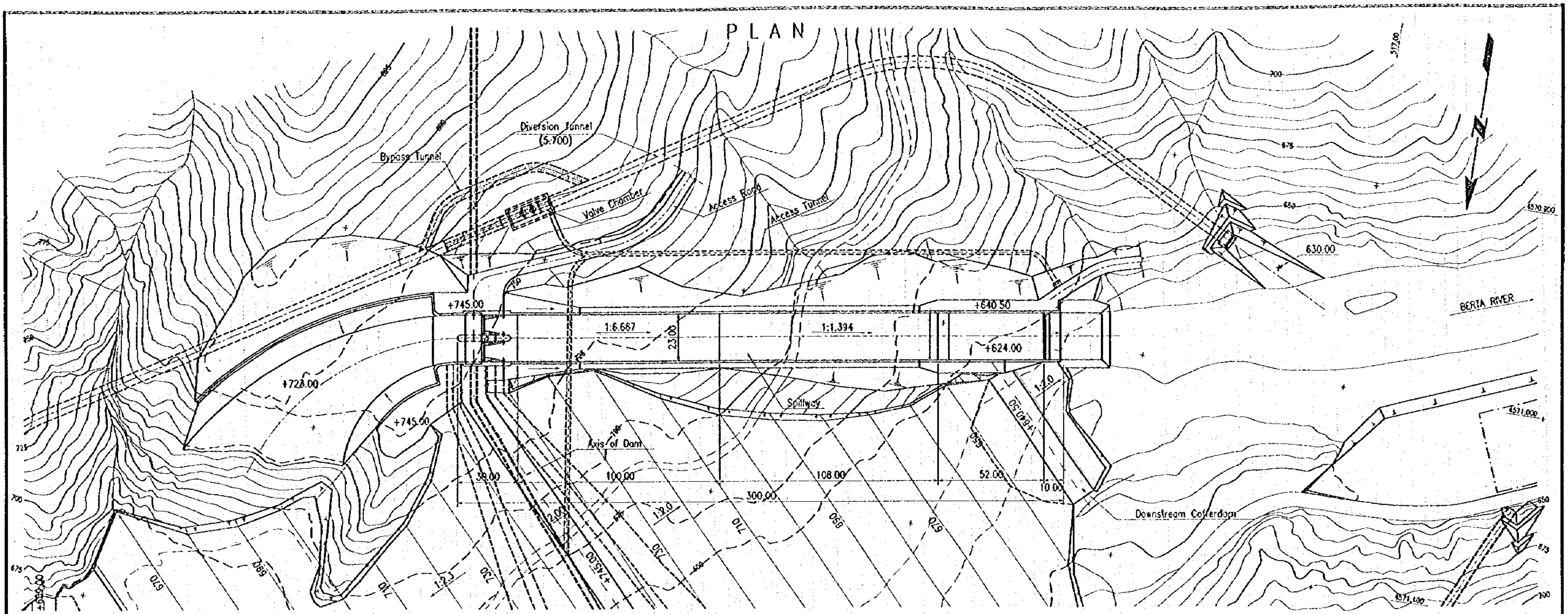


ÇORUH–BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

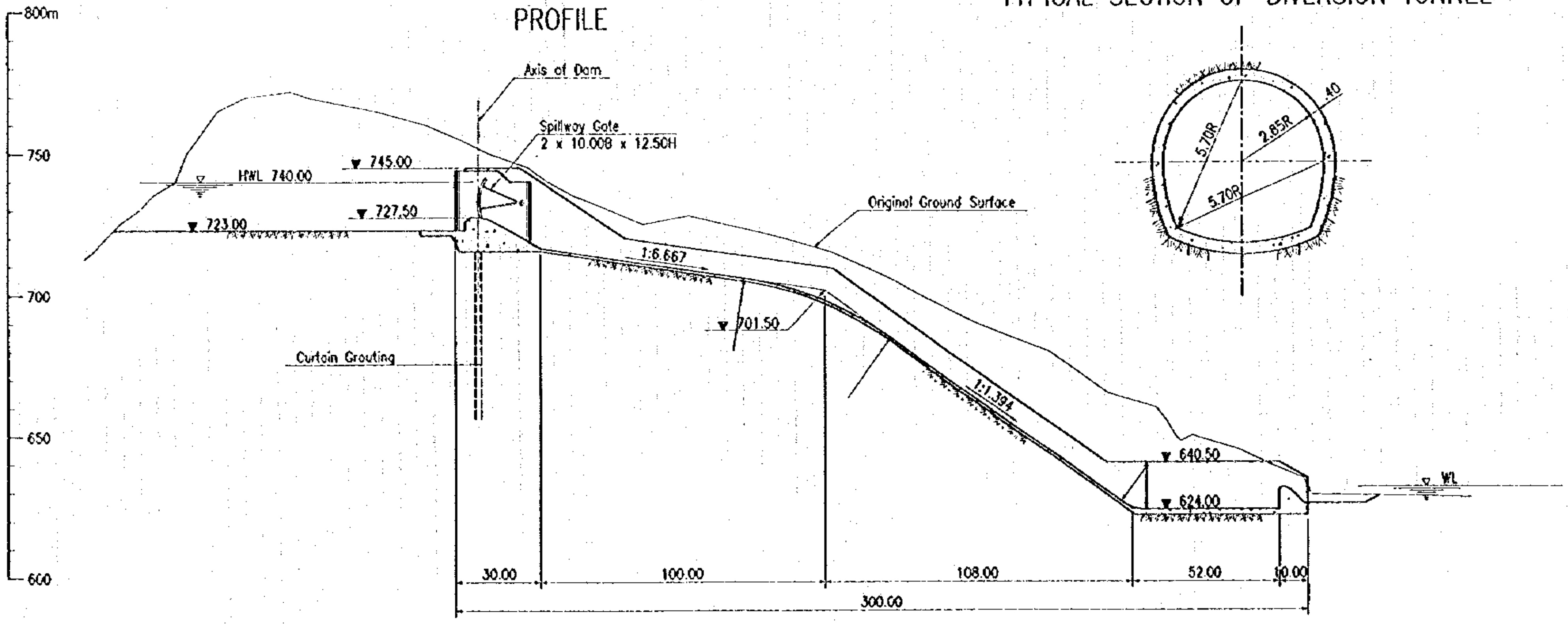
BAYRAM PROJECT
DAM
PROFILE AND SECTION

Figure 11-5

PLAN

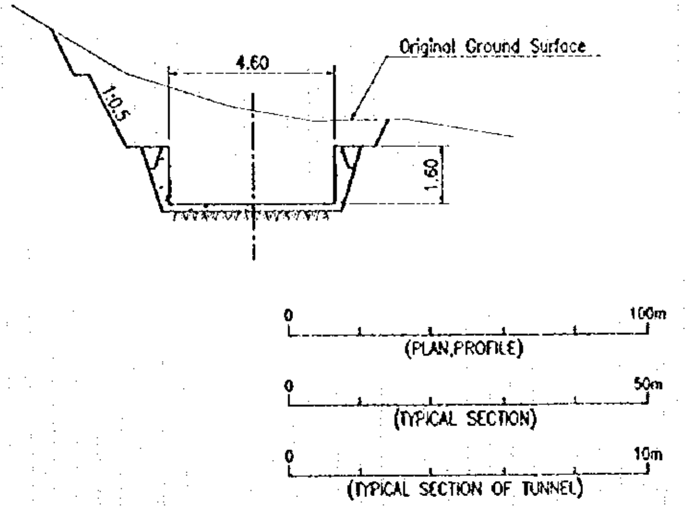


PROFILE



TYPICAL SECTION OF DIVERSION TUNNEL

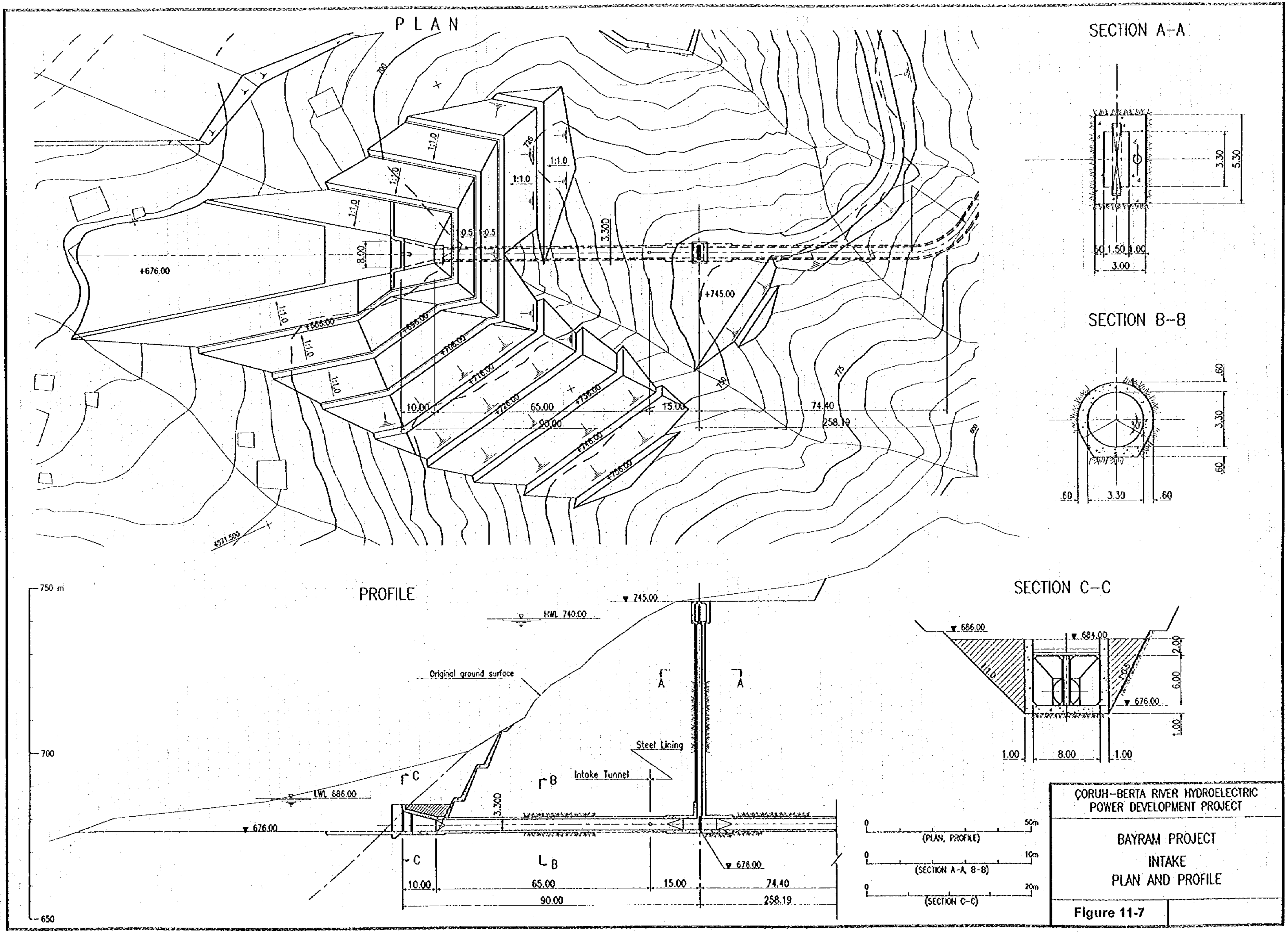
TYPICAL SECTION



ÇORUH-BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAYRAM PROJECT
SPILLWAY
PLAN AND PROFILE

Figure 11-6

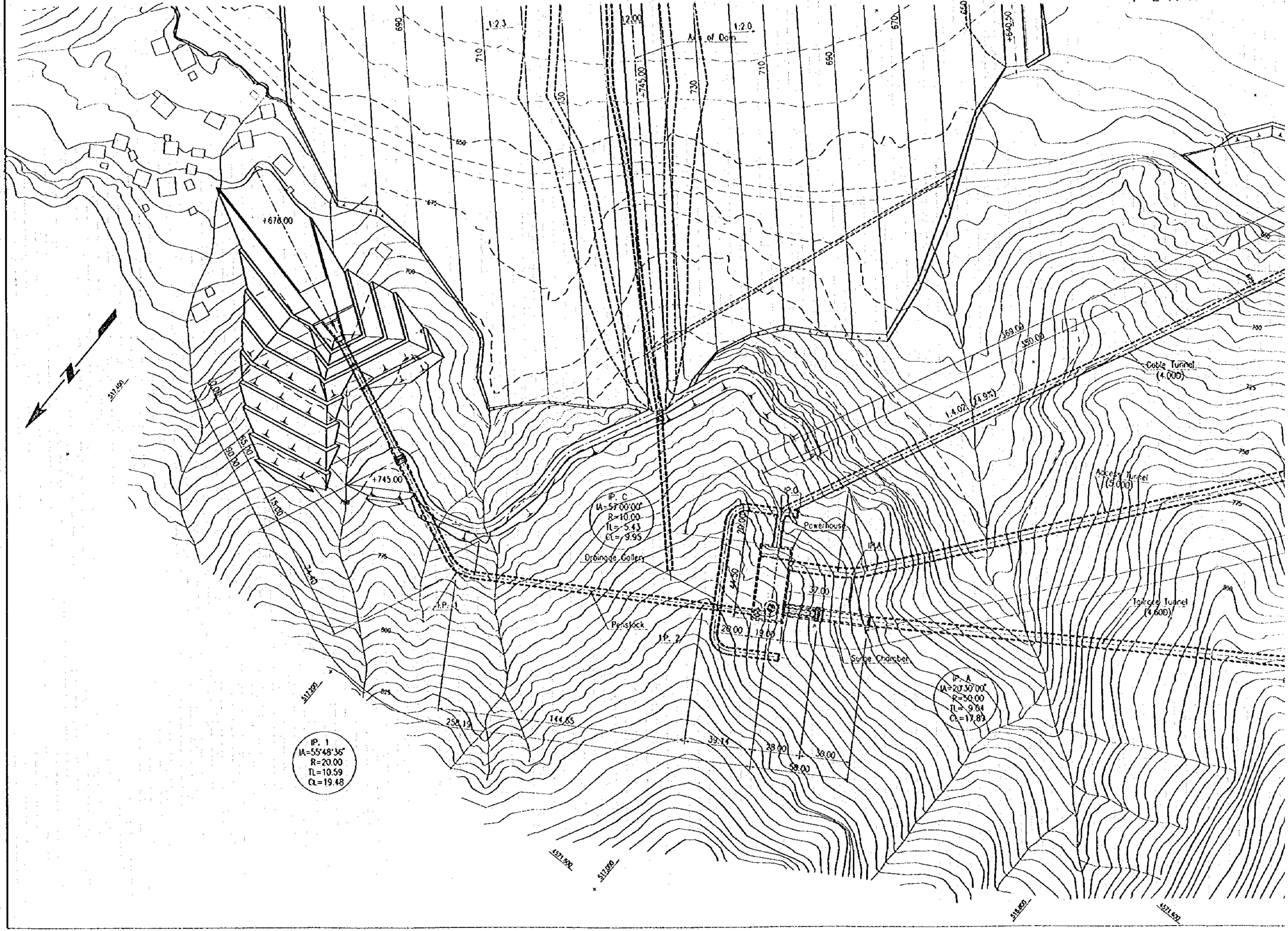


ÇORUH-BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAYRAM PROJECT
INTAKE
PLAN AND PROFILE

Figure 11-7

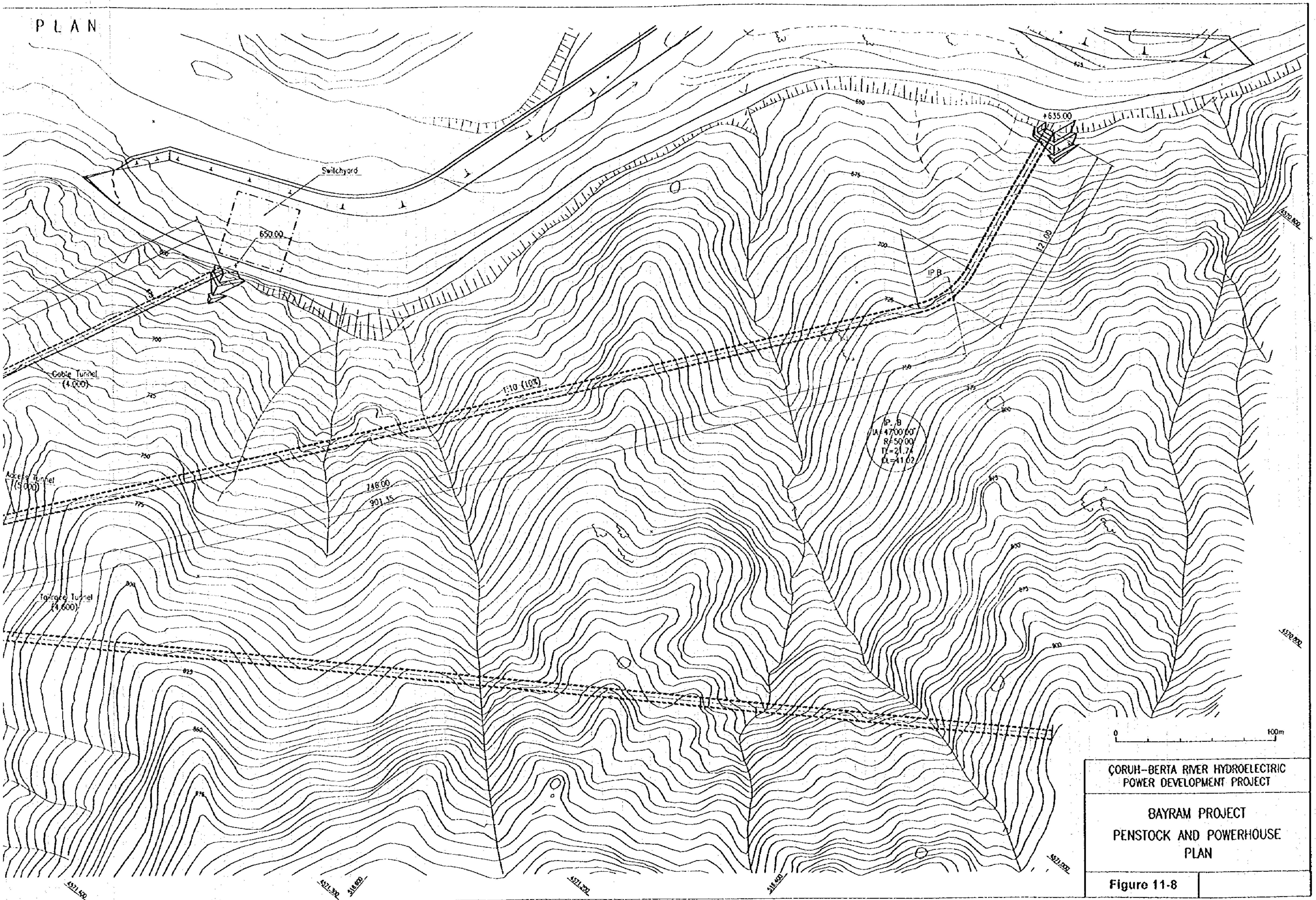
PLAN



1:2.3
12.00
1:2.0
Axis of Dam
+745.00
+640.50
690
710
730
670
650
675
700
750
775
800
825
+676.00
+745.00
N
517.400
517.200
517.000
516.800
4571.800
4571.600
12.00
65.10
90.00
15.00
34.40
369.00
350.00
Cable Tunnel
(4.000)
1:4.02 (4.9%)
Access Tunnel
(5.000)
Tailrace Tunnel
(4.600)
IP. C
IA=57°00'00"
R=10.00
TL=5.43
CL=9.95
IP. 0
Powerhouse
IP. A
Drainage Gallery
28.00
24.50
37.00
28.00
19.00
Penstock
IP. 1
IP. 2
Surge Chamber
IP. A
IA=20°30'00"
R=50.00
TL=9.04
CL=17.83
258.19
144.65
39.14
28.00
30.00
58.00
IP. 1
IA=55°48'36"
R=20.00
TL=10.59
CL=19.48

PLAN

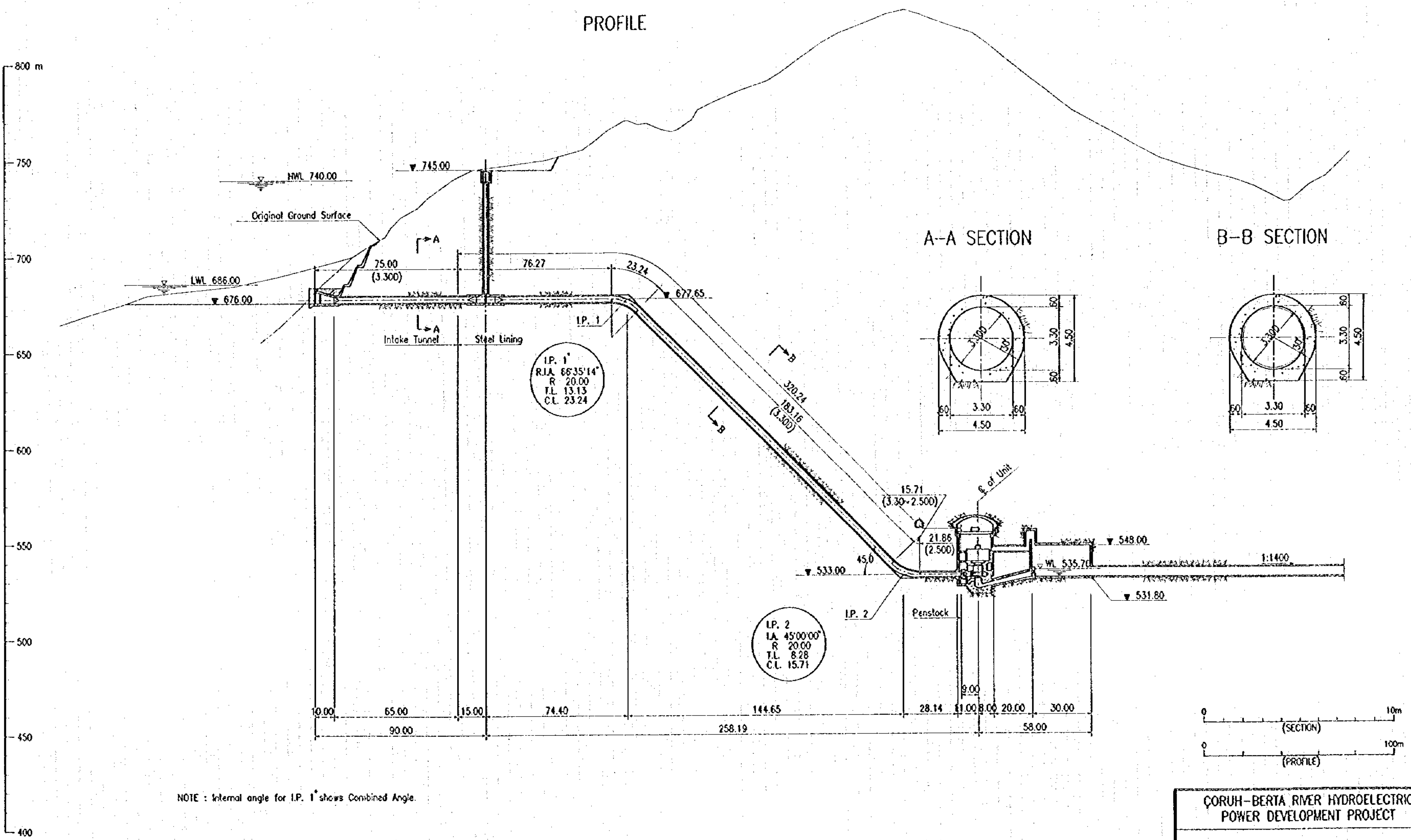
1:2.3
1:2.0
1:2.0
Axis of Dam
710
730
745.00
750
710
690
670
650
640.50
650
Switchyard
650.00
700
725
750
775
800
825
850
875
169.00
350.00
Cable Tunnel
(4.000)
1:4.02 (24.9%)
1:10 (10%)
Access Tunnel
(5.000)
748.00
901.15
Tailrace Tunnel
(4.600)
IP. C
IA=57°00'00"
R=10.00
TL= 5.43
CL= 9.95
IP. 0
Powerhouse
IP. A
22.00
34.50
37.00
Drainage Gallery
Penstock
IP. 1
IP. 2
20.00
19.00
Surge Chamber
IP. A
IA=20°30'00"
R=50.00
TL= 9.04
CL=17.89
258.19
144.65
39.14
28.00
58.00
30.00
4571.600
517.000
518.000
4571.400
4571.300
518.800
4571.200
518.400



ÇORUH–BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAYRAM PROJECT
PENSTOCK AND POWERHOUSE
PLAN

Figure 11-8

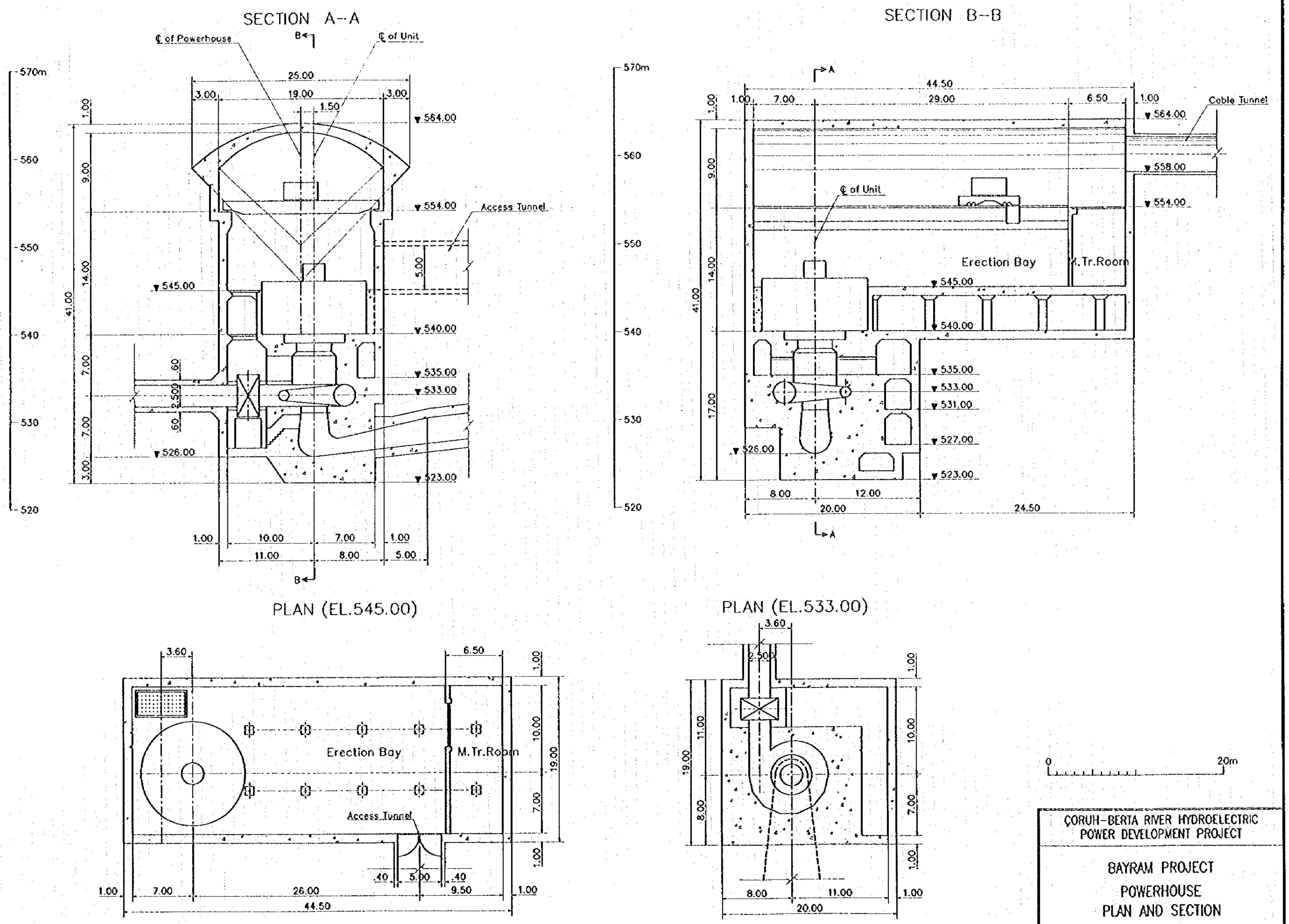


NOTE : Internal angle for I.P. 1* shows Combined Angle.

ÇORUH-BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAYRAM PROJECT
PENSTOCK AND POWERHOUSE
PROFILE AND SECTION

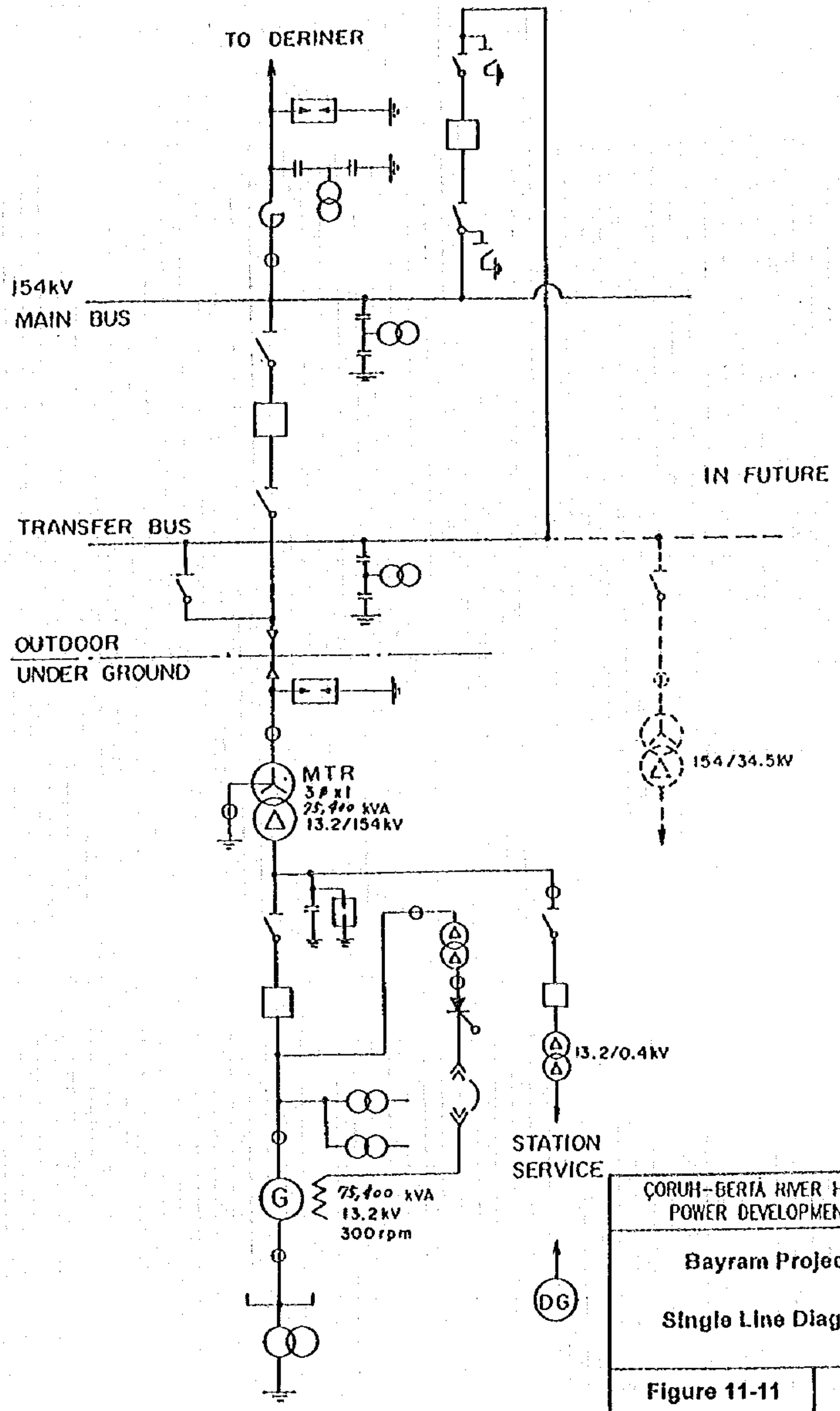
Figure 11-9



ÇORUH–BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAYRAM PROJECT
POWERHOUSE
PLAN AND SECTION

Figure 11-10

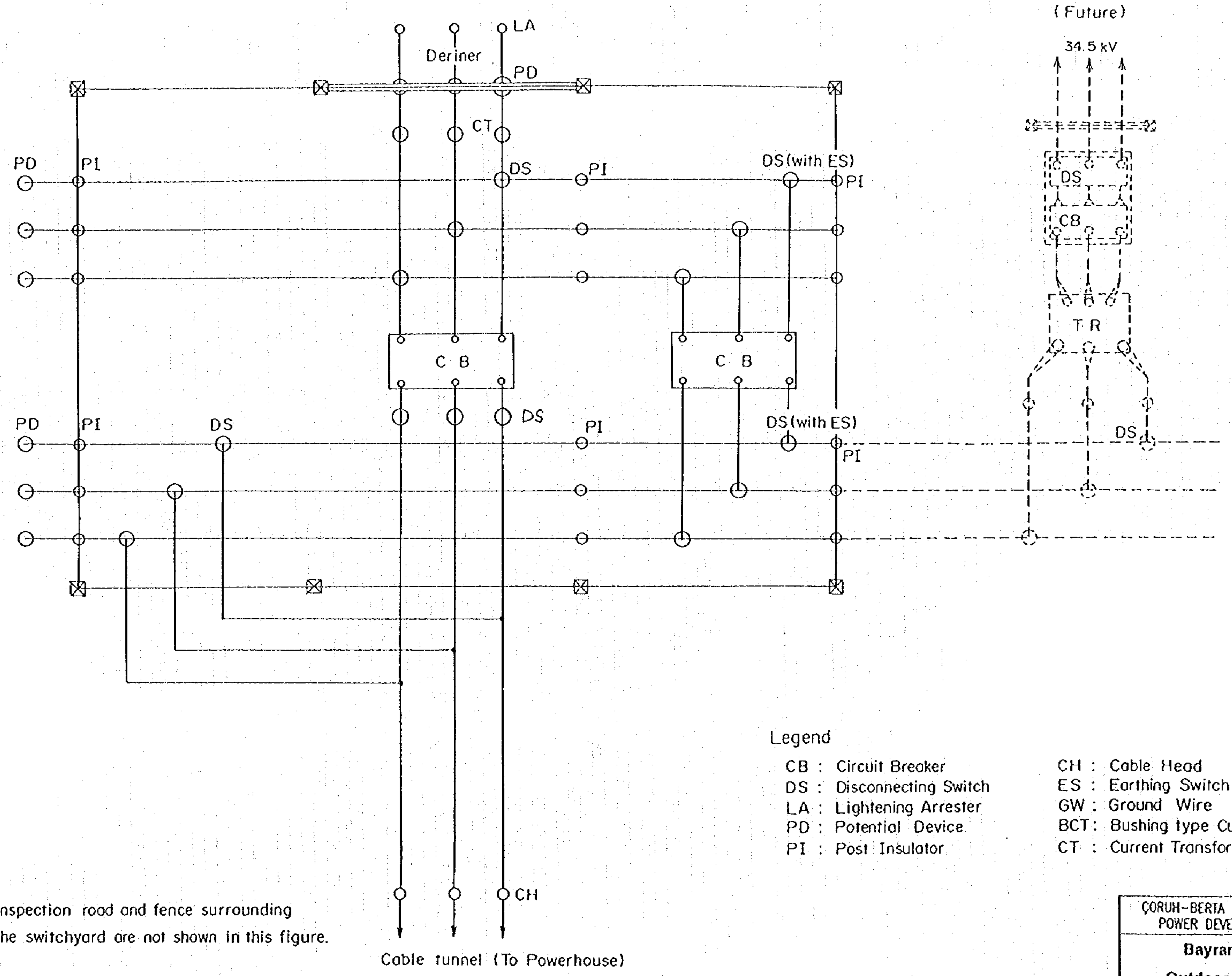


ÇORUH-BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

Bayram Project

Single Line Diagram

Figure 11-11



Legend

CB : Circuit Breaker
DS : Disconnecting Switch
LA : Lightening Arrester
PD : Potential Device
PI : Post Insulator

CH : Cable Head
ES : Earthing Switch
GW : Ground Wire
BCT: Bushing type Current Transformer
CT : Current Transformer

Foot note : Inspection road and fence surrounding the switchyard are not shown in this figure.

ÇORUH-BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

Bayram Project
Outdoor Switchyard
Plan

Figure 11-12

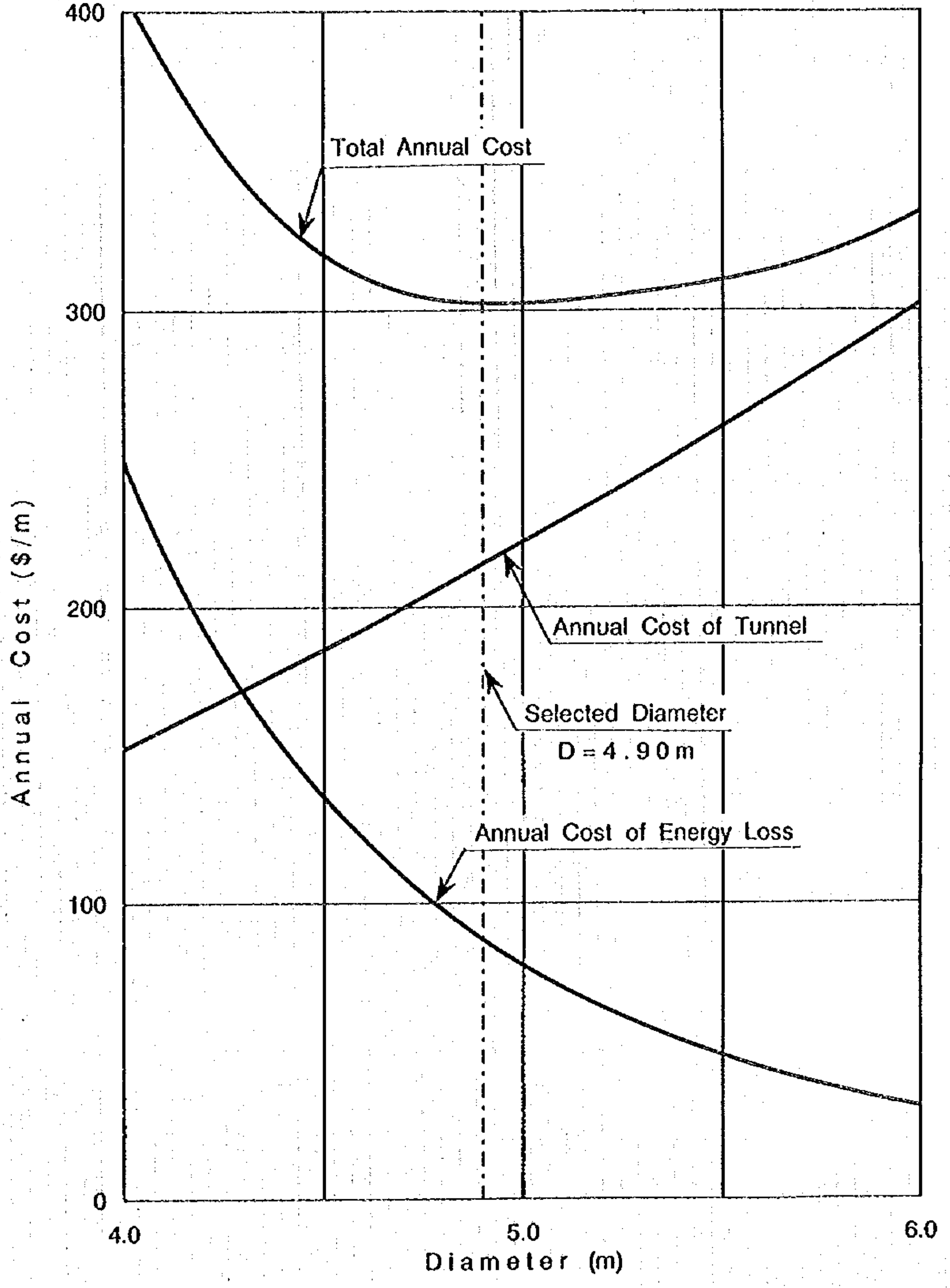
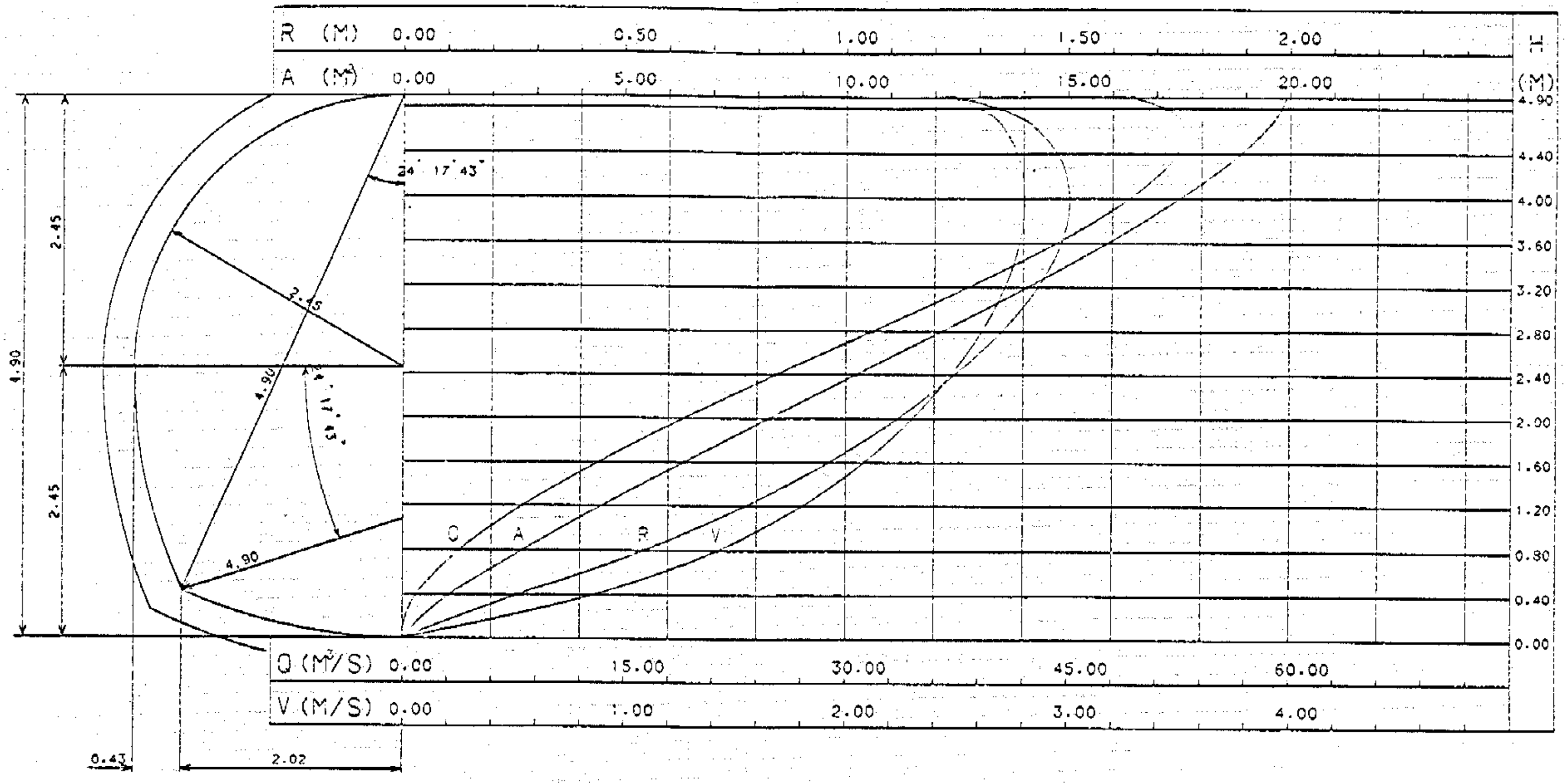


Figure 11-13 Estimation of Optimum Diameter of Tailrace Tunnel Bağlık Project



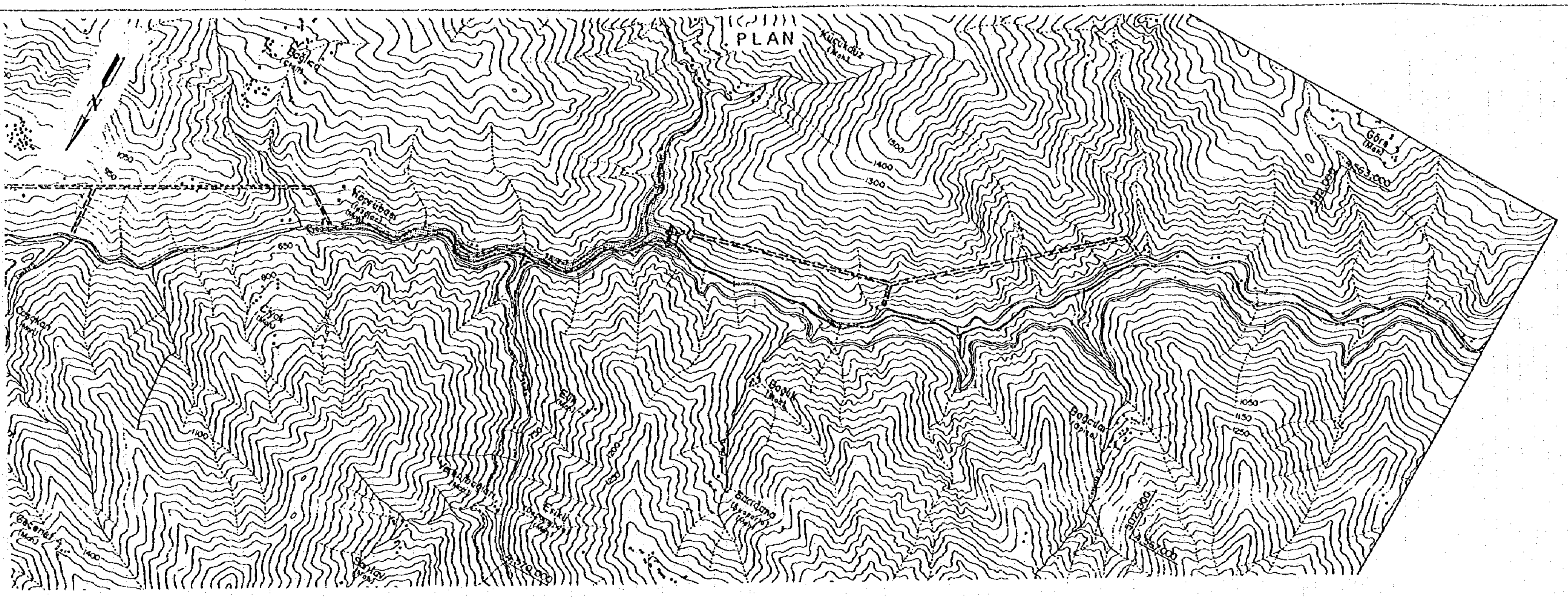
FORMULA

$Q = A \cdot V$

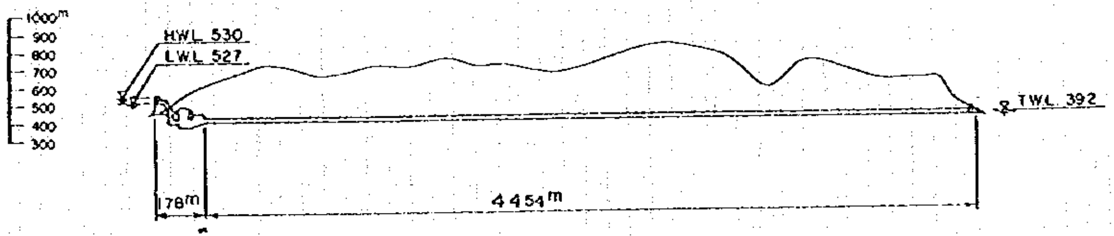
$= A \cdot R^{\frac{2}{3}} \cdot I^{\frac{1}{2}} / N$

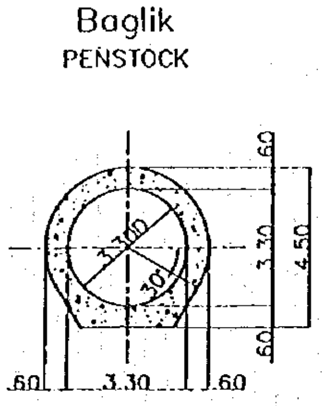
V ;VELOCITY (M/S)
Q ;DISCHARGE (M³/S)
A ;CROSS-SECTIONAL AREA OF FLOW (M²)
R ;HYDRAULIC RADIUS (M)
N ;COEFFCIENT OF ROUGHNESS (NC=0.0125)
I ;CHANNEL GRADE (1:1400)
H ;WATER LEVEL (M)

Figure 11-14 Rating Curve of Tailrace Tunnel Bağlık Project

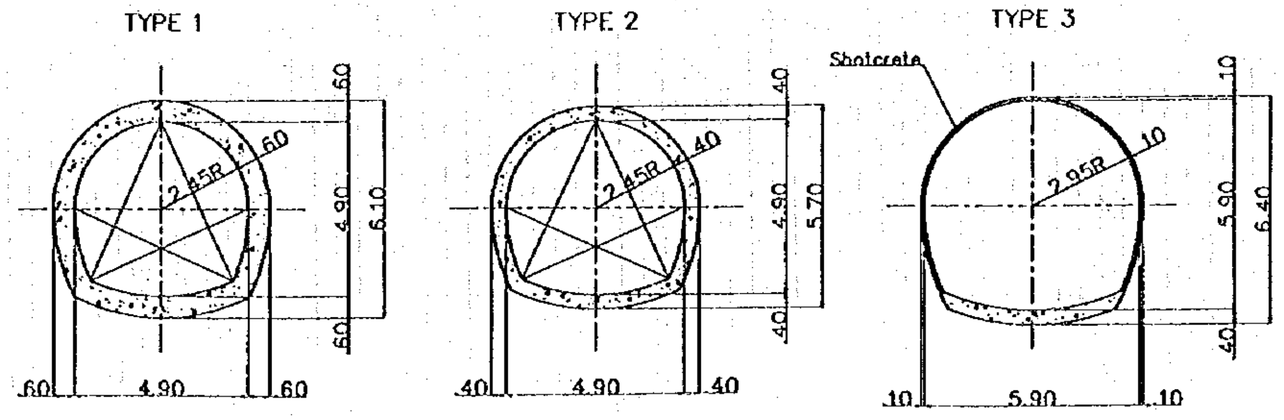


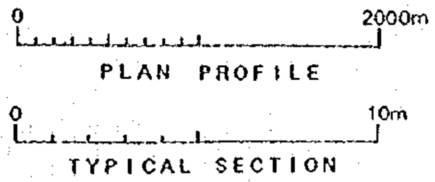
PROFILE





TYPICAL SECTION
TAILRACE

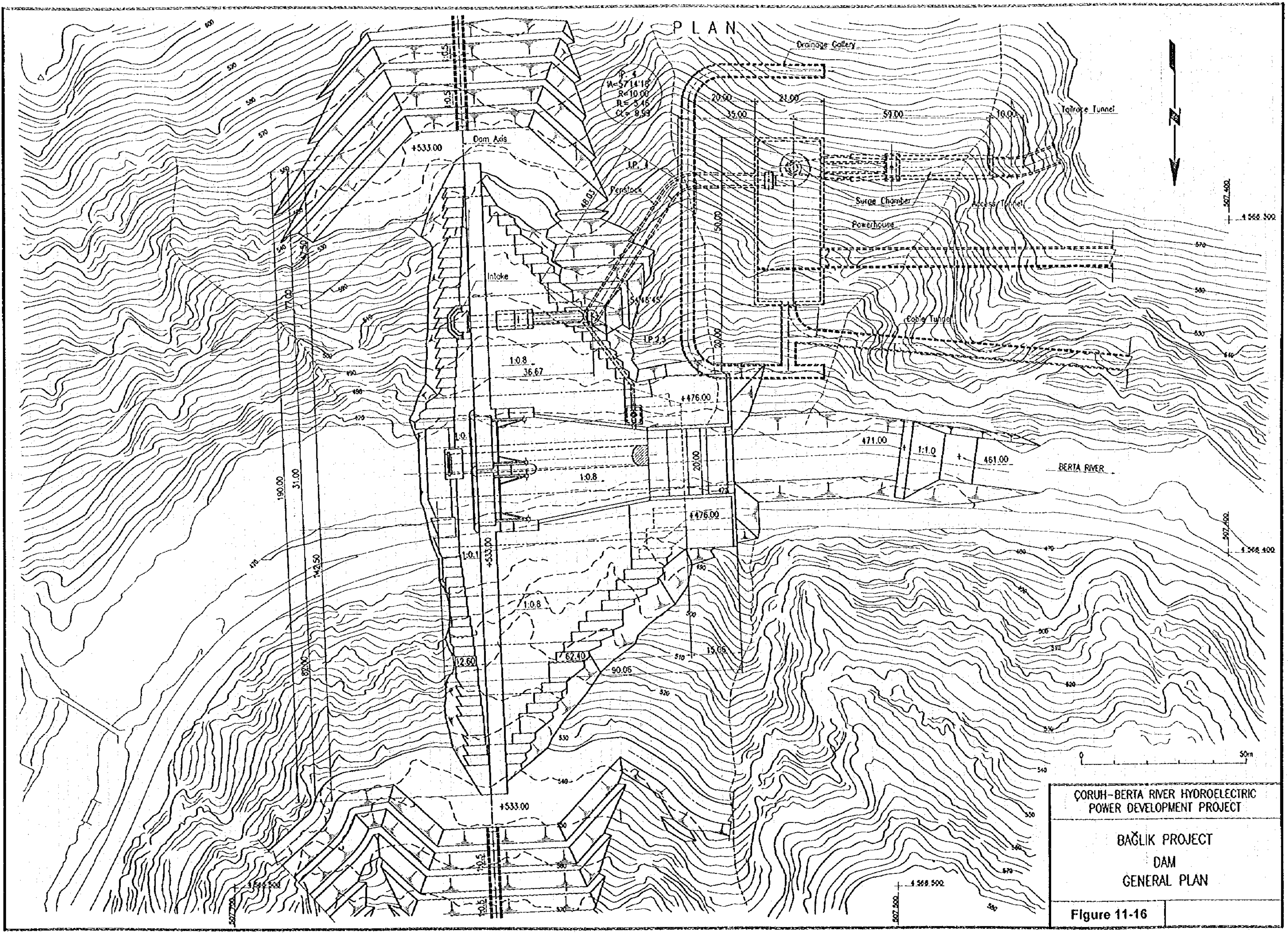




CORUH - BERTA HYDROELECTRIC
POWER DEVELOPMENT PROJECT

Bağlık Project
Water Way
Plan and Profile

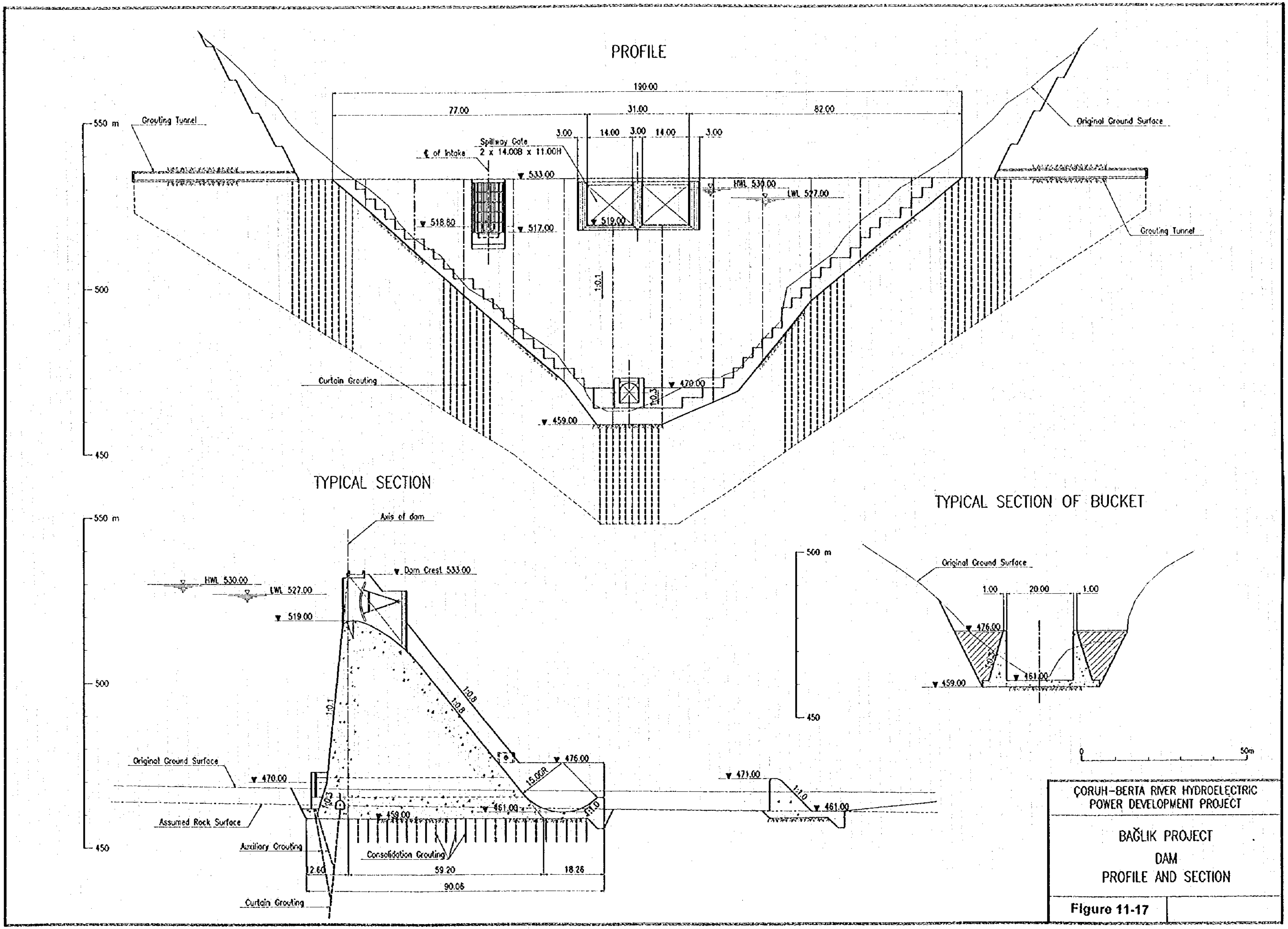
Figure 11-15



ÇORUH-BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAĞLIK PROJECT
DAM
GENERAL PLAN

Figure 11-16



ÇORUH–BERTA RIVER HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAĞLIK PROJECT
DAM
PROFILE AND SECTION

Figure 11-17