prevent backwater from the open channel when discharge valves do not work due to some troubles. The settled water flows into the transition channel passing over the weir.

The transition channel leads the water smoothly to the open channel. The dimension is determined to fulfill this function.

The head tank is mainly of a reinforced concrete structure. The head tank is located on the top of hill and excavation and backfill will be made for its construction. About 10 m in depth of excavation is required at the maximum and a high groundwater pressure and uplift will act on the structure without drainage system since the water could not be drained naturally.

In due consideration of the above condition, it is required that underdrain system is provided to drain the groundwater due to rainfall. The underdrain system is designed beneath the entire part of the head tank. The system consists of three lanes of underdrain made by perforated concrete pipes and sand and gravel surrounding the pipes and transverse drain made by sand and gravel to connect the underdrain transversely. Free draining backfill with a thickness of 40 cm is also provided behind side wall. The water collected by the system will be drained through 300 mm in diameter concrete pipe into side ditch of the penstock.

Structural analysis is made assuming that the structure is rigid frame as described in the "Design Calculation Report".

Inlet portion connecting from the penstock is composed of embankment and concrete gravity wall. The embankment slope with a gradient of 1: 1.5 is protected by stone pitching, where the penstock pipes encased by concrete pass through to the settling basin.

Design drawings of the head tank is shown in Drawing Nos.2-HT-001 to 2-HT-007.

4.3.4 Severino Open Channel

(1) General

La Esperanza ~ Poza Honda Transbasin consists of Severino Pumping Station, Severino Penstock, Severino Head Tank, Severino Open Channel and La Esperanza ~ Poza Honda Diversion Tunnel for water transbasin. Optimum scale of the open channel and the tunnel as well as their formation level are interrelated to energy cost for pumping. It is therefore required that a comparative study is conducted taking the transbasin facilities into consideration as an integrated system to define technical features of each facility.

Pumping levels at the pumping station and invert elevation at the diversion tunnel outlet (Los Cuyuyes Outlet) are set out based on the integrated reservoir operation study and the anticipated sediment level in La Esperanza reservoir etc.

Route of the open channel and the diversion tunnel proposed in the feasibility study is basically applied for the comparative study. A trapezoidal channel section with concrete lining is also applied to the open channel and a standard horse-shoe section is applied to the diversion tunnel in consideration of the geological condition and hydraulic prospect, as proposed in the feasibility study.

Basic conditions for the comparative study are shown below;

Water level at Severino Pumping Station	
High Water Level (HWL)	: EL. 66.0 m
Minimum Operation Level (MOL)	: EL. 47.0 m
Design water level	: EL. 58.5 m
Max. Transbasin Discharge	: 16 m^3/sec
Open Channel	: Trapezoidal section, side slope 1 : 1.2
Diversion Tunnel	: Standard 2R horse-shoe section

The following configuration of open channel and the tunnel are selected for the alternative study, taking account of topographic conditions as well as the basic conditions.

Open Channel				Diversion Tunnel		
Configuration	Slope	Width (m)	Depth (m)	Configuration	Slope	Section 2R (m)
OP-1	1/2,000	1.6	2.3	TN-1	1/1,000	3.3
OP-2	1/3,000	1.6	2.5	TN-2	1/1,500	3.5
OP-3	1/4,000	1.9	2.6	TN-3	1/2,000	3.7

To arrange and combine the identified configurations of the open channel and the diversion tunnel, the following nine (9) alternatives are established as shown below.

Alternative	Combined Configuration
1	OP-1 + TN-1
2	OP-1 + TN-2
3	OP-1 + TN-3
4	OP-2 + TN-1
5	OP-2 + TN-2
6	OP-2 + TN-3
7	OP-3 + TN-1
8	OP-3 + TN-2
9	OP-3 + TN-3

Construction cost of the respective alternative is estimated at basic design level for the purpose of the comparative study, based on rough construction quantities and the estimated unit price in the feasibility study. The estimated cost is presented as follows;

	Construction Cost		Unit : US $ thousand
Alternative	Open Channel	Diversion Tunnel	Total
1	8,164	23,068	31,232
2	8,164	25,949	34,113
3	8,164	29,011	37,175
4	9,027	23,068	32,095
5	9,027	25,949	34,976
6	9,027	29,011	38,038
7	9,916	23,068	32,984
8	9,916	25,949	35,865
9	9,916	29,011	38,927

The above cost is specifically for the pumping equipment, the open channel and the diversion tunnel. The construction costs of civil works for the pumping station, the penstock and the head tank could be regarded as common and are not needed to the present comparative study.

The annual electricity charge is estimated based on the recent regulation in Ecuador for basic tariff of electricity.

The optimum configuration will be selected among 9 alternatives on the basis of a least-cost criterion. Evaluation horizon is determined at 30 years and all costs are converted into the present worth at a discount rate of 10 % and summarized below.

Annual Equivalent Cost Unit : US $ thousand

Alternative	Annual Equivalent Cost for construction	Annual Energy Cost	Total
1	3,150	5,634	8,784
2	3,441	5,335	8,775
3	3,749	5,185	8,934
4	3,237	5,546	8,783
5	3,528	5,246	8,774
6	3,836	5,097	8,933
7	3,327	5,502	8,829
8	3,617	5,202	8,820
9	3,926	5,053	8,979

The alternative 5, open channel slope of 1/3,000 (OP-2) and tunnel slope of 1/1,500 (TN-2), is the least cost one. It is, therefore, concluded that the configuration of the open channel and the diversion tunnel should be in accordance with Alternative 5.

In due consideration of the basic configuration as described above, site reconnaissance was conducted to grasp the site condition along the open channel route in detail, referring to the topographic map with a scale of 1:200 newly prepared.

Principal features of Severino Open Channel is finally determined as shown below.

Total distance : 6,394.929 m
- Open channel : 5,513.369 m
- Siphon : 881.56 m

Bottom level at
- Beginning point : EL. 110.756 m (Severino Head Tank)
- Ending point : EL. 107.363 m (Caña Dulce Tunnel Inlet Culvert)

Design discharge : 16.0 m^3/s

Related structure
- Siphon : 5 nos.
- Cross drainage structure : 28 nos.
- Side channel spillway : 1 no.
- Pedestrian bridge : 11 nos.

The general plan and profile of the open channel are shown in Drawings Nos.2-OC-001 and 002. The details of each facility of the open channel are described hereinafter.

(2) Open channel

Severino Open Channel starts from Severino Head Tank to connect to a culvert which will be constructed at Caña Dulce Inlet (Caña Dulce Tunnel Inlet Culvert).

The alignment of the open channel was reviewed based on the site reconnaissance and was slightly altered from the basic design. The final alignment was determined considering the basic principles as follows.

- To keep the channel route as straight as possible in order to minimize the channel length,
- To avoid high embankment and deep cut,
- To keep 80 m in horizontal radius of curves basically, in viewpoint of smooth flow of water, and
- To keep minimum 10 m straight portion at the entrance and exit of siphon barrel.

On the channel route, 5 inverted siphons and 28 cross drainage facilities are required to cross over/ under the existing rivers/rivulets.

The detailed alignment of open channel is shown on Drawings Nos.2-OC-003 to 007, and a total length of open channel portion is 5,648.409 m.

The section is trapezoidal with a side slope gradient of 1:1.2, that is the most hydraulically efficient and economical section having a maximum flow volume with a minimum wetted perimeter. Thickness of lining concrete is 15 cm.

Normal maximum discharge is 16 m^3/s, and velocity is about 1.4 m/s at this volume. The channel height is determined at 2.8 m consisting of water depth of 2.5 m and the freeboard of 0.3 m.

Sand and gravel bedding of 100 mm in thickness is provided under the bottom of the channel along the whole route. Moreover, a perforated pipe is provided under lining concrete to collect and discharge the leakage water for avoiding uplift against lining concrete due to groundwater pressure.

An emergency discharge to be caused by unexpected misoperation of Severino Pumping Station is calculated at 20.8 m^3/s. For this occasion, larger size open channel section is required between the head tank and the entrance of open transition of Siphon No.1 in which side channel spillway is provided. A height of the channel is estimated at 3.0 m for this requirements (see Drawing No.2-OC-008).

Sod facing is applied for embankment slope and excavation slope in common earth and shotcrete lining is used for excavation slope protection in weathered rock and in rock.

Typical sections of open channel are shown on Drawing No.2-OC-008. Description of open channel is as follows.

Design discharge	:	16.0 m^3/s
Cross section		
Type	:	Trapezoidal, concrete lining
Bottom width	:	1.6 m
Side slope	:	1:1.2
Height	:	2.8 m including freeboard
		3.0 m (B.P. ~ Sta. 1+86.500 m)
Length	:	5,648.409 m
Bottom gradient	:	1: 3,000
Water level at beginning point	:	EL. 113.256 m

(3) Related structure

i) Siphon structure

As said above, there are so many rivers/rivulets on the open channel route. For river/rivulet crossing having a relatively wide section and a huge of storm discharge, siphon structure is applied. Five (5) siphons are identified on the whole Severino Open Channel route.

Two sectional types of siphon barrel are selected depending on their depth, one is rectangular type and the other is circular type. The circular type is applied to siphons with a depth of more than 20 m.

Flow velocity in siphon is designed at about 2.0 m/s , in order to flush out the sediment in siphon barrel and for less damage for concrete surface of siphon. Thickness of siphon barrel is designed at 50 cm for water pressure and preventing the lifting-up by under ground pressure due to ground water or leakage of water.

The siphons are protected against erosion due to water by gabion mattress which is laid up to original ground surface level.

For a maintenance of the siphon bottom, blow-off structure is provided for No. 2,3,and 5 siphons having distance of some length (Drawing No.2-OC-066).

Consequently, the siphons are designed as follows.

	Distance (m) (including open transition)	Depth (m)	Section
No.1	72.000	9.694	Rectangular
No.2	232.768	37.534	Rectangular & Circular
No.3	326.130	48.542	Rectangular & Circular
No.4	76.285	6.491	Rectangular
No.5	174.337	18.465	Rectangular

ii) Cross drainage facilities

A cross drainage structure is necessary for drainage of storm runoff water from the mountain side under the open channel to avoid storm runoff coming into the open channel.

The design storm discharge for the cross drainage structure is determined based on Rational formula with a rainfall intensity of 25-year probable rainfall. A runoff coefficient of 0.4 is applied in consideration of vegetation and topography in and around the structure site.

Two types of cross drainage structure are designed, one is concrete pipe type and the other is box culvert type. Sectional area of the drainage structure is designed to have a capacity which enough to discharge twice capacity of design storm discharge, because such structure is apt to be logged by debris, driftwood and so on. Dimensions of each cross drainage are selected by the required discharge capacity as follows.

Type	Discharge (m^3/s)
Concrete pipe	
ø800 mm	~ 0.5
ø1,000 mm	0.5 ~ 1.0
Box culvert	
1.2 m x 1.2 m	1.0 ~ 2.0
1.5 m x 1.5 m	2.0 ~ 4.0
2.0 m x 2.0 m	4.0 ~ 8.0

Hydraulic and structural design calculations of the cross shown in the "Design Calculation Report". Standard designs of the cross drainage facility are shown on Drawings Nos.2-OC-067 to 069.

iii) Side channel spillway

When the pumping system of Severino Pumping Station are fully operated at HWL, the discharge flown into the Severino Open Channel will amount to 20.8 m^3/s. Then, the design discharge of side spillway is calculated to be 4.8 m3/s, that is excess discharge over the design one (20.8 - 16.0 = 4.8).

Design of side channel spillway is shown on Drawing Nos.2-OC-056 to 059.

iv) Pedestrian bridge

Pedestrian bridge is for only human and livestock passing through. Vehicle is not permitted to go through the bridge. Eleven (11) locations are identified along the whole open channel route.

Single span reinforced concrete bridge is designed for the pedestrian bridge. Desgin of the pedestrian bridge is shown on Drawing No.2-OC-070.

4.3.5 Severino ~ Caña Dulce Inspection Road

The inspection road is to be provided on the mountain side and berms of the open channel at the cross drainage facilities. The road has functions of inspecting a condition of transbasin flow in the open channel such as water level and discharge and of maintenance and repairing for the open channel facilities. Daily and/or weekly safety patrol will also be done driving through the inspection road.

Its route is typically aligned parallel to the open channel. And its longitudinal slope at typical portion is the same as the open channel. The width of road is determined at 3.0 m and the width of shoulder is 0.5 m.

The road surface is paved with 15 cm thick graded crushed stone. For the purpose of drainage, the road surface is to be inclined to the outside direction of the open channel with a slope of 4%.

A side drain ditch will be provided at places where the road is constructed below the original ground surface in order to drain the water from the excavated slopes and also from the road surface. The geometrical design criteria for the inspection road are as follows.

Design speed of vehicle	:	40 km/hr
Road width	:	3.0 m

Shoulder	:	0.5 m
Min. radius of curves	:	30 m
Max. longitudinal slope	:	10 %
Crossfall	:	4.0 %

On the other hand, at river crossing points in which the open channel crosses the river by siphon, any crossing facility such as bridge/causeway is not considered. However, three (3) connection points between the inspection road and the Severino Access Road are provided to avoid separating the inspection road at the crossing points. The access road is utilized for the bypass of the crossing points in part. The connection points are shown on Drawing Nos.2-OC-001 and 002.

Typical section of inspection road is shown on Drawing No.2-OC-003.

4.3.6 Caña Dulce Inlet

The diversion tunnel is connected with Severino open channel at Caña Dulce inlet to discharge the pumped up water of 16m^3/sec in maximum.

The invert elevation of the tunnel inlet is EL. 107.3 m, which is lower than the existing level of a small river (EL. 115.0 m) crossing the canal route just before the inlet. An inlet culvert is provided therefore, between the open channel and the diversion tunnel in order not to interrupt flow of the existing river. The inlet culvert is a reinforced concrete structure of 78.0 m long having dimensions of 3.5 m wide and 3.5 m high and its slope is 1: 1,500.

The inlet culvert will be laid under the existing river and it is backfilled up to the riverbed level. The backfill surface is protected by gabion mattresses to prevent scouring.

Back water of Poza Honda reservoir at H.W.L. 106.5 m doesn't come to the inlet because its sill level is EL. 107.3 m and at the time of F.W.L. 110.30 m, its backwater comes to the inlet of the open channel. In this case, water supply to Poza Honda reservoir by pumping up at Severino pumping station is completely stopped.

4.3.7 La Esperanza - Poza Honda Diversion Tunnel

(1) General

At the Feasibility Study stage and the Basic Design stage,the route of the diversion tunnel was selected so as to be the shortest length between the inlet and the outlet and taking account of the topography along the tunnel route as well as geology. Two curves were designed in the route to obtain a sufficient covering depth from the ground surface.

The diversion tunnel is a non pressure tunnel of 11.4 km long having a diameter of 3.5 m in standard horseshoe - shaped and its slope is 1: 1,500. The mean flow velocity in the tunnel is 1.81 m/sec at the maximum dischage (16.0 m^3/sec).

The geological conditions of the bedrock surrounding the diversion tunnel are almost the same as that of the Daule Peripa ~ La Esperanza diversion tunnel. So, the La Esperanza ~ Poza Honda diversion tunnel will be constructed using the same tunneling method as the Daule Peripa ~ La Esperanza diversion tunnel. Typical cross sections of the tunnel are determined according to the results of the tunnel structural analysis by FEM.

Two work adits will be provided at La Seca and Los Cuyuyes to facilitate and expedite the tunnel construction works.

The design of the La Esperanza ~ Poza Honda diversion tunnel is shown on Drawing Nos.2-ET-001 and 2-ET-004.

(2) Hydraulic Design

The water level at the connection part with the open channel is obtained to be EL. 110.22 m by a non-uniform flow calculation in the tunnel on condition that water level at the tunnel outlet is EL. 102.5 m (Target water level).

(3) Structural Design

The tunnel structural analysis was carried out for the following two parts. The main tunnel part is analized by Finite Element Method based on the theory of viscoelasticity and the inlet and outlet parts of the tunnel are carried out by frame analysis.

(A) Tunnel Structural Analysis

Tunnel structural analysis was carried out by FEM in the same manner as for Daule-Peripa ~ La Esperanza Diversion Tunnel. Since the diameter of the tunnel is 3.50 m which is only 0.2 m smaller than Daule-Peripa ~ La Esperanza Diversion Tunnel (refer to Figure 4.1.3), the structural analysis was made applying the same input data meshes as shown in Figure 4.1.5.

Procedure of the analysis is completely the same as for Daule-Peripa ~ La Esperanza Diversion Tunnel.

(a) Conditions of Analysis

Based on the topographical and geological conditions, the tunnel was classified into the following 4 cases for the analysis.

	Overburden (m)	Tunnel Length (m)
Case A-1	60	400 (4%)
Case A-2	140	1,300 (11%)
Case A-3	250	3,500 (31%)
Case A-4	320	6,200 (54%)

(b) Structural Analysis

Tunnel structural analysis was made by FEM applying the same meshes as for Daule-Peripa ~ La Esperanza diversion tunnel.

(c) Design Values of Foundation Rock

Design values of base rock at the proposed route of La Esperanza ~ Poza Honda Diversion Tunnel are shown in Table 4.1.1. They are common with Daule-Peripa ~ La Esperanza Diversion Tunnel.

Design values of shotcrete concrete, rock bolt and lining concrete is the same as Daule-Peripa ~ La Esperanza Diversion Tunnel as described in 4.2.2.

(d) Results of Analysis

The results of tunnel structural analysis are described hereunder.
The cases A-1, A-2 and A-3 are common to Daule-Peripa ~ La Esperanza Diversion Tunnel.

Case A-4: Overburden 320 m

- Primary lining

  Since the stress resultant which acts on the 10 cm thick shotcrete exceeded the strength of the shotcrete, thickness of shotcrete was changed to 15 cm and the structural analysis was carried out on the shoterete of 15cm in thickness.

Increment of compressive stress and tensile stress which acts on the concrete and rock bolt is shown in Figure 4.1.10.

Stress resultant in the shotcrete of 15 cm thick is 97% and 104% of the strength of the shotcrete at the time of 2 months and 3 months after tunneling, respectively (refer to Table 4.1.3).

Thus, secondary lining with concrete has to be made within 2.5 months after tunneling.

- Secondary lining
  Maximum compressive stress, maximum tensile stress and maximum shear stress which act on the lining concrete are less than the strength of the concrete (refer to Table 4.1.4).

Tunnel type to be applied for La Esperanza ~ Poza Honda diversion tunnel is shown in Figure 4.1.13.

From the results of FEM analysis, typical cross sections of Type II and Type III are applied to the main part of the diversion tunnel. However, cross sections of Type I and IV are added to the typical cross sections to cope with unforeseen geological conditions to be encountered during the construction.

Therefore, following four types are designed to be applied in the diversion tunnel.

	Type I	Type II	Type III	Type IV
Distance applied (m)	0	5,177	6,300	0
Shotcrete thickness (cm)	10	10	15	10
Rock bolts	D25x5Nos.x2m (1.2m pitch)	D25x8Nos.x2m (1.2m pitch)	D25x8Nos.x2m (1.2m pitch)	D25x8Nos.x2m (1.2m pitch)
Concrete lining (cm)	30	30	30	30
Reinforcement	Nil	Nil	Nil	Nil
H-steel support	Nil	Nil	Nil	H-125, 1.2 m pitch

The tunnel typical cross sections are shown on Drwaing No.2-ET-004.

(B) Structural Analysis of Tunnel Inlet and Outlet Parts

The design conditions to be used for the structural analysis of the tunnel inlet and outlet are as follows.

- Design loads
  - Case 1 : After construction
    Dead weight of lining concrete + Bedrock pressure + Water pressure
  - Case 2 : During construction
    Dead weight of lining concrete + Bedrock pressure + Grout pressure + Water pressure

- Design values

Design values of bedrock	Inlet part	Outlet part
Unit weight	2.0 tf/m^3	1.8 tf/m^3
Elasticity modulus	20,000 kgf/cm^2	10,000 kgf/cm^2
Cohesion	5.0 kgf/cm^2	2.5 kgf/cm^2
Internal angle of friction	40.0 degree	35.0 degree

Design values of concrete

Unit weight 2.4 tf/m^3

Elasticity modulus of concrete	235,000	kgf/cm^2
Elasticity modulus of reinforcing bar	2,100,000	kgf/cm^2
Ultimate tensile strength of reinforcing bar	4,200	kgf/cm^2

The structural analysis of the tunnel transition parts at the inlet and outlet is carried out according to the above design conditions. Cross sections of the tunnel inlet and outlet parts are shown on Drwaing Nos.2-ET-003 and 2-ET-006.

4.3.8 Los Cuyuyes Outlet

A huge amount of sediment has been observed in upper reach of Poza Honda reservoir and present sedimentation level reaches about EL. 98 m. Thus, to minimize the influence of sedimentation, location of the outlet was shifted from the site in Pata de Pajaro proposed in the feasibility study to Los Cuyuyes, and invert level of the outlet is set at EL. 99.7 m taking some allowance and the proposed target water level of EL. 102.5 m into account.

The outlet structure will be founded on the fresh rock, and cut slope is protected by shotcrete on the rock portion. Concrete facing will be provided up to EL. 111.0 m to protect the cut slope from erosion and to secure stability of the cut slope.

An access road for construction and maintanance purpose is set on the outlet at EL. 111.0 m .

The design of the outlet structure is shown on Drawing Nos.2-ET-005 and 2-ET-006.

4.3.9 Work Adit

Two work adits are to be provided as follows to facilitate and expedite the tunnel construction works. Locations of the work adits are decided according to the construction plan and taking account of the access road routes.

La Seca work adit	7,502 m downstream from the tunnel inlet
Los Cuyuyes work adit	270 m upstream from the tunnel outlet

The structure of the above work adits is the same as mentioned in Section 4.2.4.

The La Seca work adit is provided to expedite the tunnel construction of 11.4 km long at about 7.5 km downstream from the tunnel inlet. The adit entrance will be at EL. 210 m and the adit length will be 519 m.

The Los Cuyuyes work adit is needed to construct the tunnel from the outlet side. The adit entrance will be at EL. 111.0 m and the adit length will be 130 m.

These adits are entirely at the Contractor's option and detailed design of the adits will be carried out by the Contractor based on the construction method of the tunnel to be submitted by the Contractor.

The reference design of the work adits is shown on Drawing Nos.2-ET-007 and 2-ET-008.

4.4 Poza Honda Mancha Grande Transbasin

4.4.1 Poza Honda Inlet

(1) General

The Poza Honda inlet consists of an inlet channel, an inlet culvert, an inlet tunnel and a valve chamber. The minimum intake water level from Poza Honda reservoir should be low enough to allow continuous water transbasin to Mancha Grande, but should be high enough to enable a gravity flow to the tunnel outlet with EL. 89 m, to facilitate a coffering during construction of the tunnel entrance and to avoid possible sedimentation problem.

The minimum intake water level is decided to be EL. 94 m with the intake sill level of EL. 91.4 m. According to the water level duration curve of Poza Honda, the reservoir water level is lower than EL. 94 m only for 4 %, which is acceptable.

The designed inlet sill elevation of EL. 91.4 m is reasonably higher than the tunnel outlet sill level of EL. 89 m, to allow water transbasin by gravity. The Poza Honda reservoir has a capacity of 16 MCM between EL. 94 m and EL. 88.3 m (LWL) and of 10 MCM between EL. 92 m and EL. 88.3 m (LWL). In the later part of the dry season from September to November, the reservoir water level can be drawn down to EL. 92 m, securing water supply to Guarumo treatment plant of 0.5 m^3/s as well as the river maintenance flow of 0.25 m^3/s utilizing the reservoir capacity of 10 MCM for about 5 months even if no natural inflow to the reservoir is taken into account. It is suggested, therefore, to keep the reservoir water level lower than EL. 92 m for a certain period during which the tunnel entrance should be constructed with minor coffering work.

Original riverbed elevation in front of the tunnel inlet was EL. 77 m and the sediment level after 50 years is estimated to be EL. 82 m, which is far below the proposed intake sill level of EL. 91.4 m. No sediment problem will take place at the tunnel inlet.

The inlet channel of 4.0 m in bottom width and the inlet culvert of 4.0 m x 2.5 m in size are provided to lead stable flow to the diversion tunnel.

The inlet tunnel connects the inlet culvert with the valve chamber. The tunnel length is 26.5 m and the tunnel section is semi-circular with a height of 2.5 m and a width of 4.0 m. A part of the inlet tunnel is plugged with concrete after steel pipes have been installed. Contact grout will be carried out for the plugged part to prevent the leakage.

The valve chamber is designed as a vertical shaft with an oval shape having dimensions of 18.0 m in length, 14.0 m in width and 22.7 m in depth from the roof level of EL. 112.5 m. The size of the valve chamber is determined taking account of the spaces to provide the pits of cone sleeve valves and the butterfly valves. The oval shape valve chamber is adopted to better withstand against rock and water pressure acting around it. The valve pits of 3.8 m x 3.8 m x 7.6 m in size are designed beneath the valve chamber to dessipate energy of water discharged from the cone sleeve valves.

Floor slabs are provided at EL. 95.5 m and at EL. 104.0 m. The floor slab is set at EL. 95.5 m taking account of the maximum water level due to mis-operation of the sleeve valves.

The Poza Honda Inlet House is a one story reinforced concrete structure to house the access stairs and ventilation fans for the lower parts of the inlet facilities. Since it will not be usually occupied, the architectural furnishings and finishes will be kept to a basic minimum. Building facilities shall be composed of electric lighting and ventilation system.

Two steel pipes of 900 mm in diameter are installed at EL. 90.8 m and these pipes are extended to lead water into valve pits. The cone sleeve valves are installed for purposes of energy dissipation and flow control. Two butterfly valves of 900 mm in diameter are installed as guard valves for the main valves.

(2) Hydraulic Design

The maximum operational water level in valve pit is EL. 92.06 m for the maximum discharge of 4.0 m^3/sec. This water level was obtained from the result of uniform flow calculation of the tunnel.

(3) Structural Analysis

The structural analysis for the inlet structure is carried out using the computer program, SAP 90. The inlet structure is analized as frame structure considering the dead loads of concrete and external pressure loads consisting of the bedrock pressure, water pressure and backfill grout pressure.

The design conditions used for the structural analysis are as follows;

- Design loads
  - Case 1 : After construction
    Dead weight of lining concrete + Bedrock pressure + Water pressure
  - Case 2 : During construction
    Dead weight of lining concrete + Bedrock pressure + Backfill grout pressure + Water pressure

- Design values

Design values of bedrock

Unit weight	1.8	tf/m^3
Elasticity modulus	10,000	kgf/cm^2
Cohesion	2.0	kgf/cm^2
Internal angle of friction	30.0	degree

Design values of concrete

Unit weight	2.4	tf/m^3
Elasticity modulus of concrete	235,000	kgf/cm^2
Elasticity modulus of reinforcing bar	2,100,000	kgf/cm^2
Ultimate tensile strength of reinforcing bar	4,200	kgf/cm^2

The structural analysis was carried out based on the above design conditions.

The design of the Poza Honda inlet structure is shown on Drawing Nos.2-PT-002 to 2-PT 007.

4.4.2 Poza Honda Mancha Grande Diversion Tunnel

(1) General

The route of the diversion tunnel was selected to be the shortest length between the inlet and the outlet and taking account of the topography along the tunnel route as well as geology. Two curves were provided in the route to obtain a sufficient covering depth from the ground surface.

The diversion tunnel is a non pressure tunnel of 4.1 km long having a diameter of 2.5 m in standard horseshoe section and its slope is 1: 3,900. The mean flow velocity in the tunnel is 0.89 m/sec at the maximum dischage of 4.0 m^3/sec.

The bedrock surrounding the diversion tunnel is of dominantly finer comonents, i.e., mudstones and muddy (silty) fine sandstones which are moderately cemented or compact. The Poza Honda ~ Mancha Grande diversion tunnel will be constructed using the same tunneling method (NATM) as the other diversion tunnels.

Typical cross sections of the diversion tunnel are determined according to the results of the tunnel structural analysis by FEM.

The design of the Poza Honda ~ Mancha Grande diversion tunnel is shown on Drawing Nos.2-PT-001 and 2-PT 008.

(2) Hydraulic Design

The required capacity of the diversion tunnel is 4 m^3/s. The minimum tunnel diameter is considered to be 2.5 m to secure workability in the tunnel. A tunnel section is standard horseshoe and the flow type is an open free flow under the same consideration as to other diversion tunnels.

The tunnel length is 4,093 m and a slope of 1/3,900 is sufficient to discharge the capacity of 4 m^3/s with a tunnel of the minimum diameter of 2.5 m. This gentle slope will reduce the flow velocity in the tunnel and no specific facility for energy dissipation is required at the tunnel outlet.

(3) **Structural Design**

The tunnel structural analysis was carried out accoring to the same design concept as for the other diversion tunnel.

(A) Tunnel Structural Analysis

Tunnel structure analysis was carried out by FEM in the same manner as before mentioned diversion tunnels.

(a) Conditions of Analysis

Initial stress in the proposed tunneling route is estimated on the basis of overburden from ground surface to the tunnel elevation. The initial stress is classified into 2 cases as shown in Figure 4.1.1, and overburden pressure is estimated as shown in Table 4.1.2.

Design values of base rock at the proposed route of Poza Honda ~ Mancha Grande diversion tunnel are shown in Table 4.1.2.

Design values of shotcrete and rock bolt as primary lining and lining concrete as secondary lining are completely the same as the other tunnels.

Typical cross section of the tunnel is shown in Figure 4.1.4.

(b) Structural Analysis

Tunnel structural analysis was carried out by FEM. Input data meshes were made for the analysis. They are shown in Figure 4.1.6.

(c) Results of Analysis

The results of tunnel structural analysis is described hereunder.

(i) Case B-1: Overburden 60 m (593 m long, 14% of total tunnel length)

- Primary lining
  Compressive stress in the shotcrete of 10 cm thick is about 36% of the strength of the shotcrete at the elapsed time of 12 months after tunneling. Tensile force acting on the rock bolt is about 28% of the strength of the rock bolt.

Increment of compressive stress and tensile force which acts on the sotcrete and rock bolt from immediately after tunneling to 12 months is shown in Figure 4.1.11.

- Secondary lining

  Maximum compressive stress, maximum tensile stress and maximum shear stress which act on the concrete are less than the strength of the concrete (refer to Table 4.1.4).

(ii) Case B-2: Overburden 300 m (3,500 m long, 86% of total tunnel length)

- Primary lining

  Compressive stress in the shotcrete exceeds its strength at the time of 3 months after tunneling. On the other hand, tensile force in the rock bolt is 96% of its strength at time of 12 months after tunneling (refer to Table 4.1.3 and Figure 4.1.12).

The results of the analysis suggests that secondary lining has to be done within 2 months after tunneling.

- Secondary lining

  The maximum compressive stress and maximum tensile stress are within the strength of the concrete as shown Table 4.1.4. The maximum shear stress (9.6 kgf/cm^2) is over the strength (8.5 kgf/cm^2). However, it will act on a limited part, and average maximum shear stress in the lining concrete is 8.0 kgf/cm^2, which is less than the strength of the concrete.

Tunnel type to be applied for Poza Honda ~ Mancha Grande diversion tunnel is shown in Figure 4.1.13.

From the results of FEM analysis and to cope with unforeseen geological conditions to be encountered during the tunnel construction, typical cross sections of four types are applied to the main part of the diversion tunnel.

Therefore, the following four types are designed to be applied in the diversion tunnel.

	Type I	Type II	Type III	Type IV
Distance applied (m)	0	593	3,500	0
Shotcrete thickness (cm)	10	10	15	10
Rock bolts	D25x3Nos.x2m (1.2m pitch)	D25x5Nos.x2m (1.2m pitch)	D25x5Nos.x2m (1.2m pitch)	D25x5Nos.x2m (1.2m pitch)
Concrete lining (cm)	30	30	30	30
Reinforcement	Nil	Nil	Nil	Nil
H-steel support	Nil	Nil	Nil	H-125, 1.2 m pitch

The tunnel typical cross sections are shown on Drwaing No.2-PT-008.

(B) Structural Analysis of Tunnel Inlet and Outlet Parts

The design values to be used for the structural analysis of the tunnel inlet and outlet are as follows;

Design values of bedrock	Inlet part	Outlet part
Unit weight	1.8 tf/m³	2.0 tf/m³
Elasticity modulus	10,000 tf/m³	12,000 tf/m³
Cohesion	2.0 kgf/cm²	3.0 kgf/cm²
Internal angle of friction	30.0 degree	40.0 degree

Design values of concrete	
Unit weight	2.4 tf/m³
Elasticity modulus of concrete	235,000 kgf/cm²
Elasticity modulus of reinforcing bar	2,100,000 kgf/cm²
Ultimate tensile strength of reinforcing bar	4,200 kgf/cm²

The cross sections of the tunnel inlet and outlet parts are shown on Drwaing Nos.2-PT-007 and 2-PT-012.

4.4.3 Mancha Grande Outlet

Location of the outlet is shifted to the mountain side from the site proposed in the feasibility study taking account of the geological conditions at the site. At the end of the diversion tunnel, the tunnel section is gradually changed from the standard horseshoe to semi-circular. The tunnel flow is released into a trapezoidal open channel of about 200 m in length and discharged into the Mancha Grande river. No specific energy dissipator is needed because the flow velocity in the tunnel is less than 1.0 m/sec. Side slopes are protected with concrete facing wall for 60 m section to avoid erosion by water flow.

The design of the Mancha Grande outlet is shown on Drawing Nos.2-PT-021 to 2-PT-027.

4.4.4 Work Adit

Poza Honda work adit is to be provided at 255 m downstream from the tunnel inlet to facilitate and expedite the tunnel construction works. Locations of the work adits are decided according to the construction plan and the access road route.

The Poza Honda work adit is proposed to proceed with the tunnel construction from the inlet side in parallel with the construction of the inlet structures including the valve chamber. The adit entrance will be at EL. 110.3 m and the adit length will be about 168 m. The structure of the adit tunnel is the same as other work adits.

The reference design of the work adit is shown on Drawing Nos.2-PT-021 and 2-PT-022.

4.5 Access Roads

4.5.1 General

Since the structures are spread in the broad project area, 8 access roads were studied to connect the existing roads to the structure sites for construction and maintainance purposes. Location of these access roads are shown in Figure 4.5.1.

Name of access roads and structures to be connected are shown below.

NAME OF ACCESS ROADS	StTRUCTURES TO BE CONNECTED
(A) Conguillo Access Road	(i) Conguillo Inlet (ii) Conguillo Work Adit
(B) El Guasmo Access Road	(i) El Guasmo Work Adit
(C) Membrillo Outlet Access Road	(i) Membrillo Outlet (ii) MembrilloWork Adit
(D) Severino Access Road (E) Caña Dulce Inlet Access Road	(i) Severino Pumping Station (ii) Severino Substation (iii) Severino Head Tank (iv) Severino Open Channel (v) Caña Dulce Inlet
(F) Los Cuyuyes Access Road	(i) Los Cuyuyes Outlet (ii) Los Cuyuyes Work Adit
(G) La Seca Access Road	(i) La Seca Work Adit
(H) Poza Honda Inlet Access Road	(i) Poza Honda Inlet (ii) Poza Honda Work Adit

4.5.2 Basic Design

(1) Type of Road

All access roads are designed based on the Type 4 and 5, specified in the Design Book of Ministry of Public Works, Ecuador. The access road are classified into 2 types, permanent access road which will be used during and after construction and temporary access road which will be used during construction only.

(2) Design Speed

Design speed is designated as 30 km/h.

(3) Typical Cross Section

Typical cross section of the access roads are shown in Figure 4.5.2.

(4) Geometrical Design Standards

Geometrical design standards are shown below.

GEOMETRIC DESIGN OF ACCESS ROAD

Standard	Class 4 and 5
Design speed (km/hour)	30
Horizontal Alignment	
Minimum Curve Radius (m)	30 (15)
Minimum Curve Length (m)	40m
Minimum Curve Radius without Inverse Cant (m)	80m
Longitudinal Alignment	
Maximum Longitudinal Gradient (%)	7.0 (8.0 ~ 10.0)
Minimum Curve Radius, Crest Shape (m)	250
Minimum Curve Radius, Sag Shape (m)	250
Minimum Curve Length (m)	25
Cross Section	
Standard Crossfall (%)	4.0
Maximum Superelevation Runoff	1/75
Minimum Superelevation Runoff	1/300
Maximum Combined Grade (%)	11.5 (12.5)
Mimimum Sight Distance (m)	30

Note : Values in ( ) are for exceptional case.

4.5.3 Study on the Access Road Routes

(A) Conguillo Access Road

The access road has a function of connecting the Canuto Access Road at Buenaventura with the Conguillo Inlet passing through Membrillo village. A road is required to be newly constructed between Buenaventura and Membrillo village since there exist no roads. Between Membrillo village and Conguillo Inlet, there is an unpaved road with a width of about 2.5 m.

Two routes were identified in F/S in 1992 and Brazilian design in 1987, however both routes between Buenaventura and Membrillo village are not suitable for a driveway in terms of their geometric design. In the existing road between Membrillo village and Conguillo Inlet, a longitudinal gradient is more than 20 % which are not suitable for an access road.

A new route along the whole section is studied. This new route is defined the route in Buenaventura ~ 5 km from Membrillo section and the two routes in the previous studies are omitted. In the rest section, 5 km from Membrillo (the 5 km point) ~ Conguillo Inlet section, a comparative study was made among three routes, that are Route A (new identified route), Route B (F/S route) and Route C (Brazilian Design route), as shown in Figure 4.5.3. The principal features of the respective alternative routes are summarized below.

Route A : The road is routed along left bank of Estero Cañales from the 5 km point to Conguillo Inlet via Cañales Grande village. The topographic condition along the route is gentle and the designed longitudinal gradient is not steep. Total length of the route is about 7 km.

Route B : From the 5 km point, the road traces the existing road along most of the route, passing through mountain ridge. Its slope is steep along the whole route. There is no existing crossing facility over Estero Cañales and a longitudinal gradient of 2 km section around the crossing point is very steep and then it is required to realign the route near the crossing point. Its total length is about 8 km.

Route C : The road is newly constructed along the whole route between the 5 km point and Conguillo Inlet through El Ajo village. The road passes on the mountain ridge along most of the route and its slope is as steep as Route B. A longitudinal gradient near Estero Cañales is very steep and it is required to construct bridge for the crossing considering its formation elevation. Total length of the route is about 7 km.

It is judged that Route A is preferable for the route of Conguillo Access Road in terms of economical and constructional aspects.

(B) El Guasmo Access Road

The road branches off from the Conguillo Access Road connecting the El Guasmo Work Adit. The road will therefore be designed after due consideration of horizontal and longitudinal alignments of the Conguillo Access Road.

(C) Membrillo Outlet Access Road

Membrillo Outlet Access Road also branches off from the Conguillo Access Road and connects the Membrillo Outlet. As same as the El Guasmo Work Adit

Access Road, the design of the road will therefore be conducted following the design of the Conguillo Access Road.

(D) Severino Access Road

The road has a function to access from the existing Pichincha road to the Severino Pumping Station or Caña Dulce Inlet and should be newly constructed. A gap of 300 m in elevations between the roads should be overcome.

(E) Caña Dulce Inlet

The road will be constructed mainly in parallel with the Severino Open Channel connecting point with the Severino Access Road to the Caña Dulce Inlet. An alignment of the road will be determined by using the existing road adequately.

Conceivable routes of the access road are as follows, as shown in Figure 4.5.4.

Route A : The road branches off from the Pichincha road at Las Delicias village to Caña Dulce Inlet passing through the ridge on right bank of Estero Capilla. Elevation difference is about 300 m. The road with a width of 2.5 m upto 500 m point from Las Delicias village and a footpath with a width of 2 m on the ridge exist. Total length of the road is about 6.0 km. On the route there are lots of horizontal curve portions and steep longitudinal gradient sections.

Route B : The route connects from Piedra Azul village to Bijagual village having an elevation difference of about 240 m. There is only footpath on the route. Total length of the road is about 3.5 km. Only one section of steep longitudinal section is encountered on the route and there are a small number of horizontal curve portions compared with other routes.

Route C : The route connects from Piedra Azul village to El Zambo village along Estero Chontillo having an elevation difference of about 330 m. There are no existing road and/or footpath along the whole route. Total length of the road is about 5.7 km. As same as Route A, there are lots of horizontal curve portions and steep longitudinal gradient sections on the route.

Route B was selected as a preferable route for Severino Access Road in comparison of their economical and constructional aspects with those of the other two routes.

(F) Los Cuyuyes Access Road

The road connects from Poza Honda dam to Los Cuyuyes Outlet via Mercedes No.1 and No.2 villages and Los Cuyuyes village. On the route between Poza Honda dam and Los Cuyuyes village, there exists a road with a width of 3 m. A large number of inhabitants live on both sides of the existing road and their farm lands exist on an area around the road gently sloping to Poza Honda reservoir.

(G) La Seca Access Road

The access road connects to La Seca Work Adit for La Esperanza ~ Poza Honda Diversion Tunnel. For the route alternatives, two connecting ways, connecting from Pichincha Road and (B): from Los Cuyuyes Access Road which is required to access to Los Cuyuyes Outlet of La Esperanza ~ Poza Honda Diversion Tunnel, are taken into consideration as shown in Figure 4.5.5 and their features are summarized below.

Route A1 : The road branches off Los Cuyuyes Access Road at Mercedes No.1 village passing through La Laguna village and right bank of Rio Pata de Pajaro. The route almost lies along riverine area of Rio Pata de Pajaro, which has a relatively gentle slope. In the section with a steep slope, retaining wall is required to protect embankment slope. No crossings over Rio Pata de Pajaro are required. Total length of the road is about 4.0 km. The road could be constructed at the same time as Los Cuyuyes Access Road.

Route A2 : As same as Route A1, the road branches off Los Cuyuyes Access Road at Mercedes No.1 village, and then passes through La Laguna village and left bank of Rio Pata de Pajaro in which relatively gentle slopes are encountered. However two bridges are required for crossing over Rio Pata de Pajaro. Total length of the road is about 4.0 km.

Route B : The route connects from Pichincha road and passes through private farm land to La Seca Work Adit. In a part of the farm land there exist a road with a width of 2.5 m, which is required to be improved as an access road and a new road will be constructed in most of the section. There are lots of horizontal curve portions and steep longitudinal gradient sections on the route. Total length of the road is about 4.1 km. A compensation and land acquisition should be made along the most of the route.

Route B is clearly unfavorable compared with Routes A1 and A2 as a road to carry excavated muck from the tunnel. Route A1 is preferable to Route A2 economically since Route A2 is required to construct bridges.

Accordingly, it is judged that a new construction of an access road should be avoided and the access road will be constructed by improving and widening the existing road in order to minimize a compensation for the inhabitants and an acquisition of the land on the route between Poza Honda dam and Rio Pata de Pajaro. The conceivable routes between Rio Pata de Pajaro village and Los Cuyuyes Outlet are described below and are illustrated in Figure 4.5.6. These alternative routes are selected in consideration of crossing point over Rio Pata de Pajaro and passing through Los Cuyuyes village.

Route A : Crossing point over Rio Pata de Pajaro is sited at the same location as the existing road and the route is selected to avoid passing through Los Cuyuyes village. A longitudinal gradient is 10 % near the crossing point. A length of the route is about 2.35 km.

Route B : The route traces the existing road upto Los Cuyuyes village. To keep a maximum longitudinal gradient specified in the standard, 10 m excavation in depth is required in Los Cuyuyes village. A length of the route is about 2.40 km. The route passes through Los Cuyuyes village, therefore, some influences on the inhabitants are expected due to the construction.

Route C : Crossing point over Rio Pata de Pajaro is sited upstream of that of Route A to be gentle slope near the crossing point and to shorten a length for the crossing. However at the crossing point there are lots of large stone deposited which are not suitable for a construction of the crossing facility. A length of the route is about 2.30 km.

Route A was selected as a preferable route for Los Cuyuyes Access Road in comparison of their economical and constructional aspects as well as influences on the inhabitants in Los Cuyuyes village with the other two routes.

(H) Poza Honda Inlet Access Road

Paza Honda Inlet Access Road branches off from Los Cuyuycs Access Road and connects to the Poza Honda Inlet and Poza Honda Work Adit. Length of the road is about 0.7 km.

4.5.4 Detailed Design of Access Roads

Detailed design of eight (8) access roads was made based on the study on their routes. Length of each access road is shown below.

(A)	Congullo Access Road	22.6 km
(B)	El Guasmo Work Adit Access Road	1.6 km
(C)	Membrillo Outlet Access Road	0.4 km
(D)	Severino Access Road	9.3 km
(E)	Caña Dulce Inlet Access Road	2.7 km
(F)	Los Cuyuyes Access Road	14.8 km
(G)	La Seca Access Road	3.8 km
(H)	Poza Honda Inlet Access Road	0.7 km
	Total	55.9 km

Plan and profile, and cross sections of the Access Roads are shown in Volume XI of the Final Report, Design Drawings.

4.6 Mechanical and Electrical Equipment

4.6.1 Main Pump and Motor Equipment

(1) Main pumps

(i) General

Several studies were made on Various plans embodying deferent numbers and size of pumping units to determine the most desirable and economical arrangement. The studies also involved selection of suitable pump type, necessity of stand-by unit, types of intake facilities, etc. As the results of the studies, it was decided that six-unit vertical shaft single suction volute pumps, each having a capacity of 3.2 m^3/sec, including one stand-by duty unit with the same capacity are to be installed in the Severino Pumping Station. In addition to such design conditions, six pump units shall also be capable of discharging total Q = 16 m^3/s. during suction water level between MOL 47.0 m and the design WL 58.5 m. In any case, no discharge control by the guard valve or pump will be expected; rather in combination with number of pump units and pump operations hours. Design conditions of the pumps are as summarized below:

- Maximum discharge water requirements	16.0 m^3/sec (at basic design point)
- Water level in pump suction pit	
Flood water level (FWL)	EL. 69.00 m
High water level (HWL)	EL. 66.00 m
Design (averaged) water level	EL. 58.50 m
Minimum operation water level (MOL)	EL. 47.00 m
- Design water level in the head tank	EL. 114.02 m (design discharge)
	EL. 114.06 m (over discharge)
- Design actual head	55.52 m

(ii) Pumping head

Rated total head for pump design was decided to be 60.0 meters, which is the sum of 55.52 meters of the design actual head and 4.48 meters of head losses in the pipe line. In calculating the head losses, the following formulas were employed:

- Friction losses : by Darcy-Weisbach's formula
- Bending losses : by Fuller's formula
- Convergent losses : by Gradel's formula

- Enlrgement losses : by Gibson's formula

(iii) Speed of pump

The speed of pump is to be determined so that no cavitation will occur in the pump under any possible operation conditions. For preventing cavitation, the available Net Positive Suction Head (NPSH av) of the pumps must be more than the required Net Position Suction Head (NPSH req) as following equation.

$$NPSH\,av \geq NPSH\,req + \alpha$$

where, α : Allowance 0.5 m

The NPSHav for the pumps at the lowest water level, i.e., WL. 46.5 m in suction pondage as the worst case is calculated as follows:

$$NPSH\,av = ha + hs - hv - hl$$
$$= 10.03 \text{ m}$$

where,	ha :	Atmospheric pressure at EL. 46.5 m	10.27 m
	hs :	Depth of impeller from minimum operation water level	1.00 m
	hv :	Saturated vapour pressure at 30°C	0.43 m
	hl :	Suction pipe loss head	0.81 m

The NPSH req of the pumps is calculated as follows:

$$NPSH\,req = \left(\frac{n\sqrt{Q}}{S}\right)^{4/3}$$

where,	n :	Pump speed (rpm)	
	Q :	Pump discharge	160 m^3/min (2.67 m^3/s. at MOL)
	S :	Suction specific speed	1,414

Therefore,

$$NPSH\,req = \left(\frac{n\sqrt{Q}}{S}\right)^{4/3} = NPSH\,av - \alpha$$

n = 606

The design speed of pump/motor is therefore set at 600 rpm, taking into account the synchronous speed of motor under the frequency 60 Hz.

(iv) Diameters of pump inlet and outlet

The diameters of the pump inlet and outlet are tentatively determined to be 1,100 mm and 800 mm, respectively, assuming that water velocity is 3.5 m/sec at the inlet and 6.5m/sec at the outlet. Final determination of the pump size will be subject to the selected Contractor (pump manufactur) based on his past experiences and various tests.

(v) Principal feature of pump

From the values of Ns and water discharge, the minimum efficiency of the pumps is assumed to be 0.88.

The suction pipe is made of steel, and is designed so as to minimize head losses, to prevent turbulent flow, and to secure higher suction ability. The impellar and shaft are made of stainless steel castings and carbon steel forgings, respectively. The bearing is of the oil-bathed type, cooling by the piped water. The seal of shaft is ground packing with sealing water.

(2) Electric motors

(i) General

Vertical shaft, three-phase wound-rotor induction type motors were selected for the main pumps, mainly in view of limiting starting current and of obtaining enough starting torque. Design conditions of the motors are summarized as follows:

a) Voltage 4.16 kV

b) Frequency 60 Hz

c) Synchronous speed 600 rpm (12 poles)

(ii) Required power of motor

The required power of each motor is calculated by the following equation based on the pump efficiency, design discharge and pumping head.

$$P = 0.163 \times \frac{Q \times H}{\eta_p} \times (1+\alpha)$$

where,	Q	:	Design discharge	192 m^3/min (at ave., WL 58.5 m.)
	H	:	Design total head	60 m
	η_p	:	Pump efficiency	0.88
	α	:	Allowance	0.1

Thus, P = 2347 kw

Accordingly, output of motor is set at 2,400 kw, taking into account some allowance for the safty design.

(iii) Starting system of motor

A secondary resistance starting system using the liquid rheostat is adopted to reduce the starting current and to get enough starting torque. For the cage rotor induction motor, the starting characteristics of this system are superior to other systems such as compensating transformer, starting reactor etc., in starting current, starting torque and power factor during starting. The rotor windings of motor is brought out through the brushes and slip rings to outside and connected to the motor-operated liquid rheostat. When the pump motor is started, the secondary resistor which is positioned at maximum resistance, is reduced its resistance according to the speed up of pump motor and shorted finally. Then, the pump motor speed is reached its normal speed and completed the starting. The liquid rheostat is installed for each pump motor unit, having a capacity of two or three times starting in a period of any one hour. Necessary interlocking is provided to present the short-circuit starting of liquid resistor when the pump motor is restarted.

(iv) Principal features of motor

The motor is of totally-enclosed, self-ventilating and recirculating type with air coolers. This cooling system is adopted for this pump motor because of high cooling effect, low noise, compact size, clean cooling air and little influence to room temperature and room air flow compared with the open type, self-ventilating system. The cooling water of air coolers will be taken from the discharge penstocks and then returned to the suction pipe by gravity flow.

The power factor and the efficiency of large induction motors like the proposed pump motors are generally expected to be more than 0.85 and 0.95, respectively. The above power factor can be raised up to 0.90 to 0.95 by providing the 4.16 kV bus circuit with static condensers.

The insulation class of the motors will be "F", which is decided based on maximum temperature rise of motor. The minimum GD^2 of motor (inclusive of that of pump) is set at 4,240 kg-m^2 to reduce pressure rise due to water hammer in the discharge pentocks.

The principal features of the motors are summarized as follows:

Enclosure:	Totally-enclosed
Cooling system:	Water cooled air cooler type
Ventilation:	Self ventilation and recirculation type
Time rating:	Continuous
Max. temperature rise:	100 °C
Min. efficiency:	0.95 (at rated load)
Min. power factor:	0.85 (at rated load)
Insulation class:	F
Min. GD^2:	4,240 kg-m^2 (including pump)

(3) Non-return valve and guard valve

(i) Non-return valve

A 1,000 mm diameter, by-pass system incorporated slow closing type check valve as the non-return valve is installed in each outlet side of the pump for preventing reverse rotation of pump and for minimizing up-surge of water hammer in the discharge penstock. This type of valve is selected mainly dependent on economical view point and its hydraulic characteristics.

(ii) Guard valve

A 1,000 mm diameter, horizontal shaft type electrically operated butterfly valve is installed as the guard valve in each outlet side of the pump, following the non-return valve. The guard valve is operated by motor driven gears and/or with a handwheel to be used in case of power faliure.

(4) Control system

(i) General

The pump operation is normally controlled either from separated desk type control switchboard provided in the control room by means of remote control under supervision of the semigrapfic supervisory control switchboad or by the local control panel located adjacent to the pump motors. The pumps are operated to suit to the water demands vs. the accumulated discharge water in combination with number of pump units and pump operation hours; the calculation of which is based on information from water level detecting devices provided in the Suction pondage and Head Tank along with flow meters provided on each penstock.

(ii) Indications and meters

The semigraphic supervisory control switchboard and the separated desk type control switch board to be installed in the control room include at least the following indicators and meters:

a) Semigraphic supervisory control switchboard

i) Graphic pumping system including suction pondage, pumping equipment, discharge penstocks and head tank.

ii) Sequence lamp indicators for pump units

iii) Fault lamp indicator

iv) Thermometers: bearing of motor and pump, starter of motor,
air at inlet and outlet of cooler of motor

v) Water level indicators: suction pondage, and head tank

vi) Flow meters for main pumps: penstocks

vii) Guard valve full opening or closing indicating lamps

b) Desk type control switchboard

i) Master control switches for start - stop of pump units

ii) Control switches for manual shutdown for emergency case

iii) Selector switches for temperature indicators

iv) Control power source switch for A.C. and D.C.

v) Audible alarm stop switch

vi) Others

(iii) Protection and alarm

The pumps and motors are so designed as to automatically stop and/or to display alarms on the supervisory control switchboard or main control switchboard whenever the following trouble happen on them:

a) Pump stoppage

i) Excessive temperature rise in pumps and motor bearings

ii) Trouble of starting

iii) Excessive temperature rise in liquid rheostat

iv) Extremely low water level at suction pit

v) Excessive high water level at head tank

vi) Excessive low voltage of electric power

vii) Over load of main motors

viii) Internal ground fault of motor

ix) Internal short circuit fault of motor

b) Alarm

i) Trouble of guard valve

ii) Low oil level of pump and motor bearing oil tank

iii) Suspension of cooling water supply

iv) Low water level of liquid rheostat

v) Low water level at suction pondage

vi) High water level at head tank

vii) Not designed water level at one-way surge tank

viii) Extraordinary pressure of auto strainer

ix) High water level of sump pits

(5) Auxiliary facilities

(i) Overhead travelling crane

Two (2) sets of low speed overhead travelling crane are installed in the pump house. One is set at the entrance platform for unloading and loading of pump equipment. The other is set at the erection and machine bays for installation and repair of pump equipment. The capacity of the crane is determined to be 32 tons based on the maximum weight of the part of equipment to be handled during construction period. The installed height, lift and span of the crane were determined so that all the equipment in the pumping station can be easily and efficiently installed or removed. The crane is operated from the cab hung from main girder. An automatic mechanical load brake is installed on the hoist of the crane to prevent the load from lowering until power is applied in the lowering direction by hoist motor. The following are the principal features of the overhead crane.

	Entrance Platform	Machine Bay
Hoisting capacity	32/8 ton	32/8 ton
Top of rail	EL. 78.100	EL. 63.000
Lifting height	22 m	20 m
Span	10.5 m	10.0 m
Travelling length	16 m	57 m
Current collector	side wall stringing type	side wall stringing type

(ii) Sump pumps

Two (2) sets of sump pump are installed in each of two sump pits for drainage of the pits. The sump pump selected is of submersible type with a capacity of 3 m^3/min. The pump control is by hand and/or automatical ON-OFF operation by means of a float switch installed in each sump pit.

The sump pumps are also used for filling water in each penstock prior to the main pump starting, which is done to boost internal pressure additionally after the penstock be filled water by gravitational flow through by-pass system of the guard valve. The principal features of the sump pumps are summarized below:

Pump type:	Submersible electric motor diven pump
Capacity:	3 m^3/min.
Numbers:	4 sets (2 sets for stand by)
Total pumping head:	30.0 m

(iii) Repair shop

A repair shop is established in the pumping station. It is provided with such equipment as are necessary for routine maintenance and minor repairing of pumps, motors, and other electrical and mechanical equipment installed in the pumping station.

(6) Intake facilities

(i) Trash racks and rake

Six (6) vertical fixed type trash racks are provided at the inlets of the pump suctions pits. Pitch of the bar element of the trash rack was determined at 75 mm to keep out debris which might damage the pumps. A rugged rake mechanism is provided to assure positive removal of debris from the face of the trash racks. The rake is provided with rollers to ride in the guides. The rollers are located and sized to ensure that the rake is positioned for complete clearing of the bar elements of the trash racks. The rake is operated by means of a gantry crane installed on the intake deck. Trashes collected by the rake will be dumped onto 4 tons. class long body truck, being located inside but beneath the gantry crane to dispose of. The principal features of the trash racks are as follows:

i)	Required number	:	6 sets
ii)	Type	:	Vertically fixed type
iii)	Span	:	6.00 m
iv)	Height	:	7.50 m
v)	Design water head	:	3.00 m
vi)	Element bar pitch	:	75 mm

(ii) Intake gates and lifting beam

Two (2) vertical lift fixed wheel type intake gate are provided for six inlets of the suction pits, considering one for 3- inlets in each penstock line for the convenience of operation and maintenance, etc. The function of the gates is to close off the inlets when it is necessary to unwater the pits for inspection and maintenance of either equipment or structure. Guide frames are installed for all of the six suction pits. Two sets of dogging device are provided in the uppermost portion of the side guide frames. The devices are designed to support and hold the gate leaves in gate slots during rest in gate operation.

The gate leaves are raised and lowered by means of a gantry crane though a lifting beam. The lifting beam is provided with two-point engagement and lifting hooks for picking up or releasing the gate leaf.

The principal features of the gates are as summarized below:

i)	Required number	:	Gate	2 sets
			Guide frame	6 sets
			Lifting beam	1 set
ii)	Type	:	Fixed-wheel gate	
iii)	Clear span	:	6.00 m	
iv)	Clear height	:	3.00 m	
v)	Design head	:	26.90 m	

(iii) Gantry crane

One (1) gantry crane is installed on the intake deck (EL. 70.0 m), and is used for lowering and raising the gate leaves and for operation of the trash rack rake. The lift and traveling length of the crane were determined so that the gate leaves and rake can be easily and efficiently handled, and trash loading operation on 4 tons. class long body truck be easily performed beneath the hoist. For which purposes, the design loads for gratings are therefore the truck and trash weights. The rail gauge is determined to be 3.7 m mainly in view of the stability of the crane. The crane lift and travel are done by the respective mechanism driven by electric motors, and the electric power is supplied to the crane by a cabtype cable. The principal features of the gantry crane are as follows:

i)	Required number	:	1 set
ii)	Type	:	hoist traverse type
iii)	Lift	:	30.00 m
iv)	Traveling length	:	77.00 m
v)	Rail gauge	:	3.70 m
vi)	Current collector	:	Cabtype cable w/cable reel
vii)	Power source	:	AC 220 - 127 V, 3 phase, 4 wire, 60 Hz

4.6.2 Severino Penstock

(1) Discharge penstocks

(i) Type of penstock

Conceivable alternative types of installation of the penstock are;

i) above ground with anchor blocks and saddle supports,

ii) buried in a ground with anchor blocks, and

iii) inclined shaft tunnel.

A cost comparison among the above three alternatives was made at a preliminary level as shown below;

Unit : 1,000 US $

Alternatives	above ground	buried	inclined shaft
Civil works	580	612	1,313
Mechanical works	1,851	1,931	1,725
Total	2,431	2,543	3,038

The above ground type is the least cost alternative one and it is further considered that its maintenance is easier as compared with other types on account of access to inside of the pipe for a inspections and visual inspection of outside of pipes . Accordingly, it is selected the above ground type for the penstock.

(ii) Economical diameter

The economical diameter of the discharge penstock was studied on the following conditions:

a) Power rate : 0.06 US$/KWH

b) Pump characteristic curve : See Fig. 4.6.1

c) Water level of suction pit : EL. 58.50 m

d) Water level of head tank : EL. 114.50 m

As a result of the study shown below, 2,000 mm in diameter of the penstock is selected as the most economical one. The velocity of flow in the penstock is 3.06 m/sec for the design maximum discharge of 9.6 m^3/sec./ one lane.

Unit :US $ 1,000

Diameter (mm)	Construction cost	Annual energy cost	Annual equivalent cost
1,800	1,200	3,167	3,294
1,900	1,270	3,148	3,282
2,000	1,330	3,133	3,275
2,100	1,520	3,123	3,284

Note : Above table shows on one (1) line of penstock.

(iii) Water hammer

Having decided the layout and diameter of the pipeline, it is necessary to study water hammer which gives influence to the design head of the pipeline.

Rated pumping head:	60 m
Rated pump speed:	600 rpm
Pump design discharge:	3.2 m^3/sec x 3
Pump design efficiency:	0.88
Flywheel effect (GD^2): (Pump and motor)	4,240 kg-m^2
Pipe diameter:	1.0 - 2.0 m
Length of penstock:	173 m for No.1 pump
Design actual head:	55.52 m

The analysis result of water hammer is shown in Fig. 4.6.5. Up surge line is shown as a symmetric line of down surge line based on the hydraulic gradient line. As shown in the figure by dotted lines, negative pressure will likely occur in the penstock if the pump motors are suddenly tripped. Accordingly, one - way surge tank is provided for each lane. The maximum water head at the center of pump is estimated at about 122.2 m.

(iv) Design of penstock

The discharge penstocks will be constructed mostly along the original ground line, anchored with concrete blocks and supported by ring girders. One pipeline is provided for three (3) pumps from the economical viewpoint of the penstock construction. The radius of curvature of bend pipes is designed to be at least two times the pipe diameter for reducing the head losses. The arrangement and layout of the penstocks and their accesories are shown in the relevant drawing attached to this report. The principal design data for the discharge penstock are summarized as follows:

a)	Number required	:	2 lanes
b)	Diameter	:	2.0 m
c)	Total center length	:	173 m (through No. 1 pump and penstock) 170 m (through No. 6 pump and penstock)
d)	Max. design discharge	:	9.6 m^3/sec for one lane
e)	Max.design head	:	130 m. (include. due allowance)
f)	Welding efficiency	:	0.9
g)	Material to be used	:	Rolled steel for welded structure specified by JIS G 3106 - SM 41B or equivalent
h)	Allowable stress of material	:	1,300 kg/cm^2 (Tensile stress) 1,300 kg/cm^2 (Compressive stress) 700 kg/cm^2 (Shearing stress)
i)	Corrosion allowance	:	2.0 mm

The design head is the sum of the static head and dynamic head by the pressure rise due to water hammer. The pressure rise due to the water hammer is decided in design, assuming that the dynamic head is linearly changed from the maximum rise at the center of pump to zero at the outlet.

The calculation formula for pipe shell thickness is as described in the Design Calculation Report. Combined stress in pipe shell is calculated from the following formula:

$$\sigma g = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 - \sigma 1 \cdot \sigma 2 + 3\tau^2}$$

where;

σg	=	Combined stress
σ1	=	Circumferential tensile stress
σ2	=	Longitudinal stress
τ	=	Shearing stress

The thickness of each piece of pipe shell is calculated against design head as shown in Fig. 4.6.6.

Each penstock will be anchored by the concrete blocks and be supported by the roller type ring girders at interval of 14 m. An expansion joint is placed in every span between two anchor blocks of the penstock to absorb the expansion or shrinkage of the penstock due to variation of temperature of 40°C in maximum with plus 5.0 cm allowance. The manholes are fitted on the pipe shell for inspection and repair of the inside of the penstock. The inside surface of pipe is coated with coaltar epoxy resin paint and the outside surface, except the portions embedded in the concrete, is coated with phenol resin paint.

(2) Surge tanks

The function of the surge tanks to be provided for this pump station is to prevent a destruction of the penstocks due to a growth of negative pressure at the time of pump trip phenomenon. The following three types of surge tank are conceivable:

i) One-way surge tank

ii) Conventional surge tank

iii) Pressre water tank

As the results, One-way surge tank is deemed to be enough for pipeline layont of this Project and then selected taking into account of advantageous view points, that are (i) low initial cost due to small size than the standard type, (ii) low operation running cost and (iii) ease of maintenance.

The principal features of the one-way surge tanks are summarized as follows:

Effective capacity of tank	:	15 m^3
Water level in tank	:	EL. 101.00 m
Connection pipe with butterfly valve and no-return valve	:	2 sets per a one-way surge tank
Diameter of connection pipe	:	1.1 m

4.6.3 Electrical Facility in Pumping Station

(1) General

Electric power required for the pumping station is supplied from the planned Daule Peripa Power Station, which will be constructed by the Comision de Estudios el Desarrolle de la Cuenca del Rio Guayas (CEDEGE), at 138 kV. To receive power through a 138 kV transmission line to be constructed in this Project, Severino substation is constructed at the pumping station site.

The substation is composed of main transformer yard, 138 kV switchgera yeard and 138 kV connecting circuit to connect both above-mentioned yards. The main transformer yard is located on the premises of the pumping station and the 138 kV switchgear yard is constructed with a space area, 30 m x 60 m, at the hilly area at a distance of about 200 m from the main transformer yard.

The capacity of the substation is dethermined as 20 MVA. Secondary voltage of the transformer is adopted at 4.16 kV to directly connecte the pump motors. Other than this, local power supply for the base camp (project office and quarters) and 138 kV switchgear yard, and station service power supply is designed. The local power supply is made by 13.8 kV feeders after stepped up the voltage from 4.16 kV to 13.8 kV by a local transformer. The station service supply is distributed by 220/127V 3-phase, 4-wire system after stepping down by two 300 kVA station service transformer, of which one is stand-by.

(2) Design of electrical equipment

The main features of electrical equipment are as follows;

(i) Transformers

a) Main transformer

i) Capacity and number

Two bank of 10 MVA main transformer is adopted..

ii) Type

The main transformer will be of 3-phase, oil immersed, natural-air-cooled with some radiators, outdoor use type. Natural-air-cooled type is low in price or simple in operation and maintenance for the transformer of such capacity.

iii) Voltage Ratio

The voltage ratio of the transformer is selected at the no load ratio of 138/4.16 kV.

iv) No voltage tap-changer

The main transformer will equip a no-voltage tap-changer on the 138 kV side to keep the secondary side voltage of transformer as 4.16 kV as possible irrespective of fluctuation of the 138 kV side voltage due to variation of the receiving power. The voltage tap of the no-voltage tap-changer is selected at 138 kV ± 5%, 5 taps of 2.5% step based on 138 kV at mid-tap in due consideration of maximum voltage fluctuation range on 138 kV transmission line.

v) Connection

The transformer will be connected in star-delta, vector symbol Yd_1 (IEC Publication 76, 1967) and the neutral point of the 138 kV windings will be grounded solidly.

b) Local transformers:

One 3-phase 1,000 kVA local service transformer for stepping up the voltage from 4.16 kV to 13.8 kV is installed in the main transformer yard to supply power for the base camp, 138 kV switchgear yard and also the general demand in the Project area in future. The transformer is of oil immersed, self-cooled, outdoor use type.

c) Station service transformer

Two 3-phase 300 kVA station service transformer for stepping down the voltage from 4.16 kV to 220/127V 3-phase, 4-wire are installed in the low tensin switchgear room of pump house to supply power for station service loads such as auxiliary machines for pumping equipment, overhead crane, drainage pumps, lighting, etc. The transformer is of silicone-insulated, self-cooled, dry type enclosed with steel cabinet.

(ii) Static condensers

To improve the power factor of pump motors and to reduce the load losses on the main transformer and the transmission line, four banks of 800 kVA static condenser together with series reactor and discharge coil will be provided on the 4.16 kV bus circuits and installed in the main transformer yard.

Capacity of each bank and number of banks of static condenser are determined with due consideration for the capacity and power factor of each pump motor unit and number of pump motor units to be operated during a year.

(iii) 138 kV switchgear

Single bus system is adopted for 138 kV outdoor switchgear which are installed in the 138 kV switchgear yard except two (2) set of arrester for protecting main transformers installed in the main transformer yard.

a) Circuit breaker

One (1) circuit breaker for 138 kV transmission circuit will be of three-pole, single-throw, high speed outdoor, SF6 gas type. The rupturing capacity of circuit breaker is selected as 25 kV symmetrical which is one of standard capacity and to correspond to that of circuit breakers at the Daule Peripa Power Station to be installed by CEDEGE. Other two (2) circuit breaker are installed for two transformer circuits.

b) Disconnecting switches:

One (1) pneumatic or motor operated,3-pole, single throw, outdoor type disconnecting switch with earthing switch is installed on the incoming circuit of transmission line and two (2) mechanical hand operated disconnecting switch will also be installed for main transformer circuits.

c) Lightning arresters

One (1) set of lightning arrester is placed on the 138 kV transmission line circuits and two (2) set of lightning arresters are placed close to the main transformer to protect it from lightning or other surge phenomena.

d) Potential devices and current transformers

Followings are installed for requirement of measurement and protection.

i) One (1) set of current transformer for 138 kV transmission line circuit
ii) Two(2) set of current transformer for main transformer circuits
iii) Two(2) capacitor potential device for 138 kV transmission circuit
iv) One (1) coupling capacitor potential device for 138 kV transmission line circuit

(iv) 13.8 kV switchgear

13.8 kV switchgear is provided to supply the power to base camp,and 138 kV switchgear yard in the project completion, and also to the general demand in the Project area in future. The outdoor type cubicle with two (2) feeders is provided for the switchgear, which is installed in the main transformer yard.

(v) 4.16 kV switchgear

4.16 kV circuits for the main transformer secondary, two buse connection,main pump motors, static condensers, local transformer and station service transformers are arranged in the dead-front sheet steel cubicles with safety to the operator, and installed in the high tension switchgear room.

(vi) Low tension switchgear

Self-supporting type metal-enclosed cubicles is provided for receiving the power from station service transformers and diesel engine generator in emagency case and for distributing the power to three (3) motor control centers, two (2) AC-panel and battery charger.

The cubicle are located in low tension switchgear room and following equipments are accommodated in the cubicle.

a) One (1) set of 220/127V 3-phase, 4-wire bus

b) Seven (7) air circuit breakers

c) Two (2) moulded case circuit breakers

d) Nine (9) current transformers

e) Two (2) potential transformers

(vii) Main control switchboard

Control of the electric facilities in the pumping station are made on the main control switchboards to be installed in the control room of the pump house. The main control switchboard is of vertical, duplex type with access door at both end. The indicating, integrating instruments, control switches, mimic diagram of bus bars, motors, transformers, static condensers, switchgears, etc. with indicators showing the position of circuit breakers and disconnecting switches are arrenged on the front panels and protective relays on the rear panels

a) Metering

Instruments are provided on each control switchboard to indicate the following.

i) 138 kV transmission line

- Line current
- kW power received
- 138 kV line voltage
- System frequency
- kWh energy
- kV meter
- Power factor meter

ii) 4.16 kV circuits

- Main transformer current
- Main transformer kW output
- Power factor
- 4.16 kV bus voltage
- 4.16 kV bus ground voltage
- Static condenser line current
- Pump motor line current
- Pump motor kW output
- Main motor kWh energy
- Local transformer line current
- Station service transformer line current

iii) 13.8 kV circuits

- 13.8 kV bus voltage
- 13.8 kV ground voltage
- 13.8 kV feeder current
- 13.8 kV feeder kW output
- 13.8 kV feeder kWh energy

iv) Low tension circuits

- Station service transformer current
- 220/127 V bus voltage

b) Relaying

Relaying panels are provided for each machine and equipment incorporating the following protective and alarm features.

i) Protection for pump-motor units
- Diffrential protection on the motor
- Overcurrent protection on the motor
- Ground fault protection on the motor
- Bearing temperature, extremely high
- Other necessary protection

ii) Protection for main transformer
- Differential protection on the main transformer
- Overcurrent protection on the main transformer
- Buchholtz relay operating (2nd stage)
- Other necessary protection

iii) Protection for local transformer
- Overcurrent protection on the local transformer
- Buchholtz relay operating(2nd stage)

iv) Protection for static condenser
- Overcurrent protection on the static condenser
- Mechanical fault detector

v) Protection for 4.16 kV circuit
- Undervoltage protection
- Overvoltage protection
- Ground protection on 4.16 kV bus section

vi) Protection for 138 kV transmission line
- Distance protection both phase and earth faults
- Overcurrent protection
- Under voltage protection

vii) Protection for 13.8 kV circuit
- Overcurrent protection on the 13.8 kV feeders
- Ground fault protection on the 13.8 kV circuit

- Directional ground fault protection on the 13.8 kV feegers
- Undervoltage protection on the 13.8 kV feeders

viii) Protection for station sevice
- Under voltage protection on 220/127 V bus

ix) Alarm for pump motor units
- Bearing temperature high (1st stage)
- Cooling air temperature high
- Cooling water flow stopped for motor air cooler, motor bearing, pump bearing
- Pump and motor bearing oil level low
- Other necessary alarms

x) Alarm for main transformers
- Oil temperature high
- Oil level low
- Buchholtz relay operating (1st stage)
- Winding temperature high
- Gas pressure low for circuit breakers
- Unhealth of disconnecting switches
- Other necessary alarm

xi) Alarm for 138 KV transmission line
- Gas pressure low for circuit breaker
- Unhealthy of disconnecting switches
- Other necessary alarm

xii) Alarm for local and station service transformers
- Oil temperature high for local transformers
- Buchholtz relay operating for local transformers (1st stage)
- Other necessary alarm

xiii) Alarm for station services
- Ground fault on 125 volt, D.C. bus
- Water level high, in the drainage sump pits
- Other necessary alarm

(Viii) Sub-control switchboard

The sub-control switchboards are provided to feed AC 220-127V, three phase, four wire and DC 125V power to pumping station common use facilities, and is installed in the low tension switchgear room (EL.60.0m).

The panel mounted eqipment and devices will include the followings.

a) A..C. panel-1

- One(1) A.C, ammeter
- Twelve(12) No-fuse breakers
- One(1) A.C. ammeter selector switch
- One(1) set of terminal block

b) A.C. panel-2

- One(1) A.C. ammeter
- Sixteen No-fuse breakers
- One(1) A.C.ammeter selector switch
- One(1) set of terminal block

c) D.C. panel

- Sixten(16) No-fuse breakers
- Two(2) Magnetic contactor for D.C. emergency lighting circuits
- One(1) set of terminal block

(ix) Other electrical facilities in pumping station

a) Battery charger panel

One metal enclosed battery charger, having doors in front to facilitate inspection, is provided in the low tension switchgear room. The rectifier element for the battery is of silicon. Fuse protection is provided for individual rectifier diodes.

The battery charger is capable of initial charging, floating operation and equalizing charge for 200 AH storage battery.

b) Storage battery

One set of storage battery is installed in the battery room (EL.70.2m) to be used for the control of pump-motor and electrical facilities and for emergency lighting. The battery will be of lead acid, enclosed type, 125 V, 200 ampere-hour.

c) Telephone facilities

One set of private automatic telephone-exchange having an extensible capacity of 60 lines will be installed in the telephone room (EL.70.2m) for communication between pumping house inside, 138 kVswitchgear yard and base camp.

Besides, communication between Daule Peripa power station and the pumping station is made by means of Power Line Carrier(PLC) Equipment provided under the project.

Followings are provided for PLC system:

- One(1) set of power line carrier terminal equipment
- One(1) set of line trap
- One(1) set of coupling capacitor potential devices
- One(1) set of coupling device
- One(1) set of power supply unit

d) Diesel engine generator

To supply power in emergency case of power supply stoppage from Daule peripa power station, one diesel engine generator is provided. Capacity of the generator is adopted to be 200 kVA to deliver power for essential loads such as sump pump motor system in the pump house, battery charger for D.C.control source, emergency lighting etc. The power supply to the main pumps and to base camp is not taken into consideration.

To prevent the parallel operation with normal power system, the circuit breaker for the diesel engine generator circuit is interlocked with the circuit breaker for the station service transformer circuit.

The generator is of 3-phase, 4-wire,220/127 V and indoor use package type.

(3) **Additional facilities at Daule Peripa Power Station**

Daule Peripa power station planned by CEDEGE is prepared an installation space of 138 kV single circuit switchgear for Severino pumping station. However, CEDEGE's plan does not consider to provide the facilities related to Severino pumping station.

Then, the following equipment and structurs are provided in the outdoor switchgear yard and power house of Daule Peripa power station.

a) 138 kV outdoor switchgear yard

- One(1) set of circuit breaker for transmission line circuit
- One(1) set of disconnector with earthing switch for transmission line
- Two(2) sets of disconnectors for transmission line circuit
- Two(2) sets of disconnector for connecting with existing buses
- Three(3) sets of current transformers
- Two (2) sets of capacitor potential devices
- One(1) set of coupling potentor potential device
- Three(3) set of lightning arresters
- One(1) set of line trap
- One(1) set of coupling device
- One(1) lot of electrical conductors and fittings
- One(1) lot of insulators and fittings
- One(1) lot of steel structures
- One(1) lot of other materiajs

b) Power house inside

- One(1) panel of main control switchboard
- One(1) set of power line carrier terminal equipment
- One(1) set of power supply unit for PLC.

The equipment and structure to be added for this project will be provided in similar specification with Sevierino one as far as possible.

(4) 13.8 kV distribution line

Two circuits of 13.8 kV distribution line will be fed from the pumping station for supplying electric power to 138 kV switchgear yard and base camp.

The routes of lines are selected along the access road in view of the easy operation and maintenance except of shout-cut laying between pumpinp station and 138 kV switchgear yard.

To receive power from 13.8 kV distribution line and deliver power to the respective low tension loads, receiving facilities which consist of distribution transformer, disconnecting switch and arrester are required.

The installed capacity of these distribution transformers to be provided in 138 kV switchgear yard and base camp are as follows:

138 kV switchgear yard	50 kVA, 3-phase, 13.8 kV/220-127V for outdoor lifhting, repair work power source, testing power source in completion test,etc.
Base camp:	100 kVA, 3-phase, 13.8 kV/220-127V for project office, resident quarter, domestic water supply pump, etc.

Distribution line voltage and capacity is decided at 13.8 kV and 1,000 kVA respectively, thinking over the future extension of power demand in the project area. The power conductor and ground wire are selected at ACSR 50 sq.mm(Al 6/3.5, St 1/3.5) and GSW 22 sq.mm(7/2.0) respectively.

Arrangement of line conductors will be in horizontal on one cross-arm and overhead groundwire will be fixed on the top of the support. Supports will be local concrete poles.

It is noted that communication cables for PLC and telephone and control cable for 138 kV switchgear are attached to these distribution line.

(5) Earthing system

General earthing systems are provided at pumping house, main transformer yard and 138 kV switchgear yard for the following three main purposes:

i) To safeguard operating personnel and the public.

ii) To provide connections to the earth for transformers and other power equipment neutrals.