iii) To provide a discharge path to a earthing system for lightning arresters, overvoltage gaps, and similar devices.

The earthing mesh is designed to be laid under the ground of main transformer yard, the bottom of the pump house and 138 kV switchgear yard.

The earthing resistance is designed to be less than one ohm for this pumping station for the above purposes. As a result of calculation, typical design of earthing mesh is decided, assuming that earth specified resistivity is 12,000 ohm-cm. However, if earthing resistance is not less than one ohm since the earth specific resistivity is higher than 12,000 ohm-cm, the earthing mesh will be connected among three mesh block to obtain the resistance lower than specified value.

4.6.4 Daule-Peripa ~ Severino Transmission Line

(1) Basic design condition

(i) General

This sub-section will discuss the basic design feature for the transmission line.

(ii) Applied standards

The standards to be applied for the Project will be basically IEC (International Electrotechnical Commission) standards, JIS (Japanese Industrial Standards), JEC (The Japanese Electrotechnical Committee) standards, other international standards and design practices applied in Ecuador, Japan or international market will also be used in the design of particular items.

(iii) Meteorological conditions

There is a meteorological station at Daula Peripa in the Project area.

Following are the meteorological records or reference to determine the design conditions of the facilities in the Project.

a)	Maximum air temperature	39.9 °C
b)	Average air temperature	26.38 °C
c)	Absolute minimum air temperature	13.0 °C
d)	Mean wind velocity	1.38 m/sec.
e)	Mean monthly rainfall	163.56 mm

f) Mean relative humidity 87.6 %

Maximum conductor temperature is assumed at 60 °C based on the maximum air temperature of 39.9 °C and temperature rise of conductors due to current flow. Minimum conductor temperature is assumed at 5 °C for safety.

There are no records for maximum wind velocity and earthquake in the Project area. However, maximum wind velocity of 60 km/hr was recommended by design practice in Ecuador, which will be used for design maximum wind velocity for more safe design of the project facilities.

Generally, wind loads are much more than loads due to earthquake to the towers and supporting structures, and accordingly no earthquake loading will be considered in the design.

(iv) Route selection

The transmission line route should be selected in consideration of easy and economical construction, operation and maintenance of the line as well as environmental viewpoint.

Following alternatives as shown on the attached map Fig.4.6.8 were examined for selection of the optimum route for the transmission line between the Daula Peripa hydropower station and the Severino substation.

(a) Route-A is running on the shortest distance through the hilly area. Total distance of the route is 32 kilometers. There are no approaching roads to the route in its middle section over the distance of approximate 10 kilometers.

(b) Route-B is aligned to be along the existing road via La Balsa, Puente de Solamilo, Cuatro Hermanos and El Topadero. Total distance of the route is approximate 46 kilometers. The first 8 km section from the Severino substation is on the same route as Route-A.

(c) The first section from the Severino substation of Route-C is aligned along the project access road newly constructed from the existing public road. The route is running from the substation via La Torre, San Sebastian, Azucena Baja, El Desvio and then joined with the Route-B at Puente de Solamillo. Total distance of the route is approximate 53 kilometers.

General comparisons of the alternatives are summarized as below:

	Route-A	Route-B	Route-C
Total distance of route	32 km	46 km	53 km
Construction of Line	normal	easy	easy
Maintenance of Line	normal	easy	easy
Construction cost of Line	100%	125%	135%
Annual Energy Loss on Line	148 MWh	213 MWh	246 MWh

Although the Route-A is aligned in the hilly area and about 30% of the route are away from the major road, maintenance cost of the line stands on the almost same level as other routes because of the shorter route length. While, transmission line facilities of the Route-A are not viewed from the major road so that it is environmentally evaluated. Besides, as seen in the above table, the Route-A is both economically and technically advanced. Thus, the Route-A is selected for the 138 kV transmission line of the project.

The selected route of the 138 kV transmission line is shown on the drawing No. 3-I-023 and 3-I-024.

(v) Transmission line voltage

a) Standard voltage

The present standard voltage applied in Ecuador is 230 kV, 138 kV, 69 kV, 46 kV and 34.5 kV. The transmission line voltage for the project should be selected from these standard voltages for unity of the country's power system.

b) Transmission line voltage for the Project

The line is to transmit of 20 MW between the power station and the pumping station over a distance of about 32 km. Taking account of the project scale, either 138 kV or 69 kV is appropriate for the transmission line voltage. The Manabi Electrical Company suggests to apply the voltage of 138kV for this project in combination with the system voltage of the Daule-Peripa hydropower project which is closely relating to this project. Therefore, 138 kV, one of the standard system voltage in the country will be applied for the transmission line of this project.

(2) Power conductor and overhead earthwire

(i) Selection of conductor

From the following computation of corona critical voltage, the minimum diameter of power conductor used for 138 kV line should be 18.7 mm.

(Peek's Formula)

$$V = \sqrt{3} \times 48.6 \times m_o \times m_l \times d \times r \times \log_{10}(D / r)$$

where,

V : corona critical voltage (phase to phase voltage)

m_0 : conductor surface factor (0.85)

m_1 : weather factor (1.0 for fine and 0.8 for rainy condition)

d : air density = 0.386 x b / (273 + t)

b : atmospheric pressure (mmHg) (720 for elevation of 400 m to 500 m)

t : air temperature (average 25 °C in the project site)

r : radius of conductor (cm)

D : equivalent phase spacing (cm) (550 cm for 138 kV) = $\sqrt[3]{D_{ab} \bullet D_{bc} \bullet D_{ac}}$

D_{ab}, D_{bc}, D_{ac} : distance between phases (cm)

The smallest conductor size for 138 kV system will be ACSR Oriole (outside diameter = 18.83 mm) from ASTM B232 to avoid unacceptable corona disturbances.

Aluminium Cable Steel Reinforced (ACSR) is economically and technically used for the overhead transmission lines and also generally used in the country. For this project, ACSR will be applied accordingly.

Current carrying capacity of the ACSR Oriole (Approximately 490 amperes) is quite sufficient for transmission of 20 MW. Power loss and voltage drop of the 138kV ACSR Oriole line when 20 MW flows on the Project line will be approximately 1% and 2.5 %, respectively. The values are adequate for operation of the trunk transmission line.

From those points, ACSR Oriole is recommended to be used for the line between the power station and the pumping station.

Number of circuit was studied either one circuit or two circuits to be applied to this project with consideration of construction cost and power transmission stability. The plan of two circuits is excellent in the view point of the stability, but the cost is higher about 50% than that of one circuit plan.

In the view point of water management in the Poza Honda dam, we find that no influence will be observed for water supply demand, even if the pumps are stopped for 2 or 3 days, because the dam has the sufficient water supply allowance.

Accordingly, one circuit transmission line is recommended for the project.

(ii) Technical particulars of power conductors

Following are technical particulars of ACSR Oriole recommended for the project.

Particulars		ACSR Oriole
Nominal Section	:	170 mm^2
Calculated Section: Aluminium	:	170.5 mm^2
: Steel	:	39.8 mm^2
: Total	:	210.3 mm^2
Conductor Stranding (A1 + St in nos./mm)	:	30/2.69 + 7/2.69
Outside Diameter	:	18.83 mm
Unit Weight of Conductor	:	737 kg/km
Ultimate Tensile Strength	:	7,590 kg
DC Resistance at 20°C	:	0.1579 ohm/km
Approximate Current Carrying Capacity	:	490 amperes

Single circuit line of 138 kV ACSR Oriole has transmissions capacity of approximate 117 MVA taking account of conductor's current capacity.

(iii) Sag design of ACSR Oriole

Sags of power conductor are necessary for profile design of the line route, determination of standard height of supports and works of conductor stringing.

Sag of conductor are computed under the following conditions referring to the local climatic conditions.

a) Most severe design condition : maximum wind pressure under 18°C of conductor temperature

b) Max. wind pressure on conductor : 39 kg/m^2

c) Maximum conductor temperature : 60 °C
d) Average conductor temperature : 25 °C
e) Min. conductor temperature : 5 °C
f) Factor of safety
- max. working tension : more than 2.5 against ultimate tensile strength
- everyday stress : more than 4.0 against ultimate tensile strength
g) Young's modulus of aluminium : 6,300 kg/mm^2
Young's modulus of steel : 21,000 kg/mm^2
h) Linear expansion coeff.
- aluminium : 23 x 10^{-6}/°C
- steel : 1.5 x 10^{-6}/°C
i) Ultimate tensile strength : 7,590 kg

Sag computation of power conductor ACSR Oriole resulted in the maximum working tension to be 2,400 kg with the safety factor at its maximum working stress of 3.16 and 1,750 kg with the safety factor at its everyday stress of 4.34 against its ultimate tensile strength.

Computation process of the sag is shown in DESIGN CALCULATION REPORT. Following are maximum and minimum sags of conductor at equivalent span length of 350 m.

Span length	(m)	100	200	300	350	400	500	800	1,000
Max. sag	(m)	0.58	2.32	5.23	7.12	9.30	14.59	37.18	58.10
Min. sag	(m)	0.44	1.75	3.94	5.37	7.01	10.95	28.03	43.80

A sag template for equivalent span of 350 m for the profile design purpose is illustrated in Figure 4.6.9 from the above computation.

(iv) Accessories for power conductor

In order to prevent fatigue of power conductors due to repeated vibration caused by breeze, following devices will be applied on the conductors.

- Trunnion type suspension clamps
- Vibration dampers
- Armour rods

Following are general descriptions for those devices to power conductors.

a) Trunnion type suspension clamps

Suspension clamps will be of trunnion type which is designed to avoid any possibilities of deforming the stranded conductors and of separating the individual wires, and are free to pivot in the vertical plane containing the conductor.

b) Vibration dampers

Stockbridge type vibration dampers will be applied on all conductors in every spans except slack spans to the power station and the pumping station. Unit weight of the dampers will be 4.5 kg (10 lbs) for the power conductors. Number of the dampers to be installed per span will be 2 pieces per conductor for spans up to 600 m and 4 pieces per span for longer spans than 601 m.

The first and second dampers will be positioned at 1.1 m and 2.2 m from the center of suspension clamps or the mouth of tension clamps

c) Armour rods

Preformed armour rods will be wound on power conductors at all suspension clamps except for jumper suspension points. Suspension clamps for those conductors protected by armour rods should be suitable for the enlarged conductors.

(v) Overhead earthwire

a) General

In order to protect the power conductors from direct strokes of lightning, one (1) overhead earthwire will be provided above the power conductors with the shielding angle of 30 degrees. The wire is selected from its mechanical strength for keeping the sufficient shielding effect and for preventing back-flashover from the earthwire to the power conductors in the midspans. The wire should keep its sag to be less than 80 % of the power conductor sag under the condition of still air and minimum temperature.

b) Overhead earthwire

Computation of the overhead earthwire is shown in DESIGN CALCULATION REPORT. As seen in the computation, galvanized steel stranding wire of 55 mm^2 is adequate for the overhead earthwire for ACSR Oriole.

Maximum working tension of the earthwire will be 1,754 kg with safety factor of 2.66 against its ultimate tensile strength. Minimum safety factor is generally suggested to be more than 2.5.

c) Technical particulars of overhead earthwire

Nominal section	:	55 mm^2
Standing (nos./mm)	:	7/3.2 mm
Calculated section	:	56.29 mm^2
Outside diameter	:	9.60 mm
Unit weight of wire	:	0.446 kg/m
Ultimate tensile strength	:	4,660 kg

d) Accessories for overhead earthwire

Following devices will be applied for the earthwires for the same purpose to the power conductors.

- Trunnion type suspension clamps
- Vibration dampers

Since steel stranded wire is more elastic than aluminium conductor, preformed armour rods will not be necessary to be applied for the earthwire.

Unit weight of Stockbridge type vibration dampers for the wire will be 1.8 kg (4 lbs), and same number of dampers as for the conductors will be applied but with positioning of the first unit to 0.6m and second unit to 1.2 m from the center of suspension clamps or from the mouth of tension clamps.

(3) Insulation

(i) General

Insulation of the transmission line will be determined on such basic design philosophy that flashover should not be occurred by internally induced abnormal voltages.

(ii) Insulator unit

Insulator unit to be applied for the project will be a ball and socket type toughened glass or porcelain standard suspension insulator of 254 mm in diameter and 146mm in spacing.

Electrical and mechanical characteristics of insulator unit will be as below:

a)	minimum flashover voltage	power frequency: dry	: 78 kV
		power frequency: wet	: 45 kV
		50% impulse: positive	: 120 kV
		50% impulse: negative	: 125 kV
b)	minimum withstand voltage	power frequency: dry	: 70 kV
		power frequency: wet	: 40 kV
c)	electromechanical failing load		: 12,000 kg

Retaining pins will be of stainless steel or phosphor bronze and so shaped that when set and under any condition of handling and service the retaining pin will not allow separation of insulator units or fittings or will not cause any risk of displacement.

(iii) Insulator sets

Single strings of suspension and tension insulator sets will be employed.

Number of insulator unit per string will be determined so that;

a) the switching surge withstand voltage of an insulator string in wet condition should be higher than the crest value of switching surge induced in the system, and

b) the power frequency withstand voltage of an insulator string in wet condition should be higher than the effective value of short time abnormal voltage occurred on the line.

The flashover voltage of the insulator set is influenced by altitude, climate and environmental conditions such as atmospheric pressure, dust contamination, etc.

Following are insulation design of the sets for the solid neutral grounding system in the project. The sets will be provided with arcing horns on both line and earth ends for protection of the sets from lightning strokes, for preventing arc cascading over insulator discs and for equalization of electric field charged on insulator unit in the set.

Nominal system voltage	V_0	: 138 kV
Maximum operating voltage	$V=1.12 \times V_0$	: 155 kV
Switching surge	$U = \frac{2.8 \times V \times \sqrt{2}}{\sqrt{3}}$	: 355 kV
Insulation reduction factor	R	: 1.1
Over-voltage factor in short period	Q_r	: 1.3
Required withstand voltage		
for switching surge	$U_0 = U \times R$	: 391 kV
for short period over-voltage	$U_o' = (V / \sqrt{3}) \times R \times Q_r$	: 128 kV
Required Nos. of insulator unit	N	: 9 units for suspension set
	N	: 10 units for tension set
Withstand voltage of insulator unit for switching surge	to be more than U_0	: 530 kV for suspension set
		: 575 kV for tension set
for short period over-voltage	to be more than U'_0	: 300 kV for suspension set
		: 330 kV for tension set
Length of insulator set	Z_0=Nx146(mm)	: 1.314 m for suspension set
		: 1.460 m for tension set
Design horn gap length	$Z=0.85 \times Z_0$	: 1.12 m for suspension set
		: 1.24 m for tension set
Impulse withstand voltage of horn gap	to be more than U_0	: 500 kV for suspension set
		: 560 kV for tension set
Power freq. withstand voltage of gap	to be more than U'_0	: 320 kV for suspension set
		: 360 kV for tension set

As analyzed above, it is recommended to apply 9 insulator units for a suspension set and 10 insulator units to a tension set with sufficient allowance.

Following safety factors will be applied for design of the electromechanical strength of insulator sets under the most severe climatic condition.

a) suspension insulator sets : more than 3.0
b) tension insulator sets : more than 3.0

Outline of insulator sets used for the project are shown in Drawing No. 3-I-026.

(iv) Support footing resistance

Published statistics indicate that approximately 95% of the lightning current to transmission line is less than 100kA and 95% of the discharged current through a tower is not more than 50kA. For preventing the back-flashover from supports to insulator sets, the footing resistance of the supports should be less than the following value.

$$(V - E) / \{(1 - C) \times I\}$$

where, V : impulse flashover voltage of insulator set, 560 kV
E : crest value of the highest system voltage, $(2/3)^{1/2} \times 155 = 127$ kV
C : coupling factor between conductor and overhead earthwire, 0.2
I : crest value of tower discharged current, 50kA

Thus, support footing resistance should be lower than 11 ohms to prevent the back flashover to insulators, for which grounding rods will be provided at each foundation anchorage and, if needed, counterpoise grounding system will be added.

(v) Minimum clearance of live parts to support

The minimum electrical clearances of live parts to earthed structures are determined in insulation coordination. Spatial diagrams as shown in Drawing No. 3-I-025 are generally used for keeping necessary clearance of live parts to earthed materials.

a) The standard clearance is equivalent to the gap coordinated with lightning impulse flash-over voltage of insulator sets. The gap is practically to be more than the value obtained from the experimented formula "L=1.115Z+0.021(m)". Since Z is the designed horn gap of insulator sets (1.12m for suspension and 1.24m for tension set), the necessary gap is as follows.

For suspension set:	1.115 x 1.12 + 0.021 = 1.27 (m) minimum
For tension set:	1.115 x 1.24 + 0.021 = 1.40 (m) minimum

b) The minimum clearance required should be more than the gap coordinated with the minimum required withstand voltage for switching surge of insulator sets (391 kV) and also more than a gap for the short-period over-voltage in wet power frequency (128 kV). The necessary gap will be 900 mm minimum.

c) Special clearance 350 mm is the gap coordinated with withstand voltage for switching surge of insulator sets.

d) The minimum space of jumper loop to cross-arms of towers is usually taken as 120 % of the standard clearance, i.e., 1.2 x 1,400 = 1,680 (mm).

e) The conductor clearances employed for tower configuration design in the project are as follows:

i)	In still air (vertical position)	: for suspension sets : for tension sets	1,300 mm 1,400 mm
ii)	Under 20 degree swing	: for suspension sets : for tension sets	1,300 mm 1,400 mm
iii)	Under 40 degree swing of suspension insulator sets or jumper conductors	: 900 mm	
iv)	Under 60 degree swing of suspension insulator sets or jumper conductors	: 350 mm	

Required clearance diagram of conductors at suspension type and tension type towers are shown in Drawing No. 3-I-025.

(vi) Minimum ground clearance of conductors

Minimum ground clearances of power conductor to be applied to 138 kV transmission line are as mentioned below.

a)	above general terrain	: 6.8 m
b)	above main roads	: 9.0 m
c)	above secondary roads	: 7.8 m

d) above rail roads : 9.0 m

e) above other lines : 4.0 m

(4) Supports

(i) General

Supports will be of self-standing and broad base galvanized steel lattice type on concrete foundations. The towers are for 138kV single circuit of ACSR Oriole with one (1) overhead earthwire of 55 mm^2 galvanized and stranded steel wire. The standard height towers will be provided with body extensions of 3-meter step and hillside extensions of 1-meter step. The hillside extensions are applied or each tower leg on the slope of land so that each leg is suited to the original land slope of the tower site and that excessive land cutting around its foundations and land collapse are prevented.

(ii) Type of towers

Towers used for the project are classified into the following types:

a) Type-SS : tower for straight section or for angle point up to 2 degrees of horizontal deviation point, provided with suspension type insulator sets

b) Type-LA : angle tower to be applied at positions of horizontal deviation of the line up to 15 degrees, provided with tension type insulator sets

c) Type-MA : angle tower to be applied at positions of horizontal deviation of the line up to 30 degrees, provided with tension type insulator sets

d) Type-HA : angle tower to be applied at positions of horizontal deviation of the line up to 45 degrees, provided with tension type insulator sets

e) Type-TA : terminal tower or angle tower up to 60 degrees, provided with tension type insulator sets

(iii) Height of towers

Height of towers will be determined as under-mentioned.

$$H = Gc + Sg + Li + 2 \times Hc + Hg$$

where,

H	:	total height of standard tower
Gc	:	necessary clearance of the lowest power conductors above ground
Sg	:	maximum conductor sag
Li	:	length of a suspension insulator set, but nil for tension towers
Hc	:	vertical spacing of conductor crossarms
Hg	:	vertical spacing between upper conductor crossarm and overhead earthwire arm

Standard towers of suspension and tension types are illustrated in Drawing No. 3-I-025.

(iv) Design span

Towers will be designed under assumptions of the following basic, wind and weight spans:

Type of Tower		SS	LA	MA	HA	TA
Basic design span	(m)	350	350	350	350	350
Wind span (normal)	(m)	500	500	450	450	450
Wind span (broken-wire)	(m)	400	400	350	350	350
Weight span (normal)	(m)	900	1,000	800	600	600
Weight span (broken-wire)	(m)	400	700	600	350	350
Uplift weight span	(m)	300	800	300	300	300

The term "basic span" means the horizontal distance between centers of adjacent towers on the level ground which the height of standard tower is derived with the specified conductor clearance to ground in still air at the maximum temperature.

The term "wind span" means half the sum of adjacent horizontal span lengths supported on any one tower.

The term "weight span" means the equivalent length of the weight of conductors and earthwire supported on any one tower at the minimum temperature in still air.

Span length under "normal" means design span length for the normal loading condition. Span length under "broken-wire" means design span length for a conductor or earthwire assumed to be broken.

(v) Design loads

Following loads will be applied for design of towers:

a) Wind loads

- on power conductors and overhead earthwire (on the projected area of conductors and earthwire) : 39 kg/m^2
- on tower structures (on the projected area of structural members) : 80 kg/m^2
- on insulator sets (on the projected area of the sets) : 50 kg/m^2

b) Maximum working tensions of power conductor and overhead earthwire

- power conductor : ACSR Oriole : 2,400 kg
- overhead earthwire : galvanized steel stranded wire 55mm^2 : 1,750 kg

c) Vertical loads

- tower structures : actual weight of tower structures with accessories
- power conductors : weight of conductors of specified weight span
- overhead earthwire : weight of earthwire of specified weigh span
- erection load : such loads as workers' weight on tower members, reaction of temporary backstays during stringing operation, etc.

d) Horizontal angle effect of power conductors and overhead earthwires

: horizontal component of maximum working tension of conductors and earthwire due to the specified horizontal angle deviation

(vi) Design conditions

a) Assumed normal loading condition:

Following loads are assumed to work simultaneously on a tower.

i) vertical loads : as above-mentioned

ii) transverse loads : wind loads and horizontal angle deviation effects

iii) longitudinal loads : wind loads and erection loads but together with maximum working tension of power conductors and overhead earthwires for their termination for type TA tower

b) Assumed broken-wire condition:

Under the condition, any one (1) power conductor or any one (1) earthwire is assumed to be broken at their maximum working tension in addition to the loads under the normal condition. In the case of type SS type tower, the pull will be assumed to be 60% of the specified maximum working tensions with the reason that displacement of the suspension insulator set or the broken conductor will reduce the conductor tension.

c) Factor of safety

Following factors of safety for tower structures are taken in design.

i) more than 2.0 for the synthetic maximum load under the normal loading condition
ii) more than 1.25 for the synthetic maximum load under the broken-wire condition, but 1.5 for the cross-arms

Those factors of safety will be taken for yield strength of tower steel materials and proven in the tower loading test to be carried out in the manufacturer's testing station.

(vii) Application of towers

For applying the specified types of towers for the selected tower positions economically, angle-span chart is used in the profile design.

The chart is made giving the relation of horizontal loads between wind pressures on power conductors/overhead earthwires and transverse component of conductor's/ earthwire's tensions due to their horizontal angle deviation, using the following equation.

$$2T \times \sin(\phi/2) + W_i \times d \times S = \text{constant}$$

where, T = maximum working tension of conductor or earthwire (kg)
ϕ = horizontal angle deviation (degree)
W_i = wind pressure on conductor/earthwire (kg/m2)
S = loading wind span length (m)
d = diameter of conductor / earth wire (m)

Relation between span length and horizontal deviation angle for each type of towers is summarized below substituting standard loadings and variable span length into the equation.

Type of Tower		SS	LA	MA	HA	TA
(Power Conductor)						
S =	0 m	10° 47'	23° 54'	38° 15'	53° 41'	69° 20'
	450 m			30° 00'	45° 00'	60° 00'
	500 m	2° 00'	15° 00'	-	-	-
	800 m	—	9° 43'	23° 41'	38° 26'	53° 02'
ø = 0° (m)		614	1,353	2,142	2,951	3,718
(Overhead Earthwire)						
S =	0 m	8° 08'	21° 12'	35° 45'	51° 08'	66° 29
	450 m	-	-	30° 00'	45° 00'	60° 00'
	500 m	2° 00'	15° 00'	-	-	-
	800 m	-	11° 18'	25° 35'	40° 24'	55° 06'
ø = 0° (m)		663	1,720	2,870	4,027	5,124

Figure 4.6.10 shows the angle-span chart which is used for the profile design.

(viii) Tower accessories

Tower will be provided with the following accessories for operation and maintenance works of the line. General arrangement of those accessories are shown in Drawing No. 3-I-027.

a) Step bolts

Two diagonal legs of towers will be provided with step bolts for climbing-up and down of workers and maintenance crew. The bolts will be installed at an about 45cm interval starting from 2m above the ground to the top of tower. After completion of the erection works of the line, step bolts below the anti-climbing device under-mentioned will be removed for prevention of tower climbing of local inhabitants.

b) Anti-climbing devices

All towers will be provided with a device on each leg at height of 3m to 5m above the highest ground level at its tower site. The device will be constructed with galvanized barbed wires and a pad lock on one of the step bolted legs.

c) Indicating plates

A number plate will be provided on each tower. The plate will be numbered starting from the pumping station.

A danger signal plate may be installed on such towers as located nearby road, village or river.

Indicating plates are shown in Drawing No. 3-I-027.

d) Grounding rods and counterpoise wires

In order to reduce tower footing resistance, each leg of tower will be provided with a grounding rod connected with a galvanized steel stranded wire to a cleat of tower foundation stub. In case of footing resistance to be higher than the specified value after installation of the grounding rods, one or more counterpoise wires will be added to the tower leg(s) at positions above concrete foundation cap(s). Those counterpoises will be of galvanized steel stranding wire buried about 50cm below ground surface. All tower legs will be provided with a hole for fixing the counterpoise.

(5) Tower foundations

(i) General

Sub-soil conditions at all tower positions will be examined by a construction contractor using a soil sounding tester for obtaining general information of sub-soil characteristics. Results of the tests will be used for determination of foundation type to be applied for the tower.

(ii) Type of foundation

Standard foundations are of concrete pad and chimney type and are classified into the following types to apply various soil conditions at each tower site.

Type of Foundation		Ultimate Bearing Capacity (ton/m2)	Unit Weight of Soil (ton/m3)	Angle of Repose (degree)
Light	(L)	60	1.6	30
Medium	(M)	40	1.5	20
Heavy	(H)	20	1.4	10

The term "angle of repose" means the angle between the vertical plane and a slope of inverted frustum of a pyramid assumed to resist against uplift load of foundations.

(iii) Nature of concrete

Nature of concrete to be installed will be assumed as follow:

allowable compressive strength	(kg/cm^2)	60.0
allowable tensile strength	(kg/cm^2)	6.0
allowable shearing strength	(kg/cm^2)	6.0
weight of non-reinforced concrete	(kg/m^3)	2,300
weight of reinforced concrete	(kg/m^3)	2,400
allowable adhesive strength of concrete on		
galvanized steel section	(kg/cm^2)	3.6
round reinforcing bar	(kg/cm^2)	7.2
deformed reinforcing bar	(kg/cm^2)	12.0

(iv) Design of foundations

Each type of foundations will be designed on the basis of the following formulas:

(Against compression load)

$$\frac{q}{F} \geq \frac{C+G+W_s}{A}$$

where,
- q : ultimate bearing capacity of sub-soil (ton/m^2)
- F : factor of safety
- C : total compressive load transferred from superstructure (ton)
- G : total weight of concrete (ton)
- W_s : total weight of sub-soil above foundation pad (ton)
- A : area of foundation pad (m^2)

(Against uplift load)

$$G+\frac{W_s'}{F}\geq T$$

where, T : uplifting load transferred from superstructure (ton)

W_S' : total weight of sub-soil in frustum (ton)

(Against lateral load)

$$\frac{q'\times A'}{F}\geq Q$$

where, Q : horizontal load transferred from superstructure (ton)

q' : yield lateral bearing capacity of sub-soil (ton/m^2)

A' : projected area of foundation chimney and pad (m^2)

Upper surfaces of foundation pads unless reinforced will be either sloped within 45° to the horizontal or flattened providing the difference of which between the pad and chimney will not be more than twice thickness of pad. The minimum thickness of the edges of base pad will be specified not to be less than 300mm.

The frustum for resisting against uplifting load will be assumed to start from the top edges of the pad for safety purpose unless undercut excavation is employed.

Concrete coverage over steelworks will be at least 100mm and the chimney will be extended above the ground for the minimum height of 250mm.

(Factor of Safety)

Following factors of safety will be taken in design of foundations for all types of foundations.

- not less than 2.5 against the maximum working load under the normal conditions, and
- not less than 1.5 against the maximum working load under the broken-wire condition.

(6) Ground survey of transmission

(i) General

The ground survey works were carried out along the transmission line route selected as the optimum route between the Daule-Pelipa hydropower station and the Severino Pumping Station.

The survey works were conducted for preparing topographical maps, i.e., the profile and plan of the line route and also for obtaining general information of the local soil conditions along the line route.

This sub-section will discuss the ground survey works executed in the field and results of examination of their results.

(ii) Profile and plan

The line route was selected as discussed in sub-section (1) aforementioned. The ground survey was carried out using electronic survey equipment and the results were drawn by a computerized machine.

Profile design was made on the profile and plan drawn by the machine using the sag template computed in sub-section (2) and the Angle-Span Chart worked out in sub-section (4).

On the drawings tower positions were carefully selected in technical and economical consideration. Tower type and tower height at the selected positions were determined taking into account of the tower classification specified for span length and horizontal deviation angle and the required ground clearances of conductor.

As discussed in sub-section (4), each type of tower has body extensions of 3 meters step. Therefore tower positions were determined also adjusting span length to suit 3 meters stepped tower height.

Results of the ground survey and profile design are shown in DATA BOOK NO.3.

Summary of the results are as below:

i)	Total route length	32.894km
ii)	Number of towers	90
iii)	Average span length	370m
iv)	Number of each type of tower	
	Type - SS	51
	Type - LA	32
	Type - MA	4
	Type - HA	1
	Type - TA	2
	Total	90
v)	Number of suspension type insulator sets	153
vi)	Number of tension type insulator sets	228
vii)	Number of conductor armour rods sets	153
viii)	Number of overhead earthwire suspension sets	51
ix)	Number of overhead earhtwire tension sets	40
x)	Number of dampers : for conductors	546
	: for earthwire	182

(iii) Tower plot plan

Tower position selected were to be surveyed in approximately 15m x 15m for determination of hillside extensions of tower legs.

(iv) Soil investigation

In order to obtain a general information for the soil conditions along the selected line route, some representative tower positions were investigated by a soil sounding tester.

In general solid condition along the line route is stiff and fairly good for tower foundations.

(7) Construction

(i) Land preparation and compensation

Before the commencement of the contractor's field work or before the conclusion of the contract for the transmission line, lands required for construction of the transmission line and towers should have been completely procured or compensated, and all houses, huts, trees and other valuable objects in the right of way for the transmission line should have been compensated and removed by the Government.

(ii) Design and manufacturing

The contractor will design all materials and equipment in accordance with the specifications and submit the documents and drawings to the Engineer for its approval.

Upon the Engineer's approval, materials and equipments will be manufactured and subjected to the Engineer's inspections and tests.

The materials and equipment thus inspected will be delivered to the site for erection.

(iii) Check survey and soil tests

The contractor will carry out check survey along the transmission line and each substation site to confirm the profiles and plans given by the Employer/Engineer. After the check survey, the contractor should have full responsibility for the profiles and plans. At the same time, the contractor will mark trees on the both borders of the right of way (20m on both sides of the center line) of the transmission line for tree clearing.

After confirmation of profiles and plans, the contractor will perform soil sounding tests at all tower positions and/or determination of foundation types to be applied.

(iv) Tree clearing

In advance of all erection works, trees in the right of way (20m on both sides of the center line) and so-called danger trees which may fall within the conductors' range, those all trees and bushes should be cleared so that no trunks or branches will project over 30cm above the ground for the transmission line.

Measure to prevent re-growth of tree stubs will be taken during the work execution. However, application of special chemicals for the purpose should be prohibited because of consideration of environment.

Prior to taking-over the project, the contractor will reclear them as specified.

(v) Foundation works

According to the approved foundation types, all foundations should be placed at the exact positions specified.

No over-excavation will be allowed for maintaining original ground strength and undercut practice will be required for foundations of transmission line towers to reinforce the uplift resistance of foundations. In the soft ground, excavation will be executed with timber or iron sheet shuttering with sufficiently strong supports. After excavation of pits, additional soil sounding tests may be required by the Engineer for confirmation of ground bearing capacity.

Setting of foundation stubs of transmission line towers will be made using the approved setting templates so as to avoid mal-placing.

Before concreting of foundations, each stub will be fixed with a grounding rod underneath the foundation. Concrete used for foundation will be mixed in volume ratio of 1:3:6. Mixing should be, in any case, made by mixing machine and no manual mixing will be allowed. In the pits, concrete will be compacted by the mechanical vibrators. Forms of foundations will be of either timber-made or iron-made. The forms should be kept at least 48 hours for their removal from foundations.

Concrete test cubes will be taken from batches and tested their compression strength to be more than $180 kg/cm^2$. In case reinforced concrete foundations will be applied by the contractor, reinforcing bar will also be tested for its strength upon the Engineer's request during erection works.

Piled foundations will be allowed to be provided with either driving piles or bored hole piles depending on the contractor's proposal.

Backfilling of foundations should be done with suitable soil as soon as forms are removed, and compacted firmly with mechanical rammers.

(vi) Erection of structures

Towers will be erected as specified in the erection drawings. Before or during erection, those steel members will be carefully observed on their galvanization and suitable treatment should be made to remove white rust from the galvanized surfaces if generated.

After erection of the structures, a part of threads of all bolts will be pressed for prevent loosening of nuts caused by repeated vibration of structures. Before conductor stringing operation footing resistances of all towers and structures should be measured and those whose resistances are more than 11 ohms will be provided with counterpoise earthing systems to reduce resistances. The counterpoise earthing systems will be laid along conductors' direction and in deeper ground of more than 50cm.

(vii) Conductor stringing

An overhead earthwire and power conductors will be strung in a mechanical and tension stringing operation so as to prevent damages to the wire and conductors caused by scrubbing to ground or tree stumps.

Strong scaffoldings will be provided at crossing points over road, river, railway, power and telephone lines or dense populated areas, etc. for the purpose of public safety. All the stringing works will be operated in radio communications among its working groups for the safe and smooth execution. Arrangement of watchmen at crossing points and other important places and installation of strong backstays will also be specified for the safety purpose.

(viii) Work schedule

The transmission line and substations are expected to be commissioned in 17 months after the verification of the contract as shown on Figure 4.6.11, but subject to the overall construction schedule.

4.6.5 CONGUILLO INLET

(1) Outlet valves

(i) General

A part of the tunnel inlet structure has been constructed in 1990, including a trashrack and three steel pipes with a butterfly valve and a blind flange, two in 1,200 mm diameter and the other one in 800 mm .

Design conditions of the outlet valves to release max. Q = 18 m^3/s. are as summarized below:

- Maximum diversion water requirements 18.0 m^3/sec
- Water level in Daule-Peripa reservoir

Flood water level	EL.88.00 m
High water level	EL.85.00 m
Low water level	EL.60.00 m
- Minimum operable water level for 18.0 m^3/sec	EL.76.60 m
- Lowest operable water level at 0.0 m^3/sec.	EL.66.6 m
- Water level in portal of diversion tunnel	
Design water level at 18.0 m^3/sec	EL.69.00 m
- Setting EL. of outlet valves	EL. 67.2 m for main valves 2 Nos. x 1.4 m dia.
	EL. 65.5 m for sub valve 1 No. x 0.8 m dia.

(ii) Minimum effective head

Minimum effective head for valve design was to be 3.6 meters, which is 7.6 meters of the design static head minus 4.0 meters of head losses in the pipeline.

(iii) Type of outlet valves

The type of outlet valves was selected a cone sleeve valve for main valves, because a cone sleeve valve has mainly two functions, i.e. (1) energy dissipation and (2) flow control.

(iv) Diameter of valve

The diameter of the main valve is calculated as follows:

$$D = \sqrt{\frac{4Q}{c\pi\sqrt{2gH}}}$$

$$= 1.4 \text{ m}$$

where,

D :	Diameter of valve (m)	
Q :	Maximum design flow	9.0 m^3/sec/unit
c :	Flow coefficient	0.7
g :	Gravitational acceleration	9.8 m/sec^2
H :	Minimum effective head	3.6 m

(v) Flow control range

Due to the characteristic of a corn sleeve valve, the flow control range is as follows:

W.L. in reservoir	Flow control range (valve opening)
H.W.L. 85.00	1.5 ~ 9.0 m^3/sec/unit
	(9 ~ 55 %)
M.O.L. 76.60	1.0 ~ 9.0 m^3/sec/unit
	(7 ~ 80 %)

Note: (1) Flow control range is shown under operation by 2 units of sleeve valve.
(2) Controrable valve opening range is normally 5 % to 80 %.

(vi) Cavitation

The cavitation phenomena will occur in case of minimum flow at high water level in the Reservoir. For preventing cavitation, the cavitation coefficient (σ) must be more than the cone sleeve valve own cavitation coefficient (σ_0) as shown in the following equation.

$$\sigma > \sigma_0$$

where, $\sigma = (H_2 + 10) / (H_1 - H_2) = 3.2$

H_1 = (static head) - (pipe loss head)=18.069-0.111=17.96 m

H_2 = (W.L. in tunnel) - (E.L. of stilling well bottom)=66.931-55.631=11.3m

$\sigma_0 = 0.2 \sim 0.4$

Therefore, the cavitation phenomena will not occur in this case.

(vii) Control system

The main valve operation is normally controlled from the valve control panel provided in the control room by means of remote control, and the local valve control panel located adjacent to the valve is used at the time of inspection/adjustment. The valves are operated to suit to the water demands vs. the accumulated discharge water; the calculation of discharge is based on information from water level detecting devices provided in the reservoir and beside the stilling well along with valve opening position meters.

The guard valve for main valve is opened/closed by manual operation device located on the floor of E.L.70.231. The sub valve operation is also manually by a handle equipped with a valve body.

4.6.6 POZA HONDA INLET

(1) Outlet valves

(i) General

Design conditions of the outlet valves to release max. Q = 4 m^3/s. are as summarized below:

- Maximum diversion water requirements	4.0 m^3/sec
- Water level in Poza Honda reservoir	
Flood water level	EL.110.30 m
High water level	EL.106.50 m
Low water level	EL. 88.30 m
- Minimum operable water level for 4.0 m^3/sec	EL. 94.00 m
- Lowest operable water level at 0.0 m^3/sec.	EL. 91.40 m
- Water level in portal of diversion tunnel	
Design water level at 4.0 m^3/sec	EL. 92.0 m
- Setting EL. of outlet valves	EL. 90.8 m for main valves 2 Nos. x 0.9m dia.

(ii) Minimum effective head

Minimum effective head for valve design was to be 1.09 meters, which is 1.94 meters of the design static head minus 0.85 meters of head losses in the pipeline.

(iii) Type of outlet valves

The type of outlet valves was selected a cone sleeve valve for main valves, because a cone sleeve valve has mainly two functions, i.e. (1) energy dissipation and (2) flow control.

(iv) Diameter of valve

The diameter of the main valve is calculated as follows:

$$D = \sqrt{\frac{4Q}{c\pi\sqrt{2gH}}}$$

$$= 0.9 \text{ m}$$

where, D : Diameter of valve (m)

Q	: Maximum design flow	2.0 m^3/sec/unit
c	: Flow coefficient	0.7
g	: Gravitational acceleration	9.8 m/sec^2
H	: Minimum effective head	1.09 m

(v) Flow control range

Due to the characteristic of a corn sleeve valve, the flow control range is as follows:

W.L. in reservoir	Flow control range (valve opening)
H.W.L.106.50	0.5 ~ 2.0 m^3/sec/unit (7 ~ 31 %)
M.O.L. 94.00	0.5 ~ 2.0 m^3/sec/unit (15 ~ 78 %)

Note: (1) Flow control range is shown under operation by 2 units of sleeve valve.
(2) Controrable valve opening range is normally 5 % to 80 %.

(vi) Cavitation

The cavitation phenomena will occur in case of minimum flow at high water level in the Reservoir. For preventing cavitation, the cavitation coefficient (σ) must be more than the cone sleeve valve own cavitation coefficient (σ_0) as shown in the following equation.

$$\sigma > \sigma_0$$

where, $\sigma = (H_2 + 10) / (H_1 - H_2) = 2.54$

H_1 = (static head) - (pipe loss head)=15.666-0.053=15.61m

H_2 = (W.L. in tunnel) - (E.L. of stilling well bottom)=90.834-82.450=8.38m

$\sigma_0 = 0.2 \sim 0.4$

Therefore, the cavitation phenomena will not occur in this case.

(vii) Control system

The main valve operation is normally controlled from the valve control panel provided in the control room by means of remote control, and the local valve control panel located adjacent to the valve is used at the time of inspection/adjustment. The valves are operated to suit to the water demands vs. the accumulated discharge water; the calculation of discharge is based on information from water level detecting devices provided in the reservoir and beside the stilling well along with valve opening position meters.

The guard valve for main valve is opened/closed by manual operation device located on the floor of E.L.93.050.

4.7 Operation and Maintenance Plan

4.7.1 Operation and Maintenance of Project Facilities

Upon construction completion of the Project facilities, CRM will hand over the transmission line between the Daule-Peripa substation and the Severino substation to INECEL for operation and maintenance, and will conclude a contract with INECEL for bulk purchase of electric energy with a contracted unit price per kwh. Also, the access roads will be handed over to the Ministry of Public Works (MOP) for maintenace because the access roads once used for construction purpose are intended to be used by local people as a public road as well as by the operation and maintenance staff of the Project for access to the Project facilities. Therefore, CRM will be responsible for operation and maintenance of the remaining Project facilities.

The operation and maintenance of the remaining Project facilities will be done by force account of CRM as a principle in the following manner.

The Severino Project office which is used for construction supervision during the construction of the Project facilities will become a Severino Operation and Maintenance Center. Chief of the Severino O&M Center will be appointed by CRM. The Severino O&M Center is responsible for the following.

- Operation of the Severino pumping station in accordance with an operation manual, based on such data as reservoir water levels of Daule-Peripa, La Esperanza and Poza Honda, discharge data at La Esperanza and Poza Honda including diversion discharge from Poza Honda to Mancha Grande.

- Water demand data are collected at the Severino O&M Center through the La Esperanza dam O&M office for demands in the Chone river basin and through the Poza Honda dam O&M office for demands in the Portoviejo river basin.

- The operation manual of the Severino pumping station will be established during the construction period under the following conditions.

(1) All the water demands should be met with the highest guarantee.

(2) Operation hours of the Severino pumping station should be kept in minimum to save energy cost for pumping.

(3) La Esperanza reservoir water level should be kept as high as possible to reduce the pumping head resulting in less energy cost at the pumping station.

(4) Spill-over from the dams, especially from the Poza Honda dam should be limited to the minimum, making the most use of the natural flows into the dams.

- Instruction to the Conguillo O&M branch office of a required discharge to be diverted from Daule-Peripa to La Esperanza.

- Instruction to the Poza Honda O&M branch office of a required discharge to be diverted from Poza Honda to Mancha Grande.

- Maintenance of the electro-mechanical works of the Severino pumping station and the Severino discharge penstock in accordance with the maintenance manual to be established based on the recommendations of the equipment manufacturers.

- Maintenance of the civil and architectural works of the Severino pumping station, the Severino discharge penstock, the Severino head tank, the Severino open channel with inspection road and the diversion tunnel to Poza Honda including the Caña Dulce tunnel inlet and the Los Cuyuyes tunnel outlet.

- To inform the CRM headquater in Portoviejo of the operation and maintenance of the Project on a daily, weekly and monthly basis in a pre-established format.

The Conguillo branch office which is used for construction supervision will become a Conguillo O&M branch office, which is responsible for the following.

- Operation of the Conguillo valve chamber at the inlet of the diversion tunnel to La Esperanza in accordance with the operation manual and the instructions about a required diversion discharge given by the Severino O&M Center.

- Report on a daily basis the water level of Daule-Peripa to the Severino O&M Center.

- Maintenance of the electro-mechanical works of the Conguillo inlet in accordance with the maintenance manual to be prepared based on the recommendations of the equipment manufacturers.

- Maintenance of the civil and architectural works of the Conguillo inlet, the Conguillo valve chamber, and the diversion tunnel to La Esperanza including the Membrillo outlet and the outlet open channel.

- Maintenance of the tunnel inlet approach channel by dredging and of the inlet water surface surrounded by the trash boom by removing aquatic plants and other floating materials.

- To inform the Severino O&M Center of the Conguillo operation and maintenance records on a daily, weekly and monthly basis.

The Poza Honda branch office which is used for construction supervision will become a Poza Honda O&M branch office, which is responsible for the following.

- Operation of the Poza Honda valve chamber at the inlet of the diversion tunnel to Mancha Grande in accordance with the operation manual and the instructions about a required diversion discharge given by the Severino O&M Center.

- Report on a daily basis the water level of Poza Honda to the Severino O&M Center.

- Maintenance of the electro-mechanical works of the Poza Honda inlet in accordance with the maintenace manual to be prepared based on the recommendations of the equipment manufacturers.

- Maintenance of the civil and architectural works of the Poza Honda inlet, the Poza Honda valve chamber, and the diversion tunnel to Mancha Grande including the Mancha Grande outlet and the outlet open channel.

- To inform the Severino O&M Center of the Poza Honda operation and maintenance records on a daily, weekly and monthly basis.

The proposed organization of CRM for Project operation and maintenance is shown in Fig. 4.7.1.

4.7.2 Operation and Maintenance Cost

The operation and maintenance cost of the Project is composed of the personnel cost, O&M equipment cost, vehicles, office running cost and energy cost for pumping.

The O&M cost except the energy cost is estimated to be US$ 820,000/year as shown in Table 4.7.1.

The energy cost is also estimated to be US$2.69 million/year as shown in Table 4.7.2 at the demand level of 2020 onward. The energy cost in 2002, the first operation year of the Project, as well as in 2010 and 2015, is estimated to be US$1.55 million/year, US$1.93 million/year and US$2.28 million/year, respectively, on the basis of the following.

Year	Raw Water Requirement for Water Supply of Poza Honda System (MCM/year)	Difference (MCM/year)
2002	22.1	89.9
2010	51.9	60.1
2015	79.4	32.6
2020	112.0	0

Year	Water Volume to be pumped (MCM/year)	Energy Cost (US$ million/year)
2002	123.1	1.55
2010	152.9	1.93
2015	180.4	2.28
2020	213.0	2.69

The total operation and maintenance cost is thus estimated as follows.

Year	O&M Cost (US$ million/year)
2002	2.37
2010	2.75
2015	3.10
2020	3.51

Chapter 5

CONSTRUCTION PLAN
AND
SCHEDULE

Chapter 5 CONSTRUCTION PLAN AND SCHEDULE

5.1 General

A construction plan of the project is prepared on the basis of the detailed design discussed in the preceding chapters, giving an outline of possible procedures, construction sequences, methods and types of plant and equipment to implement the construction works. The construction works will be divided into three packages as shown below and will be executed by the contractor selected by international competitive tenders for respective packages. As for the engineering services, a consultant will be required to assist the CRM for the execution of the project on the construction supervision stage.

a. Package 1: Civil Works for Daule-Peripa ~ La Esperanza Transbasin

b. Package 2: Civil Works for La Esperanza ~ Poza Honda Transbasin and Poza Honda ~ Mancha Grande Transbasin.

c. Package 3: Electrical and Mechanical Works for Daule-Peripa ~ La Esperanza, La Esperanza ~ Poza Honda and Poza Honda ~ Mancha Grande Transbasins.

The Package 3 includes the following three sections:

- Section-1 : Severino Pumping Station
- Section-2 : Conguillo Inlet
- Section-3 : Poza Honda Inlet

5.2 Construction Plan

5.2.1 Basic Conditions

The construction method and sequence are planned on the basis of the mode of construction and the target schedule of construction. Availability of construction forces, weather condition, geological and topographic conditions at the site and the mechanized construction method are taken into consideration.

The commencement of the construction works is scheduled in June 1997 and the Project is planned to be ready for operation in November 2001, giving a construction period of 4.5 years (54 months).

With regard to the workable days, 240 days are assumed in a year for earthworks. Workable days for concrete and tunnel works are planned to be 252 days and 276 days per year, respectively. As for the daily working hours, one 8 hours shift per day is applied for earthwork and concrete work, and two 10 hours shift per day is applied for tunnel work.

5.2.2 Preparatory Works and Construction Facilities

(1) Access Road

The road between Guayaquil and Portoviejo is about 200 km and the entire length is an asphalt pavement road. The access to the project site from Portoviejo is available for passing the existing pavement road for Rocafuerte-Tosagua, San Plácido-Pichincha and Santa Ana-Poza Honda. However, the permanent access roads are required to connect the particular work sites from the existing roads.

The permanent access roads will be constructed at early stage of the construction as a temporary use and a haulage. For the Package 1 work, the access road of about 25 km long will be constructed from Buenaventura to Conguillo inlet, El Guasmo work adit and Membrillo outlet.

The Package 2 work requires about 31 km long access road in total, comprising of Severino access road, Caña Dulce inlet access road, La Seca access road, Los Cuyuyes access road and Poza Honda inlet access road.

(2) CRM Base Camp and Temporary Buildings

The CRM base camp is planned to be located 800 m apart from the pumping station along the Severino access road. The CRM base camp comprises of main office, branch offices and housing for campground. The CRM base camp will be constructed at early stage of the construction to supervise and manage the project. The permanent resident quarters will be used for the operational and maintenance staff after the commissioning of pumping station.

The temporary buildings such as a contractor's office, quarters, a repair shop, a warehouse, labor quarters, etc. will be mainly constructed at the Severino pumping station site, Poza Honda, Mancha Grande, Membrillo and Conguillo.

(3) Power Supply System

The electric power supply for the construction and camp use is planned to be done by diesel generator provided by each package contractor. The power supply system for the main base camp is planned to be 13.8 kV distribution line extended from the proposed transmission line connected to the Severino pumping station.

The diesel generator sets will be provided at each work adit and the Severino pumping station site. The distribution line covered on all project area is not considered, since the electric demand sites are isolated each other.

(4) Water Supply System

The water supply system for the construction use and domestic use at base camp is planned at each project package. The water sources, the location at the work adit portals are taken into consideration for providing water supply facilities. The water sources and locations are as follows: Conguillo river, El Guasmo river, Membrillo river, Severino river, Pata de Pájaro river, Poza Honda reservoir and Mancha Grande river.

(5) Telecommunication System

The telecommunication systems consisting of radio communication system and wireless telephone system (micro wave) will be installed for construction use and operation and maintenance. These facilities will be provided by Package 2 contract.

The wireless radio communication system is planned to be VHF radio equipment and will be established for communications among the CRM's main office and the branch offices, while the wireless telephone system will be installed between Calceta transmission station and CRM's main office at Severino.

The contractor may use the above telephone system as an emergency purpose. The radio communication system will be installed by each package contractor. The wired telephone facilities will be required within each tunnel work site including all work adit and open construction sites.

5.2.3 Major construction works

(1) Pumping Station

The pumping station is planned to be located at Severino, upstream of the La Esperanza reservoir. The La Esperanza dam impounding will be reached at the H.W.L 66.00 m before starting the pumping station construction. The lowering of reservoir water level is required to be at EL.45.0 m and a temporary cofferdike will be provided in front of the inlet portion. The open construction work is necessary for the pumping station construction.

The first stage construction consists of open excavation, substructure concrete and embedded metal and pipe installation. The second stage construction consists of structural concrete for walls, piers and beams, encasement concrete of penstock, superstructure concrete and overhead crane installation. The architectural work will follow the structural concrete work and carried out in parallel with the superstructure work.

The inlet channel concrete work and the removal of cofferdike is scheduled to be made during two months from April to May 2001, by lowering again the La Esperanza dam reservoir level below EL.45.0 m. The impounding level to EL.58.5 m will be required for wet testing of pumps and the impounding-period is estimated at four months diverting the water from the Daule-Peripa.

The excavation work will be carried out by 21 ton bulldozer and 32 ton bulldozer with ripper. The soft rock will be excavated by a combined method of low bench blasting and ripping. The excavated material will be loaded by 2.2 m^3 tractor shovel into 11 ton dump truck and hauled to the spoil area located along the open channel route.

The concrete plant will be installed near the head tank area or the beginning point of open channel. The concrete will be transported by 3.0 m^3 agitator truck from the concrete plant of 0.75 m^3 x 2, and placed by 1.0 m^3 concrete bucket with 30 ton truck crane and 45 m^3/hr concrete pump car. Two nos. of fixed type tower crane with 1 ton lifting load and 30 m working radius will be provided for handling formwork material, reinforcement bars and so on.

The embedded pipes and penstock below EL.70.0 m will be installed at the early stage of pumping station work, using 30 ton truck crane and fixed tower crane.

(2) Penstock

The penstock installation is divided two stages. The penstock under backfilling of EL.70.00 m will be installed for three months from July to September 1999. The remaining length to connect the head tank is scheduled to be installed from October 2000 to January 2001.

The open excavation work and concrete work are the same method applied for the pumping station. The saddle concrete slab will be placed before the installation of penstock. The steel pipe segment of 6 m long will be transported from the Guayaquil port to the stockyard. The steel pipe segments will be installed using inclined machine, dolly and 30 ton truck crane. And then the pipes will be set in position and adjusted to the correct alignment for joining by welding. As for the flat portion, the saddle concrete and anchor bars will be first provided. The ring girder will be set to the anchor bolt.

(3) Open Channel

Before starting the excavation work, the temporary access road will be constructed on the right side of open channel alignment. The haulage road to the spoil area will be branched from the above access road. This temporary access road will be also used for the La Esperanza - Poza Honda diversion tunnel work.

The excavation work above planned inspection road surface will be carried out using 21 ton bulldozer and 32 ton bulldozer with ripper. The material will be loaded by 2.2 m^3 tractor shovel into 11 ton dump truck for hauling to the spoil area. As for the channel section, the excavation work will be made by 11 ton bulldozer, 0.6 m^3 backhoe and rock breaker with 0.6 m^3 backhoe. The final stage excavation adjacent to the channel slope will be made using pick hammer and manpower trimming and finishing.

The embankment section will be first filled entirely, and then the channel section will be excavated. The embankment work will be made only during dry season from June to December.

The concrete placement is planned to be made by a conventional method using a portable metal form. The slab concrete will be first placed, and then the slope concrete will be placed at two lifts. The metal forms will be installed and removed by 20 ton truck crane with manpower. The concrete will be transported by 3.0 m^3 agitator and handled by 0.5 m^3 concrete bucket and one wheel buggy with manpower.

Before concrete placement, the underdrain of 100 mm dia. perforated pipe with sand and gravel is provided at the bottom. The drainage layer of 100 mm thick on the bottom will be filled and compacted by manpower.

Syphon concrete work will be made by a conventional method using 45 m^3/hr concrete pump car and 1.0 m^3 bucket with 30 ton truck crane.

(4) Inlet and Outlet Work

- Daule-Peripa ~ La Esperanza Diversion Tunnel

The Conguillo access road will be constructed to connect the inlet structure. The common and weathered rock will be excavated by 21 ton bulldozer and 32 ton bulldozer with ripper. After the open excavation, the inlet shaft will be sinked downward. The rock excavation will be made by 7 m^3 crawler drill and 2.9 m^3/min sinker drill. The broken rock will be gathered by 0.4 m^3 tractor shovel and 0.3 m^3 backhoe and loaded into a deposit bucket. The deposit bucket will be pulled up by 30 ton truck crane and discharged into 11 ton dump truck vessel.

Succeeding to the shaft excavation, the inlet tunnel will be driven by blasting method and the broken rock will be loaded by 0.4 m^3 tractor shovel into deposit bucket handled with 30 ton truck crane. The concrete bulkhead will be demolished carefully after the confirmation of the interior water in the previous tunnel. The demolishing will be made by manpower with hand type concrete breaker and pick hammers.

The concrete will be discharged into 1.0 m^3 concrete bucket and handled to the concrete hopper by 30 ton truck crane and distributed into the placing spot through chutes from the hopper. The concrete lining of inlet tunnel will be carried out by means of concrete placer applied for the diversion tunnel lining work.

The dredging of inlet channel will be carried out by a 200 HP class dredger and the sand material will be delivered through 200 mm dia.delivery pipes. The delivered sand will be dried and then loaded by 0.6 m^3 backhoe into 11 ton dump truck for hauling to the spoil bank.

The outlet structures of tunnel portal are scheduled to be constructed from January 2001 after constructing temporary coffer dams. The remaining tunnel of 10 m long at the outlet will also be driven and concrete lined by the same method applied for the diversion tunnel work. However, the outlet channel construction will require the water lowering of La Esperanza dam reservoir.

- La Esperanza ~ Poza Honda Diversion Tunnel

Caña Dulce inlet structures between the open channel and the diversion tunnel is scheduled to be constructed during dry season of 2000. The outlet structures are scheduled to be made for two months from July to August 2001, after lowering Poza Honda reservoir.

- Poza Honda ~ Mancha Grande Diversion Tunnel

The inlet facilities are designed to be similar with the Conguillo inlet facilities. The shaft excavation will be carried out by a sinking method as applied for the Conguillo shaft. The tunnel driving will be made by blasting method and the excavated material will be loaded by 0.4 m^3 tractor shovel into deposit bucket.

The inlet channel and a part of inlet tunnel are scheduled to be made for two months of July and August 2001, after lowering the Poza Honda reservoir. The impounding period of Poza Honda reservoir is to be one month of October 2001, after the completion of the inlet channel construction.

(4) Diversion Tunnel Work

A horse-shoe type tunnel with concrete lining is planned for all tunnel construction such as Daule-Peripa ~ La Esperanza tunnel (8,296 m long, 3.7 m dia.), La Esperanza ~ Poza Honda tunnel (11,417 m long, 3.5 m dia.) and Poza Honda ~ Río Mancha Grande tunnel (4,095 m long, 2.5 m dia.). Three tunnels are mainly aligned in massive and soft sandy mudstone with a compressive strength of about 60 kg/cm^2 and anticipated to encounter neither fault nor water problem. The tunnel construction will be a critical path of the construction work. In order to shorten the construction period, the following work adits are required for each tunnel considering the construction sequences:

(a) Daule-Peripa ~ La Esperanza tunnel: Conguillo work adit (183 m), El Guasmo work adit (350 m) and Membrillo work adit (137 m)

(b) La Esperanza ~ Poza Honda tunnel: La Seca work adit (532 m) and Los Cuyuyes work adit (130 m)

(c) Poza Honda ~ Río Mancha Grande tunnel: Poza Honda work adit (168 m)

The work adit is designed to be a vertical wall and arch roof type, 4.0 m wide x 4.0 m high. The supporting system is to be a rock bolting and shotcrete method applied for the diversion tunnel supporting. The tunnel excavation is planned to be made by applying a full face attack method. The drilling rock will be carried out by 4 nos.leg drill with portable deck. The broken rock will be loaded by 0.4 m^3 inclined type muck loader into 2 nos. of 4.5 m^3 muck car, and then the muck cars will be pulled up outsite of tunnel portal by using 150 kW winch. The broken rock will be loaded by 1.2 m^3 tractor shovel into 8 ton dump truck. As for the Poza Honda work adit, 3.0 m^3 muck car and 100 kW winch will be used.

Typical tunnel cross section is planned to be four sections such as type I, II, III and IV according to the geological conditions and NATM tunnel supporting system will be applied. A full-face attack method is applied for driving the tunnel, while hauling of broken rocks is to be a rail haulage method. Three tunnel faces will be attacked simultaneously for La Esperanza~Poza Honda and Daule-Peripa~La Esperanza tunnels using three sets of tunnel equipment crew. As for the Poza Honda~Río Mancha Grande tunnel, two tunnel faces will be provided.

Tunnel excavation work will be carried out using an arm type mechanical tunneling machine with a cutting head, considering the geological conditions and the following supporting system comprising of rock bolting and shotcreting. Broken rocks will be loaded into 4.5 m^3 and 3 m^3 muck cars with the 8 ton and 6 ton battery locomotives for hauling respectively. The broken rocks carried to the open yard by those equipment will be loaded by 1.2 m^3 tractor shovels into 8 ton dump trucks and will be hauled to the spoil bank.

Just after finishing one cycle excavating operation of 1.2 m progress, a primary shotcrete of 100 mm thick with 100 x 100 wire mesh and rock bolts of 2.0 m long will be provided. As for the lower compressive strength sections and fault zones, steel H beam ribs and additional shotcreting are provided.

A concrete lining thickness is designed to be 300 mm except for the shotcrete supporting thickness. The concrete lining work will be performed in parallel with the tunnel excavation works for La Esperanza - Poza Honda tunnel and Daule-Peripa~La Esperanza tunnel according to the NATM analysis. The concrete lining work of Poza Honda~Río Mancha Grande tunnel will be made after the completion of every 200 m long tunnel excavation work because of the limited tunnel internal working space area.

Lining concrete will be placed in the arch portion first and then placed in the invert portion. The concrete lining progress rate is planned to be the same progress rate of tunnel excavation to keep 200 m interval, with 12.0 long concrete lining span. The lining progress rate of the Poza Honda~Río Mancha Grande tunnel is planned to be 276 m per month. The concrete will be transported by 3.0 m^3 agitator trucks from the concrete batcher plant, and then discharged into 6 m^3 and 4.5 m^3 concrete placer with 6 ton battery locomotive to transport to the placing spot in the tunnel. The concrete will be placed behind sliding forms of 12.0 m long by means of compressed air from the concrete placer. The invert concrete placing will be carried out using 3 m^3 agitator cars.

5.3 Construction Schedule

5.3.1 Project Schedule

The construction period required for the Project is planned to be in 4.5 years including three contract packages. The construction works are scheduled to be commenced at the beginning of June 1997 and be completed by the end of November in 2001.

The financial arrangement of foreign loan is expected to be concluded in ten months period after the submission of a formal loan application. The arrangement of foreign loan will be completed before starting the selection of consultant. Financial arrangement of national budget should also be concluded at the same time of foreign loan arrangement.

The implementation schedule is shown in Figure 5.1 and the construction schedule is shown in Figure 5.2. The land acquisition and compensation for the Project will be settled by CRM prior to the commencement of the construction.

The following basic schedule is established in order to secure the commissioning target of the Project.

(a)	Financial arrangement for the construction work	:	10 months from April 1995 to January 1996
(b)	Selection of a consultant	:	3 months from February 1996 to April 1995
(c)	Tendering and contracts including prequalification		
	Package 1	:	13 months from May 1996 to May 1997.
	Package 2	:	13 months from May 1996 to May 1997
	Package 3	:	11 months from July 1997 to May 1998

(d) Construction works :

Package 1	:	54 months from June 1997 to November 2001
Package 2	:	54 months from June 1997 to November 2001
Package 3	:	42 months from June 1998 to November 2001

(e) Commissioning of the Project : December, 2001

5.3.2 Construction Schedule

The construction schedule of the Project is shown in Figure 5.2 by bar chart. The work schedule for the major items are summarized by year as follows:

(1) Package 1

1997

(a) Award of contract for Package 1
(b) Mobilization and construction of site facilities
(c) Conguillo access road earthwork

1998

(a) Work adit construction (Conguillo, El Guasmo and Membrillo)
(b) Conguillo access road earthwork
(c) Access road construction (El Guasmo and Membrillo outlet)
(d) Diversion tunnel (excavation and concrete lining)

1999

(a) Diversion tunnel construction
(b) Conguillo access road construction

2000

(a) Inlet excavation work
(b) Dredging of inlet channel portion
(c) Intake shaft and inlet tunnel work
(d) Diversion tunnel construction

(e) Conguillo access road construction

2001

(a) Outlet channel construction (La Esperanza reservoir lowering)
(b) Diversion tunnel construction
(c) Demobilization

(2) Package 2

1997

(a) Award of contract for Package 2
(b) Mobilization and construction of site facilities
(c) Los Cuyuyes and Poza Honda work adits excavation
(d) Access road construction (Severino, Caña Dulce, La Seca, Los Cuyuyes and Poza Honda inlet)

1998

(a) Excavation work of Severino pumping station and open channel
(b) La Esperanza - Poza Honda tunnel construction
(c) Poza Honda - Mancha Grande tunnel construction
(d) Work adit construction (La Seca, Los Cuyuyes and Poza Honda)
(e) Access road construction (Severino, Caña Dulce inlet, La Seca and Los Cuyuyes)

1999

(a) Pumping station concrete work
(b) A port of penstock encasement concrete work
(c) Penstock civil works
(d) Severino open channel construction
(e) Tunnel construction for La Esperanza - Poza Honda and Poza Honda - Mancha Grande.
(f) Los Cuyuyes access road construction

2000

(a) Backfilling behind pumping station building
(b) Superstructure concrete work and building works
(c) Concrete works of penstock line
(d) Severino head tank construction

(e) Open channel construction (channel concrete and syphon)

(f) Diversion tunnels construction

(g) Poza Honda intake shaft and tunnel construction

2001

(a) Removal of coffer dike and inlet channel construction (La Esperanza reservoir lowering).

(b) Building works

(c) Open channel concrete work and syphon construction

(d) Diversion tunnels construction

(e) Poza Honda inlet construction

(f) Demobilization

(3) Package 3

1998

(a) Award of contract for Package 3

(b) Design, manufacturing and delivery

1999

(a) Preparatory works

(b) Embedded pipes and penstock installation in the substructure concrete

(c) Transmission line construction

2000

(a) Installation of overhead cranes, valves, pipes, pumps and motors, gates and crane, trashracks, surge tank and penstock.

(b) Transmission line construction

2001

(a) Installation of motors, switchgears and transformers

(b) Transmission line construction

(c) Substation construction

(d) Mechanical works for Conguillo and Poza Honda inlets

(e) Dry and wet tests.

TABLES

Table 1.3.1 General Features of Daule-Peripa Dam

(constructed in 1987)

(1)	Hydrology	
	Catchment area	4,200 km^2
	Annual mean basin rainfall	2,700 mm
	Annual mean inflow	5,000 MCM
	Runoff coefficient	44 %
	Probable max. flood	14,350 m^3/s
(2)	Reservoir	
	Gross storage capacity	5,300 MCM
	Dead storage	1,300 MCM
	Effective storage	4,000 MCM
	Flood water level	EL. 88.0
	Normal high water level	EL. 85.0
	Low water level	EL. 60.0
	Riverbed level	EL. 12.0
	Reservoir area at FWL	290 km^2
	Reservoir area at HWL	270 km^2
(3)	Allocation of Reservoir Capacity	
	Flood space	700 MCM
	Power generation	3,500 MCM
	Irrigation	1,800 MCM
	Water supply	500 MCM
	Use in Manabi province	500 MCM
(4)	Main Dam	
	Type	Zoned earthfill
	Height from foundation	90 m
	Crest elevation	EL. 90.0 m
	Crest length	250 m
	Dam volume	3,000,000 m^3
(5)	Sub-dam	
	Type	Homogeneous earthfill
	Length	18 km
	Average height	10 m (max. 27m)
	Embankment volume	5,900,000 m^3
(6)	Spillway	
	Type, Control structure	Gated overflow weir
	Water conveyance	Open chute
	Energy dissipator	Stilling basin
	Width of overflow weir	59 m
	Overflow weir level	EL. 77.0 m
	Design peak discharge	3,480 m^3/s
	Spillway gates	
	No. of gates	3 No.
	Type	Tainter gate
	Dimensions	H = 8.0 m, W = 17.0 m
(7)	Power facilities (Not yet installed as of end 1993)	
	Installed capacity	65 MW x 2 units = 130 MW
	Annual energy output	510 Gwh (firm)
	Design head	58.2 m
	Design discharge	132.3 m^3/s per unit
(8)	Outlet facilities	
	Tunnel diameter and length	9.0 m, 530 m
	Outlet capacity	400 m^3/s