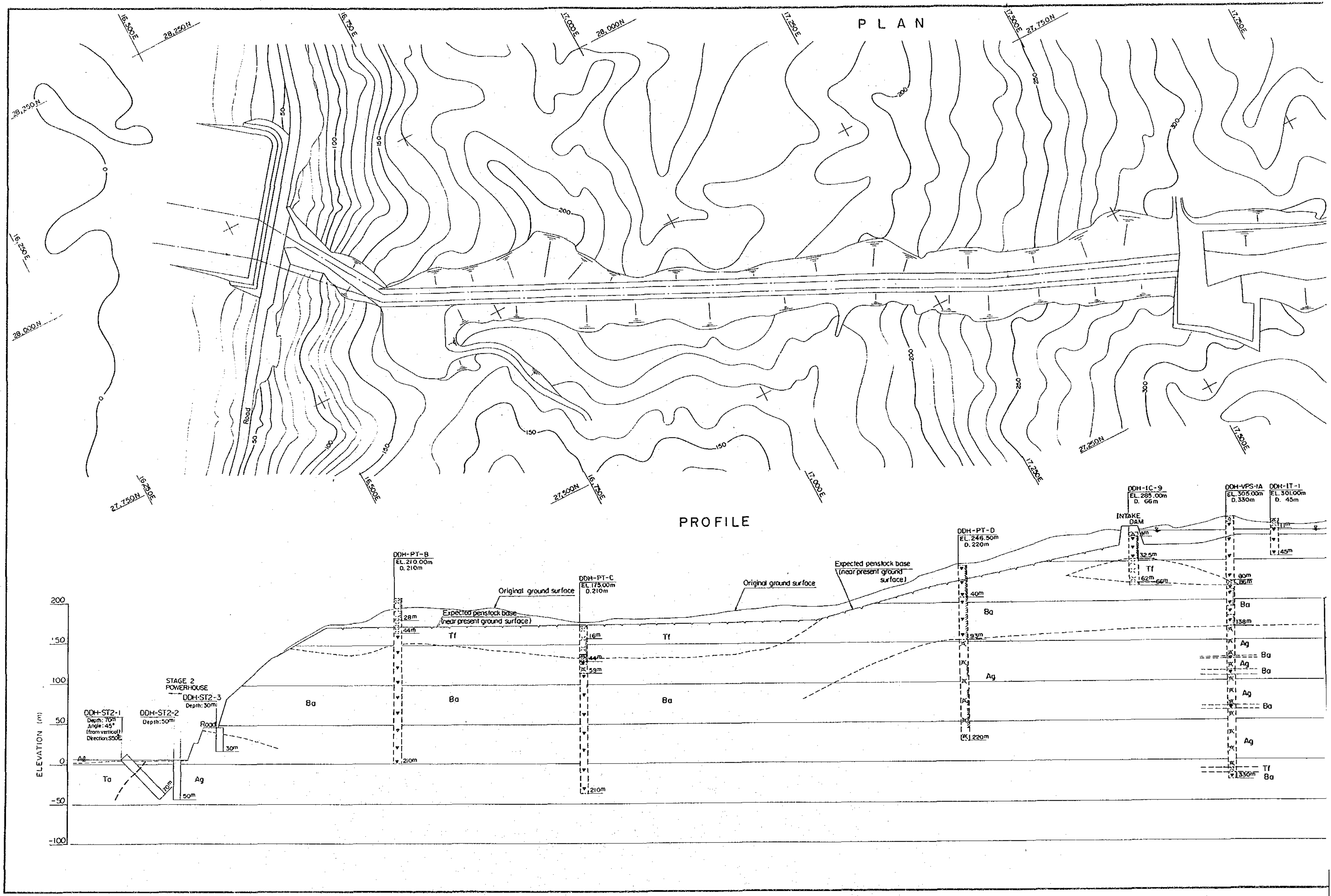
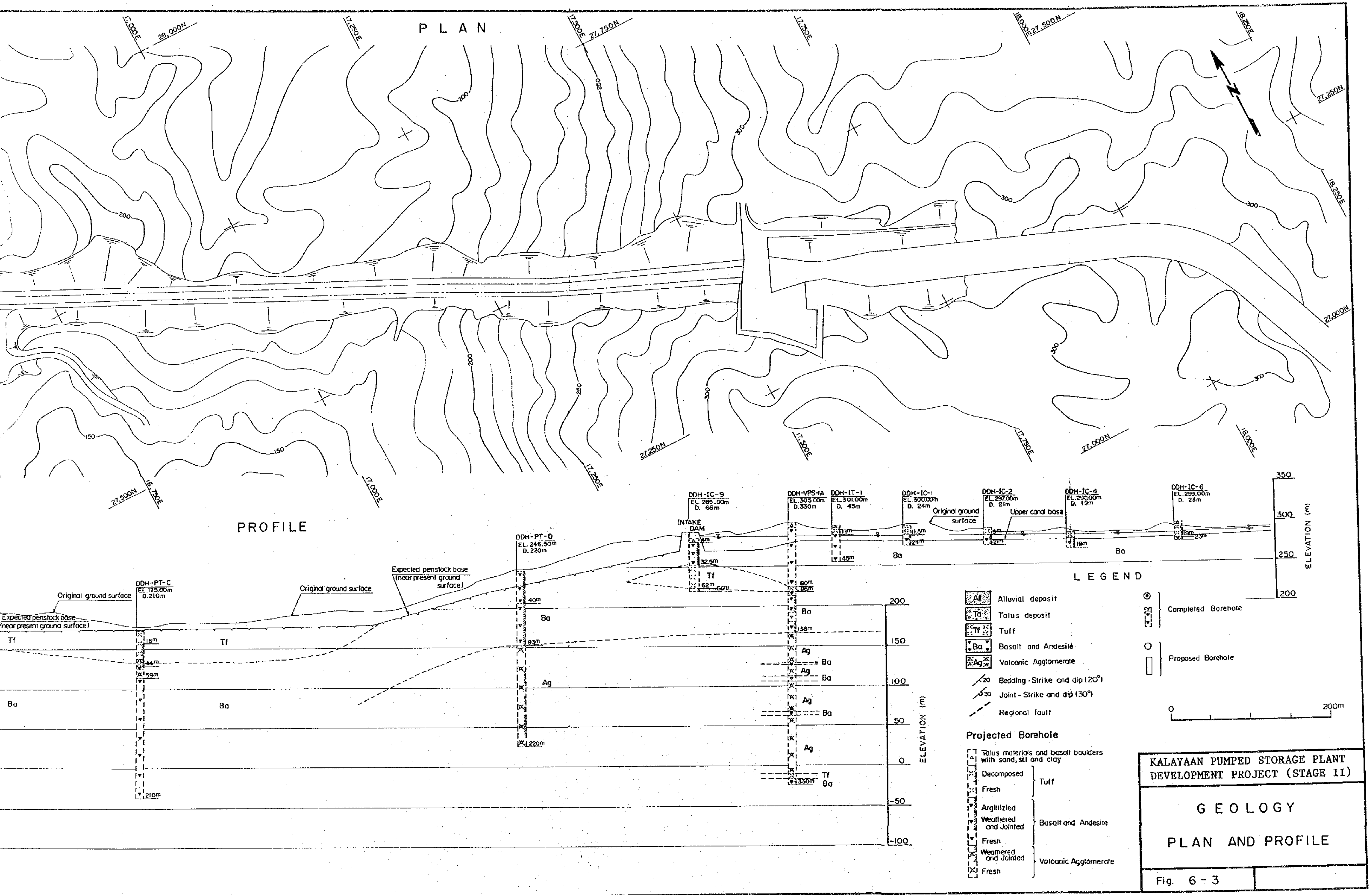

PLAN
16,500E
28,250N
16,750E
17,000E
28,000N
17,250E
17,500E
27,750N
17,750E
28,250N
16,250E
28,000N
Road
27,750N
16,250E
16,500E
27,500N
16,750E
17,000E
17,250E
27,250N
17,500E
PROFILE
DDH-PT-B
EL.210.00m
D. 210m
DDH-PT-C
EL.175.00m
D. 210m
DDH-PT-D
EL.246.50m
D. 220m
DDH-IC-9
EL.285.00m
D. 66m
INTAKE DAM
DDH-VPS-IA
EL.305.00m
D.330m
DDH-IT-1
EL.301.00m
D. 45m
Original ground surface
Expected penstock base
(near present ground surface)
STAGE 2
POWERHOUSE
DDH-ST2-3
Depth: 30m
DDH-ST2-1
Depth: 70m
Angle: 45°
(from vertical)
Direction: S50E
DDH-ST2-2
Depth: 50m
Road
ELEVATION (m)
200
150
100
50
0
-50
-100
Tf
Ba
Ag
Ta
Al



KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

GEOLOGY

PLAN AND PROFILE

Fig. 6 - 3

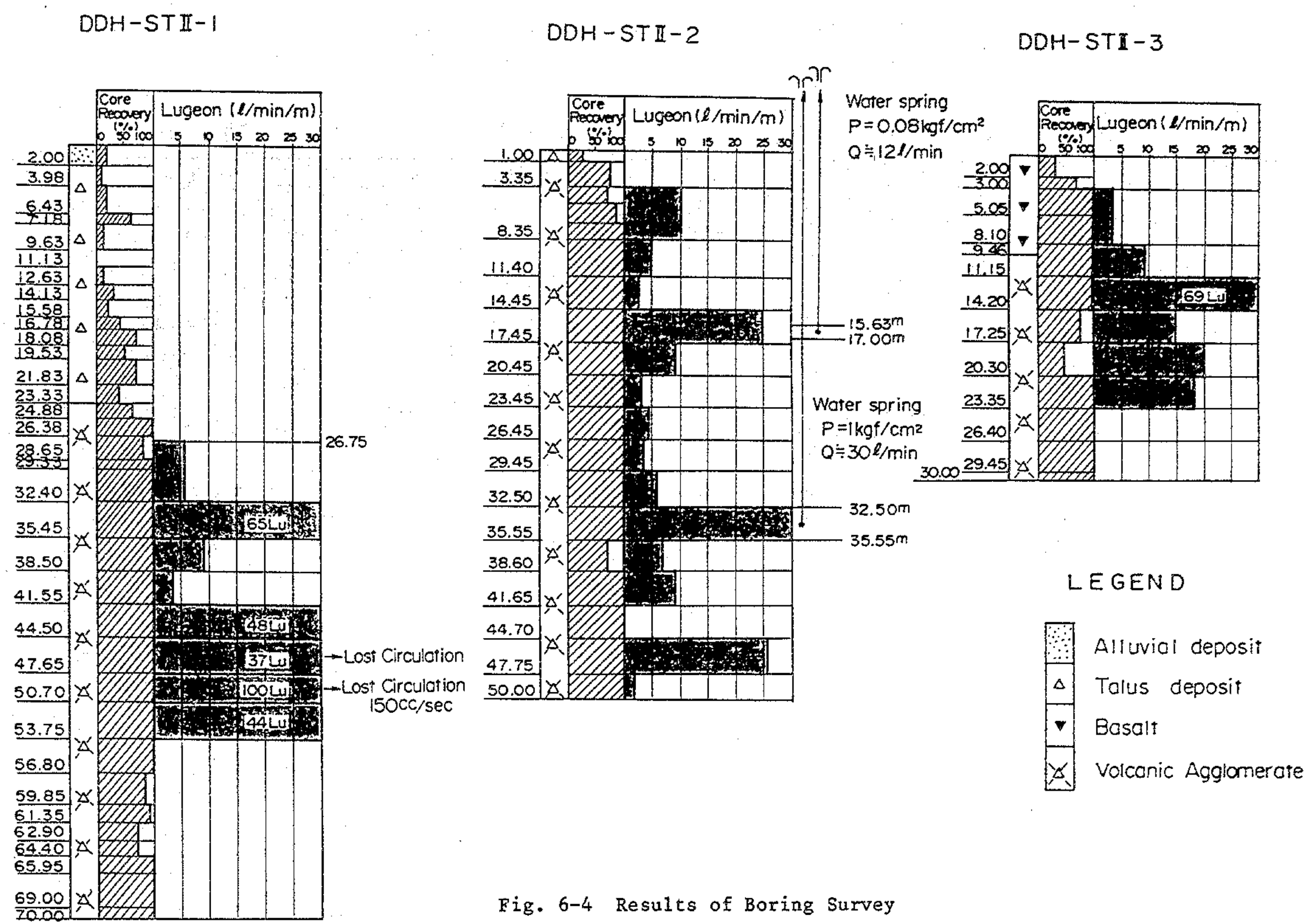


Fig. 6-4 Results of Boring Survey

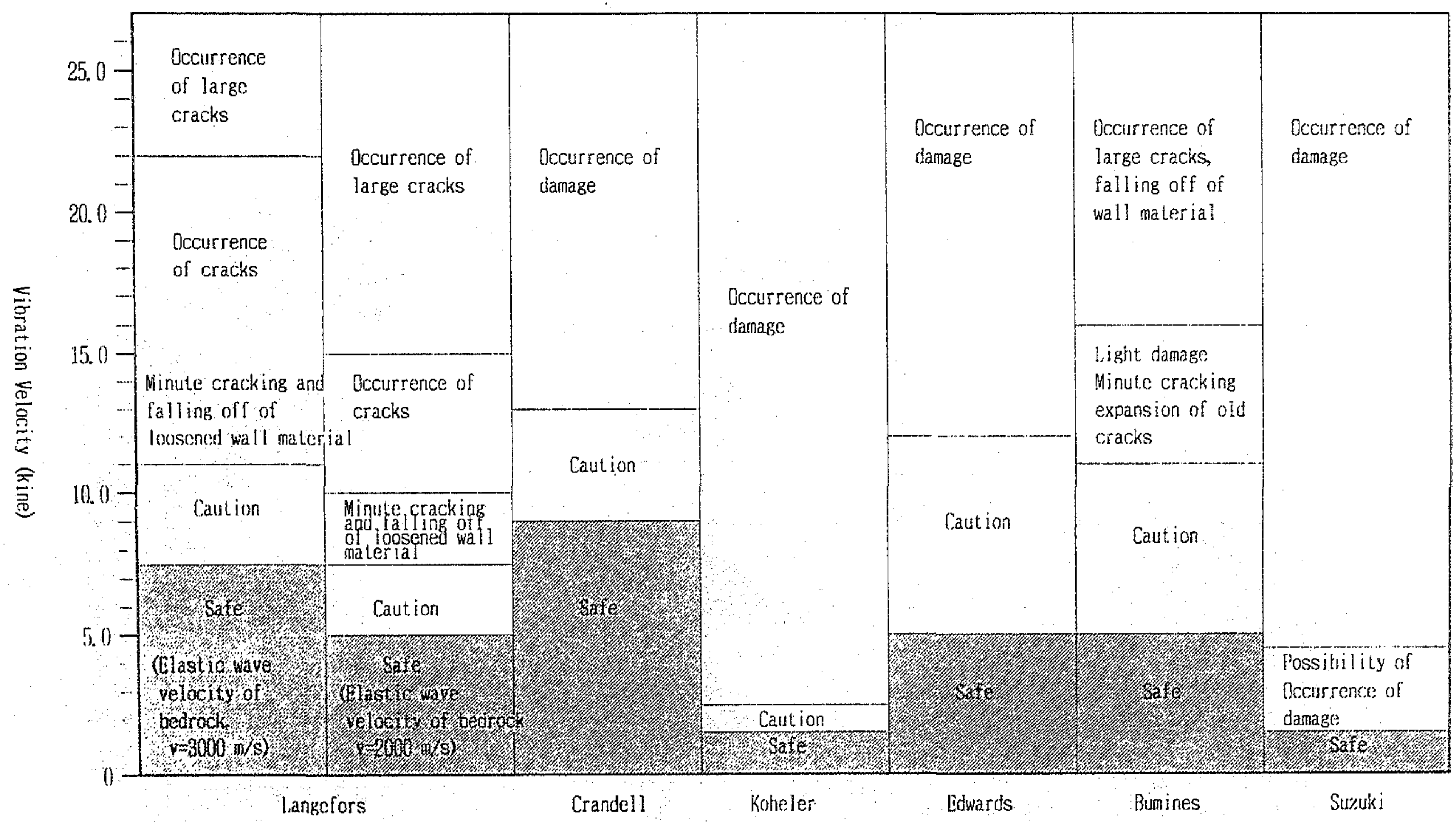
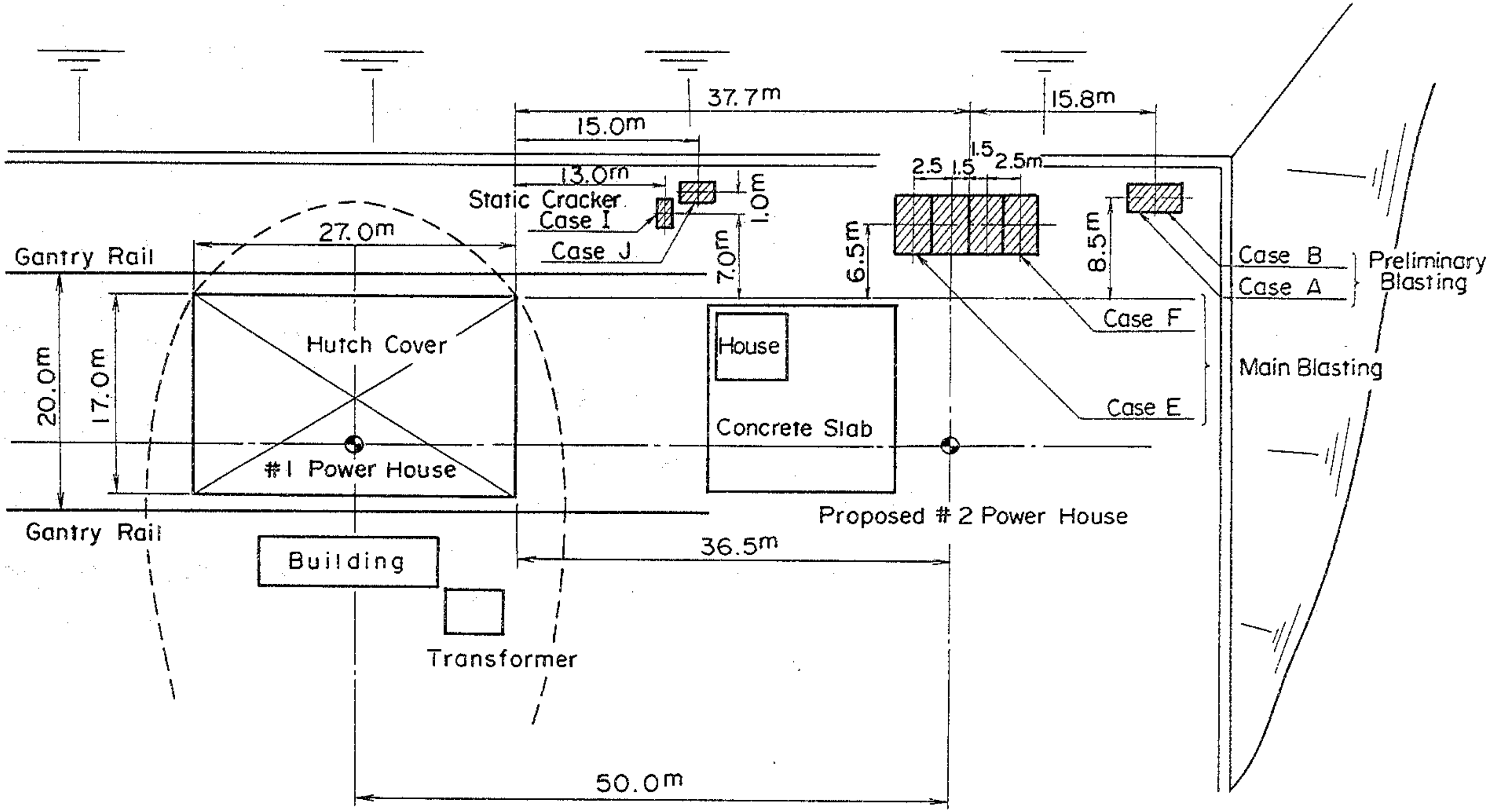


Fig. 6-5 Intensity of Blasting Vibration and Damage Caused



PLAN (S=1/500)

Fig. 6-6 Blasting Test Area

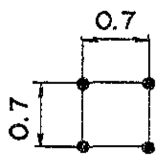
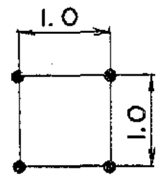
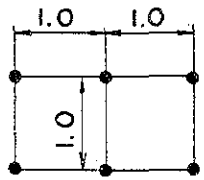
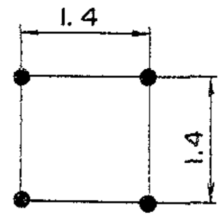
Case	A	B	E	F
Blasting Pattern				
Explosive Used	Conventional Dynamite	Conventional Dynamite	Conventional Dinamite	Conventional Dinamite
Charge	75g x 2.5rods/hole x 4holes = 750g	75g x 4rods/hole x 4holes = 1200g	75g x 4rods/hole x 6holes = 1800g	75g x 7rods/hole x 4holes = 2100g
Depth of Drilling	1.3m	1.3m	1.3m	1.5m
Diameter of Drilling	35mm	35mm	35mm	70mm

Fig. 6-7 Preliminary and Main Blasting Test Pattern

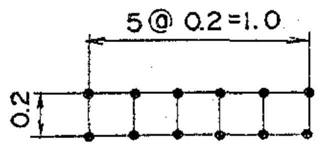
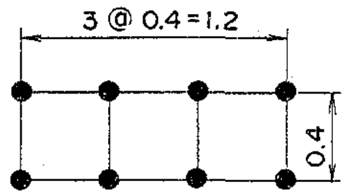
Case	I	J
Blasting Pattern		
Explosive Used	Static Cracker (calmmite)	Static Cracker (calmmite)
Charge	1.36kg/m x 1.5m x 12holes = 24.48kg	5.46kg/m x 1.5m x 8holes = 65.52kg
Depth of Drilling	1.5m	1.5m
Diameter of Drilling	35mm	70mm

Fig. 6-8 Static Cracker Test Pattern

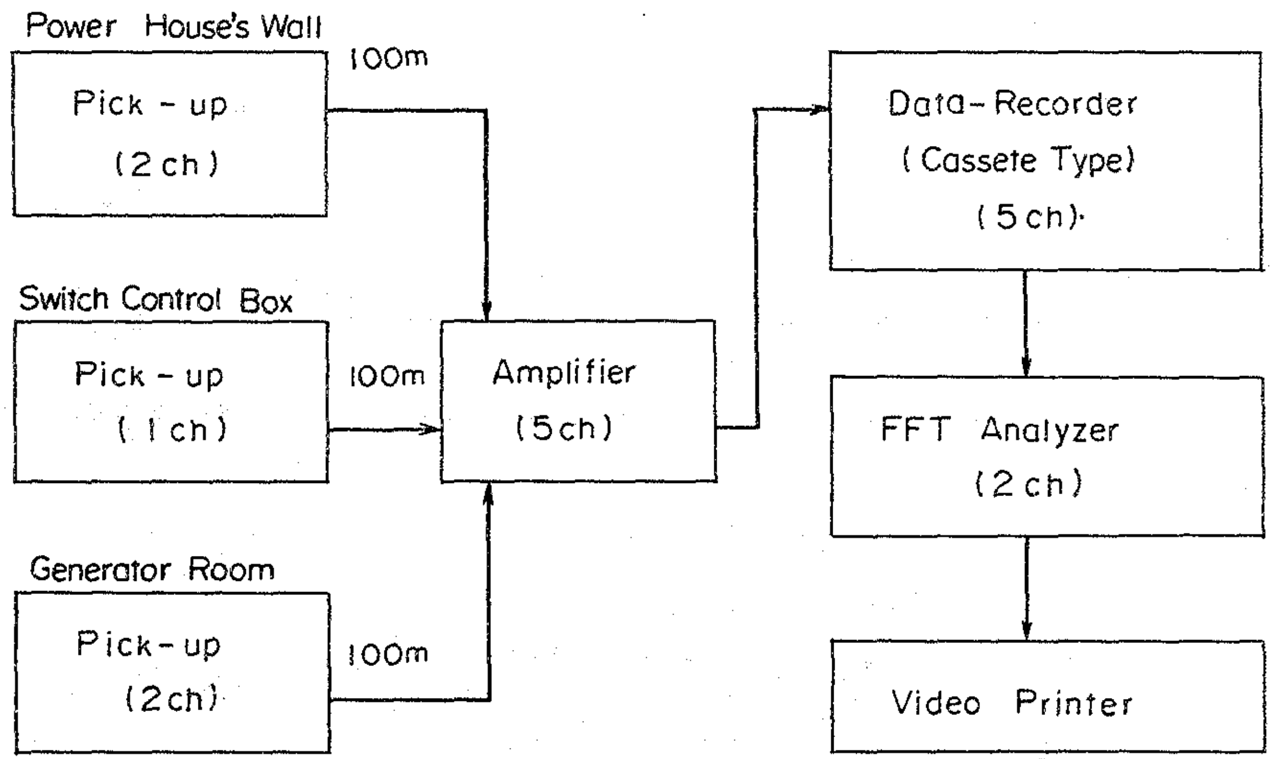


Fig. 6-9 Measuring Instruments Configuration

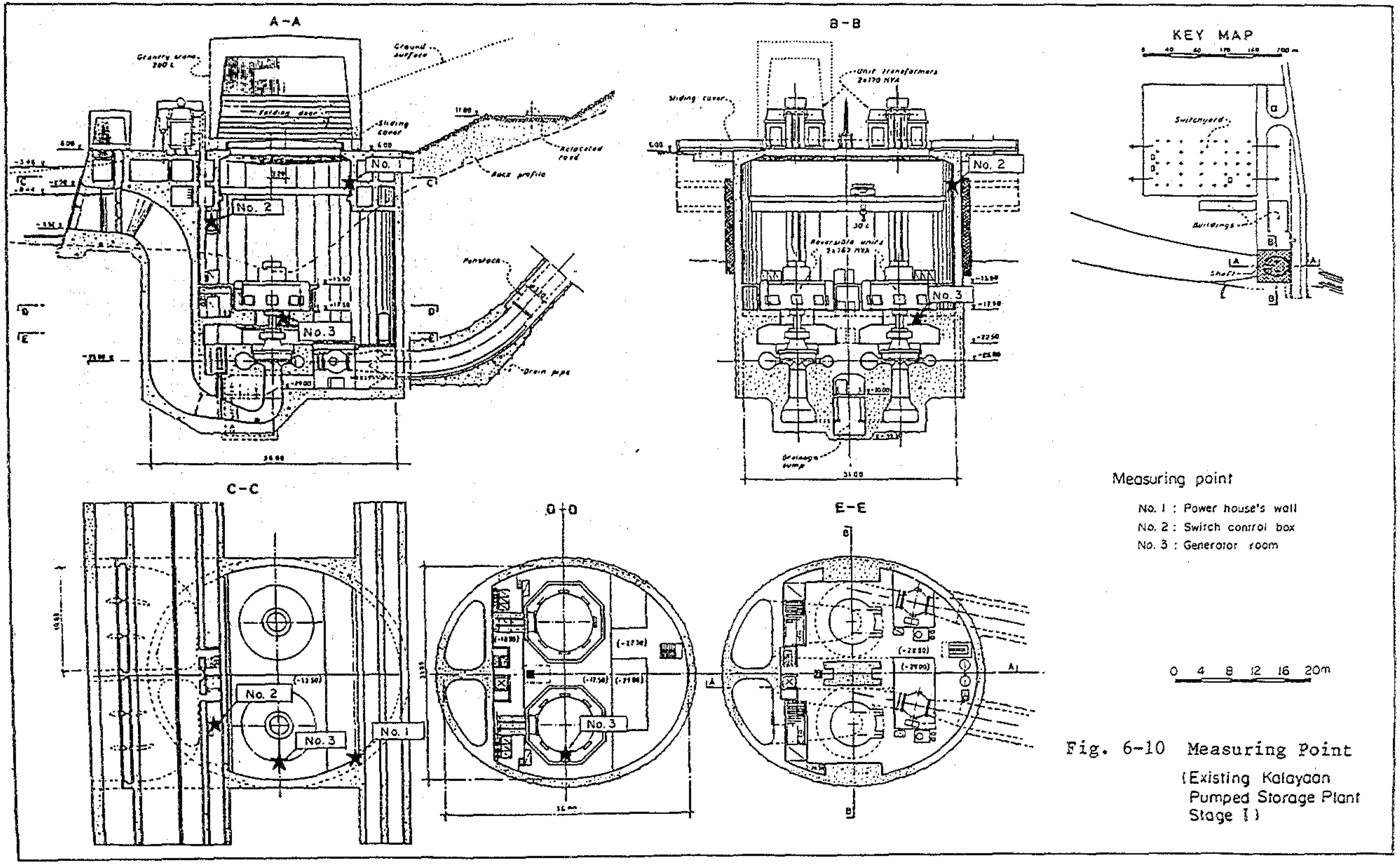


Fig. 6-10 Measuring Point
(Existing Kalayaan Pumped Storage Plant Stage I)

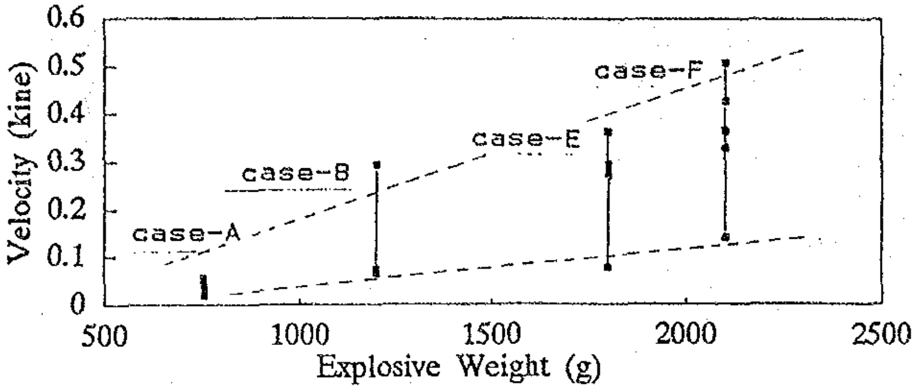


Fig. 6-11 KALAYAAN P.S.P.P. (II) Blasting Test
Explosive Weight - Velocity

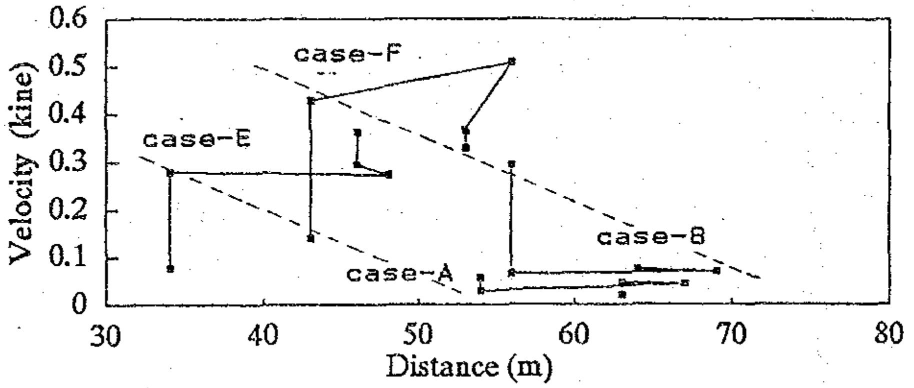


Fig. 6-12 KALAYAAN P.S.P.P. (II) Blasting Test
Distance - Velocity

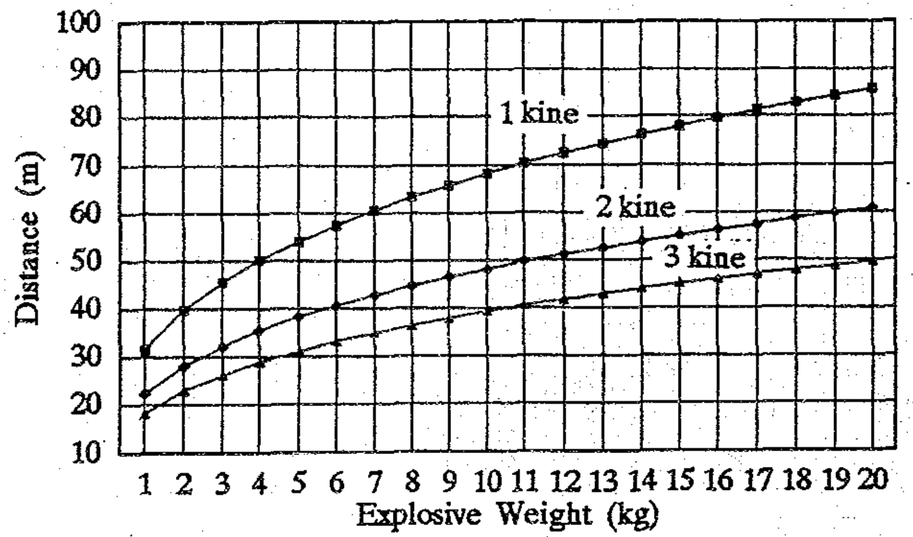


Fig. 6-13 KALAYAAN P.S.P.P. (II) Blasting Test
Explosive Weight - Distance - Velocity

Chapter 7 Earthquake

Chapter 7 Earthquake

7.1 Outline of Characteristics of Seismicity in the Philippines

(1) Earthquake Occurrence Mechanism

The Philippine Islands, as shown in Fig. 7-1, are located near the boundary between two great tectonic plates called the Philippine Sea Plate and the Eurasian Plate. Of the two, the Philippine Sea Plate on the east side is pushed approximately 7 cm annually by the Pacific Plate located further to the east, so that at its boundary with the Eurasian Plate, it sinks under the Eurasian Plate at a rate of approximately 3 cm annually. Further, due to the northeastern-direction component of the Eurasian Plate's tectonic movement, Palawan and Mindoro, and the northern part of the Zamboanga peninsula and the western part of Mindanao repeatedly collide against each other aggressively.

The high seismicity of the Philippines is owed to the interactions of these tectonic plates, relative displacements along the Philippine Trench, and the tectonic movements along other active faults (Fig. 7-2).

(2) Characteristic of Seismicity

The epicenters of 1,182 earthquakes occurring within a radius of approximately 600 km from the Project site at the center during the 93 years from 1897 to 1989 are shown in Fig. 7-3. Figs. 7-4 (1)-(5) show these epicenters according to the magnitudes of the earthquakes.

It is seen from these epicenter distributions that where seismicity is high in the Philippines are eastern Mindanao, Samar, and Leyte situated at the eastern part of the islands, and this is due to the sinking under of the tectonic plate along the Philippine Trench. It may also be seen that other than the above, there are zones of comparatively high seismicities in the vicinities of northern Luzon, Lubang, and Mindoro.

7.2 Design Seismic Coefficient

(1) Evaluation of Maximum Acceleration at the Project Site

An evaluation of the maximum acceleration at the Project site was made by statistical techniques in order to select the design seismic coefficient. The earthquake data used in this case were those obtained from NAPOCOR at the time of the field survey (Jan., 1990) and comprise data of 1,182 earthquakes from 1897 to 1989. In the evaluation of maximum acceleration, four kinds of models indicated below were employed, and the probable earthquake accelerations corresponding to various return periods were obtained from the maximum accelerations calculated from the individual models.

i) Kawasumi's Formula

$$M_k = 2\ (M_n - 4.85)$$

$$Rn = \overline{\ ^2 + \ _n^2}$$

$$R_{100} = \overline{100^2 + \ _n^2}$$

If $\ _n \geq 100$ km:

$$I_n = M_k - 0.00183\ (\ _n - 100) - 4.605\ \log_{10} \frac{\ _n}{100}$$

If $\ _n < 100$ km:

$$I_n = M_k - 0.01668\ (R_n - R_{100}) - 2\ \log_{10} \frac{R_{100}}{R_n}$$

If $I_n \leq 5.5$:

$$\ _n = 0.45 \times 10^{0.5 I_n}$$

If $I_n > 5.5$:

$$\ _n = 18.849 \times 10^{0.2041 I_n}$$

where, M_n: magnitude

: focal depth (km)

$\ _n$: epicentral distance (km)

R_n: hypocentral distance (km)

I_n: Earthquake intensity scale defined by Meteorology Agency of Japan

${}_n$: maximum acceleration (gal)

ii) Okamoto's Formula

$$i = \frac{{}_n + 40}{100} \left(-7.604 + 1.7244\, M_n - 0.1036\, M_n^2\right)$$

$${}_n = 640 \times 10^i$$

where, M_n: magnitude

${}_n$: epicentral distance (km)

${}_n$: maximum acceleration (gal)

iii) Estuva-Rosenbluth's Modified Formula

$${}_n = \frac{110\, e^{0.8M_n}}{R^{1.6}}$$

where, M_n: magnitude

R: hypocentral distance (km)

${}_n$: maximum acceleration (gal)

iv) New Aseismatic Design Method (Class 1 Ground) Formula defined by Ministry of Construction of Japan

$${}_n = 28.5 \times 10^{0.207M_n} \times {}_n^{-0.598}$$

where, M_n: magnitude

${}_n$: epicentral distance (km)

${}_n$: maximum acceleration (gal)

(2) Design Seismic Coefficient

The results of evaluation of maximum acceleration by a statistical technique is ${}_n$ = 80 gal for a return period of T = 1,000 years. Judged by this, it is considered that k_H = 0.10 g is reasonable as the horizontal design seismic coefficient of the Stage II Project.

On the other hand, the horizontal design seismic coefficient used in design of the Stage I Project was k_H = 0.15 g.

Judged comprehensively based on the above, the horizontal design seismic coefficient for the Stage II Project is to be k_H = 0.15 g.

Maximum Accelerations for Return Periods

(unit: gal)

Model No.	2	10	20	30	50	100	200	300	500	1000
(1) Kawasumi	3	20	28	33	38	46	54	59	64	72
(2) Okamoto	3	20	27	32	37	45	53	57	63	70
(3) Estuva & Rosenbluth (modified)	3	18	25	30	35	42	49	53	58	66
(4) Ministry of Construction	3	22	31	36	42	51	60	65	71	80

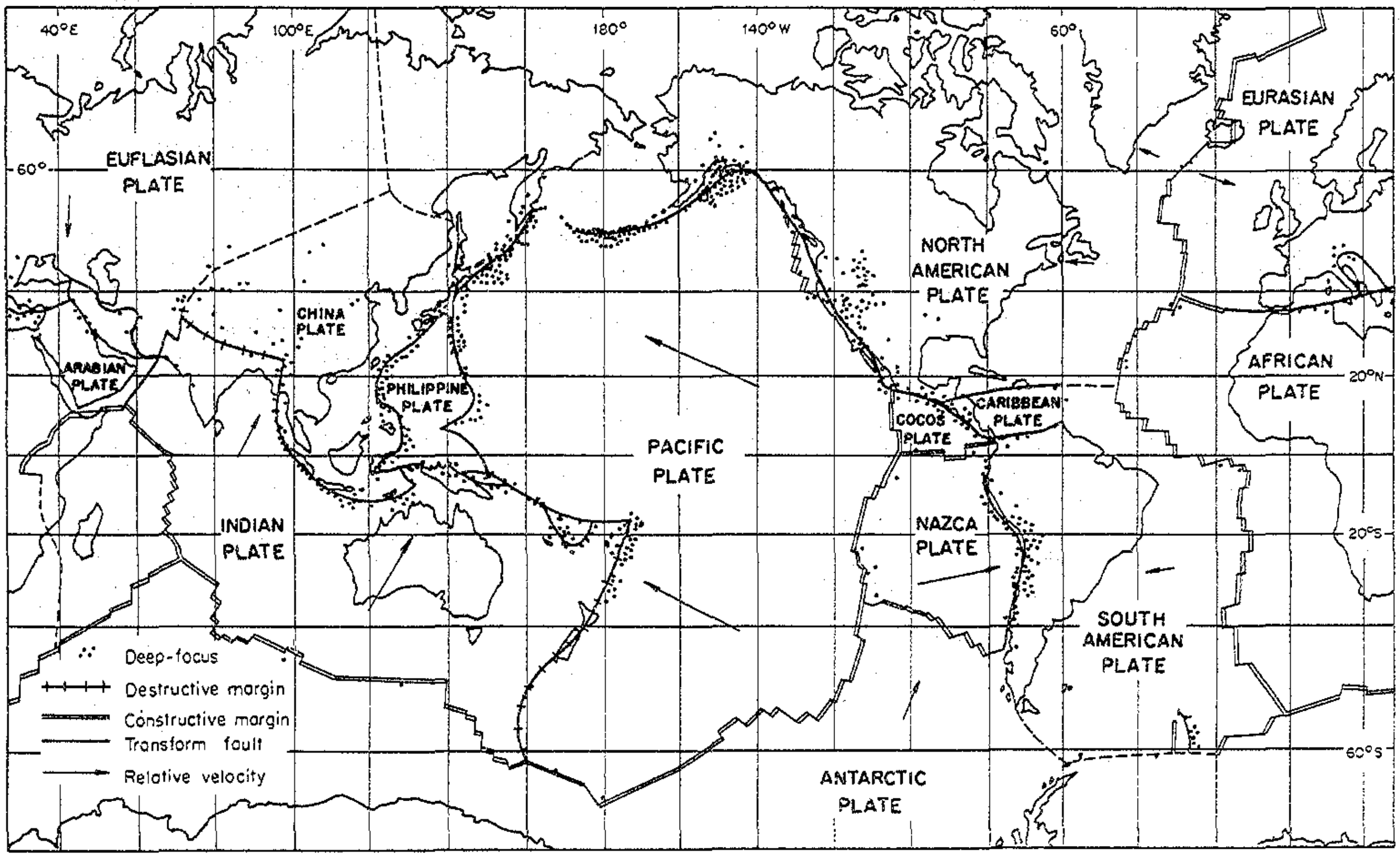


Fig. 7-1 Tectonic Plates in the World

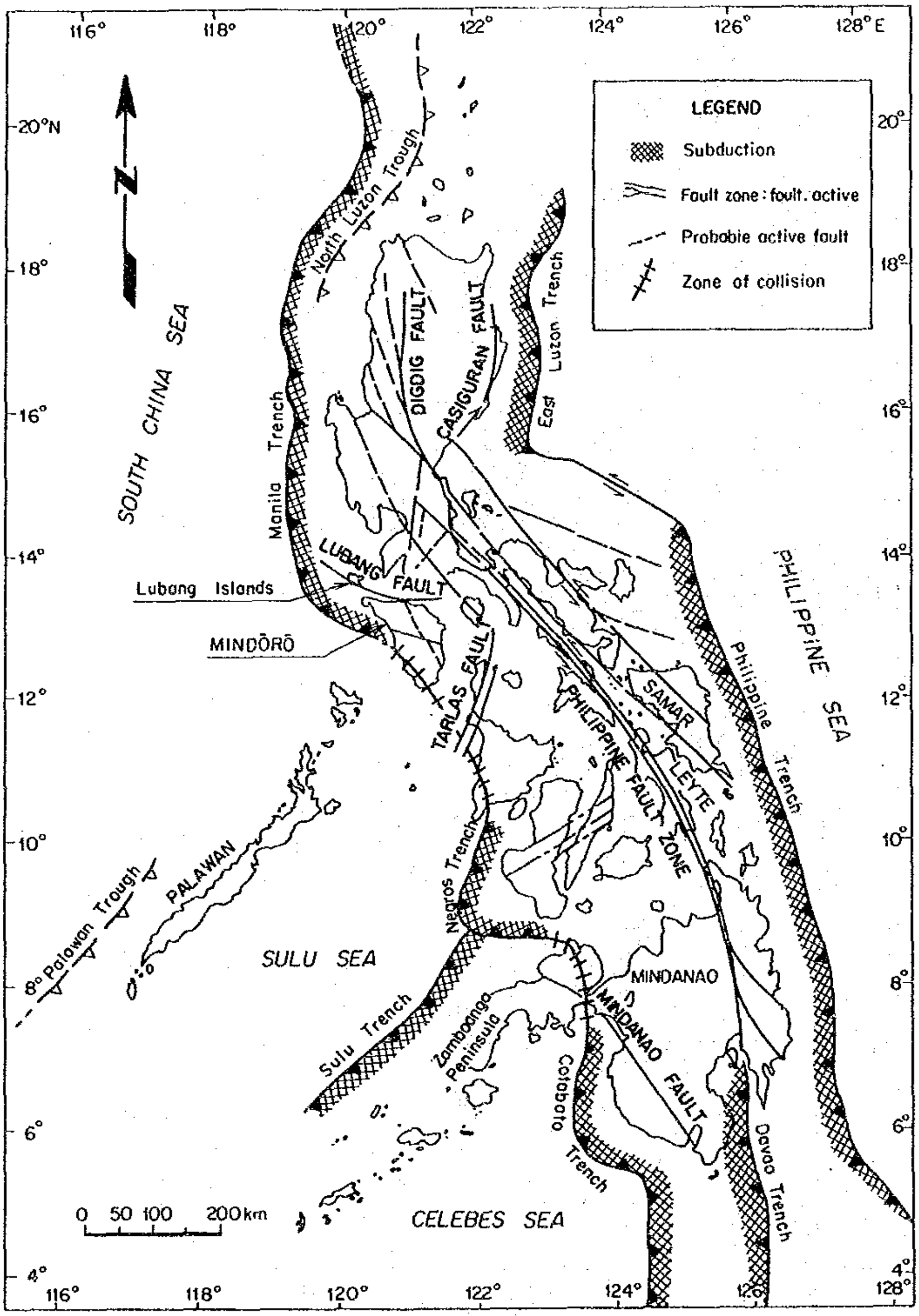


Fig. 7-2 Distribution of Earthquake Generators in the Philippines

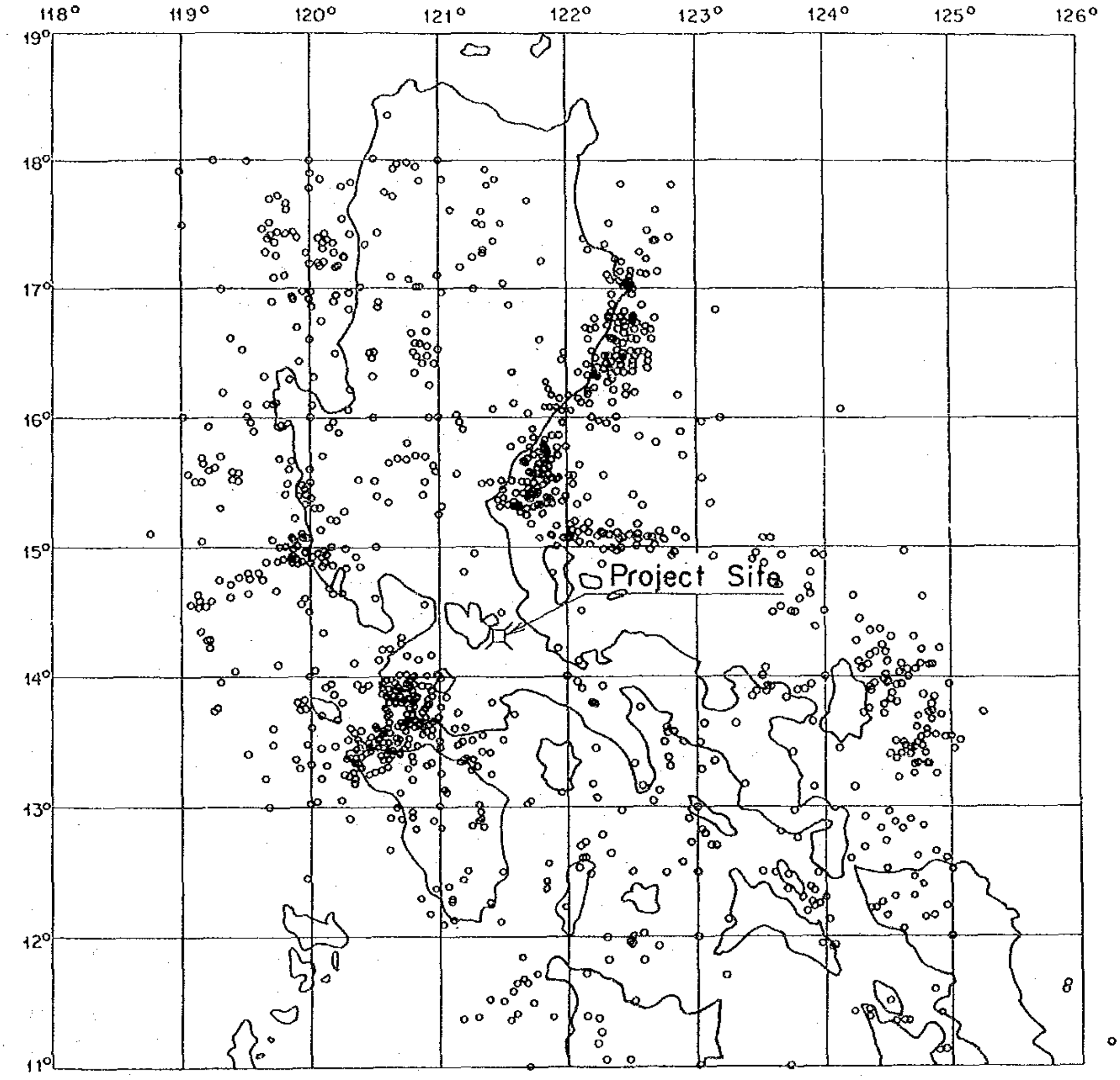


Fig. 7-3 Seismicity around the Project Site during 1897 - 1989

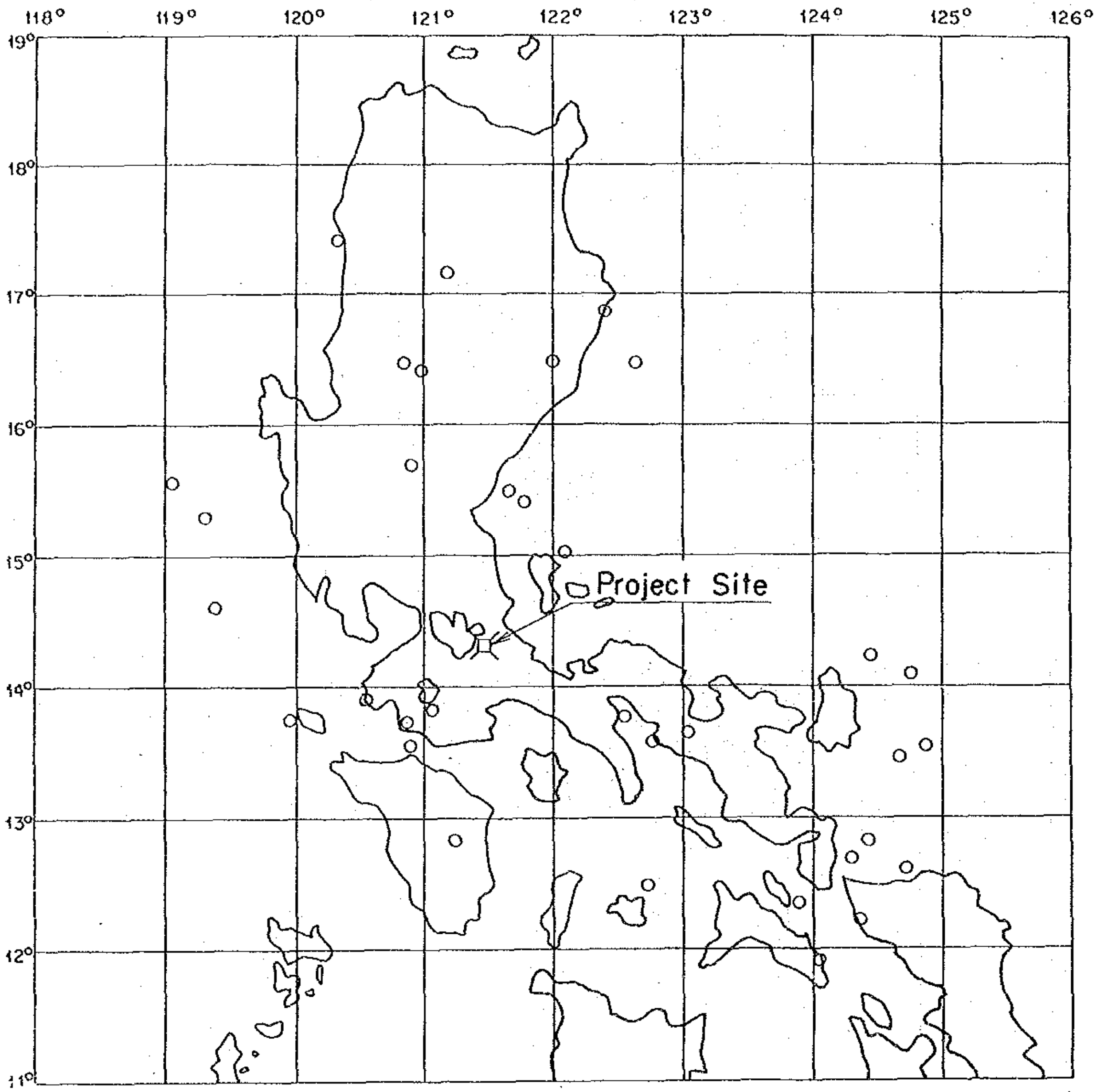


Fig. 7-4 (1) Seismicity around the Project Site during 1987 - 1989
(3.0≦M<4.0)

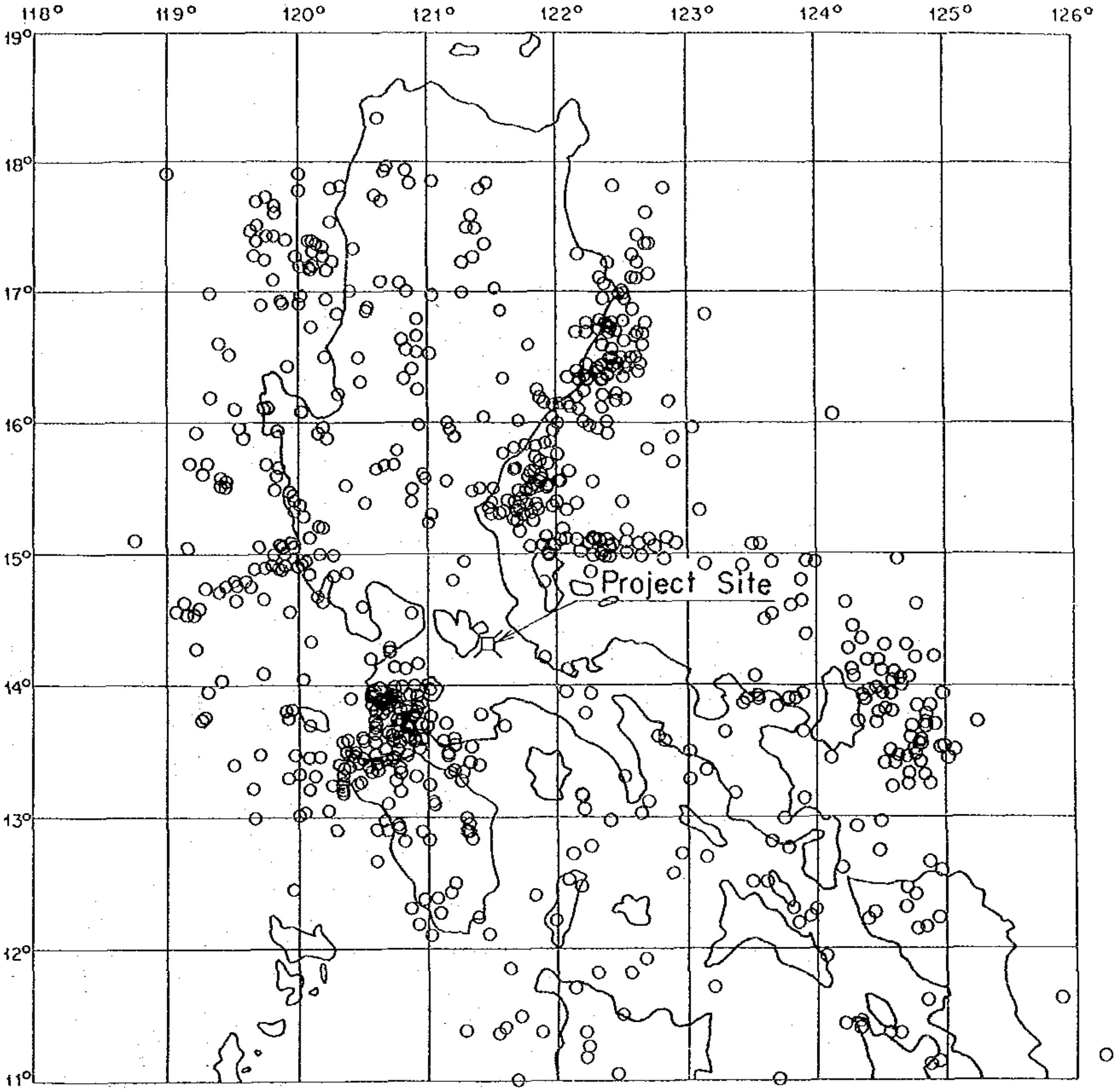


Fig. 7-4 (2) Seismicity around the Project Site during 1897 - 1989
(4.0≦M<5.0)

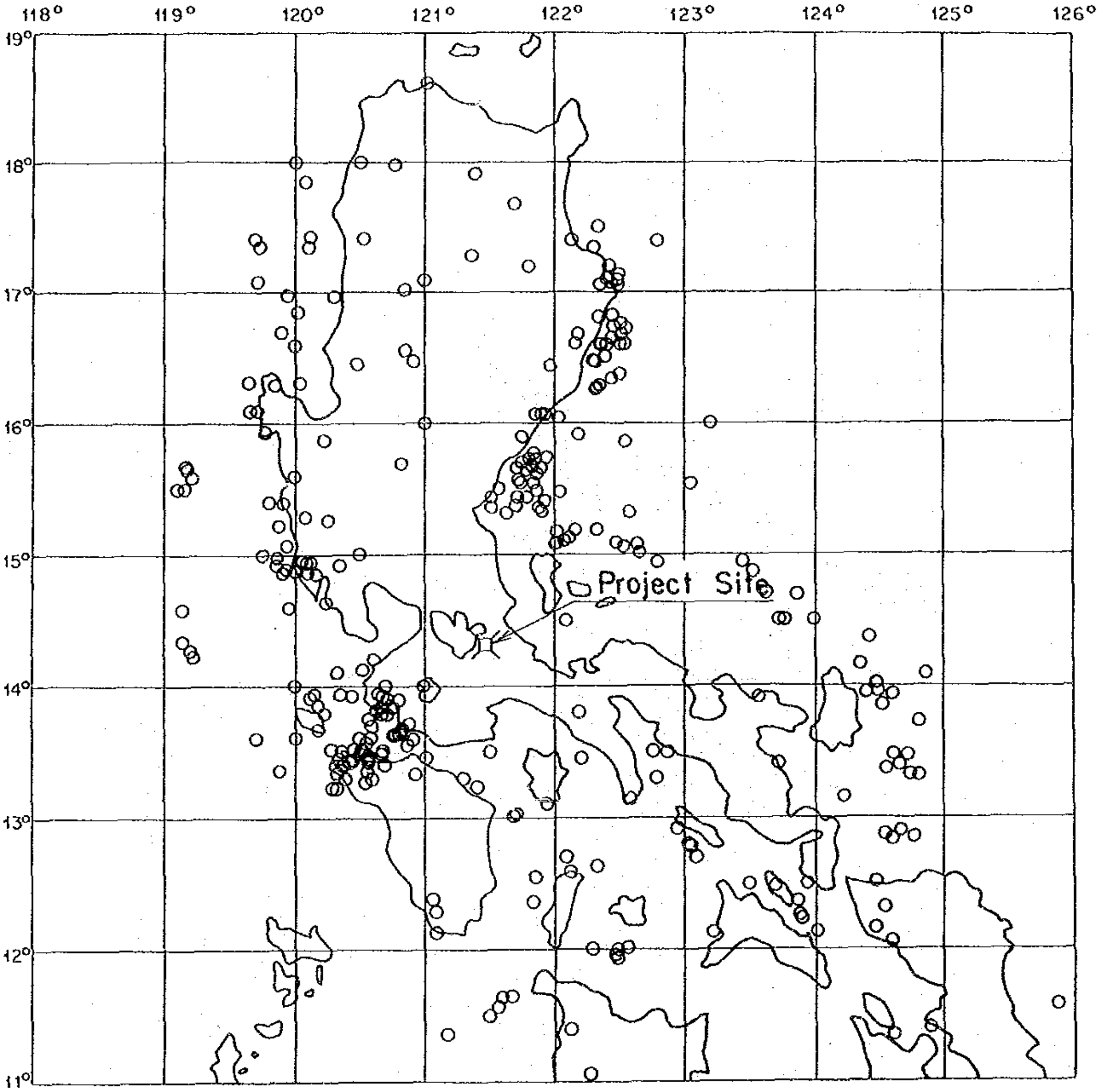


Fig. 7-4 (3) Seismicity around the Project Site during 1897 - 1989 (5.0≦M<6.0

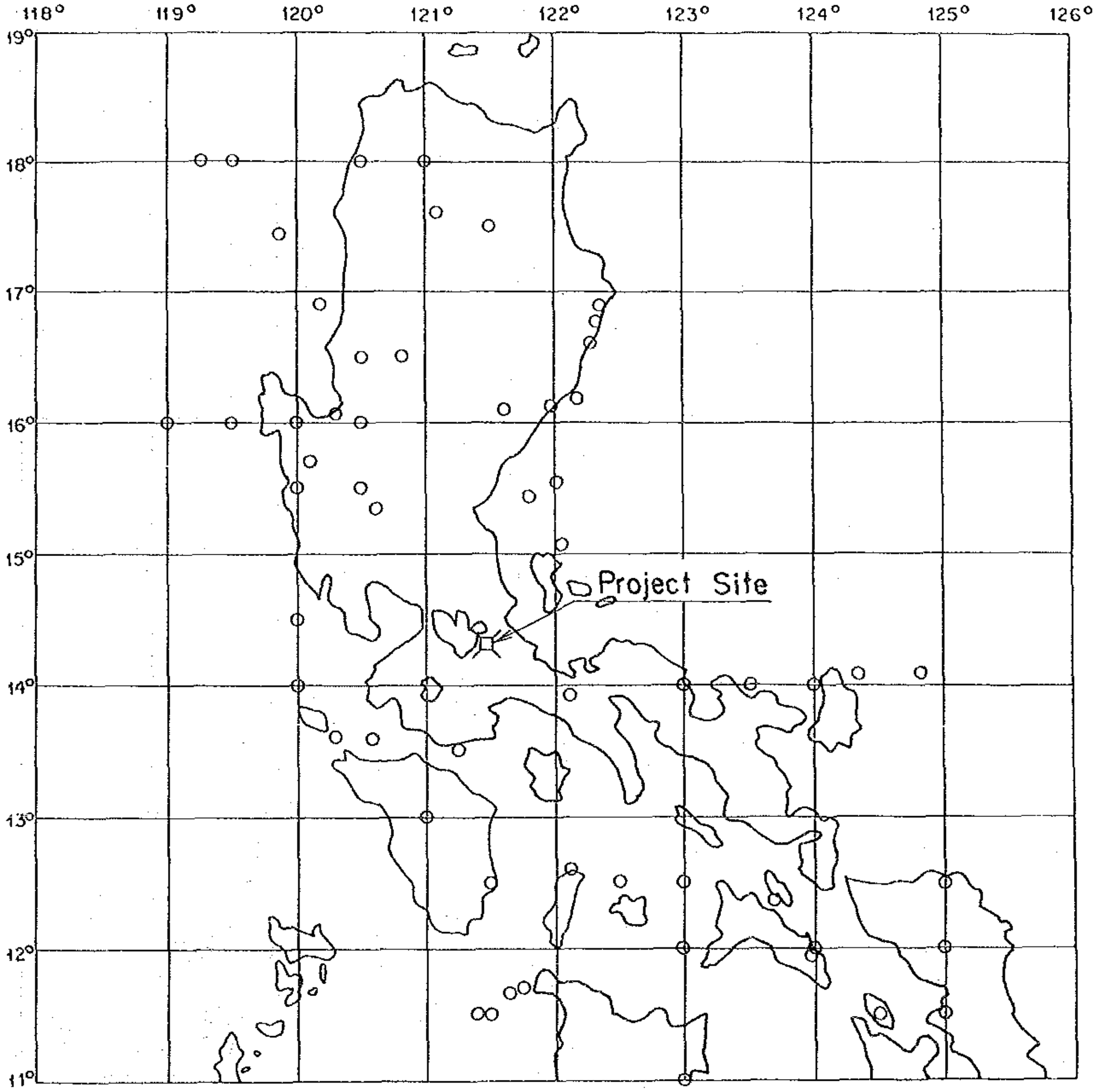


Fig. 7-4 (4) Seismicity around the Project Site during 1897 - 1989
($6.0 \leqq M < 7.0$)

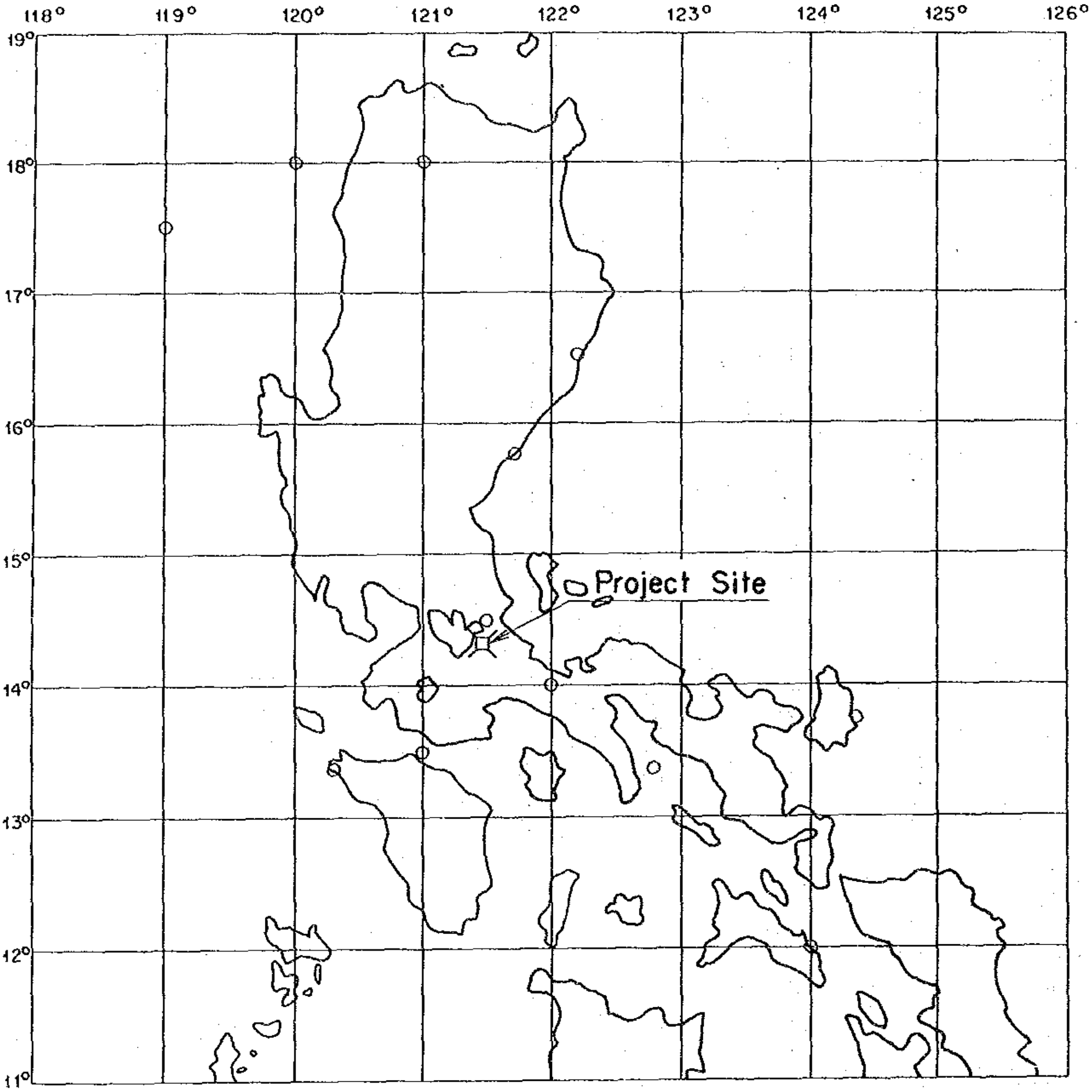


Fig. 7-4 (5) Seismicity around the Project Site during 1897 - 1989
(7.0≦M<8.0)

Chapter 8 Development Plan

Chapter 8 Development Plan

8.1 Size of Project

When it is assumed that the Kalayaan Pumped Storage Power Plant is operated for a duration of 6 hours to generate peak power, this power plant could be expanded to approximately 2,000 MW at its final stage if the storage capacity of Caliraya Reservoir is fully utilized. However, a capacity of this size is too large as a peak supply source in the later half of 1990s.

The Mission studied the optimal project size of the pumped storage plant in near future from the point of view of the "best mix" of power supply sources. As described in Section 4.1 of Chapter 4, the off-peak power demand in the Luzon Grid on weekdays is expected to be around 60% of the peak demand, and the daily load factor around 80%.

A load factor can be generally regarded to represent the average demand of a day, and the incremental 20%, which is the difference between the peak demand and the average demand, represents the loads having peaking trend. Such loads must be supplied with generating sources having superior response, such as reservoir type hydroelectric plant, pumped storage plant and gas turbine.

It was chosen to supply about one half of this peaking load of 20%, or 10%, with the pumped storage power plants which have high response and load-following characteristics.

As the peak power demand in the late 1990s (1996 to 2000) will be 5,800 MW on average, 10% of this amount, or around 600 MW should be supplied by pumped storage power plants.

As 300 MW of pumped storage plants are now in operation, it can be seen that an additional 300 MW will have to be developed.

It is also assumed that the energy to be supplied by pumped storage power plants are also 10% of the total daily energy demand. Then, the amount of energy which has to be supplied daily by Stage I and Stage II Projects will be 3,480 MWh, as deduced by the following equation.

E (MWh) = 5,800 MW x 0.1 x 12 hours/2 = 3,480 MWh

When the Mission divide this 3,480 MWh with the total output of Stage I and Stage II Projects, which is 600 MW, 5.8 hours are obtained. That is, Kalayaan units will be operated for approximately 6 hours a day. For power generation of 6 hours, the power plants will have to be operated in pumping mode for around 8 and half hours, considering the pumped storage efficiency. If this pumping energy can not be secured in daily operations, the deficit will be supplemented by weekly operations.

In developing 300 MW, two 150-MW units will be installed, because the optimal unit size has been determined as 150 MW by the "Power System Analysis" which is described in Section 9.2 of Chapter 9.

8.2 Pumping Energy and Schedule of Development

The timing of development of the Stage II Project was studied by estimating the pumping energy and reserve margin based on the demand projection and development program illustrated in Chapter 4.

(1) Study Conditions

* It was decided to acquire the pumping energy for the Stage I Plant from the oil-fired thermal power plant, so that the reserve supply capacity can be maintained.

* The pumping energy for the Stage II Project will be obtained from the coal-fired thermal power plants, in view of improving the economy of pumped storage operation.

* The off-peak factor was assumed at 60%.

* The guaranteed output of coal-fired thermal power plants and geothermal power plants was assumed to be 95% of the rated output.

Based on the above premises, the pumping energy can be calculated by the following equation:

Pumping Energy = (base power sources x 0.95) - (peak load x 0.6)

(2) Study Results

As shown in Table 8-1 and Fig. 8-2, the pumping energy becomes available after 1997. As the kW supply margin is low at this time, the deployment of a new pumped storage plant has a significant meaning in power system operation because it can replace gas turbine plants as a peak supply source, and at the same time levels out the off-peak load.

The following two alternatives can be conceived as the development schedule.

(Two-Stage Development Schedule)

January 1997: First unit (No. 3 Unit), 150 MW, commissioned.

July 1997 : Second unit (No. 4 Unit), 150 MW, commissioned. (The alternative power supply source is 2 x 188 MW gas turbine units.)

(Single Stage Development Schedule)

July 1997 : 2 units; 2 x 150 MW (No. 3 and 4 Units), commissioned. (The alternative power supply source is 376 MW gas turbine units.)

8.3 Pumping Operation Pattern

The output for each kind of generating sources in the power system and the operation mode of the Kalayaan pump-turbines, on a peak day (a weekday) in July 1997, are illustrated in Fig. 8-3.

The operation cycle of the Kalayaan pumped storage plant for 1 week from a Monday in 1998 to the next Sunday is given in Fig. 8-4.

8.4 Study of Reservoir Operation

In preparing the reservoir operation plan, the past operations of existing power plants (Caliraya and Kalayaan) related to Caliraya Reservoir and the available functions of the upper reservoirs

(Caliraya and Lumot Reservoirs) and lower reservoir (Laguna de Bay) will be studied, and an operation plan will be formulated within the limit of functions of these reservoirs.

8.4.1 Background of Existing Facilities

(1) Caliraya Reservoir and Power Station

Work on Caliraya Reservoir, which serves as the upper reservoir, began with a survey in March 1938 to make it the reservoir of Caliraya Power Station of dam-and-waterway type and construction was started in December 1939. Two units of Caliraya Power Station were commissioned in August 1942 during the World War II, but these were destroyed in March 1945. Rehabilitation was begun in April 1945 and the dam was completed in 1946. The power station started operation in March 1950 with an installed capacity of 32 MW (8 MW x 4).

Lumot Reservoir was completed in 1951 to supplement inflow to Caliraya Reservoir, and 37 km^2 of catchment area was diverted to Caliraya.

(2) Kalayaan Pumped Storage Power Plant

In 1973, NAPOCOR, in order to secure stability of peak demand for the Metro Manila Area, prepared Feasibility Report of Kalayaan Pumped Storage Plant (ELC, EDCOP) on a large-scale pumped storage power plant development scheme which recommended that Caliraya Reservoir should be used as upper reservoir and Laguna de Bay as lower reservoir. This report was on a scheme for development of peak power plant starting with a Stage I of 300 MW, and expanding in four stages to an ultimate capacity of 1,200 MW.

The two 150-MW units of the Stage I Project were commissioned in May and August 1982.

At the time of Stage I construction, the upper canals and intakes for Stage II and Stage III Projects, and the gently-sloped part of the penstock route, underground passage, and ground leveling works for power-house site and switchyard site for the Stage II Project were constructed in advance.

According to the Feasibility Report of Kalayaan Pumped Storage Plant (May 1973, by ELC, Milano, Italia), the specifications of the original development scheme of the Stage II Project are as follows:

Specifications

Upper Reservoir		Caliraya Reservoir	Lumot Reservoir
High Water Level	m	EL. 288.00	EL. 290.00
Low Water Level	m	EL. 286.00	EL. 286.00
Effective storage capacity	10^6 m^3	22.60	22.00

Lower Reservoir		Laguna de Bay
High Water Level	m	EL. 3.24
Av. Water Level	m	EL. 0.60
Low Water Level	m	EL.-0.36

Penstock		
Surface portion		
Dia. x length	m	6.00 x 1,210
Tunnel portion		
Dia. x length	m	33.0 x 68 x 2 lines

Power Generation Scheme		Generating	Pump-up
Normal effective head	m	282.00	289.50
Max. effective head	m	286.50	291.00
Power discharge	m^3/s	120 (60 x 2)	
Pump-up quantity	m^3/s		96
Max. output	MW	300 (150 x 2)	
Generator capacity	MVA	334 (167 x 2)	
Rated speed	rpm	300	

8.4.2 Function of Upper and Lower Reservoirs

In preparing a plan for the Stage II Project, function of upper and lower reservoirs are studied as follows:

(1) Upper Reservoir

(a) Functions of Lumot Reservoir

Lumot Reservoir exists as a supplement, but cannot function as the upper reservoir of a pumped storage power plant because of the following:

- In the first place, the purpose of the reservoir is annual regulation of inflow of the Lumot catchment with the discharge of 14.74 m^3/s for Caliraya Power Plant.

- The water channel connecting these two reservoirs have a diameter of 2 m, with which only 4.1 m/s water velocity can be created by a head difference of 3 m, which is a small amount as compared to the maximum discharge of 120 m^3/s and pumping-up of 96 m^3/s used by the pumped storage plant of Stage I. Therefore, Lumot Reservoir does not have supply of water and a supplementary function for Caliraya Reservoir when the units of the Stage I are operating.

- Integration with Caliraya Reservoir by additional connecting waterway did not make reservoir operation simple, since the high water level of Lumot Reservoir is 2 m higher than that of Caliraya Reservoir.

(b) Functions of Caliraya Reservoir

The functions of the reservoir may be considered to be the following based on the dam and appurtenant structures:

- Regarding the high water level of the reservoir, according to Feasibility Report of Caliraya Dam Rehabilitation Project (September 1986, JICA), it is not safe from the standpoints of stability of the dam and design flood discharge unless high water level is made EL. 288.0 m.

- With regard to the operating water level of the reservoir, according to the abovementioned report, the safety of the dam with respect to cracking of the concrete slab at the upstream slope of the dam under present conditions has been confirmed for sudden water level fluctuation to the low water level of EL. 286.0 m.

  If low water level was to be lowered even more hereafter, water level fluctuation below the present low water level would become abrupt per unit length of time, and be undesirable for safety of the dam.

- The regulating capacity based on effective storage capacity for drawdown of 2.0 m from water level of EL. 288.0 to EL. 286.0 is 22.09 x 10^6 m^3 according to the Table of Caliraya Reservoir Plants Characteristic presently being used by NAPOCOR. The effective storage capacity corresponds to approximately 50 hours of power generating time for the 300 MW of power plant. Caliraya Reservoir Capacity is shown in Fig. 5-1 in Chapter 5.

- For annual inflow from the catchment basin the total inflow including that of Lumot Reservoir (effective runoff excluding runoff loss) is 200 x 10^6 m^3, corresponding to approximately 460 hours in terms of operating time of the 300 MW of Power Plants (Refer 5.2.2 (1) in Chapter 5).

- Although the amount of evaporation of the reservoir is included to above-mentioned inflow loss, it is estimated as follow, based on 1,200 mm of the annual evaporation resulting from hydrological observation.

  Total Amount of Evaporation =
  observed evaporation x coefficient x Reservoir Area

  $10{,}200{,}000\ m^3 = 1{,}200\ mm/1{,}000 \times 0.7 \times 12.2 km^2 \times 1{,}000{,}000$

  The total amount of Lumot Reservoir is as below.

  $5{,}400{,}000\ m^3 = 1{,}200 mm/1{,}000 \times 0.7 \times 6.4 km^2 \times 1{,}000{,}000$

  The total estimation corresponds to slightly lower than 8% of total inflow.

Based on the functions of Caliraya Reservoir, the specifications of the upper reservoir may be summarized as follows:

Specifications of Upper Reservoir

HWL	EL. 288.00 m
LWL	EL. 286.00 m
Available drawdown	2.00 m
Effective storage capacity	$22.09 \times 10^6\ m^3$
(Duration of Maximum Output Operation)	(300 MW, 50 hr)
Natural inflow	$200 \times 10^6\ m^3$
(Duration of Maximum Output Operation)	(300 MW, 460 hr)

(2) Lower Reservoir

The functions of the lower reservoir may be considered to be as follows:

- The location where power generation discharge is to be made is in the vicinity of the remotest corner of the northeast part of Laguna de Bay where the depth of water is shallow and not more than 2 m. There will be a continued trend hereafter for the lake to become shallower annually because of the sediment brought in by the Pagsanjan River and in the tailrace work of Stage I, dredging had been done a length of more than 2 km, and dredging has become necessary from the standpoint of maintenance (See 5.3.3 in Chapter 5).

- The distance from the Pagsanjan River to the outlet is approximately 2 km, and the mouth of the river juts out into the lake 6 km from there. However, as the location of the outlet, the location of the outlet for the Stage I Project is recommendable from the standpoint of the economics of the waterway.

- In the vicinity of the Stage I outlet in Laguna de Bay, there are aquatic plants clustered in ring form, and roots of the plants affect intake during pump-up incidentally.

- The water level of Laguna de Bay is discussed in 5.3.2 of Chapter 5, Water Level of Laguna de Bay and it is considered that the design water level of the Stage I Project is reasonable from the standpoint of pumped storage power plant planning.

Based on the functions of Laguna de Bay, the following conditions would be applicable as the lower reservoir:

Outlet location	Present location
Design water level:	
High Water Level	EL. 3.24 m
Av. Water Level	EL. 0.60 m
Low Water Level	EL.-0.36 m

8.4.3 Study of Reservoir Operation

(1) General Operation Pattern

Effective storage capacity of the upper reservoir is 22.09 x 10^6 m^3.

There are two general operation patterns of daily peak generating time, and water level variations as stated hereunder.

Condition: Effective Storage Capacity 22.09 x 10^6 m^3

Power generating operation is hypothesized as follows:

Unit		4 units for Stage I and II
Water level at start of generation	HWL	EL. 288.00
Generating discharge	Qt	240.0 m^3/s
Pump-up quantity	Qp	200.0 m^3/s
Natural inflow quantity	qi	0.4 x 10^6 m^3/dy

It is not considered that the inflow caused by difference of water level between Caliraya and Lumot reservoirs.

(a) Daily Operation Pattern

A trial calculation was made for the case of the daily capacity balance of the upper reservoir taken to be the same (See Fig. 8-5.).

Tt	Vo	Vp	h	Tp
Peak Generating Time	Power Discharge	Pump-up Quantity	Water Level Variation	Time Required for Pump-up
Hr	10^6 m^3	10^6 m^3	m*	Hr
3	2.59	2.19	287.79	3.04
6	5.18	4.78	287.57	6.64
8	6.91	6.51	287.43	9.04
9	7.78	7.38	287.35	10.25
12	10.37	9.97	287.13	13.85
15	12.96	12.56	286.90	17.44

Note: * For the reservoir storage capacity for water level variation, the cummulated discharge was deducted from storage capacity at the high water level and the natural inflow quantity entering during the generating time was added (low water level of the day).

$Vo = 3{,}600 \cdot Tt \cdot Qt$
$Vp = Vo - qi$
$Tp = Vp/(3{,}600 \cdot Qp)$

The following would be considered based on the results described above:

- When the fact that the pump-up time during a day is in reality not more than 9 hours, the peak generating time would be restricted to not more than 8 hours.

- With peak generation not more than 8 hours, the water level variation of the reservoir would be about 0.5 to 0.6 m, and when the available drawdown of 2.0 m is considered, the utilization efficiency is poor. Therefore, it is necessary for the utilization efficiency to be improved by considering operation based on a weekly pattern.

- When peak power generation is for not more than 8 hours, there will be a generating time of about 18 hours as the reserve capacity of the reservoir (See Fig. 8-2.).

(b) Weekly Operation Pattern

In case of peak power generation for five days from Monday to Friday when power demand is greatest, considering weekly operation of the upper reservoir, pump-up on Saturdays and Sundays of weekends will shorten pump-up times of days on which peak power generation is performed. The incremental generating times of days of peak power generation were examined taking into account the reductions in time per day of peak power generation (See Fig. 8-6.).

Tp Weekends Pumping Time Hr	Vp Pump-up Quantity 10^6 m^3	Tp Pumping Time Reduced Hr/day	Tt Incremental Duration* of Peak Generation Hr/day
9	6.48	1.8	1.69
12	8.64	2.4	2.19
18	12.96	3.6	3.19
24	17.28	4.8	4.19

Note: * The incremental duration of peak generation includes 2 days of natural inflow quantity in the pump-up discharge.

$Vp = 3{,}600 \cdot Qt \cdot Tp$
$Tp = Tp/5$
$Tt = (Vp+2 \cdot qi)/(5 \times 3{,}600)Qp$

The following considerations would be made from the abovementioned results:

- In the preceding paragraph, it was assumed that power generating time would be restricted to about 8 hours if the pump-up time were to be made about 9 hours per day, but it is thought 12 hours of peak power generation would become possible through 24-hour pump-up operation on Saturday and Sunday.

- The utility factor of the reservoir capacity will reach a level of 86 percent through 24 hours pump-up during the weekend.

(2) Reservoir Operation in May, 1989

The reservoir operation pattern for a cycle of generation and pump-up has been studied for a week in May 1998 when the power demand is the highest in the year.

The study was conducted based on the following data:

Effective Capacity of Upper Reservoir	22.09×10^6 m^3
Pump-turbine Units	4 units from Stages I and II
Water Level at Start of Generation Mode	High water level, EL 288.0
Generator Output P	4 x 150 MW
Discharge Qt	4 x 62 m^3/s
Pumping Input P_p	4 x 150 MW
Pump-up Quantity	4 x 49.9 m^3/s
Natural Inflow q_i	0.32×10^6 m^3/day (The average of flows in May given in Table 5-1)

The water level variation of the reservoir as shown in Table 8-2 was calculated from the operation cycle of generation and pump-up given in Fig. 8-4. The reservoir operation pattern was obtained as given in Fig. 8-7.

The following features could be pointed out from the results of the above analysis.

- The utilization factor of the reservoir during the week is 52%, and the maximum variation of water level is 0.91 m.

- The reason why the utilization factor remains at 52% is that the supply of base thermal power plants is not sufficient to provide a full pumping energy, as this is only the second year after commissioning.

- Forty-four percent of the pumping energy during a week is pumped on Saturday and Sunday, to reduce daytime pumping times from Monday through Friday.

Table 8-1 Power Development Program and Available Pumping Power

YEAR	New Power Plants	(MW)	Reiter/Power decay Site	(MW)	Installed capacity total	base p.p	Demand (MW)	Available pump pow.	Reserve Margin(%)
1989	Hydro	1227							
(existing)	Oil P.	1925							
	Geo P.	660							
	Coal P.	300							
	Gas. T	210							
	Total	4322	none	0	4322	960	2938	-850.8	47.1
1990	Hopwel GT	200							
	P. bargeGT	120							
	Sub tot.	320	none	0	4642	960	3266	-1047.6	42.1
1991	Sucat GT	30							
	New GT	300							
	Sub. tot.	330	none	0	4972	960	3520	-1200	41.3
1992	P.P Barge	27.5	Carilaya						
	BacMan Geo	110	#1, #2	-16					
	Comb cyc	200							
	Sub. tot.	337.5			5293.5	1270	3787	-1065.7	39.8
1993	P. P. Barge	27.5							
	BulsanGeo	60							
	Coal#3	300							
	MaibaraGeo	10							
	Bac-Man#2	40							
	Calaca#2	300							
	Sub. tot.	737.5	none	0	6031	1980	4069	-560.4	48.2
1994	Balo-Balo	22							
	PinatobGeo	60							
	Sub. tot.	82	GT	-105	6008	2040	4367	-682.2	37.6
1995	Cagua Geo	40	Botocan#3	-1					
	Tongo-GeoA	440	Manila#1, 2	-200					
	DelGallGeo	120	GT	-160					
	Sub. tot.	600		-361	6247	2640	4680	-300	33.5
1996	Tongo-GeoB	440							
	Coal A-1	300	GT	-165					
	SUb. tot.	740		-165	6822	3380	5012	203.8	36.1
1997	Coal A-2	300	Carilaya#3	-8					
	GT／PM	300	GT	-14					
	Sub. tot.	600		-22	7400	3680	5361	279.4	38.0
1998	Coal B-1	300	P. P. Barge	-14					
	Casecnan	268	Botocan1, 2	16					
			Sucat #1	-150					
	Sub. tot.	568		-180	7788	3980	5730	343	35.9
1999	Coal B-2	300							
	Comb. cyc	300	GT	-105					
	Sub. tot.	600		-105	8283	4580	6119	679.6	35.4
2000	Comb. cyc	600	GT	-160					
			Carilrya#4	-8					
			Sucat #2	-200					
	Sub. tot	600		-368	8515	5180	6529	1003.6	30.4

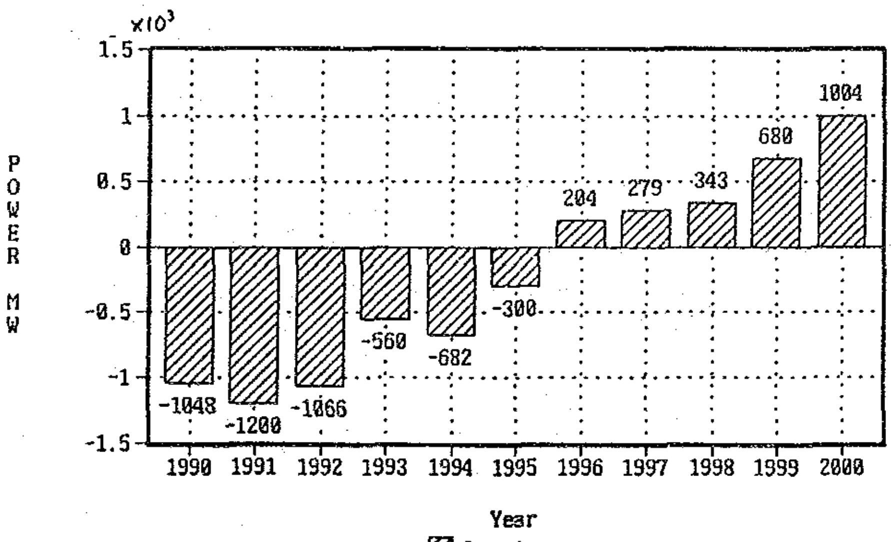


Fig. 8-2 Available Pumping Power from Base Power Plants

Table 8-2 Reservoir Operation of One Weed (May, 1998)

Week	Pumping E Mwh	Pumping V $10^6 m^3$	Generating E Mwh	Generating V $10^6 m^3$	Inflow Zi $10^6 m^3$	Reservoir Ve $10^6 m^3$	Reservoir Vg $10^6 m^3$	Reservoir WL m	Operation time hr
						17.92	74.84	287.65	
Mon	3,600	4.07	2,400	3.57	0.10	22.09	79.01	288.00	0 → 7.5Pum
					0.18	18.70	75.62	287.72	10 21 Gen
					0.04	18.74	75.66	287.72	24
Tue	1,800	2.03	2,800	4.17	0.10	20.87	77.80	287.90	0.5 → 7.5Pum
					0.20	16.90	73.83	287.56	10 22 Gen
					0.03	16.93	73.85	287.57	24
Wed	1,800	2.03	2,800	4.17	0.10	19.07	75.99	287.74	0.5 → 7.5Pum
					0.20	15.10	72.02	287.41	10 22 Gen
					0.03	15.12	72.05	287.41	24
Thu	1,800	2.03	2,800	4.17	0.10	17.26	74.18	287.59	0. → 7.5Pum
					0.20	13.29	70.21	287.25	10 22 Gen
					0.03	13.31	70.24	287.25	24
Fri	1,800	2.03	2,800	4.17	0.10	15.45	72.37	287.44	0.5 → 7.5Pum
					0.20	11.48	68.40	287.09	10 22 Gen
					0.03	11.51	68.43	287.09	24
Sat	2,800	3.16	0	0	0.11	14.78	71.70	287.38	0 → 8 Pum
					—	—	—	—	24
					0.22	14.99	71.92	287.40	
Sun	5,800	6.55	0	0	0.23	21.78	78.70	287.97	1 → 17 Pum
					—	—	—	—	24
					0.09	21.87	78.79	287.98	
Total	19,400	21.92	13,600	20.24	2.27				

Note : P = 2× 300 MW, Qt = 2 × 124 m^3/s
Pp = 2× 318 MW, Qp = 2 × 99.8 m^3/s

Imflow qi = 324,194 m^3/dy

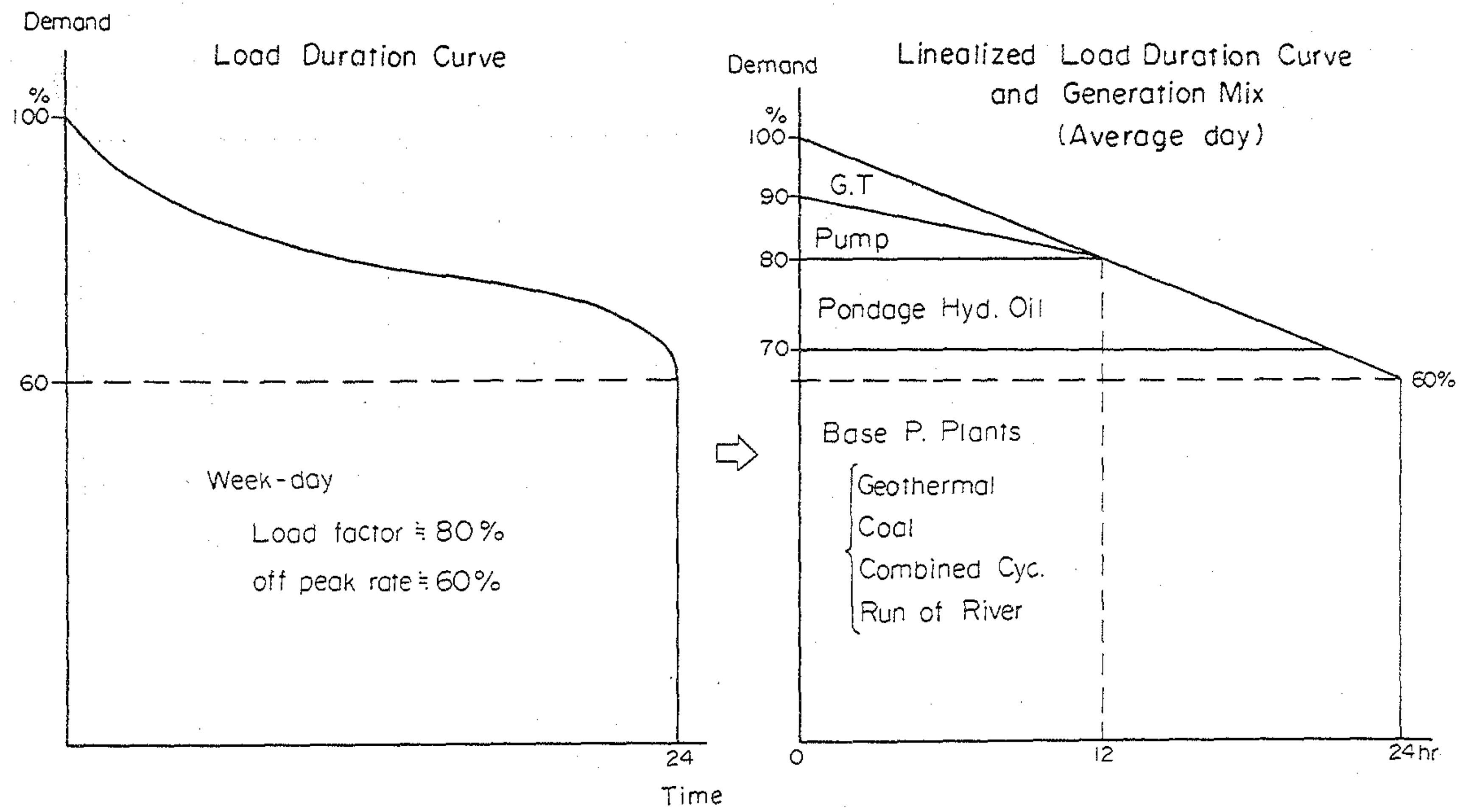


Fig. 8-1 Preferable Generation Mix in Future

Oil. P.		Rate	MIN	60%
BAT 1	:	75MW	50	45
BAT 2	:	150	80	90
SUC 1	:	150	50	90
SUC 2	:	200	120	120
SUC 3	:	200	120	120
SUC 4	:	300	120	180
MAL 1	:	300	120	180
Total	:	1 375	660	825

Peak demand : 5361 MW
off peak rate : 60%
Load factor : 82%

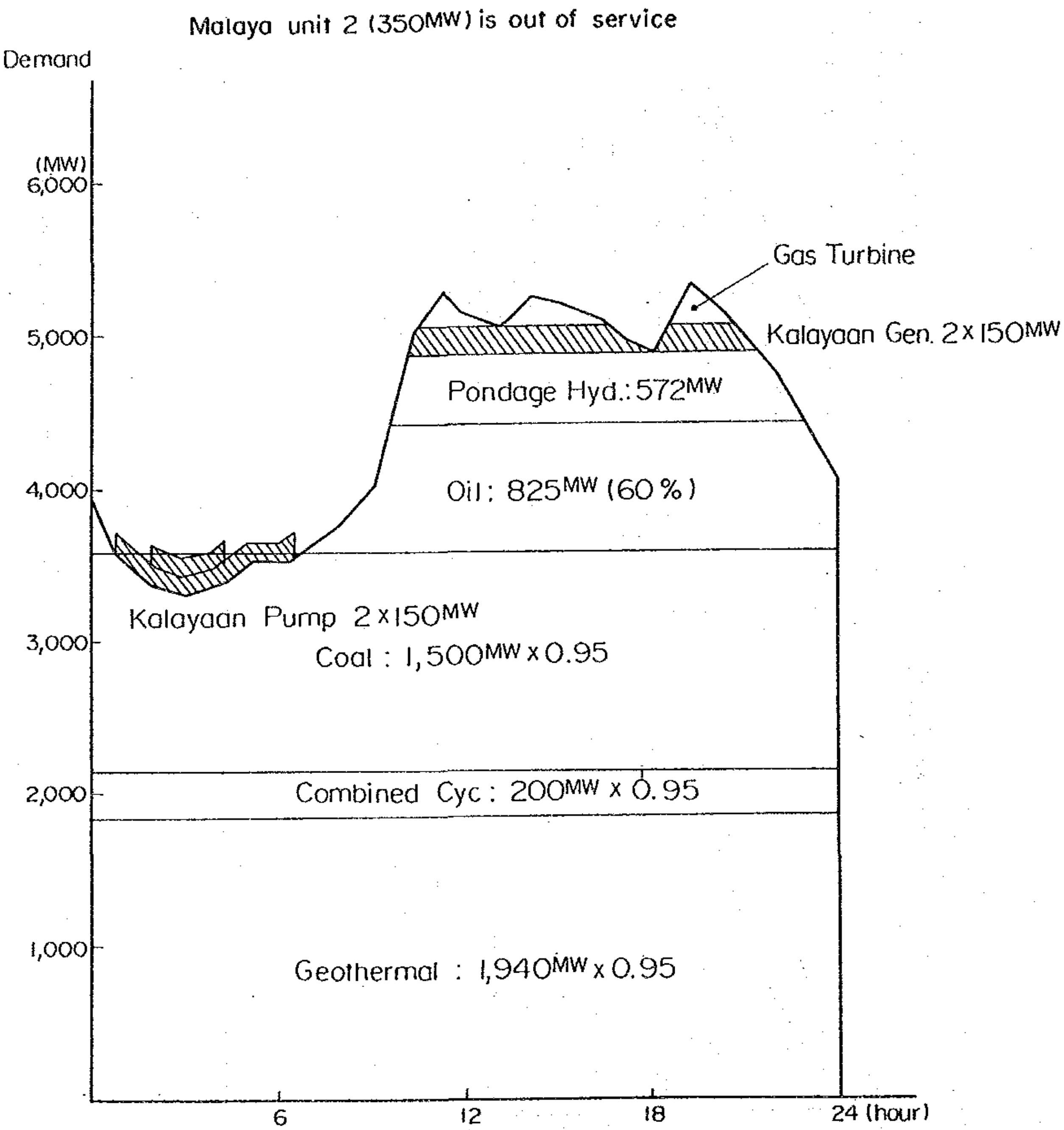


Fig. 8-3 Pumping and Generation Cycle of a Weekday in July 1997

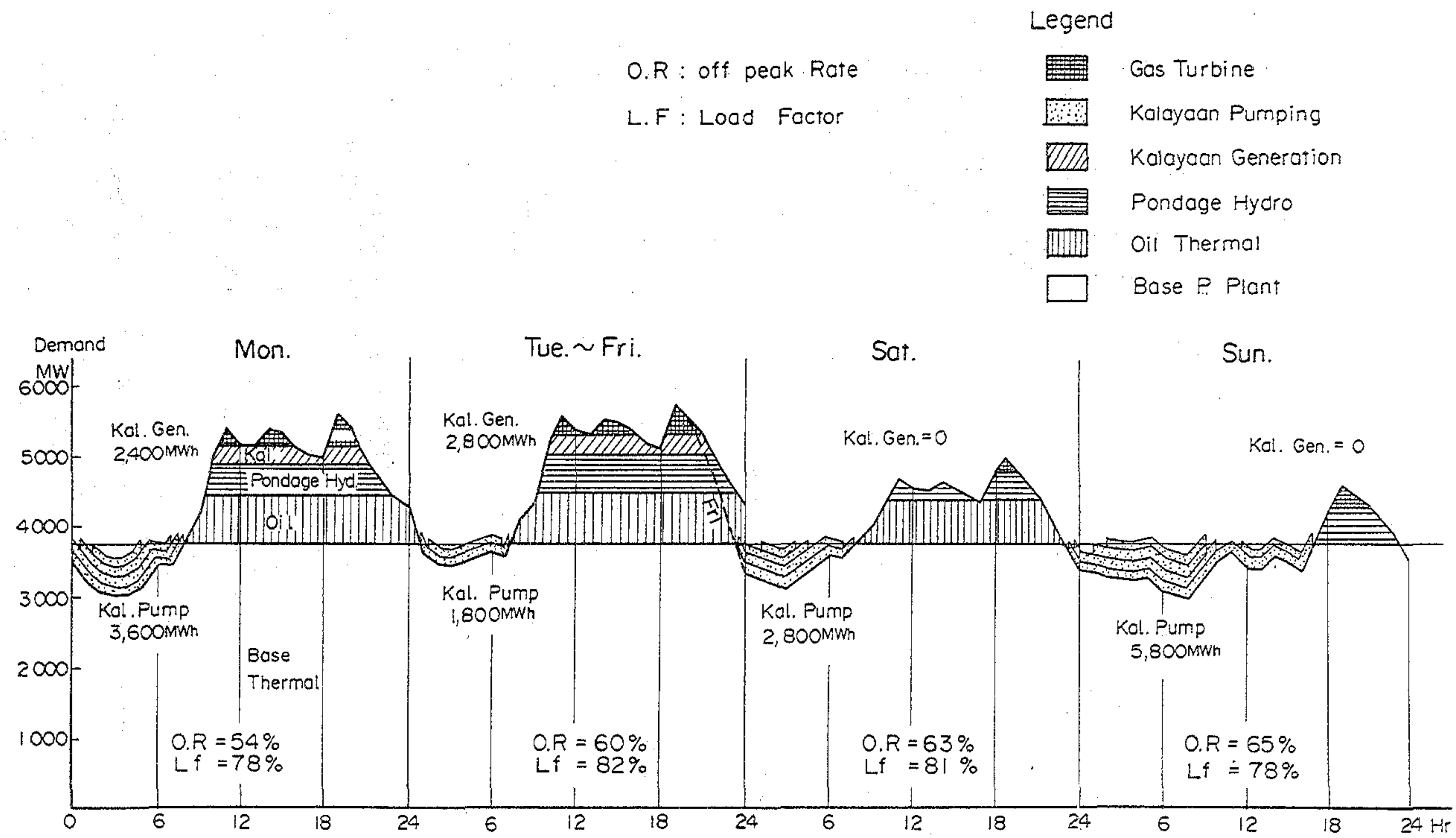
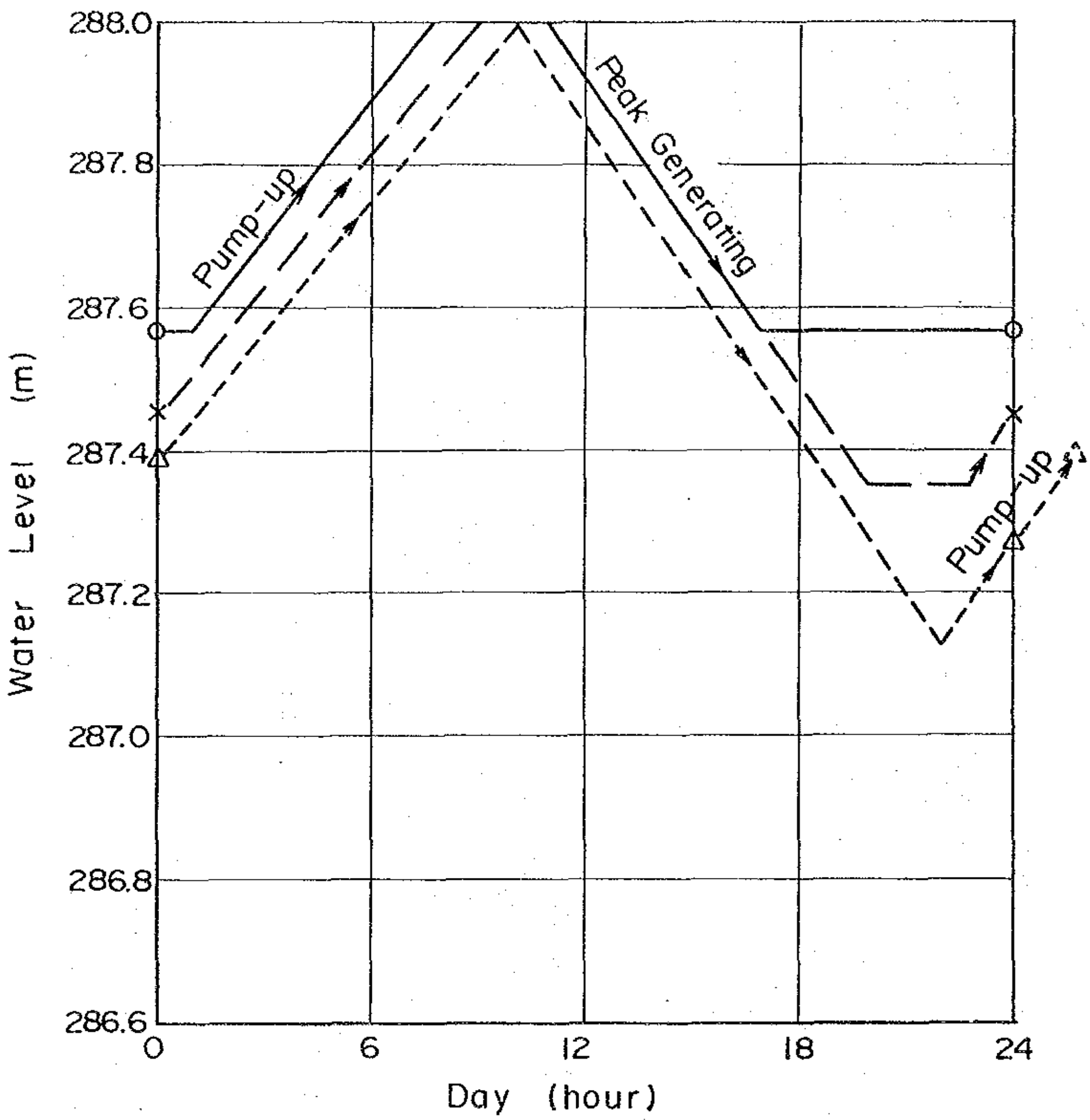


Fig. 8-4 Pumping and Generation Cycle of One week in May 1998



Notes ;

	Peak Generating Time	Time Required for Pump-up
o——o	6 hr	6.64 hr
×— —×	9 hr	10.25 hr
△----△	12 hr	13.85 hr

Fig. 8-5 Daily Operation Pattern of Caliraya Reservoir

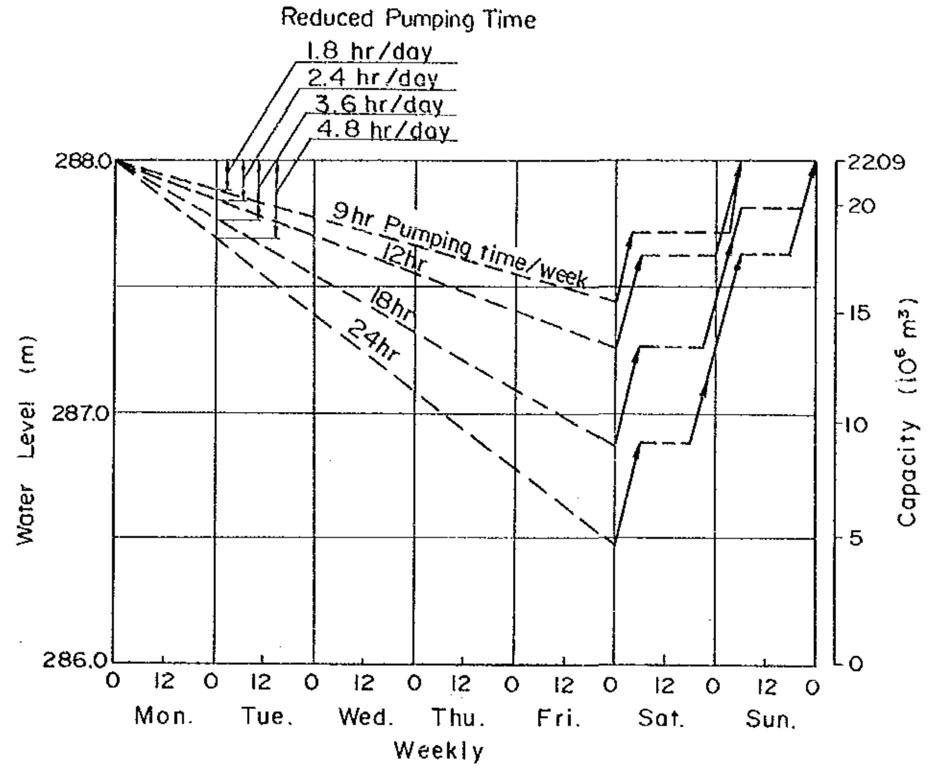


Fig. 8-6 Weekly Operation Pattern of Caliraya Reservoir

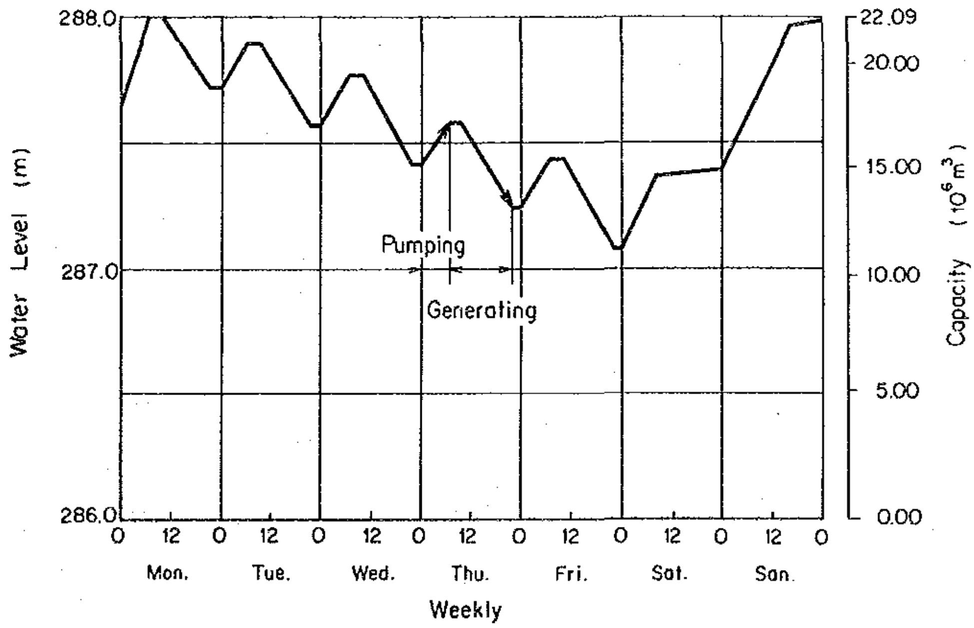


Fig. 8-7 Reservoir Operation of One Week (May, 1998)

Chapter 9 Transmission Line and Power System Analysis

Chapter 9 Transmission Line and Power System Analysis

9.1 Transmission Line

The Luzon Grid is presently interconnected by 230-kV transmission lines of a total length of approximately 3,300 km. In subordinate systems and the MELARCO System responsible for power supply to Metro Manila, 115-kV transmission lines are being used.

The transmission line of 500-kV design and 490 km in length, which was completed in 1988, has not been charged, but it is being planned to operate this transmission line at 500-kV in 1995 when Tangonan Geothermal Power Plant is completed. Today, additional 500-kV transmission lines are being constructed from Kalayaan to San Jose, and this transmission line will be extended to a point near Pantabangan in the late 1990s in relation to the development of Casecnan Hydroelectric Project.

It is likely that Leyte Island, where Tangonan Geothermal Power Plant exists, and Luzon Island will be interconnected by a HVDC ±400-kV line via Samar Island.

The old transmission line (230kV, 795 MCMx1) running from Kalayaan to Malaya was replaced by a new line carrying two circuits of ACSR 795 MCMx4 several years ago. As this new transmission line has sufficient thermal capacity (1,200 MW per circuit), the transmission plan for the Stage II Project has been studied based on the concept of connecting this 230-kV line to the power plant switchyard.

The power system diagram of 500-kV lines on Luzon Island, at a time cross section of around year 2000, is presented in Fig. 9-1.

9.2 System Analysis

Calculations for power flow, simplified frequency and power system stability were carried out for 1998, one year after the Stage II Project is commmissioned.

(1) Power Flow Calculations

(a) Conditions of Calculations

Peak demand of Luzon Grid in 1988 : 5,730 MW
Off-peak demand of Luzon Grid in 1988: 3,440 MW
Load power factor: 95% (lagging)

Substations receiving new power supply
- Tongonan Geothermal (1995, 1996) ------ Naga 500 kV bus
- Coal A (1996, '97) ------ Batangas 230 kV bus
- Coal B (1998) ------ Tayabas 500 kV bus

Voltage regulation target for all substations: 95 - 105%

(b) Results of Study

The results of power flow calculations are shown in Figs. 9-2 and 9-3. After the completion of the Stage II Project there will be no transmission line of related systems which would be overloaded, but in order to maintain voltage at the pumping-up operation during midnight hours, it will be desirable for the pump-up power factor to be made about 95 percent.

(2) Simplified Frequency Calculations

(a) Present Situation in Frequency Fluctuation

The frequency regulation target in the Luzon Grid is in the range of 60 $\pm$ 0.3 Hz, but in reality, there are fluctuations of about $\pm$0.3 Hz in the daytime, and about $\pm$0.5 Hz in the nighttime when system capacity is small. In general, the pump-up machine shows a greater pump-up input variation at the stopping mode than the starting mode operation, and in the present state, stopping of 150-MW unit shows a frequency rise of about 0.6 Hz.

In order to suppress this great frequency fluctuation range, NAPOCOR has been coping through measures taken in operation such as carrying out power regulation of hydropower station in advance so that the frequency fluctuation range will be kept within specified limits.

Incidentally, to estimate the system constant K of the system in its present state in the midnight hours, the following calculation is made.

From the definition of system constant,

$$K = 0.6 \text{ Hz}/150 \text{ MW}/ \text{PG}$$

where,

PG: midnight system capacity in 1989

$\fallingdotseq$ 1,800 MW

Consequently,

$$K = 7.2 \text{ Hz/puMW}$$

(b) Appropriate Unit Capacity

When making the addition of Stage II, it will be necessary to give consideration to the aspect of equipment with which starting and stopping can be done freely without prior frequency adjustments as at present. For this purpose, it is necessary for the range of frequency variation when starting and stopping pump-up in the nighttime in the future to be within 0.3 Hz.

Determining the unit capacity satisfying this condition, it is found to be approximately 150 MW with 1997 as the year scheduled for commissioning of 1 unit.

$$dF = 7.2 \text{ Hz/puMW} \times \text{PM}/ \text{PG} \leq 0.3 \text{ Hz}$$

Substituting

PG: 3,500 MW (midnight system capacity in 1997)

in the equation above,

$$PM \leq 145 \text{ MW}$$

is obtained. The unit size of 150 MW is the same as for the No. 1 and No. 2 units of the Stage I Project, which may be said to be easy to accept from the standpoint of coherent operation of the plant.

(3) Stability

In terms of power system stability of generator/motor, the condition is severer while the plant is in the pumping mode in midnight, rather than during the daytime when the units are operated in the generating mode. For this reason, the stability at nighttime was analyzed.

(a) Study Conditions

Power Flow Condition:	Off-peak midnight in 1998 (with Kalayaan in full operation).
Assumed System Fault:	A three-phase short circuit occurs on one circuit of 230 kV transmission line at just out of Kalayaan switchyard, and the fault is permanently cleared after 80 ms.
Others:	The effect of generator control system (AVR and governor) is neglected.

(b) Study Result

As illustrated in Fig. 9-4, it was verified that the power system remains stable even when a three-phase short circuit occurs on the 230-kV transmission line at very close to the switchyard while all units of Kalayaan Stage I and Stage II are in full pumping operation.

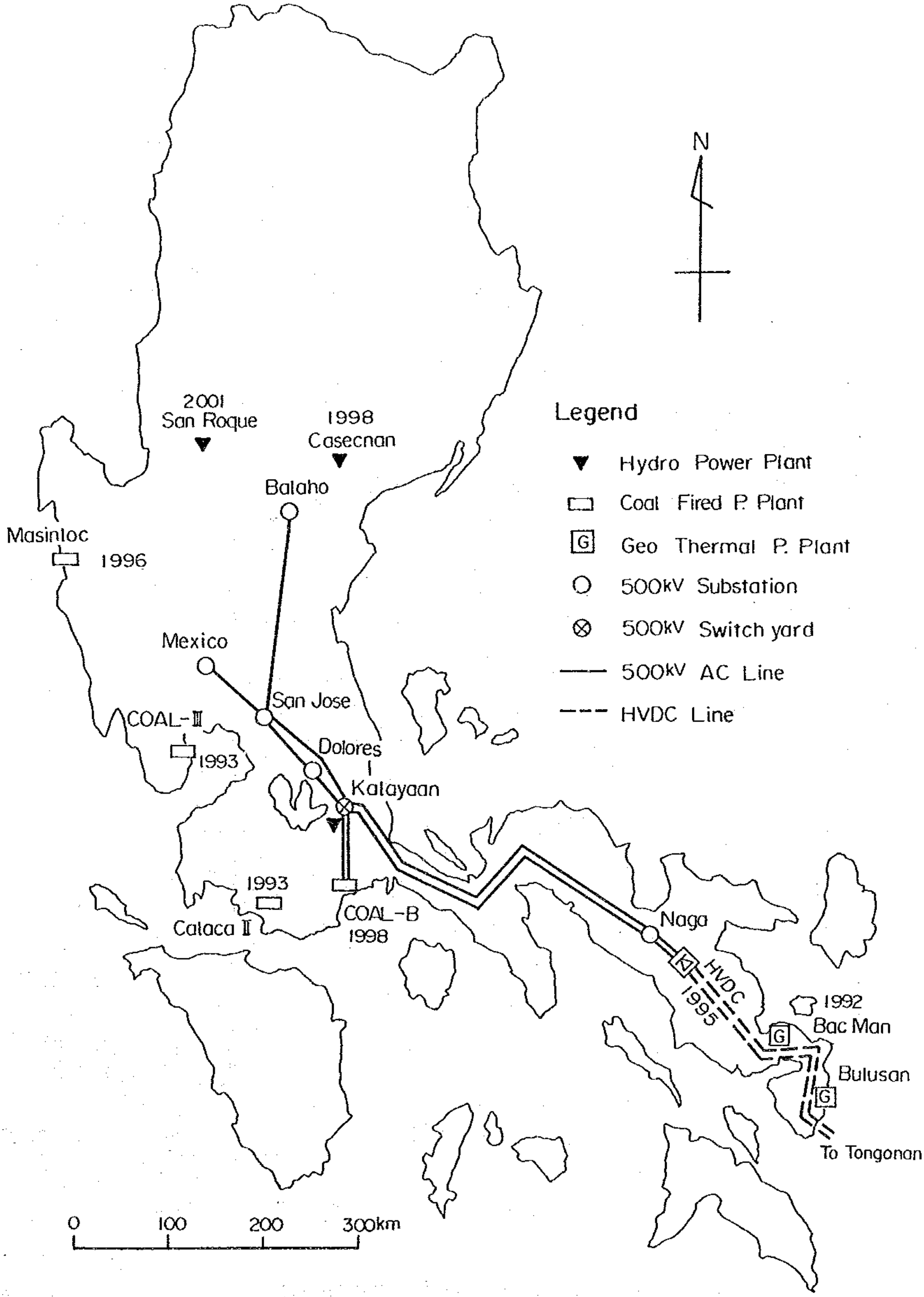


Fig. 9-1 Map of the Luzon Grid in the Late 1990s

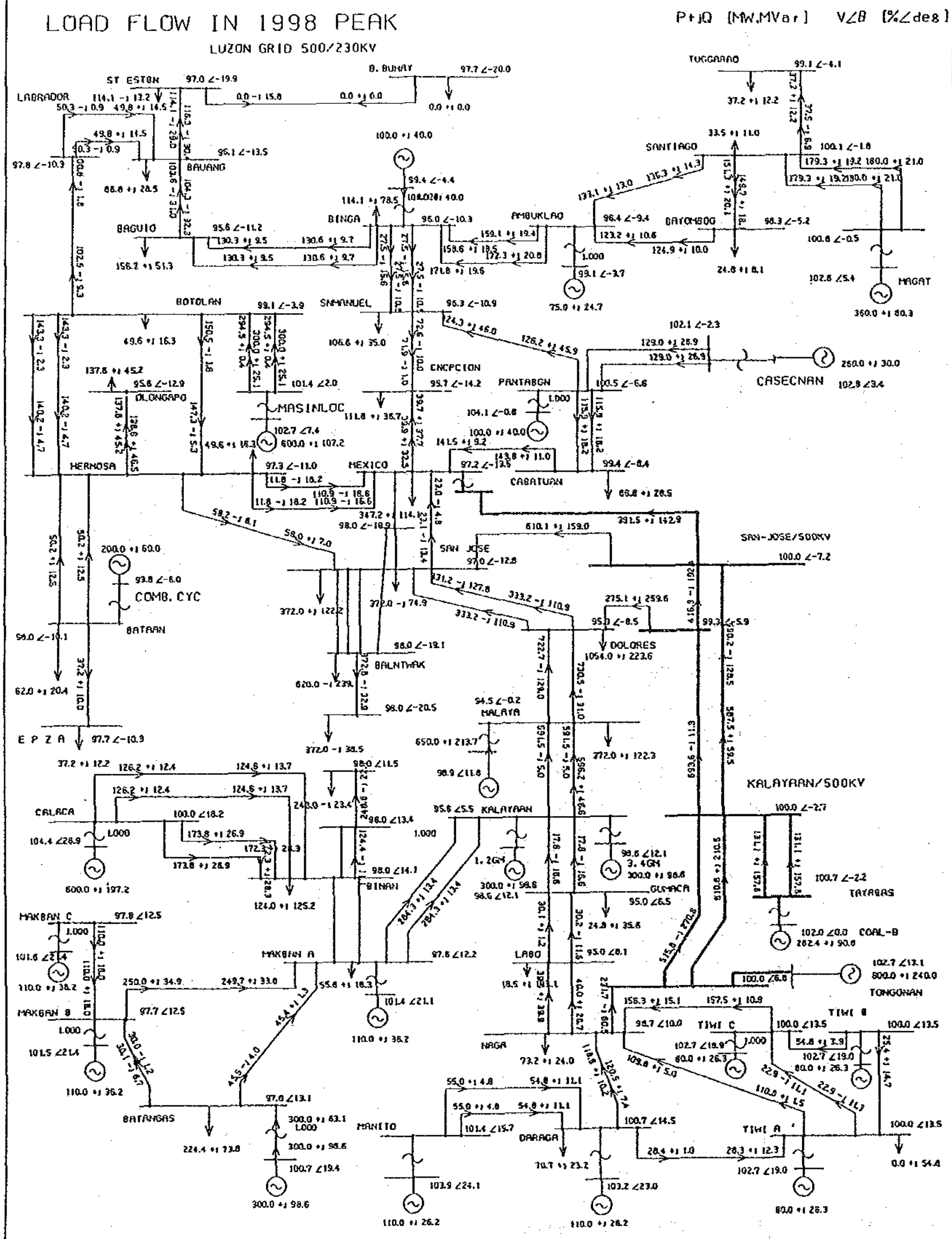


Fig. 9-2 Load Flow in 1998 (peak)

EPOC

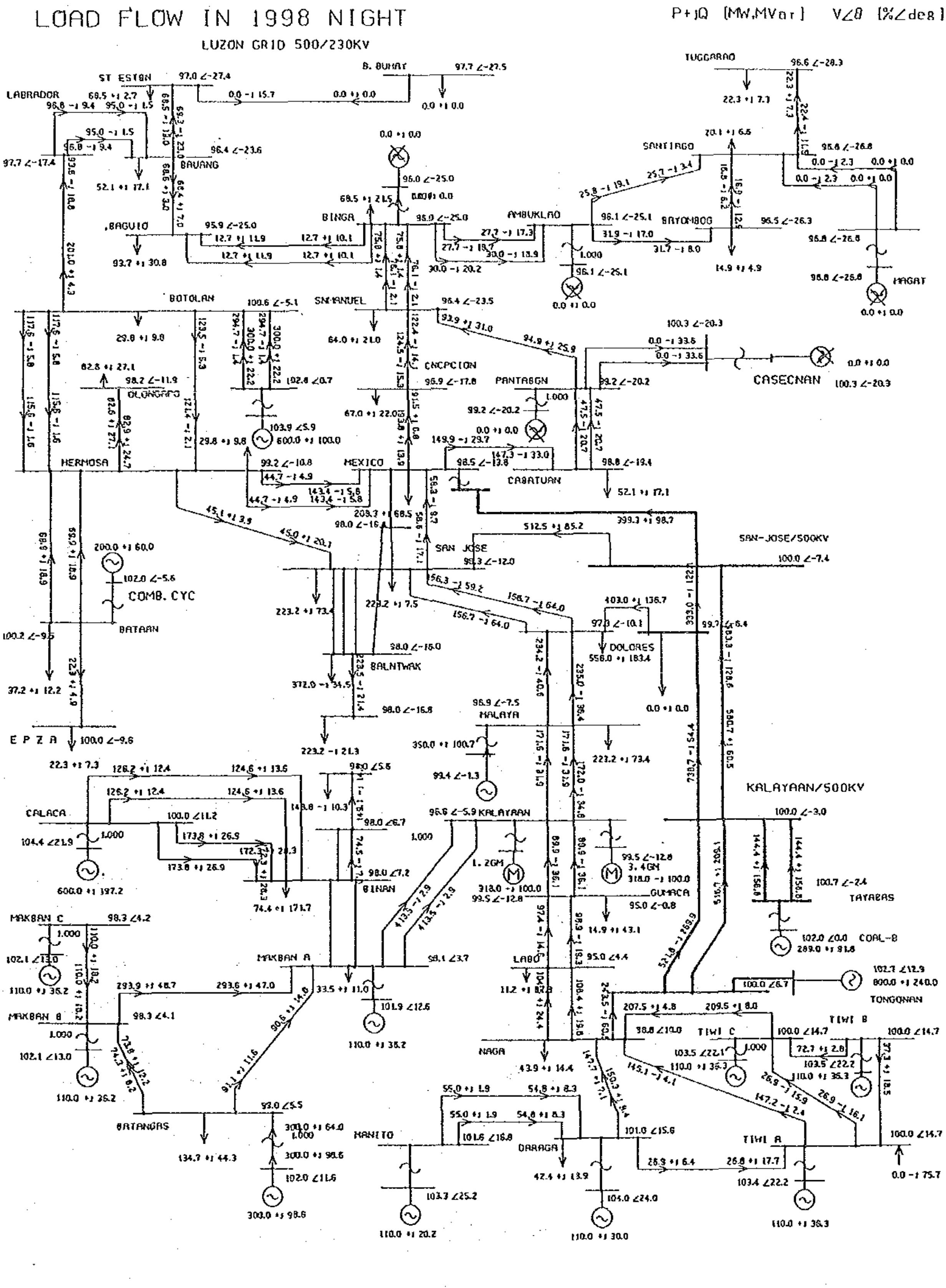


Fig. 9-3 Load Flow in 1998 (night)

EPDC

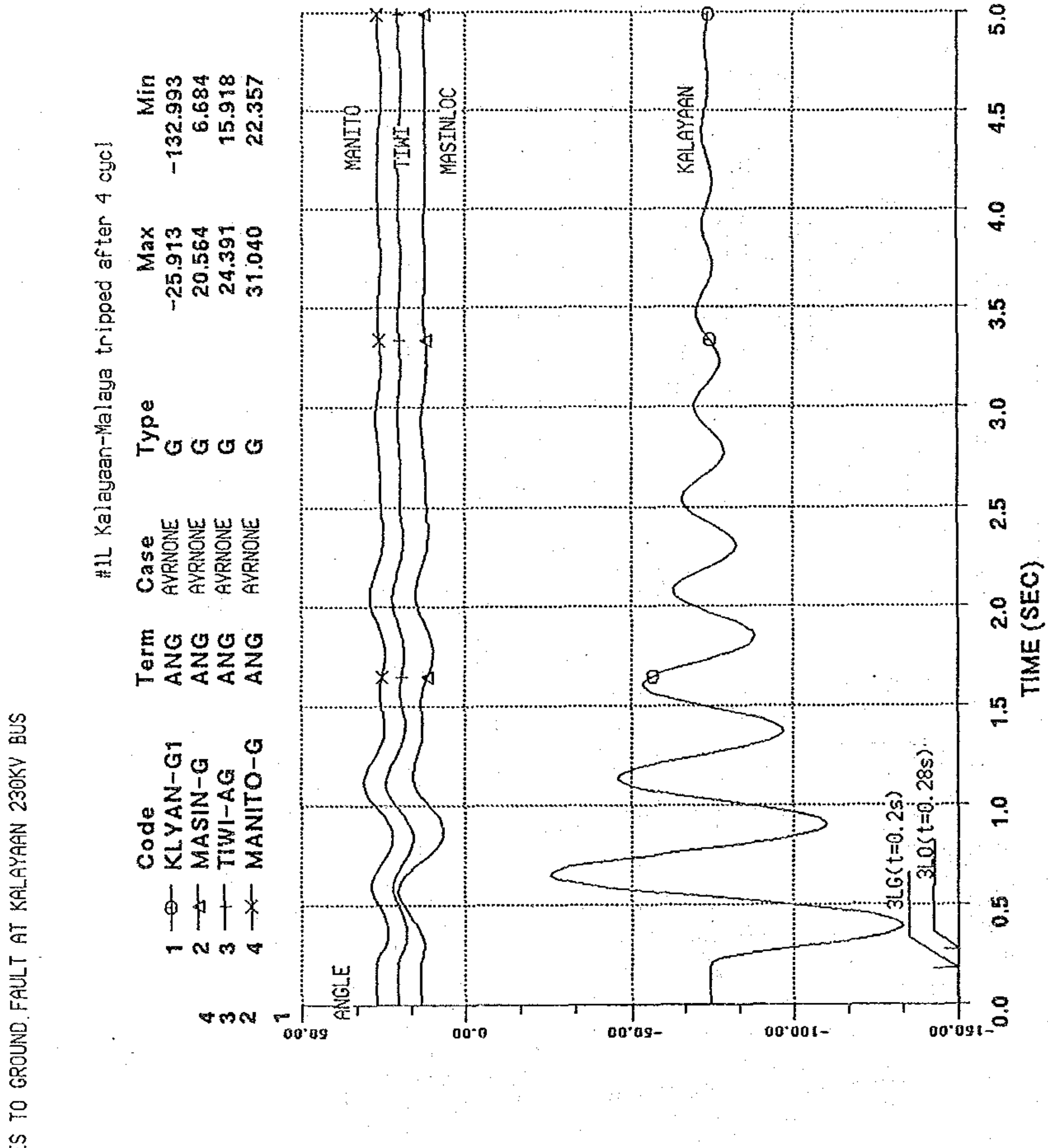


Fig. 9-4 Result of Stability Study

Chapter 10 Feasibility Design

Chapter 10 Feasibility Design

10.1 Present Condition of Existing Facilities

10.1.1 Caliraya Reservoir

Caliraya Dam and its service spillway were briefly inspected. Both structures were built about 50 years ago and are showing their age.

Small scale erosion phenomena can be seen all along the lake shore, induced by the continuous filling and drawdown due to pumped storage plant operation. Erosion was also seen in some sections of the upstream concrete facing of the dam.

Rehabilitation work is presently under way in the spillway and is planned to start at the dam in the near future. This rehabilitation work is not intended to modify the present operation levels of the reservoir.

10.1.2 Upper Canal and Intake

The upper canal was briefly inspected from the intake structure and left bank of canal, without detecting any evidence of possible problems, in view of the future expansion of the plant. The terminal end of upper canal is in good condition.

Traces of sliding could be seen at the upper part of the excavated right-bank slope of the canal. Certain countermeasures had been applied against this sliding. Although there is no clear evidence that these slide areas are still moving, continuous monitoring may be necessary for a certain period.

Meanwhile, NAPOCOR carried out survey works for confirming the situation of sedimentation in Caliraya Reservoir including the upper canal in 1988. According to the results, there is considerable sedimentation at the upper canal bottom (Fig. 10-1).

Given low water velocities currently prevailing in the canal, operated at only one third of design capacity, it may be possible that some silt, carried from the tailrace during pumping operations, has become deposited on the channel bottom.

The intake structure was examined in detail including a diving inspection to the racks and gate slots already prepared for the Stage II Project.

No special problems were found during this diving inspection; it appears that only a good cleaning of the gate slots and of the floor will be necessary before installation of the racks and gates.

In addition, some general maintenance on this structure will be necessary before implementation of the Stage II Project. In general, the intake appears to be the project component least well maintained. The lighting system wires have probably been stolen and replaced many times, with precarious connections, and all steel grills are severely weakened by rust and must be replaced.

In any case, no substantial problems which might create undue difficulty in relation to the use of this structure for the Stage II project have been detected.

10.1.3 Penstock

The penstock has been inspected from the intake down to before the last anchor block, before the terminal subvertical stretch, and then from the national road.

The existing penstock has been found in good order and recently painted, with only minor spots of rust on its surface. Leakage in the order of a few liters per minute, but with little or no pressure, was seen in all expansion joints where the sealing rings have a already been replaced. There may be some structural or installing problem for expansion joint. The pipe of the auxiliary hydraulic unit, which runs parallel to the Stage I penstock, also appears to be in good condition.

A lighting system has been installed all along the penstock, to provide better surveillance during the night.

The excavated trench is wide enough, along the subhorizontal part of the alignment, to accommodate the Stage II penstock to the left of the first one, as foreseen in the original design.

To avoid the affection to this new penstock during the future construction for the third penstock structures, considerable volume excavation is recommendable in this section.

Additional provisions already taken, in anticipation of the extension of the plant, include the concrete lining of the more inclined part of the trench bottom in the Stage II extension zone, and construction of the terminal block of the subhorizontal section for the Stage II Project.

On the other hand, the trench for the second penstock has not been excavated in the subvertical part of the alignment just above the Lumban - Kalayaan road where according to the original design, the two penstocks diverge.

10.1.4 Powerhouse Shaft and Tailrace Canal

No particular problems were detected or reported concerning the civil structure of the powerhouse shaft of Stage I, which in any event will not be directly affected by the construction of the Stage II structures.

Siltation and aquatic plant (lilium) problems were reported in the tailrace canal, where dredging has been carried out after about five years of operation for the purpose of deepening the bottom of the original design level.

Provisions for plant expansion were limited in the powerhouse area to enlargement of the general platform at elevation 6.00 to include the zone where the second shaft will be located, and to construction of the Stage II tailrace canals.

10.1.5 Service and Control Buildings

The service building, where the auxiliary hydraulic unit is located and the main gantry crane is housed, was found to be in good condition. If the original general layout of the powerhouse is maintained, the building can be used for erection of new equipment without any problem. The control building is also in good maintenance condition.

10.1.6 Switchyard

In the switchyard, space has been provided for the additional bays required for the Stage II Project. The corresponding cable galleries have already been built.

Significant horizontal displacements and differential settlements have been reported in the galleries and in the pier built further downstream to unload the plant equipment during the construction of Stage I. As a consequence, some joints of the galleries in the downstream part of the switchyard are displaced (horizontal displacements in the order of 5 cm, differential settlements of about 2 cm) and there is water leakage where the waterstops have been broken by the movement.

The horizontal movement had most likely already started at the pier during the construction period (it can be appreciated that the crane rails were installed after part of the differential horizontal movement had developed), and then progressively extended into the actual switchyard area.

At present, it appears that the movement has already fully developed (the joint indicators installed in the galleries are not showing further significant displacement). Therefore, it will be possible to use the galleries already built for Stage II after the joints have been properly repaired.

10.2 Comparison Study of Alternative Layouts

10.2.1 Basic Conditions and Alternative Layouts

Comprehensive alternative layout studies were carried out during the initial feasibility studies of the Kalayaan Project (Kalayaan Pumped Storage Plant Technical Feasibility Report, May 1973, by ELC), analyzing in particular the following aspects:

- General location of the plant,
- Alignment and design capacity of the upper canal, in relation to the staged development of the scheme
- Position and structural characteristics of the intake
- Powerhouse type: shaft, at Laguna de Bay shore, or underground, at different distances from the intake
- Consequent alternative designs of the penstock

The layout selected according to the results of those studies was essentially maintained in the successive final and detailed construction drawings.

In addition to the general criteria originally applied to the alternative layout studies, the analysis of the alternate design possibilities specifically related to Stage II Project should now take into account the restrictions introduced by the existing structures, including the structures already built for Stage II, and experience gained in the construction of Stage I.

The following design criteria have been applied in the alternative layout studies for Stage II:

- The implementation of Stage II should not cause damage or significant interruption to the operation of Stage I.

- The layout of Stage II should not prevent a possible future further expansion of the plant.

- The total capacity of Stage II will be 300 MW (in generation mode); two 150-MW units will be installed.

- Pending detailed studies of the electromechanical equipment including the penstock to be provided in the feasibility design stage, the same technical characteristics of the existing facilities have been considered.

- The operation levels of Caliraya Reservoir will remain unchanged after the implementation of Stage II.

Three basic alternative layouts have been identified:

- Alternative A: Original layout for Stage II

- Alternative B: Terminal part of the penstock embedded in a vertical shaft: shaft type powerhouse

- Alternative C: Underground Powerhouse

These alternatives are described below. In this identification process, the following aspects have been identified.

- In any case, the existing intake structure should be used. No attractive alternatives have been identified in this respect.

- The morphology prevents the possibility of economical constructing a surge tank at the edge of the slope near the existing powerhouse. The ground level at the end of the subhorizontal part of the existing penstock is around 175 m high. Thus, a surge tank in this position will be more than 100 m high: such a structure is considered practically unfeasible, especially given seismic conditions in the area.

Additional possibilities, such as:

- Fully underground penstock and shaft type powerhouse,

- Underground powerhouse located just downstream of the intake, with long tailrace tunnel, were briefly considered and discarded, being clearly much more expensive, subject to higher risks in relation to the geological conditions or requiring a substantially longer construction period.

10.2.2 Alternative A

This alternative corresponds to the Stage II development of the plant, as foreseen in the original design, and is shown in Fig. 10-2.

Principal features include:

- Use of the existing intake, installing the required service gates,

- Essentially open air steel penstock, generally parallel to the existing one, with the following characteristics:

  - Sub-horizontal stretch (from intake to anchor block 5): 6.00 m in diameter, approximately 1.0 km in length.

  - Short inclined stretch, between anchor blocks 5 and 6, about 80 m long, and 5.50 m in diameter.

  - Sub-vertical stretch approximately 100 m long, between anchor block 6 and the crossing with the national road, with 5.00 m diameter and terminal bifurcation.

  - Two 3.30 m diameter penstocks, approximately 100 m long up to the entrance into the powerhouse, installed in two parallel inclined shafts, 15 m apart.

- Powerhouse shaft, 50 m apart and identical to the existing one, equipped with two 150 MW reversible units.

- Tailrace canal, as foreseen in the original design.

- Installation of the required additional equipment in the existing control building and switchyard.

10.2.3 Alternative B

This alternative, shown in Fig. 10-3, includes the following principal features:

- Use of the existing intake, installing the required service gates, as in Alternative A.
- Essentially open-air steel penstock, generally parallel to the existing one, with the following characteristics:
  - Subhorizontal stretch (from intake to anchor block 5), as in Alternative A (penstock diameter 6.00 m, reduced to 5.50 m at the end of anchor block). Vertical curve, followed by the bifurcation, from 5.50 to 3.50 m in diameter.

    165 m long vertical stretch, the two penstocks are installed in separate vertical shafts, 15 m apart. At the bottom of the shafts, the diameter is reduced from 3.50 to 3.30 m.
  - Terminal horizontal stretch approximately 110 m long, with the two 3.30 m diameter penstocks installed in parallel horizontal tunnels, 15 m apart.
- Powerhouse shaft and tailrace canal, as in Alternative A.
- Installation of required additional equipment in the existing control building and switchyard.

10.2.4 Alternative C

This alternative, shown in Fig. 10-4, includes the following principal features:

- Use of the existing intake, as in Alternatives A and B.
- Essentially open-air steel penstock, generally parallel to the existing one, with the following characteristics:

- Sub-horizontal stretch (from intake to anchor block 4), 0.7 km long, 5.40 m in diameter, reduced to 4.90 m at anchor block 4.

- Underground portion, installed in an inclined shaft 280 m long. The upper half of this portion has a diameter of 4.9 m, reduced to 4.5 m in the lower half.

- Terminal vertical curve and bifurcation, from 4.5 to 3.2 m, just before the entrance into the powerhouse.

- Underground powerhouse, located some 250 m inside the rock mass, equipped with two-150 MW reversible units and provided with its own erection and service area. The main transformers to be installed in a separate adjacent cavern.

- The entrance of the access tunnel located adjacent to the existing Stage I service building.

- Separate cable gallery to the existing powerhouse shaft of Stage I and connecting with the cable galleries already provided for Stage II in the shaft structure.

- Tailrace pressure tunnel, 220 m long, 6.00 m in diameter.

- Tailrace canal, as in Alternatives A and B.

- Installation of required additional equipment in the existing control building and switchyard.

10.2.5 Additional Considerations

(1) Alternative A

Key technical aspects of alternative A are:

- Excavation of the powerhouse shaft, where the same difficulties faced in Stage I (poor rock quality and high seepage) should be expected. In addition, the excavation of the new shaft should be carried out with special care (strict blasting control), in view of the proximity of the existing units.

- How to keep the Lumban - Kalayaan road open during the excavation of the inclined stretch of the penstock.

In this aspect two operations will directly interfere with traffic:

- Excavations for the sub-vertical stretch of the penstock,

- Erection of the underground part of the penstock and especially the bifurcation.

The entire operation could last 12 months, without special restrictions on construction planning, or longer if strict limits on the blasting operations are specified.

The following possibilities can be considered:

- Strictly limit the volume to be excavated in each blasting carry out the blasting itself late in the evening and specify that at least half the road shall be open early the following morning.
  With these restrictions, the entire excavation of the trench may last very much.

- Provide a temporary by-pass road through the power plant area.
  This will place minimum restrictions on the excavation itself.

- Provide a completely new temporary by-pass road. This can be done by upgrading the existing road from Lumban to the Kalayaan intake and building a new section, from the intake down to Kalayaan village. This new section of road will be approximately five km long.

- Provide a by-pass tunnel to go round the construction section.

(2) Alternative B

In comparison with Alternative A, Alternative B, with the entire terminal part of the penstock embedded in two parallel vertical shafts, has the advantage of reducing interference with road traffic.

From the point of view of the future operation of the plant (Stage I plus Stage II), Alternative B is essentially equal to Alternative A. It also provides for the possibility of further expansion of the plant in the future, although the physical space available at the top of the slope, where the two parallel shafts start, is barely sufficient to install the bifurcation.

(3) Alternative C

Alternative C has the advantage of minimizing any interference between Stage II construction and the operation of Stage I, avoiding in particular the excavation of new powerhouse shaft near the existing one.

On the other hand, this alternative presents many uncertainties and disadvantages:

- The joint operation of the two stages will be more difficult, since Stage II is considered as a separate plant.

- It will be almost economically impossible to develop a rational plan for further future expansion of the plant. The only possibility will be to have an independent powerhouse for each future stage, with all relevant operation difficulties.

- The geological conditions to be faced in the excavation of the underground powerhouse are not sufficiently known. Additional extensive geological investigations would be necessary to fully support this type of design, at least for the preparation of tender documents.

10.2.6 Economic Comparison

Preliminary quantity estimates of the main civil construction items have been formulated based on the attached drawings.

Accordingly, cost estimates have been carried out, using the preliminary unit prices derived from international prices recently applied or estimated for similar works in Philippine and adding adequate percentages for minor and miscellaneous works and for technical contingencies.

An economic comparison including the cost of civil works and the hydromechanical and electromechanical equipment cost of the three alternatives is shown below:

Unit: US$M

Alternative	A	B	C
Civil Works	28.5	30.5	40.0
Hydraulic Equipment	31.2	30.3	24.2
Electromechanical Equipment	66.2	66.2	69.0
Administration Cost	7.5	7.6	8.0
Physical Contingency	8.6	8.6	9.0
Total Cost	142.0	143.2	150.2

10.2.7 Results of Comparison Study for Alternative Layouts

Taking into account both the results of the economic comparison and the technical aspects discussed above, it is proposed that Alternative A be selected for the feasibility design of the Stage II Project (Fig. 10-5).

This Alternative A has the basic advantages of allowing easier joint operation of the two stages, and keeping open the possibility of further expansion of the plant according to the original plans.

In addition, the detailed design and the construction planning of the proposed solution can take full advantage of the experience already obtained during the construction of Stage I, avoiding the uncertainties typically related to large underground works.

The basic features of the proposed layout, and the key aspects to be further studied in the feasibility design stage are described in the next section.

10.3 Proposed Design of Civil Structures

After the selection of the general project layout, further in-depth studies and analyses were carried out to verify the hydraulic and structural adequacies of the design and to optimize the characteristics of the main structures.

10.3.1 Upper Canal

The hydraulic behavior of the canal with the increased discharges foreseen has been verified. Considering the original design characteristics (length about 1,120 m, bottom width 45 m, bottom elevation 281.50, side slopes 1.7H/1V), the following preliminary results have been expected:

- In steady conditions, the maximum velocity (all units in turbine mode, minimum water level in Caliraya reservoir) will be approximately 1.1 m/s.

- In steady conditions, maximum and minimum water levels at the intake are 290.02 (all units in pumping mode, maximum exceptional water level in the reservoir 290.00) and 285.80 (with all turbines operated and with water level in the reservoir 286.00) respectively.

- The sudden closure of all turbines will produce a surge at the intake not higher than 0.7 m.

- When all of 4 turbines are started up simultaneously for generation, the water level at the intake is instantaneously lowered by 3.5 m.

These results are considered acceptable. It will be advisable, especially with low reservoir water level, to start turbine operation of four units simultaneously to avoid the risk for absorption of air into the penstocks.

The increased water velocity in the canal will increase the risk to have the silt deposits in the bottom dragged into the penstocks and the turbines, especially in the initial period of the operation with four units. To minimize this problem, a dredging of the canal will be advisable.

Given the traces of past slides observed in the banks, it is proposed to install suitable measuring devices, to check possible ground movements and in case to plan the necessary remedial measures.

10.3.2 Intake (Fig. 10-6)

The existing intake will be used for the Stage II Project (see Fig. 10-5). The implementation of Stage II will require:

- Installation of two service gates, each 2.80 m wide and 6.00 m high,

- Installation of a steel-lined transition to be embedded in the existing structure and of the initial part of the surface penstock.

A complete inspection of the upstream bottom part of the existing temporary plug must be required, all silt and debris deposits must be removed and the gate slots must be repaired if necessary.

Then the service gates will be installed, allowing the removal of the concrete plug and the installation of the penstock.

At the same time, a complete rehabilitation of the existing intake structures shall be carried out.

10.3.3 Penstock (Fig. 10-7)

The penstock for Stage II will be installed along the alignment originally foreseen, essentially parallel to the existing one. According to the original design, the penstock route is divided into the following sections:

- Initial subhorizontal section, from the intake to the edge of the slope above the national road, with a total length around 1,000 m.

  In the study so far conducted, the alignment of this section is installed in the trench already excavated during the construction of Stage I. Five anchor blocks are foreseen in this stretch, including the anchor block No. 5, already built during the construction of Stage I.

- Short inclined section, between anchor blocks No. 5 and No. 6, approximately 80 m long,

- Subvertical section approximately 100 m long, between anchor block No. 6 and the crossing with the national road, with terminal bifurcation,

- Two separate penstock, approximately 100 m long, from the bifurcation up to the entrance of the powerhouse, installed in each parallel inclined shaft, 15 m apart from each other.

(1) Economical Diameter

An economic analysis has been carried out. To determine the economical diameter of each section of the penstock, an economical comparison study was conducted applying the conventional method of minimizing the total present value of construction cost plus energy and power losses (in both pumping and generating modes) during the economic service life of the plant.

The results are the following:

Section	Economical Diameter (m)
Between intake and anchor block 2	4.8
Between anchor blocks 2 and 3	4.5
Between anchor blocks 3 and 5	4.3
Between anchor blocks 5 and 6	4.1
Between anchor blocks 6 and the road crossing	4.0
Underground stretch (two shafts)	2.9

(2) Recommended Diameter

It is necessary to check whether turbine stability is maintained during output variation for the economical diameter.

In order to keep within acceptable limits the frequency variations induced by a change in the power output, the penstock time constant, defined as

$$T_c = (L_1v_1 + L_2v_2 + L_3v_3 + \dots L_nv_n) / gH$$

where, L_i and v_i are the length and maximum flow velocity of each penstock section,
g is the gravity acceleration, and
H is the minimum head,

shall be generally kept not higher than about 2.0.

In the present case, should the economical diameters be adopted, the penstock time constant will be about 3.75, far too high to have an acceptable behavior from a frequency regulation point of view, considering also the importance of the Stage II plant for the overall performance of the Luzon Grid.

Since the lengths of the different stretches are given by the topographical conditions, in order to reduce penstock time constant to acceptable values, it is necessary to reduce the flow velocities, and therefore, to increase the diameters.

According to the original design of the Stage I Project, the diameter of each section has been selected as follows:

- Initial subhorizontal stretch, from the intake up to anchor block No. 5: 6.00 m

- Inclined stretch between anchor blocks No. 5 and No. 6: 5.50 m

- Subvertical stretch, between anchor block No. 6 and the road crossing: 5.00 m

- Embedded section, after bifurcation: 3.30 m

With these diameters, the penstock time constant would be reduced to 2.10, which can be considered acceptable.

Therefore, for feasibility design purposes, it is proposed to adopt for the penstock of Stage II the same diameters as used for the penstock of Stage I.

The position of the branching may be considered to be at the beginning of the inclined shaft, as has been done in Stage I. Because the bifurcator is relatively large, 7 m x 6 m x 5 m, but this can be installed easily from the Lumban - Kalayaan national road.

Being the penstock diameters equal to the ones of Stage I, the corresponding civil works (anchor blocks and saddles) are also essentially equal.

In the subhorizontal part of the alignment (up to anchor block No. 5), a specific problem to be faced will be the blasting control during the excavations for the penstock foundations, due to the close vicinity with the penstock of Stage I. In this same area, in order to provide acceptable conditions for construction of a possible future Stage III, it is proposed to include in the scope of work of Stage II the enlargement of the existing penstock trench, on the left side, for a width of 10 m.

Even with the traffic diverted into the temporary by-pass tunnel, some blasting control measure will be also required for the excavation of the subvertical stretch above the national road, to limit the risk of rock fragments falling into the powerhouse area.

10.3.4 Temporary Detour of the Lumban - Kalayaan Road during Construction

As already mentioned, a by-pass tunnel is proposed to maintain safe and continuous traffic conditions along the Lumban - Kalayaan road during the construction.

This tunnel will branch from the national road some 70 m before the crossing with the existing Stage I penstock, reaching again the road 70 m after the alignment of the new penstock. A minimum distance of 30 m will be maintained between the tunnel and the excavation slopes of both the existing and planned penstocks.

The section of the detour tunnel will be 5 m wide by 5.00 m high, allowing one-lane traffic, with a walkway on one side. Lighting will be provided and signals installed at both ends to control the traffic. The tunnel bottom will be concrete paved. In principle, no lining is foreseen, except at the portals and where required by stability problems.

10.3.5 Powerhouse Shaft

The powerhouse will be located 50 m away from the existing one, as originally foreseen, and will be equipped with two 150-MW reversible units (Fig. 10-8).

As discussed in depth in the next sections, the advances made in the technology of the pump-turbine since the design and implementation of Stage I allow the selection of 360 rpm units, maintaining the same turbine center elevation of the 300 rpm units adopted in Stage I. The general arrangement of the powerhouse equipment will be very similar to Stage I.

From the civil design point of view, the shaft will be therefore similar to the existing one, with the same depth and somewhat smaller horizontal dimensions, as allowed by the higher speed of the new units.

The excavation method will be essentially the same as that used for Stage I, with temporary concrete diaphragms to seal the pervious loose materials up to the rock surface, and grouting carried out in advance of the excavation to reduce seepage and to improve stability conditions (Figs. 10-9, 10).

One of the more important technical problems to be faced for the construction of Stage II will be blasting control to be applied during excavation of the new powerhouse shaft, in order to prevent damage to civil structures and to the equipment of Stage I. The countermeasures are studied and described in Chapter 6.

In order to facilitate a possible further extension of the plant (Stage III) reducing future blasting control problems, it is proposed to include in the scope of works of Stage II the enlargement of the general platform at elevation 6 m to the left of the second shaft for a width of 50 m, corresponding to the zone for a third shaft could be located. This additional excavation will also be very useful for installation of construction equipment and related facilities.

10.3.6 Tailrace Canal (Fig. 10-11)

Since most of the canal had already been excavated during the construction of Stage I and dredged again a few years later, the work will now be essentially limited to the area just in front of the new shaft, plus the dredging that will be necessary to reach the original bottom level at the full width. According to the new survey available, some dredging will be required along the left margin of the canal, where the water velocity is presently low and thus siltation has occurred (Fig. 10-12).

In any case, it is considered that maintenance dredging during the initial period of operation of Stage II, as allowed by the new dredging equipment provided, will be sufficient to keep the problem under control.

10.3.7 Switchyard

Civil works in the switchyard area will include repair of leaking joints of the existing galleries and construction of foundations for the new equipment.

In order to repair the leaking joints, pits will be excavated to expose the external faces of the galleries at the joints locations. Then some concrete will have to be demolished and the waterstops changed.

10.3.8 Equipment Unloading and Transportation Facilities

As already mentioned, rehabilitation works will be required at the existing unloading facilities to allow their use during the construction of the Stage II.

The gantry crane originally installed at the pier, which has remained out of operation and unprotected for quite a long period, will be inspected, repaired as necessary, and tested.

The crane rails, now dislocated because of the differential displacements of the concrete structure of the pier, will be reinstalled, and a suitable road branch will be prepared, passing behind the switchyard area and connecting the pier with the existing main access to the plant.

10.4 Electrical Equipment

10.4.1 Powerhouse

The specifications and equipment layout for the Stage II Project are to be designed on the basis of the Stage I Project in consideration of the following.

- The Stage I Project was designed and constructed taking into due consideration the Stage II and subsequent projects. For example, common use of the assembly crane and the erection bay (service building), and configuration of outdoor switchyard equipment and galleries for power and control cables of the Stage II Project can be cited.
- As to the equipment layout concerning the powerhouse building structure, the Stage I Project was designed rationally, and there are no detrimental points through which requirement of extensive changes cannot be observed in particular. Furthermore, when considering the ease of operation and maintenance, it is an important factor to achieve harmony with the Stage I Project.

(1) Pump-Turbine

Type : Reversible vertical-type Francis pump-turbine
Number: 2 units

(a) Turbine Mode

	(Max.)	(Normal)	(Min.)
Effective head (m)	287.2	282.0	278.4
Discharge (m^3/s)	60.7	62.0	61.6
Output (MW)	154	154	150
Rotating speed (rpm)	360	360	360
Specific speed (m-kW)	119.4	122.3	122.6

(Note) Discharge is approximate.

(b) Pump Mode

	(Max.)	(Min.)
Net pump head (m)	291.4	283.8
Pump discharge (m^3/s)	47.4	49.9
Input (MW)	152	155
Rotating speed (rpm)	360	360
Specific speed (m^3/s)	35.1	36.8

(Note) Pump discharge is approximate

The rotating directions, seen from the generator are to be counter-clockwise for turbine mode and clockwise for pump mode, similarly to the Stage I Project.

The different points from the Stage I may be of selection of the rotating speed. The rotating speed of the Stage I is 300 rpm, but as a result of study on cavitation characteristics and water-hammer phenomena, in case the pump-turbine center elevation is determined the same EL. -25.00 as that of the Stage I, it is possible to select 360 rpm for the Stage II. On the other hand, in case of adopting 300 rpm similarly to the Stage I, it will be possible to raise the turbine center elevation to EL. -21.00 m, and on comparison of construction costs for the 300 rpm and 360 rpm proposals, the 360 rpm proposal will be more economical as shown below.

(Unit: 10^3 US$)

	300 rpm	360 rpm
Civil Works	-560	0
Electrical Equipment	+1,200	0

(2) Generator-Motor

Type	3-ph, AC, synchronous Generator-motor	
Number	2 units	
Generator output (MVA)	167	
Motor output (MW)	155	
Voltage (kV)	13.8	
Frequency (Hz)	60	
Rotating speed (rpm)	360	
Number of poles	20	
Power factor	Generator	0.90 (lagging)
	Motor	0.95 (leading)
Short-circuit ratio	1.0	

The thrust-bearing support system may be cited as a point which differs from the Stage I.

The Stage I has a turbine top cover support system, but instead of this, the generator-motor is to be of a semi-umbrella type adopting a supporting construction by concrete barrel which accommodates thrust bearings inside a lower bracket.

The major features of each construction are described below.

(a) *Supporting Stiffness*

- Top Cover Support System
  The thrust load is transmitted to the concrete foundation through bearing support, turbine top cover, and speed ring, and in order to obtain the required stiffness in vertical direction, it is especially necessary to increase stiffness of bearing supports. As for horizontal load acting on guide bearings, since support is provided through bearing supports and the top cover, it is difficult to obtain a high horizontal support stiffness.

- Barrel Support System

  Thrust load and lateral load acting on guide bearings are transmitted directly to the concrete foundation through lower brackets so that it is possible to obtain a great stiffness.

(b) Operating Characteristics and Maintenance Properties

- Top Cover Support System

  Since thrust bearings are supported through the top cover of the turbine, effects such as deformation and vibration of the top cover due to water pressure are directly sustained. Spaces around the turbine top cover are confined and inspection is difficult to perform.

- Barrel Support System

  Thrust bearings are directly supported from the concrete foundation through lower brackets avoiding from effects due to turbine vibrations. There is much space around the turbine top cover, and inspection and disassembling of turbine guide bearings and shaft seal packing can be easily performed.

In case of high-speed and large-capacity machines, the barrel support system is normally advantageous from view point of stiffness of the equipment and is widely used.

(3) Pump-up Starting System

For the pump-up starting system in the Stage I, the pony motor starting system is adopted as main for both the No. 1 and No. 2 units, with a back-to-back starting system as back-up.

With back to back starting, starting from No. 1 to No. 2 or vice versa is possible, and as the bus for synchronizing, one bus of two buses consisting of one-and-a-half system (230 kV) of the switchyard is used. Therefore, it is possible to start pumping up the Stage II units pump-up from the Stage I without especially adding equipment such as buses and disconnecting switches for the purpose of synchronizing, and the most economical system could be made by adopting a back to back starting system for the Stage II.

However, when considering the actual operation of this system, there are drawbacks as below, and consequently it cannot be adopted.

- The back-to-back starting system cannot self-start so that in the event of trouble with or penstock dewatering of the Stage I pump-up of the Stage II cannot be done.

- The control sequence will become considerably complex for both the Stage I and the Stage II.

Therefore, the Stage II Project shall have a system making possible self-starting as main with a back-to-back starting system as back-up, similarly to the Stage I Project.

As a self-starting system applicable to the Stage II Project, there is besides the pony motor starting system, the thyrister starting system (static frequency changer) which has become the mainstream of pump-up starting method in recent years, and the characteristics of the two are given below.

(a) Pony Motor Starting System

- Since a pony motor is directly mounted on the top of the generator-motor, the axial length of the entire rotating part becomes long, which is disadvantageous from the standpoint of suppressing axial vibration.

- Loss (windage loss) during operation is increased.

- In addition to the pony motor which is a rotating machine, there are a liquid resistor for controlling the rotating speed, slip rings, brushes, etc. as accessories which are undesirable from the standpoint of maintenance.

- The cost is low compared with the thyrister starting system.

(b) Thyrister Starting System

- There are many components which require a large space for installation.

- The cost is high, and provision of an exclusive system for each unit would be disadvantageous both economically and space-wise.

- Countermeasures against harmonies caused by thyristers are to be studied.

A comparison of the two systems is made below.

	(Cost)	(Space)
Pony motor starting system (2 sets)	100%	100%
Thyrister starting system (1 set)	125%	200%

Regarding the reliability when one set of thyrister starting apparatus is provided for 2 main units, it can be amply secured by provision of a thyrister element reserve circuit and of a complete duplication of control circuits with addition of automatic inspection circuit, while furthermore, since a back to back starting system will be adopted as a back-up, there will be no problem at all.

Upon the above comparison of the pony motor starting system and the thyrister starting system, the pony motor starting system is presently advantageous from the aspect of price. However, the thyrister starting system can be adopted if there is a future reduction in price.

The specifications of the pony motor starting system are given below.

Type	3-ph, induction motor
Number	2 units
Motor output (MW)	11
Voltage (kV)	4.16
Frequency (Hz)	60
Rotating speed (rpm)	400
Number of poles	18

(4) Control and Protective Relay Device

Advances made in digital technology in recent years have been extremely great, and it has become an era where not only automatic operation control device, but also Turbine Governor (GOV), Automatic Voltage Regulator (AVR), and further, protective relay device for generating facilities and transmission lines are being digitalized.

As the background for such digitalization, there are the pursuit of higher degrees of control and protective functions, and the desire for improvement in reliability and maintenance-free conditions.

However, in the event trouble should occur, due to the higher level of technology and the greater density, there might be difficulties on disposal of the trouble, in particular when foreign-made products are involved.

In consideration of the above points, conventional types (stationary analog) will be adopted for the GOV and AVR possessing regulating functions and for protective relaying device that are the linch pins of safe operation. On the other hand, with regard to automatic operation and control devices, Programmable Logic Controller (PLC) will be adopted for the following reasons:

- A pumped storage power plant has large varieties of auxiliary equipment and operating modes compared with conventional plants, and the control sequence will be complex. When this is structured with device comprising combinations of conventional electromagnetic relays, it will be difficult for reliability to be secured over a long period of time.

- Digitalization of sequence control device has a longer history compared with digital GOV and AVR, and has an ample track record. With the recent advent of microprocessors, increased memory capacities, and improvements in automatic monitoring and abnormality diagnosis functions, the technological advances in both hardware and software aspects have worked together resulting in a product with high degree.

- In the event of trouble, it will be possible for operation to be continued by manual operation isolating the PLC.

The operating mode is to be the following, similarly to the Stage I.

(a) Generating operation
(b) Condenser operation
(c) Pumping operation (pony motor starting and back to back starting)
(d) Spinning reserve operation at pumping mode (ditto)
(e) Generating-pumping (pumping-generating) changeover operation

(5) Inlet Valve

Rotary valves are to be adopted similarly to the Stage I Project.

(6) Auxiliary Equipment

The specifications and layouts of pressure oil supply system for governor, compressed air supply system, water supply and drainage systems are to follow those for the Stage I.

Grease supply system can be omitted by adopting oil-less metal for guide vane bearings and inlet valve main shaft bearings.

10.4.2 Study of Cavitation Characteristics and Water Hammering

(1) Cavitation Characteristics

The cavitation coefficient [sigma] is obtained by the following formulae.

$$[\sigma] = (Ha - Hv - Hs)/He$$

where:

Ha: atmospheric pressure (m)
Hv: saturated vapor pressure (m)
Hs: draft head (m)
He: effective head or pumping head (m)

(a) Cavitation Coefficient [sigma] in Turbine Mode

Ha = 10.33 m (value at elevation 0 m)
Hv = 0.43 m (value at 30°C water temperature)
Hs = -24.64 m [turbine center elevation (-25.00)]
- [minimum tailrace water level (-0.36)]

The value of [sigma] with the maximum effective head is:

$$[\sigma] = (10.33 - 0.43 - (-24.64))/287.2 = 0.120$$

(specific speed of turbine: nst = 119.4 m-kw)

(b) Cavitation Coefficient [sigma] in Pump Mode

The value of [sigma] with the maximum effective head is:

$$[\sigma] = (10.33 - 0.43 - (-24.64))/291.4 = 0.119$$

(specific speed of pump: nsp = 35.1 m-m3/s)

The cavitation characteristics tends to be degraded as the operating conditions depart from the maximum efficiency point.

In this Project, the pump-turbine can be operated near the maximum efficiency point, because the variations in head and pumping head are small, and this is a favorable condition in terms of cavitation characteristics.

The values of cavitation coefficient (values of plant [sigma] at runner center) obtained above can be judged as appropriate based on the past experience.

(2) Water Hammering

The water hammering pressures, that occur when load (or input) on two units are interrupted simultaneously, were calculated by computer simulation.

(a) Calculation Condition

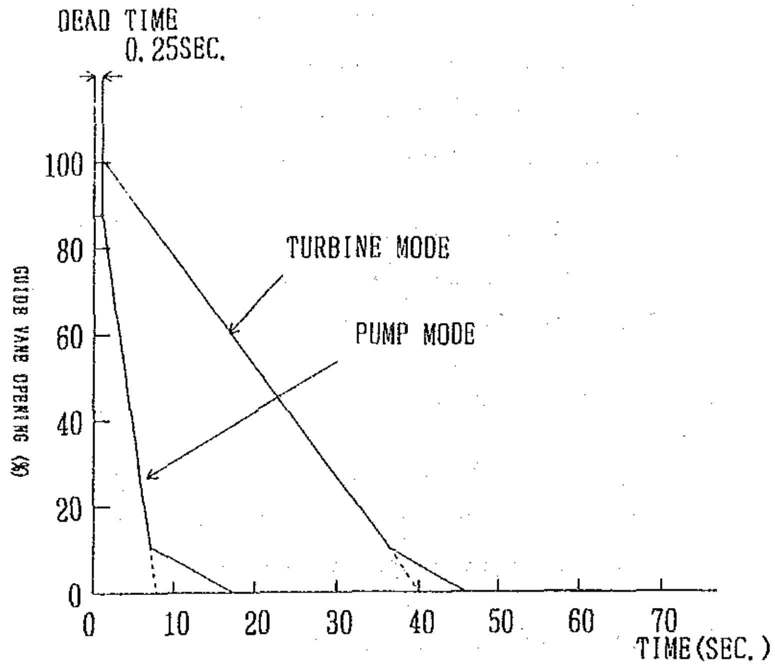
- The conditions of water system were assumed to be the same as in the Phase 1 system.

- Runner center elevation: EL. - 25.00 m

- Operating condition

	Turbine Mode	Pump Mode
Upper Reservoir Water level (EL - m)	287.0	286.0
Lower Reservoir Water level (EL - m)	0.6	3.24
Effective Head/Pumping Head (m)	282.0	283.8
Discharge (m3/s)	62.0	49.9
Turbine Output/Pump Input (MW)	154.0	155.0
Rotating Speed (rpm)	360	360

- GD2: 4,900 ton-m2
- Guide Vane Closing Time



GUIDE VANE CLOSING TIME

(b) Calculation Results

The calculation results are as follows (refer to Fig. 10-13 and Fig. 10-14)

(Turbine Mode)	Unit 3	Unit 4
Maximum Penstock Water Pressure (m)	408.0	408.0
Minimum Draft Tube Water Pressure (m)	13.9	13.9
Maximum Speed Rise (rpm)	484.8	484.8

(Pump Mode)		
Maximum Penstock Water Pressure (m)	345.0	345.0
Minimum Penstock Water Pressure (m)	194.0	194.0
Minimum Draft Tube Water Pressure (m)	36.0	36.0

Generally, pressure rise of higher harmonic component is induced when the load on high head pump-turbine is interrupted in a turbine mode operation.

This value was assumed to be 3% based on the past experience, and was added to the above calculation values. The pressure rise due to higher harmonic component is:

(287.0 m - 0.6 m) x 0.03 = 8.6 m

Therefore, a pressure rise of 9 m was assumed, which gives the maximum penstock pressure rise of 417 m (408 m + 9 m), which is below the guaranteed pressure rise of 426.5 m for the units of the Stage I.

The speed rise is 34.7%, which is below the guaranteed value of Phase 1 of 45%.

10.4.3 Outdoor Switchyard, Other Items

(1) Main Transformer

Type	Outdoor, 3-ph, forced oil, air-cooled
Number	2 units
Capacity (MVA)	167
Voltage (kV)	230/13.8
With on-load tap changer	

The place of installation is to be outdoor adjacent to the powerhouse building similarly to the Stage I, and fire extinguishing system using water spraying will be provided.

(2) Starting Transformer

As the power supply for the pony motor of the Stage I, there are two transformers with capacity of 15 MVA (230 kV/4.16 kV), and joint use will be possible on the premise that simultaneous starting of all units be avoided. They have also the capacities to take care of station power supply.

(3) Outdoor Switchgear

The bus configuration of the outdoor switchyard equipment is of a 230 kV, 1-1/2 CB system, and there are presently outgoing transmission lines of 6 circuits. The existing spaces for the installation of the equipment for the Stage II such as circuit breakers, disconnecting switches, and cable heads are already taken into accounts, and these are to be of the same layout as that of the Stage I.

SF_6 gas-insulated circuit breakers will be adopted similarly to Stage I, but instead of porcelain insulator type, the tank type with CT which is presently used most frequently is to be adopted. As for 230 kV power cable, instead of OF cable, XLPE cable having an ample operation record will be adopted by which ancillary apparatus for regulating oil pressure can be omitted.

The single line diagram and the general layout are shown in Figs. 10-15 and 10-16.

(4) Assembly Crane and Unloading Crane

The assembly crane (340 ton gantry crane), erection bay (service building), and unloading crane for equipment transported by barge (130 ton gantry crane) used in the Stage I Project can be used directly for the Stage II Project.

The 340 ton crane is kept inside the service building at all times and is in good condition.

On the other hand, with regard to the 130 ton unloading crane, it has no housing and has been exposed outdoors for a long time so that a thorough check including loading tests will be necessary before using.

10.4.4 Transportation

Transportation of large articles, similarly to the Stage I Project, is to be carried out by barge utilizing the Pasig River which flows from Laguna de Bay, the lower reservoir, to the port of Manila.

A cargo landing dock and the previously-mentioned crane are available for unloading of generating facilities such as pump-turbine, generator-motor, transformer etc. for the Stage II Project. Transportation from the dock to the service building would be by trailer truck.

The principal articles with large size are the following:

	Dimensions (m)			Weight	Number of Pieces
	H	W	L	(ton)	
- Runner	1.5	4.5	4.5	45	1
- Main Transformer	4.5	3.5	6.0	100	1

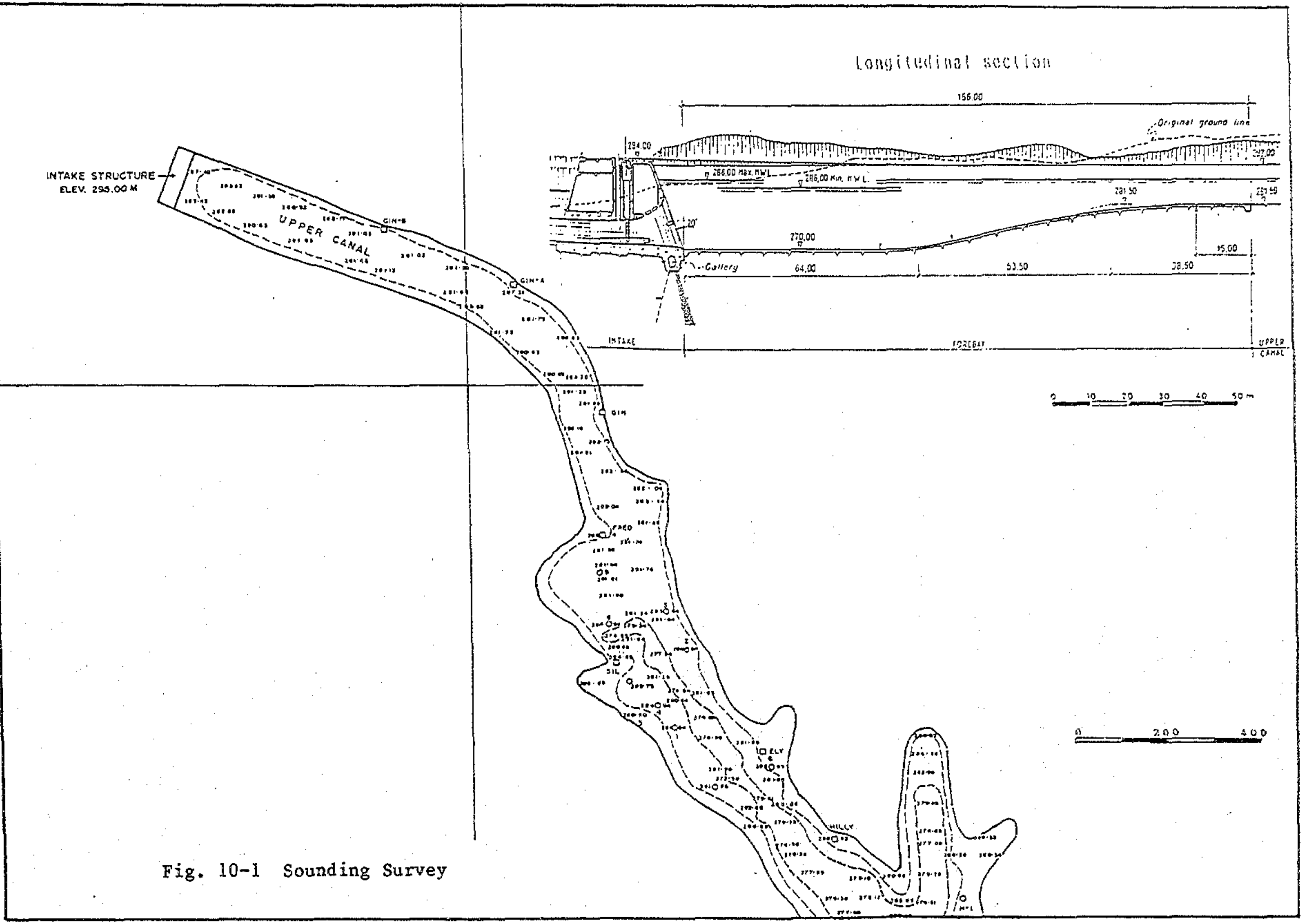
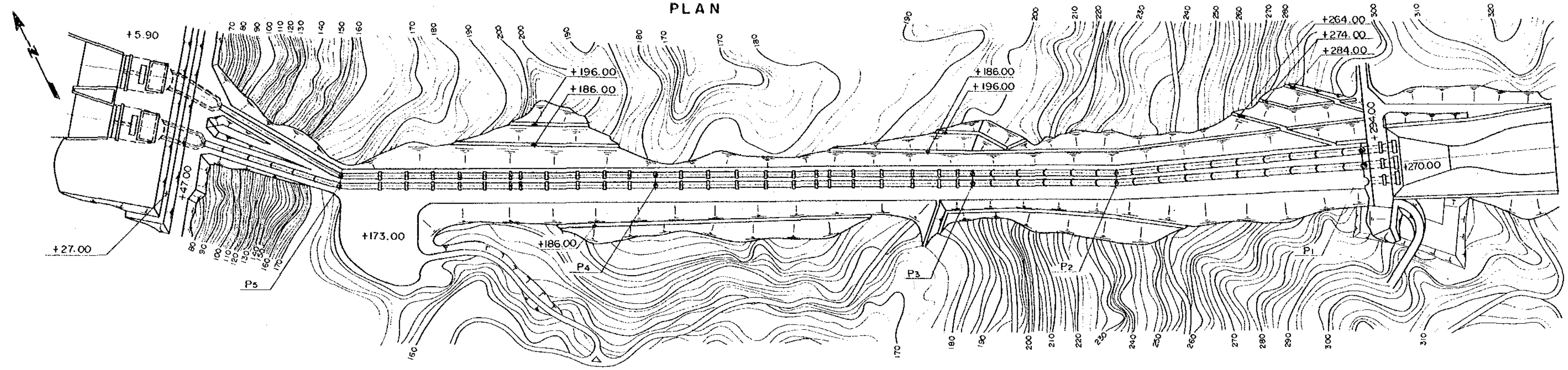
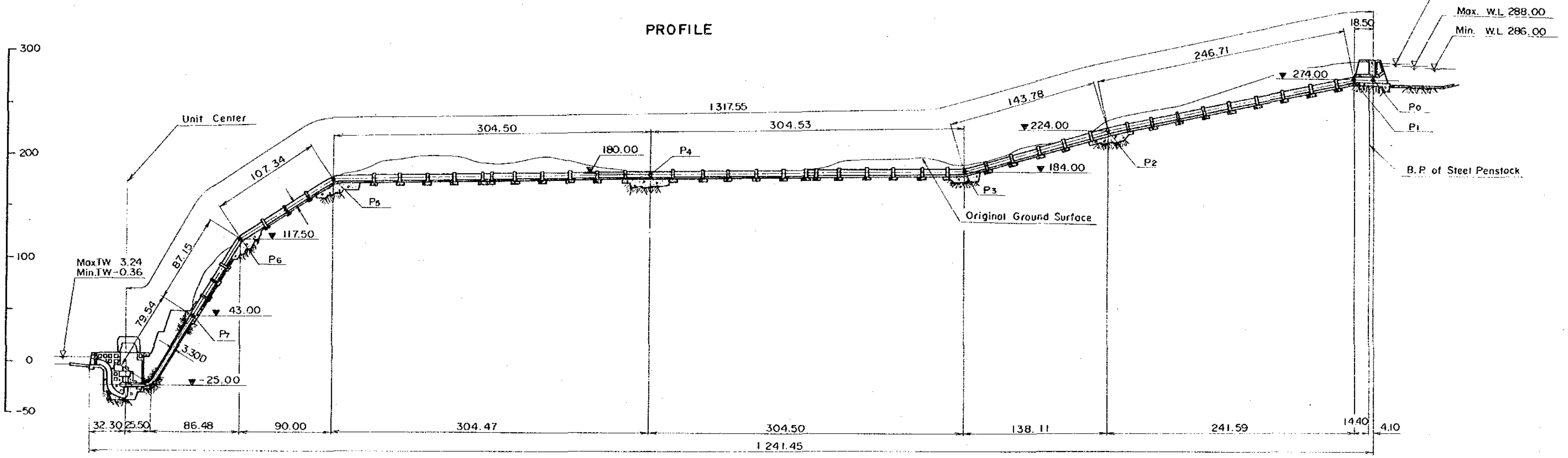


Fig. 10-1 Sounding Survey

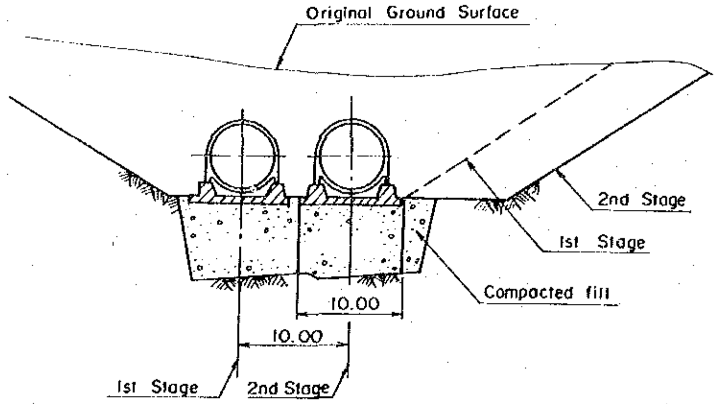
PLAN



PROFILE

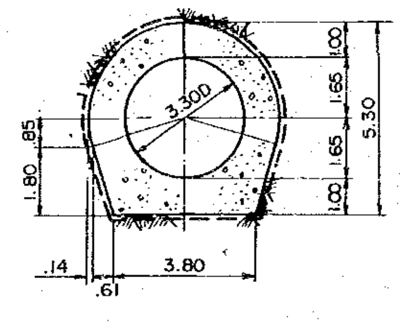


TYPICAL SECTION (OPEN PART)



TYPICAL SECTION (UNDERGROUND)

Horizontal and Inclined



0 20m

Note

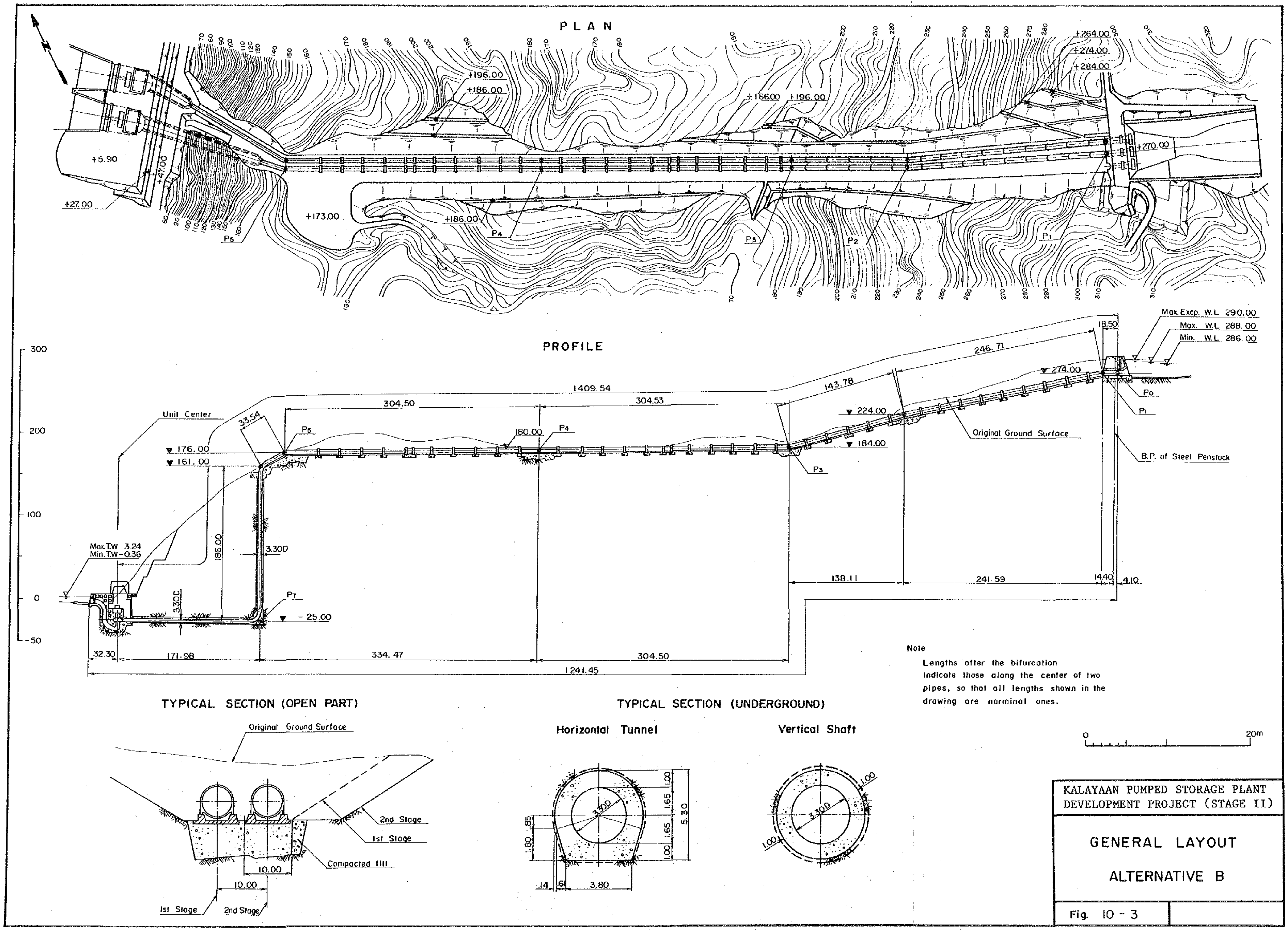
Lengths after the bifurcation indicate those along the center of two pipes, so that all lengths shown in the drawing are narminal ones.

KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

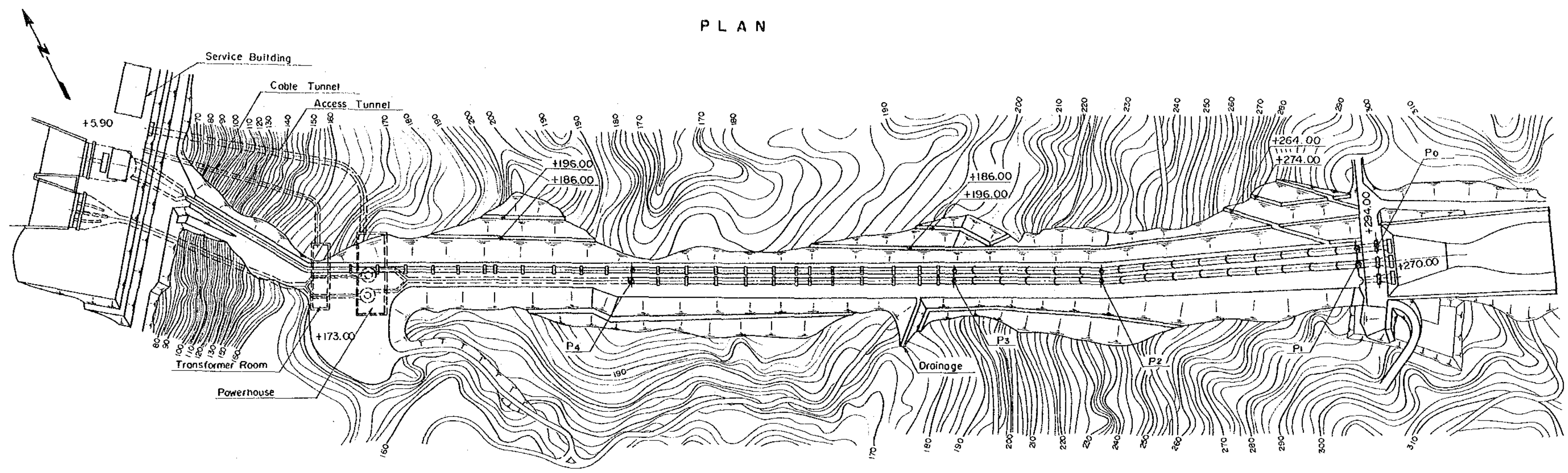
GENERAL LAYOUT

ALTERNATIVE A

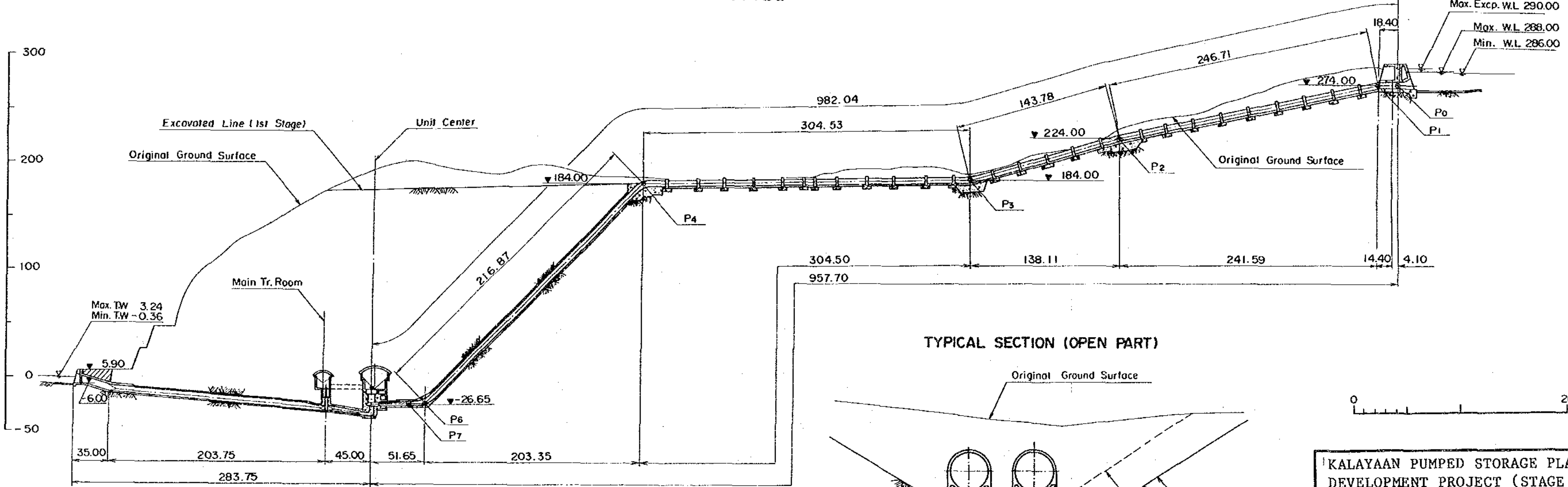
Fig. 10 - 2


PLAN
+5.90
+27.00
+47.00
+173.00
+196.00
+186.00
+186.00
+186.00 +196.00
+264.00
+274.00
+284.00
+270.00
P1
P2
P3
P4
P5
PROFILE
Unit Center
176.00
161.00
33.54
304.50
1409.54
304.53
143.78
246.71
18.50
Max. Excp. W.L. 290.00
Max. W.L. 288.00
Min. W.L. 286.00
274.00
224.00
184.00
180.00
Original Ground Surface
B.P. of Steel Penstock
Po
P1
P3
P4
P5
P7
3.30D
186.00
Max.T.W 3.24
Min.T.W -0.36
- 25.00
138.11
241.59
14.40
4.10
32.30
171.98
334.47
304.50
1241.45
Note
Lengths after the bifurcation indicate those along the center of two pipes, so that all lengths shown in the drawing are norminal ones.
TYPICAL SECTION (OPEN PART)
Original Ground Surface
2nd Stage
1st Stage
Compacted fill
10.00
10.00
1st Stage
2nd Stage
TYPICAL SECTION (UNDERGROUND)
Horizontal Tunnel
Vertical Shaft
3.30D
1.00
1.65
1.65
1.00
5.30
1.80
.85
.14
.6
3.80
1.00
1.00
0
20m
KALAYAAN PUMPED STORAGE PLANT
DEVELOPMENT PROJECT (STAGE II)
GENERAL LAYOUT
ALTERNATIVE B
Fig. 10 - 3

PLAN



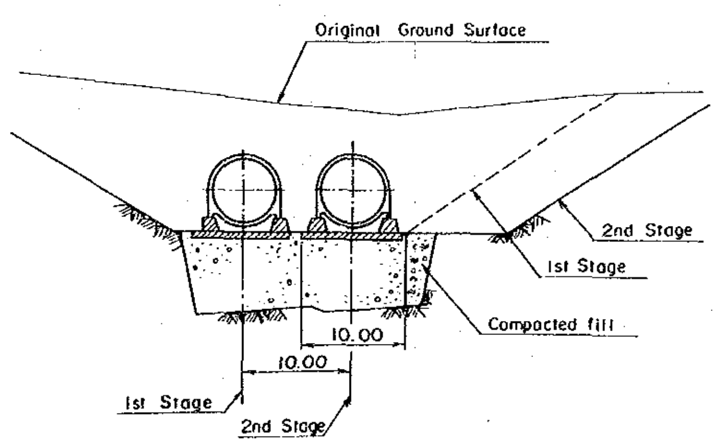
PROFILE



Note

Lengths after the bifurcation indicate those along the center of two pipes, so that all lengths shown in the drawing are narminal ones.

TYPICAL SECTION (OPEN PART)



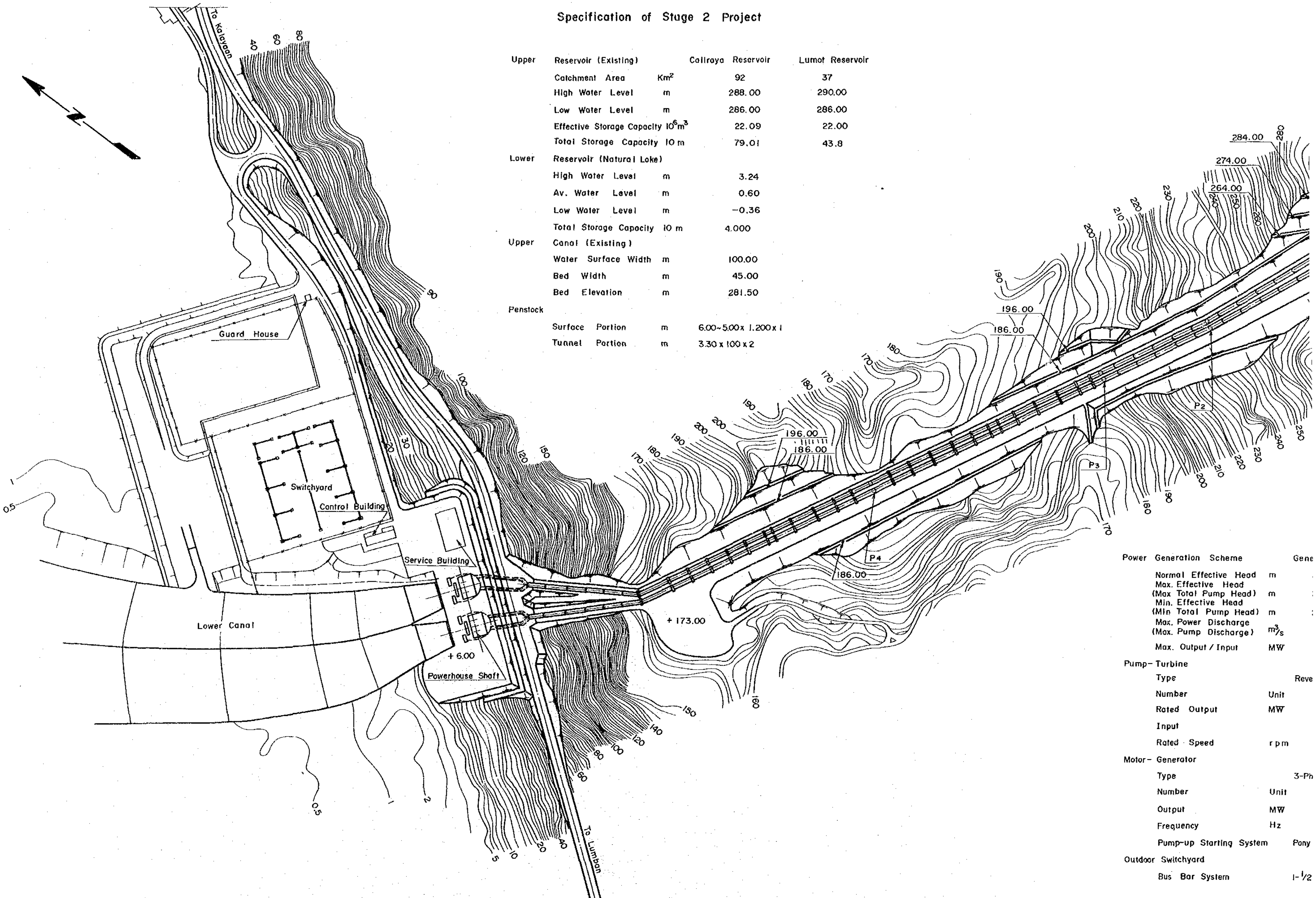
0 20m

KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

GENERAL LAYOUT

ALTERNATIVE C

Fig. 10 - 4



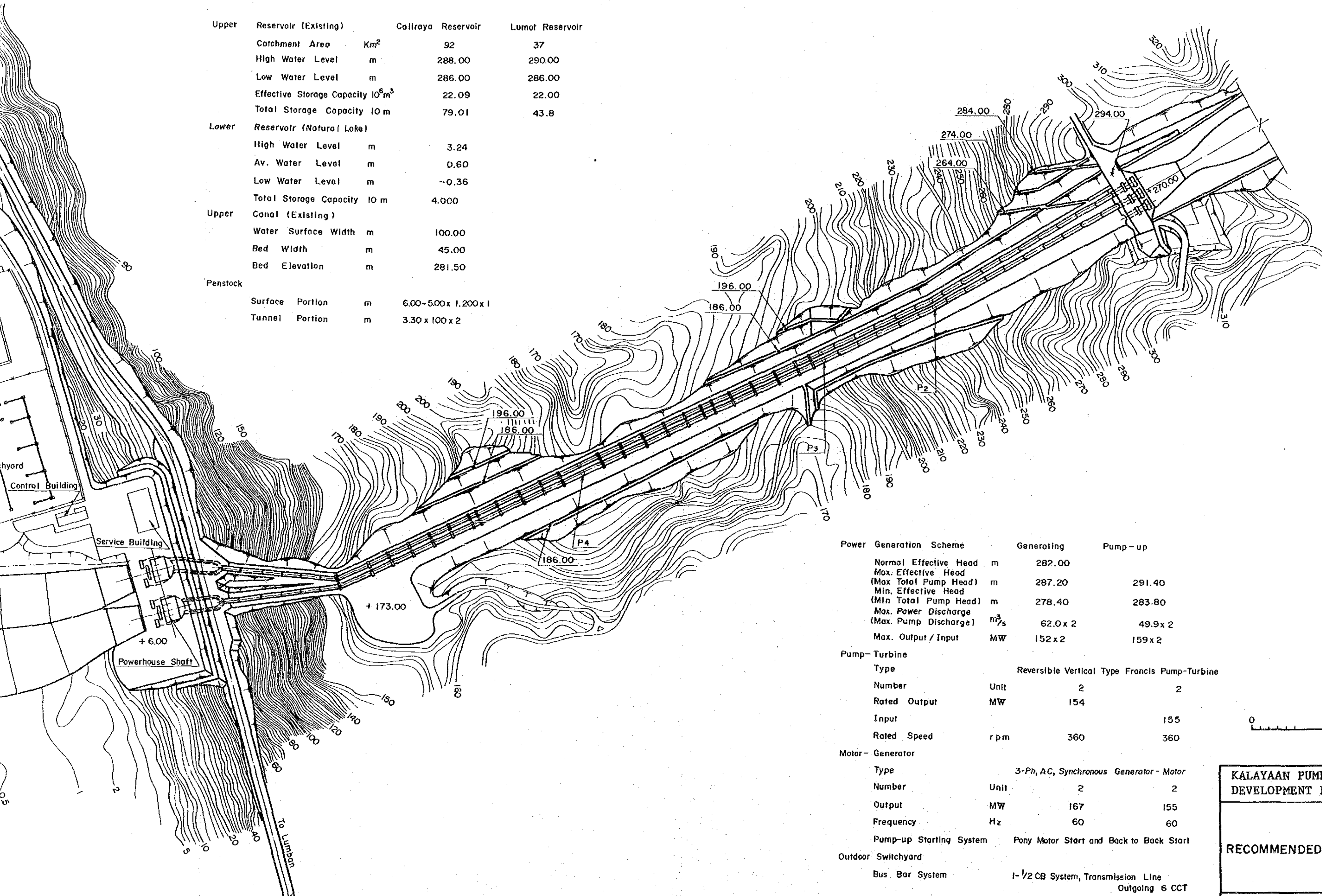
Specification of Stage 2 Project

Upper	Reservoir (Existing)		Caliraya Reservoir	Lumot Reservoir
	Catchment Area	Km^2	92	37
	High Water Level	m	288.00	290.00
	Low Water Level	m	286.00	286.00
	Effective Storage Capacity	$10^6 m^3$	22.09	22.00
	Total Storage Capacity	10 m	79.01	43.8
Lower	Reservoir (Natural Lake)			
	High Water Level	m	3.24	
	Av. Water Level	m	0.60	
	Low Water Level	m	−0.36	
	Total Storage Capacity	10 m	4.000	
Upper	Canal (Existing)			
	Water Surface Width	m	100.00	
	Bed Width	m	45.00	
	Bed Elevation	m	281.50	
Penstock				
	Surface Portion	m	6.00~5.00x 1.200x 1	
	Tunnel Portion	m	3.30 x 100 x 2	

Power Generation Scheme			Gene
	Normal Effective Head	m	
	Max. Effective Head (Max Total Pump Head)	m	
	Min. Effective Head (Min Total Pump Head)	m	
	Max. Power Discharge (Max. Pump Discharge)	m^3/s	
	Max. Output / Input	MW	
Pump-Turbine			
	Type		Reve
	Number	Unit	
	Rated Output	MW	
	Input		
	Rated Speed	rpm	
Motor-Generator			
	Type		3-Ph
	Number	Unit	
	Output	MW	
	Frequency	Hz	
	Pump-up Starting System		Pony
Outdoor Switchyard			
	Bus Bar System		1-1/2

Specification of Stage 2 Project

			Caliraya Reservoir	Lumot Reservoir
Upper	Reservoir (Existing)			
	Catchment Area	Km^2	92	37
	High Water Level	m	288.00	290.00
	Low Water Level	m	286.00	286.00
	Effective Storage Capacity	$10^6 m^3$	22.09	22.00
	Total Storage Capacity	10 m	79.01	43.8
Lower	Reservoir (Natural Lake)			
	High Water Level	m	3.24	
	Av. Water Level	m	0.60	
	Low Water Level	m	-0.36	
	Total Storage Capacity	10 m	4.000	
Upper	Canal (Existing)			
	Water Surface Width	m	100.00	
	Bed Width	m	45.00	
	Bed Elevation	m	281.50	
Penstock				
	Surface Portion	m	6.00~5.00 x 1,200 x 1	
	Tunnel Portion	m	3.30 x 100 x 2	



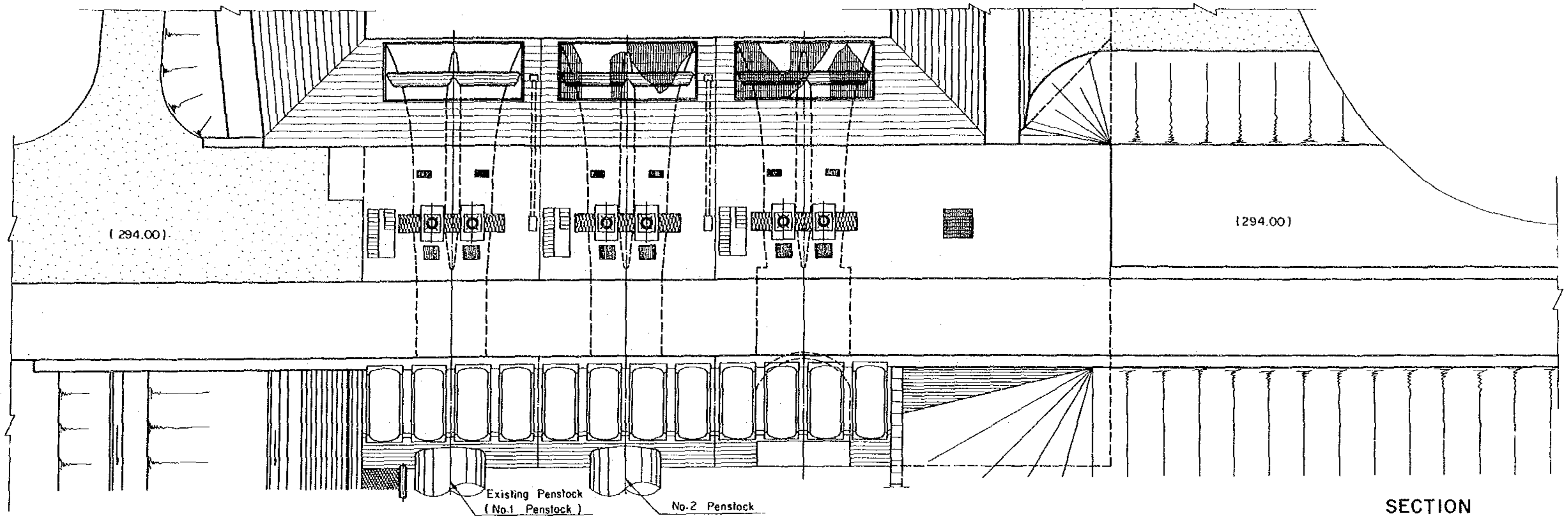
			Generating	Pump-up
Power Generation Scheme				
	Normal Effective Head	m	282.00	
	Max. Effective Head (Max Total Pump Head)	m	287.20	291.40
	Min. Effective Head (Min Total Pump Head)	m	278.40	283.80
	Max. Power Discharge (Max. Pump Discharge)	m^3/s	62.0 x 2	49.9 x 2
	Max. Output / Input	MW	152 x 2	159 x 2
Pump-Turbine				
	Type		Reversible Vertical Type Francis Pump-Turbine	
	Number	Unit	2	2
	Rated Output	MW	154	
	Input			155
	Rated Speed	rpm	360	360
Motor-Generator				
	Type		3-Ph, AC, Synchronous Generator-Motor	
	Number	Unit	2	2
	Output	MW	167	155
	Frequency	Hz	60	60
	Pump-up Starting System		Pony Motor Start and Back to Back Start	
Outdoor Switchyard				
	Bus Bar System		1-1/2 CB System, Transmission Line Outgoing 6 CCT	

KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

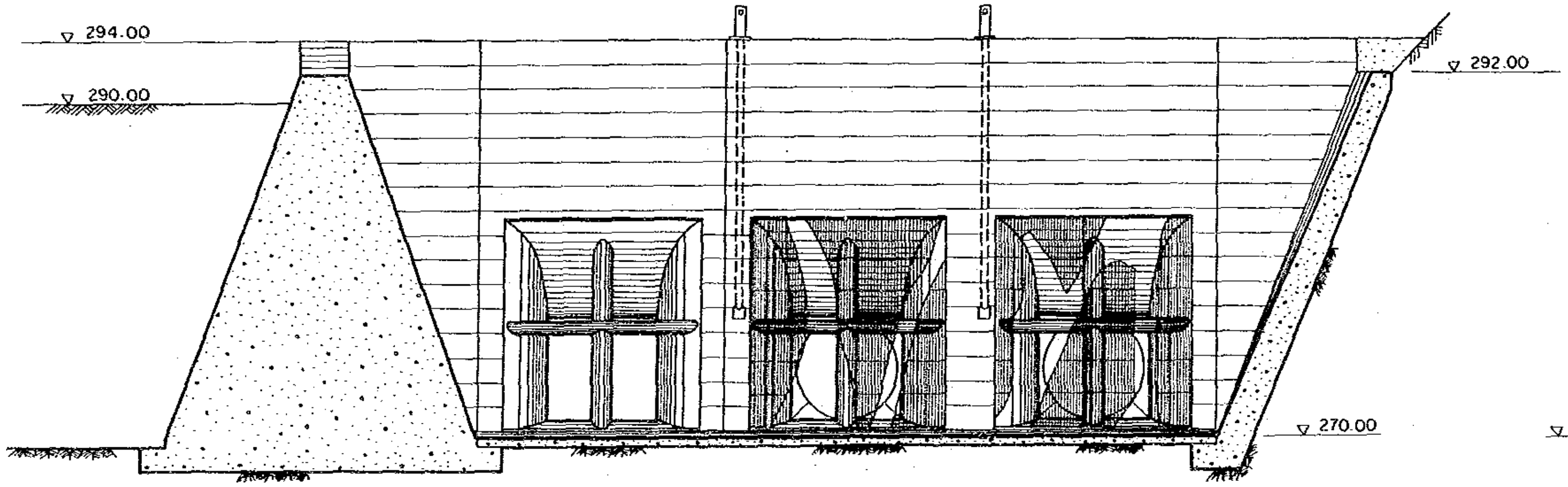
RECOMMENDED GENERAL LAYOUT

Fig. 10 - 5

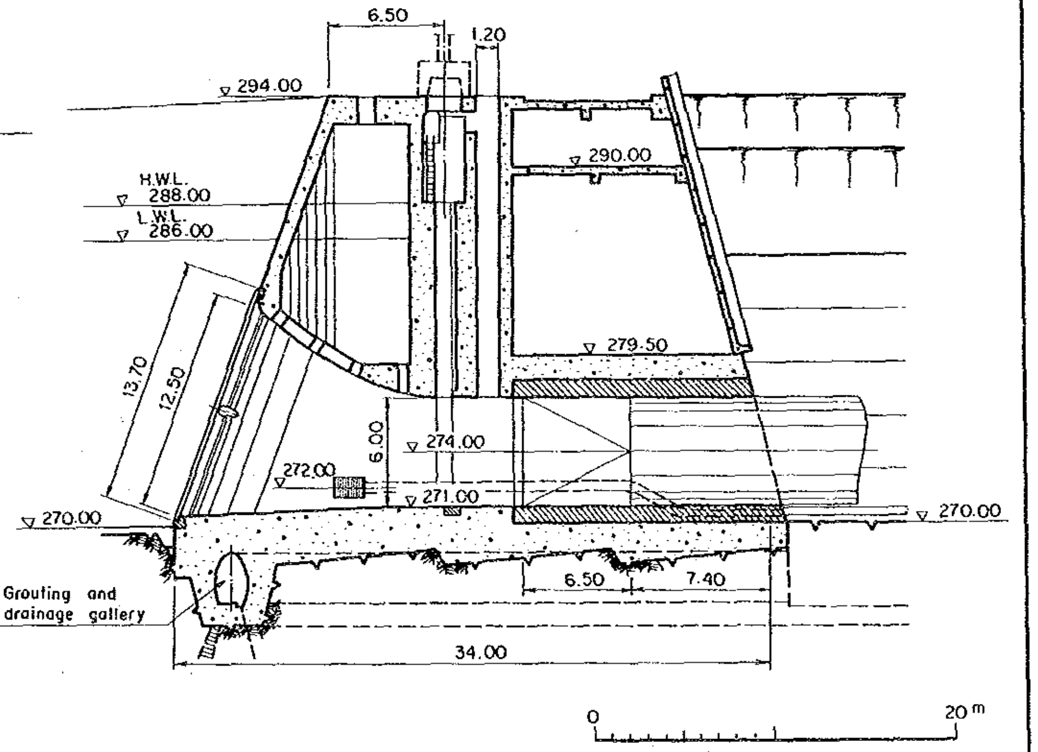
PLAN



UPSTREAM VIEW



SECTION



LEGEND

INTAKE STRUCTURE

DAM

Dam Height	30 m
Dam Type	Concrete Gravity
Crest Length	115 m

GATE

No. of Gate	2 Wheel Mounted Gates

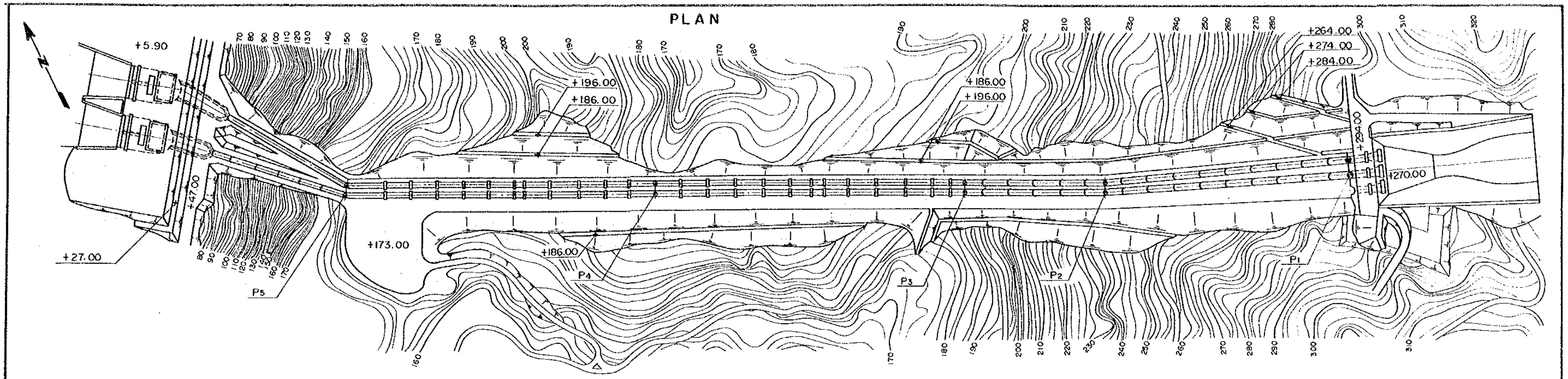
KALAYAAN PUMPED STORAGE PLANT
DEVELOPMENT PROJECT (STAGE II)

INTAKE

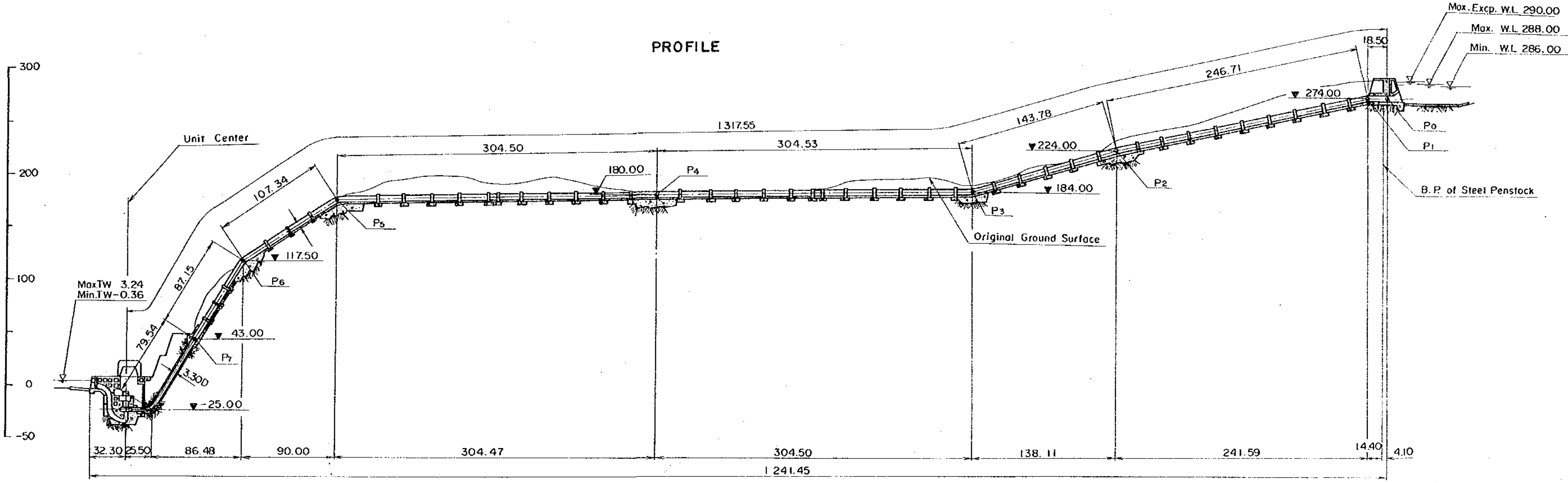
PLAN UPSTREAM VIEW AND SECTION

Fig. 10 - 6

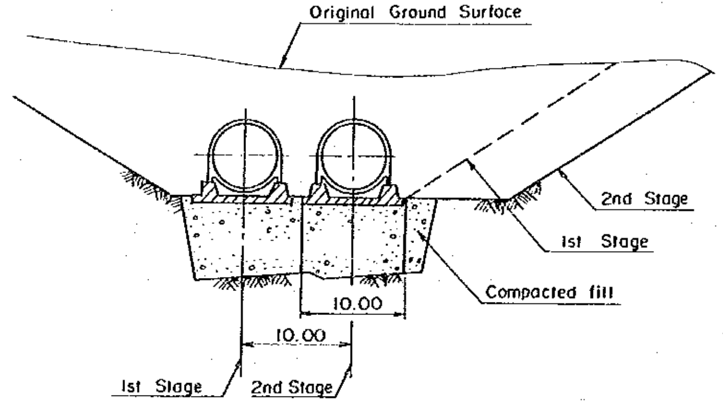
PLAN



PROFILE

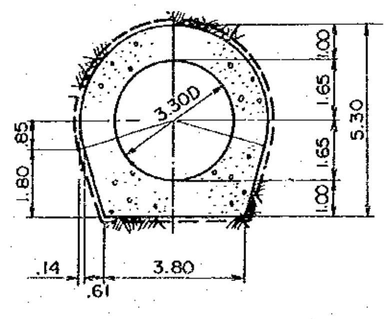


TYPICAL SECTION (OPEN PART)



TYPICAL SECTION (UNDERGROUND)

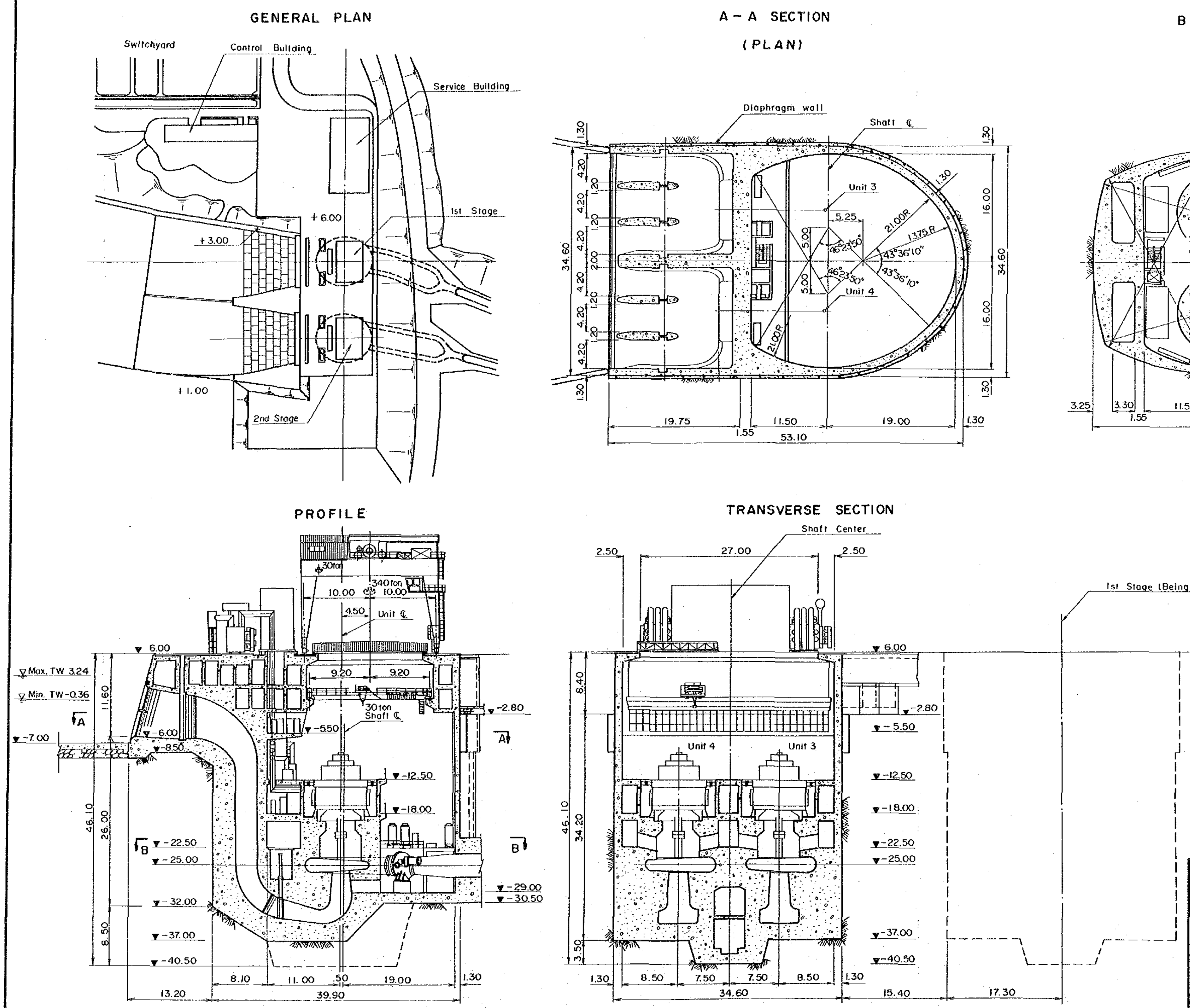
Horizontal and Inclined



Note

Lengths after the bifurcation Indicate those along the center of two pipes, so that all lengths shown in the drawing are norminal ones.

KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)
RECOMMENDED GENERAL LAYOUT
Fig. 10 - 7

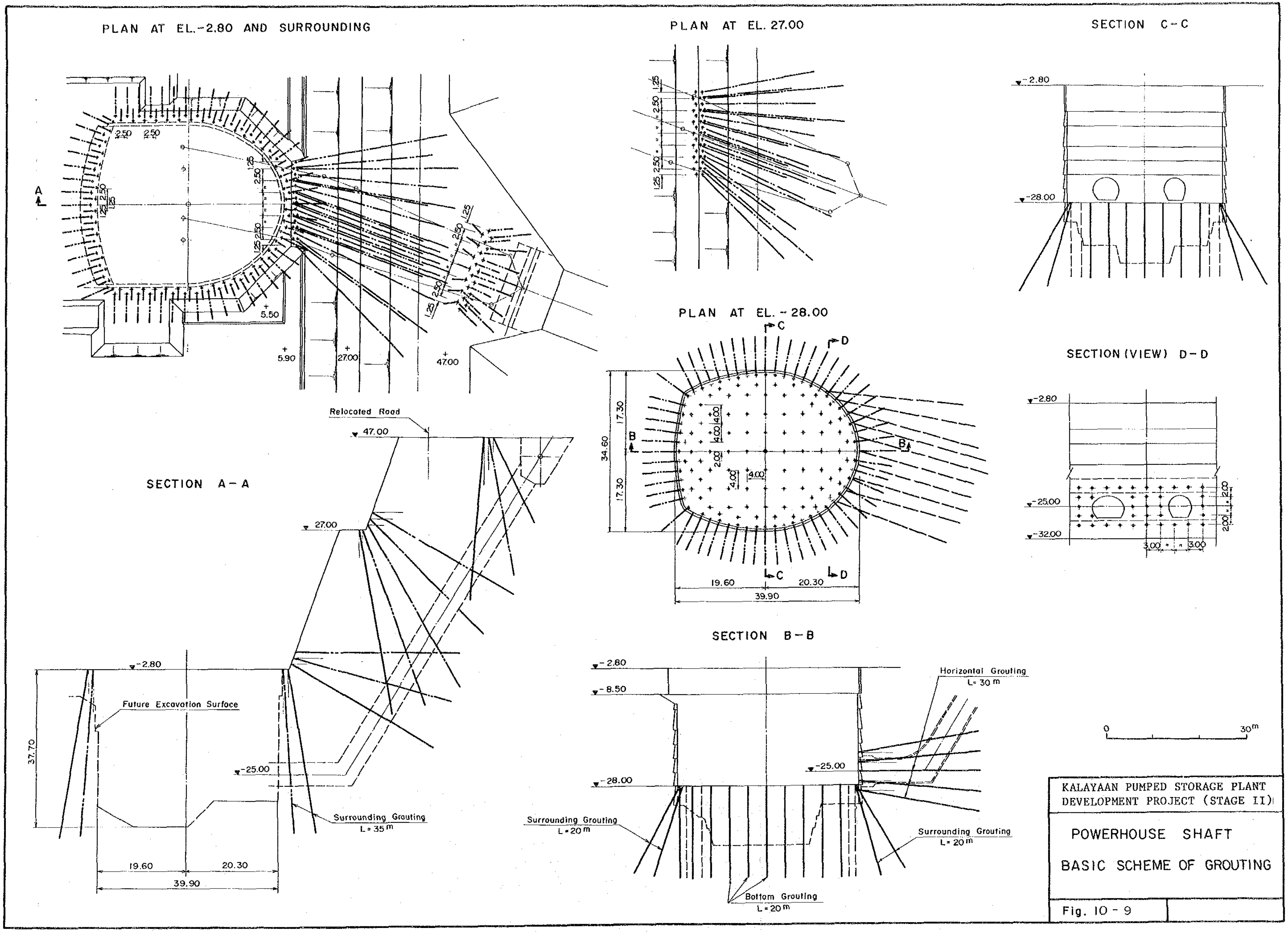


Note
1. All dimensions shown in the drawing are for A line, excluding 10cm addition as B line.
2. Lining thicknesses (1.30) shown in the drawing include ones for prelining (0.50)

KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

POWERHOUSE GENERAL LAYOUT

Fig. 10 – 8

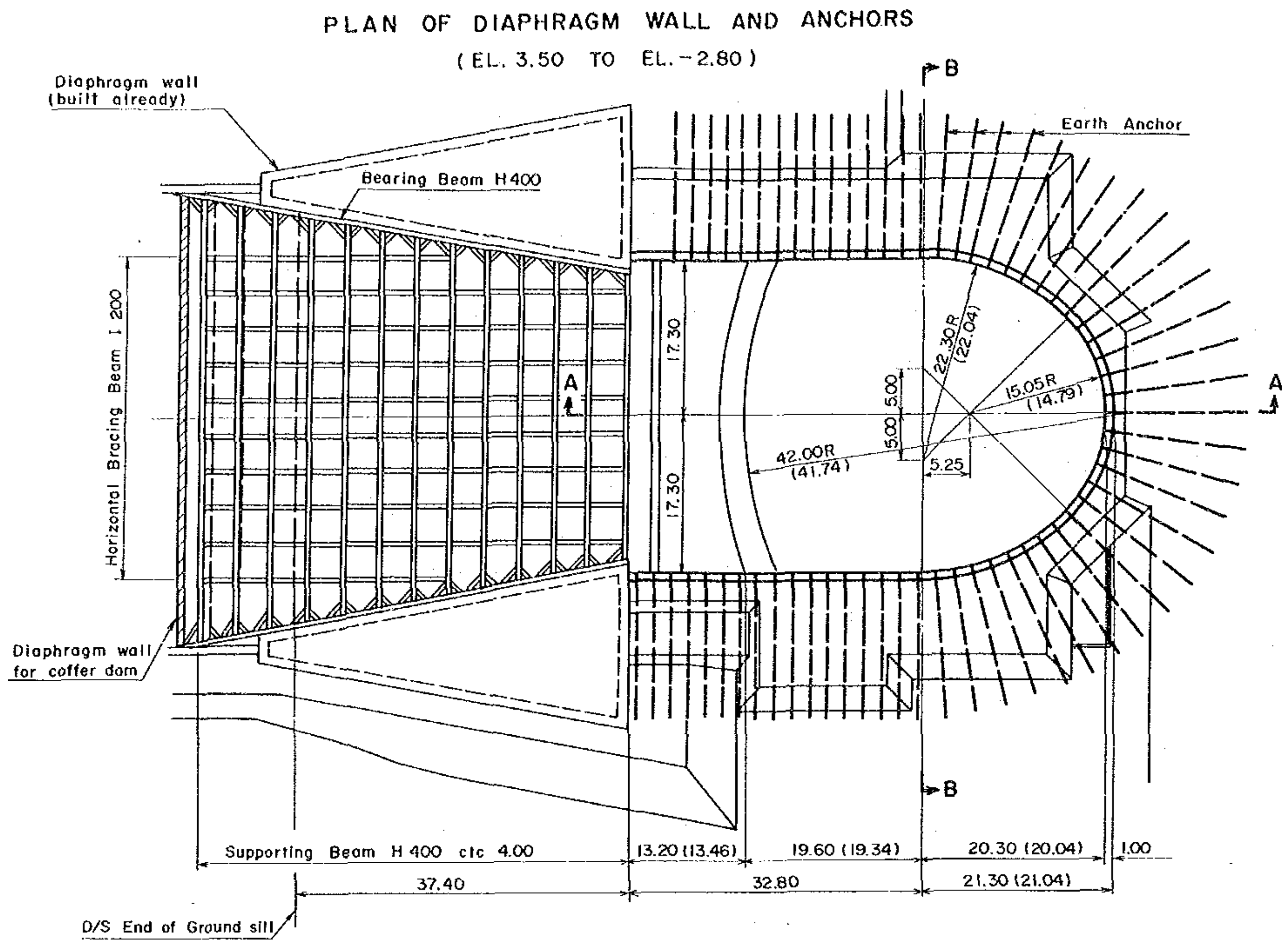


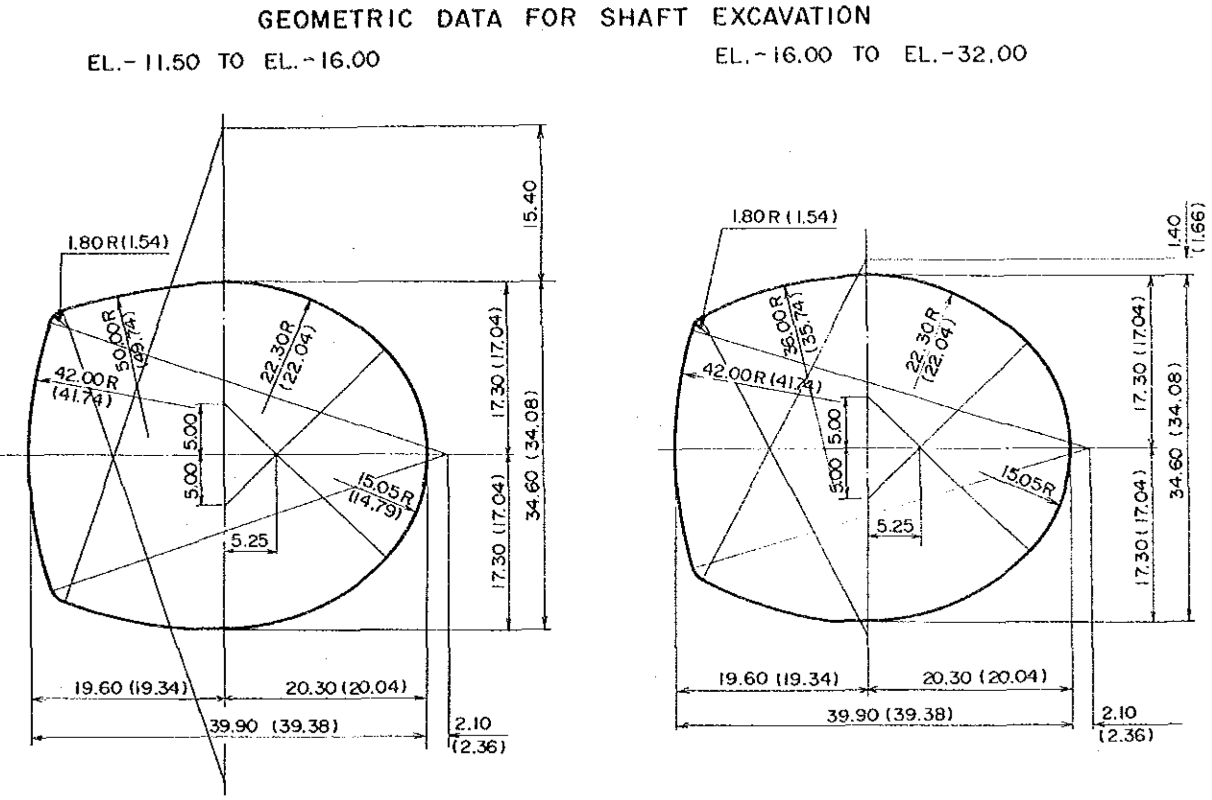
KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

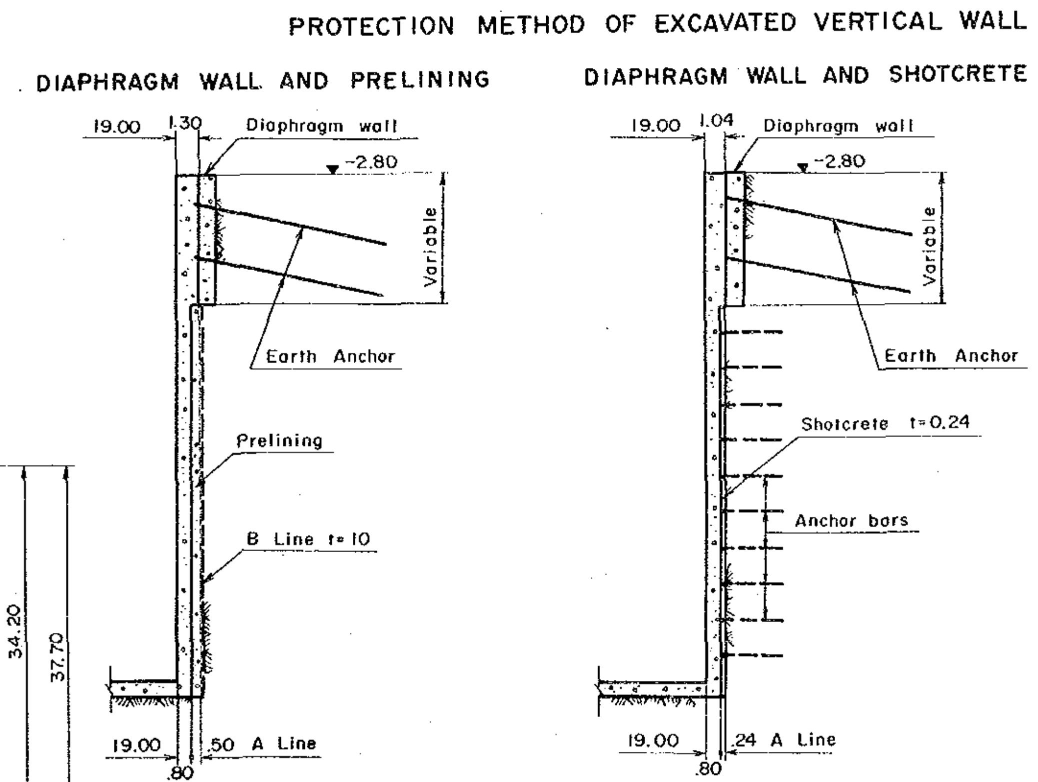
POWERHOUSE SHAFT

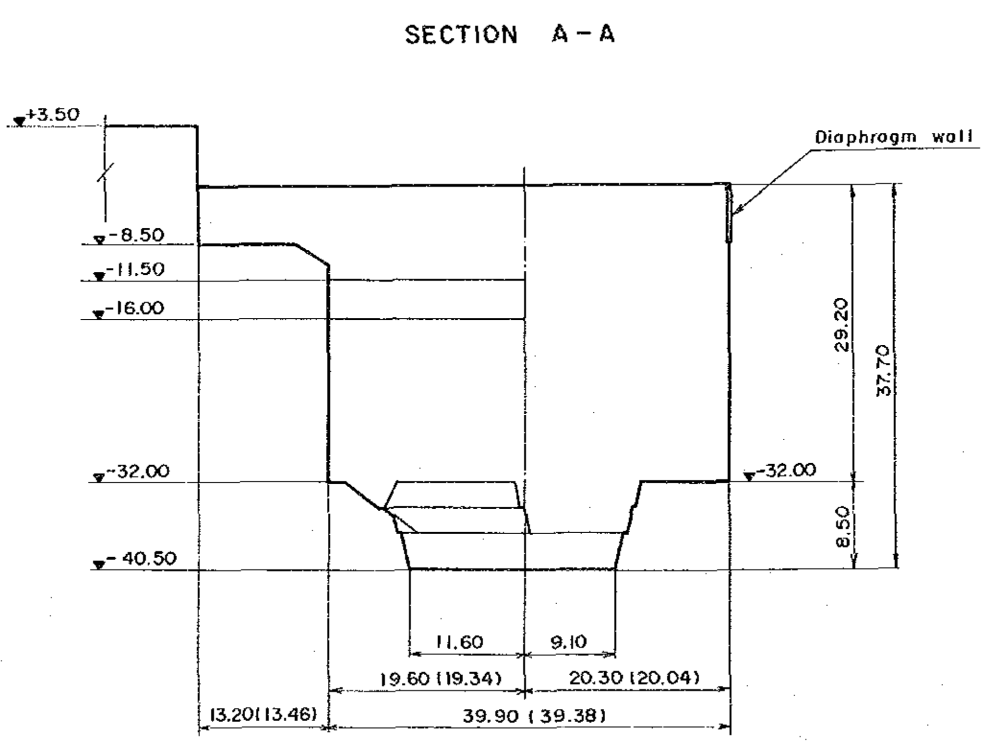
BASIC SCHEME OF GROUTING

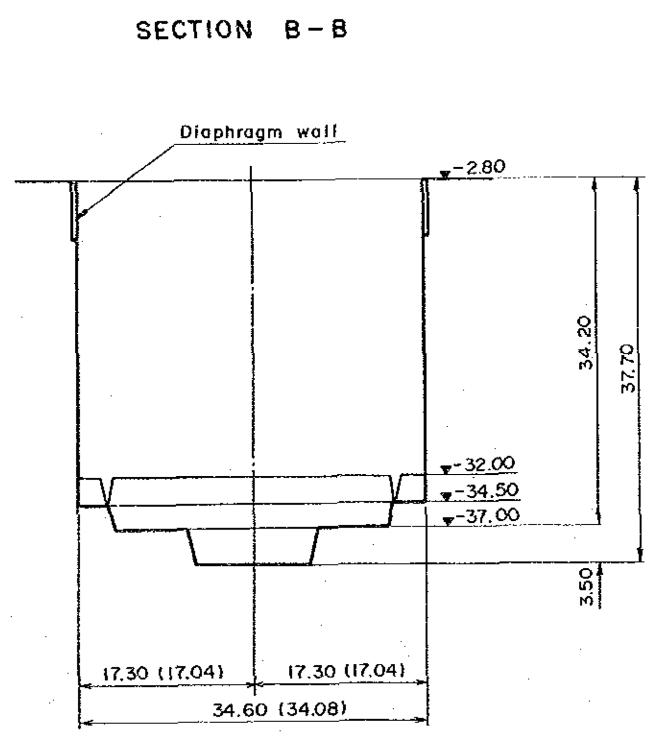
Fig. 10 - 9











NOTES

1. All figures in parentheses are for the shotcrete protection.
2. All figures are shown as A line's dimensions. 10 cm is added to each figure as B line.

KALAYAAN PUMPED STORAGE PLANT DEVELOPMENT PROJECT (STAGE II)

POWERHOUSE SHAFT EXCAVATION

Fig. 10 - 10