3.2 POWER DEVELOPMENT PROGRAM AND COMMISSIONING YEAR OF THE PROPOSED COAL-FIRED POWER STATION

3.2.1 Power Development Program

According to IRHE's "Plan Maestro de Expansion", power development projects for the coming 10 years from 1986 to 1995 are divided into the following two categories:

(1) Period 1986-1990 (Sanctioned plan)

- Rehabilitation of No.2, No.3 and No.4 units of Bahia Las Minas power station to improve thermal efficiency and to prolong service life. The project is scheduled to be completed in 1989.

- Construction of 80.0 MW combined cycle power plant consisting of two units of each 30.0 MW gas turbine combined with No.1 unit (22.0 MW) of Bahia Las Minas power station. The project is planned to be commissioned in 1988.

- Fortuna Phase II project to increase firm capacity and energy by raising dam height 40 m. The project is planned to be completed in 1990.

(2) Period 1991-1995 (Tentative plan)

- Construction of 150.0 MW coal-fired power station in Colon district for the purpose of inter-fuel substitution by resorting to the use of imported coal instead of oil for power generation from viewpoint of economy. This project is just objective of this study.

- Development of medium-scale hydro power stations of a total capacity of around 114.0 MW at two sites of Esti and Barrigon.

As to priority for execution of the above projects it is said that IRHE has an intention to commission firstly coal-fired power station because of a huge amount of investment required for Esti-Barrigon project.

3.2.2 Power Demand and Supply Balance

(1) Supply Capability of Hydro Power Stations

The supply capability of hydro power stations to be considered in the power demand and supply balance must be their integrated firm capacity and energy.

According to IRHE's "ELEC" data base for system expansion, the integrated hydro firm capacity and energy are 209.2 MW and 2,320.4 GWh respectively until 1989, and with the completion of Fortuna Phase II project in 1990 these firm capacity and energy are estimated to increase to 465.2 MW and 2,398.1 GWh respectively as shown in Tables 3.2.2 (1) and 3.2.2 (2).

(2) Cold Reserving of Superannuated Diesel Power Stations

Due to shortage in capacity of the power system caused by shutdown of one generating unit of Bahia Las minas power station, the superannuated diesel power stations including San Francisco, "GM", Chitre, Capira and Pto Armuelles will have to be operated until 1990 when Fortuna Phase II project is planned to be completed. However, with the completion of that project these diesel power stations shall be kept in cold reserve from viewpoint of economy.

(3) Reliability Criteria (Reserve Capacity)

The criteria of power generation planning must be established as a result of studies and analysis on actual records of operation performance, availability and reliability of power plants for the past several years. As a practice, the reserve margin must be sufficient to cope with shutdown of power plant for scheduled maintenance and forced outage.

The reliability of IRHE's power system was computed in terms of loss-of-load probability (LOLP) which is defined as the proportion of days per year or hours per year when available generating capacity is unsufficient to serve all the daily and hourly loads. The reliability criteria for LOLP as adopted by IRHE is that the LOLP from 1986 to 2005 should not be more than 2 days per year, i.e. 2/365 = 0.00548.

The relationship of LOLP and percent reserve (excess of installed capacity over annual peak load expressed in percentage of annual peak load) was also analized by IRHE from computer studies on various generation plans, and by optimization as well as simulation process, and it is reported that for IRHE's power system 15% reserve is required to secure LOLP of 2 days per year.

In this connection it is to be noted that the target LOLP is different by country; in U.S.A. it is one day in 10 years for large interconnected systems, in European countries the corresponding standard varies from one day in 15 years to one day in 2.5 years. The percent reserve and LOLP figures are considered as normal practice in the mixed hydro-thermal systems, and broadly used in the world.

For small power system a formula broadly adopted to define the value of the reserve margin is as follows:

> Reserve margin (R) shall be the larger one of the following two values:
>
> r = a certain percentage of the value of peak load (15 to 20% in general)
>
> G1 + G2 = capacity of the largest and the second largest units

Therefore, when adopting the above criteria, it is possible to cope with a capacity drop caused by forced outage of the second largest unit during shutdown period of the largest unit for scheduled maintenance, or vice versa.

In the IRHE's power system the largest unit is 100 MW of Fortuna hydro power station and the second largest unit is 75 MW of Bayano hydro power station. However, it would not be appropriate to take their sum of 175 MW as a criteria of reserve margin for the following reasons:

a) For thermal power station it is necessary to conduct regularly inspection and maintenance every year, but for hydro power station its maintenance cycle is one time per 10 years with shutdown period of 25 to 30 days for Francis turbine-generator and 30 to 35 days for Kaplan turbine-generator. Therefore, for hydro power station it is possible to conduct intentionally maintenance without affecting power demand and supply conditions.

b) Visual and routine inspections of hydro power station can be conducted during light load time in the mid-night without affecting power demand and supply conditions.

c) For hydro power stations the forced outage ratio expressed by the following formula is very low, namely 0.5%:

$$\frac{\text{Shutdown hours due to forced outage}}{\text{Operation hours + shutdown hours due to forced outage}} = 0.5\%$$

In general, reserve capacity of hydro power stations is calculated from their installed capacity and forced outage ratio. For IRHE's power system the reserve capacity of hydro power stations is calculated to be 551.6 MW x 0.5% = 2.8 MW only. This value is very small and almost negligible.

Therefore, for IRHE's power system it would be appropriate to adopt the following reserve margin criteria:

Reserve margin (R) shall be the larger one of the following two values:

r = capacity equivalent to 15% of peak load

G1 + G2 = capacity of the lagest and the second largest thermal power generating units

G1 + G2 of the IRHE's power system will be the following:

Year	G1 + G2
1986	37.5 (BLM) + 22.0 (BLM-1) = 59.5 MW
1987	37.5 (BLM) + 18.5 (Mount Hope) = 56.0 MW
1988-1991	37.5 (BLM) + 40.0 (Combined cycle) = 77.5 MW
1992-	40.0 (Combined cycle) + 70.5 (Coal-fired) = 110.5 MW

Reserve margin to be used for power demand and supply balance is thus obtained as follows:

Year	Peak load (P) (MW)	P x 15% (MW)	G1 + G2 (MW)	Adopted value (MW)
1986	436.0	65.4	59.5	65.4
1987	460.0	69.0	56.0	69.0
1988	487.0	73.1	77.5	77.5
1989	513.0	77.0	77.5	77.5
1990	539.0	80.9	77.5	80.9
1991	571.0	85.7	77.5	85.7
1992	598.0	89.7	110.5	110.5
1993	642.0	96.3	110.5	110.5
1994	676.0	101.4	110.5	110.5
1995	718.0	107.7	110.5	110.5

3.2.3 Expected Commissioning Year of the Proposed Coal-Fired Power Station

Power demand and supply balance shown in Tables 3.2.3 (1) and 3.2.3 (2), made on the above conditions, shows that shortage in power generating capacity will continue until 1990 when Fortuna Phase II project is planned to be completed. And, if all the diesel power stations are kept in cold reserve with the completion of that project, shortage in capacity will again appear in 1993 if new power station is not commissioned by that time as shown below.

		Balance in 1993 (MW)
Existing capacity (without new power plant)	(A)	712.2
Maximum power demand		642.0
Reserve margin (without new power plant)		96.3
Required capacity	(B)	738.3
Balance (A) - (B)		-26.1

This means that the generating capacity in the power system must be increased in 1992/1993. To ensure reliability of electricity supply it is recommended that the proposed coal-fired power station be commissioned with the following time-schedule:

	Installed capacity (MW)	Effective capacity (MW)	Commissioning
No.1 unit	75.0	70.5	October 1992
No.2 unit	75.0	70.5	January 1993

Table 3.2.3 (1) and Fig. 3.2.3 show also that another new power station will have to be commissioned in around 1995/1996.

Table 3.2.2 (1) Firm Capacity of Hydro Power Plants

(MW)

Power plant	Yeguada Chiriqui	La Estrella	Los Valles	Bayano	Fortuna	System Total
Installed capacity	11.0	43.0	47.0	150.0	300.0	551.0
1986 - 1989						
January	3.6	13.0	15.1	148.7	62.1	242.5
February	3.8	15.7	17.0	140.1	138.9	315.5
March	3.3	12.3	15.1	138.6	84.9	254.2
April	3.2	11.9	13.2	130.8	50.1	209.2
May	5.2	19.4	26.8	123.9	140.1	315.4
June	6.9	26.1	38.9	118.5	112.8	303.2
July	6.7	25.1	38.9	116.7	99.0	286.4
August	5.6	20.9	30.2	114.8	125.7	297.2
September	9.5	35.9	47.0	114.8	167.7	374.9
October	11.0	43.0	47.0	122.3	171.6	394.9
November	8.2	31.4	43.4	135.5	181.5	400.0
December	11.0	43.0	47.0	150.0	171.6	422.6
1990 and thereafter						
January	3.6	23.9	24.1	150.0	300.0	501.6
February	3.8	15.7	14.7	150.0	300.0	484.2
March	3.3	11.4	12.4	145.8	299.1	472.0
April	3.2	20.7	21.2	140.1	294.9	480.1
May	5.2	17.2	19.1	137.1	294.0	472.6
June	6.9	22.3	27.6	137.1	289.8	483.7
July	6.7	17.0	19.6	137.1	289.8	470.2
August	5.6	22.1	28.0	134.0	288.0	477.7
September	9.5	26.1	30.8	132.3	288.0	486.7
October	11.0	29.1	36.9	132.3	288.9	465.2
November	8.2	30.9	35.3	134.0	289.8	498.2
December	11.0	30.1	33.1	135.5	288.9	498.6

Note: Calculated from "Generation Expansion Plan" - 02/05/86.

Table 3.2.2 (2) Firm Energy of Hydro Power Plants

(GWh)

Power plant	Yeguada Chiriqui	La Estrella	Los Valles	Bayano	Fortuna	System Total
1986 - 1989						
January	2.6	9.7	11.2	80.2	46.2	149.9
February	2.8	10.6	11.4	30.5	93.3	148.6
March	2.4	9.2	11.3	67.3	63.1	153.3
April	2.3	8.5	9.5	88.6	36.2	145.1
May	3.8	14.4	19.9	94.5	77.4	210.0
June	5.0	18.8	28.1	77.1	81.3	210.3
July	4.9	18.7	28.5	80.5	73.7	206.3
August	4.1	15.5	22.4	73.6	93.6	209.2
September	6.9	25.9	33.8	20.3	120.7	207.6
October	8.0	32.0	35.0	13.1	127.7	215.8
November	6.0	22.6	31.3	15.5	130.8	206.2
December	8.0	32.0	35.0	55.4	127.7	258.1
Total	56.8	217.9	277.8	696.6	1,071.7	2,320.4
1990 and thereafter						
January	2.6	17.8	18.0	63.0	103.1	204.5
February	2.8	10.6	9.8	44.8	130.7	198.7
March	2.4	8.5	9.2	48.4	127.6	196.1
April	2.3	14.9	15.2	44.9	119.4	196.7
May	3.8	12.8	14.2	44.1	118.9	193.8
June	5.0	16.1	19.9	52.3	108.3	201.6
July	4.9	12.6	14.6	50.6	118.4	201.1
August	4.1	16.4	20.8	38.5	112.4	192.2
September	6.9	18.8	22.2	41.7	112.1	201.7
October	8.0	21.7	27.5	44.4	102.5	204.1
November	6.0	22.2	25.4	38.3	110.6	202.5
December	8.0	22.4	24.7	43.8	106.2	205.1
Total	56.8	194.8	221.5	554.0	1,370.2	2,398.1

Source: IRHE- "Generation Expansion Plan" - 02/05/86

Table 3.2.3 (1) Power Demand and Supply Balance

(MW)

Item		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Maximum power demand		436.0	460.0	487.0	513.0	539.0	571.0	598.0	642.0	676.0	718.0
Reserve capacity		65.4	69.0	77.5	77.5	80.9	85.9	110.5	110.5	110.5	110.5
Required capacity	(A)	501.4	529.0	564.5	590.5	619.9	656.9	708.5	752.5	786.5	828.5
Hydro											
Installed capacity											
Yeguada-Chiriqui hydro		11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
La Estrella		43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0	43.0
Los Valles		47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0	47.0
Bayano		150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
Fortuna		255.0	255.0	255.0	255.0	300.0	300.0	300.0	300.0	300.0	300.0
Sub-total		506.0	506.0	506.0	506.0	551.0	551.0	551.0	551.0	551.0	551.0
Firm capacity	(B)	209.2	209.2	209.2	209.2	465.2	465.2	465.2	465.2	465.2	465.2
Thermal											
Effective capacity											
Steam (BLM 2, 3, 4)		75.0	75.0	75.0	112.5	112.5	112.5	112.5	112.5	112.5	112.5
Steam (BLM 1)		22.0	-	-	-	-	-	-	-	-	-
Combined cycle		-	-	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0
Gas turbine (Panama SS)		36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0	36.0
Gas turbine (Mount Hope)		18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5
Diesel (San Francisco)		24.0	24.0	24.0	24.0	-	-	-	-	-	-
Diesel "GM"		20.0	20.0	20.0	20.0	-	-	-	-	-	-
Diesel (Chitre, Capira ...)		22.1	22.1	22.1	22.1	-	-	-	-	-	-
Coal-fired		-	-	-	-	-	-	70.5	141.0	141.0	141.0
Sub-total	(C)	217.6	195.6	275.6	313.1	247.0	247.0	317.5	388.0	388.0	388.0
Total capacity	(B) + (C) = (D)	426.8	404.8	484.8	522.3	712.2	712.2	782.7	853.2	853.2	853.2
Balance	(D) - (A) = (E)	-74.6	-124.2	-79.7	-68.2	+92.3	+55.5	+74.2	+100.7	+66.7	+24.7

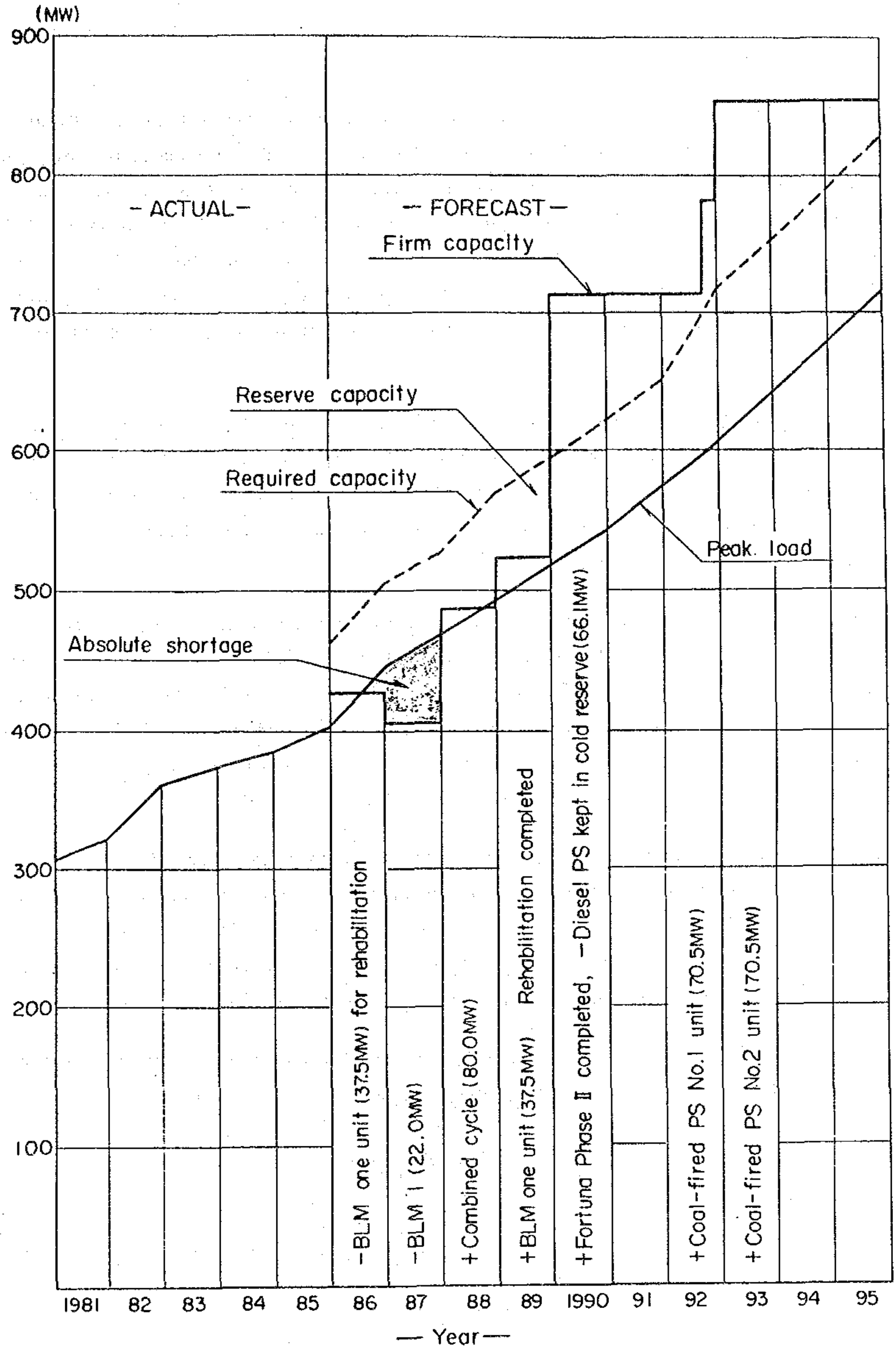
Note: With the completion of Fortuna Phase II project (raising up dam height 40 m), the effective capacity will increase from 255.0 MW to 300.0 MW.

Table 3.2.3 (2) Power Demand and Supply Balance

(GWh)

Item		1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Energy demand	(A)	2,522.9	2,661.3	2,820.5	2,976.5	3,110.7	3,298.8	3,460.1	3,718.2	3,904.5	4,152.1
Hydro											
Annual average generation											
Yeguada-Chiriqui hydro		57.0	57.0	57.0	57.0	57.0	57.0	57.0	57.0	57.0	57.0
La Estrella		237.0	237.0	237.0	237.0	237.0	237.0	237.0	237.0	237.0	237.0
Los Valles		272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0	272.0
Bayano		605.0	605.0	605.0	605.0	657.6	657.6	657.6	657.6	657.6	657.6
Fortuna		1,242.0	1,242.0	1,242.0	1,242.0	1,483.3	1,483.3	1,483.3	1,483.3	1,483.3	1,483.3
Sub-total		2,413.0	2,413.0	2,413.0	2,413.0	2,706.9	2,706.9	2,706.9	2,706.9	2,706.9	2,706.9
Firm energy	(B)	2,320.4	2,320.4	2,320.4	2,320.4	2,398.1	2,398.1	2,398.1	2,398.1	2,398.1	2,398.1
Thermal											
Effective energy											
Steam (BLM 2, 3, 4)		560.6	560.0	560.0	841.0	841.0	841.0	841.0	841.0	841.0	841.0
Steam (BLM 1)		154.0	-	-	-	-	-	-	-	-	-
Combined cycle		-	-	560.6	560.6	560.6	560.6	560.6	560.6	560.6	560.6
Gas turbine (Panama SS)		94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
Gas turbine (Mount Hope)		48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6	48.6
Diesel (San Francisco)		171.7	171.7	171.7	171.7	-	-	-	-	-	-
Diesel "GM"		122.6	122.6	122.6	122.6	-	-	-	-	-	-
Diesel (Chitre, Capira ...)		56.9	56.9	56.9	56.9	-	-	-	-	-	-
Coal-fired		-	-	-	-	-	-	209.0	836.1	836.1	836.1
Sub-total	(C)	1,208.4	1,054.4	1,615.0	1,896.0	1,544.8	1,544.8	1,753.8	2,380.9	2,380.9	2,380.9
Total energy	(B) + (C) = (D)	3,528.0	3,374.8	3,935.4	4,216.4	3,942.9	3,942.9	4,151.9	4,779.0	4,779.0	4,779.0
Balance	(D) - (A) = (E)	+1,005.1	+713.5	+1,114.8	+1,239.9	+832.2	+644.1	+691.8	+1,060.8	+874.5	+626.9
Balance ratio	(E)/(A)=(F)	+39.8%	+26.8%	+39.5%	+41.7%	+26.8%	+19.5%	+20.0%	+28.5%	+22.4%	+15.1%

Fig. 3.2.3 Power Demand and Supply Balance



3.3 POWER GENERATION PROGRAM AND EXPECTED PLANT FACTOR OF THE PROPOSED COAL-FIRED POWER STATION

3.3.1 Hydro Power Duration Curve

In the IRHE's power system, hydro power stations including Fortuna, Bayano, Los Valles, La Estrella, Yeguada and Chiriqui play preponderant role in supply of electricity. Thermal power stations are operated to cover shortage in supply capability of hydro power stations. This situation will further be accelerated with the completion of Fortuna Phase II project. Therefore, it is necessary to take into account the integrated hydro power duration curve in order to estimate the plant factor of the proposed coal-fired power station.

Yeguada and Chiriqui hydro power stations are of run-of-river type and their supply capability has no relation with operation of other power stations, but supply capability of Los Valles and La Estrella power stations is controlled by the operation rule of Fortuna power station which is located in their upstream.

Fortuna Phase II project to increase firm capacity and energy by raising dam height 40 m is scheduled to be completed in 1990. With the completion of this project monthly capacity and energy of Los Valles and La Estrella power stations will inevitably be changed. According to IRHE's system expansion plan, operation rule of Bayano power station is also planned to be changed with the completion of Fortuna Phase II project.

Monthly capacity and energy by hydro power station reported in the IRHE's "ELEC" data base for system expansion plan are as shown in Tables 3.2.2 (1) and 3.2.2 (2). Based on these data integrated monthly capacity and its duration expressed in days for the years after completion of Fortuna Phase II project can be calculated as shown in Table 3.3.1 (1).

Table 3.3.1 (1) shows that operation of hydro power stations is divided into the following three combined operations:

Operation	Power plants operated	Duration/year
A	Yeguada, Chiriqui, Los Valles, La Estrella	166.3 days
B	Above power stations + Bayano or Fortuna	36.0 days
C	All hydro power stations	162.7 days
	Total	365 days

By rearranging monthly capacity and its duration expressed in days given in Table 3.3.1 (1) in the order of capacity size, Table 3.3.1 (2) can be obtained, and this leads to integrated hydro power duration curve given in Fig. 3.3.1.

3.3.2 Power Generation Program

As described before, it is expected that the proposed coal-fired power station be commissioned in October 1992 for No.1 unit and January 1993 for No.2 unit.

As to thermal power stations, the highest performance power station is operated at the largest load and during the longest time possible, followed by the second highest performance power station with the similar operation, then comes operation of the third highest performance power station and so on, until the portion of load not fed by hydro power stations is totally supplied by these thermal power stations.

After commissioning of the proposed coal-fired power station, thermal power stations will be operated in the following order of priority from viewpoint of economy:

1st: Coal-fired power station (150.0 MW)
2nd: Combined cycle power station (80.0 MW)
3rd: Bahia Las Minas No.2, No.3 and No.4 units (112.5 MW)
4th: Gas turbines at Panama substation and Mount Hope (54.5 MW)

Assuming that the minimum load for steam turbine be 50% of the installed capacity, the power generation programs for 1993 and 1995 can be established as shown in Fig. 3.3.2 (1) and 3.3.3 (2).

3.3.3 Expected Plant Factor of the Proposed Coal-Fired Power Station

From Fig. 3.3.2 (1) and 3.3.2 (2), it is expected that the proposed coal-fired power station be operated at the plant factor of approximately 63% in 1993 and 68.5% in 1995.

With the growth in demand for electricity, the above plant factor may become higher, but it would be reasonable to estimate a long-run average plant factor of around 68.5% for this power station, taking account of the fact that in most countries the plant factor of this type of power station is in general 70% at the highest. This plant factor represents an annual generation of about 900 GWh for an installed capacity of 150.0 MW.

Table 3.3.1 (1) Monthly Hydro Firm Capacity and Duration After Completion of Fortuna Phase II Project

Month	Yeguada, La Estrella and Los Valles			Bayano			Fortuna			
	(GWh)	(MW)	(Days)	(GWh)	(MW)	(Days)	(GWh)	(MW)	(Days)	
Firm power and energy by plant										
January	38.4	51.6	31	63.0	150.0	17.5	103.1	300.0	14.3	(1)
February	23.2	34.2	28	44.8	150.0	12.4	130.7	300.0	18.2	
March	20.1	27.1	31	48.4	145.8	13.8	127.6	299.1	17.8	
April	32.4	45.1	30	44.9	140.1	13.3	119.4	294.9	16.9	
May	30.8	41.5	31	44.1	137.1	13.4	118.9	294.0	16.9	
June	41.0	56.8	30	52.3	137.1	15.9	108.3	289.8	15.6	
July	32.1	43.3	31	50.6	137.1	15.4	118.4	289.8	17.0	
August	26.3	55.7	31	38.5	134.0	12.0	112.4	288.0	16.3	
September	47.9	66.4	30	41.7	132.3	13.1	112.1	288.0	16.2	
October	57.2	77.0	31	44.4	132.3	14.0	102.5	288.9	14.8	
November	53.6	74.4	30	38.3	134.0	11.9	110.6	289.8	15.9	
December	55.1	74.2	31	43.8	135.5	13.5	106.2	288.9	15.3	
Total			365			166.2			195.2	

Month	Operation of Yeguada, Estrella, Valles only (Operation A)		Operation A + Bayano or Fortuna (Operation B)		Operation of the total hydro power system (Operation C)		
	(MW)	(Days)	(MW)	(Days)	(MW)	(Days)	
January	51.6	13.5	201.6	3.2	501.6	14.3	(2)
February	34.2	9.8	334.2	5.8	484.2	12.4	
March	27.1	13.2	326.2	4.0	472.0	13.8	
April	45.1	13.1	340.0	3.6	480.1	13.3	
May	45.1	14.1	335.5	3.5	472.6	13.4	
June	56.8	14.1	193.9	0.3	483.7	15.6	
July	43.3	14.0	333.1	1.6	470.2	15.4	
August	55.7	14.7	343.7	4.3	477.7	12.0	
September	66.4	13.8	354.4	3.1	486.7	13.1	
October	77.0	16.2	365.9	0.8	465.2	14.0	
November	74.4	14.1	354.2	4.0	498.2	11.9	
December	74.2	15.7	363.1	1.8	498.6	13.5	
Total		166.3		36.0		162.7	

Note: Method for calculating load duration in days is as follows:

Example: Bayano – January

(1) 63,000 MWh ÷ 150.0 MW ÷ 24 hours = 17.5 days

(2) 56.1 MW operation : 31 days – 17.5 days = 13.5 days
501.6 MW (56.1 + 150.0 + 300.0) operation : 14.3 days
201.6 MW (56.1 + 150.0) operation : 17.5 days – 14.3 days = 3.2 days

300.0 MW | 14.3 days
150 0 MW | 17.5 days
56.1 MW | 31 days

Table 3.3.1 (2) Hydro Power Duration After Completion of Fortuna Phase II Project

No.	Load (MW)	Duration Days	Duration Hours	No.	Load (MW)	Duration Days	Duration Hours	No.	Load (MW)	Duration Days	Duration Hours
1	501.6	14.3	343	13	365.9	0.8	19	25	77.0	16.2	389
2	498.6	13.5	324	14	364.2	4.0	96	26	74.4	14.1	338
3	498.2	11.9	286	15	363.1	1.8	43	27	74.2	15.7	377
4	486.7	13.1	314	16	354.4	3.1	74	28	66.4	13.8	331
5	484.2	12.4	298	17	343.7	4.3	103	29	56.8	14.1	338
6	483.7	15.6	374	18	340.0	3.6	86	30	55.7	14.7	353
7	480.1	13.3	319	19	335.5	3.5	84	31	51.6	13.5	324
8	477.7	12.0	288	20	334.2	5.8	139	32	45.1	13.1	314
9	472.6	13.4	322	21	333.1	1.6	38	33	43.3	14.0	336
10	472.0	13.8	331	22	326.2	4.0	96	34	43.2	9.8	235
11	470.2	15.4	370	23	201.6	3.2	77	35	41.5	14.1	338
12	465.2	14.0	336	24	193.9	0.3	7	36	27.1	13.2	320
								Total:		365	8,760

Fig. 3.3.1 Hydro Power Duration Curve After Completion of Fortuna Phase II Project

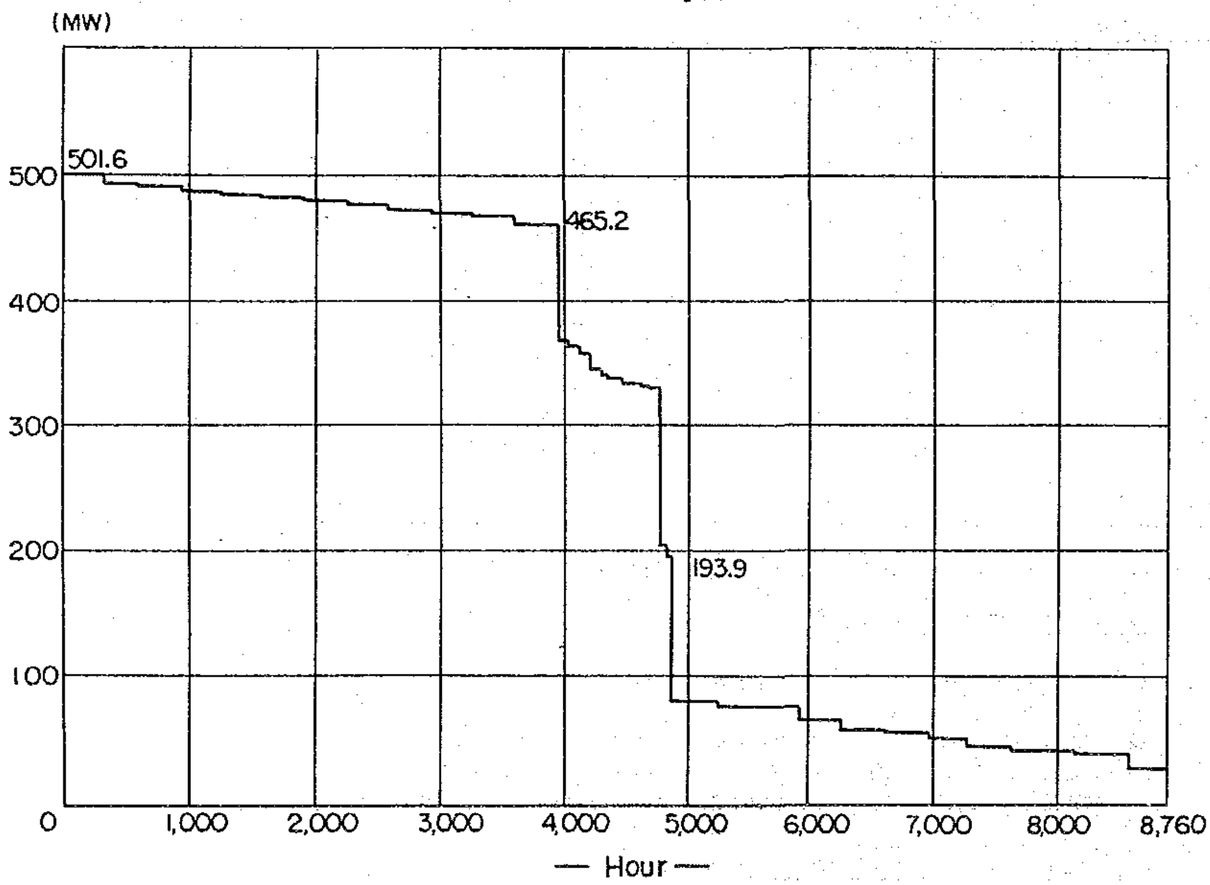


Fig. 3.3.2 (1) Power Generation Program for 1993

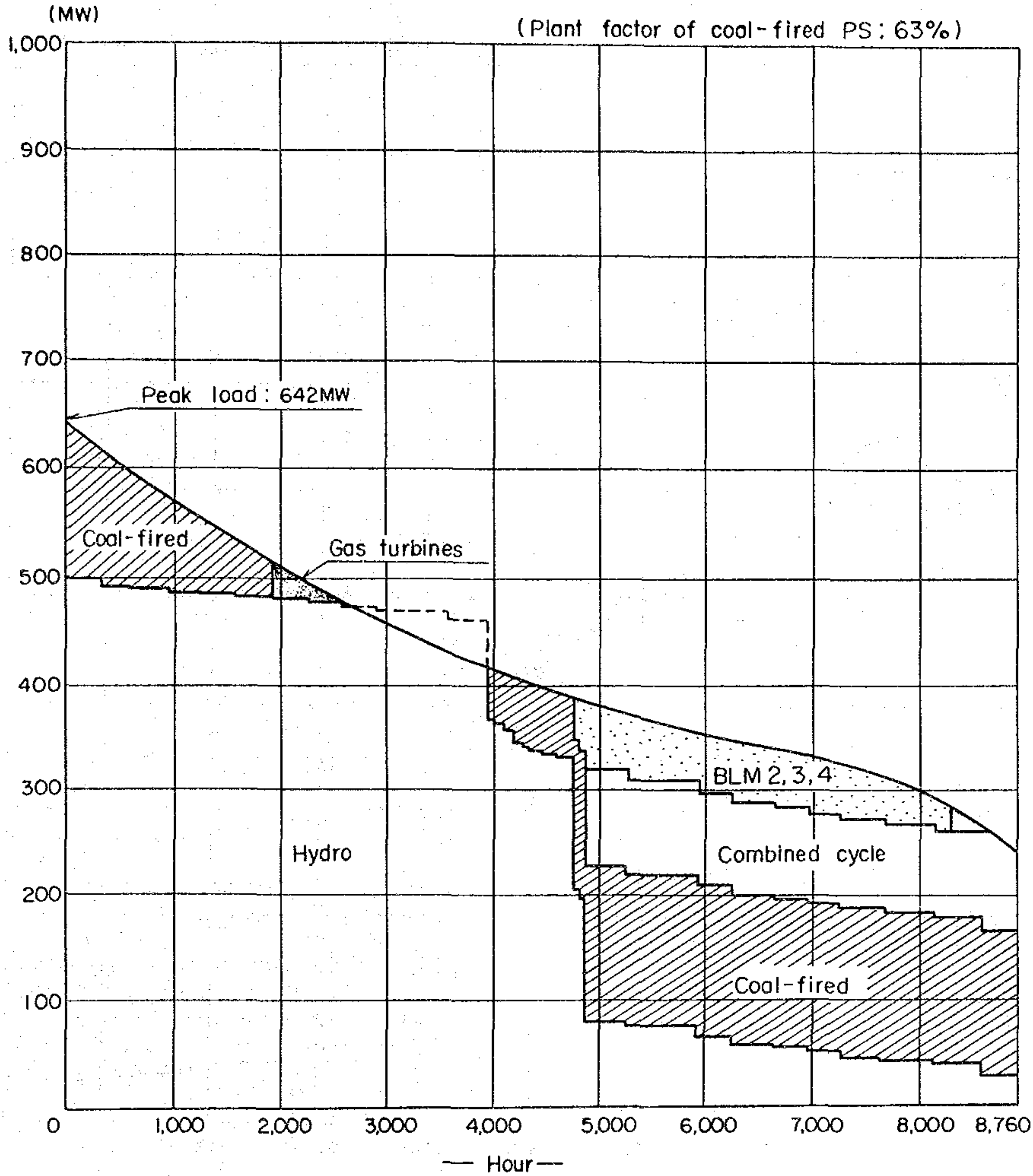
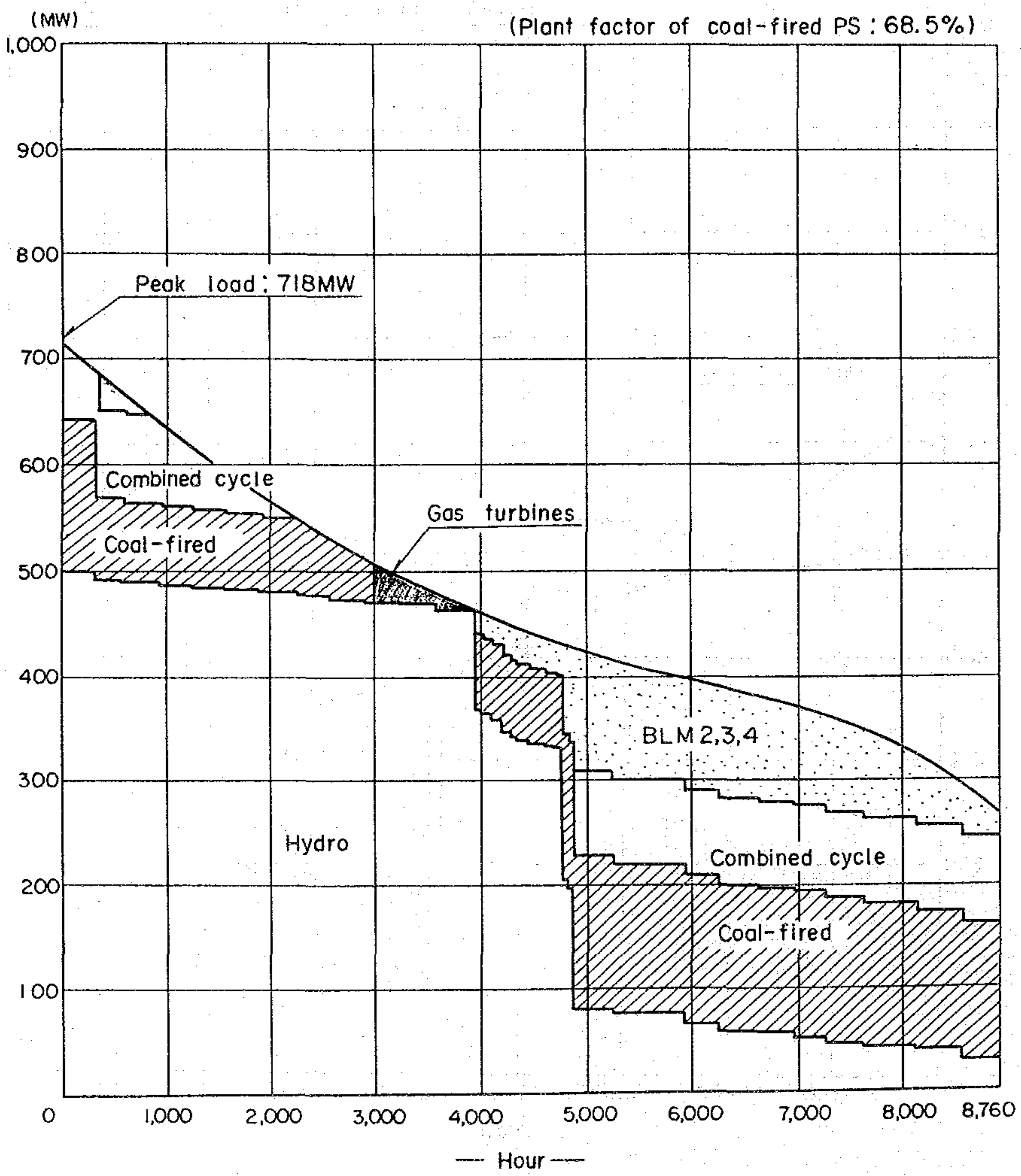


Fig. 3.3.2 (2) Power Generation Program for 1995



CHAPTER 4 SITE SELECTION OF POWER PLANT SITE

CHAPTER 4 SITE SELECTION OF POWER PLANT SITE

4.1 SURVEY ON CANDIDATE SITE

JICA Survey Mission spent three months commencing on June 16, 1986 in Panama to operate the local survey in cooperation with IRHE as to two plant candidate sites recommended by Pre-feasibility Survey of IRHE, Telfers island and Bahia Las Minas, and collected data and information by visiting Panama Foreign Ministry, Economy Planning Agency, DEPAT (Departmento Direccion Effectivo para Asuntos del Tratedo), PCC (Panama Canal Commi-ssion), Bahia Las Minas Oil Refinery, existing power plant, sub-station, load dispatch center, Colon Branch and Water Supply Bureau.

4.2 SITE SELECTION STANDARD

JICA Survey Mission compared two candiate sites cited above, viz. Bahia Las Minas and Telfers island, to identify the suitability for 75 MW x 2 units coal-fired power plant on the basis of the following standard:

(1) Soil conditions and configurations

(2) Ease in coal transportation and unloading

(3) Availability of condenser cooling water of good quality without recir-culation of heated effluent

(4) Availability of coal storage yard and ash disposal area with ample space

(5) Easy access to the site

(6) Ease in unloading and transportation of construction heavy equipment and materials

(7) Availability of raw water of good quality and ample quantity in the area adjacent to the site

(8) Easy availability of electric power for constructing the power plant from adjacent area

(9) Easy availability of break water material for construction

(10) Availability of extension area for future expansion of the power plant

(11) Short distance to the power consumption territory for transmitting elecric power

(12) Plant construction can be accomplished in a brief time so that the commencement of commercial operation of the power plant may be achieved not later than 1992

(13) Panama Canal operation and surrounding environment may not be adversely affected

(14) Economical power generating cost

Survey/investigation included the possibility of procuring the site, apart from the comparison cited above.

4.3 SITE COMPARISON AND ORIENTATION

4.3.1 Site Comparison

Two candidate sites in the preceding section, i.e., Bahia Las Minas and Telfers island, have been compared and investigated. Table 4.3.1 (1) shows the comparison/investigation results. Fig. 4.3.1 (3) and 4.3.1 (4) represent the candidate site program layout respectively.

4.3.2 Site procurement

(1) Bahia Las Minas Site

This is a private land which is neither used as a farm nor utilized as an industrial site but left under a mangrove bush. It is deemed possible to procure this site since there are no additional values except the necessity for procurement discussion with land owners.

(2) Telfers Island Site

This site is located in a territory called Panama Canal zone under the joint control of PCC (Panama Canal Commission) which is a cooperative of Panama. Since, however, the Panama Canal is to be returned to Panama by Dec. 1999 following the agreement between Panama and the U.S.A., the use of the PCC land requires the licence until the return of the Canal.

The above-cited situation has led the Panama Government to establish an office (representative) called DEPAT in the Ministry of Foreign Affairs for the administration of future utilization programs and licence in the Panama Canal zone.

Under the above circumstances, JICA Survey Mission was instructed by IRHE as follows as to the possibility of construction of a coal-fired power plant in the Panama Canal zone:

a) Already IRHE negotiated with DEPAT with respect to this subject.

b) DEPAT explained that, unless the coal-fired power plant affects the Panama Canal operation and surrounding environment, there existed no reason to deny the construction of the power plant cited above.

c) Already Orilla S.A. has projected a ship dismantling plant in the area adjacent to the candidate site, with an application filed with the authorities, and the licence is likely to be authorized shortly (as of Aug. 1986).

d) Application for the licence for constructing the power plant is filed by DEPAT from IRHE and authorized by PCC.

e) In the case of Orilla S.A., it took about one year to authorize the licence.

f) The site may be procured if the licence is authorized (authorization expenses are not required).

The above facts imply the possibility of procurement of the site if the power plant facilities are designed to satisfy the DEPAT conditions.

4.3.3 Site Orientation

Investigation in preceding Item 4.3.2 and 4.3.3 have led JICA Survey Mission to select and recommend Telfer island finally as the power plant site, by reason of:

a) Possibility of plant operation being commenced by 1992 in which the power supply is a pressing need

b) Good soil and configurational conditions

c) Economical power generating cost

d) Advantages in coal transportation

e) Ease in future expansion

Table 4.3.1 (1) Comparison of Tow Alternative Sites for the Proposed Power Plant

Condition: A - Good
B - Moderate
C - Bad

Bahia Las Minas Site		Telfers island Site	
Condition	Description	Condition	Description
1. Sub-soil Conditions			
C	This is a small island having a land elevation of approximately 0 to 2 meters. The greater part of the land is swampy area extended at the sea water level. The land, for a great part, is covered by mangrove. The ground is very soft. It is considered that the land is consisted of humus soil.	A	The land is well-drained and extended at an elevation of about 3 to 4 meters above sea level. It is considered that the land is consisted of sand, coral, and excavated or dredged materials obtained at the time of construction of the Panama Canal.
2. Coal Transportation and Unloading			
B	The sea area in front of the site is very small and further there is a jetty of the oil refinery on the opposite bank. These conditions will give various constraints on the location of coal unloading jetty, anchorage of coal vessel, as well as, tonnage and number of entrance of the coal vessel. The maximum size of available coal vessel will be 30,000 D.W.T. taking into account the depth of channel and the area of turning basin for ships.	A	On teh Pier 16 of the Cristobal port, cracks in concrete, rust in steel and structural deterioration are found. It is considered that this pier cannot bear to the surcharge of coal unloading machine. The front sea of the site, which is used as an anchorage area at present, has a large area with enough depth. Therefore, when constructing coal unloading jetty along dredging limit, the berthing will be possible for coal vessel of maximum 60,000 D.W.T.
3. Cooling Water for Steam Condenser			
B	For water intake and discharge the following matters should be taken into account:	A	(1) The water taken from the Limon Bay has relatively good quality, and oil floated on the sea seems small.

Bahia Las Minas Site		Telfers island Site	
Condition	Description	Condition	Description
	(1) The Las Minas Bay is shallow and the sea bottom is considered to be covered by thick sediment of sludge. (2) The front sea of the site has a small area with tidal variation of only 30 cm, so the seas water does not circulate well from and into the open sea. Therefore, counter-measures will have to be taken against recirculation of discharged warmer cooling water. (3) Effects on the cooling water intake of the existing Las Minas power station must be taken into account.		(2) The warmer cooling water can be discharged into the French Canal located for from water intake point. Therefore, there will probably be no recirculation of discharged warmer cooling water. However, the water discharge point should be dredged because the canal is relatively narrow and shallow.

4. Space for Power Station

B	Available	A	Enough

5. Access to the Power Station Site

C	It is necessary for access road to be constructed for a stretch of about 3 to 4 km from the existing road.	A	There is paved road along the site, so the access to the site is very easy.

6. Unloading and Transportation of Heavy Equipment (Maximum Weight: 100 tons)

For unloading heavy equipment the following two piers will be available:

Bahia Las Minas Site		Telfers island Site	
Condition	Description	Condition	Description

(1) Pier No.9 of the Cristobal Harbour

Pier No.9 belongs to the country. In 1985 improvement works were executed, and thereafter the pier has been used mainly for unloading containers. The pier has an enough space and connects directly to paved road. Therefore, for unloading heavy equipment this pier will be the most suitable.

(2) Pier of the Coco Solo Harbour

It will also be possible to use pier of the Coco Solo harbour for unloading heavy equipment. However, the transportation distances from this pier to the proposed plant sites are larger than those of the Pier No.9.

Condition	Description	Condition	Description
B	Transportation distance: - 20 km from Pier No.9 to the site - 20 km from Coco Solo to the site	A	Transportation distance - 4 km from Pier No.9 to the site - 9 km from Coco Solo to the site

7. Availability of Raw Water
(Maximum Requirement: 500 m^3 (132,000 gal)/day)

Condition	Description	Condition	Description
B	About 8 km south of the site Sabanita water treatment plant is operating. The actual water production of this plant is 23,000 m^3 (6,000,000 gal)/day against treatment capacity of 15,000 m^3 (4,000,000 gal)/day. This represents a 50% overload. Due to this situation it is judged impossible to feed the proposed power station with water from this treatment plant.	A	About 1.5 km south of the site Mount Hope water treatment plant is operating. The general characteristics of the plant are as follows: - Water produced: Mainly drinking water - Installed capacity: 75,000 m^3 (20,000,000 gal)/day - Maximum capacity: 79,000 m^3 (21,000,000 gal)/day - Actual production: 72,000 m^3 (19,000,000 gal)/day - Reserve capacity: 3,000 m^3 (10,000,000 gal)/day

Bahia Las Minas Site		Telfers island Site	
Condition	Description	Condition	Description
	Therefore, it will be necessary to take water from Gatun Lake. In this case the following works and process will be necessary: - Installation of pipeline for a stretch of 8 km - Pretreatment process of water		The above reserve capacity of 3,000 m^3/day will allow to feed the proposed power station (Maximum requirement: 500 m^3/day). Installation of pipeline is easy.
8. Source of Power for the Construction			
C	From Colon No.4 substation 13.8 kV line runs along the road in the east. For supplying power for the construction works a distribution line should be constructed along an access road to be constructed from Rio Alejandro which is located about 3 km south east of the site.	A	It is possible to receive power from 12 kV feeder of Colon No.5 substation located about 1.5 km from the site. Since 12 kV is not standard voltage (13.8 kV is standard), it is necessary to prepare transformer for this voltage at the stage of construction.
9. Availability of Breakwater Materials (Rock materials)			
	(1) About 1 km north east of Villa Alondra there is a quarry site of the Ministry of Public Works. A paved road is branched from highway to the quarry site. (2) It is considered that rock materials in the required quality and quantity can be supplied from this quarry site.		
B	The transportation distance is estimated to be 6 to 7 km.	B	From quarry site to the power plant site all transportation of the rock materials can be made by the existing road, but the transportation distance is estimated at about 20 km.

Bahia Las Minas Site		Telfers island Site	
Condition	Description	Condition	Description
10. Space of Land for Future Extension			
C	In the island there is no space for future extension. Therefore, if extension of power station is planned, the land necessary should be found in the hinterland or created by filling-up.	A	There is ample space for future extension.
11. Connection of Transmission Line			
B	230 kV transmission line (2cct) is planned to be constructed from power station to Panama II substation. The transmission line length is estimated at approximately 63 km.	C.	230 kV transmission line (2cct) is planned to be constructed from power station to Panama II substation. The transmission line length is estimated to be approximately 72 km.
12. Commissioning Year of the Power Station			
C	It takes long time for preparation works and foundation works due to bad sub-soil condition. Therefore, commissioning of the power station cannot be expected until 1993. (Refer to Fig. 4.3.1 (1))	A.	Due to good sub-oil condition, it will be possible to complete the preparation works and foundation works in 9 months. Therefore, the power station can be commissioned in 1992. (Refer to Fig. 4.3.1 (2))
13. Environment Matters			
A	No relation on the canal operation No effect will be exerted on the environment from the power plant.	A.	No effect will be exerted on the canal operation and on environment from the power plant.

Bahia Las Minas Site		Telfers island Site	
Condition	Description	Condition	Description

14. Construction Cost

Items	Million US$	Items	Million US$
Direct Costs	170.76	Direct Costs	148.60
. Electro-mechanical facilities	96.10	. Electro-mechanical facilities	96.20
. Civil work	45.12	. Civil work	22.70
. Architectural work	17.46	. Architectural work	16.20
. Transmission and substation facilities	12.08	. Transmission and substation facilities	13.50
Indirect Costs	15.36	Indirect Costs	13.40
Escalation	26.89	Escalation	19.99
. Interest during construction	38.99	. Interest during construction	27.80
. Import Tax	41.50	. Import Tax	35.09
. Total Construction Cost	293.50	. Total Construction Cost	244.88
. Unit Construction Cost	1,957 $/kW	. Unit Construction Cost	1,633 $/kW

Fig. 4.3.1 (1) Implementation Schedule of Telfers Island Site

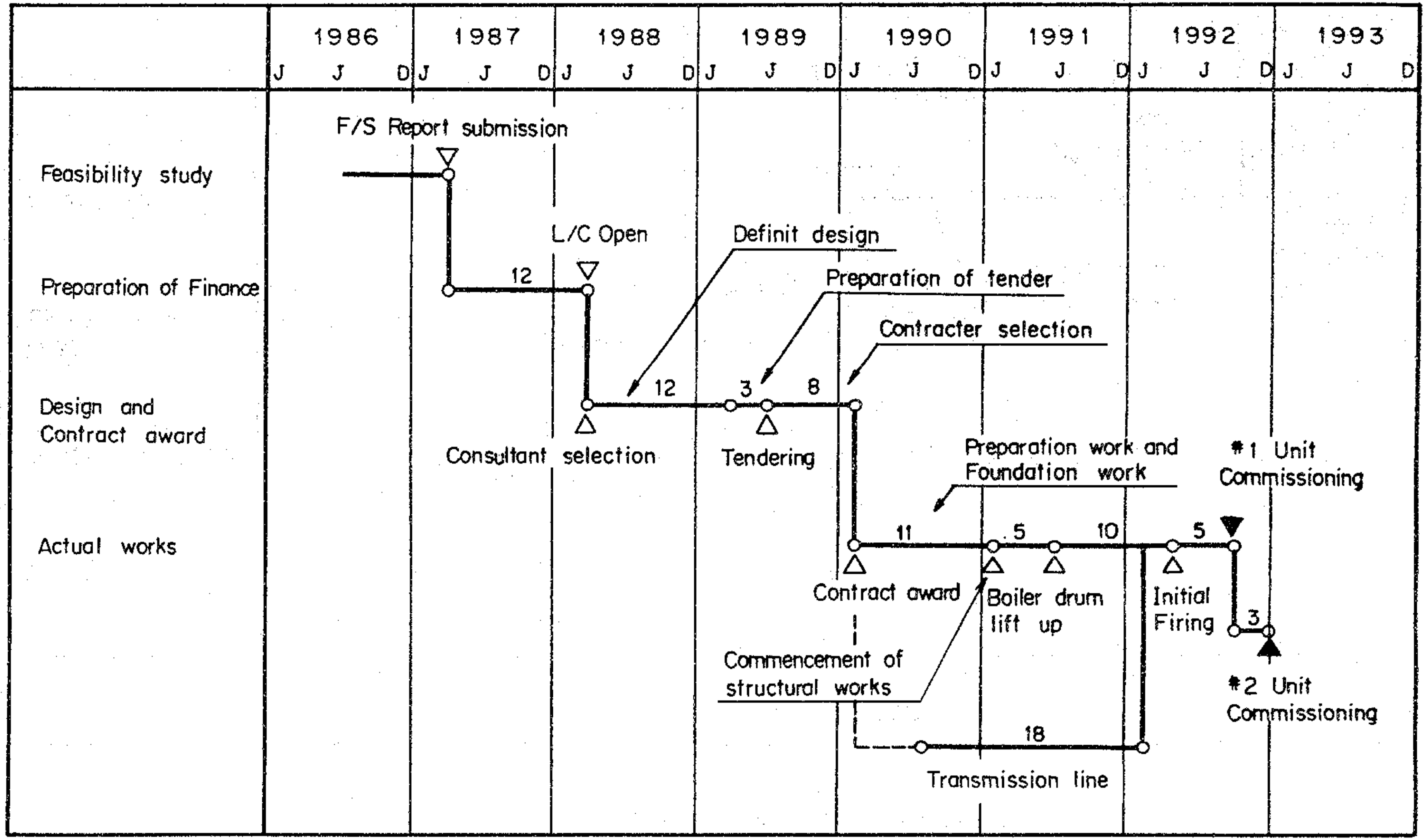


Fig. 4.3.1 (2) Implementation Schedule of Bahia Las Minas Site

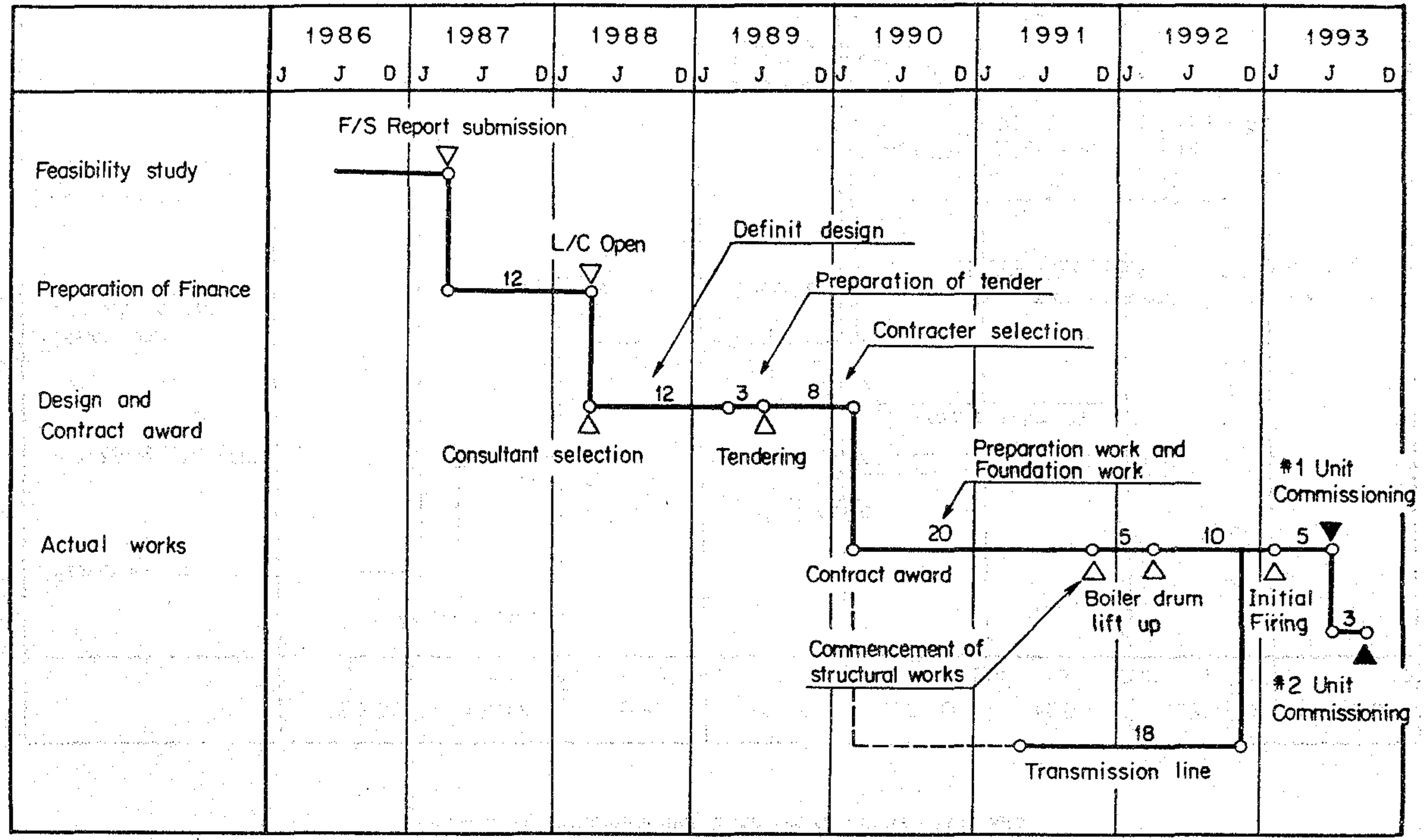


Fig. 4.3.1 (3) Power Layout of Terfers Island Site

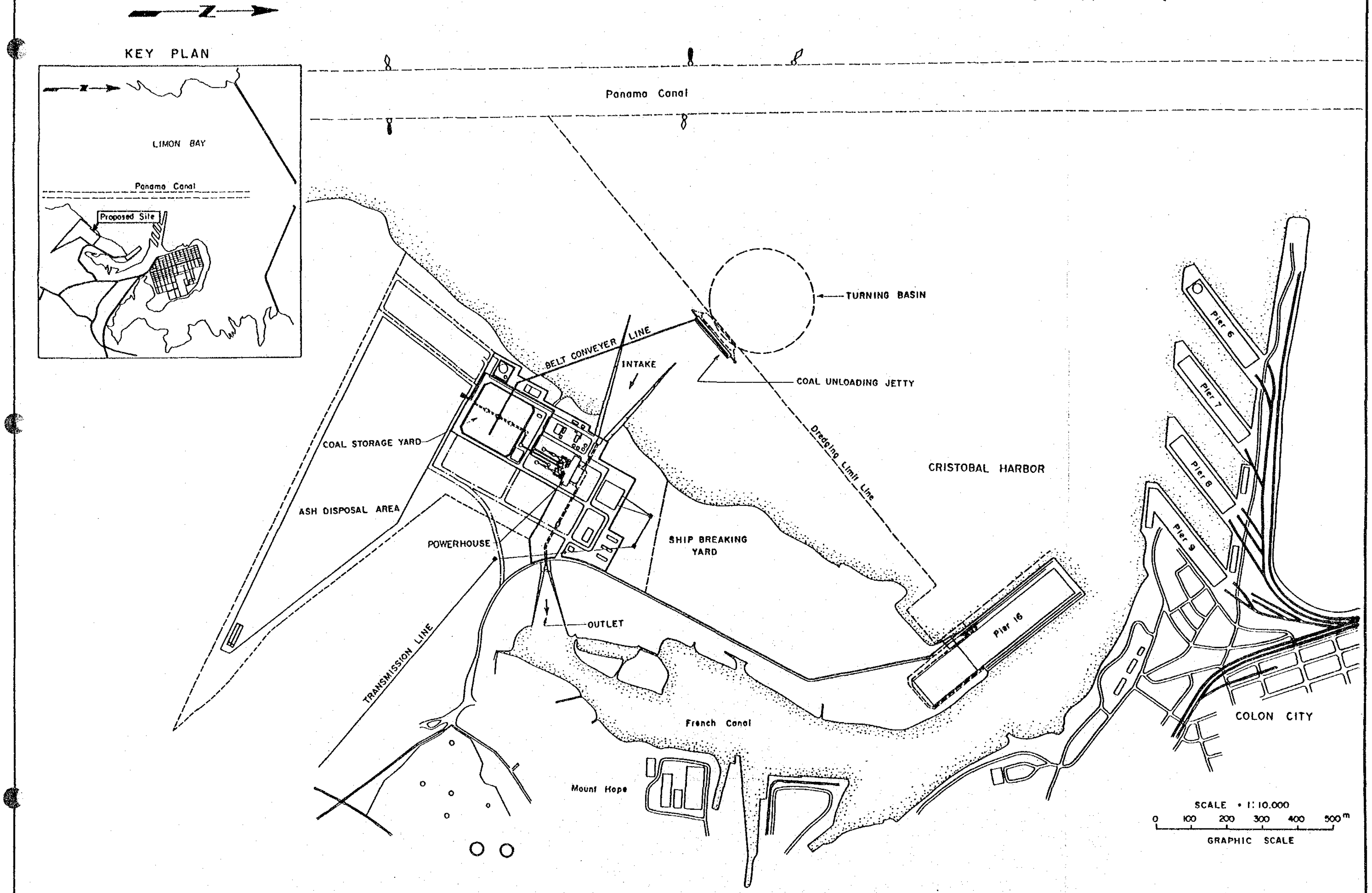
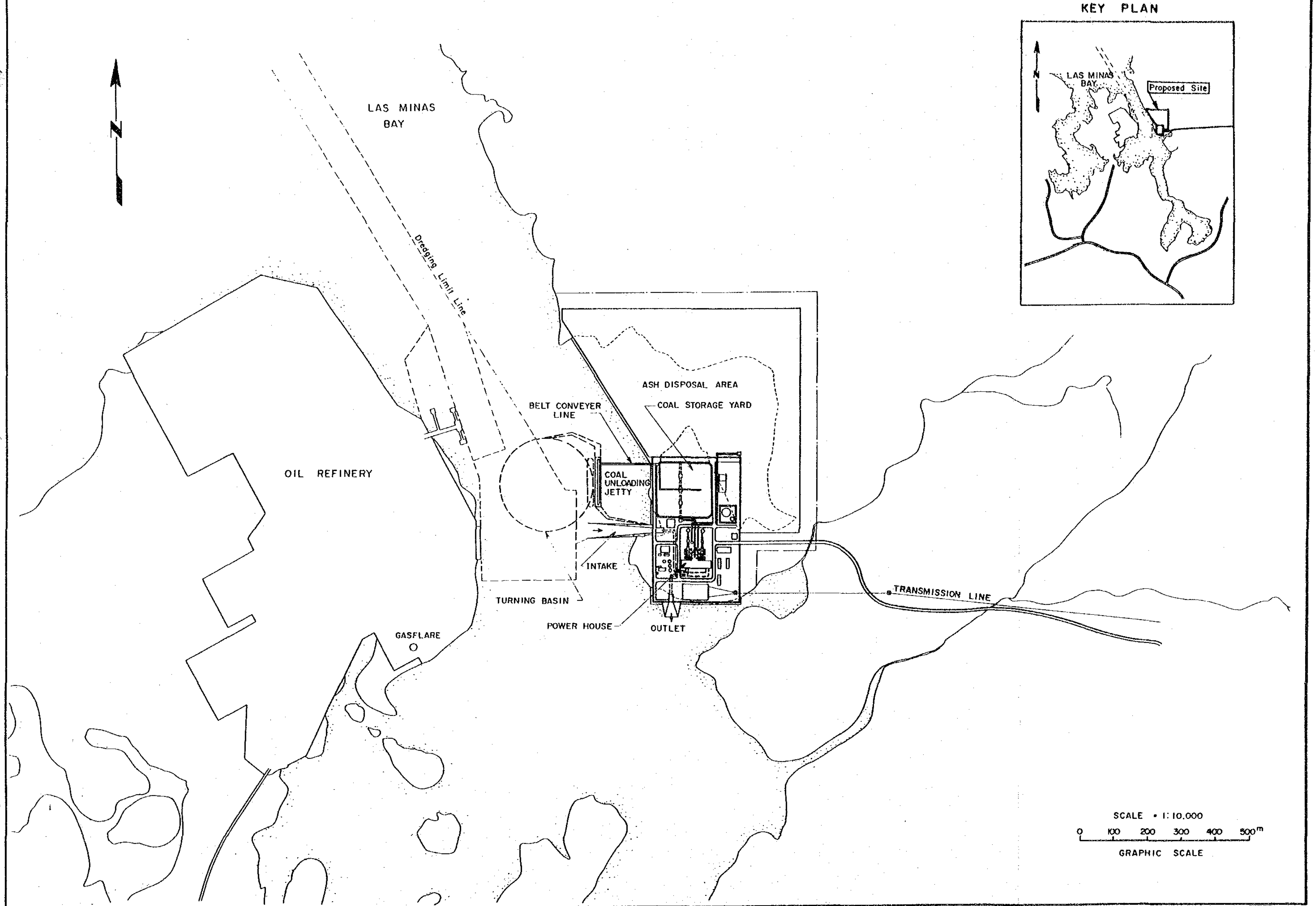


Fig. 4.3.1 (4) Power Plant Layout of Bahia Las Minas Site



CHAPTER 5 PROJECT SITE CONDITIONS

CHAPTER 5 PROJECT SITE CONDITIONS

5.1 LOCATION

The power plant construction project site is located at 9° 20' 10" N.L. and 79° 54' 35" W.L., or in the Telfers Island on the Limon Bay which is an entrance of the Panama Canal on the Caribbean Sea.

The site is adjacent with its north border to Cristobal Harbour which is situated southwest of Colon City. It is about 3 km from the Colon City heart, and about 70 km from the Panama City, on the Pacific Coast to the site. The Bolivar Highway which connects Colon City to the Lake Gatun runs about 1.5 km east of the site. A pavement road which is a junction from this highway runs along the east border of the site, leading to the Pier 16 at the north end of the Telfers island.

5.2 ACCESS

5.2.1 Road

The site provides an easy access from Panama City, which is the use of the road to Pier 16 from Colon No. 5 Power Plant, Mount Hope, through the above-cited Bolivar Highway before Colon City is reached by the visitor from Panama City via Boyd-Roosevelt Highway.

From Colon City, the Bolivar Highway provides a similarly easy access.

5.2.2 Marine Traffic

Heavy-weight equipment can be transported using Pier 9, Cristobal Harbour, or jetty in Coco Solo Harbour. The upland transportation distance represents about 4 km from the former to the site, and about 9 km from the latter to the site.

The depth of waters in front of the site is too shallow to permit the unloading of construction materials or excavated materials. It is therefore suggested to construct a temporary pier near the transitional part of Pier 16.

5.3 METEOROLOGICAL AND MARINE PHENOMENA

The climate in the site is characterized by a dry season which ranges from January to April and a rainy season, from May to December. P.C.C.(Panama Canal Commission) Cristobal Report, Fig. 5.3.(1), describes that the averaged atmospheric temperature is 26.9°C without appreciable fluctuation through the year. The water temperature averages at 27.4°C in the dry season and 28.4°C, rainy season, without significant fluctuations except it rises by 1°C in the rainy season.

There is a remarkable difference between rainy and dry season in precipitations. Averaged precipitations in the dry season and rainy season respectively represent 67 mm and 377 mm, averaged yearly precipitations being 3,268 mm.

Humidity averages in the dry and rainy season respectively 78.5% and 85.0%.

Fig. 5.3.(2) represents the wind direction diagram and averaged wind velocity. North wind dominates in the dry season at the averaged velocity of 6.2 m/sec. There is no wind predominance in the rainy season and the wind velocity averages 3.5 m/sec. Fig. 5.3.(2) also shows the tide level record, where there is little range of tide more than 30 cm about.

5.4 CONFIGURATIONS

Reportedly the Telfers Island territory where the power plant site exists was originally an island under the heavy carpet of mangrove bushes until connected to the continent by being reclaimed when used as excavated materials disposal area at the time of the Panama Canal construction.

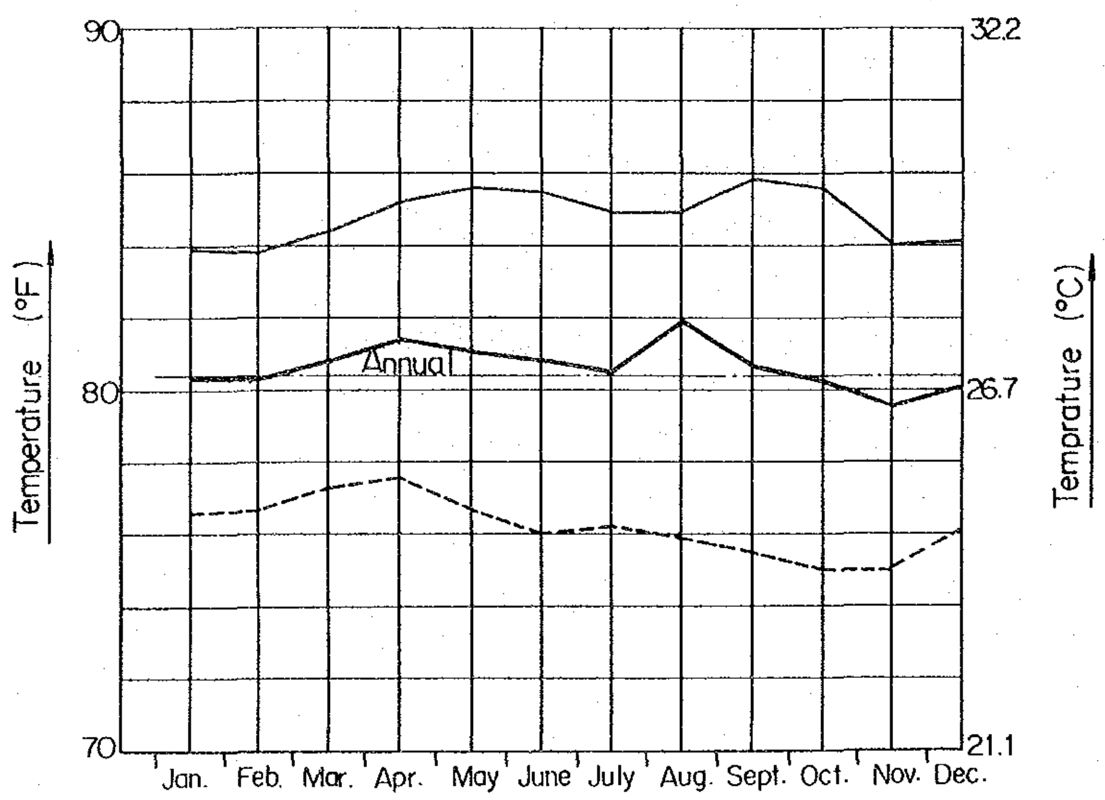
Today the territory is controlled by PCC and used as the dredged materials disposal area as well as the garbage disposal area.

There exist at present no pavements except a road to the Pier 16 in this territory where high grasses dominate except some woods.

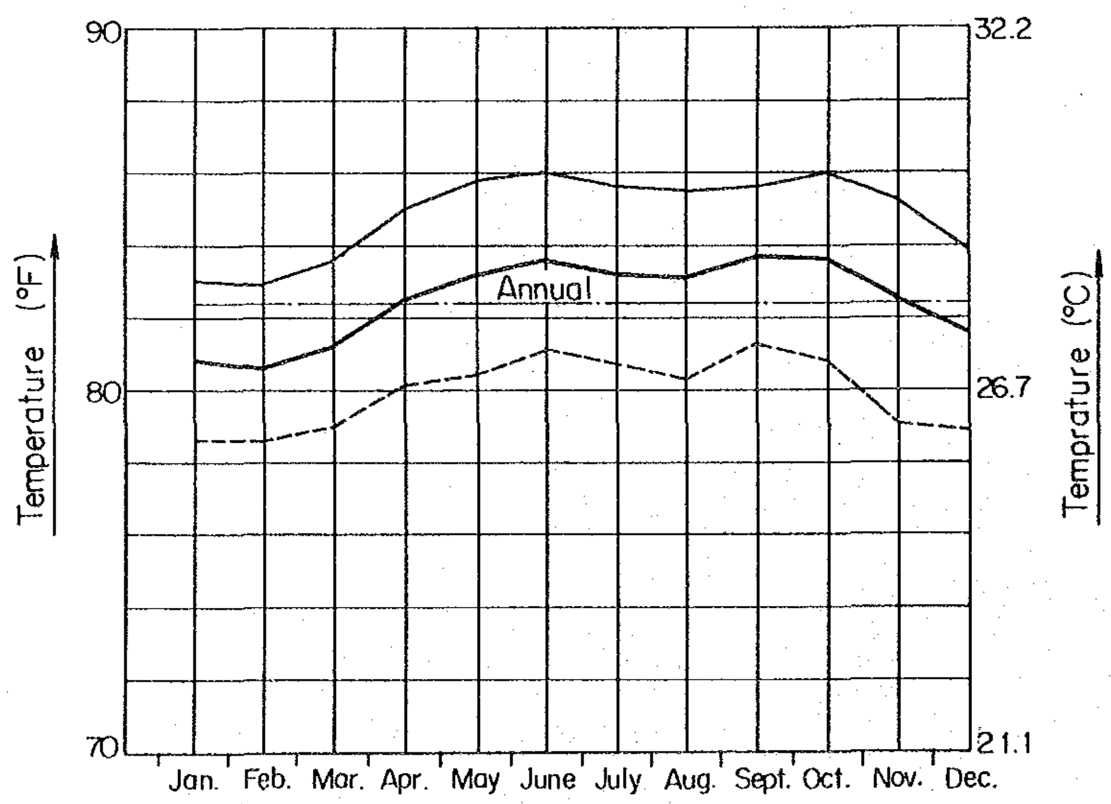
The territory demonstrates an almost flat configuration in which the power plant site altitude represents about 2.5 - 5.5 m above the sea level while the ash disposal area under the Project, 3.0 - 5.0 m.

Fig. 5.3 (1) Meteorological Data

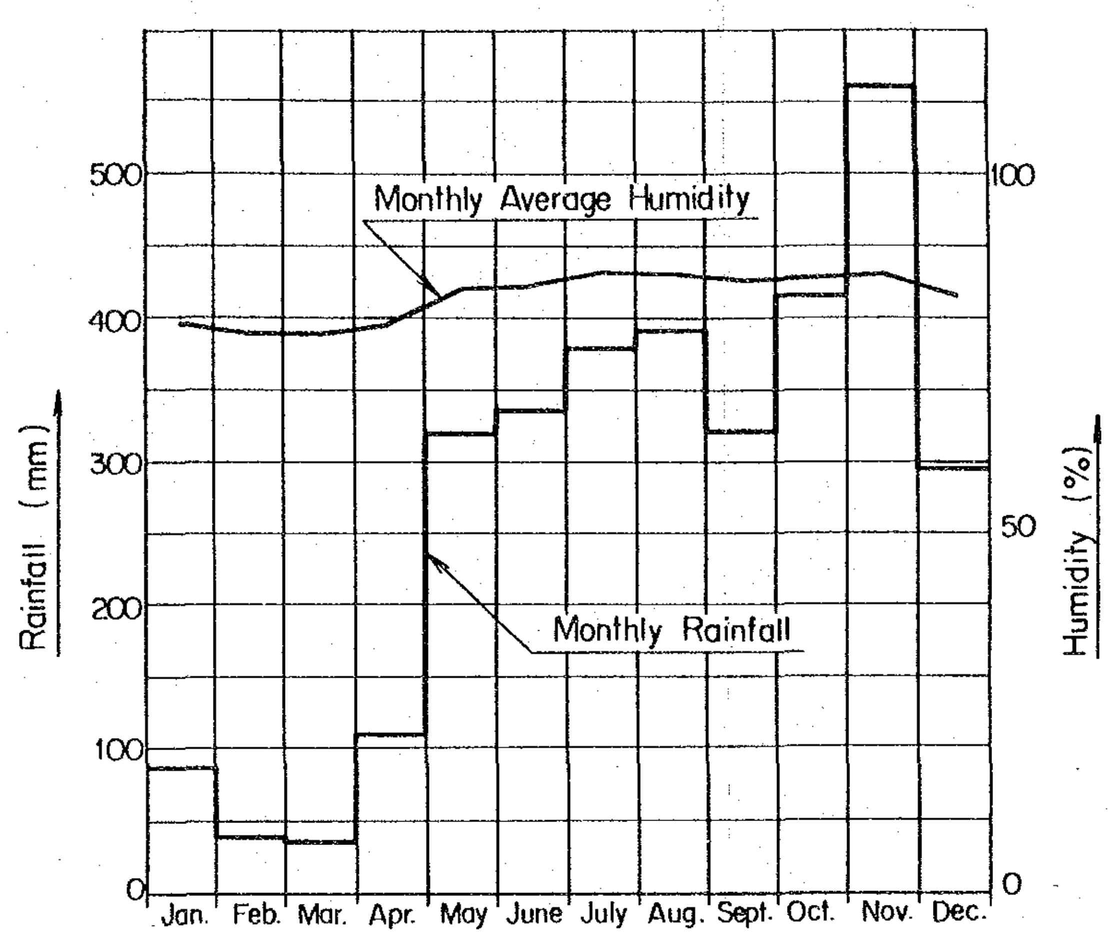
AIR TEMPERATURE



SEA WATER TEMPERATURE



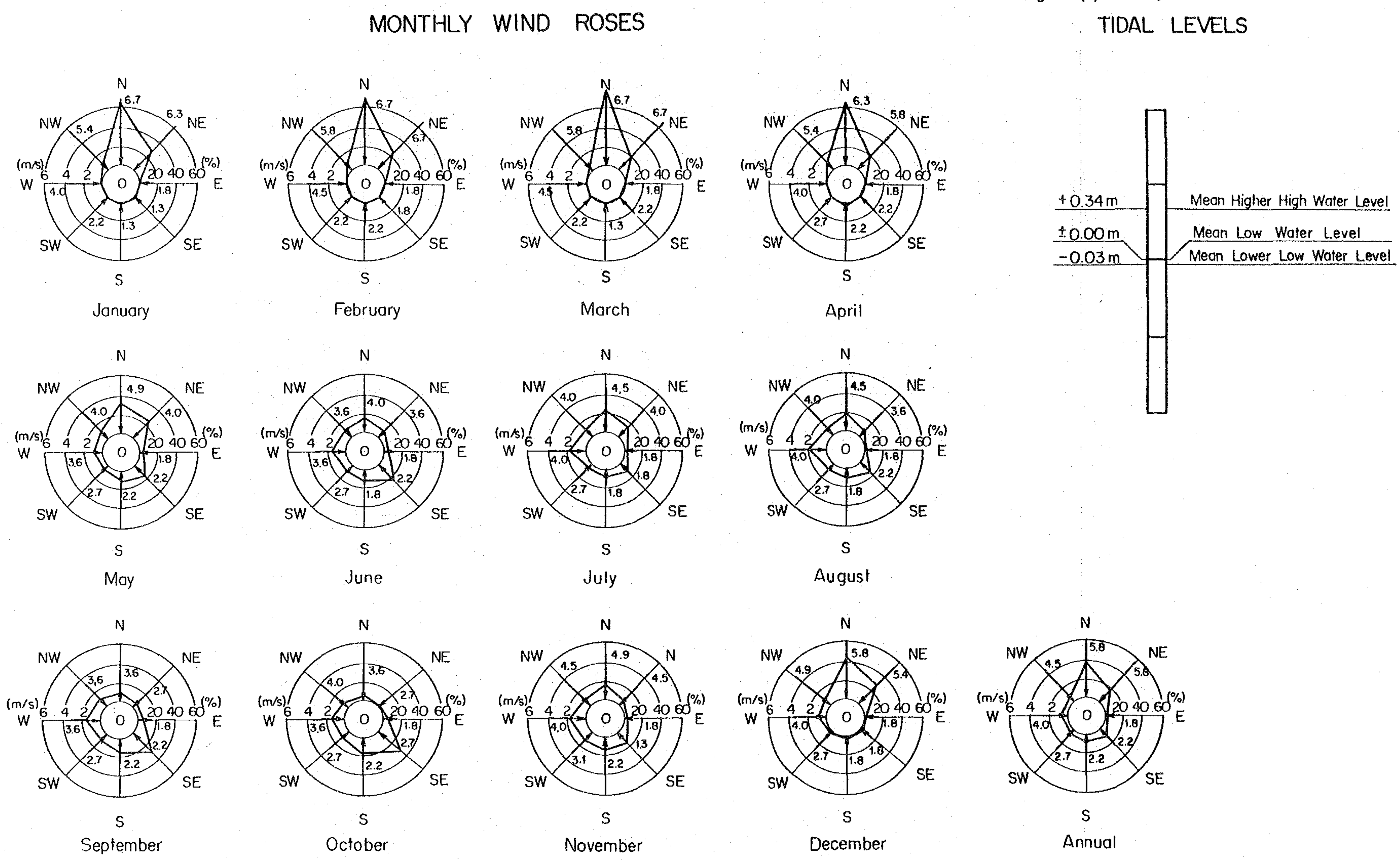
RAINFALL & RELATIVE HUMIDITY



LEGEND

- ——— Average Maximum
- ━━━ Monthly Average
- - - - - Average Minimum

Fig. 5.3 (2) Monthly Wind Roses and Tidal Level



※ Length of arrow from circumference of circles represents the average velocity from the indicated direction in meter per secound.
The figure in the center circle indicates the percentage frequency of calms.

There exists still at present some pit near the power plant site, used by PCC for collecting corals from dredged materials. It is a pit whose width and length approximate respectively to 120 m and 350 m, with its four sides filled up with soil, and used as a disposal pit in which dredged materials are pumped.

As for the details of configurations, the recent local survey has revealed that already PCC had surveyed the Telfers Island territory, preparing 1/1000 topographic maps. It is therefore decided that the topographic maps from PCC should be checked by comparing with the configurations.

While originally the survey date not known, the PCC topographic maps indicate the operation of corrective survey on the territories including the power plant site in January 1986, though partially. Comparison in August 1986 between the corrective survey results and configurations disclosed some discrepancies, revealing that the configurations had partially changed recently, which were conceivably due to the construction of the pit cited above for collecting corals.

Nontheless the discrepancies cited above are not significant, and, because the PCC topographic maps suffice in the feasibility study and there is the possibility of ground surface configurations altering due to the dredged materials disposed, it has been decided that no topographic survey will be operated anew at the phase of adopting the PCC 1/1000 topographic maps as the current topographic map. In the stage of detail design, therefore, it is necessary to operate the detail topographical survey on the power plant site and ash disposal area after the delivery of the site.

Meanwhile the fact that the marine chart No. 26068 (Puerto Cristobal) which has already been published in useful in identifying the sea bottom topography and the PCC 1/4000 sounding survey map (January 1986) is useful as the information of the depth of water near the coal ship jetty under the Project has led to the conclusion that there is no necessity of carrying out anew a sounding survey.

These survey reports indicate the boundary line for dredging the Panama Canal which runs about 500 m off and almost parallel with the coastline of the power plant site; the sea bottom slopes gently from the land at about 1/90 - 1/100 gradient to the boundary line until the -12 m crevass near the boundary which was a result of the canal dredging (gradient: abt. 1/10 - 1/15); beyond the crevass, the water depth ranges from -12 m to -14 m constantly. The waters surveyed are at present used as anchorage area for small-sized ships.

There is a creek, called the French Canal, in the east of Project site. Reportedly it is a part of ruins of waterway projected by French party at the time of the Panama Canal construction.

The hydrographic chart and local reconnaissance have revealed the water depth in the creek accounts for about -1.5 m nearby the power plant water outlet under the Project, and about -13 m near Pier No.16, suggesting some deposits of soft sludge on the bottom of the sea.

5.5 GEOLOGY

5.5.1 General Geology

The Republic of Panama lays between 7°9' N.L. and 9°37' N.L., and between 77°9' W.L. and 85°1' W.L., in an irregular S-shape contour, with the longest distance of approximately 630 km in the east-andwest direction, and approximately 270 km in the north-andsouth direction.

The republic is geopolitically divided into Western Panama, Central Panama, and Eastern Panama. The subject area of the project is in Colon State in Central Panama. Colon State is situated in the region where the width of the land is narrowest even in the Isthmus of Panama. The Panama Canal, connecting the Pacific Ocean with the Caribbean Sea, crosses the central part of the region, so the region and its vicinity are called the canal zone. The area of the project is located near the inlet of the Panama Canal in the Caribbean Sea, behind which the Gatun Lake expands.

Geologically, the basement rock of Panama district is lava or volcanic clastic rocks, of basalt or consesite of the Cretaceous or the older period. The about half of the ground surface in Panama is held by the above stated basement rocks and igneous rocks mainly composed of basic extrusive rocks of the Tertiary period. The remaining half is mainly composed of sedimentary rocks of the Tertiary period, distributed with a small quantity of alluvium of the Quaternary period and coral reefs along the seashore.

In the canal zone where the area of the project locates, the basement rock of the anterior Tertiary period, consisting of igneous rocks of basalt and consesite, are widely distributed in the north-eastern side of the Gatun Lake. In the area extending from the Gatun Lake to the Pacific coast, igneous rocks, mainly composed of basalt and andesite of the Miocene of the Tertiary period, are generally distributed. In the region towards the Caribbean Sea from the lake, sedimentary rocks, such as the Camito layer of the late Oligocene, the Gatun layer of the middle Miocene, Toro Limestone and Chagres Sandstone of the late Miocene or the early Pleistocene, etc., are distributed in a gentle slope.

The structure of the area extending from Eastern Panama to Central Panama is indicative of the arcuate structure, expanding towards the Caribbean Sea. At the northernmost part of the structural areas, a continental divide is formed from the Colombian border to several miles east of the canal zone. The core of the continental divide is composed of the basement complex.

There exist the transisthmian fault zones radially crossing the arcuate structure, and one of the significant fault zones exists in the vicinity of the canal zone also. It has been concluded that the existence of this fault zone was the fundamental reason why the canal was digged in the vicinity of the canal zone.

5.5.2 Geology of the Area of the Project

The geology near the area of the projected power plant has its bedrock of Gatun layer of the middle Miocene of the Tertiary period. This layer is mainly composed of mudstone near the area of the project.

Covering Gatun layer, the alluvium, consisting of silt, clay and sand, and the deposit of the Recent Epoch, consisting of coral reefs, are distributed along the seashore.

Further, in the whole neighborhood of the area of the project, a considerable quantity of dredged soil from the Panama Canal has been dumped on the aforesaid existing ground.

5.5.3 Geological Survey Results

A geological survey was carried out locally in the period between July 29, 1986 and September 2, 1986.

The survey involved seven inland borings and three offshore borings as well as seismic prospecting over 5,300 m of total survey line distance with nine survey lines. Fig. 5.5.3 (1) shows the boring points and survey line positions. The boring also involved standard penetration tests which were operated at every 1.5 m, sampling and laboratory tests. Table 5.5.3 describes the contents of the survey and tests.

The object of the recent geological survey is to collect the basic data for preliminary design by identifying the characteristics of the ground and bed rock from the information of the geology in the optimum candidate site. Using those data we can improve accuracy with respect to the preliminary design of civil engineering construction foundation structures, project budget calculation and F/S report.

The above-cited geological survey has resulted in a geological profile as represented by Fig. 5.5.3 (2), which indicates a deposit of dredged materials of the thickness ranging from 0.9 m to 4.4 m as the surface layer of such softness as N value 2 except in Bor. L-2 where N value 9 - 16 in the upland part power plant project site. Beneath the deposit cited above, there exist clay or silt, clayey sand, or sand with coral fragments formations.

The clay or silt and clayey sand formation are soft with N value ranging from 2 to 6. Sand with coral fragments formations are loose in Bor. L-2 and L-3 where N value 1 - 9, whereas compact in Bor. L-4 through L-6 where N value 12 - 50. Beneath these formations there exists Gatun Formation which is the bedrock. The surface of Gatun Formation is a weathered rock layer of the thickness of 0 - 3 m, which is followed by layers whose N value exceeds 50. The recent survey has confirmed the continuity of the layers by probing in L-5 a 30 m drilling which is the longest of borings operated on Gatun Formation.

This bedrock called Gatun Formation consists of soft rock (mudston) whose unconfined compression strength is as low as 46.0 kg/cm^2 in average (Min. 20.8 kg/cm^2. Max. 186.4 kg/cm^2) according to boring core test. The bedrocks nontheless provide strength enough to serve as a pile foundation bearing ground for thermal power plant structures, which has led to the conclusion in the present Project that in the upland they may be designated as the pile bearing layer.

The recent survey has revealed remarkable undulations over the Gatun Formation, shallow around Bor. L-4 and L-5 with EL-7.0 - -9.0 m depth and deep around Bor. L-6 and L-7 with EL-17.0 - -29.0 m in the upland area.

The above fact indicates that the ground near L-4 and L-5 where pile length becomes less will be acceptable for supporting structures such as main buildings, stack, cooling water path, etc. which are in general applying their weight concentratively and require piles.

Meanwhile the offshore boring operated in Bor. S-1 - S-3 has revealed the depth of the Gatun Formation increasing as it extends to the sea with a very compact granular coral layer on it.

The granular coral layer demonstrates N value over 50 and appears to be rigid enough to bear the piles for jetty and marine belt conveyor. It has been found meanwhile that in the jetty area normal pile driving system may fail to ensure any acceptable pile penetration. There exists a clay or silt layer whose N value is about 15 above the granular coral layer which is covered by a very soft loam deposit of the thickness ranging from 2 m to 7 m forming the sea bottom. The loam deposit underwent several tests by sampling undisturbed specimens to identify its properties which have revealed its unconfined compressive strength.

$$qu = 0.86 - 1.04 \text{ kg/cm}^2$$

The ground is characterized by two formations, i.e. the soft deposit and the bedrock which is present in a short distance beneath the deposit and called Gatun Formation. In selecting a bearing layer for structures, there is no problem in recommending Gatun Formation as the vertical bearing layer (in the jetty area, the coral fragment layer becomes bearing layer).

In the case of such a construction as coal storage yard where coal is piled up to a certain degree of height, however, it is obviously uneconomical to design the whole construction on piles when considering the space. Meanwhile, the existing grounds as they are may possibly develop the settlement or slide. It will be necessary to investigate these problems.

Fig. 5.5.3 (1) Location of Boreholes and Seismic Refraction Survey Lines

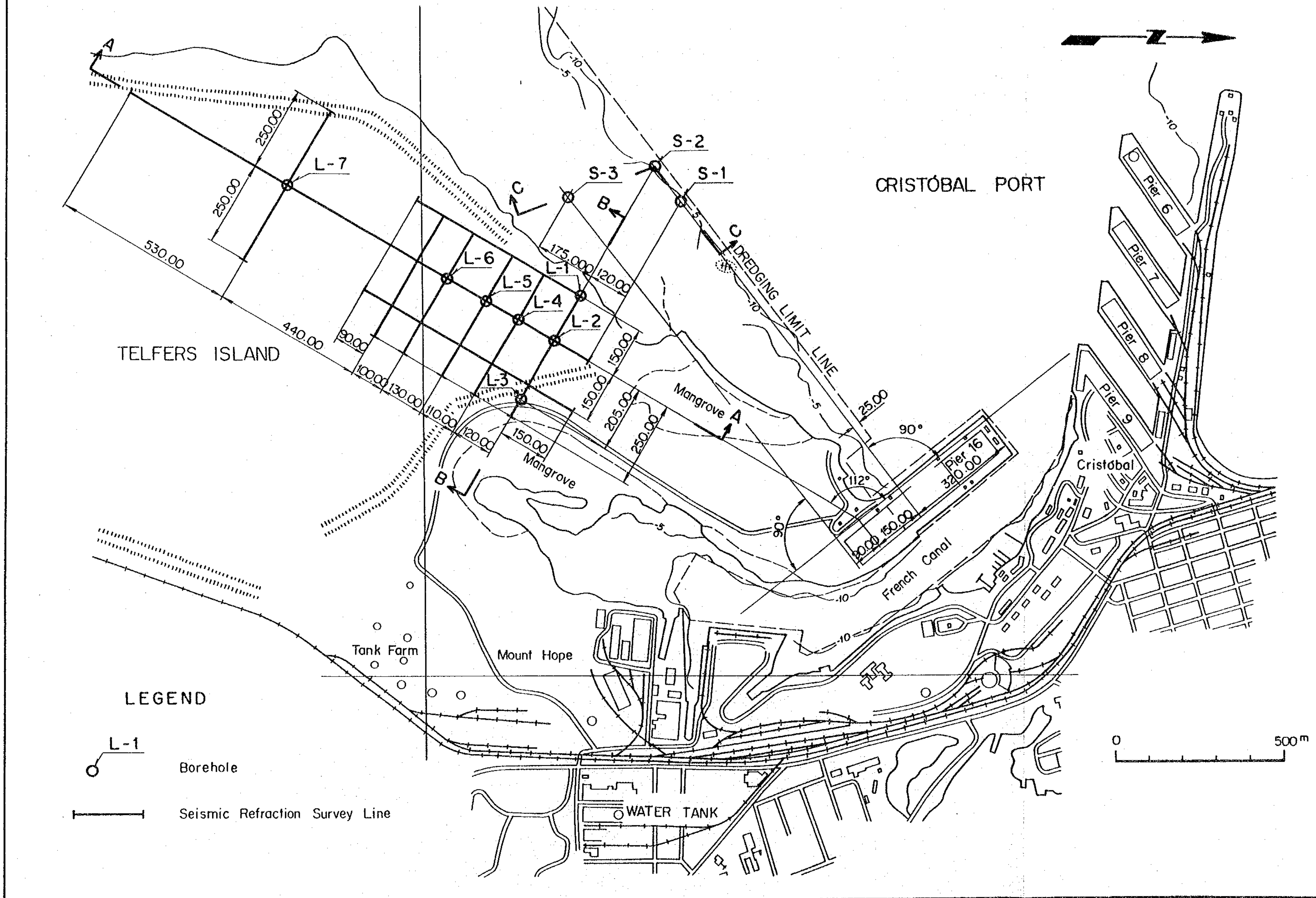


Table 5.5.3 Quantity of Boring, Standard Penetration Test and Laboratory Test

Hole Number	Length of Borings (m)			Standard Penetration Test (time)			Laboratory Test (piece)				
	Soil	Rock	Total	Soil	Rock	Total	Grain size distribution	Consolidation	Density	Unconfined compression	
										Soil	Rock
S - 1 (off-shore)	24.0	7.5	31.5	10	0	10	2	2	2	2	3
S - 2 (off-shore)	26.0	8.4	34.4	7	0	7	2	2	2	2	1
S - 3 (off-shore)	12.9	7.0	19.9	5	1	6	2	2	2	2	1
L - 1 (inland)	16.0	7.0	23.0	11	1	12	0	0	0	0	4
L - 2 (inland)	16.9	10.6	27.5	11	1	12	0	0	0	0	6
L - 3 (inland)	7.0	5.0	12.0	5	1	6	0	0	0	0	1
L - 4 (inland)	13.0	14.4	27.4	8	1	9	0	0	0	0	9
L - 5 (inland)	7.0	33.0	40.0	5	1	6	0	0	0	0	21
L - 6 (inland)	17.0	7.5	24.5	12	0	12	0	0	0	0	4
L - 7 (inland)	29.0	6.0	35.0	16	1	17	0	0	0	0	1
Total	168.8	106.4	275.2	90	7	97	6	6	6	6	51

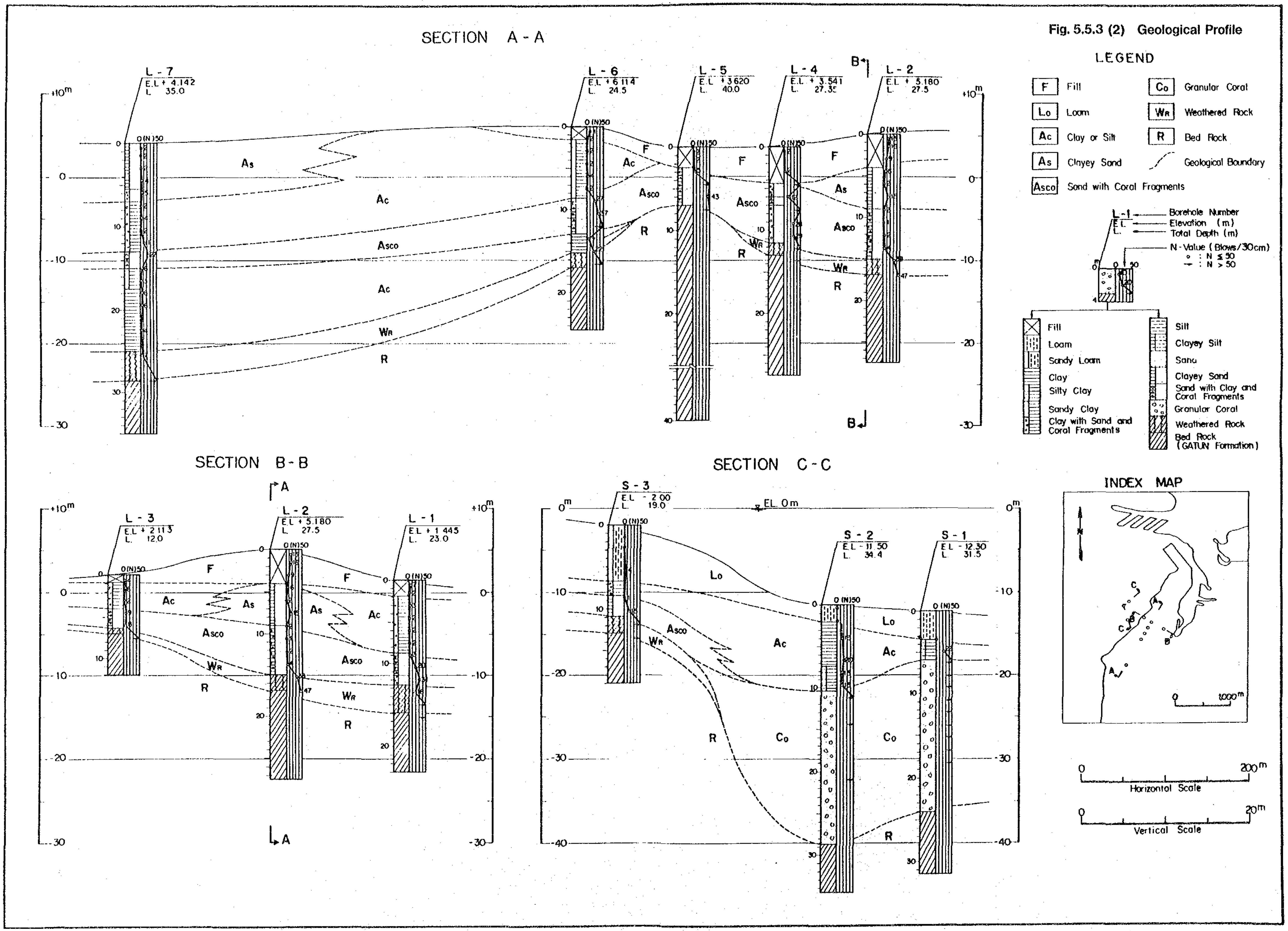


Fig. 5.5.3 (2) Geological Profile

CHAPTER 6 COAL PROCUREMENT PROGRAM

CHAPTER 6 COAL PROCUREMENT PROGRAM

6.1 DOMESTIC COAL IN PANAMA

We understand that no coal mine is in operation in Panama, though we can not jump at conclusions, judging from the material on the domestic coal in Panama dating back 10 years with limited amount of information. As far as the results of analysis of coal samples (TEXACO INC.) are concerned, the quality of coal in the Rio-Indio district shown in Table 6.1 is considered best, though it is hardly a match for high quality bituminous coal, and firing of the designed boiler exclusively with the above coal seems difficult. Besides, many values in the analysis are unclear, and we can not make a definite decision before obtaining the results of boring in the future.

If economical domestic coal of good quality is found in Panama in the future, its utilization is desirable from the standpoint of the national economy. In planning the use of domestic coal at Telfers island, the following items must be studied fully:

6.2 COAL PROCUREMENT MIX

For the above reasons, the best mix of coal procurement for Panama coal fired power station should be considered on the assumption that imported coal will be used.

6.2.1 Coal Procurement

In coal procurement, the following are important points of consideration;

a) To secure long-term stable supply... (explained in 6.2.2)
b) To secure supply maintaining economic efficiency... (explained in 6.2.3)
c) To use coal fitted to the design of plant.

Table 6.1 Coal Specification

Item		Designed Coal	Grevsa No.1 Rio Indio
Calorific value (kcal/kg)		6,600 (AD)	5,273 (AR)
Total moisture	(%)	9.0 (AR)	17.59 (AR)
Surface moisture	(%)	5.2 (AR)	-
Proximate analysis			
Inherent moisture	(%)	4.0	-
- Ash		13.0	8.96 (AR)
- Volatile matter		35.0	33.05 (AR)
- Fixed carbon		48.0	40.40 (AR)
Total sulfur	(%)	1.0	1.15 (AR)
Total nitrogen	(%)	1.5	-
H.G.I.		45 - 55	-
Fusion temperature	(°C)	1,300 - 1,400 (ID)	-
Composition of ash			
SiO_2		58.3	-
Al_2O_3		26.4	-
Fe_2O_3		6.5	-
CaO		1.6	-
MgO		1.6	-
Na_2O		0.8	-
K_2O		2.2	-
P_2O_5		0.3	-
SO_3		1.3	-
TiO_2		0.8	-
Others		0.2	-

Note: AR: As received AD: Air dry ID: Initial deformation

6.2.2 Long-term Stable Supply of Coal

Generally speaking, to secure long-term stable supply of coal;

a) Combination of supply patterns is necessary, namely procurement mix of long-term contract, spot deal and equity participation.

b) Diversification of supply sources by countries and by loading ports is necessary, and at the same time.

c) It is important to build up channels for establishing mutual trust relationships with suppliers.

First, the supply patterns in a) above are explained in the following table.

	Price Fluctuation	Stability, Rigidity, Sales obligation, Purchasing obligation	Involvement of buyer in coal mine	Loans & investments and returns to buyer
Spot	Large	Short/small	None	None
Long-term Contract	Small	Medium	Little	None
Equity Participation	Small	Long	Yes	Yes

Therefore, a balanced view of supply patterns should be taken in securing long-term supply of coal in a large quantity. In the case of this project, however, the annual consumption of coal is only 300 thousand tons, and equity participation (development import) is unpractical. Procurement mix of long-term contract and spot deal will be enough.

Second, the meaning of diversification of supply sources in b) is not to depend on the sole source for the whole supply. In the course of long-term transactions, unexpected accidents or strikes may occur at coal mines, on railroads and at ports, and it is advisable to have more than one supply sources. Lastly, concerning the establishment of mutual trust relationships with suppliers in c), the supply/demand and market prices of coal sometimes become unstable and fluctuate as other primary products, so, efforts should be made usually to build up mutual understanding.

6.2.3 Maintaining Economic Efficiency

a) It is essential to grasp the movements of supply/demand and prices of coal through collection and analysis of coal-related information. For this purpose, investigations should be made widely on the coal reserves of respective countries, production volume, exportable quantity, quality, transaction statistics, infrastructure conditions such as railroads and ports, natural resources policy and economic trends as well as spot market movements.

b) It is a matter of course that studies on the combination of supply patterns in 6.2.2 (a) and b) are useful in comparing economics.

6.2.4 Reference to Coal Procurement

In connection with coal procurement, the following suggestion was given by JICA Team:

a) Method of contract

It is not necessary for IRHE to contract directly with the coal mine companies in Colombia and in U.S.A. Instead, it will be appropriate to contract with a trading company in Panama to import coal from these countries.

b) Co-purchase with cement company

At present, coal is imported by a cement company in Panama. Therefore, a co-purchase of coal by IRHE and cement company will be conceivable.

c) Start in negociation for the contract

The initial firing of boiler is scheduled for May, 1992. It is suggested that the negociation for contract with a trading company be started in around May, 1989, i.e. about 3 years prior to the initial firing.

6.3 OCEAN TRANSPORTATION

"Security of long-term stability" and "economics" are also important in the ocean transportation of coal. To actualize these factors, studies on the best mix of spot charter and COA (contract of affreightment) are necessary.

6.4 RECOMMENDATION

The ocean freight of coal per ton becomes cheaper as the size of carrier gets larger, in principle, but in turn, the equipment cost of coal unloaders and the berth accommodating larger carriers will increase with the lower utilization ratio of facilities. Besides, the coal yard must be enlarged to provide against changes in storage, and operating costs including interests on coal stock will increase, requiring adequate administration of coal stock such as measures for spontaneous ignition in case of receiving large coal carriers.

When planning procurement of fuel for a large scale coal-fired thermal power station with the power output of 0.7-1.0 million kW, berth, unloaders and other facilities must be upgraded and the design of boiler should enable burning of various kinds of coal at the sacrifice of a considerable increase in equipment expenses. However, Panama coal fired power station is of a small scale of 75 MW x 2 units with no concrete expansion plan in the future. It is considered realistic and reasonable that the berth has been designed for 10,000 D.W.T. carriers as stated in Chapter 7.

The ocean freight for transportation of coal from South Africa or Australia cost as high as about 50 US$/MT and about 30 US$/MT, respectively, and such procurement plan is unrealistic. A reasonable idea is to procure coal from the coal exporting countries near Panama. Procurement of coal from neighboring countries is the same as having coal stock yards of Telfers island power station close by, contributing much to the stable supply of coal. South African coal and Australian coal generally have high fuel ratio ($\frac{FC}{VM}$), causing an increase in equipment cost of boiler of suitable design. Therefore, it is reasonable to eliminate these kinds of coal from studies in view of quality. The ocean transportation distance for Canadian coal and U.S. West Coast coal is shorter than that for South African coal and Australian coal, but it is not so easy to find out coal which is fitted to the design of boiler.

6.4.1 Coal

As stated above, it is judged reasonable to procure coal from the U.S. and Colombia. The following table shows the actual results of export of U.S. steam coal.

Table 6.4.1 (1)

Destination	Quantity (1,000 S/T)		
	1982	1983	1984
Canada	13,304	9,838	12,438
France	4,785	1,676	645
United Kingdom	203	266	55
Netherland	2,883	1,911	1,975
Denmark	2,749	1,602	614
Belgium/Luxemboug	1,234	703	648
Spain	2,688	1,495	757
Japan	3,402	1,741	825
Italy	3,641	3,086	1,825
F.R. Germany	1,338	704	85
Taiwan	1,719	1,535	2,405
Chile	1	58	-
Romania	147	-	-
Norway	238	40	-
Finland	652	518	-
Ireland	176	138	237
Brazil	-	-	105
Mexco	44	3	16
Korea	158	44	27
Portuguese	148	40	44
Swizerland	-	1	-
Yugoslavia	-	-	61
Hellenic	344	532	315
Sweden	437	492	255
Hong Kong	91	203	-
Peru	27	-	-
Turkey	124	155	244
Pakistan	60	28	-
Others	66	97	240
Total/Average	40,659	26,905	23,816
(M/T Rate)	(36,886)	(24,408)	(21,606)

New Orleans is the port from which the coal most fitted to the design of boiler for Telfers island power station is shipped in the largest quantity. The kinds of coal produced in the said area, generally called "Gulf", are as follows:

Table 6.4.1 (2) Proposed Coal for Panama P/S

Brand	-	Ashland	-	-	Noranda	Drummond
Company name	Peabody	Ashland	Westmoreland	NERCO	Noranda	Drummond
Location of coal name	Kentucky	Extending over West Virginia and Kentucky	West Virginia Kentucky	East Kentucky	Kentucky	Alabama
Loading port	New Orleans	New Orleans	New Orleans	New Orleans	New Orleans	Mobile
Standard of quality						
Moisture (%)	8 Max (A.R.)	10 (A.R.)	9 (A.R.)	11 (A.R.)	10 Max (A.R.)	8.0 (A.R.)
Fixed moisture (%)	2.5 (A.D.)		1.5 (A.D.)			3.0 (A.D.)
Ash (%)	11 - 13 (A.R.)	15 (")	10 (A.R.)	14 (")	14 Max (")	12.0 (")
Volatile (%)	34 (")	32 (")	35 (")	34 (")	32 Min (")	31.0 (")
Fixed carbon (%)	45 - 47 (")		46 (")	48 Max (")		48.0 (")
Calorific value (%)	6,390 (")	6,280 (")	6,666 (")	6,500 (")	6,375 Min (")	6,390 (A.R.)
Sulfur (%)	1 Max (")	1.0 (A.D.)	1 Max (")	1 Max (")	1.0 Max (")	1.0 (")
H.G.I	45 Min	45 - 52	46	47	50	45
Ash fusion Temp. (°C)	1,409 (I.D.)	1,399 (I.D.)	1,397 (I.D.)		1,492 (I.D.)	1,280 (I.D.)
Ash composition analysis (%)						
SiO_2	54 - 56	55.0	54.23		57.64	40.4
Al_2O_3	24 - 33	33.2	28.57		26.23	29.5
Fe_2O_3	6 - 13	4.7	6.49		7.13	13.5
CaO	1 - 3	0.8	2.37		1.59	4.7
MgO	1 - 2	1.3	0.78		1.14	1.5
Na_2O	0.2 - 0.4	0.7	1.15		0.23	0.5
K_2O	1.2 - 2.5	2.2	1.94		2.93	2.1
P_2O_5	0.1 - 0.2	0.2	0.40		0.28	0.4
SO_3	0.5 - 1.5	0.4	0.72		1.09	4.9
TiO_2	1.0 - 1.5	0.7	1.82		0.90	1.3
Remarks	Blend coal Reabody Inc. Production - 64.5 million tons ('84) No.1 in the U.S.A. Sales - 94% of production is for domestic electric power	O/C Total production of mine lot '81 - 4.74 mil. tons '82 - 4.60 mil. tons	Bland coal Westmoreland Inc. Production - 12.51 mil. tons ('84) No.17 in the USA Sales - 17.51 mil. tons ('84) including exports of 3.0 mil. tons. (The difference with own production is purchased coal)	Blend coal NERCO Production - 16.34 mil. tons ('84) No. 10 in the USA	O/C (Mountain Top Removal) Mine production '81 - 0.61 mil. tons '82 - about 0.3 mil. tons	O/C Drummond Inc. Production - 1.22 mil.tons ('82) Sales - 1.23 mil.tons ('82) including exports of about 0.3 mil. tons.

Table 6.4.1 (3) Average Coal Quality

Cerrejon Coal-Total North Block Area
Initial 5 Years of Mining

TYPE: High Volatile B. Bituminous

Proximate Analysis

	"As Received" (2)	Dry	Dry Ash Free
% Moisture	9.0	-	-
% Ash	9.6	10.5	-
% Volatile	33.2	36.5	40.8
% Fixed Carbon	48.2	53.0	59.2
	100.0	100.0	100.0
% Sulphur	0.7	0.8	
Calorific Value		(gross)	
MJ/kg	27.50	30.22	33.77
kcal/kg	6560	7210	8055
BTU/lb	11810	12980	14500
		(net)	
MJ/kg	26.30	29.21	32.64
kcal/kg	6280	6970	7800
BTU/lb	11300	12550	14020

Fusion Temperatures of Ash

	Reducing °F	Reducing °C	Oxidizing °F	Oxidizing °C
Initial Deformation	2270	1240	2370	1300
Softening (H=W)	2410	1320	2520	1380
Softening (H=1/2W)	2480	1360	2570	1410
Fluid	2590	1420	2610	1430

Other Qualities

Hardgrove Grindability Index	48	
Equilibrated Moisture, weight %	8.0	
Air Dried Moisture (approx.)	4.0	
Base Acid Ratio	0.18	
Free Swelling Index	3.0	
T250	2800°F	1540°C

Ultimate Analysis

	"As Received"	Dry
% Moisture	9.0	-
% Carbon	66.5	73.1
% Hydrogen	4.5	4.9
% Nitrogen	1.2	1.3
% Chlorine	0.07	0.08
% Sulphur	0.7	0.8
% Ash	9.6	10.5
% Oxygen (diff)	8.43	9.32
	100.00	100.00

Mineral Analysis of Ash
(% Weight Ignited Basis)

Silica, SiO_2	61.6
Alumina, Al_2O_3	19.5
Titania, TiO_2	0.9
Ferric Oxide, Fe_2O_3	8.3
Lime, CaO	2.2
Magnesia, MgO	1.8
Potassium Oxide, K_2O	2.1
Sodium Oxide, Na_2O	0.9
Sulphur Trioxide, SO_3	2.1
Phos Pentoxide, P_2O_5	0.3
Undetermined	0.3
	100.0

Note: 1) Analyses by ASTM Standards
2) As Received Basis" as defined in ASTM D-3180

Colombia is an emerging export nation, starting export in 1985 and increasing exports by 3 million t/y. Colombia is a neighboring country of Panama, and procurement from said country is most desirable. Explanation on the nation's Cerrejon Project will be omitted. The nation ash another development project called LA Loma, which plans to export 3 million t/y in 1988 and 6 million t/y thereafter. The property of Cerrejon coal is indicated in 6.4.1 (3).

The estimated C&F prices of U.S. Gulf coal and Colombia Cerrejon coal as of Nov., '86 are assumed as follows.

(Calorie: 6,600 Kcal/kg, Freight for 10,000 D.W.T. carrier, Unit: US$/MT)

	FOB	Freight	C&F
U.S. Gulf coal	31 - 33	9.0 - 10.0	40 - 43
Colombia Cerrejon coal	29 - 31	6.0 - 7.0	35 - 38

L/C opening charge, usance interests and other charges are added to the above price for P/S arrival price. Further, coal yard delivery price additionally includes coal unloading expense. In the procurement of U.S. coal and Colombia coal, economics are not the only factor of judgement as stated in 6.2.1.

The FOB and freight mentioned in the above table are based on the current spot rates, and it is difficult to get these rates on a long-term contract basis. Both the coal and freight markets are currently bearish, and the long-term contract rate of FOB and the COA rate of freight are respectively higher than those on the spot market, but once the market conditions recover, the spot rates of FOB and freight suddenly rise, remarkably exceeding long-term contract rate and COA rate. Some measures become necessary to minimize such effects. Our recommendable procurement mix, considering the points in Chapter 6.2, is stated hereunder:

The U.S.A. occupies a very high place in the world as regards production and exports of coal, playing the role of the swing producer in the world coal market. On the other hand, Colombia is an emerging nation regarding coal production and exports, developing coal projects under fixed plans. In view of the above circumstances, the following combination of coal procurement for Panama is generally most desirable:

- 340,000 t/y ....
  - 170,000 t/y - Colombia (50%) ... The whole quantity on a long-term contract basis
  - 170,000 t/y - U.S.A. (50%) ...
    - 100,000 t/y (30%) - Long-term contract
    - 70,000 t/y (20%) - spot contract

(Remarks)

1. New Orleans functions as coal center.
2. Spot procurement quantity fluctuates according to P/S capacity factor and burning ratio.

The above is an ideal procurement mix, but practically, procurement of U.S. coal at FOB 31-33 US$/t on a long-term contract basis is difficult. Actual measures may be to purchase U.S. coal when its price declines, procuring it on a spot basis in the main. Shifting to the procurement on a long-term contract basis should be considered when the world coking coal market turns upward to the level which is high enough to cover the cost of U.S. coal. An alternative is to shift the share of U.S. coal to Colombia coal, but procurement of approximately 30% of total quantity (about 100,000 t/y) from the U.S.A. should be planned in view of the diversification of supply sources as explained in Chapter 6.2.2.

6.4.2 Transportation

As stated previously, Panama coal fired plant has a 10,000 D.W.T. berth. New Orleans functions as coal center and entry into and departure from said port has no problem for 10,000 D.W.T. vessels. As for Puerto Boliver, the port of shipment of Cerrejon coal, we have inquired of the port authority through a shipping company if the port can accommodate a 10,000 D.W.T. vessel. We could not obtain a definite replay, but were informed that the port can receive some of the vessels of the above class depending on their designs. Therefore, it is necessary to confirm the following items before deciding the scale of berth of Panama coal fired power plant.

(1) Availability of 10,000 D.W.T. bulk carriers

(2) The Colombian government's intention of handling 10,000 D.W.T. vessels at Puerto Boliver

(3) The possibility of transportation from Cerrejon to another port of shipment (availability of another port).

Concerning the transportation ratio between COA and spot, it may be a natural idea to form the transportation plan as follows:

(i) Transportation under COA for the quantity of coal to be procured on a long-term basis

(ii) Transportation using spot chartered carriers for the quantity to be procured on a pot basis.

CHAPTER 7 DESIGN CONCEPTS OF THE COAL-FIRED POWER STATION

CHAPTER 7 DESIGN CONCEPTS OF THE COAL-FIRED POWER STATION

7.1 BASIC DESIGN CONCEPTS

7.1.1 Scale and Unit Size of the Power Station

Using reference materials and information gathered by the JICA, studies were conducted on the Power demand forecast and power development plans. As a result, it was found out that it should be commissioned the coal-fired power station with an installed capacity of 150MW in 1992.

Furthermore, after performing stability tests of the electric power system based on the collected materials and information, we have found out that the appropriate unit size for the power generating facilities is 75MW.

7.1.2 Design Standards

Japanese standards, that are equal to or more stringent than the following internationally recognized standards, shall be applied to materials, design standards and tests to be employed when designing equipment and structures.

Some of these major standards are listed below:

(1) The American Society of Mechanical Engineer (ASME)

(2) The American Society for Testing Materials (ASTM)

(3) American National Standard Institute (ANSI)

(4) International Electrotechnical Commission (IEC)

(5) National Fire Protection Association International (NFPAI)

(6) Japanese Industrial Standard (JIS)

(7) Standard of the Japanese Electrotechnical Commitee (JEC)

(8) The Japan Electric Machine Industry Association Standard (JEM)

(9) Japan Society of Civil Engineers Standards

(10) Technical Standard for Port and Harbour Facility in Japan

(11) Architectural Institute of Japan Standard

7.1.3 Design condition for Equipment and Structure

The design condition for equipment and structures in preliminary design, will be determined based on results of analysis of field investigation, considering the characteristics of Panama.

(1) Atmospheric Temperature

Maximum	35°C
Average	27°C
Minimum	19°C

(2) Electrical Equipment

design temperature	40°C

(3) Wind Velocity

Maximum velocity	20 m/sec
Design velocity	30 m/sec

(4) Humidity

Average	83%
Mechanical, electrical design	90%

(5) Seismic Coefficient 0.1G

(6) Sea Water Temperature

Maximum temperature	31.7°C
Monthly average temperature	27°C to 29°C
Minimum temperature	23.3°C
Condenser cooling water design temp.	29°C

7.1.4 Items to be Especially Considered in Basic Design

(1) Although the thermal power station shall be designed as coal-fired power station, its design shall also incorporate the capability to maintain 50 percent of the total boiler load by heavy oil firing in consideration of various factors such as the start-up of the, power generating plant and the repair of the coal pulverizer.

(2) Since the thermal power plant will be operated as a base-load thermal power station, reliable equipment and systems shall be adopted for its designs.

(3) Coal produced in Cerrejon, Colombia and in the eastern states of the U.S.A. shall be used as main fuel for the coal-fired power station.

As for the specifications of the coal to be used on the design of the coal-fired power station, shall be designed to combustion an adequately broad variety of coal in terms of quality although a 50-50 mixture of Colombian coal and East American coal shall be adopted as design coal.

Heavy oil and light oil shall be used as auxiliary fuel.

(4) As steam conditions, the following two types of conditions are considered: 102 kg/cm^{2}g at 538°C and 127 kg/cm^{2}g at 538°C. Considering ease of operation and maintenance as well as actual past operation experiences in Panama, the following conditions have been planned to be adopted:

Main steam pressure (at the main stop valve inlet)	: 102 kg/cm^{2}g
Main steam temperature (at the main stop valve inlet)	: 538°C

(5) Adoption of the Central Control System

Since the coal-fired power station is designed to combustion coal, a greater variety and larger number of auxiliary equipment must be installed and more complicated control systems are used when compared with a heavy-oil-fired power station. For this reason, the control room shall be installed at the center of the powerhouse. Major monitoring instruments, the control switches of major equipment, etc. shall be installed in this room so that operators can perform various control operations such as equipment startup/stop, emergency, and adjustment operation while checking readings on the monitoring instruments to eliminate operational mistakes.

For this purpose, major control systems shall be equipped with automatic sequence control systems.

However, control panels shall be installed for those equipment that must be started, stopped or tested by operators on site while observing their operating conditions.

(6) Prevention of Slagging, Fouling and Erosion

In the case of coal-fired boilers, slagging, fouling and erosion are caused by burnt ash. The extent of slagging, fouling and erosion varies with the properties of coal used.

a) Slagging

The deposit and accumulation of solid or molten ash particles on furnace wall and other heating surface that are exposed to radiant heat, is referred to as slagging.

Although coal to be adopted for the design of the boiler in this project is considered to be low in slagging characteristics, measures to further reduce slagging shall be devised by studying the furnace volume, the size of burners, gas temperature at the outlet of the furnace, etc.

b) Fouling

The deposit of ash particles on heating surfaces that are not directly exposed to radiant heat is referred to as fouling.

Although the coal to be used features low fouling characteristics, measures to further decrease fouling shall be devised by studying gas temperature at the outlet of heating surfaces, the spacing of tubes, the number of soot blowers, etc.

c) Erosion

Erosion is a phenomenon in which tube surfaces wear out due to the abrasion of ash particles contained in flue gas. Erosion is associated with the properties of ash, the concentration of ash contained in flue gas, the diameter of ash particles, the flow velocity of ash, etc. Measures to reduce erosion shall be devised by studying the flow velocity of flue gas, the spacing of tubes, the design of tube protectors, etc.

(7) Unit Capabilities

a) Condenser cooling water temperature

i) Operation at the continuous rated output (75MW) should be possible at a cooling water temperature of 29°C.

ii) A 5 percent overload operation should be possible at a cooling water temperature of 28°C.

b) The boiler steam temperature control should be possible over a range from 40% to 100% of the boiler rated load.

c) The minimum load of 40 percent boiler rated load should be possible when coal firing.

7.2 OUTLINE OF POWER PLANT FACILITIES

7.2.1 Basic Factor of Power Plant Facilities

Basic Factor of power plant facilities is showed at Table 7.2.1.

Table 7.2.1 Basic Factor of Designing for Generating Facilities

Items	Description
(1) Installed capacity	150.0 MW (75.0 MW x 2)
(2) Annual capacity factor	68.5%
(3) Thermal efficiency	
1) Net thermal efficiency at 100% load	36.0%
2) - ditto - Annual average	35.0%
(4) Station service loss factor	
1) At kW	6.0%
2) At kWh	7.1%
(5) Gross calorific value of coal (Air dried base)	6,600 Kcal/kg
(6) Capacity of coal vessel	10,000 D.W.T.
(7) Capacity of coal storage yard	1.5 month of 2 units 63,600 t (as received base)
(8) Utility	
1) Raw water	500 t/day
2) Electricity for construction (maximum)	500 kVA

7.2.2 Outline of Power Plant Facilities

Outline of civil structures, architectural facilities, mechanical facilities, electric facilities and transmission and substation facilities are shown at Table 7.7.2 (1) - 7.2.2 (5).

Table 7.2.2 (1) Civil Structures

Items	Description
(1) Land Reclamation	
a) Site area	Total 620 x$10^3$$m^2$ Power station 81 x$10^3$$m^2$ Coal yard 26 x$10^3$$m^2$ Ash disposal area 230 x$10^3$$m^2$ Others 283 x$10^3$$m^2$
b) Site formation level	Power station +4.0 m Coal yard +4.0 m
(2) Port Facilities	
10,000 D.W.T. coal unloading jetty	
a) Type	Steel piped pier
b) Dimension	Length 150 m Width 17 m Depth 9 m
Mooring dolphin	
a) Type	Steel piped pier
b) Number	2
(3) Condenser Cooling Water Facilities	
Intake & pump pit	
a) Type	Reinforced concrete structure
b) Dimension	Width 10.0 m Height 9.0 - 11.2 m Length 24.0 m
Intake Pipe line	
a) Type	Embedded steel pipe
b) Dimension	Inner Diameter 1.20 m Length-mean 130 m x 2 lines

Items	Description
Outlet pipe line	
a) Type	Embedded steel pipe
b) Dimension	Inner Diameter 1.20 m
	Length-mean 166 m x 2 lines
Discharge pit	
a) Type	Reinforced concrete structure
b) Dimension	Width 6.40 m
	Height 8.40 m
	Length 13.40 m
Discharge channel	
a) Type	Reinforced concrete structure
b) Dimension	Inner width 2.00 m
	Inner height 2.00 m
	Length 120.0 m x 2 lines
Outlet	
a) Type	Reinforced concrete structure
b) Dimension	Width 6.40 - 12.40 m
	Height 6.00 m
	Length 18.60 m
(4) Coal Storage Yard	
Coal storage yard	
a) Dimension	160 m x 160 m
Coal draw-out culvert	
a) Type	Reinforced concrete structure
(5) Ash Disposal Area	
a) Area	$230 \times 10^3 m^2$
b) Capacity	$1,280 \times 10^3 m^3$ 25 years

Table 7.2.2 (2) Architectural Works

Item	Description
(1) Powerhouse	
(a) Structure	
Foundation	Precast reinforced concrete piles Reinforced concrete footing
Frame	Steel structure
Exterior wall	Corrugated asbestos cement sheet
Roof	"
(b) Size	
Ground floor area	3,020 m^2
Building volume	67,700 m^3
Height	Turbine room 24 m Bunker room 29 m
(c) Appurtenant facilities	Air conditioning and ventilation system Plumbing and sanitary system Extinguishment facilities Fire alarm apparatus Lighting system
(2) Foundation of Equipment	
(a) Foundation of Boiler	Precast reinforced concrete pile Reinforced concrete footing
(b) Foundation of Transformer	Precast reinforced concrete pile Reinforced concrete footing
(c) Foundation of Erectro-static Precipitator	Precast reinforced concrete pile Reinforced concrete footing
(d) Foundation of Induced Draft Fan	Precast reinforced concrete pile Reinforced concrete footing
(3) Administration Building	
(a) Structure	
Foundation	Precast reinforced concrete pile Reinforced concrete footing
Frame	Reinforced concrete construction

Item	Description
(b) Size	
Total area	1,510 m^2
(c) Rooms Accommodated	
1st floor	Chemical laboratory, Dining room, Rest room Air conditioner room, Storage
2nd floor	Office, Conference room, Plant manager room, Locker room, Library
(d) Appurtenant facilities	Air conditioning and ventilation system Plumbing and sanitary system Extinguishment facilities Fire alarm apparatus Lighting system
(4) Other Buildings	
(a) Workshop	Reinforced concrete construction 1 floor 800 m^2
(b) Warehouse	" 1 floor 1,000 m^2
(c) Coal Handling Control Building	" 2 floors 270 m^2
(d) Demineralization House	" 1 floor 250 m^2
(e) Oil Drum and Cylinder Storage	" 1 floor 200 m^2
(f) Worker's Room	Reinforced concrete construction 1 floor 300 m^2
(g) Garage	" 1 floor 150 m^2
(h) Guardhouse	" 1 floor 50 m^2
(5) Stack	
(a) Foundation	Precast reinforced concrete pile
(b) Outer Tube	Reinforced concrete construction
Diameter Top Bottom Height	5 m 8 m 94 m

Item	Description
(c) Inner Flue	Steel structure
Diameter	2 m
Height	95 m
Lining	Acid resistant cementitious coating

Table 7.2.2 (3) Mechanical Equipment

Items	Description
(1) Boiler system	
a) Boiler	
Type	Single drum, natural circulation, outdoor type
Evaporation	
Maximum continuous rating (MCR)	240 t/h
Economical continuous rating (ECR)	228 t/h
Steam pressure	105 kg/cm^{2}g
Steam temperature (SH/RH)	541/541°C
Number	1 set / 1 boiler
b) Economizer	
Type	Horizontal multi-loop type
Number	1 set
c) Air preheater	
Type	Rotally regenerative type
Number	1 set
d) Steam air preheater	
Type	Cu-fined steel pipe type
Number	1 set
e) Soot blower	
Type	Steam blowing type with electric motor drive
Number	
Boiler long retractable	8 sets
short retractable	6 sets
Air preheater Swing	1 set
(2) Draft system	
a) Induced draft fan	
Type	Centrifugal type
Capacity	8,300 m^3/min.
Number	1 set

Items	Description
b) Forced draft fan	
Type	Centrifugal type
Capacity	5,400 m^3/min.
Number	1 set
c) Gas recirculation fan	
Type	Centrifugal type
Capacity	3,300 m^3/min.
Number	1 set
(3) Fuel unloading system	
a) Coal unloader	
Type	Level lufting type
Capacity	250 t/h
Number	2 sets
b) Unloading berth belt conveyor (BC-1)	
Capacity	600 t/h
Number	1 set
c) Heavy oil unloading system	
Type	Loading arm type with transporting piping
Number	1 set
(4) Fuel storage and handling system	
a) Coal yard supply conveyor-1 (BC-2)	
Capacity	600 t/h
Number	1 set / 2 units
b) Coal yard supply conveyor-2 (BC-3)	
Type	Stationary stacker type with tripper
Capacity	600 t/h
Number	1 set / 2 units
c) Bulldozer	
Capacity	35 t
Number	2 sets / 2 units

Items	Description
d) Coal yard draw-out hopper	
Number	3 sets
e) Coal yard draw-out conveyor (BC-4)	
Capacity	250 t/h
Number	1 set / 2 units
f) Powerhouse supply conveyor (BC-5, 6)	
Capacity	250 t/h
Number	2 sets / 2 units
g) Coal bunker supply conveyor (BC-7A, 7B)	
Capacity	250 t/h
Number	1 set
h) Coal bunker	
Type	Steel plate type
Capacity	300 m^3
Number	3 sets
i) Heavy oil tank	
Type	Steel plate, cone roof type
Capacity	2,000 kℓ
Number	1 set / 2 units
j) Diesel oil tank	
Type	Steel plate, cone roof type
Capacity	200 kℓ
Number	1 set / 2 units
(5) Fuel firing system	
a) Coal feeder	
Type	Gravemetric type
Capacity	16 t/h
Number	3 sets
b) Coal pulverizer	
Type	Vertical, balls and race type
Capacity	16 t/h
Number	3 sets

Items	Description
c) Primary air fan	
Type	Centrifugal type
Number	2 sets
d) Sealing air fan	
Type	Turbo-blower type
Number	2 sets
e) Coal burner	
Type	Circular burner type (with flame detector)
Capacity	5.0 t/h
Number	9 sets
f) Heavy oil pump	
Type	Rotally screw type
Capacity	10.6 t/h
Number	2 sets / 2 units
g) Heavy oil heater	
Type	Horizontal u-tube type
Capacity	21.0 t/h
Number	1 set / 2 units
h) Heavy oil burner	
Type	Steam atomizing type
Capacity	2.4 t/h
Number	9 sets
i) Diesel oil pump	
Type	Screw type
Capacity	10 t/h
Number	2 sets / 2 units
j) Diesel oil light-up burner	
Type	Electric oil lighter type (with flame detector)
Number	9 sets
k) Diesel oil start-up burner	
Type	Air atomizing type
Number	2 sets

Items	Description
(6) Ash handling system	
a) Chain conveyor	
Capacity	1.5 t/h
Number	1 set
b) Crinker crusher	
Capacity	2 t/h
Number	1 set
c) Boiler bottom seal water pump	
Capacity	20 t/h
Number	2 sets / 2 units
d) Bottom ash carrying conveyor-1	
Capacity	2 t/h
Number	1 set
e) Bottom ash carrying conveyor-2	
Capacity	5 t/h
Number	1 set / 2 units
f) Fly ash silo	
Type	Steel plate type (with cyclone separator, bag filter and fluidizer
Capacity	100 t
Number	1 set / 2 units
g) Vacuum blower	
Type	Rotally blower type
Number	2 sets / 2 units
h) Dustless unloader	
Capacity	10 t/h
Number	1 set / 2 units
i) Fluidizer blower	
Type	Rotally blower type
Number	2 sets / 2 units

Items	Description
j) Fly ash carrying conveyor	
Capacity	15 t/h
Number	5 sets / 2 units
(7) Turbine system	
a) Turbine	
Type	Tandem compound, impulse type, two-cylinder, single flow, exhaust reheat condensing turbine type
Rated output (at generator end)	75 MW
Steam pressure	102 kg/cm^2g
Steam temperature	
At main stop valve inlet	538°C
At reheat stop valve inlet	538°C
Number of extraction	5 stages
Exhaust vacuum	700 mmHg
Rotating speed	3,600 rpm
b) Governor	
Type	Mechanical hydraulic type
Number	1 set
c) Protective device	
Number	1 set
d) Hydraulic control system	
Number	1 set
e) Lubricating oil system	
Auxiliary oil pump	
Type	Vertical centrifugal type
Number	1 set
Emergency oil pump	
Number	1 set
Main oil tank	
Number	1 set
Oil cooler	
Number	1 set

Items	Description
Vapour extractor Number	 1 set
Oil purifier Number	 1 set
Oil storage tank Number	 1 set / 2 units
f) Turning gear device	
Number	1 set
g) Grand sealing system	
Grand steam seal regulator Number	 1 set
Grand steam condenser Number	 1 set
(8) Condenser cooling water system	
a) Bar screen	
Number	1 set
b) Chlorine injection equipment	
Number	1 set / 2 units
c) Rotary screen	
Number	1 set
d) Screen washing pump	
Number	1 set / 2 units
e) Mesh screen	
Number	1 set
f) Intake crane	
Type Capacity Number	Gantry type 15 t 1 set / 2 units

Items	Description
(9) Condensate system	
a) Condenser	
Type	Double pass, divided water box type, surface condenser
Cooling seawater inlet temperature (Design)	29°C
Cooling seawater quantity	14,200 m^3/h
Cooling seawater discharge temperature (Design)	36°C
Material of condenser tubes	Aluminum brass
Number	1 set
b) Condenser cooling water pump	
Type	Vertical diagonal flow type
Capacity	4 m^3/s
Number	1 set
c) Main air ejector	
Type	Single-stage steam jet type
Number	1 set
d) Condensate pump	
Type	Vertical type
Capacity	100 t/h
Number	2 sets
(10) Boiler feed water	
a) Low pressure feed water heater	
Type	U-tube type
Number	2 sets
b) Deaerator	
Type	Horizontal, tray type
Number	1 set
c) Boiler feed water pump	
Type	Motor driven, horizontal shaft, barrel, multi-stage turbine pump

Items	Description
Capacity	120 t/h
Number	2 sets
d) High pressure feed water heater	
Type	U-tube type
Number	2 sets
e) Make-up water pump	
Type	Centrifugal type
Number	1 set
(11) Miscellaneous facilities	
a) Raw water tank	
Capacity	600 m^3
Number	2 sets / 2 units
b) Raw water pump	
Number	2 sets / 2 units
c) Drinking water head tank	
Capacity	5 t
Number	1 set
d) Miscellaneous water head tank	
Number	1 set / 2 units
e) Auxiliary cooling water cooler	
Type	
Inner of tube	Seawater
Outer of tube	Demineralized water
Capacity	600 t/h
Number	2 sets / 2 units
f) Cooling water pump	
Type	Vertical, volute type
Capacity	600 t/h
Number	2 sets / 2 units

Items	Description
g) Demineralization plant	
Type	2 bed 3 tower type
Number	1 set / 2 units
h) Demineralized water tank	
Type	Cone roof type
Capacity	600 m^3
Number	2 sets / 2 units
i) Neutralization tank	
Type	Concrete type
Capacity	150 m^3
Number	1 set / 2 units
j) Boiler chemical injection equipment	
Kind of chemicals	Phosphate, ammonia, hydrazine
Number	
k) Fire protection equipment	
Air foam type fire extinguishing equipment	1 set
water type fire extinguisher	1 set
Fire extinguishing pump	1 set / 2 units
l) Powerhouse crane	
Type	Overhead travelling crane
Capacity	40/15 t
Number	1 set / 2 units
m) House service boiler	
Type	Package type
Steam condition	10 kg/cm^2g
Capacity	10 t/h
Fuel	Diesel oil
Number	1 set / 2 units

Items	Description
(12) Environmental protection facilities *)	
a) Electrostatic precipitator	
Type	Dry type electrostatic precipitator
Number	2 units
Treated flue gas capacity	282 x 10^3 Nm^3/h
Inlet temperature	140°C
Outlet dust concentration	0.1 g/Nm^3 or less
Dust removal efficiency	99.25% or more
Number of section	4 sections/unit
b) Waste water treatment	
Type	Sedimentation, filter, neutralization method
Number	1 unit
Treatment capacity	210 m^3/day
Outlet water quality	PH 5 - 9 Suspended solid (SS) 200 mg/ℓ or less Oil 5 mg/ℓ or less
c) Coal yard water treatment	
Type	Gravity sedimentation method
Number	1 unit
Treatment capacity	140 m^3/day
d) Waste water treatment for ash deposit area	
Type	Gravity sedimentation method
Number	1 unit
Treatment capaicty	800 m^3/day

*) For the environmental protection measurement for coal fired thermal power station, and only the installation of each environmental equipment (i.e. ESP, sound proofing wall, etc.), but also the consideration of the basic design and layout of power station's major equipment including boiler, turbine and so on must be taking into account upon the economical reason.

Following table (supplement table) shows the measurement list of environmental protection measurement of this power station devided into each item.

Table 7.2.2 (4) Electric Facilities

Items	Description
(1) Generator	
a) Type	Indoor type, horizontal shaft, 3 phase, totally enclosed, hidrogen-cooled turbine generator
b) Rating	
Generator output Voltage Current Power factor Short circuit ratio	75,000 kW, 88,250 MVA 13,800 V 3,692 A 85% 0.58 (Minimum)
c) Exciter	Thyristor direct excite type with AVR
d) Number	2 units
(2) Main transformer	
a) Type	Outdoor type, 3 phase, oil circulating, air-cooled transformer
b) Rating	
Capacity Voltage	85,600 kVA 13.8/230 kV
c) Connection method	Y-Δ connection, neutral point direct earthing
d) Number	2 units
(3) House transformer	
a) Type	Outdoor type, 3 phase, oil circulating self-cooled transformer
b) Rating	
Capacity Voltage	7,500 kVA 13.8/4.16 kV
c) Connection method	Δ-Δ connection

Items	Description
d) Number	2 units
(4) Starting transformer	
a) Type	Outdoor type, 3 phase, oil circulating air-cooled transformer
b) Rating	
Capacity Voltage	7,500 kVA 230/4.16 kV
c) Connection method	Y-Δ connection, neutral point direct earthing
d) Number	1 unit
(5) Switchyard	
a) Method	Outdoor double bus bar method
b) Circuit breaker	
Type	Porcelain-clad type, air or vacuum type circuit breaker
Rating	242 KV, 1,200 A 31.5 kV (Interrupting current)
Number	6 units
c) Disconnecting switch	
Type	Porcelain-clad type single or double breaking switch
Rating Number	242 kVA, 1,200 A 14 units
d) Others	° Steel structure ° Bus bar ° Instrument transformer ° Instrument current transformer ° Arrester ° Compressor
(6) 4 kV house switchgear	
a) Cubicle type	Indoor, single bus, enclose type power board

Items	Description
b) Circuit breaker	
Type	Vacuum type circuit breaker
Rating	4.76 kV 1,200 A 20 kA (Interrupting current)
c) Number of group	4 groups
(7) 210 V Power center	
a) Cubicle type	Indoor, single bus, enclosed type power board
b) Circuit breaker	
Type	Air blast circuit breaker
Rating	600 V 1,200 A 20 kA (Interrupting current)
c) Number of group	3 groups
(8) 210 V Control center	
a) Cubicle type	Indoor, single bus, enclosed type power board
b) Circuit breaker	
Type	Magnetic-blast breaker
Rating	600 V
c) Number of group	11 groups
(9) Power center transformer	
a) Type	Indoor, 3 phase, dry type
b) Rating	
Capacity	1,500 kVA
Voltage	4,160/208 V
c) Connection method	Δ-Δ connection
d) Number	3 units
(10) Emergency power source	
a) Type	Diesel-engine generator
b) Rating	

Items	Description
Output Voltage Current Power factor	250 kW, 315 kVA 208 V 875 A 80%
c) Fuel	Light oil
d) Number	1 unit
(11) Control and instrumentation	
a) Boiler, Turbine, Generator control board	
Type	Enclosed, selfstanding bench type board
Kind of automatic control	° Automatic start up and shut down control equipment ° Automatic boiler control equipment (ABC) - Boiler master control - Fuel flow control - Combustion air flow control - Furnace pressure control ° Feed water control equipment (FWC) - Drum water level control - Deairator water level control ° Steam temperature control - Superheater steam temperature control - Reheater steam temperature control ° Automatic load regulator ° Turbine automatic starting speed control ° Generator automatic synchronizer ° Other local control systems ° Operation supervisory and alarm announciator systems

Items	Description
Number	2 sets
b) Electronic computer	
Type	Digital type computer
Memory method	Magnetic disk method
Number	2 sets
c) Auxiliary operation board	
Type	Enclosed, selfstanding type
Number	2 sets
d) Auxiliary relay board	
Type	Enclosed, self standing type
Number	2 sets
e) Coal unloading and handling control board	
Type	Enclosed, self standing bench type
Number	1 set
f) Ash treatment control board	Enclosed, self standing bench type
Number	1 set
g) Water treatment control board	
Type	Enclosed, selfstanding type
Number	1 set
h) Generator hydrozen hermetically-sealed system control board	
Type	Enclosed, selfstanding type
Number	1 set
i) Supervisory television	
Type	Industrial color television
Purpose, Number	for drum level 2 sets for furnace 2 sets for stack 1 set

Items	Description
(12) Miscellaneous equipment a) DC power source b) Compressor for control air c) House lighting system d) Paging system e) Private telephone system f) Private telecommunication system for coal vessel	

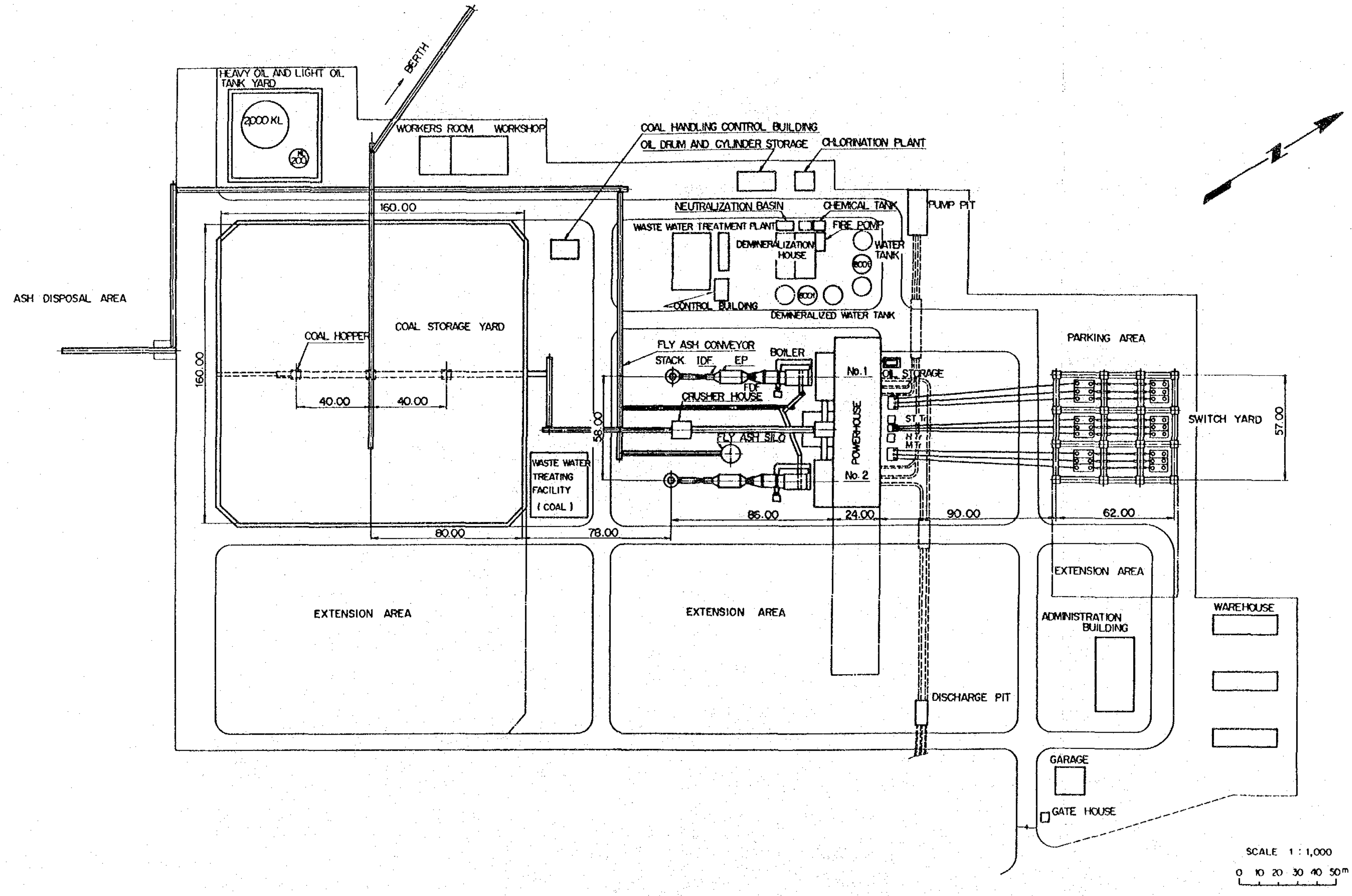
Table 7.2.2 (5) Transmission Line and Substation Facilities

Item	Description
(1) Transmission Facilities	
Section	Telfers island - Panama II S/S
Length	72 km
Voltage	230 kV
Electrical system	3 phase 3 line, 60 Hz
Conductor	ACAR 750 MCM
Overhead ground-wire	7 x No.8 AWG, 2 line
Insulator	250 mm standard disc type suspension insulator 14-unit strings
Supporting structure	2 circuits, vertical arrangement angle steel tower
(2) Substation Facilities	
a) Circuit breaker	
Type	Gas circuit breaker
Rate	242 kV, 1600 A, 31.5 kA
Quantity	9
b) Disconnecting switch	
Type	Insulator type, horizontal one or two breaking disconnecting switch
Rate	242 kV, 1200 A
Quantity	24
c) Protection equipment for transmission line	
230 kV transmission line protection equipment	2 circuits
Power line carrier directional comparison system with single phase reclosing	
d) Other facilities	
Potential device	
Current transformer	
Lighting arrester	

Item				
(3) Telecommunication Facilities				
	Specification	Central Dispatching Office	Panama II S/S	Telfers island
Power line carrier equipment	4ch Type, 20W	2 sets	3 sets	1 set
Power line carrier relay equipment	Earth return coupling system		2 sets	2 sets

Item	Description
Power line carrier equipment	4 ch par 1
Dispatching and maintenance telephone circuit	1 ch
TM circuit of CDT system	1 ch
Data circuit	2 ch

Fig. 7.2.2 Detailed Plant Layout



7.3 STUDY OF POWER GENERATING FACILITIES

7.3.1 Basic Specifications of the Power Station

(1) Annual Power Factor of Power Station, Generating-end Thermal Efficiency and Station Service Power Ratio

The annual power factor, the generating-end yearly average , average thermal efficiency and station service power ratio of the power-generating facilities are to be determined as follows:

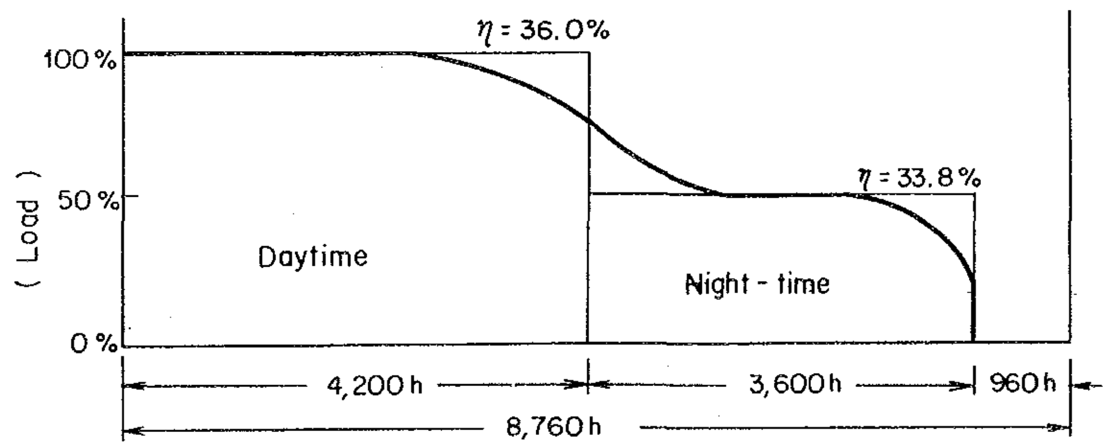
a) Annual power factor of the power-generating facilities

The annual power factor can be calculated using the following equation:

$$F_C = \frac{P}{P_G \times H_y}$$

F_C :	Annual power factor of power generation facilities	(%)
P_G :	Installed capacity of the power station	75 (MW)
Hy :	Number of yearly hours	8,760 (h)
P :	Yearly generation	(MWh)

Fig. 7.3.1 (1) Duration Curve



From the duration curve, it is understood that the number of hours during which the facilities operate at 100%-load capacity and 50%-load capacity is 4,200 hours and 3,600 hours, respectively.

And the number of shutdown hours are:

$Hs = hs + ht$

Hs : Number of shutdown hours (h)

hs : Number of scheduled shutdown hours
= 24 h x 30 days = 720 h

ht : Number of accidental shutdown hours
= (Hs - hs) x 0.03 = 240 h

The annual power factor of power generating facilities can, therefore be obtained as follows:

$$Fc = \frac{(75MW \times 4,200\ h) + (37.5MW \times 3,600\ h)}{75MW \times 8,760\ h} \times 100$$

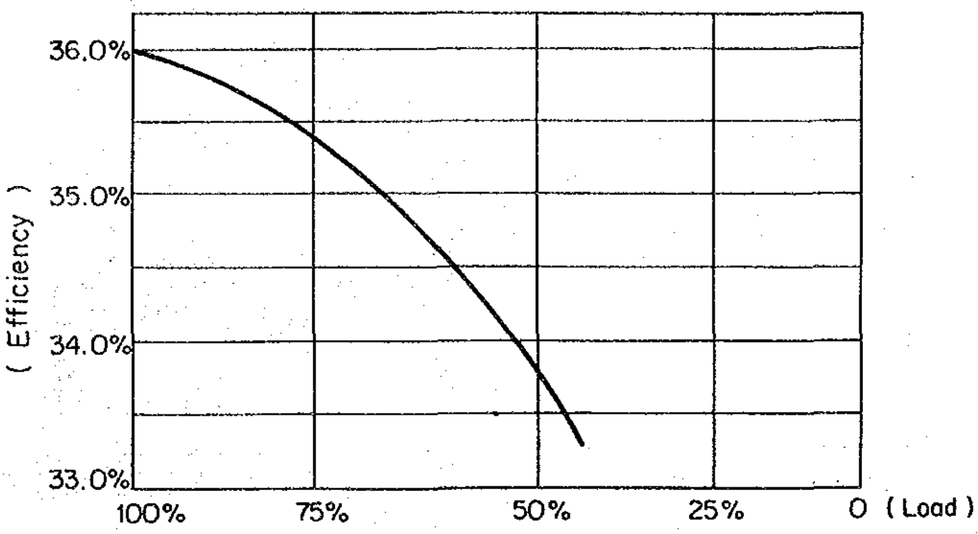
$$= \frac{450,000\ MWh}{657,000\ MWh} \times 100$$

$$= 68.5$$

b) Generating-end Yearly Average Thermal Efficiency

Partial load efficiency curve of 75MW coal-fired power plant is shown as follows:

Fig. 7.3.1 (2) Partial Load Efficiency curve



The generating-end yearly average thermal efficiency is obtained using the equation as follows:

$$\eta_G = \frac{(\eta_{100} \times hd) + (\eta_{50} \times hn)}{Hyo} \times 100$$

η_G	: Generating-end yearly average thermal efficiency	(%)
η_{100}	: Generating-end efficiency at 100% load	36 (%)
hd	: Number of operating hours at daytime	4,200 (h)
η_{50}	: Generating-end efficiency at 50% load	33.8 (%)
hn	: Number of operating hours at nighttime	3,600 (h)
Hyo	: Number of yearly operation hours	7,800 (h)

$$\eta_G = \frac{(0.36 \times 4{,}200\ h) + (0.338 \times 3{,}600\ h)}{7{,}800\ h} \times 100$$

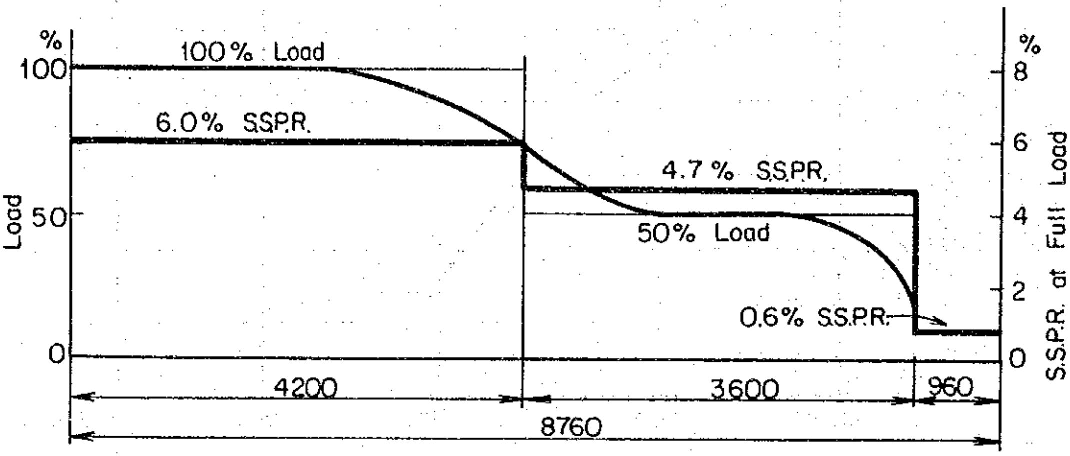
$$= \frac{2{,}728{,}800}{7{,}800\ h}$$

$$= 34.98\%$$

$$= 35.0\%$$

c) Station Service Power Ratio

Fig. 7.3.1 (3) Duration curve
(Include Station Service Power Ratio)



S.S.P.R : Station Service Power Ratio

Station service power ratio yearly average is calculated using the following equation:

$$R_H = \frac{(Rd \times hd) + (Rn \times hn) + (Rs + hs)}{Hy \times Fc}$$

R_H :	Station service power ratio	(%)
Rd :	Station service power ratio at daytime	6.0 (%)
hd :	Number of operating hours in daytime	4,200 (h)
Rn :	Station service power ratio at nighttime	4.7 (%)
hn :	Number of operating hours in nighttime	3,600 (h)
Rs :	Station service power ratio during power generating plant is out of operation	0.6 (%)
hs :	Number of shutdown hours	960 (h)
Hy :	Number of yearly hours	8,760 (h)
Fc :	Annual power factor of power station	68.5 (%)

$$R_H = \frac{(0.06 \times 4{,}200\ h) + (0.047 \times 3{,}600\ h) + (0.006 \times 960\ h)}{8{,}760\ h \times 0.685} \times 100$$

$$= 7.1\%$$

(2) Capacity of Coal Vessel

For the power plant, it is planned to use imported coal from Colombia and the eastern states of the United States.

Ocean freight (transportation costs) for the coal varies with the size of vessels to be employed. In other words, the larger vessels are, the less expensive per-ton coal transportation costs become.

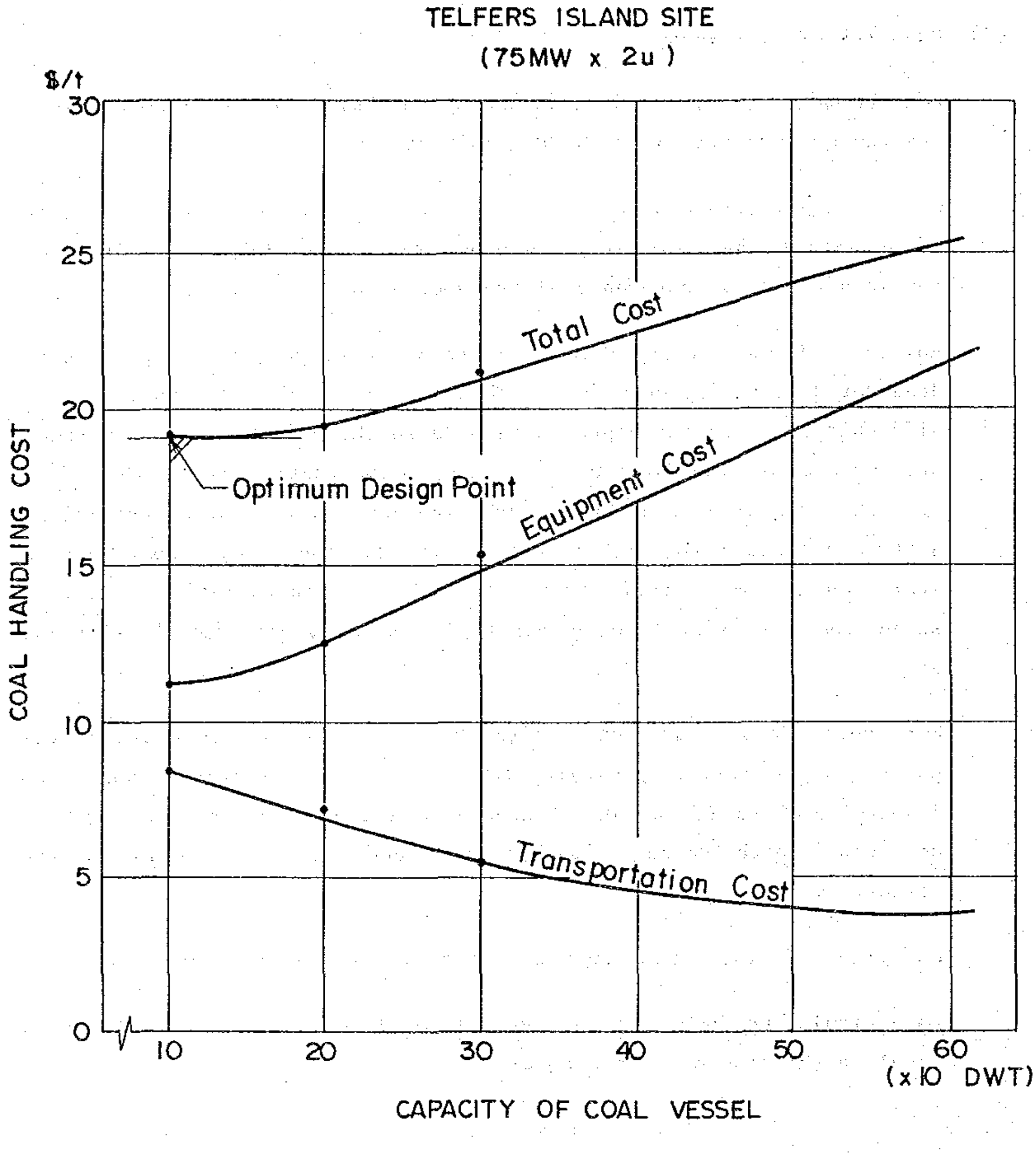
However, if excessively large vessels are employed, the cost of coal does not necessarily come down. This is because they not only make it difficult to select an appropriate site in the port for berthing them, but also give rise to increased civil construction costs that stem from the execution of dredging work, the construction of a large-sized jetty and large-scale coal storages. In addition, they also result in increased equipment costs that arise from the installation of large-scale coal unloader, large-capacity land-transportation facilities, etc.

For above reasons, we have studied how the construction costs of the power station change by varying the size of vessels over a range from 10,000 D.W.T to 60,000 D.W.T and conducted comparisons in order to determine which vessel size is most economical in terms of the following.

equation: Freight + Construction costs = Coal handling costs

As a result, we found out that vessels of 10,000 D.W.T are most economical in the case of this project.

Fig 7.3.1 (4) Capacity of Coal Vessel



7.3.2 Layout of the Power Station

The power station is planned to be constructed adjacent to a site owned by Orilla S.A., where its Shipbreaking Factory is planned to be erected, or approximately 1 km southwest of the No. 16 pier of Cristobal Harvour, the site for the power station extends from the northeast to the southwest along the Panama Canal Zone and its facilities are laid out in the following order: the switchyard, the condenser cooling-water waterway, the turbine room, the boiler, the coal storage yard, and the ash disposal area.

The jetty capable of berthing 10,000-D.W.T coal vessels is planned to be constructed approximately 500 meters northwest of the coal storage yard, adjacent to the canal's dredging limit line.

(1) Required Space of the Power Station

The areas required for the construction of the power station are as follows: approximately 81,000 m^2 as a plant area for 2 units, approximately 26,000 m^2 for the coal storage yard, approximately 230,000 m^2 for the ash disposal area, in a combined total area of 337,000 m^2. For information, when the No. 3 and No. 4 units will be added in the future, the total area increases to approximately 620,000 m^2 including spaces for an extension plant area, coal storage yard, and a switchyard.

(2) Switchyard

The switchyard shall be constructed at the northeastern extremity of the power station site.

(3) Water Intake and Discharge

To prevent warm discharged water from entering the water intake, the water intake for taking in condenser cooling water shall be installed at the northern extremity of the power station site, or on the Cristobal Harvour side, and the discharged water outlet shall be installed at the French Canal which is located at the northern extremity of the site.

However, various water-intake equipment such as rotary screens and mesh screens shall be installed at the intake pump pit which is located in close proximity to the powerhouse to facilitate the monitoring and removal of refuse, driftwood, sea weed, etc.

(4) Powerhouse

The powerhouse shall be constructed in the northeastern section of the power station area. A space for future plant expansion shall be planned to be secured on the east side of this section.

Principally, the turbine facilities and the central control room, etc. shall be installed inside the powerhouse and the coal bunker, boiler, dust collector, etc. shall be installed outdoors on the southwestern side of the powerhouse, adjacent to the powerhouse.

(5) Administration Building

The administration building shall be installed midway between the front gate and the powerhouse, or on the southeastern side of the switchyard extension space.

(6) Water Facilities

All water facilities such as water tanks, demineralization house, demineralized tanks, and waste water treatment facility are collectively installed on the western side of the power generating plant.

(7) Coal Handling Control Building

The building shall be constructed in a location which is close to both the coal unloading jetty and the coal storage yard to facilitate the receiving, storage, discharge and ash handling.

(8) Fuel Storage Facilities

a) Coal

Coal shall be unloaded using a coal unloader installed at the coal unloading jetty, and then transported to the coal storage yard by a belt conveyor.

An area of approximately 26,000 m^2 must be acquired for the construction of the coal storage yard with a capacity of 63,000 tons on the assumption that it is necessary to store 45 days' amount of coal consumption.

b) Heavy oil

Heavy oil shall be transported from Panama Refinery using oil tankers, and then stored in the heavy oil tank via the oil unloading facility installed at the coal jetty.

(9) Ash Disposal Area

All of both clinker ash and fly ash shall be humidifying and then transported to the ash disposal area using belt conveyors.

An area of approximately 230,000 m^2 must be acquired for the No. 1 and No. 2 units on the southwestern side of the heavy oil-tank yard and the coal storage yard.

7.3.3 Powerhouse Layout

(1) The turbines, generators and of their equipment shall be of indoor types while the bunkers, pulverizers, and burners shall be of semi-outdoor types. The boilers shall be of an outdoor type.

(2) The turbines and generators shall be installed in a T-type positional relationship with respect to the boiler.

(3) The coal bunker shall be of a front bunker type.

(4) The layout of each individual equipment should be decided with easy assembling, disassembling and transportation in mind.

(5) For the carrying-in and taking-out of large-sized equipment, an entrance common to both No. 1 and No. 2 units shall be constructed on the side of the No. 1 unit. In addition, the overhead traveling crane shall be installed in such a way that it can be travelled for both No. 1 and No. 2 units.

(6) The steam condenser shall be installed at a right angle to the shaft of the turbine. In addition, a tube-drawing door shall be installed in the wall of the powerhouse so that its condenser tube can be easily

extracted and replaced with a new one in the event of a leak in the tube.

(7) The deaerator shall be installed on the fifth floor in order to secure a sufficient net effective suction head for the boiler feed water pump.

(8) Instrument, general-service compressors, and emergency diesel engines, as well as boiler feed-water pumps shall be installed inside the main building in order to reduce noise.

(9) Other equipment to be installed on the first floor includes condensate pumps, cooling water pumps, cooling water coolers, turbine oil tanks, etc.

(10) Major equipment to be installed on the second floor includes air ejectors, gland steam condensers, high-pressure feed-water heaters, low-pressure feed-water heaters, switchgears, batteries, etc.

(11) On the third floor, the steam turbines, generators, control room, relay room, locker rooms, shower room, etc. shall be installed.

(12) A turbine oil storage tank, main transformers, station-service transformers and starting transformers shall be installed on the northern outer wall of the powerhouse.

(13) Since the bunker shall be of a front bunker type, a set of pulverized coal firing equipment consisting of the coal pulverizer, coal feeder, coal blowers, etc. can be installed in close proximity to the boiler. This equipment layout minimizes the need for fuel transport pipes and thereby contributes to decreased equipment and facility-installation costs.

(14) A roof shall be installed above the bunker chamber in order to prevent the bunker and coal feeding pipes from getting clogged up by excessively moist coal.

7.3.4 Civil and Architectural Structures

(1) Condenser Cooling Water Facilities

a) Location

It has been so decided that the intake will be located in the west of the power plant in such a position that is the nearest to the power plant. It has been so dicided that the outlet will be located on the French Canal in the east of the power plant so that it may be free from the influence of recirculation of discharged warm cooling water. It is expected that the above location will be useful for water quality improvement in the French Canal which is a closed water area.

b) Intake and pump pit

The intake has been designed in a surface water taking system under the following conditions:

1) The intake fronts Limon Bay where waves are comparatively moderate.

2) There is no possibility of recirculation of discharged warm cooling water. (Refer to Appendix II).

The intake, screen pit and pump pit have been designed to form a single system from the viewpoint of power plant layout, elevation of the site, space for cooling water system and economics, in a reinforced concrete structure of 10.0 m (W) x 9.00 - 11.20 m (H) x 24.00 m (L) with foundation supported by concrete pile, as shown in Fig. 7.3.4(1) - 7.3.4(2).

- The front of the intake is a coast with moderate slope and therefore it is necessary to excavate the front and to dredge an open waterway for ensuring the stabilized supply of cooling water ($Q = 8.0\ m^3/sec$) which is necessary for this Project. It has been so decided that the opening of the intake will be equipped with a wing wall of steel pile type sheet pile for protecting the slope of the open waterway.

- The front wall of the opening has been designed to minimize the waves invading inside from the opening, by lowering the wall height about 1 m below the low water level.

- The screen pit has been provided with 2 berth screens with rake and rotary screens, as well as water drains for drying the screen pit in reparing the screens.

  Flow rate of water in approaching the screen has been designed to 0.3 m/sec, taking into consideration the filtering capacity of the screen.

- The hydrodynamic calculation with respect to the pit and pump pit considers a 10 cm buildup of marine growth.

c) Condenser cooling water pipes

- Condenser cooling water pipes have been designed as underground pipes on a reinforced concrete foundation supported by concrete pile at a 6.0 m interval, with steel pipes across the road strengthened by reinforced concrete.

- The thickness of condenser cooling water pipe has been decided, taking into investigation such factors as buckling, tensile stress due to inside water pressure, maximum deflection, maximum stress due to external load, etc.

- The hydro-dynamic calculation considers no marine growth buildup inside the pipe.

- Lining of steel pipe is tar-epoxy coating on interior surface and coal tar and enamel glass cloth (double) on exterior surfaces.

d) Discharge channel and outlet

- The discharge channel which is a waterway from the discharge pit to the French Canal through the discharge channel and outlet has been designed as a reinforced concrete structure.

- As for the construction, the discharge channel has been designed to form a reinforced concrete culvert which is advantageous in economics over the underground pipe system, with foundations supported by concrete pile.

The water flow in the discharge channel has been designed as an open waterway flow from hydrodynamic consideration.

The hydrodynamic calculation considers no marine growth buildup.

e) Temporary coffering

The temporary coffering which comprises such supports as steel sheet piles, wales, struts, intermediate stays, etc. shall be constructed in the intake, discharge pit, discharge channel and outlet where excavated bottom is so deep that underground water must be drained when constructing the above-cited structures.

In the case of the condenser cooling water pipeline which will be installed in an open cut, the ground water level shall be lowered by constructing well points for stabilizing the excavated slope face.

f) Protection against corrosion

Steel pipe type sheet piles in front of intake and sheet piles in front of outlet shall be protected against corrosion in such a way that their heads ± 0.0 m above the sea level are covered with concrete while submerged parts are applied with aluminium alloy anodes against corrosion.

g) Summary of the condenser cooling water facilities

The outlines of the above-cited design are shown in Fig. 7.3.4.(4), (5) and Table 7.3.4.(1).

Table 7.3.4 (1) Summary of the Condenser Cooling Water Facilities

Items	Description
Intake & pump pit	
a) Type	Reinforced concrete structure
b) Dimension	Width 10.0 m Height 9.0 - 11.2 m Length 24.0 m
Intake pipe line	
a) Type	Embedded steed pipe
b) Dimension	Inner Diameter 1.20 m Length-mean 130 m x 2 lines
Output pipe line	
a) Type	Embedded steel pipe
b) Dimension	Length 166 m x 2 lines
Discharge pit	
a) Type	Reinforced concrete structure
b) Dimension	Width 6.40 m Height 8.40 m Length 13.40 m
Discharge channel	
a) Type	Reinforced concrete structure
b) Dimension	Inner width 2.00 m Inner height 2.00 m Length 120 m x 2 lines
Outlet	
a) Type	Reinforced concrete structure
b) Dimension	Width 6.40 - 12.40 m Height 6.00 m Length 18.60 m

(2) Coal Unloading Jetty

a) Jetty location and direction

Following conditions are taken into consideration for deciding the jetty location plan :

i) Availability of a straight course of ample length from the harbor entrance to the jetty.

ii) Feasibility of securing a water area with ample depth for operating a 10,000 D.W.T. coal vessel in the front of the jetty.

iii) The location should be such that permits a free operation of the Panama Canal.

iv) The location should be the nearest to the power plant.

The location which satisfies the above requirements is as shown in Fig. 1.1 near the border of the dregded area (-12 m - -14 m) in Cristobal Harbour, with the jetty direction parallel to the dreding limit line.

This location represents a water area in the recesses of the Limon Bay with the harbour entrance protected by the west and east breakwater from the open-sea waves behind the quay of Cristobal Harbour.

It is desirable if the jetty direction is parallel to the prevailing wind direction in this territory, viz., north and/or north-west.

The direction is a matter of comparatively little importance, however, since in this territory the wind data indicates a relatively low wind velocity and meanwhile the prevailing wind tends to push coal vessel to the jetty.

b) Geologic conditions

The sea-bottom geology beneath the jetty is a Gatun layer or a bedrock on which lie a very compact Granular Coral layer of about

18 m thickness (N value 50 or more), hard Clay layer of 3 - 8 m thickness (N value 15 - 22) and soft Loam layer of 2 - 4 m thickness, in this order from bottom to top.

c) Design

- The jetty has been designed to berth a 10,000 D.W.T coal vessel and a 1,000 D.W.T oil tanker with a space to permit two coal unloading machines to run and operate and with a capacity to support their load.

  - The length and type of the coal unloading jetty -

  The length and type of the coal unloading jetty have been designed in accordance with the following requirements:

  i) Length of the jetty is required to approximately equal the length of the ship, from the viewpoint of coal ship hatch position, unloader wheel position and dimensions.

  ii) Since the bow and stern ropes serve to prevent the ship from moving either forward or rearward and to retain her in position, it is necessary to run them at the angle upto 30° with respect to the jetty longitudinal direction.

  The above-cited requirements have chosen the type in which a jetty whose length approximately equals that of the ship (150 m) is equipped with two units of dolphin.

- The mooring position of the 1,000 D.W.T oil tanker has been designed in accordance with the following requirements:

  i) The tanker should be moored nearby the coal unloading belt conveyer so that the length of the oil pipe line is shortened.

  ii) Bow and stern ropes should be run at the angle upto 30°.

  iii) The Bollards for the 10,000 D.W.T coal vessel double the mooring post for the tanker.

iv) Fender should be arranged so that it is set on the point of about 1/4 of the ship length.

The above-cited requirements led to the selection of the oil tanker mooring point as shown in Fig. 7.3.4(6), thereby Blocks No. 2 through No. 6 are provided respectively with a fender to the oil tanker.

- Since the 1,000 D.W.T oil tanker has less upperworks than a coal vessel, the jetty fender attaching mark must be marked so that its lower frame is about 1 m lower than normal, and the fender length increased by 1 m.

- Since the belt conveyer connects the jetty with onshore facilities, the personnel for daily inspection can approach to the jetty by walking on the walkway along the belt conveyer. It is, however, necessary to arrange a boat to carry the materials and products between the jetty and the onshore facilities and the crew for boarding and leaving. The boat landing point has been prepared by extending a part of the rear of Block No. 10. The boat landing point on the shore side will use the existing harbour facilities which are not included in the Project.

- Jetty structure -

The jetty structure is required to safely support the superstructures under the surcharge, e.g., 200 dead-weight-tons unloaders and belt-conveyers, etc., without differential settlement.

To satisfy the above-cited structural requirements, the jetty has been designed as a pile-structure jetty with reinforced concrete, cross beam upper structures.

- Selection of pile material -

The steel piles which ensure the construction of long pile at the sea, good installation of piles into rigid bearing strata and high durability of piles have been selected. The selected steel piles are characterized by fllowing factors:

i) High support strength permits the pile installation into rigid bearing strata, promising great bearing force.

ii) High sectional rigidity and resistance against bending moment promise ample lateral resistance.

iii) Ease in pile length adjustment by welding in the case of bearing ground undulations requiring to adjust pile length.

iv) Ease in connecting the pile with upper structure by welding iron reinforcing bars to the top of the pile.

v) Meanwhile steel pipes suffer a demerit, which is corrosion.

Therefore such parts of steel piles that are subjected to the maximum rate of corrosion due to sea-water splash and exposure to the tide should be protected by mortar, while the other parts of the piles under the sea surface protected by applying aluminium alloy anode against corrosion;

- Jetty design -

- Table 7.3.4.(2) shows the coal unloading jetty design conditions and Table 7.3.4.(3) the sequence of design.

- As for the superstructures, taking temperature variations and engineering into consideration, 10-block construction is adopted (each block size : 15 m L x 17 m W). Superstructure beam section has been examined in such a way that section force is computed with respect to unloader beam, crossbeam, stringer and each train of piles so that sectional configurations are determined.

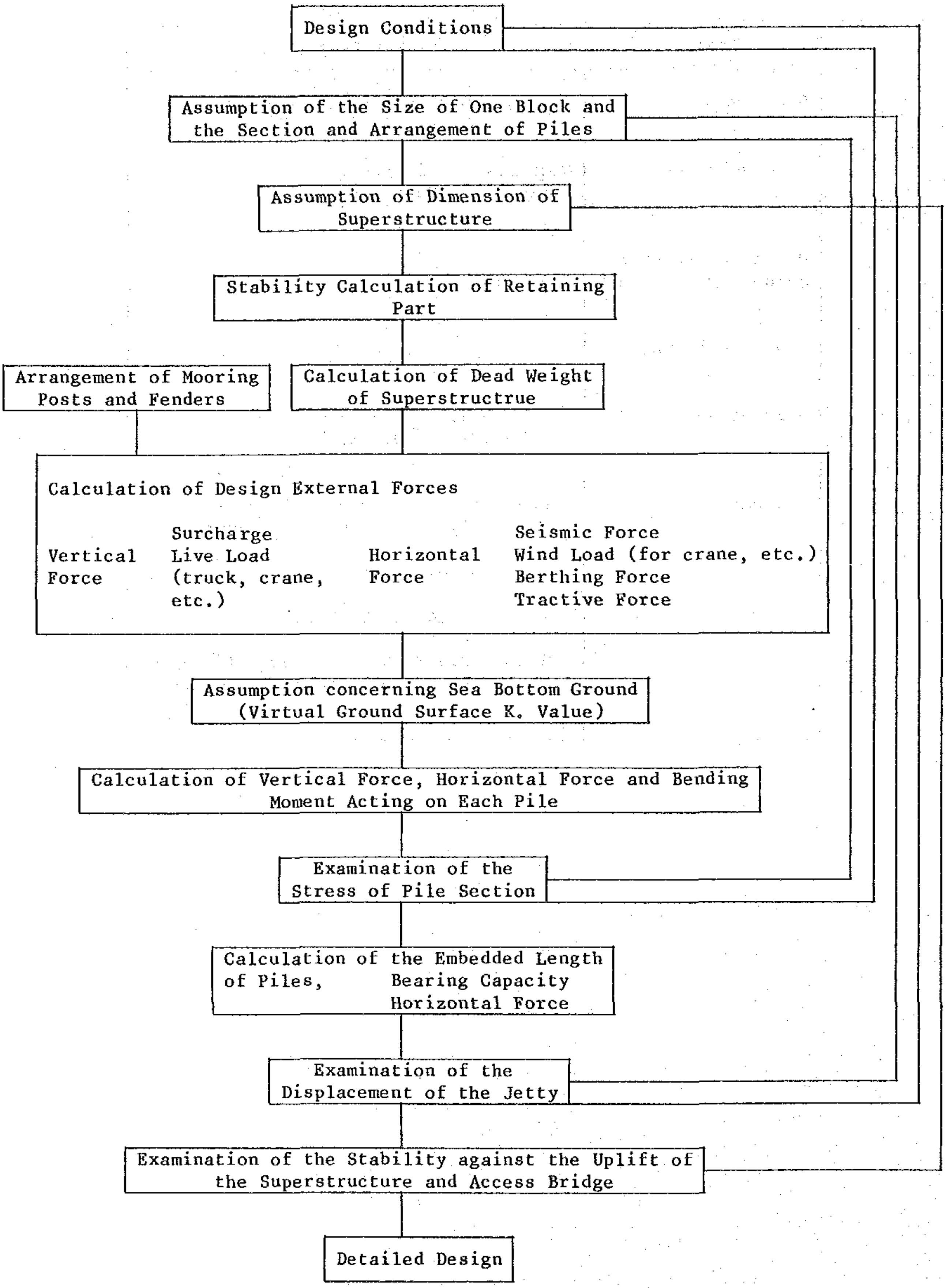
  As for foundation piles, pile diameter and pile material thickness, etc. have been determined on the basis of examination results on crossbeam line.

  It is necessary to drive piles into rigid bearing strata to the prescribed depth of penetration for the sake of stability of upper structures.

Table 7.3.4 (2) Design Condition

Item	Design Condition
Sea level	H.W.L. + 0.34 m, L.W.L. - 0.03 m
Wind velocity	Ordinary 6 m/sec Storm 20 m/sec
Design horizontal seismic coefficient	0.1 g
Depth of berth	9.0 m
Size of ship	10,000 D.W.T. Coal vessel 1,000 D.W.T. Oil tanker
Surcharge	° Coal unloading machine (250 T/H) Dead weight 200 T/unit x 2 units ° Belt conveyer (600 T/H) ° Berthing velocity of ship 10,000 D.W.T. Coal vessel : 15 cm/sec 1,000 D.W.T. Oil tanker : 30 cm/sec

Table 7.3.4 (3) Sequence of Design



While in the jetty territory well compact granular coral strata of N value > 50 provide ample rigidity as the pile bearing strata, they are too hard for normal pile driving procedures to drive a pile to the specified depth of penetration. It is therefore so designed as to drive piles in this area by excavating the ground in the steel pile.

The outline the results of above examinations are shown in Table 7.3.4.(5) and Fig. 7.3.4.(7)-(8).

As for the surcharge which is an element of design conditions, since unloader load may possibly vary with various manufacturers, it will be necessary to do an examination of the detailed design on the basis of load specifications after the manufacturer nomination.

d) Pier 16

About 1 km north from the site, there exists a 1910s-constructed jetty (Pier 16) which is a reinforced concrete structure on concrete piles.

Since the use of this jetty as a coal unloading pier for the power plant will contribute much to economics, the durability study was carried out during the local investigation, chiefly by visual observation. The study has revealed the inadequacy of the use of Pier 16 as the coal unloading pier for the power plant due to the following reasons :

- A great number of cracks has developed on the superstructure concrete beam due to the corrosion of reinforcing steel bars and steel skeletons in the concrete, leading partly to the flake-off of the concrete, with considerable structural deterioration. It is deemed difficult to use Pier 16 in such a condition for coming several decades under heavy loads of unloading machines and other equipment.

(3) Coal Storage Yard and Coal Drawout Culverts

a) Geological conditions

The geology of the ground under the coal storage yard is a Gatun layer or a bedrock on which lie a hard clay layer of about 4 m thickness (N value 7 - 22), very compact Sand with Coral Fragments layer (N value 27 - 82) of about 5 m thickness and Fill layer (N value 2 - 4) of about 7 m thickness in this order from bottom to top.

b) Design

The outlines of the coal storage yard are shown in Fig. 7.3.4(9).

The coal storage yard geologic conditions consist of a soft layer of about 7 m thickness from the ground surface, as cited above. The slide destruction investigation was conducted assuming the coal pile height of 5 m and using the original ground parameters, which has revealed that the slide takes place when the safety factor decreases below the design condition (Table 7.3.4(5)). To cope with the situation, investigation was conducted from the viewpoint of coal storage yard construction duration and economics, which has decided to construct the underground belt conveyer culvert using the sand compaction method while the coal storage yard, sand drain method from the consideration of the three-month pre-loading term.

The sand drain method is one which increases the ground strength by producing the compaction settlement in a brief time under the surcharging soil by constructing sand piles in the soft ground while excavating drains for compaction seepage.

The sand compaction method is one which serves to increase the ground bearing force and to prevent the slide from taking place, by enhancing the whole ground shearing resistance by driving sand into the soft ground by applying either vibration or impact load to form large-diameter, compact sand piles so that they may combine with clay to form a composite ground.

Table 7.3.4 (5) Design Conditions

Items	
Load condition	Coal pile height : H = 5.0 m Coal pile width : 160 m x 160 m Weight per unit measurement : rt = 0.8 t/m^3
Design condition	Safety factor with respect to slide destruction Normal condition : Fs = 1.20 or more Earthquake condition : Fs = 1.00 or more

(4) Land Reclamation

On the basis of P.C.C. topographical map (scale 1/1000) and the result of field investigation, the ground height has been determined to +4.0 m, taking into consideration the earth materials equilibrium between excavation and land-fill in the power plant site. It may be nonetheless necessary to make further investigation by conducting a topographic survey around the site in the detailed design stage, since this Project has chosen the power plant site on the PCC coral pit.

(5) Ash Disposal Area

An onshore ash disposal area has been planned from the consideration of ecological and economic advantages.

An embankment, about 1.5 m Height x 4.0 m Top Width, will be built around the ash disposal area to prevent ash from leaching.

Rainwater in the ash disposal area will be discharged out of the ash disposal area after solid suspensions in the rainwater have been removed in a sedimentation basin.

Fig. 7.3.4 (1) Condenser Cooling Water Intake

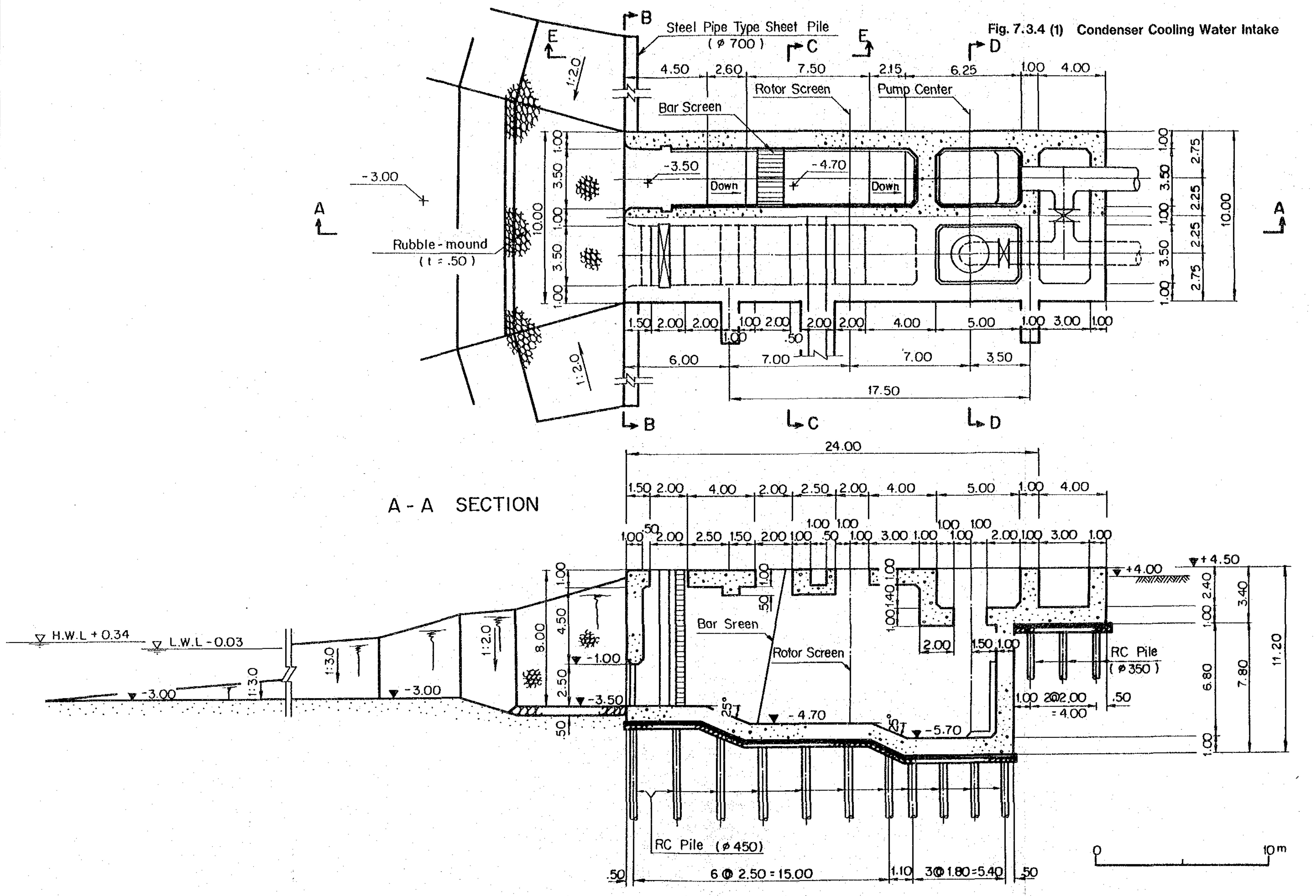


Fig. 7.3.4 (2) Section of C.W. Intake and Pump Pit

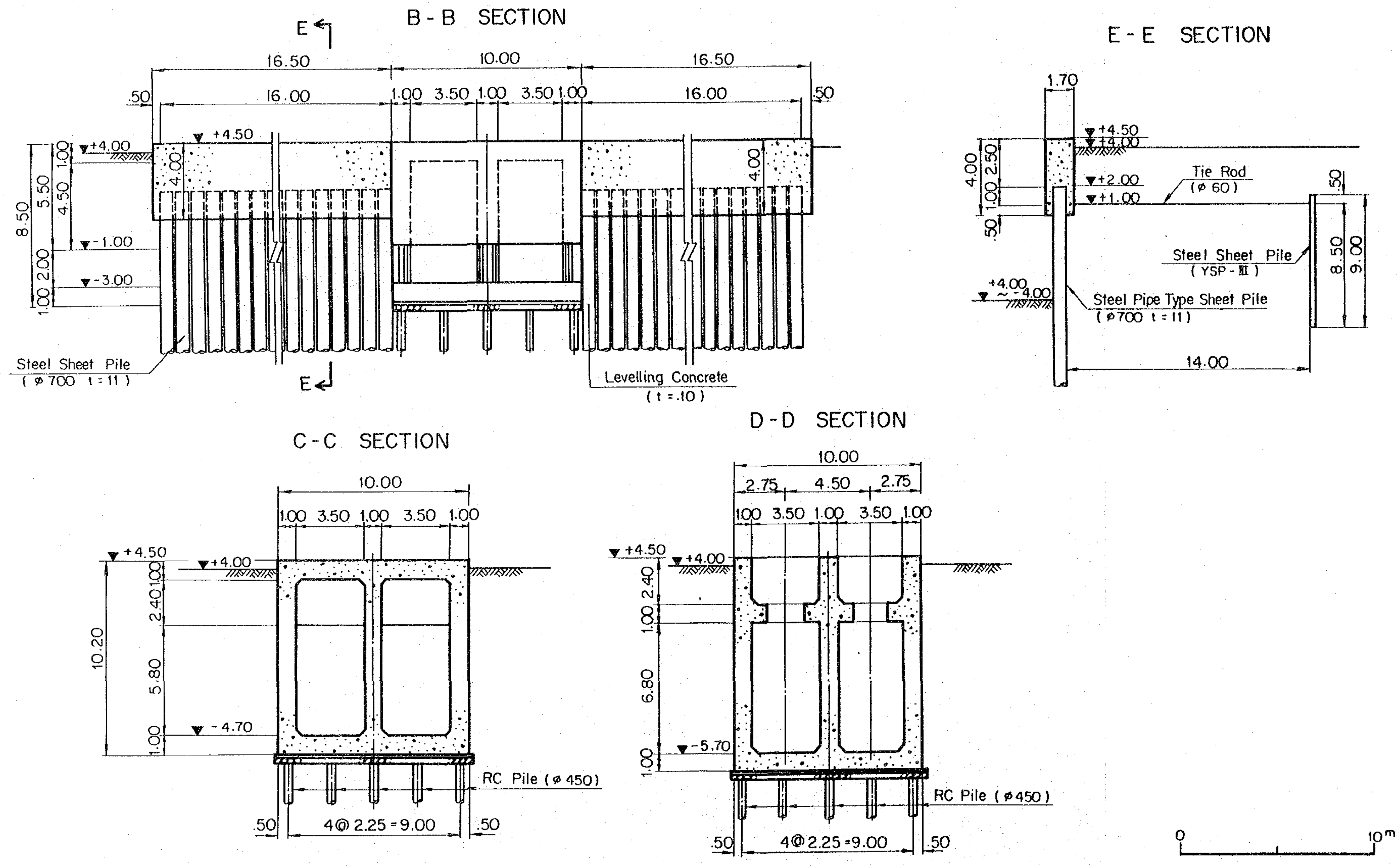


Fig. 7.3.4 (3) C.W. Pipe Layout