REPUBLIC OF PANAMA

INSTITUTO DE RECURSOS HIDRAULICOS Y ELECTRIFICACION

COAL-FIRED POWER PLANT PROJECT
FEASIBILITY REPORT

MARCH, 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of Republic of Panama, the Japanese Government has decided to conduct a feasibility survey on the Coal-Fired Power Plant Project and entrusted the study to the Japan International Cooperation Agency.

JICA sent to Panama a survey team headed by Mr. Masashi MIKUNI, Electric Power Development Co., Ltd., twice in a period from June 16, 1986 to February 15, 1987.

The team had discussion with the officials concerned of the Government of Panama and conducted a field survey. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of Republic of Panama for their close cooperation extended to the team.

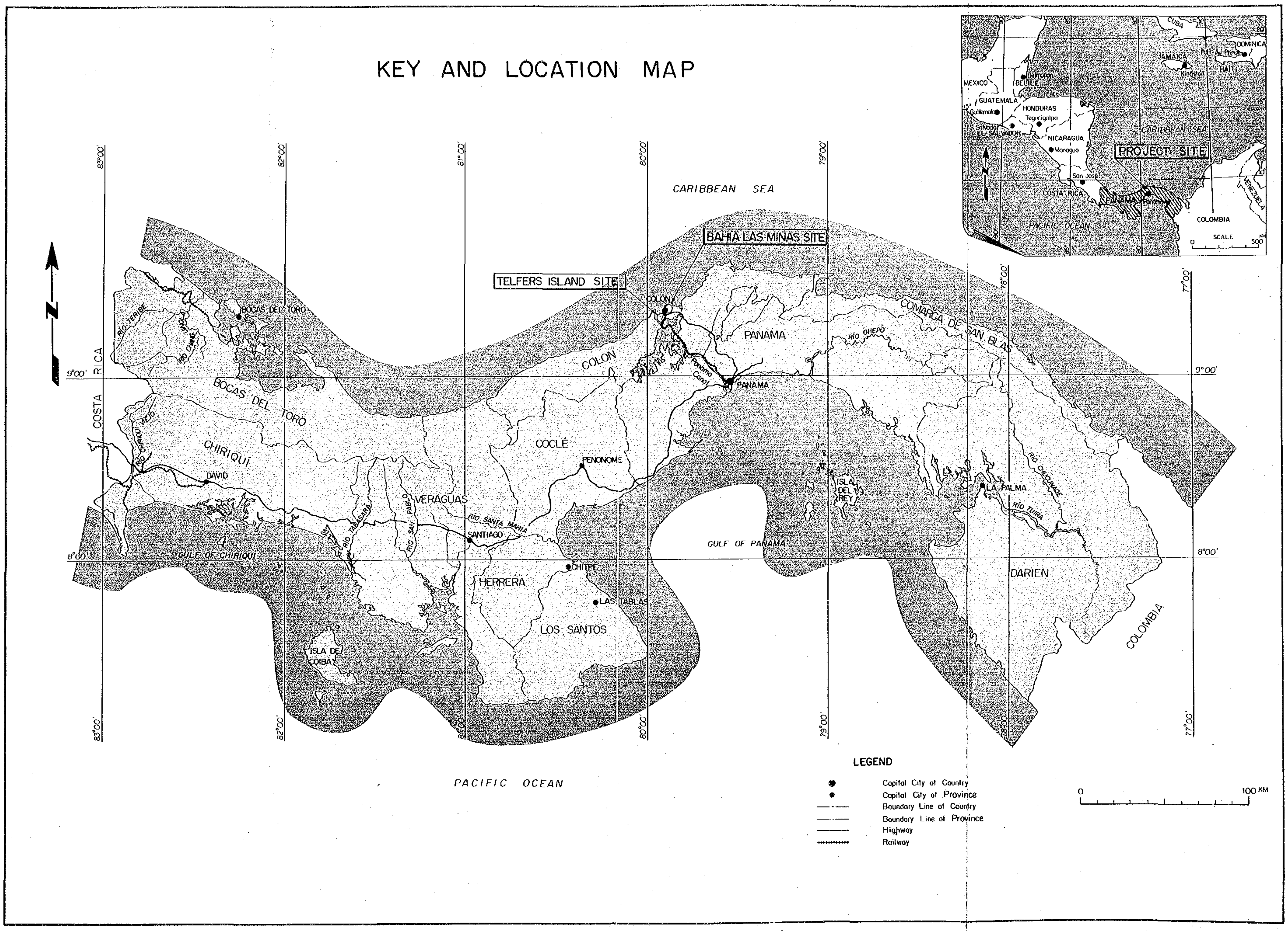
March, 1987

Keisuke Arita

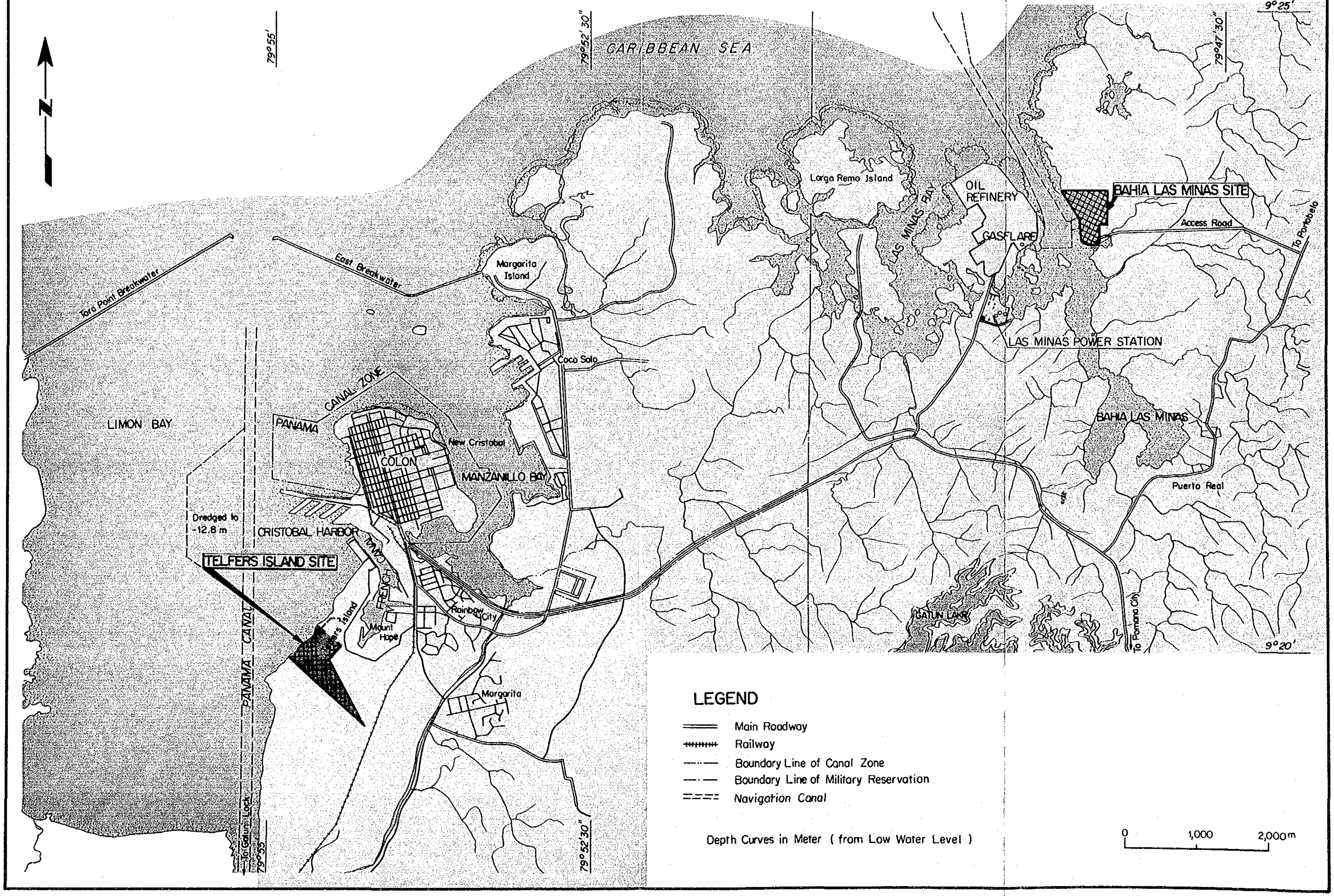
President

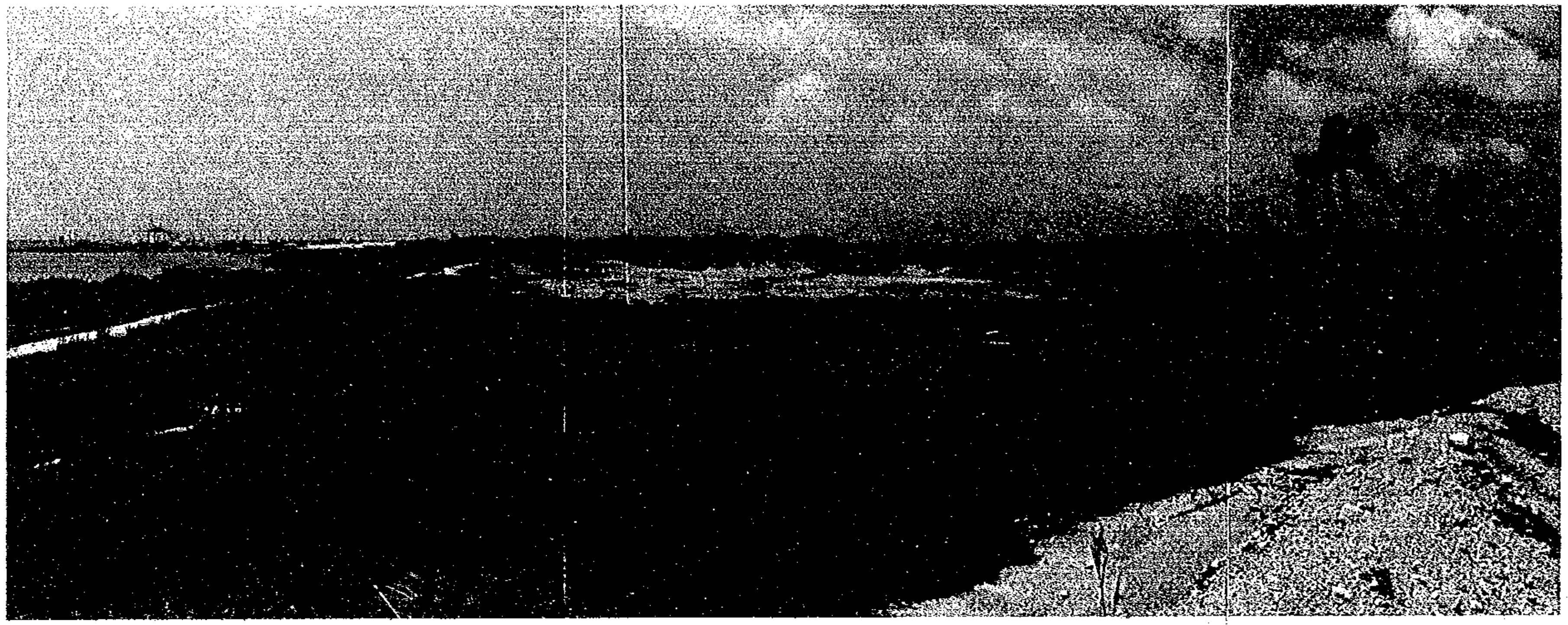
Japan International Cooperation Agency

KEY AND LOCATION MAP

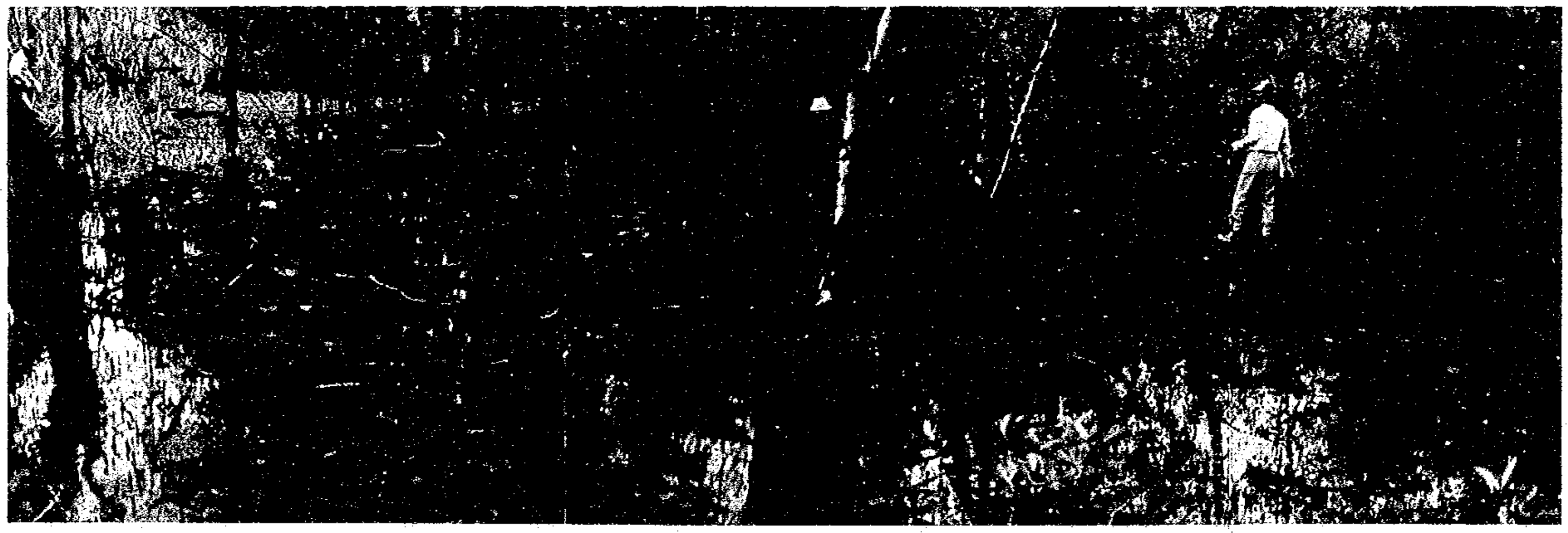


GENERAL MAP OF TELFERS ISLAND SITE AND BAHIA LAS MINAS SITE





TELFERS ISLAND SITE



BAHIA LAS MINAS SITE

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CHAPTER 1 SUMMARY AND RECOMMENDATION

CHAPTER 1 SUMMARY AND RECOMMENDATION

1.1 BACKGROUND AND NECESSITY OF THE PROJECT

Since 1980 Panama's economy has grown somewhat less rapidly than before, but the demand for electricity grew steadily at an average rate of 5.7% per annum from 1980 to 1985. The total firm capacity of the existing power stations as of the end of 1986 is about 427 MW while the annual peak load was estimated at 436 MW. This means that the supply capacity is unsufficient even if the reserve capacity is not taken into account. When considering the reserve margin to secure reliability of power supply, the IRHE's power system at present has a shortage in supply capacity of approximately 75 MW. Therefore, a power development program is on-going to commission a 80 MW combined cycle power station in 1988 and the Fortuna Phase II project in 1990. With the completion of the Fortuna Phase II project, a surplus in supply capacity of the power system will amount to some 92 MW in 1990, but it is forecast that a shortage in supply capacity of 26.3 MW will appear in 1993.

Panama has a chronic deficit in the balance of payments and a huge outstanding external debt. To cope with the growing demand for electricity in these financial difficulties, Government and IRHE policies emphasize use of coal instead of oil from viewpoint of economy, and postponement of large scale hydro power development projects which require large investment.

The proposed coal-fired power development project is judged to be the most economical and profitable among various alternatives to meet the growing power demand from the first half of the 1990s on.

The project is very important for the country, so all necessary preparations should proceed to as early as possible in order that the project may be executed on schedule.

1.2 LOAD FORECAST AND COMMISSIONING YEAR OF THE PROJECT

1.2.1 Load Forecast

It is well known that there is a close correlation between growth in GDP and growth in electricity consumption. By using time-series data for 15 years from 1970 through 1984, a multiple regression equation which takes GDP (X) as the independent variable and energy requirement (y) as the dependent variable was constructed. This regression equation, $y = aX + bX^2 + c$, has a high multiple correlation coefficient of 0.94.

Forecast of the GDP growth rate was used as input for the above quadratic regression model. Future energy requirement calculated from the above model and input was then converted to peak load at the sending-end by using estimated future values of transmission and distribution loss factor and load factor of the power system. In the JICA team's study, three growth scenarios, i.e. optimistic, moderate and conservative GDP growth, served as bases for power demand forecasts. Of these three forecasts, the forecast used as the basis for power development planning in this study is the moderate demand forecast in which GDP is expected to grow at an average rate of 3.0% per annum for the period from 1987 to 1995. From 1985 to 1987 no economic growth in real term is not estimated. The result of the moderate demand forecast is given in the table below. IRHE reviews its power demand forecast every year. As shown in the table below, the result of the JICA team's power demand forecast is very close to the IRHE's latest power demand forecast as of April 1986. According to the moderate forecast, the power demand is expected to grow at an average rate of 5.9% per annum until 1995. This growth is almost comparable to the 5.7% per annum recorded from 1980 to 1985.

Table 1.2.1 Power Demand Forecast

Item	1990	1991	1992	1993	1994	1995
Demand forecast by JICA team						
Energy sent-out (GWh)	3,111	3,299	3,460	3,718	3,905	4,152
Peak load (MW) (A)	539	571	598	642	676	718
Demand forecast by IRHE						
Energy sent-out (GWh)	3,159	3,346	3,542	3,752	3,973	4,208
Peak load (MW) (B)	549	581	615	651	690	731
Difference (A)/(B)	0.983	0.982	0.972	0.986	0.980	0.982

1.2.2 Firm Capacity of the Existing power Stations

As of the end of 1986, the total installed capacity of hydro power stations including Fortuna, Bayano, Los Valles, La Estrella, Yeguada and Chiriqui is 506.0 MW, while their total firm capacity is only 209.2 MW. However, it is expected that this firm capacity will increase to 465.2 MW in 1990 when the Fortuna Phase II project to increase firm capacity and energy by raising dam height 40 m is scheduled to be completed. On the other hand, the total effective capacity of thermal power stations as of the end of 1986 is 217.6 MW, not including the capacity of one unit (37.5 MW) of Bahia Las Minas power station on which rehabilitation work is on-going. In 1988 a 80 MW combined-cycle power station consisting of two 30 MW gas turbines and the No. 1 unit (22.0 MW) of Bahia Las Minas power station is scheduled to be commissioned, and in 1989 the rehabilitation of Bahia Las Minas power station is scheduled to be completed. Therefore, as of the end of 1989 the total effective capacity of thermal power stations will increase to 313.1 MW of which superannuated diesel power stations account for 66.1 MW. Since an ample supply margin will become available with the completion of the Fortuna Phase II project, these diesel power stations shall be kept in cold reserve for economy. By this cold reserving, the total firm capacity will become 712.2 MW consisting of 465.2 MW hydro and 247.0 MW thermal.

1.2.3 Power Demand and Supply Balance, and Commissioning Year

The reserve margin of the power system must be sufficient to cope with shutdown of power plant for scheduled maintenance and forced outage. The reliability criterion for loss-of-load probability (LOLP) (*) adopted by IRHE is that the LOLP should not be more than 2 days per year, i.e. 2/365 = 0.00548.

The relationship of LOLP and percent reserve was computed by IRHE from computer studies of various generation plans by both optimization and simulation process, and it is reported in the "Plan Maestro de Expansion" dated April 1986 that for IRHE's power system a 15% reserve is required to secure an LOLP of 2 days per year.

The other reliability criterion broadly adopted, especially for small scale power systems, is to take the capacity of the largest and second largest units as the reserve margin. Taking these into account, this feasibility study adopted the larger of the following as the reserve margin:

- Capacity equivalent 15% of the peak load.
- Capacity of the largest and second largest thermal power generating units.

If the proposed coal-fired power station does not enter service, the power demand and supply balance based on the above-mentioned reliability criteria will bring about a shortage in supply capacity in 1993 as shown below.

		Balance in 1993 (MW)
Peak load		642.0
Reserve capacity (15% of the peak load)		96.3
Required capacity	(A)	738.3
Firm capacity of the existing power stations	(B)	712.2
Balance	(B) - (A)	-26.1

Since the temperature is almost constant during the all year round, there is very small variation in monthly peak load and the annual peak load may take place in any month of the year. Therefore, it is necessary for No.1 unit of the proposed coal-fired power station to be commissioned in the latter half of 1992 in order to cope with the anticipated shortage in supply capacity for 1993.

Seen from power demand and supply balance solely, a time-lag of more than one year between commissionings of No.1 and No.2 units can be considered. However, it is preferable to commission No.1 and No.2 units with the shortest possible time-lag from viewpoint of economy, because an early commissioning of No.2 unit can save as much the fuel costs for power generation by substitution for gas turbines and Bahia Las Minas power station.

Taking the above conditions into account, it is preferable that the proposed coal-fired power station be commissioned on the following time-schedule:

Unit	Installed capacity	Sending-end capacity	Commissioning
No.1	75.0 MW	70.5 MW	October 1992
No.2	75.0 MW	70.5 MW	January 1993

If the proposed coal-fired power station enters service on the above time-schedule, the reserve margin required for the power system will be equal to the capacity of the largest and second largest units, and this leads to the power demand and supply balance shown in the following table:

Note (*) : LOLP is defined as the proportion of days per year or hours per year when available generating capacity is insufficient to serve all the daily and hourly loads.

Table 1.2.3 Power Demand and Supply Balance

(MW)

Item	1990	1991	1992	1993	1994	1995
Peak load	539.0	571.0	598.0	642.0	676.0	718.0
Reserve margin	80.9	85.7	110.5	110.5	110.5	110.5
Required capacity (A)	619.9	656.7	708.5	752.5	786.5	825.5
Existing firm capacity:						
Hydro	465.2	465.2	465.2	465.2	465.2	465.2
Thermal	247.0	247.0	247.0	247.0	247.0	247.0
Total (B)	712.2	712.2	712.2	712.2	712.2	712.2
Balance (B) - (A) = (C)	+92.3	+55.5	+3.7	-40.3	-74.3	-116.3
Proposed power plant (D)	-	-	70.5	141.0	141.0	141.0
Balance (C) + (D)	+92.3	+55.5	+74.2	+110.7	+66.7	+24.7

Note: The station service loss factor (power loss) of the proposed coal-fired power station is estimated to be 6%. Therefore:

150.0 MW (installed capacity) x 0.94 = 141.0 MW (sending-end capacity)

1.3 SITE SELECTION FOR THE PROPOSED POWER STATION

1.3.1 Criteria for Site Selection

Two candidate sites have been presented by IRHE for the proposed power station, Telfers island and Bahia Las Minas. The JICA study team conducted field investigations on these two sites. Necessary data and information were collected by interviewing personnel of the port authorities, Bahia Las Minas power station, Colon No. 4 and No. 5 substations, Mount Hope and Sabanita water treatment plants and "Refineria de Panama". The study team also visited Pier No. 9 and Pier No. 16 of Cristobal Harbour, Coco Solo Harbour and a quarry site near Villa Alondra to collect data and information.

The power plant site must satisfy various conditions and requirements. The following criteria were used for site selection:

a) Sub-soil conditions are good and land reclamation is easy.

b) The site has ample space for coal storage and future extension, and an ash disposal area can be found near the power plant.

c) Access is easy.

d) Cooling water for steam condenser is of good quality, and recirculation of discharged warmer cooling water can be avoided.

e) Coal unloading and transportation are easy.

f) There is no problem in unloading heavy equipment, and the transportation distance from the unloading point to the plant site is not long.

g) A sufficient quantity of raw water can be taken from a near by supply point.

h) Electric power needed for construction work can easily be supplied from the existing power distribution network.

i) Transportation of rock from the quarry to the plant site is easy.

j) The power station can be constructed in a short period.

k) The power station can be constructed with a small investment.

l) The transmission line length from the power station to the load center (Panama City) is short.

1.3.2 Results of Comparison

Of the above conditions, the transmission line length stated in l) is shorter for Bahia Las Minas (55 km) than for Telfers island (72 km). However, in all other conditions from a) to k) Telfers island is better than Bahia Las Minas.

As described in section 1.4.5, a coal-fired power station constructed on Telfers island will not obstract ships in the canal. Further, there will be no unfavorable effect of air pollution on the area surrounding the power station.

Therefore, the proposed power station should be built on Telfers island upon obtaining authorization of the Panama Canal Commission through related authorities of the Panamanian Government.

1.4 GENERAL DESCRIPTION OF THE PROJECT

1.4.1 Plant Capacity and Power Generation Planning

Generally speaking, the larger the unit size of a power station, the less the construction cost per kW installed. Therefore, it is desirable for the unit size to be as large as possible within the limit of harmony with the power system.

In 1993 when the proposed power station is scheduled to operate at full load, the peak load of the power system is forecast to be 642.0 MW. In this condition, around 75.0 MW is the allowable maximum unit size which can keep the frequency drop within 1.5 Hz when faults take place.

In principle, a thermal power station must be equipped with 2 or more generating units to cope with shutdown of a generating unit for scheduled maintenance or forced outage. Further, once a planned power station enters service, it is desirable that the growing demand in the power system be satisfied during 3 to 4 years. If a new 150 MW power station enters service in 1992/1993 the growing power demand in the IRHE's power system can be satisfied during 3.5 years from 1993 to the middle of 1996, as shown in section 1.2.3. Taking this into account, the proposed coal-fired power station was planned to have the following installed capacity:

150.0 MW consisting of two 75.0 MW units

The fuel cost of thermal power generation is least for coal-fired power stations, so the proposed coal-fired power station will be operated to supply base load. Seen from the shape of annual load duration curves and the capacity of existing power stations in 1993 - 1995, the following power generation is planned for the proposed power station:

Annual generation : 900.0 GWh (Plant factor: 68.5%)
Station service loss: 7.1% (Energy loss factor)
Energy sent-out : 836.1 GWh

1.4.2 Coal Procurement Planning

In Panama no coal has been produced up to the present. Judging from the existing data and information including analysis data of some coal samples, the quality of domestic coal is not so high, and the firing of boiler designed for the project exclusively with the domestic coal is considered to be difficult. Therefore, the use of domestic coal is not considered for the proposed coal-fired power plant project.

In planning coal procurement it is necessary to establish a long-term stable and economical coal supply system by maintaining a balance between long-term purchase contracts and spot purchase contracts, and also to diversify coal supply sources.

Near Panamà there are two coal exporting countries, the U.S.A. and Colombia, so it will be appropriate to import coal from these two countries.

In Colombia, the Cerrejon coal mine has a proven coal reserves of some 2.6 billion tons. This mine has a plan to increase annual coal production from

2.3 million tons in 1985 to 6.19 million tons in 1986, 9.0 million tons in 1987, 12.0 million tons in 1988 and 15.0 million tons in 1989 onward. In the same country, development of other coal mines is also planned. In the U.S.A. coal mines near Panama are located in the Gulf area.

The price of American coal is higher than that of Colombian coal, both in FOB price and in freight charges. Therefore, American coal should be purchased on a spot basis when the coal price declines.

Prior to planning coal procurement it is necessary to have sufficient knowledge about coal trading in the international market and marine transportation and handling of coal.

1.4.3 Topographical and Geological Conditions of the Plant Site

(1) Topography

At present, Telfers island is under the jurisdiction of the Panama Canal Commission. The land is used for disposal of dredged materials and garbage.

Almost all of the power plant site is grassy plain, with scattered wood. The land is almost flat, 2.5 to 5.5 m above sea level.

About 500 m offshore, the Panama Canal dredging limit line runs almost parallel with the coastline along the plant site. The sea bottom slopes gently from the land to the dredging line at a slope of about 1/90 to 1/100. Near the dredging line, the sea bottom suddenly deepens to 12 m as a result of dredging. Beyond this line, the sea bottom is almost flat with a water depth of -12 to -14 m. This sea area is used at present as anchorage area for small vessels.

East of the power plant site is a creek called French Canal. The water depth of this canal is about 1.5 m near the cooling water outlet and about 13 m near Pier No.16.

(2) Geology

In the canal zone where the project site is located, bedrocks of the early Tertiary period, igneous basalt and andesite, are broadly distributed in the north-eastern part of Gatun Lake. From Gatun Lake toward the Pacific coast, igneous rocks, Miocene (part of the Tertiary period), basalt and andesite are widely distributed. From Gatun Lake toward the Caribbean Sea, sedimentary rocks, such as the late Oligocene Camito layer, Middle Miocene Gatun formation, and Late Oligocene or Early Pleistocene, Toro limestone and Chagres sandstone form a gentle slope.

The bedrock in the project area is the mid Miocene Gatun formation. It is mainly composed of mudstone. Covering this formation, alluvium consisting of silt, clay and sand, and a Recent Epoch deposit consisting of coral reefs, are distributed along the seashore. In the whole plant site, considerable dredged soil from the Panama Canal has been dumped.

To learn the geological characteristics of the site area, 10 core borings were carried out at the power plant site. Of these, 7 borings in the land area and 3 borings in the sea area. Following these borings, standard penetration tests and laboratory tests were also carried out. Further, seismic prospecting was conducted on the whole plant site area. As the result of these geological investigations, the following conclusion was reached:

The ground of the plant site is characterized by two formations, a soft deposit layer and bedrock laying immediately below the deposit layer called the Gatun formation. When pile supporting structures are selected, there is no problem in making the Gatun formation the vertical bearing layer (in the jetty area, the coral fragment layer becomes bearing layer).

However, for the foundation of the coal storage yard where coal is piled to some height it is obviously uneconomical to use the whole ground as a pile supporting structure. On the other hand, if the existing ground is used as it is, slides may possibly take place. To cope with this situation, it was planned to construct the underground belt conveyer culvert using the sand compaction method due to short period for construction, while the coal storage yard using the sand drain method. However, at the stage of definit study optimum countermeasures must be established through detailed geological investigations.

1.4.4 Outline of Facilities

(1) Layout of Power Station (Refer to Fig. 1.2)

a) Location

The power plant site is on Telfers island at latitude 9°20'10" longitude 79°54'35", and faces Limon Bay which is the entrance to the Panama Canal on the Caribbean Sea. The site is adjacent to Cristobal Harbour in the north. North-east of the site is Colon City. The distance from the center of Colon city to the plant site is about 3 km.

b) Site area

The total area required for a 150.0 MW coal-fired power station adjacent to the future ship breaking yard of ORILLA S.A. is approximately 620,000 m^2, of which 81,000 m^2 is for the power plant, 26,000 m^2 for the coal storage yard, 230,000 m^2 for ash disposal and 283,000 m^2 for a green belt and future expansion.

c) Jetty and coal storage yard

A coal unloading jetty is planned to be constructed along the dredging limit line of Cristobal Harbour, about 500 m offshore from the plant site. Since the sea depth in front of the jetty is from 12 to 13 m, a coal vessel of 10,000 D.W.T. class carrying coal from Colombia or the eastern U.S.A. can easily be moored to the jetty. From the vessel, coal is removed by unloader to a belt conveyer to be carried to the coal storage yard having a storage capacity of 63,600 tons.

In locating the turning basin for coal vessels, attention was paid to not obstructing ships in the canal.

d) Cooling water intake and outlet

Cooling water (8.0 m^3/sec) for the steam condenser is taken from an intake facing Cristobal Harbour and sent to steam condenser by intake pump, after passing through steam condenser the warm cooling water is discharged into French Canal through an outlet.

A simulation study of discharged warm cooling water diffusion was conducted by computer. It was confirmed that discharged warm cooling water will not recirculate to the intake side.

e) Mechanical and electrical equipment, and buildings

The main mechanical and electrical equipment such as boiler and turbine-generator are installed in a steel structure but the boiler is designed for outdoor use from viewpoint of economy. Two reinforced concrete stacks 95.0 m high will contribute to the diffusion of flue gas. Other facilities such as administration building, coal transportation control building, switchyard, water tank yard, oil tank yard, work shop, parking lot, and warehouse are appropriately located on the site.

f) Ash transportation and disposal

The boiler bottom clinker ash is removed by chain conveyer to belt conveyer and carried to the ash disposal area. Both cinder ash and fly ash are temporally stored in the ash hopper, then wetted and transported to the ash disposal area. The depreciation period of coal-fired power station adopted by IRHE is 25 years. Therefore, the ash disposal area was designed to have 25 years of disposal capacity.

g) Transmission line

The proposed power station is planned to generate about 900 GWh annually. A 230 kV double circuit transmission line about 72 km long will extend from the power station to the Panama II substation from where power will be transmitted to load centers.

(2) Civil works

a) Condenser cooling water facilities

The surface suction system and surface discharge system are adopted for intake and outlet respectively, because the water suction area is in Limon Bay where waves are relatively moderate and there is no recirculation of discharged warmer cooling water due to outlet location.

Intake, screen pit and pump pit form a single system taking into account power plant layout, space and economy. This system is of reinforced concrete 10.00 m wide, 9.00 to 11.20 m high and 24.00 m long.

Two embedded cooling water pipes 1.20 m in diameter are to be supported by reinforced concrete piles to prevent sinking.

The discharge waterway consists of a discharge pit, discharge channel and outlet. The discharge pit is 6.40 m wide, 8.40 m high and 13.40 m long. Two discharge channels are each 2.00 m wide, 2.00 m high and about 120 m long. The dimension outlet is 6.40 to 12.40 m wide, 6.00 m high and 18.60 m long.

b) Coal unloading jetty

The coal unloading jetty must satisfy the following conditions:

- The jetty can berth 10,000 D.W.T coal vessels and 1,000 D.W.T. oil tankers
- The jetty has ample space for coal unloaders to run and enough bearing capacity to support their load.

Taking the above conditions into account, the coal unloading jetty is designed to be of pier type supported by steel pipes 900 mm in diameter. It has a main structure 150 m long, 17 m wide and 9 m water depth, and 2 mooring dolphins.

c) Coal storage yard

The coal storage yard is 160 m long and 160 m wide. The coal storage capacity is planned to be 63,600 tons, equal to 1.5 months consumption.

A belt conveyer to carry coal from the coal storage yard to the powerhouse is installed in coal drawout culverts of reinforced concrete.

Since the coal storage yard ground is soft, slides may possibly take place when coal is piled thickly. Therefore, the ground should be strengthened by an appropriate method such as the sand drain method.

d) Ash disposal area

For economy and environment protection, an ash disposal area is to be constructed onshore. The disposal area is about 230,000 m^2 and surrounded by an embankment about 1.50 m high and 4.50 m in top width to prevent ash from leaching.

The disposal area capacity is 1,280,000 m^3, enough for 25 years.

(3) Architectural works

a) Powerhouse

The powehouse consists of a machine area, control area and bunker area, having a total building area of 3,020 m^2.

Turbine-generators and auxiliary equipment are installed in the machine area. The 3rd floor where turbine-generators are installed is equipped with an overhead crane for inspection and maintenance.

The control area, control room, protective relay room and operation personnel room have comfortable accommodations.

Coal supply facilities such as coal bunker and pulverizer are provided in the bunker area.

The building is of steel. The powerhouse foundation is of reinforced concrete, supported by concrete piles on solid ground.

The roof and exterior wall are finished with sheet cladding.

Air-conditioning equipment, lighting facilities, water supply and drainage and sanitation facilities are provided.

b) Administration building and other buildings

The administration building is planned to accommodate about 50 administrative personnel. The building is a 2-story, reinforced concrete structure with a reinforced concrete foundation.

The chemical analysis room and dining room are on the 1st floor, and office rooms, conference room and superintendent room on the 2nd floor.

Other buildings such as the coal handling control building, workshop, demineralization house, warehouse, oil drum and cylinder storage, storehouse, coal handing control building, garage and guardhouse are appropriately located on the plant site.

c) Stack

The stack is 95 m high to permit flue gas to sufficiently diffuse. This will keep the maximum ground level concentration of SOx below the emission standard of Okinawa, where local conditions are similar to those of Panama.

The type of stack is reinforced concrete stack with interior steel pipe. To protect the interior pipe from corrosion, it will be coated with acid-resistant mortar.

(4) Mechanical and electrical equipment

The general characteristics of the mechanical and electrical equipment are as follows:

a) Boiler system

- Boiler

Type	Single drum, natural circulation, outdoor type
Evaporation (MCR)	240 t/h
Steam pressure (SH/outlet)	105 kg/cm^2g
Steam temperature (SH/RH)	541/541°C

- Coal pulverizer

Type	Vertical, balls and race type
Capacity	16 t/h x 3 sets

b) Coal handling facilities

- Coal storage capacity	1.5 month for 2 units 63,600 t (A.R)
- Coal consumption	55.8 t/h (A.D) for 2 units 318,100 t (A.D) for 2 units
- Coal unloader	250 t/h x 2 sets
- Coal stacker	Stationary type with tripper
- Coal belt conveyor	600 t/h - 250 t/h

c) Ash handling facilities

- Bottom ash	Chain conveyor draw out and belt conveyer carrying system
- Fly ash	Pneumatic vacuum conveyor collection and belt conveyor carrying system

d) Turbine facilities

- Turbine

Type	Tandem compound, impulse type, two-cylinders, single flow, exhaust reheat condensing turbine type
Rated output (as generated power)	75 MW
Main steam pressure (MSV inlet)	102 kg/cm^2g
Main steam temperature (MSV/RSV)	538/538°C
Exhaust vacuum	700 mm Hg
Rotating speed	3,600 rpm

- Condenser

Type	Double pass, divided water box type, surface condenser
Kind of cooling water	Seawater
Quantity of cooling water	4 m^3/sec

Temperature of cooling water (inlet/outlet)	29/36°C

e) Generator

Type	Horizontal shaft, 3 phase, totally enclosed, hydrogen cooled type
Rating	
Capacity	88,250 MVA
Voltage	13,800 V
Current	3,692 A
Power factor	0.85
Short circuit ratio	0.58 (Minimum)
Frequency	60 Hz

f) Main transformer

Type	Out door, 3 phase, oil circulating, air cooled type
Rating	
Capacity	85,600 KVA
Voltage	13.8/230 KV

g) Control and instrumentation system

- Major control	Automatic boiler control (ABC) Automatic load regulator (ALR) Turbine governing system Generator automatic synchronizer unit interlock system
- System control	Automatic burner control Turbine automatic start-up control
- Computer	Digital computer

- Monitoring television

Purpose	Drum level monitoring Furnace monitoring Stack monitoring

h) Environmental protection facilities

- Electrostatic precipitator

Type	Outdoor, dry, horizontal gas flow type
Gas flow	282×10^3 Nm^3/h (Dry)
Dust concentration (EP outlet)	0.1 g/Nm^3 or less
Dust removal efficiency	99.25% or more

- Waste water treating facilities

	Type
Power plant area	Sedimentation, filtration and neutralization type
Coal storage yard	Gravity sedimentation type
Ash disposal area	Gravity sedimentation type

(5) Transmission line and substation

a) Receiving substation

Three alternative substations could receive power transmitted from the proposed power station. They are (i) Panama II substation, (ii) switchyard of Bahia Las Minas power station, and (iii) Panama substation. Of these three alternatives, Panama II substation was judged to be the most suitable from viewpoints of economy, reliability and compatibility with IRHE's power system expansion plan.

In IRHE's power system, the main power sources are hydro power stations in Chiriqui province and Bayano power station in Panama province. Power generated by these hydro power stations is sent to the Panama substation by 230 kV transmission lines, then to secondary substations in the surrounding areas by 115 kV transmission lines.

However, in the rainy season, on these 230 kV lines trip occurs frequently due to lightning. This is a serious problem for supply reliability of electricity.

IRHE has a plan to construct a 400 to 500 kV transmission line in connection with the Changuinola hydro power project. To receive power transmitted by this ultra high voltage transmission line, Panama substation has unfavorable conditions in extension space, excessive concentration of power flow and supply reliability. Therefore, IRHE plans to construct a Panama II substation to receive power sent from Changuinola. This will diversify power flow and improve supply reliability of electricity.

In this condition, if power generated by the proposed power station is sent to Panama substation, the concentration of power flow to the said substation becomes more excessive and the supply reliability declines further. If power is sent to the switchyard of Bahia Las Minas power station, the transmission line from this switchyard to the Panama substation will be over-loaded, hence the reliability of the power supply will decline further.

Considering the above conditions, i.e. supply reliability and compatibility with IRHE's power system expansion plan, the Panama II substation was selected to receive power transmitted from the proposed power station.

b) Substation equipment

The bus configuration is designed to be a highly reliable one-and-half circuit breaking system consisting of 3 circuit breakers for 2 circuits. The power line carrier direction comparison relay system is to protect the transmission line. The substation equipment will be remote-controlled by a central dispatching center adjacent to Panama substation through a power line carrier.

c) Transmission Voltage

Of the two alternative transmission voltages of 115 kV and 230 kV, the latter is adopted for economy and compatibility with IRHE's power system expansion plan.

d) Others

A double circuit transmission line is planned to be constructed for a 72 km stretch. The line route is shown in Fig. 1.3. The conductor is to be ACAR 750 MCM, and 250 mm insulator strings of 14 discs.

1.4.5 Considerations Regarding Environmental Matters

The environmental protection requirements for this project are the following:

- The power station does not obstruct ships in the Panama Canal.

- The power station does not have an unfavorable influence on the environment of the surrounding area.

In order to meet the above requirements, the coal unloading jetty is to be far from the Panama Canal, and the warmer cooling water will be discharged into French Canal as shown in Fig. 1.1. These measures will avoid interference with ships in the Panama Canal.

At present there are no environmental protection regulations in Panama. The emission standard is different by country, and there is no international standard. Therefore, the JICA study team conducted comparative studies on national emission standards and ambient air quality standards of the U.S.A., West Germany, France, Sweden, Japan and others. As a result of discussions with IRHE the study team proposes to apply the Japanese emission standard for the project area.

The design values proposed by the JICA team are given in Table 1.4.5.(1). When conducting an environmental impact evaluation for the project area by using these design values, the maximum ground level concentration of flu gas is calculated to be well below the standard values adopted by the U.S.A. and Japan. Further, the maximum emergence distance is calculated to be about 6.4 km from the proposed power station, i.e., outside of the anchorage area of Cristobal Harbour and Colon city. Therefore, no unfavorable effect on the environment of the surrounding area is expected.

The results of environmental impact evaluation are as follows:

	Project area (Per unit)	Ambient air quality standard U.S.A.	Ambient air quality standard Japan
SOx	0.009 ppm (D)	0.14 ppm (D)	0.04 ppm (D)
NOx	0.009 ppm (D)	0.05 ppm (A)	0.04 ppm (D)
Dust	0.001 mg/Nm^3 (D)	0.26 mg/m^3 (D)	0.1 mg/m^3 (D)

Note: (D) Daily average value

(A) Annual average value

The main features of environmental countermeasure equipment are shown in Table 1.4.5(2).

Monitoring of Environmental Impact

Environmental impact assessment involved with power plant operation has been mentioned above. However, for inhabitants, living around the site and related government offices, it should be necessary to justify the evaluation value by measuring real value. From this point, in order to get understanding and confidence, IRHE should monitor ambient environment before and after plant operation and monitor a change of environmental impact. Table 1.4.5(3) shows preferable monitoring items, period and points. Monitoring should be started 18 months before No.1 unit comissioning (about one year before No.1 unit initial firing) in order to compare with measured values, before and after plant operation respectively. Air pollution measuring point is indicated at Fig. 1.7 with regard to estimated ground concentration, wind direction and population density.

It is economical that mobile monitoring station which installs all monitoring equipments in an air pollution monitoring car moves around four points every week and measure all monitoring items. Furthermore, all monitoring points should be selected among the points which have no influence of exhaust gas of automobiles.

Moreover, these should be the same points in order to observe a change of measured values.

Table 1.4.5 (1) Environment Protection Design Values

(1) Air Pollution Countermeasures

(a) SOx

Control method: Ground level concentration control
Maximum ground level concentration = 0.015 ppm
(It is called K-value control method in Japan.)

Therefore, the value corresponds to K = 9.0
($C_{max} = K \times 1.72 \times 10^{-3}$)

(b) NOx

Control method: Emission concentration control (at top of stack)
Maximum concentration = 300 ppm

(c) Dust

Control method: Emission concentration control (at top of stack)
Maximum concentration = 0.1 g/Nm^3

(2) Water Pollution Countermeasures

Control method: Emission concentration control (at outlet)

(a) Maximum waste water concentration

SS (Suspended Solids)	= 200 mg/ℓt
COD (Chemical Oxygen Demand)	= 160 mg/ℓt
Normal Hexane Extract (oil)	= 5 mg/ℓt
PH (Hydrogen Ion concentration)	= 5 - 9

(b) Heated effluent for cooling water

Maximum temperature rise = 7°C

(3) Noise Countermeasures

Control method: Impact level control (at the boundary)
Maximum impact level: Day time = 65 dB (A)
Night time = 60 dB (A)

(4) Vibration Countermeasures

Control method: Impact level control (at the boundary)
Maximum impact level: Day time = 65 dB
Night time = 65 dB

Table 1.4.5 (2) Main Features of Environment Countermeasure Equipment

(1) Air Pollution Countermeasure

(a) For SO_x

- Coal blending system to average sulfur content

- High and fast gas speed stack: 95 m and 30 m/s to reduce ground level concentration

  * A desulphurization system is not needed.

(b) For NO_x

- Two stage combustion systems

- Flue gas mixing system

- Low NO_x burner
  Boiler outlet NOx concentration: less than 300 ppm

- High and fast gas speed stack: same as SOx

  * A denitrification system is not needed.

(c) For Dust

- Electrostatic precipitator (low temperature gas type 140°C)
  Outlet gas concentration : less than 0.1 g/Nm^3
  Dust collecting efficiency: more than 99.25%

- High and fast gas speed stack: Same as SO_x

  * A bag-filter is not needed.

(2) Water Pollution Countermeasure

(a) For Waste Water

- SS : Sedimentation and filtration equipment
  Outlet SS concentration: less than 200 mg/lt

- Oil: Oil separator equipment
  Outlet oil concentration: less than 5 mg/lt

- PH : PH-Neutralization equipment
  Outlet PH value: 5 - 9

  * A COD-Removal system is not needed.

(b) For Heated Cooling Water Effluent

- Large cooling area condenser
  Maximum temperature : 7°C
  Cooling water quantity: 4.0 m^3/s for each unit

- Outlet of cooling water will be located at French Canal to diffuse well.

(3) Noise Countermeasure

- Main equipment will be installed in powerhouse located far from boundary to reduce noise level.

- Low noise equipment will be used.
  Impact noise level at boundary will be:
  Day time (Coal unloader operation) : less than 65 db (A)
  Night time (Coal unloader stop) : less than 60 db (A)

(4) Vibration Countermeasure

- Main equipment will be installed far from boundary.
  Impact vibration level at boundary: less than 65 db (all the time)

(5) Miscellaneous

- Water sprays will be installed at coal storage yard and coal unloader to restrain dust emission.

- Outdoor belt conveyer will be covered.

- Dry ash will be wetted by water spray and disposed ash will be covered with soil to restrain dust emission.

Table 1.4.5 (3) Monitoring Items

	Item	Point	Period	Other
Air	SOx NOx Dust Wind direction Wind velocity Ambient temperature	4 points Indicated at Fig. 1.7	each point 1/month each point 1 week continuous record	by mobile measuring station
Water quality	P.H. S.S.(Suspended solid) Water temperature	Intake Outlet French canal (Center) Ash disposal area Waste water	1/month	manual
Noise	-	Property line of power plant area 10 points	1/month (day and night)	manual
Vibration	-	ditto	1/year	manual
Exhaust gas	SOx NOx Dust Gas temperature	Stack or flue gas duct	Continuous recordd	full fine monitoring at power station

1.4.6 Implementation Schedule

The proposed project was planned to be executed on a full turn-key base including detailed design and construction, taking into account the availability of IRHE's engineering staff.

To complete this project, 5 years and 9 months are required from the submission of the feasibility study report to the commissioning of the No. 2 unit, including contact with the Panama Canal Commission to obtain authorization for land utilization, contact with financial institutions, loan agreement, L/C opening, selection of consulting engineers, preparation of tender ducuments, selection of contractor, construction work and tests.

The schedule of major events in the construction follows:

- Submission of feasibility study report	March 1987
- Start of definite study	April 1988
- Submission of offers	July 1989
- Start of civil works	March 1990
- Start of installation work	September 1990
- Drum lifting	July 1991
- Initial power receiving	February 1992
- Initial boiler ignition	May 1992
- Commissioning of No. 1 unit	October 1992
- Commissioning of No. 2 unit	January 1993

The overall implementation schedule is shown in Fig. 1.4.

1.4.7 Construction Cost Estimate

The construction cost of the project was estimated as the cost available internationally, i.e. the cost of equipment was estimated making reference to the price of equipment of a coal-fired power plant recently commissioned in Japan and price of equipment recently exported from Japan, as well as to the variation in exchange rate of US$ to several major currencies of the world during the last 2 years. The cost of civil works was estimated by using the unit costs actually available in Panama.

The estimated construction cost and power generation cost of the project are summarized as follows:

Table 1.4.7 Construction Cost and Power Generation Cost

(Millions of Balboas)

Construction cost		Power station	Transmission line and substation	Total
1986 prices	F.C.	109.20	8.69	117.89
	L.C.	38.08	6.03	44.11
	Total	147.28	14.72	162.00
Escalated total price	F.C.	139.36	11.55	150.91
	L.C.	82.40	11.57	93.97
	Total	221.76	23.12	244.88
Unit generation cost (Cent/kWh)		4.92		5.19

Currency exchange rate : 1US$ = 1 Balboas (1 B/.)

Note: Construction cost at 1986 prices does not include import tax and interest during construction.

Escalated total price includes price escalation, import tax and interest during construction.

F.C. and L.C. means foreign currency portion and local currency portion respectively.

The cost was estimated under the following conditions:

a) 5% of the direct construction cost is the physical contingencies.

b) 1.5% of the direct construction cost is the IRHE's administration cost.

c) 2.5% of the direct construction cost is the engineering fee.

d) The price escalation rate is estimated to be 2% per annum for the foreign currency portion and 3.5% per annum for the local currency portion.

e) Interest is estimated at 10% for the foreign currency portion and 8% for the local currency portion.

f) 35% import tax is to be uniformly levied on the imported equipment and materials.

The unit generation cost was calculated under the following conditions:

g) The power station is operated at a plant factor of 68.5%.

h) Service life is estimated at 25 years for the power station and 35 years for the transmission line and substation.

i) Loan conditions are 10% interest and 25 years repayment from the year of commissioning for the foreign currency portion and 8% interest and 10 years repayment from the year of commissioning for the local currency portion.

j) Cost ratio of operation and maintenance, and administration costs to the construction cost is 4.5% for power station and 2.3% for transmission line and substation.

k) Coal price is US$42.0/ton.

l) Import tax is not levied on coal.

1.4.8 Economic Evaluation

To clarify the influence of fuel price on the project, the cost of the proposed power station was compared with other thermal power stations such as oil-fired, combined-cycle and gas turbine power stations under the following conditions:

- Expected prices of fuel as of January 1987, based on a crude oil price of US$18.50 per barrel and coal price of US$42.0 per ton (base study).

- Anticipated prices of fuel, based on a crude oil price of US$29.10 per barrel and coal price of US$48.40 per ton which were experienced during 1984 and 1985 (sensitivity analysis).

The interest rate or the discount rate adopted by IRHE for economic evaluation is 12%, so this rate was used in the economic evaluation of the proposed coal-fired power plant project.

The conclusions reached are as follows:

a) At 12% interest, the proposed coal-fired power station will be the most economical if a plant factor of more than 65.6% is required in the fuel price of the "base study", and a plant factor of more than 32.4% in the fuel price of the "sensitivity analysis", as shown below:

	Plant factor as the break-even point	
	Base study	Sensitivity analysis
Coal-fired vs oil-fired	65.6%	26.5%
Coal-fired vs combined-cycle	62.9%	27.8%
Coal-fired vs gas turbine	62.5%	32.4%

b) The expected annual generation of the proposed power station is 900 GWh (plant factor of 68.5%) and the sent-out energy is 836.1 GWh. In this case, the so-called economic internal rate of return (EIRR), that is the discount rate which equalizes the total costs of the proposed power station to the total costs of its alternatives is calculated to be 12.6 to 13.4% with the fuel price of the "base study", and 29.1 to 39.3% with the fuel price of the "sensitivity analysis", as shown below:

	EIRR of the proposed power station	
	Base study	Sensitivity analysis
Coal-fired vs oil-fired	12.60%	39.30%
Coal-fired vs combined-cycle	13.25%	34.30%
Coal-fired vs gas turbine	13.40%	29.10%

In this connection, it is to be noted that in Panama the social rate of discount is estimated at 12%.

From the above, it is concluded that the proposed coal-fired power station is very recommendable from the viewpoint of economy.

1.4.9 Financial Analysis

The financial analysis of the project was done under the following loan conditions:

- Interest rate of 10% and repayment period of 25 years from the year of commissioning for foreign loans.

- Interest rate of 8% and repayment period of 10 years from the year of commissioning for local loans.

In the present international financial market, the above conditions are rather severe. However, the analysis shows that even if the construction is financed under such severe conditions the project will still have high profitability as shown below:

a) The rate of return (ratio of operating income to average net fixed assets in operation) will be very high, 13.1% on an average for the first 10 years and 20.5% for the whole service life of 25 years.

b) The rate of net income (ratio of net income to average net fixed assets in operation) will also be high, 3.3% on an average for the first 10 years and 11.1% for the whole service life of 25 years.

c) The yearly cash balance will be black every year from the commissioning of the power station to the end of its service life. Due to interest during construction, a deficit in the accumulated cash balance will continue up to the 3rd year from the commissioning, but turn to black in the 4th year.

Further, the so-called financial internal rate of return (FIRR), that is the discount rate which equalizes the total revenue of the project to the total expenses incurred from the beginning of the project to the end of its service life is calculated to be 13.5%.

Therefore, the project is judged to be feasible also from a financial viewpoint.

1.5 RECOMMENDATION

In order to commission No. 1 and No. 2 units in October 1992 and in January 1993 respectively, it is necessary for the definite study to be started in 1988. To keep this time-schedule, it is recommended that the necessary procedures shown below be taken as soon as possible.

1.5.1 Authorization of Land Utilization

Telfers island is under the jurisdiction of the Panama Canal Commission (PCC). The sea fronting the coal unloading jetty is designated as an anchorage area for ships navigating the canal. Therefore, the first step to be taken in the project is to acquire from PCC an authorization for land utilization for the power station, and to get the front sea necessary for mooring coal vessels excluded from the designated anchorage area. For this purpose, it is recommended that necessary procedures be taken as soon as posible to PCC through "Direccion Ejecutiva para Asuntos del Tratado (DEPAT)" of the "Ministerio de Relaciones Exteriores".

1.5.2 Documents Necessary for Loan Procedure

In general, it takes a long time to arrive at a loan agreement, and various documents showing actual financial performance, planned development project for the future including proposed coal-fired power plant project, and resultant overall financial projection are required. Therefore, preparation of these documents and preliminary contact with financial institutions must be commenced as soon as possible.

1.5.3 Knowledge Necessary for Coal Procurement

The coal consumption of the proposed power station is relatively small at about 300,000 tons annually, so its import will not be difficult. Further, the international coal market is becoming favorable for the buyer with the low price stabilization of crude oil.

Therefore, conclusion of a coal import agreement need not be hurried. Prior to an import agreement, it is necessary to have sufficient knowledge of the following matters:

a) Coal trading in the international market

- Coal mines, conditions of inland transportation and port of shipment in the coal exporting countries.

- Contract for sale.

- Coal price, conditions of demand and supply.

b) Marine transportation of coal

c) Coal unloading and storage

For the above purpose, studies must be commenced immediately. The training of IRHE engineers in experienced coal importing countries, or the invitation of coal experts from such countries, is considered to be useful for obtaining the above-mentioned knowledge.

1.5.4 Investigation for Determining Transmission Line Route

To construct a transmission line, three steps must be taken, i.e. study, erection of supporting facilities and wiring. In general, the cost required for study is small, only several % of the construction cost. However, the study is very important because the quality of transmission line constructed depends upon the quality of the study. Therefore, at the stage of detailed study, all of the conceivable line routes including line route suggested in this feasibility study report must be compared with each other to find the optimum transmission line route.

Study of maps alone is inadequate. For some places investigation on the ground or aerial investigation by helicopter must be executed. When the base route for the transmission line is decided, topographic survey and boring must be executed to determine the erection points of the steel towers. Preparation of drawings and calculation of work quantities are also necessary.

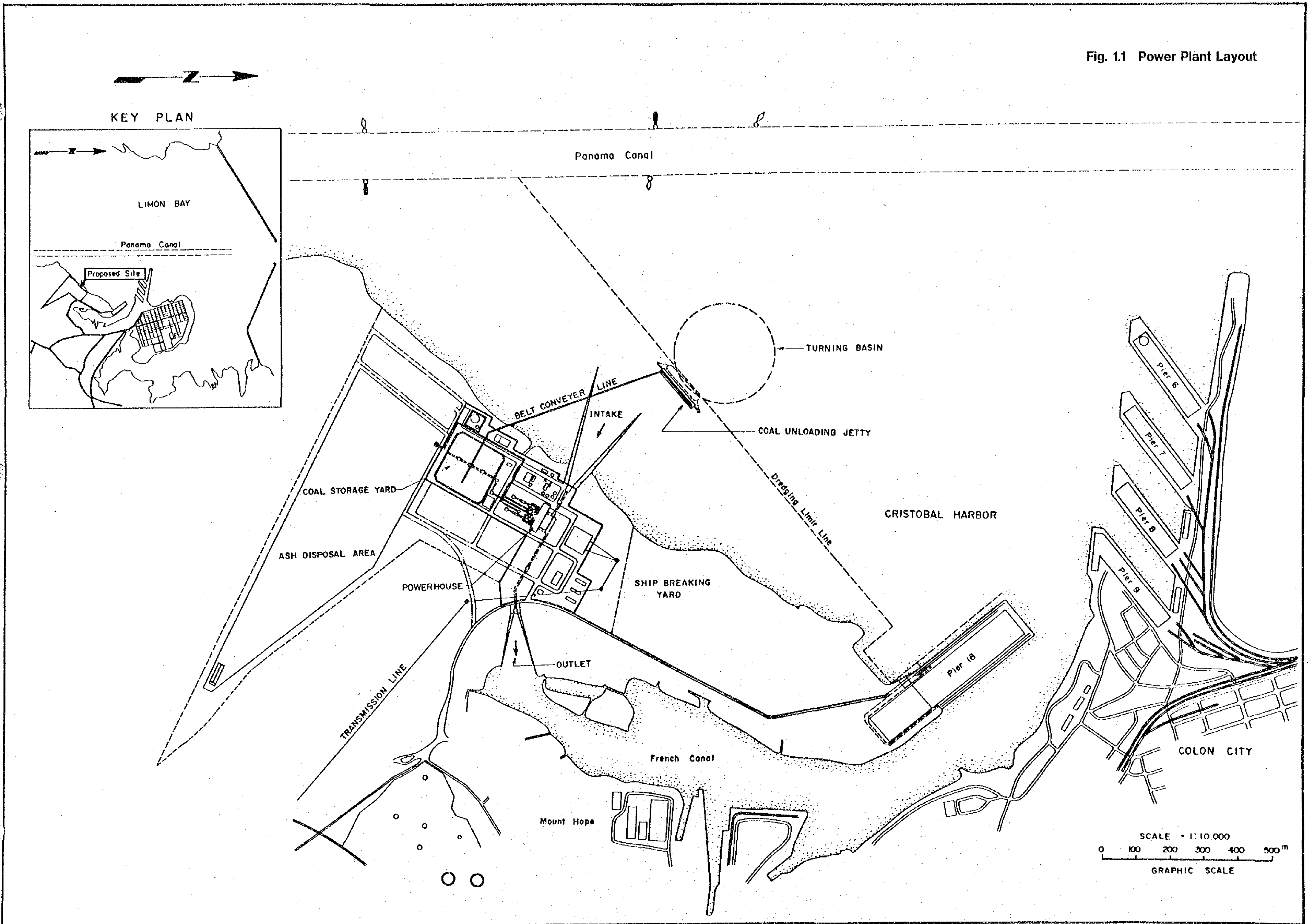
(5)

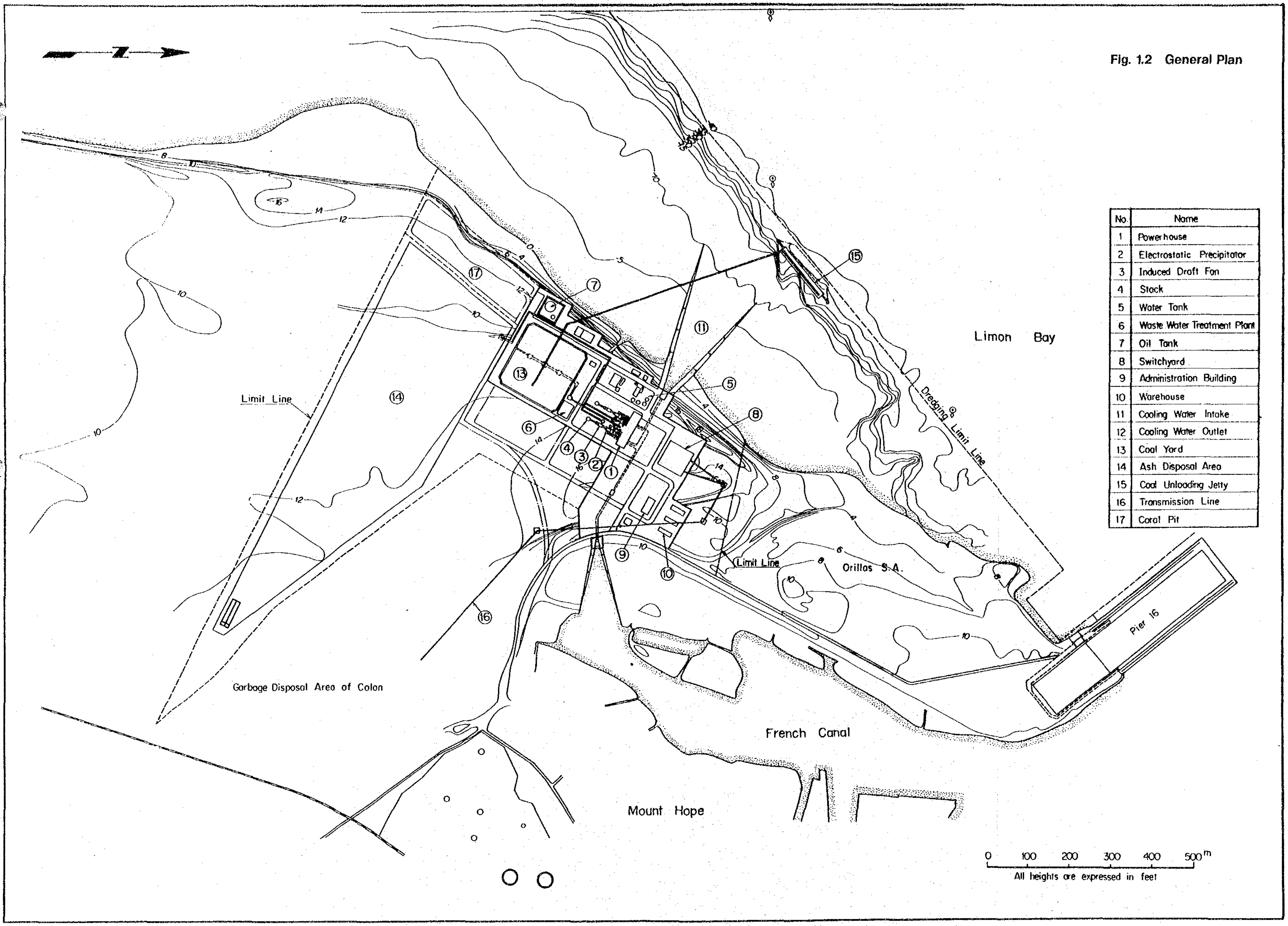
1.5.5 Topographic Survey, Sounding and Geological Investigation

At the stage when it becomes hopeful to obtain authorization for land utilization for the power station, detailed topographic survey and sounding of French Canal near the outlet shown in Fig. 1.5 should be carried out to assist the definite study.

Detailed geological investigation should also be carried out for foundation of structures, especially for foundation of the coal storage yard in connection with a countermeasure to be established as stated in section 1.4.3(2).

Fig. 1.1 Power Plant Layout





No.	Name
1	Powerhouse
2	Electrostatic Precipitator
3	Induced Draft Fan
4	Stack
5	Water Tank
6	Waste Water Treatment Plant
7	Oil Tank
8	Switchyard
9	Administration Building
10	Warehouse
11	Cooling Water Intake
12	Cooling Water Outlet
13	Coal Yard
14	Ash Disposal Area
15	Coal Unloading Jetty
16	Transmission Line
17	Coral Pit

Fig. 1.2 General Plan

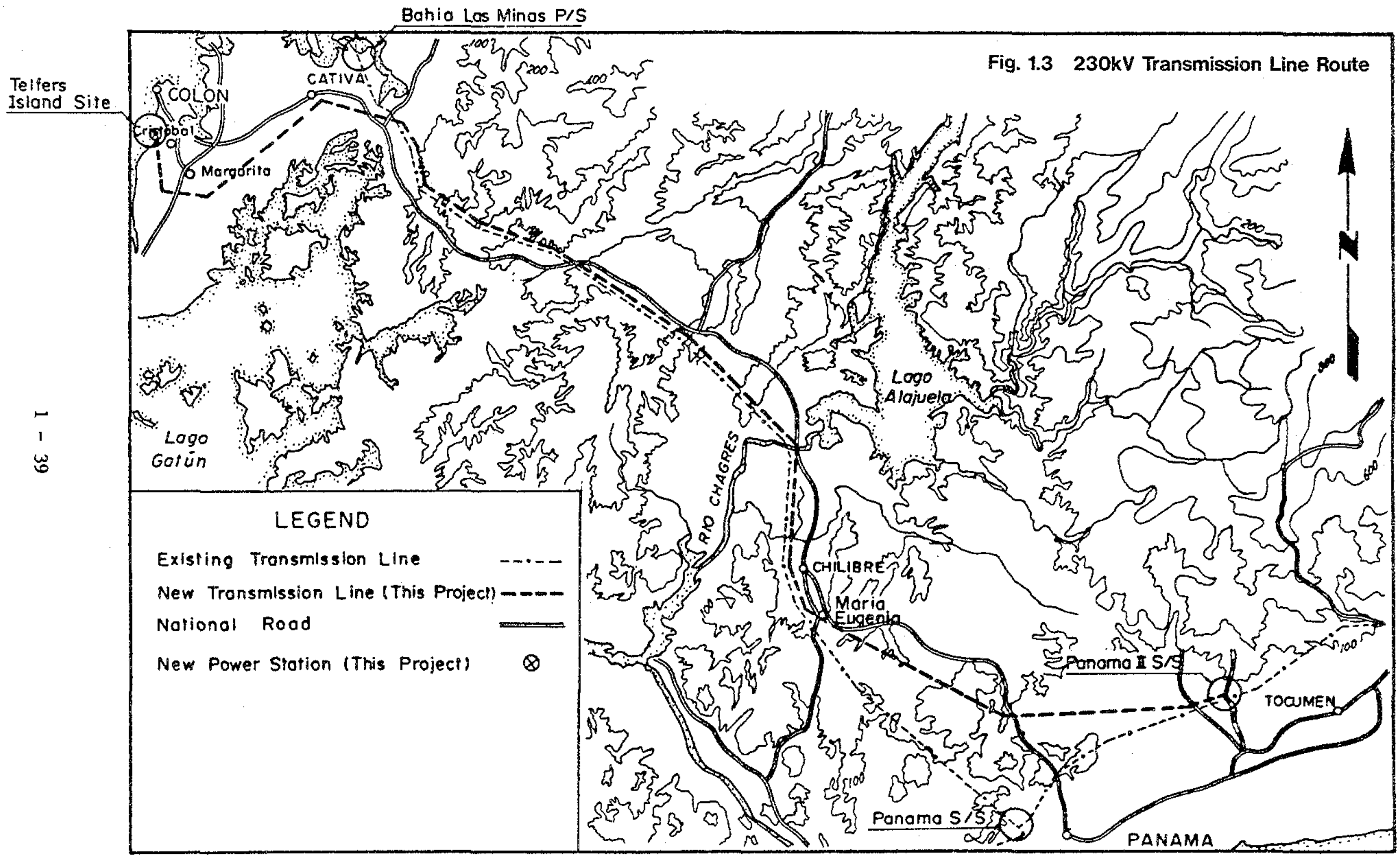


Fig. 1.3 230kV Transmission Line Route

Fig. 1.4 Inplementation Schedule of Coal-Fired Power Plant

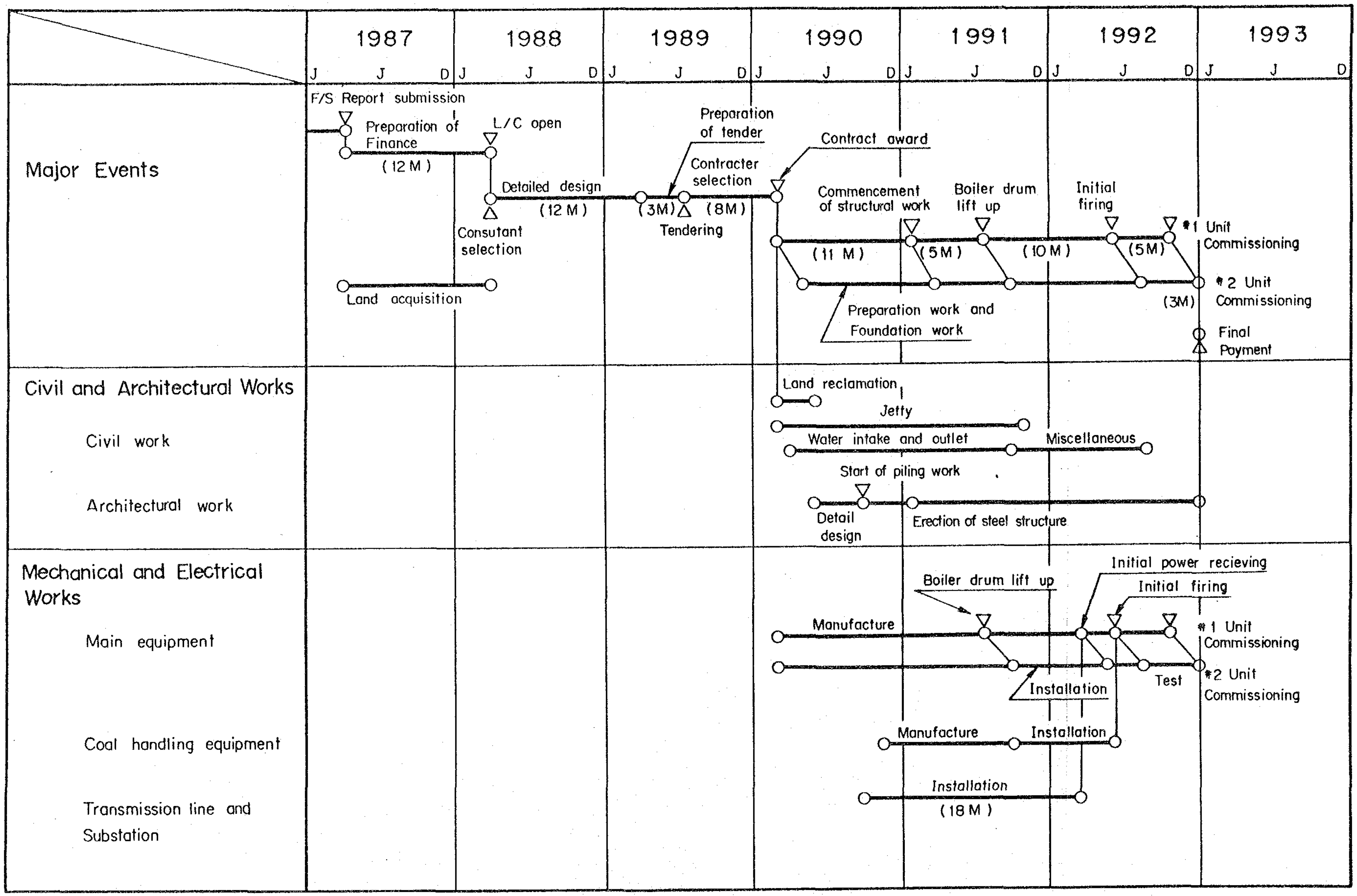


Fig. 1.5 The Areas for Topographic and Sounding Survey

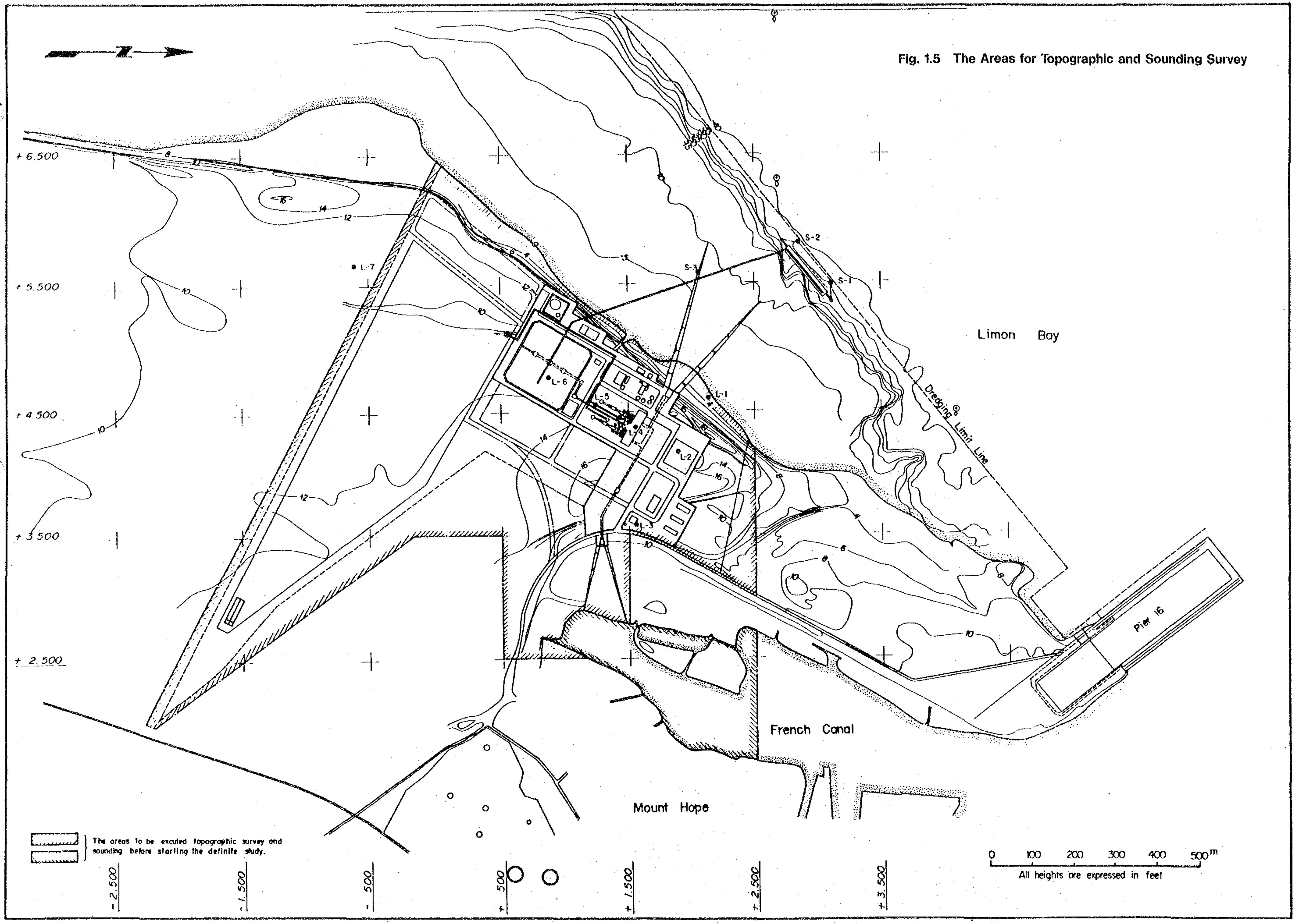


Fig. 1.6 Detailed Plant Layout

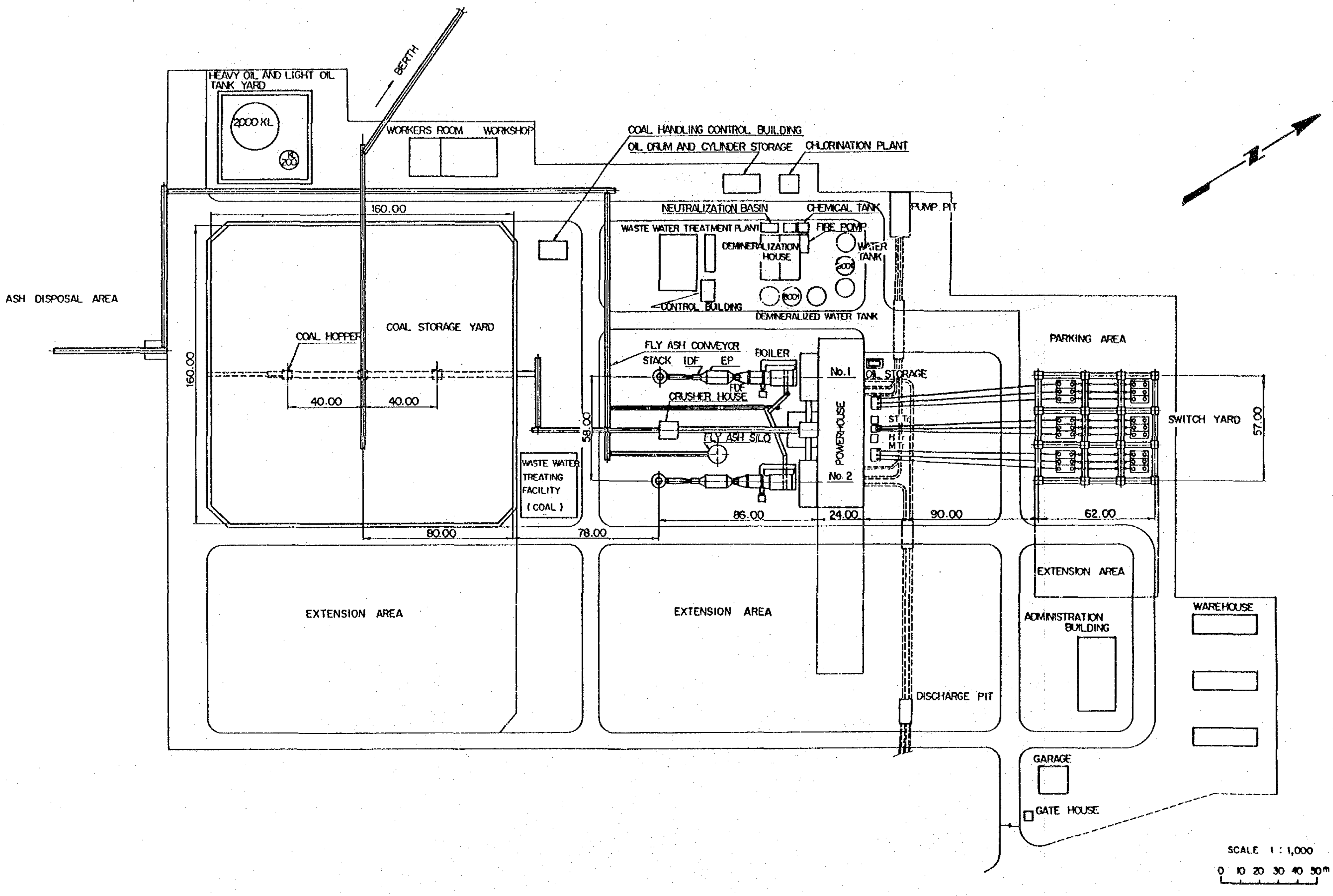
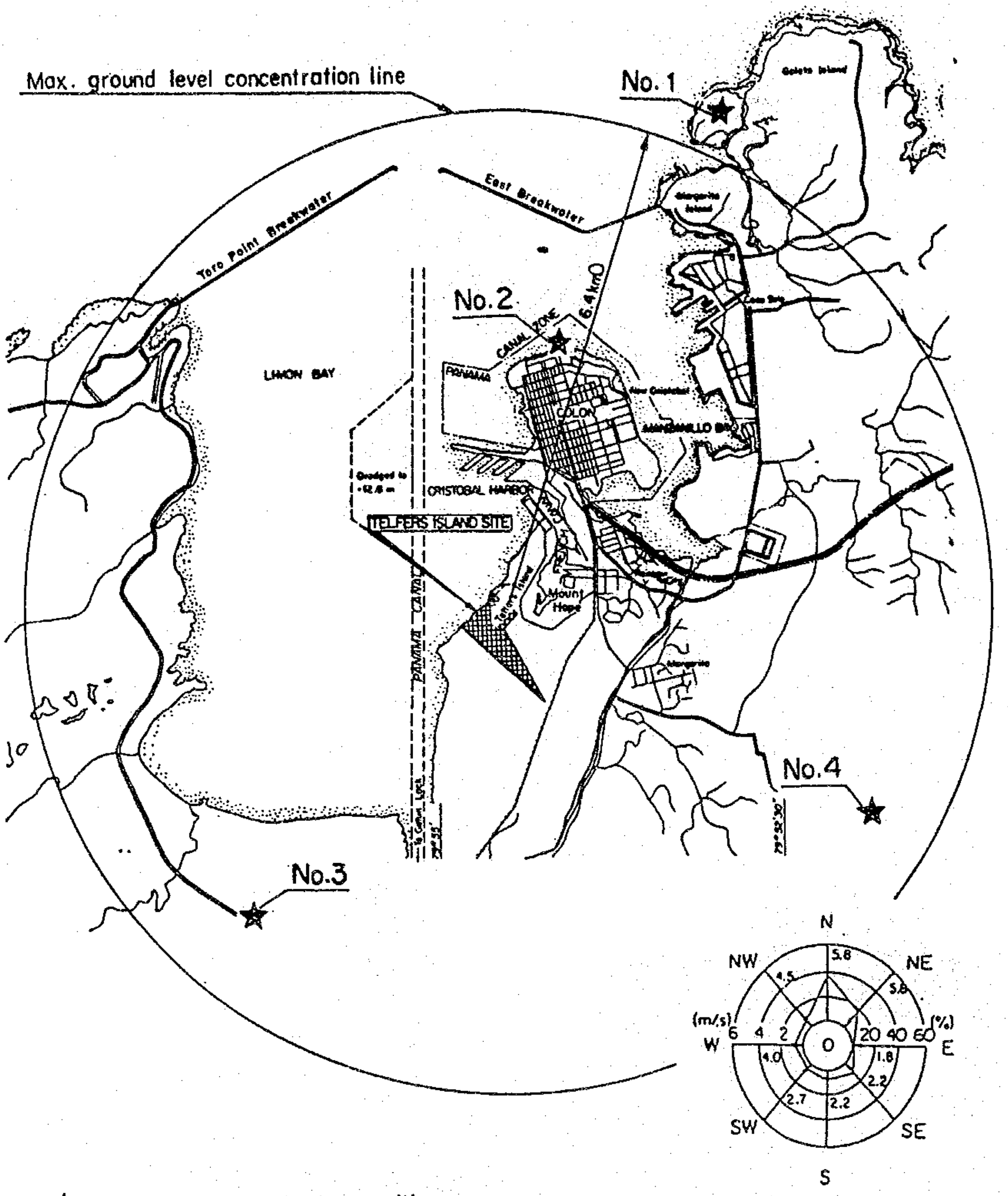


Fig. 1.7 Monitoring Position for Air Pollution



★ : Proposed monitoring position

Annual wind roses

CHAPTER 2 ECONOMIC BACKGROUND AND PRESENT CONDITIONS OF ELECTRICITY SUPPLY INDUSTRY

CHAPTER 2 ECONOMIC BACKGROUND AND PRESENT CONDITIONS OF ELECTRICITY SUPPLY INDUSTRY

2.1 NATURAL AND ECONOMIC BACKGROUND

2.1.1 Land and Climate

(1) Location

The Republic of Panama is located at the southern corner of the Central America between approximately latitudes 7°20'N and 9°60'N and longitudes 77°W and 83°W, having a total land area of 77,082 km^2. It is bounded in the east by the Republic of Colombia and in the west by the Republic of Costa Rica.

(2) Geography

The greater part of the country is mountainous areas bordered by long and narrow low-lands along the Caribbean Sea in the north and along the Pacific Ocean in the south. The highest points are in the west near Costa Rica, the Volcan Bar with peak rising up to 3,475 m in height. The eastern part of the country which extends from Panama province to the frontier with Colombia is scarcely developed, but fertile basins are scattered in the western half of the country from Panama city to the frontier with Costa Rica.

(3) Climate

The country is situated in a subtropical marine climate zone characterized by high temperature and high humidity. In the wet season which continues 8 months from May to December there are sometimes heavy rainfalls, but in the dry season which continues 4 months from January to April the climate is fairly moderate especially in the morning and evening. The annual precipitation is approximately 4,000 mm in the Caribbean coast and 2,500 mm in the Pacific coast. The annual average temperature is approximately 19°C in the mountainous areas and 28°C in the coastal areas. The humidity is fairly high at approximately 82% in the annual average.

(4) Population

The total population as of the end of 1984 was estimated at about 2,130,000 of which 510,000 people reside in Panama city and 122,000 in Colon city.

2.1.2 National Economy

(1) Economic Structure

The shares in GDP and in number of working population by sector can clearly express the country's economic structure. At present these shares are roughly estimated as follows:

Industry	Share in GDP	Share in working population
Primary	10%	25%
Secondary	18%	15%
Tertiary	72%	60%
Total	100%	100%

As shown above, the Panama's economy is characterized by heavy dependence on the tertiary industry (service sector). The share of service sector in GDP exceeds 70% and the working population engaged in this sector holds about 60% of the total working population of the country. With the Panama Canal, the Colon free trade zone and the free circulation of U.S. currency for a background, the country is steadily developing as the international financial center and also as the international trading base. This point is the most important characteristic of the Panamanian economy.

On the contrary, the primary and the secondary industries are still underdeveloped. As shown in Table 2.1.2, the contributions to GDP in 1984 of the primary and the secondary industries were only 10.1% and 17.5%, respectively.

(2) Main Products

The main products are refined petroleum and agricultural and marine products such as bananas, shrimps, sugar and coffee. The shares of agriculture, fisheries and stock farming in GDP are small but about

50% of the export amount is held by these agricultural and marine products.

As to industry, there are only oil-refinery and small-sized handicraft industries engaged in producing food, soft drink, gold and silver articles, tailoring and textiles, furniture and wooden products, cement blocks and floors for construction purposes.

(3) Growth in Economy

During the period from 1976 to 1980, emphasis of the Government policy were placed on the construction of infrastructure including roads, power stations, communication systems and housings, as well as, on the development of international trade and industries. Thus, during this period GDP in real terms grew rapidly at an average rate of 6.3% per annum in contrast to the growth rate of 4.7% per annum registered during the first half of the 1970's.

However, after 1980 the growth in national economy has become sluggish due to world-wide stagnation in economy which followed the second oil-crisis and affected by economic confusion of other Central and South American countries. In Panama also outstanding balance of external debt constitutes a serious problem and obliges the Government to restrain public investment. Thus, the average growth rate of GDP declined to 3.3% per annum during 3 years from 1980 to 1983, and in 1984 GDP decreased by 1.2% over the previous year.

Year	GDP at current prices (Millions of Balboas)	GDP at 1980 prices (Millions of Balboas)
1970	1,021.2	2,081.7
1975	1,840.8	2,620.9
1976	1,956.3	2,664.5
1977	2,069.8	2,693.7
1978	2,452.5	2,957.4
1979	2,800.2	3,091.0
1980	3,558.8	3,558.8
1981	3,878.0	3,707.6
1982	4,278.9	3,911.1
1983	4,379.4	3,926.7
1984	4,429.0	3,878.4

Annual average growth rate:

1970 - 1975	-	4.7%
1975 - 1980	-	6.3%
1980 - 1983	-	3.3%
1983 - 1984	-	-1.2%

(4) Actual Situation and Prediction

Due to increase in foreign borrowings and rise in international rate of interest, the financial deficit of the Government increased to 11% of GDP and the outstanding external debt amounted to about US$3,100 million (72% of GDP) in 1982, so the Government received in 1983 stand-by credit from IMF for 1983 and 1984 with its advise for financial improvement. Since then, the Government has endeavored to improve financial situation through drastic reduction of annual expenditure and postponement of public investment program. As the result, the ratio of financial deficit to GDP decreased to 5.2% in 1983 and 5.9% in 1984, but the outstanding balance of external debt still increased to US$3,400 million in 1983 and US$3,600 million in 1984.

It is difficult to predict future situation. But, when taking into account Panama's specific position as the international financial center and trading base, it is considered that the above-mentioned current financial difficulty will gradually be solved and the national economy will soon be restored to the past long-run growth trend.

2.1.3 Energy Resources and Policy

(1) Energy Resources

Recently, intensive investigations of inland and coastline (Gulf of Panama and Caribbean Sea) have led to some significant discoveries of oil in Veraguas, Eastern Darien and offshore San Blas island, but it is unknown whether these reserves are economically exploitable.

The only reliable indigenous energy resource is hydroelectric potential. According to investigations conducted by IRHE on 30 sites, the potential is estimated at approximately 7,200 MW with an annual energy generation of 40,400 GWh, mainly located in four provinces of Bocas del Toro (Rio Teribe and Rio Changuinola), Chiriqui, Veraguas and Darien. It is reported that of these potentials about ten sites of a total generating capacity of 2,500 MW with an annual energy generation of 10,000 GWh are considered feasible for development.

As of the end of 1986 the total installed capacity of IRHE's hydro power stations is 551.6 MW. This means that only about 22% of the total feasible potentials has been developed so far.

These energy situation, at least in the electric power sector, has an effect of exempting the country from heavy dependence on imported oil. However, attention should be paid to the fact that the development of hydro power projects requires in general very large investment to be financed locally and from abroad.

(2) Policy for Power Development

For the past 15 years from 1970 to 1984 the balance of payments has registered deficit every year except for 1976, 1978 and 1980. This situation, combined with huge amount of the outstanding external debt, has led the Government to pursue the policies of postponing the development of large scale hydro power projects and resorting to use of coal instead of oil for thermal power development from viewpoint of economy.

Table 2.1.2 GDP by Economic Sector (Current Prices)

(Millions of Balboas)

Economic sector	1980	1981	1982	1983	1984	Share (1984) (%)
1. Agriculture, forestry, stock farming and fisheries	354.1	401.1	413.0	434.4	442.1	10.0
2. Mining and quarrying	6.3	8.1	9.1	7.7	6.0	0.1
3. Manufacuring	371.2	375.5	401.2	401.8	405.9	9.2
4. Electricity, gas and water	109.1	119.8	132.0	147.6	149.5	3.4
5. Construction	253.4	273.6	345.0	242.0	218.1	4.9
6. Trade, restaurants, hotels	522.7	539.2	559.8	544.4	556.5	12.6
7. Transport and communication	780.9	863.3	1,016.5	1,128.2	1,100.3	24.8
8. Financing, insurance and buisiness services	463.1	519.2	563.4	597.4	624.4	14.1
9. Community and personal services	290.7	320.0	364.2	383.9	408.4	9.2
10. Government services	410.1	475.3	517.6	547.2	573.6	13.0
11. Domestic services	36.1	39.4	43.0	44.1	46.2	1.0
12. Import duties	57.3	59.1	66.2	74.4	71.6	1.7
13. (Less) Bank service charges	-96.2	-115.6	-152.1	-173.7	-178.6	-4.0
Total GDP	3,558.8	3,878.0	4,278.9	4,379.4	4,429.0	100.0
GDP at 1980 prices	3,558.8	3,707.6	3,911.1	3,926.7	3,878.4	
Growth rate over the previous year (%)	15.1	4.2	5.5	4.0	-1.2	

Note: Values shown in the above table were calculated from:

- International Financial Statistics (IMF) which show the total GDP at both the current prices and 1980 prices.
- Statistics published by the Banco Nacional de Panama which show sectorial GDP at 1970 prices.

2.2 ORGANIZATION OF IRHE

2.2.1 Historical Background

In 1961, in order to achieve an effective power development and electricity supply system the Government passed Law No. 37 by which IRHE was created. But, since then onwards up to 1978 the supply of electricity had been conducted jointly by IRHE and private electricity companies set up in various cities and towns. During the first stage IRHE had been engaged mainly in the electric power generation and the private electricity companies in the power distribution. However, with the development of IRHE's transmission line systems these individual entities were gradually incorporated to IRHE, i.e. Panama Electric Light and Power Company in 1972, Chiriqui Electricity Company and Santiago Electricity Company in 1973. And, with the incorporation of Chorrera Hydroelectric Company in 1978, IRHE became the single entity responsible for generation, transmission and distribution of electricity to all the consumers in the country.

2.2.2 Organization

IRHE is an autonomous governmental entity. Its statutory duty is to develop and maintain an efficient, coordinated and economical system of electricity supply for all parts of the country.

(1) Board of Directors

The supreme organ of IRHE is the Board of Directors which is constituted of nine members including related Ministers, Vice-Ministers, representatives of industrial trade-union, etc. The Board decides operational and financial policies, power development program, system expansion program and other important affairs.

(2) Headquarter

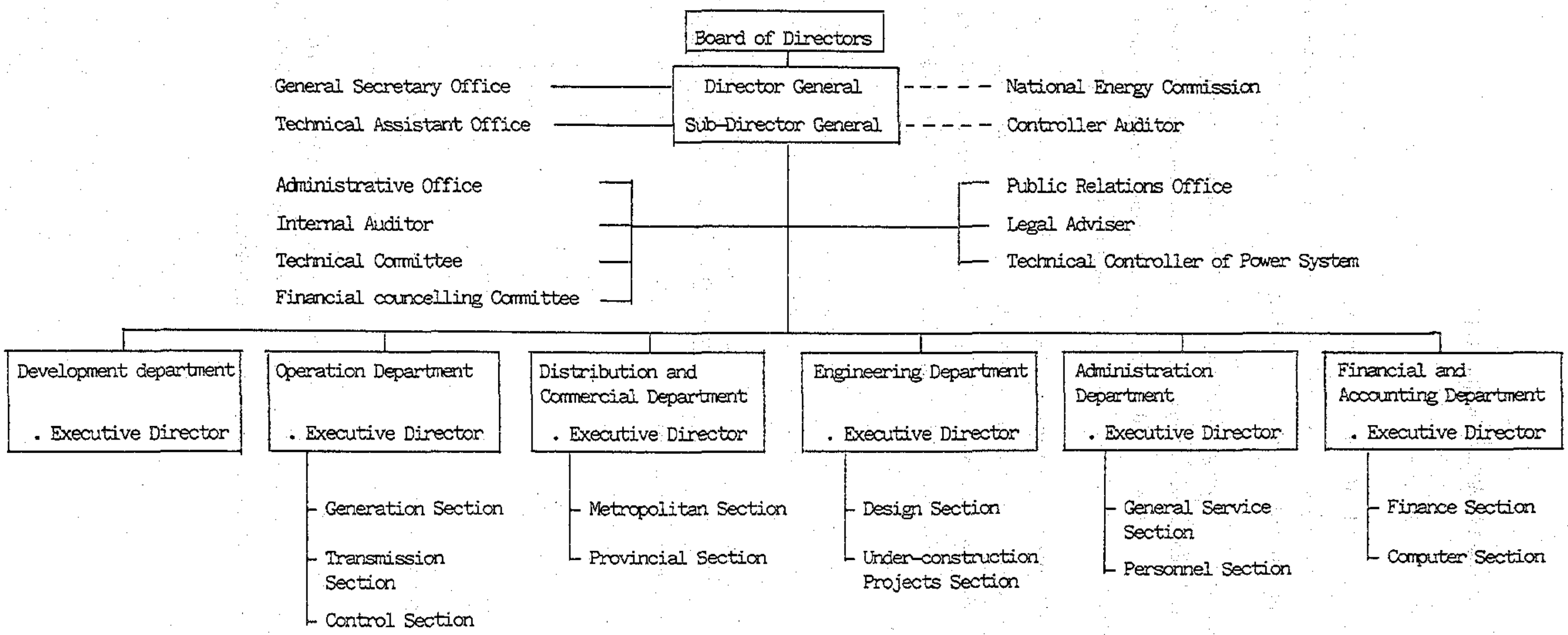
The daily business affairs are managed by Director General. The business operations are carried out by the following six functional Departments, each headed by an Executive Director:

- Administration Department
- Financial and Accounting Department

- Development Department
- Engineering Department
- Operation Department
- Distribution and Commercial Department

Detail of the above organization is shown in Fig. 2.2.2.

Fig. 2.2.2 Organization Chart of IRHE



2.3 EXISTING POWER FACILITIES

2.3.1 Power Station

As of the end of 1986, IRHE has a total installed generating capacity of 840.6 MW consisting of 551.6 MW of hydro power plants and 289.0 MW of thermal power plants - all connected to an integrated grid system.

Due to water storage limitation of Fortuna reservoir (Phase I) and fluctuation in seasonal river flows, the aggregated effective capacity of the hydro power plants and their energy generating capability are estimated to be 506.0 MW and 2,423.0 GWh, respectively.

Thermal power generating capacity, which consists of oil-fired power plant (144.0 MW), gas turbines (64.8 MW) and diesel power plants (80.2 MW) has been derated to 255.1 MW due to superannuation of steam and diesel power plants. Rehabilitation of No.2 unit of Bahia Las Minas power station is now on-going.

General characteristics of the existing power stations are as shown in Table 2.3.1 and summarized as follows:

Type of power plant	Installed capacity (MW)	Effective capacity (MW)	Energy generating capability (GWh)
Hydro power plant	551.6	506.0	2,423.0
Thermal power plant:			
Steam	144.0	134.5	995.0
Gas turbine	64.8	54.5	143.2
Diesel	80.2	66.1	351.2
Sub-total thermal	289.0	255.1	1,489.4
Grand total	840.6	761.1	3,902.4

Besides IRHE, the Panama Canal Commission (PCC) has its own power generating facilities consisting of 94.5 MW hydro and 115.5 MW thermal power plants, totalling 210.0 MW.

2.3.2 Transmission Network

Except for 150.0 MW Bayano power station, all other hydro power stations of a total installed capacity of 401.0 MW are located in Chiriqui province, while the majority of energy generated is consumed in Panama city and its surrounding area. Therefore, 230 kV double circuit transmission line from Bayano power station to Panama substation was constructed in 1976 and another 230 kV double circuit line from Mata de Nance substation to Panama substation via Llano Sanchez substation was constructed in 1979 to transport energy generated by Los Valles and La Estrella power stations to the Capital area. In 1984, this line was extended to Fortuna power station to complete an integrated National Grid System and also interconnected with Costa Rica power system through Progreso substation in Panama and Rio Claro substation in Costa Rica, both 230 kV substations.

Energy generated by Bahia Las Minas power station is transmitted to Panama substation by 115 kV 4 circuits transmission line. From three 230 kV substations of Panama, Llano Sanchez and Mata de Nance, power is transmitted to secondary substations by 115 kV transmission lines, then to all cities and towns through 13.8 kV distribution network.

Operation of Integrated National Grid System is controlled by Central Dispatching Center at Panama substation.

In the provinces of Bocas del Toro, San Blas, Darien, etc. the electricity supply is still conducted by isolated power systems. However, when taking into account the number of population and industrialization level of these areas, their integration to the National Grid System cannot be considered in the near future.

The transmission line diagram is shown in Fig. 2.3.2.

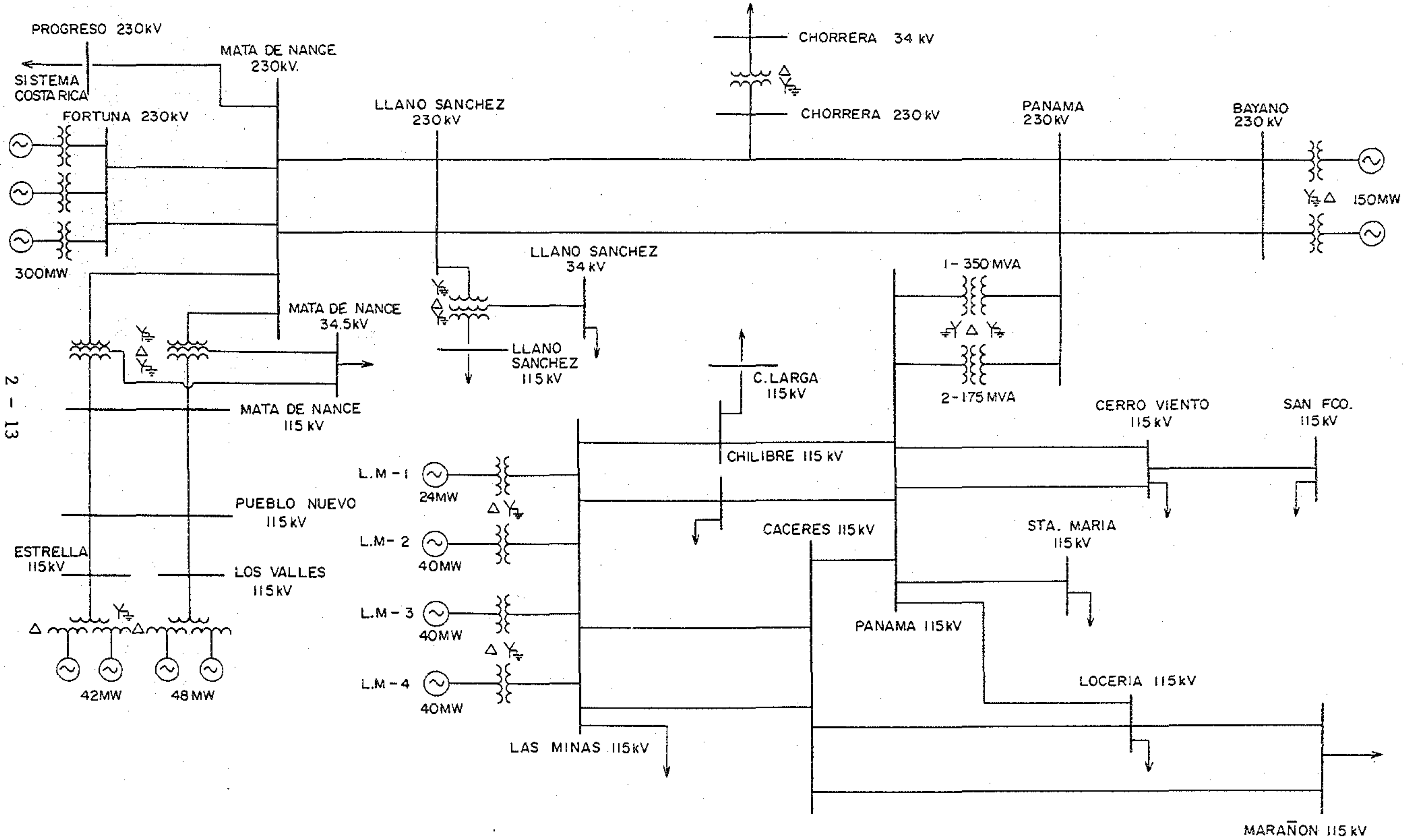
Table 2.3.1 Existing Power Stations

Power station	Unit cap. x Number (MW)	Installed capacity (MW)	Effective capacity (MW)	Annual generation (GWh)	Commissioning year
Hydro					
Bayano	75.0 x 2	150.0	150.0	605.0	1976
Los Valles	23.5 x 2	47.0	47.0	272.0	1979
La Estrella	21.5 x 2	43.0	43.0	237.0	1978
Fortuna	100.0 x 3	300.0	255.0	1,242.0	1984
Yeguada-Chiriqui	-	11.0	11.0	57.0	1967
Total hydro		551.0	506.0	2,423.0	
Thermal					
a) Steam					
Bahia Las Minas					
BLM 1	24.0 x 1	24.0	22.0	154.0	1964
BLM 2, 3, 4	40.0 x 3	120.0	112.5	841.0	1967,72,74
Sub-total		144.0	134.5	995.0	
b) Gas turbine					
Substation Panama	21.4 x 2	42.8	36.0	94.6	1983
Mount Hope	22.0 x 1	22.0	18.5	48.6	-
Sub-total		64.8	54.5	143.2	
c) Diesel					
San Francisco (PIEK)	7.0 x 4	28.0	24.0	171.7	1976
Diesel "GM"	2.5 x 11	27.5	20.0	122.6	1975
Chitre	-	12.4			1972
Capira	-	6.4	22.1	56.9	1972
Pto Armuelles	-	5.9			1961
Sub-total		80.2	66.1	351.2	
Mini hydro					
Coclesito	0.25 x 1	0.25	-	-	-
Santa Fe	0.35 x 1	0.35	-	-	-
Sub-total		0.6			
Grand total		840.6	761.1	3,902.4	

Note: No.3 and No.4 units (11.0 MW and 12.0 MW) of San Francisco power station are not included in the above table due to their superannuation (Commissioning year: No.3 in 1955 and No.4 in 1964).

Source: IRHE - Plan Maestro de Expansion - 1986.

Fig. 2.3.2 Transmission Line Diagram



2.4 POWER MARKET

2.4.1 Energy Generation and Peak Load

Table 2.4.1 shows the evolution of power market during the last 15 years. During this period energy generation grew from 838.0 GWh in 1970 to 1,811.7 GWh in 1980 and 2,346.4 GWh in 1985 at an average annual rate of 8.0% for the period from 1970 to 1980 and 5.3% for the period from 1980 to 1985, while peak load grew from 175.7 MW in 1973 to 305.5 MW in 1980 and 400.7 MW in 1985 at an average annual rate of 8.2% for the first 7 years and 5.6% for the last 5 years. Due to world-wide stagnation in economy which followed the second oil-crisis the growth in power demand after 1980 was fairly less rapid as compared with that in 1970's.

2.4.2 Energy Consumption and Rate of Access to Electricity

Energy sold grew from 710.3 GWh in 1970 to 1,472.4 GWh in 1980 and 1,944.1 GWh in 1985 at an average annual rate of 7.6% for the period from 1970 to 1980 and 5.7% for the period from 1980 to 1985.

Energy sold by category of consumers for the last 5 years is shown in Table 2.4.2. In 1985 the largest share of energy sold was to commercial use (31.4%) followed by shares to residential use (28.8%), public buildings use (23.0%) and other uses (16.8%).

As of the middle of 1985 the number of consumers was 276,445 of which residential consumers were 243,601 (88.1%) followed by commercial consumers (9.6%) and other consumers as shown below.

Category	Number of consumers
Residential	243,601 (Year-end: 249,232)
Commercial	26,618
Public buildings	2,797
Industrial	1,036
Others	2,393
Total	276,445

In 1985 the total population and number of households were estimated at approximately 2,190,000 and 436,100, respectively. Therefore, the rate of access to electricity was estimated to be 57.2% (249,232/436,100 = 0.572) for the country as a whole (83.2% in the urban area and 29.7% in the rural area).

2.4.3 Load Factor and Loss Factor

For the period from 1980 to 1985 the load factor varied from 64.0% to 66.8% with 65.8% in average, while the transmission and distribution loss factor was 16.7% in average, not including station service loss.

2.4.4 Average Rate per Unit Sold

Panama's energy pricing is made to balance social, economic and financial objectives. The structure and level of electricity pricing is set up to reflect long run marginal cost of supply. The level of domestic pricing of oil products for power generation (Bunker C and diesel oil) is fairly close to that of border prices. The tariff of electricity is classified into 9 categories.

The tariff consists of constant clause and fuel clause which is a surcharge varying with change in prices of fuel for power generation. The average rate per unit (kWh) sold for the last 15 years from 1970 to 1984 is as follows:

Year	Cent/kWh
1970	2.82
1971	2.94
1972	3.30
1973	3.48
1974	4.70
1975	5.62
1976	5.77
1977	7.05
1978	7.42
1979	7.90
1980	9.76
1981	10.63
1982	11.52
1983	12.68
1984	12.72

Table 2.4.1 Historical of Power Market

Year	Gross generation Hydro (GWh)	Gross generation Thermal (GWh)	Gross generation Total (GWh)	Net generation (GWh)	Import (GWh)	Total sent-out energy (GWh)	Energy sold (GWh)	Peak load (MW)	Load factor (%)	Loss factor * (%)
1970	83.7	753.4	838.0	793.3	8.5	801.8	710.3	–	–	11.4
1971	82.9	815.8	898.7	853.7	5.7	859.4	775.4	–	–	9.8
1972	82.9	924.5	1,007.4	958.6	21.8	980.4	869.8	–	–	11.3
1973	101.8	1,077.2	1,179.0	1,019.0	19.1	1,038.1	983.9	175.7	67.4	5.2
1974	105.5	1,093.0	1,198.5	1,103.8	17.3	1,121,1	980.7	188.3	68.0	12.5
1975	97.5	1,153.6	1,251.1	1,155.0	30.1	1,185.1	1,041.1	196.6	68.8	12.1
1976	138.3	1,269.9	1,408.2	1,314.0	9.1	1,323.1	1,143.1	227.6	66.4	13.6
1977	341.4	1,145.1	1,486.5	1,406.2	17.4	1,423.6	1,260.2	235.7	68.9	11.5
1978	718.9	782.8	1,501.7	1,438.9	10.4	1,449.3	1,268.2	252.1	65.6	12.5
1979	803.2	972.0	1,775.2	1,706.4	5.9	1,712.3	1,480.9	285.4	68.5	13.5
1980	963.5	848.2	1,811.7	1,754.3	2.1	1,756.4	1,472.4	305.5	65.6	16.1
1981	1,334.2	563.0	1,897.2	1,855.1	8.4	1,863.5	1,552.7	320.0	66.5	16.6
1982	1,074.3	1,013.8	2,088.1	2,027.0	3.5	2,030.5	1,673.3	362.2	64.0	17.6
1983	865.7	1,372.5	2,238.2	2,170.7	22.8	2,193.5	1,849.0	375.0	66.8	15.6
1984	1,491.5	719.1	2,210.6	2,167.2	60.8	2,228.0	1,816.6	385.8	65.9	18.4
1985	1,938.9	407.5	2,346.4			2,308.0	1,944.1	400.7	65.8	15.8
Annual growth rate:										
1970–1980			8.0 %				7.6 %	8.2 %		
1980–1985			5.3 %				5.7 %	5.6 %		

Source: Gross generation, net generation and sent-out energy ....IRHE – Plan Maestro de Expansion
Energy sold .... IRHE – departamento de Energia y Tarifas
* Transmission and distribution loss factor (not including station service loss).

Table 2.4.2 Energy Consumption by Category of Consumers and Rate of Access to Electricity

Item	1981	1982	1983	1984	1985
Energy consumption by category (GWh)					
Residential	474.6	499.0	527.9	521.6	559.6
Commercial	498.1	532.0	567.9	574.4	609.8
Industrial	188.4	218.0	218.8	228.7	252.4
Public building	281.2	287.4	311.3	337.2	326.6
Public lighting	32.7	34.7	36.8	37.1	37.7
Other systems	46.5	51.4	132.8	98.8	104.9
Sales in block	25.1	26.8	27.5	29.3	29.7
Total	1,522.7	1,673.3	1,849.0	1,816.6	1,944.1
Share (%)					
Residential	31.1	29.8	28.6	28.7	28.8
Commercial	32.7	31.8	30.7	31.6	31.4
Industrial	18.5	17.2	16.8	18.6	16.8
Public buildings & others	17.7	21.2	23.9	21.1	23.0
Total	100.0	100.0	100.0	100.0	100.0
Rate of access to electricity					
Total population	1,874,000	1,926,000	2,089,000	2,123,000	2,180,000
No. of families	374,800	385,300	417,700	426,800	436,100
Residential consumers	209,627	223,251	229,537	238,432	249,232
% of total population	55.9 %	58.0 %	55.0 %	55.9 %	57.2 %
Urban area	95.5 %	96.5 %	87.7 %	87.7 %	83.2 %
Rural area	17.2 %	20.2 %	21.2 %	22.6 %	29.7 %

Source: IRHE - Plan Maestro de Expansion - 1986

2.5 LOAD PATTERN

2.5.1 Typical Daily Load Curve

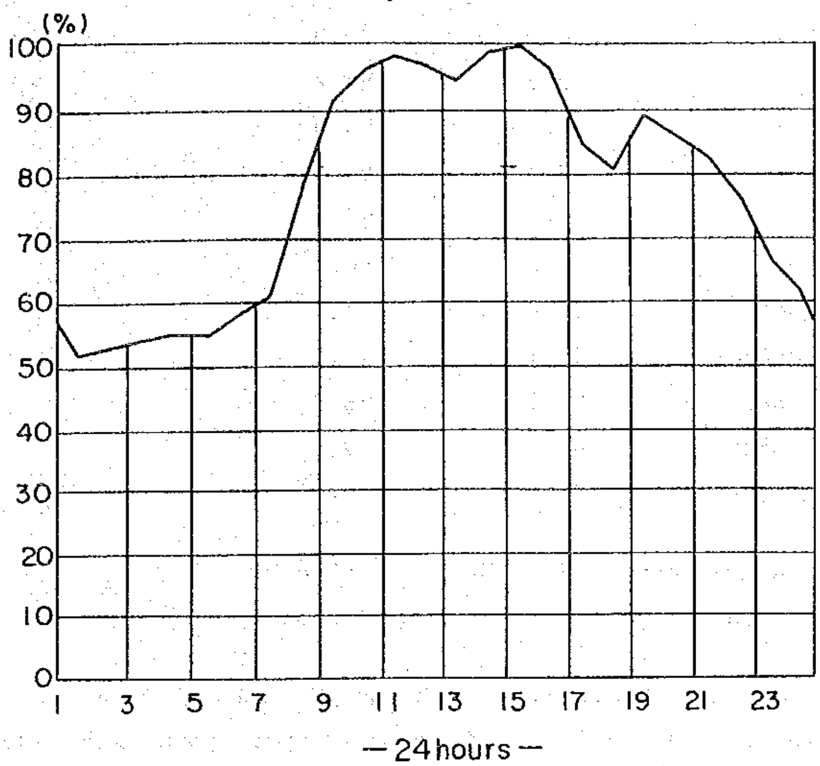
Both in the dry season and in the wet season, daily peak load occurs at around 12:00 to 15:00 hours due to air-conditioning. The second daily peak load which reflects lighting load occurs at around 19:00 to 21:00 hours. Load fairly falls down from mid-night to early morning. The minimum load is about 50 to 55% of the daily peak load.

From daily load curve of the 3rd Wednesday of January 1985, hourly variation of the load is calculated as follows:

Light load time		Heavy load time			
Hour	(%)	Hour	(%)	Hour	(%)
23.00	66.7	08:00	78.8	17:00	84.1
24:00	62.4	09:00	92.2	18:00	80.9
01:00	52.4	10:00	96.5	19:00	89.5
02:00	52.7	11:00	98.7	20:00	85.8
03:00	53.5	12:00	97.0	21:00	82.8
04:00	54.8	13:00	94.7	22:00	77.7
05:00	54.6	14:00	98.9		
06:00	58.9	15:00	100.0		
07:00	60.5	16:00	97.0		

Peak load: 372.0 MW (15:00 hour)
Minimum load: 195.0 MW (01:00 hour)
Daily load factor: 78.0%

Fig. 2.5.1 Typical Daily Load Curve-3rd Wednesday of January 1985



2.5.2 Variation in Monthly Peak Load

Because the temperature is almost constant during all year round, there is very small variation in monthly peak load. According to records for 1983 and 1984 its monthly variations are as follows:

Month	1983 (%)	1984 (%)
January	93.7	90.5
February	96.4	90.5
March	100.0	94.2
April	99.8	94.9
May	97.8	95.8
June	97.8	96.6
July	98.2	96.3
August	96.3	97.9
September	91.1	97.9
October	95.1	98.9
November	95.5	99.8
December	95.0	100.0

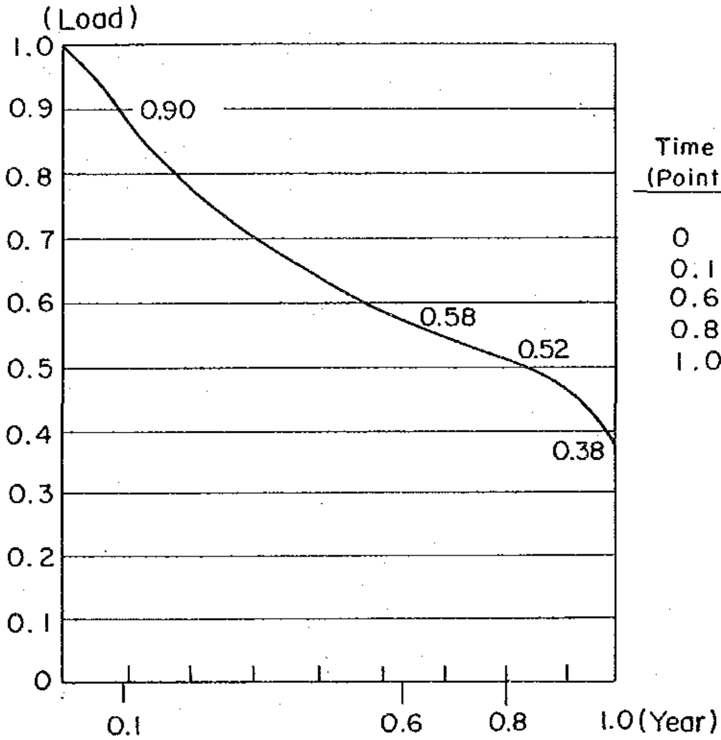
- Annual maximum: 375.0 MW 385.8 MW
- Peak month : March December

The above situation means that the annual peak load may occur in any month of the year, even in the month when aggregated hydro power generating capacity drops down to the lowest.

2.5.3 Annual Load Duration Curve

According to IRHE's system study the annual load duration curve is expressed in the following manner:

Fig. 2.5.3 Load Duration Curve



Time (Point)	Load (Point)
0	1.00
0.1	0.90
0.6	0.58
0.8	0.52
1.0	0.38

CHAPTER 3 LOAD FORECAST AND POWER DEVELOPMENT PROGRAM

CHAPTER 3 LOAD FORECAST AND POWER DEVELOPMENT PROGRAM

3.1 LOAD FORECAST

3.1.1 Methodology

Power demand forecast made on a micro-economic framework through investigations of growth trend in the past, sanctioned industrial and social development projects in the future by category of consumers is considered suitable for short-term planning. However, for medium and long-term planning it will be appropriate to use the following macro-economic method for power demand forecasting.

(1) First Approach

In general, the demand function for a given commodity consists of prices and income specified as follows:

$$Di = f(Pi, Pw, Y)$$

Where

Di: demand for the i th commodity
Pi: price of the i th commodity
Pw: prices of other commodities represented by integrated general price indices
Y : income of consumers

Since demand functions are homogeneous of degree zero in terms of prices and income, this equation can be rewritten as follows:

$$Di = f(Pi/Pw, Y/Pw)$$

This means that demand for i th commodity is a function of the relative price of the commodity, and of income in real term. The demand function for electricity takes the same form.

Table 3.1.1 shows annual energy sold, deflated GDP and deflated average rate per unit sold at 1980 prices for the period from 1970 to 1984. Based on this table, the following multiple regression equation is obtained:

$$Y = -387.4 + 0.27551\, x_1 + 98.93\, x_2$$

Where: Y : energy demand (GWh)

x_1 : income of consumers expressed by GDP (B/.million)

x_2 : average rate per unit sold (Cent/kWh)

In the above equation, it is noted that the regression coefficient of x_2 (average rate per unit sold) takes positive value instead of negative value. This is not available theoretically. Therefore, the above equation cannot be used as the method for power demand forecast in spite of its high correlation coefficient.

(2) Second Approach

When the values of GDP and energy consumption given in Table 3.1.1 are respectively plotted on a graph, taking GDP on the abscissa and energy consumption on the ordinate, two upward trend curves can be found. The one is regular trend curve for the period 1970-1979, and the other is fairly irregular trend curve for the period 1980 - 1984. There is a week continuity between these two curves. For upwars curve, a quadratic regression equation shown below is suitable.

$$y = a + b_1 x + b_2 x^2$$

Where: y : energy demand

x : GDP

a : constant

b_1 and b_2 : regression coefficients

The regression coefficients b_1 and b_2 can be obtained from the following simultaneous equations by using the least square method:

$$S_{11} b_1 + S_{12} b_2 = S_{1y}$$

$$S_{12} b_1 + S_{22} b_2 = S_{2y}$$

Where: $S_{11} = \Sigma x_i^2 - (\Sigma x_i)^2/n$ (n: number of years)

$$S_{22} = \Sigma (x_i^2)^2 - (\Sigma x_i^2)^2/n$$

$$S_{12} = \Sigma x_i^3 - (\Sigma x_i)(\Sigma x_i^2)/n$$

$$S_{1y} = \Sigma x_i y_i - (\Sigma x_i)(\Sigma y_i)/n$$

$$S_{2y} = \Sigma x_i^2 y_i - (\Sigma x_i^2)(\Sigma y_i)/n$$

The constant "a" is calculated by the following equation:

$$a = \overline{y} - b_1\overline{x} - b_2(\overline{x^2})$$

By using the given data, the following three quadratic regression equations are obtained:

a) Period 1970-1979: $y = -160.58 + 154.45\ x + 119.92\ x^2$ $R^2 = 0.94$

b) Period 1980-1984: $y = -645.44 + 404.15\ x + 54.29\ x^2$ $R^2 = 0.71$

c) Period 1970-1984: $y = -1,513.50 + 1,302.12\ x - 120.23\ x^2$

where, y : Energy demand (GWh)

x : GDP (B/. billion)

R^2 : Multiple correlation coefficient

Of the above, the equation c) is not suitable for use because the demand curve obtained by this equation becomes parabolic and, beyond a certain point, the growth in GDP has an effect of decreasing the power demand. The equation b) is also unsuitable for use due to short period of data and low correlation coefficient. Therefore, the equation a) has been used for power demand forecast taking account of the long period of data (10 years) and high correlation coefficient.

3.1.2 Conditions of Parameters

In order to forecast power demand by using the above-mentioned regression model, some predictions must be made. They are the following.

(1) Growth in GDP

In the recent years, the annual average growth rate of GDP was very low, namely 3.3% for hte period 1980-1983 and 2.2% for the period 1980-1984. Further, in 1984 GDP decreased by 1.2% over the previous year. GDP in 1985 and 1986 are unknown but, taking into account the economic growth for the previous years and the policy of austerity by the government, the following growth rate has been estimated:

	1985-1987	1987-1995
Optimistic	No growth in real time	3.2%
Moderate	"	3.0%
Conservative	"	2.8%

(2) Transmission and Distribution Loss Factor

As stated in section 2.4.3, the transmission and distribution loss factor for the last 6 years from 1980 to 1985 was 16.7% in average.

In this study, the transmission and distribution loss factor for the period from 1986 through 1995 shall be estimated as follows:

Year	Loss factor (%)
1986	17.0
1987	15.5
1988	15.5
1989	15.5
1990	15.5
1991	16.0
1992	16.0
1993	16.0
1994	16.0
1995	16.0

(3) Load Factor

Section 2.4.3 describes also that for the above period from 1980 to 1985 the average system load factor was 65.8%, so a load factor of 66% shall be used for calculating peak load from net generation.

3.1.3 Result of Load Forecast

Results of the three forecasts, i.e. optimistic, moderate and conservative load forecasts are given in Table 3.1.3. Of these three forecasts, the moderate forecast shall be used as the basis for power development planning.

The result of JICA's moderate load forecast is very close to IRHE's load forecast as shown below.

Year	JICA's load forecast (MW) (A)	IRHE's load forecast (MW) (B)	Difference (A)/(B)
1990	539.0	548.5	0.983
1991	571.0	580.9	0.982
1992	598.0	615.1	0.972
1993	642.0	651.4	0.986
1994	676.0	689.8	0.980
1995	718.0	730.6	0.982

Comparison of these three alternative load forecasts is shown in Fig. 3.1.3.

Table 3.1.1 Basic Parameters for Load Forecasting

n	Year	Energy sold (GWh)	GDP (Millions of Balboas) Current prices	Deflater (1980=100)	1980 prices	Average rate per unit sold (Cent/kWh)	Consumers price index (1980=100)	Deflated average rate (Cent/kWh)
1	1970	710.3	1,021.2	47.1	2,081.7	2.82	50.8	5.55
2	1971	775.4	1,151.9	50.5	2,281.9	2.94	51.8	5.68
3	1972	869.8	1,264.9	53.0	2,386.5	3.30	54.6	6.04
4	1973	983.9	1,446.8	57.5	2,514.5	3.48	58.4	5.96
5	1974	980.7	1,654.1	64.2	2,576.0	4.70	68.2	6.89
6	1975	1,041.1	1,840.8	70.2	2,620.9	5.62	71.9	7.82
7	1976	1,143.1	1,956.3	73.4	2,664.5	5.77	74.8	7.71
8	1977	1,260.2	2,069.8	76.8	2,693.7	7.05	78.2	9.02
9	1978	1,268.2	2,452.5	82.9	2,957.4	7.42	81.4	9.12
10	1979	1,480.9	2,800.2	90.6	3,091.0	7.90	87.9	8.99
11	1980	1,472.4	3,558.8	100.0	3,558.8	9.76	100.0	9.76
12	1981	1,552.7	3,878.0	104.6	3,707.6	10.63	107.3	9.91
13	1982	1,673.3	4,278.9	109.4	3,911.1	11.52	111.9	10.29
14	1983	1,849.0	4,379.4	111.5	3,926.7	12.68	114.3	11.09
15	1984	1,816.6	4,429.0	114.2	3,878.4	12.72	116.1	10.96
Median								
1970 - 1984		$\bar{y}$ = 1,258.5			$\bar{x}_1$ = 2,990.0			$\bar{x}_2$ = 8.31
1975 - 1984		$\bar{y}$ = 1,455.8			$\bar{x}_1$ = 3,301.0			$\bar{x}_2$ = 9.47
1980 - 1984		$\bar{y}$ = 1,672.8			$\bar{x}_1$ = 3,796.5			$\bar{x}_2$ = 10.40
Average annual growth rate								
1970 - 1983		7.6 %			5.0 %			5.5 %
1975 - 1983		7.4 %			5.2 %			4.5 %
1980 - 1983		7.9 %			3.4 %			4.4 %

Source: Energy sold and average rate per unit sold ...... IRHE - Departamento de Energia y Tarifas
GDP, GDP deflater and CPI ..... Financial Statistics (IMF)

Table 3.1.3 Load Forecast

Year	GDP at 1980 prices (Billion B/.)	Energy sold (GWh)				Net generation (GWh)	Peak load	IRHE's forecast	Difference JICA/IRHE
		154.45 x	119.93 x^2	Constant	Total				
	x_1				y		A	B	A/B
1984	3.878								
Optimistic									
1987	4.779	981.02	1,082.49	-160.58	2,242.0	2,661.3	460.0		
1989	5.198	1,067.04	1,280.63	-160.58	2,522.9	2,985.7	516.0		
1991	5.666	1,163.11	1,521.61	-160.58	2,839.6	3,360.5	581.0		
1993	6.187	1,270.06	1,814.31	-160.58	3,195.4	3,804.0	658.0		
1995	6.757	1,387.07	2,164.00	-160.58	3,595.1	4,279.9	740.0		
Moderate									
1986	4.503	924.37	961.07	-160.58	2,088.0	2,522.9	436.0	430.6	1.013
1987	4.683	961.32	1,039.42	-160.58	2,242.6	2,661.3	460.0	462.7	0.994
1988	4.870	999.71	1,133.60	-160.58	2,369.4	2,820.5	487.0	485.8	1.002
1989	5.065	1,039.74	1,215.93	-160.58	2,504.6	2,967.5	513.0	517.9	0.991
1990	5.268	1,081.41	1,315.36	-160.58	2,648.0	3,110.7	539.0	548.5	0.983
1991	5.489	1,126.78	1,428.03	-160.58	2,939.4	3,298.8	571.0	580.9	0.982
1992	5.720	1,174.19	1,550.74	-160.58	2.958.1	3,460.1	598.0	615.1	0.972
1993	5.960	1,223.46	1,683.64	-160.58	3,126.7	3,718.2	642.0	651.4	0.987
1994	6.210	1,274.78	1,827.82	-160.58	3,904.5	3,904.5	676.0	689.8	0.980
1995	6.471	1,328.36	1,984.71	-160.58	4,152.1	4,152.1	718.0	730.6	0.982
Conservative									
1987	4.589	942.03	998.13	-160.58	2,242.0	2,661.3	460.0		
1989	4.935	1,013.05	1,154.32	-160.58	2,486.4	2,942.5	509.0		
1991	5.317	1,091.47	1,339.94	-160.58	2,757.9	3,263.8	565.0		
1993	5.740	1,178.30	1,561.62	-160.58	3,058.8	3,641.4	630.0		
1995	6.197	1,272.11	1,820.18	-160.58	3,392.4	4,038.5	689.0		

Fig. 3.1.3 Comparison of Load Forecasts (Conservative, Moderate and Optimistic)