No. 2

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

CEYLON ELECTRICITY BOARD (CEB)
THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

THE FEASIBILITY STUDY ON COMBINED CYCLE POWER DEVELOPMENT PROJECT AT KERAWALAPITIYA,

THE DEMOCRATIC SOCIALIST REPUBLIC OF SRI LANKA

FINAL REPORT (SUMMARY)

JANUARY 1999

TOKYO ELECTRIC POWER SERVICES CO., LTD.

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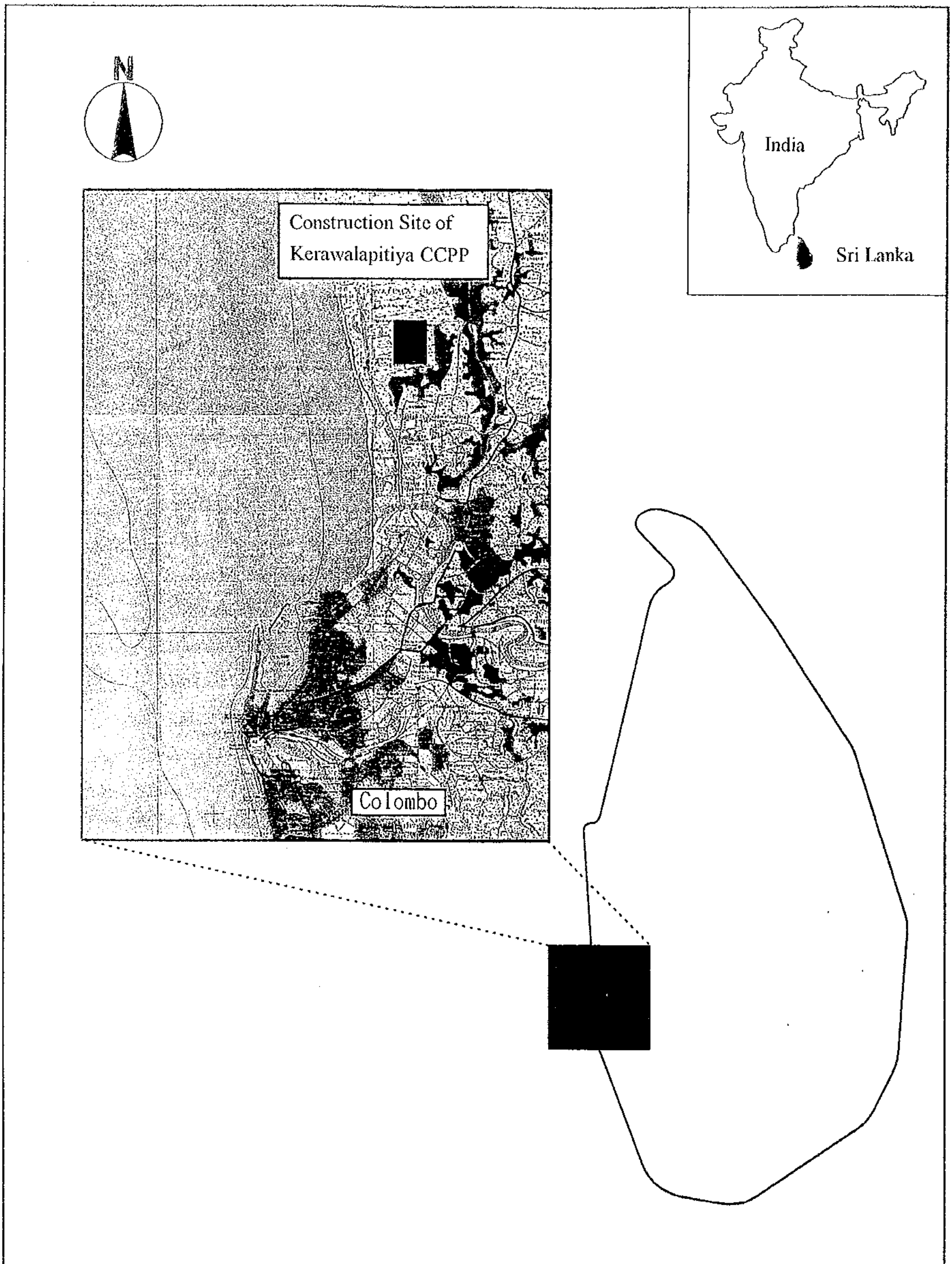
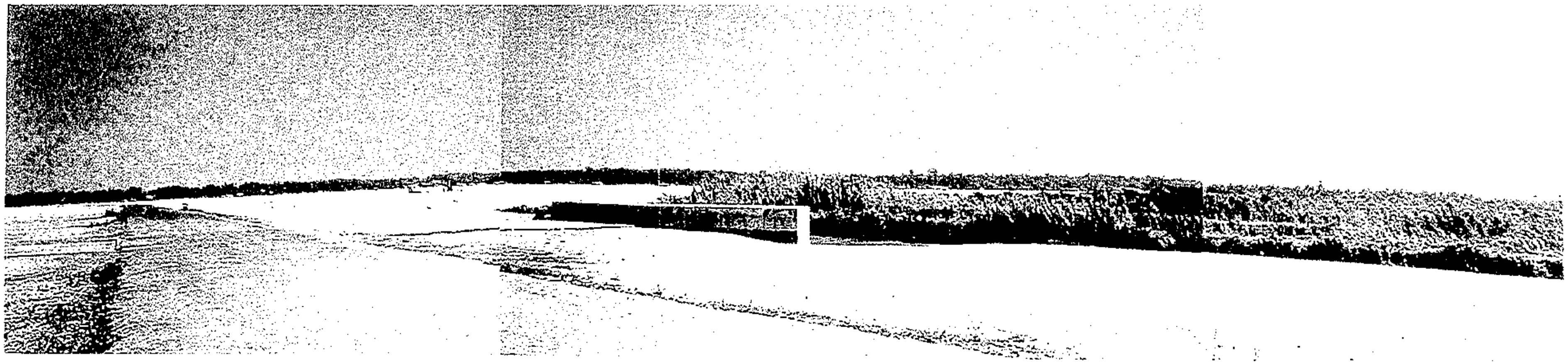
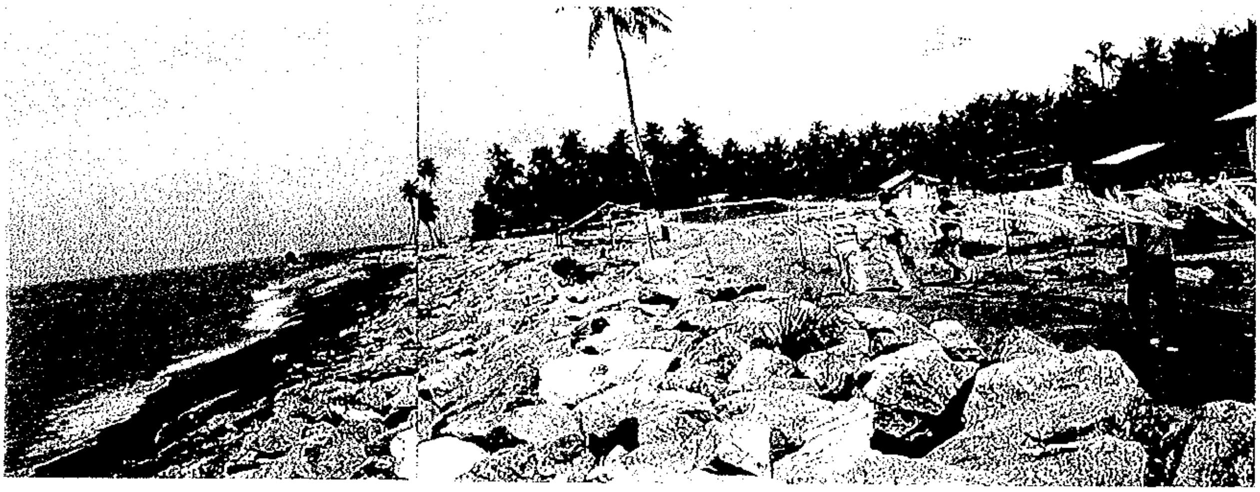


LOCATION MAP OF THE PROJECT SITE

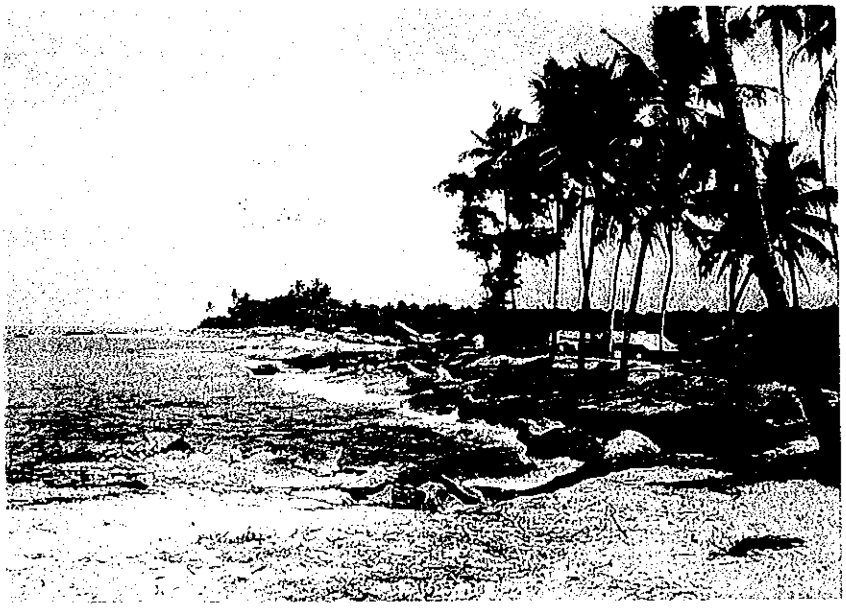
The proposed Power Plant Site at Kerawalapitiya
(The reclaimed land)



Access Road and Intake/Discharge Water Pipeline Route in the reclaimed land

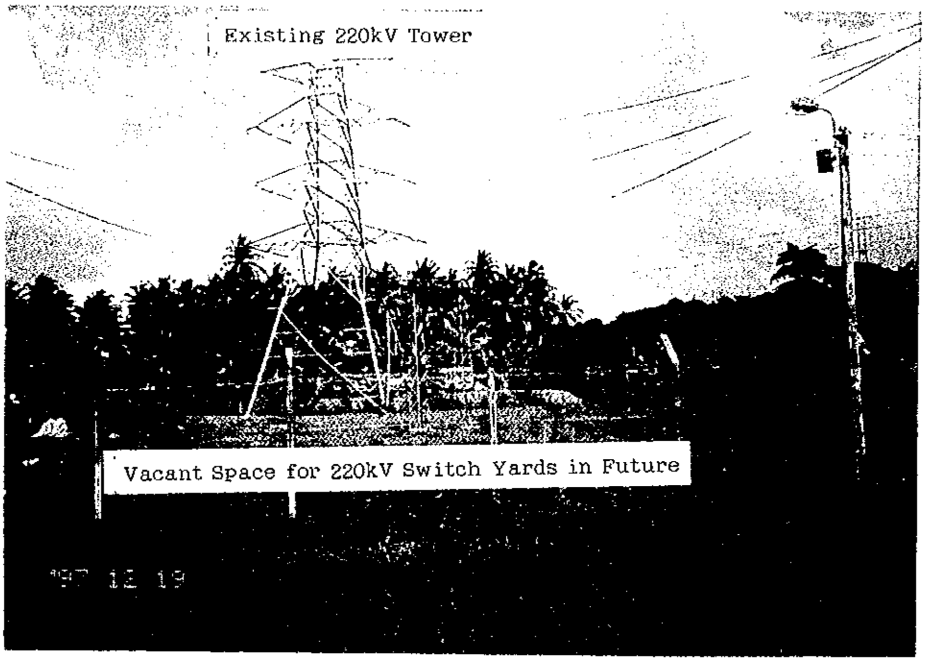


The Situation of Coast near the Site

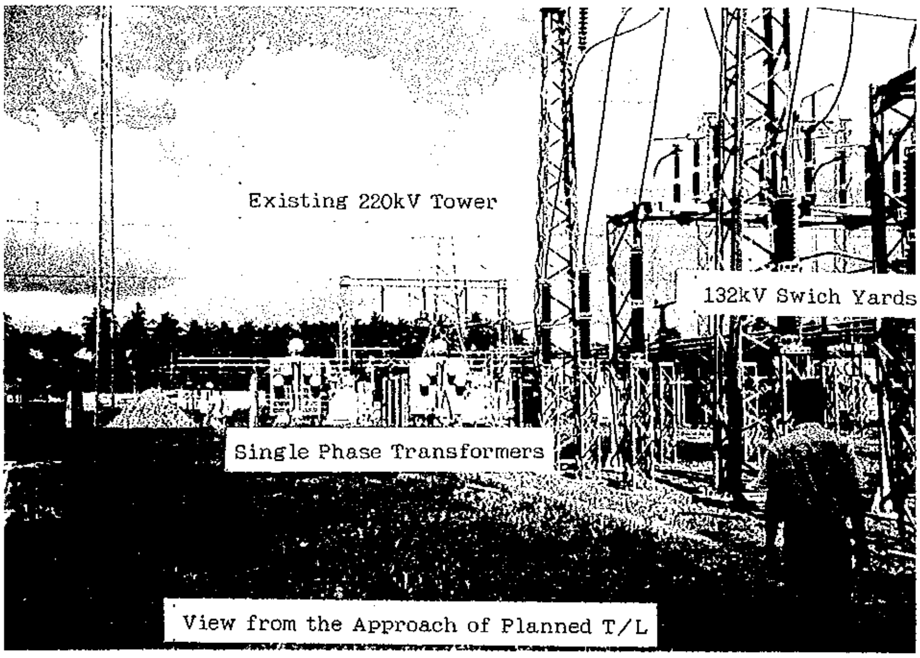


Intake/Discharge Water Pipelines Route at Coast

Sea Condition in December



New Transmission Line Route near Kotugoda Substation



Kotugoda Substation

The Feasibility Study
on
Combined Cycle Power Development Project
at
KERAWALAPTIYA
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1. INTRODUCTION

1. INTRODUCTION

1.1 Background and Process of the Study

1.1.1 Demand for Electricity in Sri Lanka

In Sri Lanka, Long Term Generation Expansion Planning Studies(LTGEPS) have been formulated by Central Electricity Board(CEB) that has been executing integrated services ranging from development of power sources to transmission and distribution. According to the LTGEPS and other data, demand and supply of electricity in Sri Lanka is presented as below.

① Main electric generation is hydroelectric and subordinate is thermal. Main hydroelectric power stations have been already developed and water flow from some rivers is concurrently used for power generation and irrigation.

② All fuels for thermal power generation are imported. Rather heavy oil, such as residual oil, heavy oil, heavy diesel oil are applied.

③ The power demand increases at an annual average of 7.8% for these 20 years.

④ Significant deterioration in performance on the existing thermal power stations is envisaged.

1.1.2 Request for the Study

In view of the situations described above, CEB intends to promote modernization of the power facilities through introducing coal-fired thermal power plant and combined cycle(c/c) power plant by 2004, in order to meet power demand in the future and improve the prevailing tight situations of electric power demand and supply during a period of water shortage.

The Government of Sri Lanka gave a top priority to the project and requested the Government of Japan to conduct the feasibility study(hereinafter to be referred to as F/S) on development of C/C power plant of 150MW class.

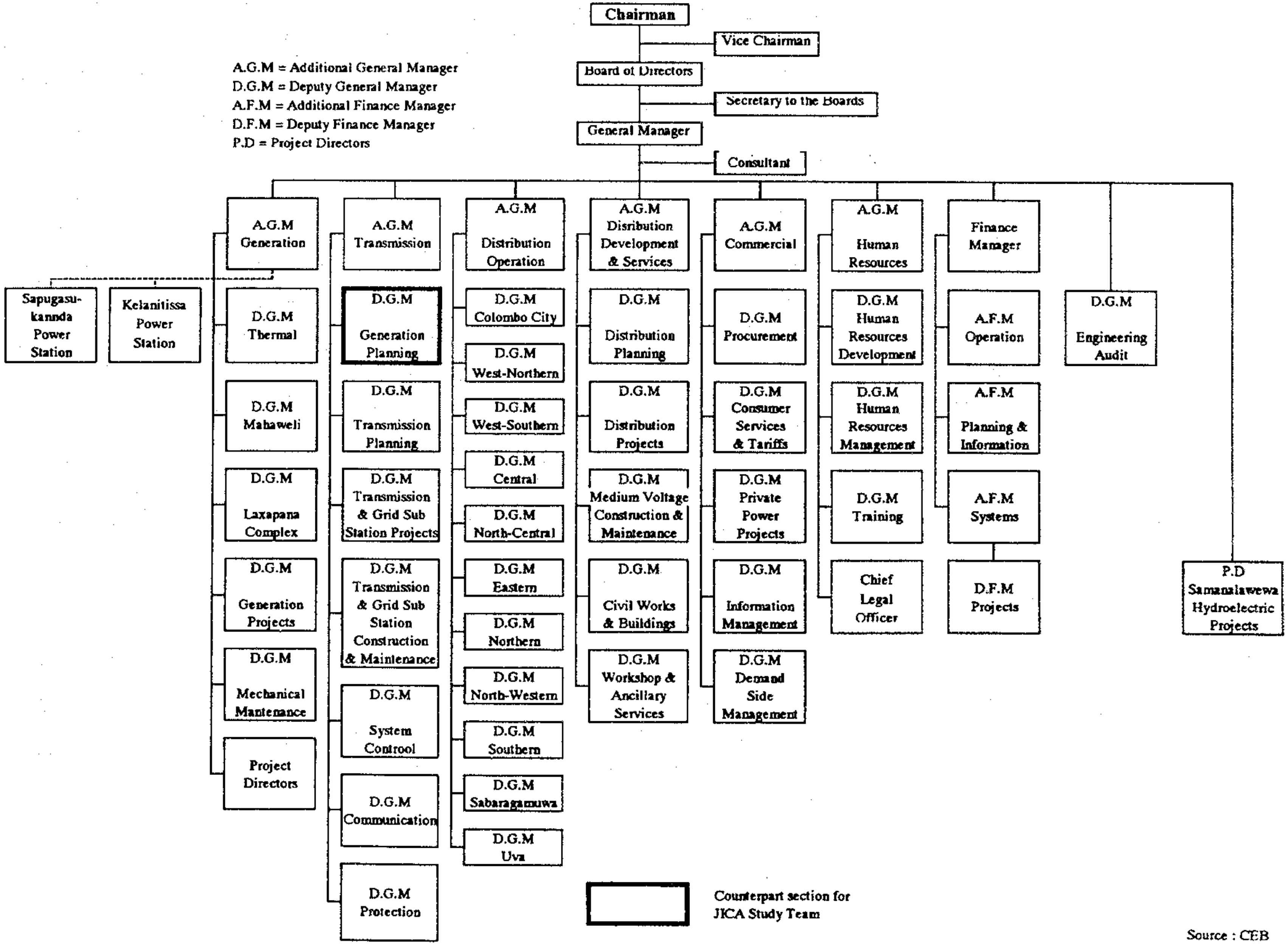
Financing for this Project is expected to be the BOO or BOT scheme based on investment from private investors or the loan from OECF or World Bank. In this Project, the establishment of fuel supply is the key point and it

should be studied from various aspects.
JICA dispatched the Preliminary-Study Team in July 1997.

1.1.3 Organization of the Counterpart

The counterpart of the Study is Ceylon Electricity Board (hereinafter called CEB) belonged to Ministry of Irrigation and Power. Headquarter of CEB is located in Colombo city and is government organization supplying the electricity to the all over the country.
Figure 1-1 shows the organization of CEB.

Figure 1-1 Organization of Ceylon Electricity Board (CEB)



Source : CEB

1.2 Purpose, Outline, Scope and Period of the Study

1.2.1 Purpose

The purpose of the study is to conduct F/S including environmental impact assessment(EIA) for Kerawalapitiya C/C plant project and technology transfer to CEB's personnel concerned.

The optimum power plant plan should be established, to make it possible that the plant is to be put into operation in 2001.

1.2.2 Study location

The project site is located in the Kerawalapitiya area, 8 km away from the Colombo Port. The site is in the industrial area where was reclaimed over swamp. The main facilities will be power plant, fuel equipment, sea water intake and discharge channel, and transmission line to sub-station in the study location.

EIA on the ambient air shall cover the area 10km from the boundary of the site, and on other items 2km.

1.2.3 Outline and Scope of the Study

This study is to be carried out based on the S/W between JICA and CEB agreed upon on July, 16, 1997. The study items are as follows.

(1) Study item

a. Review of Thermal Generation Option study (TGOS) and Long Term Generation Expansion Planning Studies(LTGEP)
b. F/S grade design of C/C power plant
c. EIA
d. Economic and financial analyses
e. Technology transfer on the above items

(2) Scope of the Study

The study was carried out at three stages as shown below.

① Preliminary Study Stage
② Feasibility Grade Design and EIA Stage
③ Financial and Economic Analysis Stage

The studies to be executed were included the following items at each stage with the scope of their services ;

a. Preliminary Study Stage

(a) General planning

1) Data collection and confirmation of CEB requirement
Collection of existing data, reports and other relevant information on the project, including topographic, geological and hydrological, meteorological, oceanographical and socio-economic data

2) Review and analysis of the existing data and reports
Review of the studies of the Thermal Generation Option Study (TGOS) completed in July 1996 and the subsequent studies by CEB to be due in August 1997, and the Long Term Generation Planning study report (LTGEP) carried out by CEB, and to this project in particular ;

- Review of the overall development plan of the project including selection of unit size
- Review of the overall implementation time schedule
- Review of appropriate fuel type to be used for the plant with the procurement aspects and delivery systems

3) Establishment of conceptual site layout

4) Preliminary site investigations and preparation of the tender specification for physical investigation at site and environmental study where necessary

(b) Review of the power system expansion planning including power transmission lines and substations, and assist CEB if necessary in the power system integration analysis for aligning the new power plant into the grid including ;

- Power flow analysis
- Fault analysis
- Steady-state stability analysis
- Optimization study of hydro/thermal plant operation

(c) Physical investigation of the site
Physical site investigation necessary for feasibility grade design and detailed cost estimates of the project including ;

1) Supplementary survey for site specific civil works
   - Meteorological investigations on land and sea (wind, rainfalls, tide, seawater temperature, etc.)
   - Topographic investigations (land survey and mapping, subsea topology if necessary, etc.)
   - Hydrographic investigations
   - Geotechnical investigations (subsurface explorations including drilling works, test pitting and seismic prospecting if necessary, etc.)
   - Oceanographic investigations (ocean current and wave height measurement, etc. and mapping, if necessary)
   - Pipe line route and water supply investigations (cooling water and fresh water)
   - Rehabilitation of the existing and/or if necessary new installations of oceanographical gauging stations

2) Investigations of surrounding development activities, existing infrastructure, and other conditions relevant to the development of the project comprising ;

   - Social, socio-economic and environmental consequences of project development and recommendation of protective measures to be taken, if necessary

- Construction costs for land acquisition (including unloading method) for delivery of fuel, equipment and construction materials
- Availability and quality of construction materials, and their procurement aspects, etc.

b. Feasibility Grade Design and EIA Stage

With evaluation and analysis of the data and information from the studies at the Preliminary Study Stage, the optimum plan or alternative plans will be prepared comprising ;

(a) Plant design and engineering

1) Technical design and engineering for all components of the project through developing optimized designs on thermal/mechanical systems (including numbers of gas turbines and heat recovery steam generators systems) and equipment/facilities layouts, etc., and provisions of key drawings and bill of materials, and those with each justification of the technical option selected as being necessary for feasibility study including finalization of ;

   - plant type and size including unit size
   - fuel type, procurement aspects and delivery system
   - cooling water and feed water systems
   - switchyard arrangements

2) Detailed project cost estimates comprising construction, operation and maintenance with cash flows in foreign and local currencies, and procurement through either international or local competitive bidding as required.

3) Environmental Impact Study (EIA) for the power plant and transmission lines, etc.,

The aspects of environmental impacts will be examined, in keeping with the requirements for environmental clearance from the Project Approving Agency in Sri Lanka can be obtained, and these studies may generally comprise ;

- Investigation of houses, roads, land utilization and various rights to be compensated in the study areas
- Existing environment-physical and biological systems
- Existing environment-human, economic and socio-economic aspects
- Construction impacts and mitigation measures
- Operational impacts and mitigation measures

c. Economic, Financial Analysis Stage

(a) Economic, financial and comparison studies

The economic study will evaluate the project in view of the near and long term generation planning prepared by CEB, and compare the economic and technical feasibility of locating a combined cycle plant at Kerawalapitiya such as taking into consideration the future extension stage of Kelanitissa Power Station of BOO/BOT scheme under discussion and a new 300 MW coal fired power plant envisaged to be commissioned before the year 2004, etc.

1) Economic evaluation with cost-benefit analysis (EIRR)

2) Financial evaluation based on the present worth comparison of different alternatives for reasonable range of discount rates (FIRR)

(b) Sensitivity

The sensitivity studies will test effects of changes in construction costs, load forecasts, construction periods, fuel choices and their costs (naphtha and/or heavy diesel, domestic and import), interest rates, etc.

(c) Formulation of recommendation

For each of alternatives, description will be made on the advantages, disadvantages and risks which cannot be quantified. All definitions and comparisons of the alternative optimal plan will be accurate enough to allow decision-making on the priority of the recommended optimal plan as compared to other projects likely under planning at the time of the Study.

(3) Period of the study

The studies will be executed by the following three (3) stages

a. Preliminary Study Stage : November 1997 to February 1998
b. Feasibility Grade Design and EIA Stage : March 1998 to June 1998
c. Financial and Economic Analysis Stage : June 1998 to January 1999

[Formation of the Study Group]

The members engaged in this study and their duties in charge are described below. The relation among the organizations in carrying out the study is shown in the attached Fig.1.

Duties	Name
Management(Team Leader)	Zenjiro TSUTSUI
Power and fuel supply plans	Osami IIDA
Economic and financial analyses	Yoshiaki ISHIZUKA
Civil engineering	Hideyo SUZUKI
Architecture	Hitoshi KAMIYAMA
Instrumentation & Control	Naohiro HIRATA
Generation/sub station equipment	Shinichi MOGI
Gas turbine facilities	Kenji MIKATA

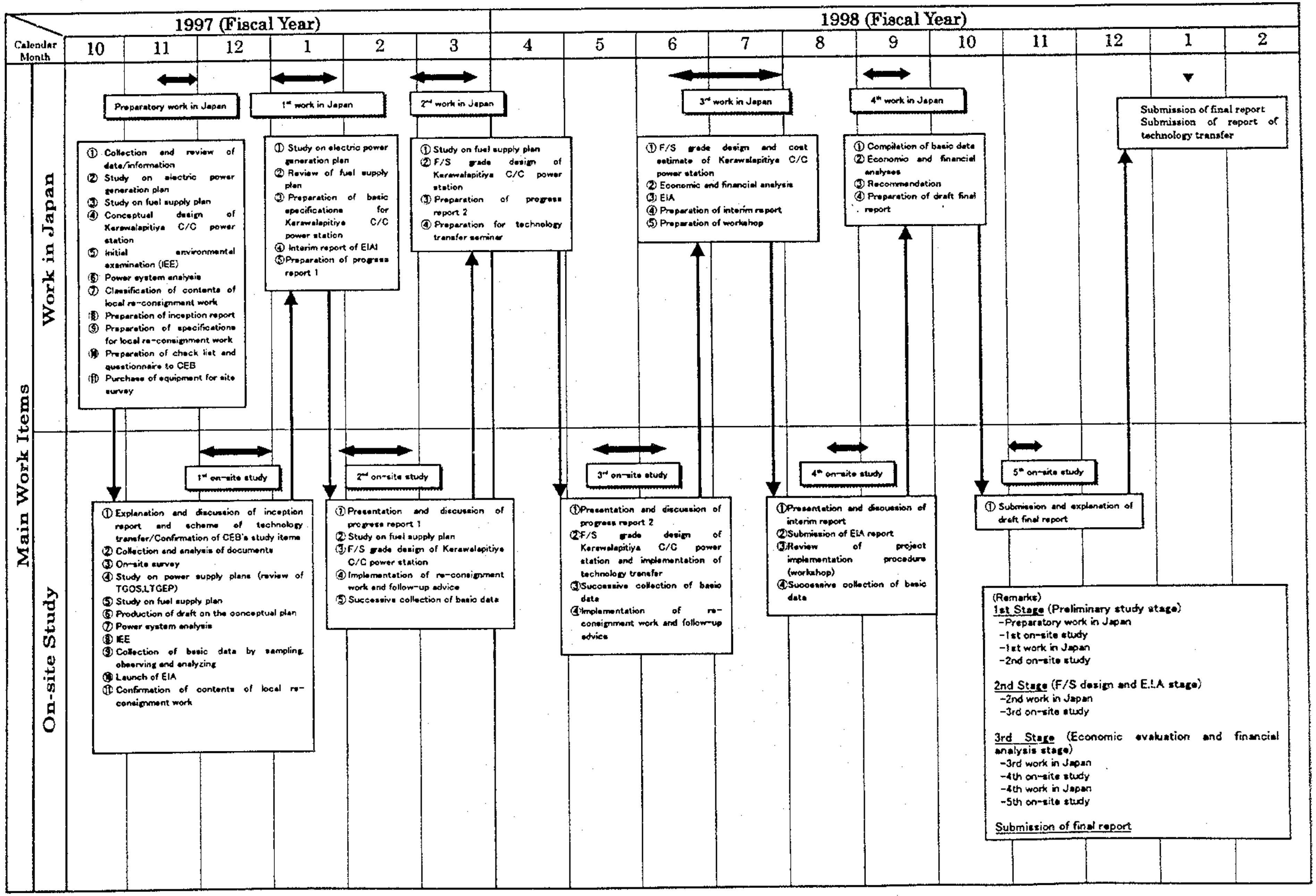
ST/HRSG facilities	Hideyuki OKANO
BOP facilities	Masayoshi ONO
Marine civil engineering / survey	Akira KOJIMA
Environment (ambient air and marine)	Kiyoshi KIKUCHI
Environment(biological, social and economic)	Mitsutake KUDO
Administration	Yuichi NAGANO/Ichiro KATAGIRI/ Takashi KAMO

Abbreviation : ST Steam Turbine
HRSG Heat Recovery Steam Generation
BOP Balance of Plant

(4) Flow chart of the study

The study was carried out in accordance with the flow chart of the study as shown in Figure 1-2.

Figure1-2 Work Flow Chart



1.3 Technology Transfer

Based on the contents of S/W, the cooperated on-site work between CEB and the Study Team shall be carried out as much as possible during the study period and such a manner will enable technology transfer be made smoothly. Technology transfer shall be practiced according to the basic policies described below.

The technical transfer is focussed on such fields as combined cycle system, environmental protection, EIA method, economic/financial analyses, power plant automatization and operation/maintenance of power plant.

1.3.1 Technology Transfer in Sri Lanka

(1) Transfer through on-site study work

The work shall be cooperated with the counterpart personnel. Each professional forms a team with their counterpart personnel in its field. Technology transfer will be successfully made in each field through the study working system.

(2) Transfer through seminars and workshop

Seminars and workshop are to be held to explain the methodology of this study, the procedure of economic/financial study and introduce the latest information of the relevant on thermal power plant technologies.

1.4 Acceptance of Trainee

As the counterpart, CEB will dispatch Mr. Ajitha Ranasinge to Japan as trainee. He will be in Japan from November 30, 1998 to December 13, 1998.

2. SITUATION OF ELECTRICITY AND POWER GENERATION DEVELOPMENT PLAN IN SRI LANKA

2. SITUATION OF ELECTRICITY AND POWER GENERATION DEVELOPMENT PLAN IN SRI LANKA

2.1 Present Situation of Electricity in Sri Lanka

2.1.1 Electricity Generation, Peak Demand

The average growth rate of generated energy over last 20 years is 7.6%.

Over last 20 years except 1996, the growth of peak demand is similar to that of electricity generation and the average growth rate is 7.1%.

As mentioned above, the electricity demand in Sri Lanka is significantly expanding and on the occasion of draught, thermal electricity generation covered the decrease of hydraulic electricity generation in the past years, but recently years it can not cover insufficiency. The urgent expansion of thermal power generation unsusceptible to rainfall is expected.

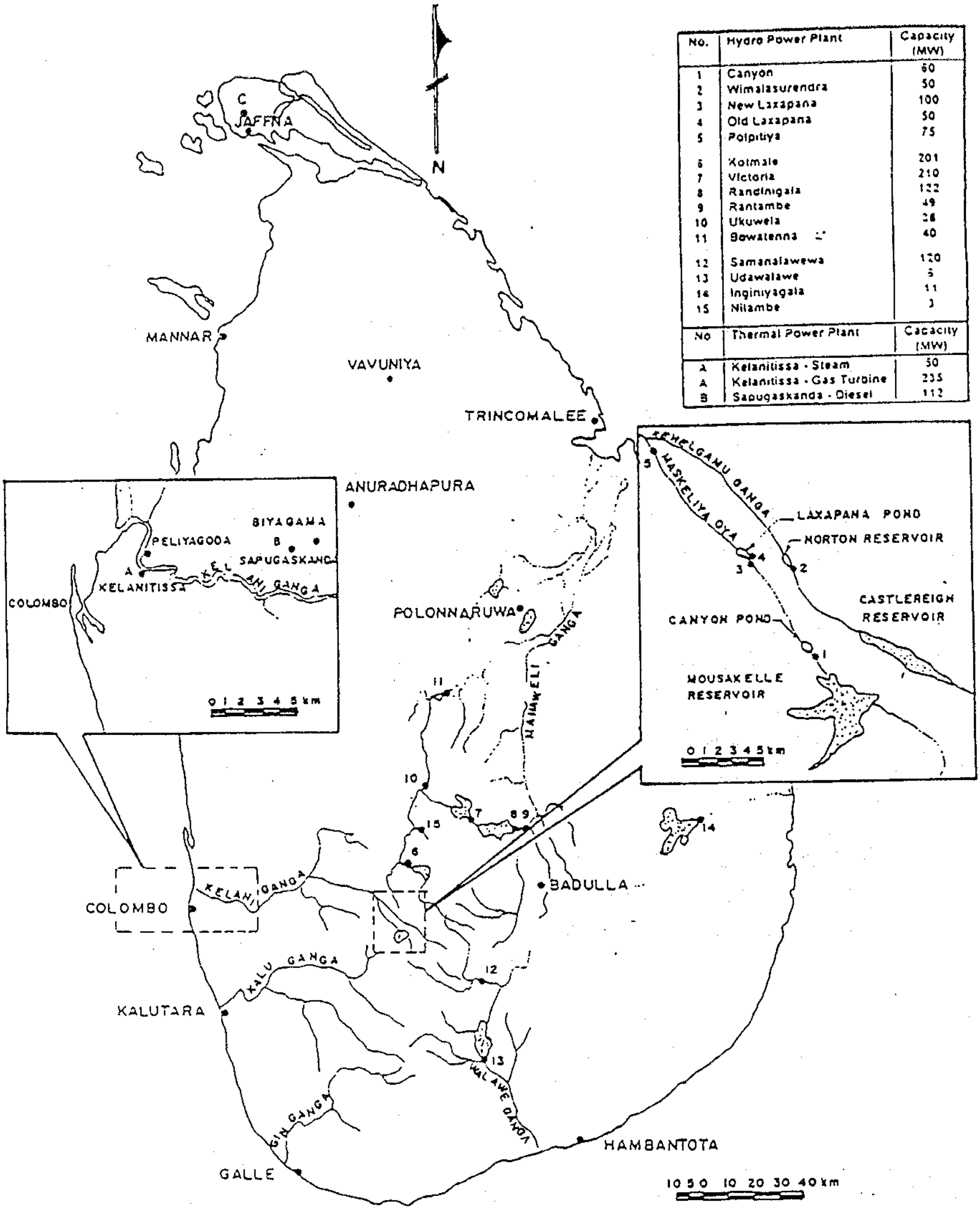
2.1.2 Existing Electricity Generation System

Geographical location of power stations is shown in Figure 2-1.

2.1.3 Electricity Consumption

Electricity consumption per capita has been increasing.

Electricity consumption of household has been increasing as well. It is caused by promotion of electrification. The electrification in 1996 is 46.8% and the Sri Lanka Government is planning to raise electrification up to 80% by 2005.



No.	Hydro Power Plant	Capacity (MW)
1	Canyon	60
2	Wimalasurendra	50
3	New Laxapana	100
4	Old Laxapana	50
5	Polpitiya	75
6	Kotmale	201
7	Victoria	210
8	Randinigala	122
9	Rantambe	49
10	Ukuwela	38
11	Bowatenna	40
12	Samanalawewa	120
13	Udawalawe	6
14	Inginiyagala	11
15	Nilambe	3

No	Thermal Power Plant	Capacity (MW)
A	Kelanitissa - Steam	50
A	Kelanitissa - Gas Turbine	235
B	Sapugaskanda - Diesel	112

Figure 2-1 Geographical Location of Power Stations

2.2 Review Result on LTGEP

2.2.1 Methodology for Development of Electricity Generation

The development plan for electricity generation has been made applying WASP(Wien Automatic System Planning Package) least cost planning program developed by IAEA(International Atomic Energy Agency).

2.2.2 Development Plan of Electricity Generation

The development plan of electricity generation is given in Table 2-1.

In the plan up to 2012, expansions of hydraulic and thermal power are 70MW and 2,588.5MW respectively and retirement of thermal unit is 116MW.

Energy and capacity balances after expansion are given in Figure 2-2 and Figure 2-3 respectively.

Table 2-1 Development Plan of Electricity Generation

Year	Hydro Add.	Thermal Additions	Thermal Retirement	LOLP
1998	-	Lakdanavi 22.5MW Diesel Plant(BOO)	-	8.266
1999	-	Sapugaskanda 40MW Diesel Extension(KFW)	-	1.002
		KHW Plant 51MW (BOO)		
		Kelanitissa 100MW Part of 150MW CC (OECF)		
2000	-	Gas Turbine 105MW		0.023
		Steam Turbine 50MW Part of 150MW CC (OECF)		
2001		Kerawalapitiya 150MW CC	Kelanitissa 2×22MW Steam Turbine	0.039
		CC Plant 150MW (BOO or BOT)		
2002	Kukule 70MW	-	-	0.080
2003	-	-	-	0.374
2004	-	West Coast 300MW Coal Fired	Sapugaskanda 2×18MW Diesel	0.249
2005	-	Gas Turbine 105MW	-	0.441
2006	-	West Coast 300MW Coal Fired	-	0.251
2007	-	-	-	0.920
2008	-	West Coast 300MW Coal Fired	Sapugaskanda 2×18MW Diesel	0.820
2009	-	Trincomalee 300MW Coal Fired	-	0.660
2010	-	Gas Turbine 105MW	-	1.229
2011	-	Trincomalee 300MW Coal Fired	-	1.112
2012	-	Gas Turbine 2×105MW	-	1.400
Total	70MW	2588.5MW	116MW	-

Notes :

LOLP : "Loss of Load" Probability

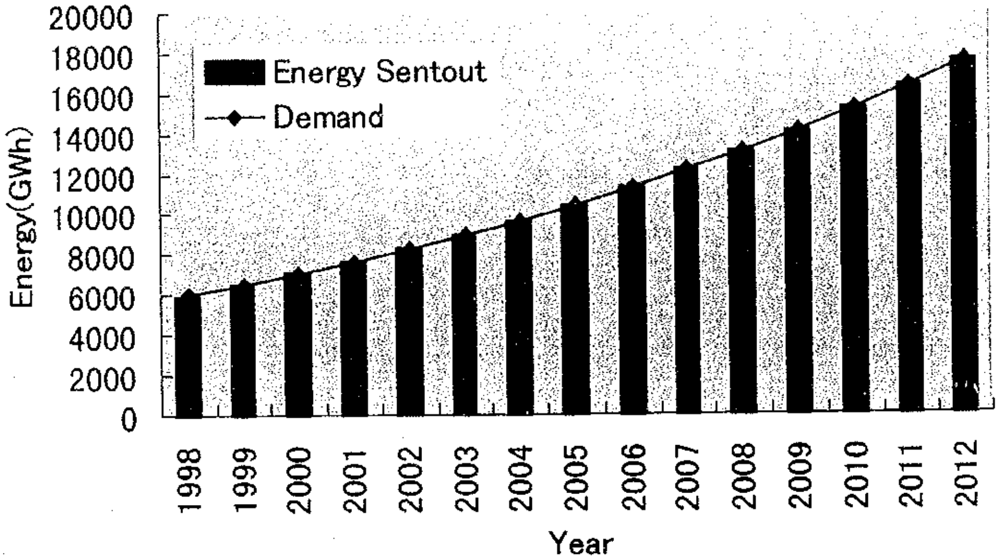


Figure 2-2 Forecast Energy Balance

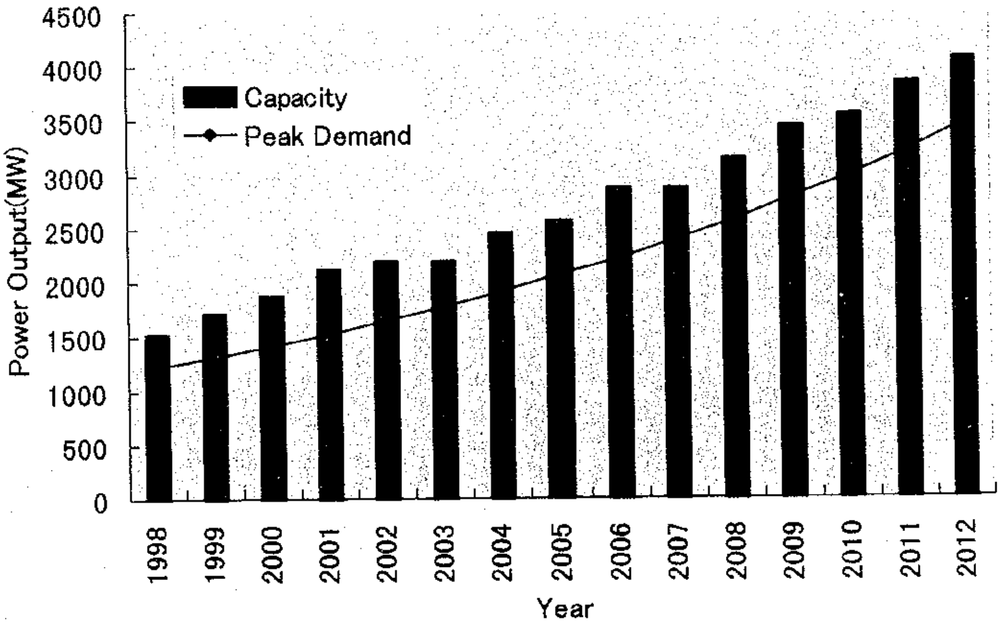


Figure 2-3 Forecast Capacity Balance

3. FUEL SUPPLY SYSTEM PLANNING

3. FUEL SUPPLY SYSTEM PLANNING

3.1 Fuel for the Project

The characteristics of each fuel are as follows.

(1) For receiving LNG, CEB or CPC must participate in the LNG project from the beginning stage. There is no flexibility in LNG trading. The LNG consumption of the Project is much smaller than LNG project capacity.

(2) Since LPG market in the world is controlled by one company, there is anxiety about the stability of market and price and LPG supply from Shell Gas Lanka Limited is not expected.

(3) Gas turbine manufacturer which can apply naphtha is limited and since it is generally impossible to start up a gas turbine with naphtha fuel, it is common manner to prepare another fuel for stating up, further, there is no way to cope with such occasion as its feeding is stopped for some causes.

(4) Heavy diesel oil is applicable for gas turbine but it is not circulated in common market further CPC stopped supplying this fuel from 1996.

(5) Auto diesel has no technical problem as gas turbine fuel and is easily obtainable because it is circulated in the world market.

As mentioned above, since LNG, LPG, naphtha, heavy diesel oil include each problem, it is said that auto diesel oil is the most adequate fuel for the Project.
As for sulfur content in auto diesel oil, 0.5% shall be applied in initial stage, which is the most common value, and when the power station is expanded, such sulfur content as can clear environmental standard shall be selected.

3.2 Unloading of Fuel under this Project

The following three plans can be considered as the methods of unloading the fuel under this project:

Plan 1: Modification and extension of the existing oil unloading berth in the Colombo Port.

Plan 2: Construction of fuel/oil unloading berth in the Colombo Port.

Plan 3: Construction of fuel unloading berth offshore near the proposed project site.

As a result of discussions with the Sri Lanka Port Authority (SLPA) managing the Colombo

Port and the Ceylon Petroleum Corporation (CPC) operating the oil unloading facilities during the site survey, it was clarified impossible to extend the existing facilities or construct new oil unloading facilities in the Colombo Port (Plans 1 and 2).

Therefore, a new oil unloading berth will be constructed in the sea area in front of the proposed project site according to Plan 3.

3.3 Study of Oil Unloading Facilities

3.3.1 Study of the Scale of Oil Tanker

The oil unloading facilities under this project have been studied on the assumption that the scale of fuel tanker is 30,000 DWT at present with the following dimensions:

Dimensions of relevant ships/tankers	: 30,0000 DWT
Overall length, L	: 185 m
Molded breadth, B	: 23.8 m
Molded depth, D	: 15.2 m
Full load draft, df	: 10.9 m

3.3.2 Selection of Mooring System

For mooring fuel/oil tankers, the following systems are deemed available:

- Pier and dolphin systems/types.
- Single point mooring system.
- Multi-point mooring system.

As a result of executing comparative study of the three mooring systems, the single point mooring system will be adopted under this project in consideration that the installation site is located in the open sea exposed to severe marine (oceanoclimatic) conditions in Monsoon Season and this system has so far been operated for the oil unloading facilities of the CPC off the Colombo Port.

3.3.3 Selection of the Type of Single Point Mooring Buoy

The single point mooring buoy is classified into a caternary anchor leg mooring (CALM) type and a single anchor leg mooring (SALM) type. Although both of the types have so far been applied for many oil unloading facilities, it is recommended to adopt the CALM type under this project.

3.3.4 Selection of Oil Unloading Site

For studying the installation point of the single point mooring buoy, the mooring basin area and water depth required of this mooring buoy are as follows:

- Required basin area : Approx.985,000 m^2 (Radius 560m).
- Required minimum water depth : Approx. 14.0m

(1) Selection of the installation site

The multiple point mooring buoys are also scheduled to be installed by Shell Gas Lanka Limited in the sea area in front of the site for unloading LPG through a submarine pipeline.

Shell Gas Lanka Limited studied a submarine pipeline route plan from the Colombo Port and started a part of the pipeline installation project in the past, the company had suspended the work due to various situations. At that time, the shore reef had partly been excavated along the shore line about 900 m off the shore. Therefore, the pipeline route of Shell Gas Lanka has been planned without changing the excavated position.

Since Shell Gas Lanka Limited has already submitted an EIA report, it is reportedly impossible for the company to change the pipeline route.

Therefore, the position of the single-point mooring buoys and route of the submarine pipeline route of the CEB have been planned based on the bathymetric survey map prepared recently under this study taking into account the following requirements:

- The minimum distance between the submarine pipelines of Shell Gas Lanka Limited and CEB should be about 90 - 100 m in view of restrictions in executing the work.
- The distance between the buoys of Shell Gas Lanka Limited and the single point mooring buoys of the CEB should be not less than 1.5 km.

On the basis of this plan, the Study Team discussed with Shell Gas Lanka Limited, and as a result of studying the plan by both of the parties, it has been confirmed to be no problem for both of the parties regarding the position and route.

- Installation water depth of single point buoy : -16.0 m
- Installation position : 200,250.00N
95,110.00E

(According to the local coordinates of Sri Lanka)

3.3.5 Study of General Construction of the Single Point Mooring Buoy

For fixing the buoy, anchors will be arranged in six directions similarly as in the case of the CPC type, and the anchors and buoy be connected by means of anchor chains taking into account the sea bed soil and topographic conditions.

The fuel (transfer/unloading) hose is classified into a floating type wherein the hose is set (floated) normally on the sea level, and a floating and sinking type wherein the hose is normally sunk on the sea bed and floated on the sea level at the time of oil unloading.

The latter sinking and floating type will be adopted under this project

3.3.6 Study of the Number of Days Available for Operation of Single Point Mooring Buoy

(1) Setting of the operating/service conditions of single point mooring buoy

		During mooring	
		During oil transfer	During leaving
Waves	Significant wave height	1.5 m	3.0 m
	Significant wave period	10 sec.	12 sec.
Wind	Wind velocity	15 m/sec.	25 m/sec.
Current	Current flow velocity	0.4 m/sec.	0.4 m/sec.

Note) The operation conditions of the SPM buoy are based on the results of hearing survey by the Study Team, and Technical Standard for Maritime Safety Agency of Japan.

(2) Calculation of the number of days available for operation of the buoy for mooring

The natural conditions (wave, wind and fog conditions) required for calculating the number of days available for operation of the buoy for mooring have been studied by using the data and information in the Study Report for the New Colombo Port Development Project of JICA (Sept. 1996) and so forth.

As a result of study based on the above data and information, the number of days available for operation of buoy for mooring per year and that during the Monsoon season (May - Sept.) have been calculated as indicated in the table below:

Yearly and Monsoon season monthly average available number of berthing operation days

			Yearly average	Monsoon season monthly average
No. of days			365	30
Unavailable No. of berthing days	Wave height	Critical value	1.5 m	1.5 m
		Excess appearance rate	7.3%	14.1%
		No. of days	27	5
	Wind velocity	Critical value	15.0 m/sec.	15.0 m/sec.
		Excess appearance rate	0.0%	0.0%
		No. of days	0	0
Available No. of berthing days			338	25

Therefore, there is deemed to be no problem in unloading fuel oil by using the single point mooring buoy in the sea area in front of the proposed power plant construction site.

3.3.7 Study of Fuel Receiving Pipeline

(1) General study of pipeline size

a. Setting of study conditions

The size of the fuel receiving pipeline pipe has been studied taking into account the following conditions:

- Fluid to be transferred

Auto-diesel oil	Fluid density ρD	:	870 kg/m^3 (15°C)
	Dynamic viscosity of fluid VD	:	5.0 cat (37.8°C)

- Service temperature

  The normal temperature (20 ~40°C).

- Discharge pressure of fuel oil tanker pump

  Po = 12 kg/cm^2G

- Maximum grabbing pressure

  Pa = 3 kg/cm^2G

- Flow rate (Fuel unloading flow rate)

  Q = 2,500 Mton/H

- Pipeline distance

  L=6,500m

b. Study of the pipe size

On the basis of the above conditions, the required size of the pipeline pipe has been calculated according to the formulas of Darcy-Weisbach:

The pipe size has been calculated to be 24B (600mm).

(2) Study of the general construction of pipeline

The general construction of the pipeline has been studied with regard to its submarine and aboveground sections as follows.

a. Submarine section

· Fuel transfer pipe		
Inside diameter	:	584.6 mm
Outside diameter	:	610.0 mm
Plate thickness	:	12.7 mm
Material	:	API 5L Grx52
· External surface coating thickness		
Coal tar enamel coating	:	t = 6 mm
Concrete coating	:	t = 35 mm
· Total outer Diameter	:	692mm (pipe+coating)
· Weight of fuel oil transfer pipe		
Aboveground (In-air)	:	424.3 kg/m
Under water	:	38.8 kg/m

b. Aboveground section

- Fuel transfer pipe

Inside diameter	:	591.0 mm
Outside diameter	:	610.0 mm
Plate thickness	:	9.5 mm
Material	:	API 5L Gr×42

- External surface coating thickness

Polyethylene coating	:	t = 6 mm

- Total Outer Diameter : 614mm (pipe+coating)

- Weight of fuel oil transfer pipe

Aboveground (In-air)	:	144.4 kg/m

(3) Study of the burial depth of submarine pipeline

The entire submarine section of the pipeline shall be buried totally under the sea bed taking into account the following conditions:

- This pipeline is an important pipeline dedicated for fuel transfer to the power plant (consisting of only one line).
- The buoys of Shell Gas Lanka Limited are located around this pipeline route and LPG tankers are navigated above the route.
- Small fishing boats, etc. are navigated around this pipeline route.
- The pipeline should be buried to ensure its security as well.

The burial depth of this pipeline should be determined taking into account the effect of anchor dropping and dragging from oceangoing vessels. In other words, the burial depth should be so sufficient that any anchor will not come into contact with the submarine fuel oil transfer pipeline, should any anchor be dropped onto or dragged around the buried pipeline route.

Therefore, the burial depth of the submarine pipeline under this project has been studied taking into account the following conditions:

- Study conditions

Relevant ships	:	30,000 DWT
Weight of anchor (in-air)	:	6,450 kg-f
Anchor dropping height	:	21.8 m (In-air : 5.8 m, Underwater: 16.0 m)
Back-filling material	:	Sandy soil

As a result of study taking into account the above conditions, the following amounts of penetration have been obtained:

- Amount of penetration of a dropped anchor into sandy soil H1 = 0.7 m
- Amount of penetration of a dragged anchor into sandy soil H2 = 1.1 m

Since the amount of penetration due to anchor dropping and dragging is estimated to be 1.8m, the covering depth over the fuel transfer pipeline under this project shall be 2.0m.

(4) Study of submarine pipeline installation method

In consideration that the installation schedule of this submarine pipeline is one of the most important

factors under this project, it would be essential to select an optimum installation method and equipment types and secure the safety of the installation work according to careful planning and management.
Under this project, the following installation methods can be considered:

- Sea bottom towing method
- Floating method
- Ship laying method

The study team has carried out comparative study of the above three installation methods while considering that a pipe yard can be provided on the aboveground side; the pipeline route is straight; and the extension distance of this submarine pipeline is about 4.6 km. As a result, the sea bottom towing method has been concluded to be optimum as a submarine pipeline installation method under this project.

(5) Study of the pipeline installation method around the shoreline and across the Hamilton Canal

Around the shoreline at the landing site of the fuel oil pipeline, waves are runup even during other than the Monsoon season.
Therefore, the dredging work around the shoreline should be planned taking into account washing-back of sand due to waves, approach of dredger to the shoreline and so forth. Since there is predicted to be a atoll section further around the shoreline section, these conditions should comprehensively be taken into consideration.
Under such situations, either of the following methods are deemed available for excavation around the shoreline section:

Method a: Open excavation method
Method b: Pipe jacking method (Straight pipe jacking method)
Method c: Horizontal directional drilling (HDD) method

As a result of executing comparative study of the above three excavation methods, the Method c is considered to be most advantageous over the other two methods because of the following reasons:

- More economical since there is no need to use any departure and arrival shaft.
- Long distance pipe drilling is possible (Maximum length L = 1,800 m; f1,000 mm)
- Free from contamination of sea water and other oceanic environmental pollution
- Drilling Work can be carried out in a shorter period.
- Any work is not required around the shoreline.
- Shell Gas Lanka Limited will also adopt this Drilling method.

By adopting this HDD method, it will be possible to execute the drilling work without any problem or any adverse effect upon the surrounding area when crossing under the Hamilton Canal over a distance of about 300 m from the shoreline.

Figure 3-1 LOCATION MAP FOR PROPOSED SINGLE POINT MOORING BUOY AND FUEL PIPELINE ROUTE

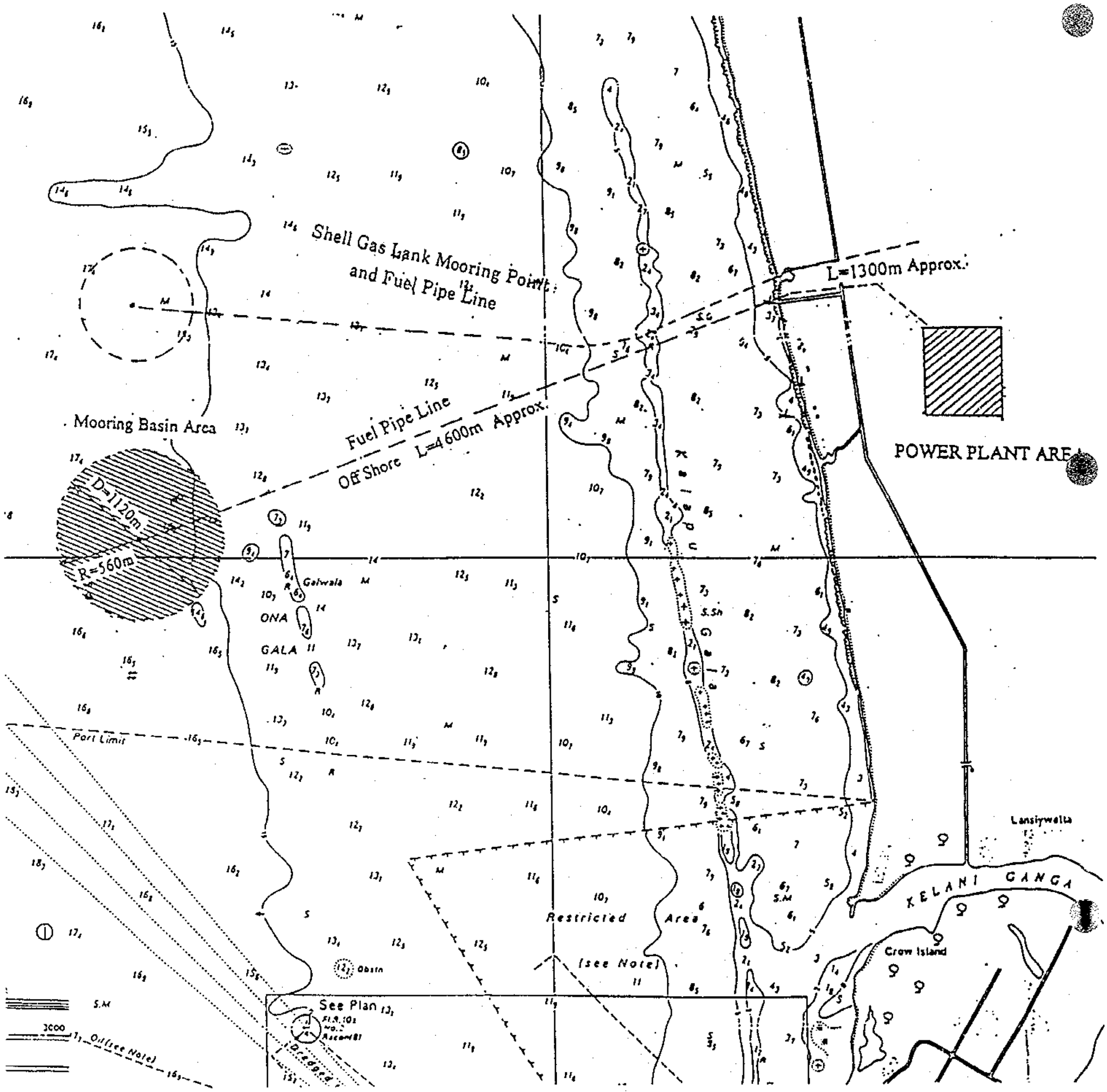
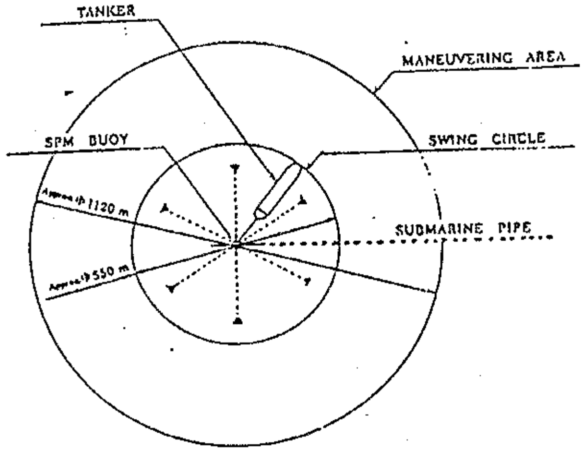
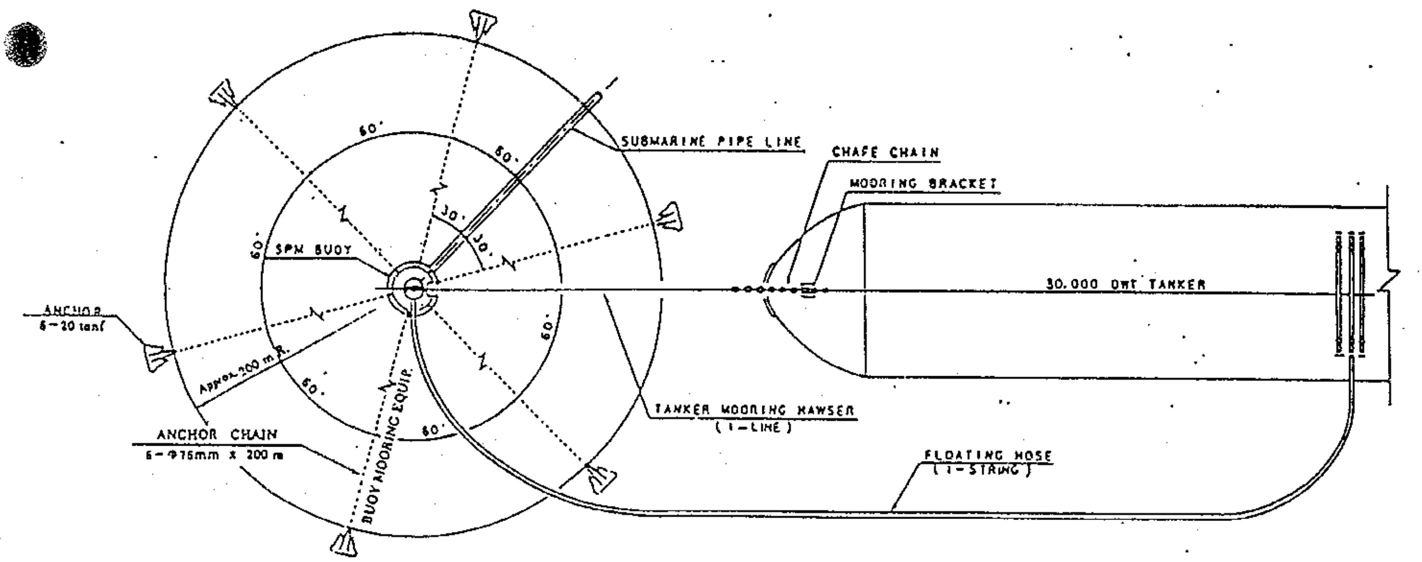


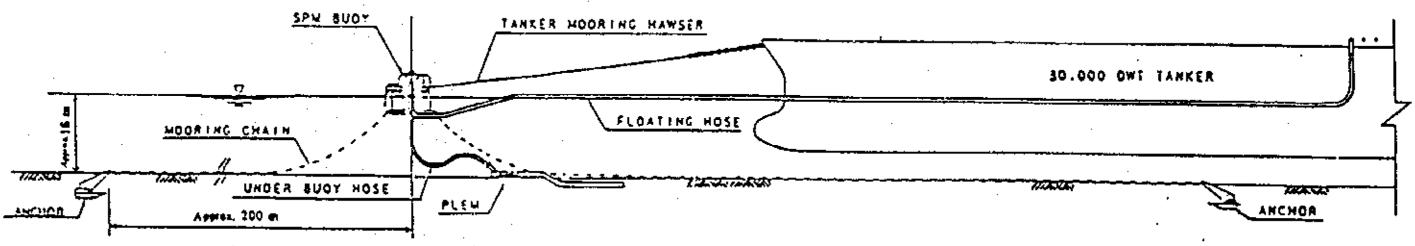
Figure 3-2 PLANNING DRAWING FOR SINGLE POINT MOORING BUOY

MANEUVERING AREA





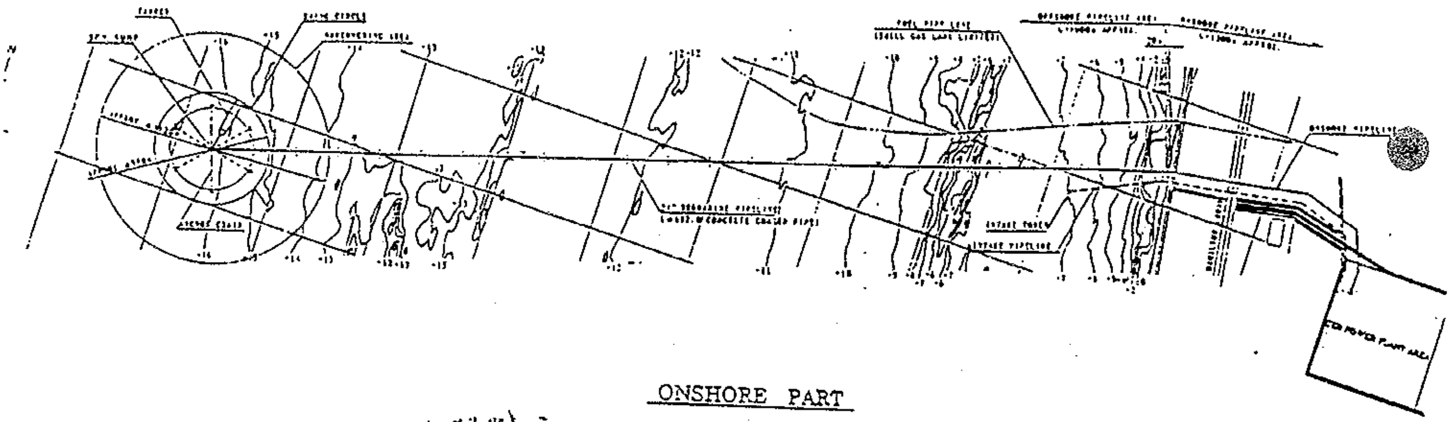
PLAN



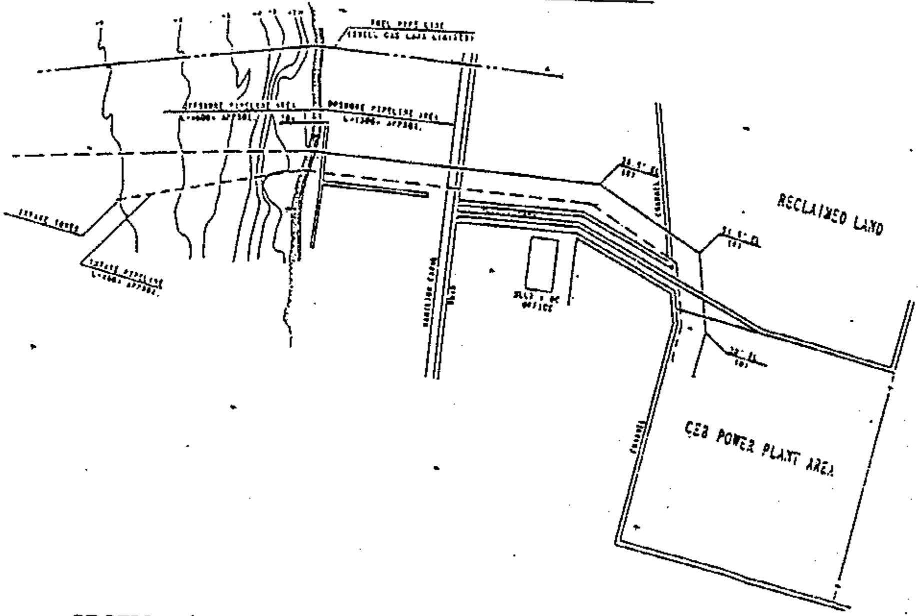
SECTION

Figure 3-3 PLANNING DRAWING FOR FUEL RECEIVING PIPELINE

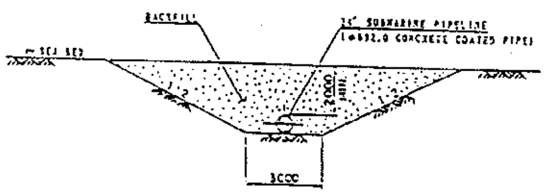
PLAN



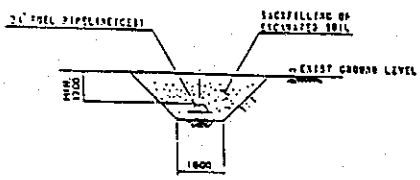
ONSHORE PART



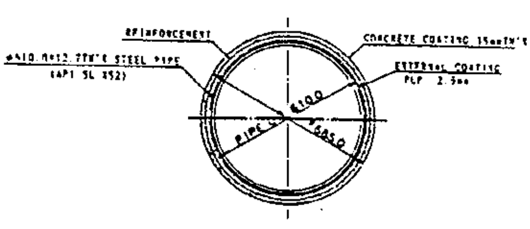
SECTION (OFFSHORE)



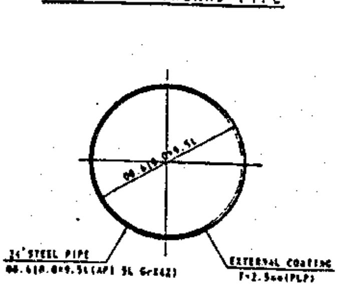
SECTION (ONSHORE)



24" CONCRETE COATED PIPE



DETAIL OF ONLAND PIPE



3.4 Fuel Importing

In Sri Lanka, fuel importing is made by CPC(Ceylon Petroleum Corporation) exclusively in accordance with the national regulation.

So, all fuel which CEB requires is supplied by CPC at the present time.

As for fuel procurement for the Project, CEB is planning to receive the fuel from CPC or other organization and CEB has no intention to procure by themselves.

Consequently, CEB should judge, considering the domestic conditions, which is adequate receiving fuel from CPC or other new organization.

Further, CPC should not interfere with the Project implementation with delay of fuel procurement.

4. STUDY OF CIVIL FACILITIES

4. STUDY OF CIVIL FACILITIES

4.1 Results of Field Reconnaissance

The proposed project site is located at the southern edge of the area consisting of the vast Muthurajawela Swamp and the Negombo Lagoon. The land of about 160 ha. around this site has been prepared by reclamation for introducing housing and industrial complexes by the Sri Lanka Land Reclamation and Development Corporation. This land reclamation had been carried out by dredging the sea bed about 10 km off the shore and using the sea sand obtained thus for reclamation with the sand discharge pipe.

Within the proposed project site of the CEB with a total area of about 28.0 ha., there are two discharge waterways (two open channels). Along a route with a distance of about 900 m from the western edge of the proposed power plant site through to the coast line, the Hamilton Canal with a width of about 20 m runs about 300 m from the sea cost in the south - north direction. In addition to the housings scattering from the sea coast through to the Hamilton Canal, there are housings, industrial and other facilities from the Hamilton Canal to the western edge of the proposed power plant site.

4.2 Site Survey Work

The topographic and geological survey including marine survey was carried out as part of the site survey work pertaining to design of the civil facilities.

4.2.1 Execution of Site Survey

The survey work was carried out by JICA and CEB according to the conditions specified in the Scope of Work.

Survey items	Executed by	Local consultant
Topographic survey	CEB	SURVEY DEPARTMENT
Geological survey	CEB	CECB
Marine survey	JICA	LHI

4.2.2 Results of Site Survey

(1) Topographic survey

a. Scope of survey

According to the scope of topographic survey, the topographic survey was carried out at the proposed project site (CEB land) and along the routes of the fuel oil receiving pipeline, intake and discharge waterways. The surveyed area is as follows:

•	Area within the reclaimed land including the proposed project site	0.67 km^2
•	Route from reclaimed land to Hamilton Canal	0.22 km^2
•	Route from Hamilton Canal to coast line	0.16 km^2
	Total	1.05 km^2

b. Setting of bench marks

During topographic survey, eight bench marks were set newly as indicated below:

Set positions	B.M. No.	Elevation	Coordinates	
			E	N
The proposed project site (4 points)	B.M.1	EL+2.124	100,496,031	200,970,207
	B.M.2	EL+1.960	100,959,515	200,968,557
	B.M.3	EL+2.315	100,961,073	201,510,276
	B.M.4	EL+1.969	100,478,587	201,552,800
Along Hamilton Canal (2 points)	B.M.5	EL+0.702	99,894,161	201,549,516
	B.M.6	EL+0.669	99,864,864	201,691,725
Along coast (2 points)	B.M.7	EL+0.961	99,574,673	201,633,007
	B.M.8	EL+1.315	99,541,928	201,702,508

c. Results of survey

The area of the proposed project site of CEB is 28.0 ha. with an average elevation of roughly EL +2.0 m, and a marshy land extends mostly over a distance of about 550 m from the power plant site through to the Hamilton Canal, where houses are dotted.

Therefore, the marshy land other than the paths to the respective houses from the road along the Hamilton Canal is inaccessible.

Moreover, the area other than the area where houses are dotted along the road running in parallel with the coast line about 350 m from the Hamilton Canal also consists of an inaccessible marshy land.

As the power plant site has been prepared by reclaiming the vast marshy land, the surrounding area other than the plant site can basically be made accessible only by reclaiming the entire marshy land.

Meanwhile, the houses dotted along the existing roads have been built after reclaiming the marshy land by 50 cm - 1.0 m.

(2) Geological survey

The geological survey was carried out for the purpose of macroscopically clarify the geological conditions at the proposed project site of CEB and the fuel oil receiving facilities as well as the routes of the intake and discharge waterways.

This survey was carried out by drilling boreholes at five positions (one of them for continuous sampling) within the proposed project site and four positions from the plant site through to the coast line.

The outline of this geological survey is as shown below:

Boring positions	Borehole No.	Elevation (m)	Borehole depth (m)
Within the proposed project site	No.1a	EL+1.869	29.98
	※No.1b	EL+1.832	40.50
	No.2	EL+2.114	17.90
	No.3	EL+2.174	25.07
	No.4	EL+2.317	20.22
Within reclaimed land	No.6	EL+1.976	30.31
Reclaimed land - Hamilton Canal	No.8	EL+1.610	23.45
Along Hamilton Canal	No.5	EL+0.593	40.06
Along coast line	No.7	EL+0.767	31.50

※Continuous sampling

(3) Marine survey

The marine survey was carried out in the sea area in front of the proposed project site with the survey items being as listed below:

- Bathymetric Survey
- Measurement of sea water temperature and salinity concentration
- Measurement of current flow and flow velocity

a. Bathymetric Survey

(a) Range and period of sounding

For the purpose of designing/planning the fuel oil receiving pipeline, cooling water intake and discharge facilities, the sounding was carried out over a range of 18.4 km^2 (4.6 km of coast line and 4.0 km off the shore) in the sea area in front of the proposed project site.

- Measuring instrument : Echo sounder
- Interval of course of traverse : 100 m
- Contour interval : 0.5 m
- Scale : 1: 2,000

During the measurement period from Jan. 9 through Jan. 12, 1998, the sounding was carried out on a survey ship and came to an end after executing supplementary sounding along the coast line on May 2 through May 8, 1998.

(b) Results of sounding

Shore reefs are dotted along the shoreline and also about 900 m offshore (with a width of 100 m and height of about 3 m) along the shoreline. The gradient of the sea bed about 900 m offshore from the shoreline adjacent to the proposed routes of the fuel oil receiving pipeline, cooling water intake and discharge waterways is as moderate as roughly 1/140. From the shore reefs further around 900 m offshore toward the offshore, the sea bed is more moderate by as much as roughly 1/375.

Judging from the fact that the contour line runs regularly along the coast line, the wave direction is deemed to be incident roughly at a right angle against the shoreline.

b. Measurement of sea water temperature and salinity concentration

(a) Measurement positions and period of sea water temperature and salinity concentration.

The sea water temperature and salinity concentration were measured by fixed point observation (one point) in the three upper, intermediate and lower layers at a water depth of -10 m adjacent to the proposed cooling water intake mouth and discharge outlet sites in the sea area in front of the proposed project site

· Measuring instrument	:	EC300 (Electric conductivity sensor)		
· Measurement depth	:	Upper layer	:	-1 m
		Intermediate layer	:	-5 m
		Lower layer	:	-8 m
· Measurement position	:	201324N		
		98259E		

This measurement (fixed point observation) was carried out twice in January and February 1998 (first measurement during other than Monsoon Season) and in June 1998 (second measurement during Monsoon season).

(b) Results of measurement

According to the results of measuring the sea water temperature, the mean temperature was 31℃ during the first measurement and 29.5℃ during the second measurement. Meanwhile, there was observed to be almost no temperature difference at a water depth of roughly -10 m in vertical direction.

According to the results of measuring the salinity concentration, moreover, the mean concentration was 32.0 during the first measurement and roughly the same during the second measurement. The concentration between the upper, intermediate and lower layers in vertical direction was almost no difference.

c. Measurement of current flow direction and velocity

(a) Positions and period of measuring the flow direction and velocity

The current flow direction and velocity were measured by fixed point observation (one point) at the position -2 m from the sea level at a water depth of -8 m adjacent to the proposed cooling water intake mouth and discharge outlet sites in the sea area in front of the proposed project site.

· Measuring instrument	:	Current Meter S-4
· Measuring depth	:	-2 m
· Measuring position	:	201324N 98259E

Meanwhile, this measurement was carried out in January and February 1998 when the measurement instruments could be set easily (during other than Monsoon Season).

(b) Results of measurement

According to the results of measurement, the current flow in south - north direction prevailed, and the coastal flow in south - north direction appeared substantially along the coast line.

Although the maximum flow velocity of 25 cm/sec. was observed, the mean velocity was roughly 6 cm/sec.

4.3 Planning/Design of the Cooling Water Intake and Discharge Facilities

The condenser cooling water intake and discharge facilities have been studied as described below on the basis of the direct condenser cooling system using sea water as a cooling medium selected from among the available two systems, namely, this direct cooling system and the indirect cooling system using fresh water.

4.3.1 Outline of the Areas along the Proposed Intake and Discharge Routes

The area along the Hamilton Canal is dotted with roads, housings, industrial plants and other facilities from the proposed project site through to the coast line.

Moreover, the front sea area adjacent to the site is shallow with a sea bed slope of approximately 1/140 according to the marine chart and there are shore reefs about 900m from the shore line.

According to the results of hearing survey from the Coast Conservation Development (CCD) in charge of managing the areas around this coast, 70% of the coast line within a range of 30 km north of the Kerani River running north of the Colombo Port tends to have been eroded. Although the coast line 2 or 3 km north of the Kerani River had been eroded particularly seriously, this erosion has so far been prevented as a result of reinforcing the coast line with armor stone and other materials. Moreover, the coast line in the area in front of the proposed site has not so extensively eroded according to information, and utmost care is reported to have been exercised for preserving the coast line in the entire area adjacent to the site. Therefore, it has been instructed by the relevant authority to be undesirable to install any such structure and facility as causing deformation of the seashore.

4.3.2 Selection of Intake and Discharge Systems

For selecting optimum condenser cooling water intake and discharge systems, the local conditions including the results of hearing survey from the CCD and other relevant authorities are summarized below:

- In the area from the proposed project site to the coast line with a distance of about 900m in straight line, there run the Hamilton Canal and roads. Moreover, the area is dotted with housings, factory and other facilities.
- The sea bed slope in front of the proposed project site is as moderate as about 1/140.
- Although the coast line in front of the proposed project site has not been eroded, the CCD is unwilling to allow installation of any structure adjacent to the area along the shore line.
- The quantity of littoral sand is so large that some fishing ports have so far been buried due to such littoral sand.

When judged from an overall point of view based on the above facts, the deep water intake system from offshore (water depth: -7 m) is deemed optimum as a system enabling stable intake of clear sea water and causing no adverse impact upon the natural sea cost while eliminating the necessity of installing the circulating water pump room and so forth near the shore line.

From among the surface discharge system from around the shore line and the deep water discharge system off the coast (from offshore) deemed available for discharging warm waste water, the former surface discharge system is considered to be economically optimum because of the following reasons: Namely, the water depth is required to be 5 m or over in the case of the latter deep water discharge system from offshore. Moreover, the diffusion range of warm waste water cannot be reduced in proportion to the higher construction cost of the latter system. Meanwhile, the discharge flow velocity, V will be limited roughly to

1.0 m/sec. in order not to cause any adverse effect upon fishing boats and other oceangoing vessels.

Meanwhile, these intake and discharge facilities will be designed as common facilities applicable for the 300 MW units (150 x 2 units) instead of installing these facilities separately for Units 1 and 2 in view of economy.

4.3.3 Selection of the Locations of Intake Mouth and Discharge Outlet as well as the Route of Intake and Discharge Waterways

(1) Selection of the route of intake and discharge waterways (Aboveground section)

As a result of field reconnaissance, the housings, churches, industrial plants and other facilities have been clarified to exist from the Hamilton Canal through to the coast line as well as from the west side of the proposed project site through to the Hamilton Canal. Therefore, the land on the northwest side distant from the above areas is deemed to be optimum as the route of the intake and discharge waterways.

As a result of studying the width of the area along the intake and discharge waterways, the width including those for the maintenance road and fuel receiving pipeline will be roughly 50 m.

The route from the northwest side of the site had been surveyed taking into account the width of the route. Thereby, it has been clarified that housings are scattered also along this route and the entire land area distant therefrom is totally covered by a swamp zone. Therefore, about twenty houses (non-registered semi-shelter) scattering around the swamp zone should be moved.

Moreover, the fuel (LPG) receiving pipeline of Shell Gas Lanka Limited is scheduled to be installed around this route. As a result of site survey, the pipeline route of Shell Gas Lanka Limited has been clarified to be as distant as 170 m or over from the waterway route which deemed optimum at the present stage. Therefore, there is deemed to be no problem regarding the distance between the pipeline route of Shell Gas Lanka Limited and waterway route under this project.

(2) Selection of the installation point of the intake mouth

The installation sites of the intake mouth have been selected taking into account the following conditions:

- The installation depth is required be about -7.0 m.
- The intake mouth and discharge outlet should be located inside the shore reef

about 900 m from the shore line.

- The sea bed form is flat around the installation site.
- The intake mouth and discharge outlet should be located on the south side of the site about 100 m distant from the fuel oil receiving pipeline.

As a result, the intake tower installation point has been selected about 460 m distant from the shore line.
Where the distance from the discharge outlet is about 460 m, any warm waste water is not considered to be recirculated since the average intake water depth is -5.3 m even if the warm waste water temperature is raised by 1°C has reached the intake mouth from the discharge outlet.

The submarine intake pipe will be routed in a straight line from the intake tower toward the land side and joined with the intake waterway pit to be provided on the land side.

4.3.4 Study of the Construction of Intake Structures

(1) Intake tower

With the intake tower of a velocity cap system vertical intake type, sea water will be taken in at a intake velocity of 20 cm/sec through a screen in the circumferential horizontal direction.
The intake tower shall be of such a construction as to prevent inflow of drifting matter and suspended water from around the surface layer as well as inflow of suspended matter from the bottom layer by using a bottom surface training plate.
Meanwhile, the intake tower shall be of a steel type which is light in weight, excellent in stability and enabling easy installation and maintenance with a wealth of application records.

(2) Submarine intake pipe

Since the intake pipe installation work will be carried out underwater, the submarine intake pipe is required to be light in weight. Therefore, the pipe shall be of a steel pipe type light in weight and enabling easy execution of its installation work with a wealth of application records.
Since the steel pipe will be joined underwater, such a pipe joining work shall be carried out based on the mechanical joint system.
Moreover, an inspection manhole shall be provided at a interval of every 100 m to enable a diver to carry out maintenance of the steel pipe.
Meanwhile, the covering depth over the intake pipe shall be about 1.0 m taking into account the effect of anchor dropping and dragging from fishing boat, etc.

(3) Aboveground section of intake culvert

In the case of the aboveground section of the intake pipe, two types, namely, the same steel pipe type as that for the submarine section and a concrete box culvert type can be considered.

From among the above two types, the box culvert type made of reinforced concrete will be adopted under this project taking into account easy execution of aboveground work as well as the economic advantage of this type.

Moreover, the cross-section of the box culvert structure will be of a square form most advantageous in terms of hydrology and construction of the structure.

Meanwhile, a connection pit will be provided about 50 m toward the aboveground side from the shore line, and the sea bottom intake pipe and concrete box culvert be connected in the pit.

(4) Method of under crossing the Hamilton Canal

In view of the hydrological conditions, the intake waterway will cross under the Hamilton Canal.

The following two methods can be considered for crossing under the Hamilton Canal.

Method A : Open excavation method (Diversion Method)

Method B : Pipe Jacking method

The above two methods have been studied considering that the traffic volume of fishing boats is comparatively large on the Hamilton Canal and that of buses and other vehicles is also large on the road.

As a result, the Method B (pipe jacking method) will be adopted under this project judging from its advantages in view of the required work period and cost.

For selecting an optimum pipe jacking method, the jacking pipe diameter will roughly be ϕ2.6 m in the case of the intake waterway and ϕ2.4 m in the case of the discharge waterway respectively according to the water passing sections of the intake and discharge waterways.

As a result of executing comparative study of the above three methods, the Hamilton Canal crossing work will be planned based on the blind pipe jacking method advantageous for executing the work in soft and clayey soil ground and lowest in the pipe jacking equipment cost.

4.3.5 Study of the Constructions of Discharge Waterway and Outlet Structures

(1) Discharge waterway

The discharge waterway shall be of a reinforced concrete box culvert type similarly as in the case of the intake waterway.
Moreover, the waterway will be routed under the Hamilton Canal and the road running in parallel based on the pipe jacking method similarly as in the case of the intake waterway.

(2) Discharge outlet

The discharge outlet shall be of a reinforced concrete construction, and stop logs be arranged around the connection sections between the discharge waterway and discharge outlet for easy execution of its installation work and maintenance.
For preventing scouring due to discharged water and waves, steel sheet piles shall be driven as a cutoff at the edge of the discharge outlet.
Also for preventing scouring due to discharged water and waves, armour stones shall be laid in front of the discharge outlet.
Moreover, both sides of the discharge outlet shall be reinforced with armour stones to protect the outlet from waves.

4.3.6 General Hydrological Study of the Intake and Discharge Waterways

(1) General hydrological study of intake waterway

The distance between the intake mouth and the circulating water pump pit within the power plant site is approximately 1,670 m. Therefore, the problem is to what extent the water level in the circulating water pump room within the power plant site can be reduced.
In the case of such an inland type power plant as that under this project, the more the extent of water level reduction, the higher the pump installation and operation costs. Whereas, the smaller the extent of water level reduction, then the greater the cross-section of the intake waterway, and the higher the installation cost of the intake facilities.
Therefore, the design water level reduction rate should be controlled roughly within -2.0 m under this project based on the past records of similar projects.

The cross-sections of the submarine intake pipe and aboveground intake culvert, in case the water level in the circulating water pump room is reduced by -2.0m, have been obtained as follows as a result of executing general hydrological calculation taking into account the design intake flow rate Q = 7.2 m3/sec, during operation of Units 1 and 2 (3.6 m3/sec. each for Units 1 and 2).

Submarine intake pipe : Inside = ϕ2.4 m; V = 2.5 m/sec.
Intake culvert : Inside = 2.7 m x 2.7 m; V = 1.0 m/sec.

Meanwhile, sea water will be taken in fully through the entire section of the intake pipe/culvert without any free water level in view of hydrology. Moreover, the design height of the top inside the waterway will be made by -10 cm lower from the intake water level.

(2) General hydrological study of discharge waterway

The extension of the discharge waterway is about 1,300 m from the circulating water pipe discharge outlet for condenser cooling within the power plant and the discharge outlet. Therefore, the discharge water level in the discharge waterway is required to be kept roughly within the design height of the power plant site (EL +2.2 m) even when the discharge outlet water level is at the HWL (EL +0.970 m).

As a result of executing general hydrological study taking into account the above requirements, the cross-section of the discharge waterway has been determined as follows:

Discharge waterway : Inside $= 2.5 \text{ m} \times 2.5$ $V = 1.15$ m/sec.

Meanwhile, warm waste water will also be discharged fully from the entire cross-section of the discharge culvert without any free water level similarly as in the case of the intake waterway, and the design height of the top inside the waterway will be made roughly by -10 cm lower from the discharge water level.

4.3.7 Maintenance Bridge

For maintenance and management of the intake and discharge waterways from the coast line through to the proposed project site, a bridge will be required across the Hamilton Canal.

Although there is a bridge across the Hamilton Canal near the proposed power plant construction site, its strength is not sufficient for frequent traffic of heavy-duty vehicles.

Therefore, a temporary bridge will be constructed across the Hamilton Canal and used during construction works of the intake and discharge waterways and installation of the fuel oil receiving pipeline without using the existing bridge. Since the above temporary bridge is scheduled to be dismantled after completion of the waterway and pipeline works, the trailer truck, truck crane and other vehicles should be crossed over the Hamilton Canal for maintenance of the intake and discharge facilities. For this purpose, a crossing bridge (with a width of 6 m and a length of 20 m) dedicated for CEB will be constructed newly.

Although this bridge will be designed as that dedicated for CEB, this bridge is also deemed to be in common use with nearby local people.

4.4 Design of Major Civil Facilities within the Power Plant Site

4.4.1 Ground Level of the Power Plant Site

The proposed project site has already been prepared by reclamation to the present ground level of EL +2.0 m.

The design ground level of the power plant site has been determined to be by 20 cm higher than the present ground level to EL +2.2 m taking into account effective utilization of foundation excavation surplus soil during construction as well as discharge of waste water from miscellaneous power plant equipment and drainage of rain water and so forth.

4.4.2 Roads within the Power Plant

The following two types of roads will be provided depending upon the purposes of the roads for construction, operation, maintenance, etc. of the power plant.

- 10 m road (two-car lanes)
  Roads around the service buildings and main powerhouse building

- 8 m road (two-car lanes)
  Roads around the fuel oil tank, water treatment and other equipment

Meanwhile, any road within the power plant site will be asphalt-paved, under this project.

4.4.3 Screen Pump Pit

The screen pump pit will be of an integral construction to be used commonly for both Units 1 and 2, and partitioned with a partition wall.

With the existing bar screen installed at the intake mouth, it will be possible to prevent inclusion of any foreign matter from the surface layer.

Therefore, only traveling screens will be installed as part of the screening section for intake of sea water from deep layer at an approach flow velocity of about 35 cm at the LWH.

Although it can be considered that washing waste water from the screen be led to the discharge waterway after removing foreign matter in a washing waste water pit to be provided beside the screen room, the water level of the discharge waterway is so high that such washing waste water will be returned to a diversion pond to be provided in front of the screen room under this project.

Moreover, an intake pit to the desalination and colorination plants will be provided at the common section beside the diversion pond to take in sea water from this pit.

Moreover, a lay-down area will be provided on both sides of the screen pump pit for maintenance.

Meanwhile, the screen pump pit foundation will be designed on the basis of direct foundation in consideration that a sand bearing stratum is available roughly around GL –9.0 m.

4.4.4 Circulating Water Pipe

For the purpose of preventing deposition of any shell inside the circulating water pipe from the circulating water pump and condenser through to the discharge waterway, the diameter of this pipe should be made maximum to satisfy a maximum flow velocity of 3.5 m/sec. or over inside the pipe and a wall surface velocity of 1.63 m/sec. (position of 0.2 mm from the wall surface).

As a result of executing overall study taking into account the above requirements, the diameter of and flow velocity in the circulating water pipe will be as follows with a covering depth of the pipe with sand being 1.5 m:

Pipe Diameter : ϕ = 1.1 m
Flow Velocity : V = 3.8 m/sec.

Meanwhile, the circulating water pipe shall be made of steel pipe with sufficient reliability, under this project

4.4.5 Fuel Oil Tank Foundation and Oil Dike

(1) Fuel oil tank foundation

The fuel oil tanks each with a capacity of 15000kl×2 & 8000kl×2 will be installed. A variety of foundation work methods considered for installing these fuel oil tanks depending upon the soil conditions.

According to the results of soil investigation carried out under this study, there are a very soft back-filled sand layer from the ground level down to GL –3.0 m, and a slightly soft peat layer from GL –3.0 through to GL –6.0 m. Whereas, a comparatively excellent sand layer appears roughly around GL –9.0 m.

In consideration that the peat layer is particularly susceptible to consolidation settlement due to the tank loads over a long period of time and the reclaimed sand layer is very soft, the following foundation work methods have been studied under this project:

Method A: Preloading method with sand pile and banking
Method B: Sand compaction method
Method C: Piling method

As a result of executing comparative study of the above three methods, a huge volume of soil and sand and a long time period for consolidation (roughly one year) will be required in the case of the Method A, and the special equipment and a large volume of good quality sand will be required in the case of the Method B. However, the Method C will make it possible to complete the foundation work within a comparatively short period and free from any settlement of tank and other problem over a long period of time in future. Therefore, the Method C will be adopted under this project.

Meanwhile, although the steel pipe pile, PC (Prestressed Concrete) pile, RC (Reinforced Concrete) pile and so forth are deemed available as the pile for the foundation work, the RC pile which can all be fabricated at the work site will be adopted as a result of executing overall study of the local situations.

(2) Oil dike

From among the retaining wall type with reinforced concrete and the banking type with soil and sand available as the constructions and types of oil dike, the banking type will be adopted under this project because of the following reasons:

- The oil dike can possibly be settled over a long period of time due to inadequate soil conditions.
- Should the oil dike be settled once, it will be easier to repair the dike in the case of the banking type than in the case of the retaining wall type.
- Since the extension distance of the oil dike is about 760 m, the banking type will be economically advantageous over the retaining wall type.

Based on the results of calculating the capacity of oil dike, its height will be 1.1 m, and the height of tank partition dike be 30 cm.

4.5 Transportation Plan of Heavy/Large Equipment and Materials

In the case of 150 MW class combined cycle power plant under this project, the weight of heavy/large equipment and materials to be transported during power plant construction is approximately 130 ton in maximum except in the case of the Heat Recovery Steam Generator (HRSG). Since it is impossible to transport the Heat Recovery Steam Generator as a complete set because of its size and weight, the HRSG components will be transported by dividing the same into several blocks within a range of not exceeding 130 ton.

4.5.1 Investigation of Transportation Route

(1) Colombo Port

According to hearing survey from the Sri Lanka Port Authority (SLPA), the North Guide Pier located on the north side of the port has so far been used for unloading heavy equipment and materials.

Therefore, this pier will also be used for unloading heavy/long power plant equipment and materials under this project.
Since this pier has not been equipped with any cargo handling facility, the cargo carrier equipped with cargo handling equipment will be required.
Although some equipment/material transfer routes may possibly be available within the Colombo port, there will be no problem in the transfer of heavy equipment and materials by temporarily dismantling part of temporary facilities in the case where any transfer route is not available partly within the port.

(2) Transportation from the Colombo Port to the area adjacent to the proposed project site (Route A3)
The national road from the Colombo Port to the entrance of the proposed project site (Route A3) is deemed generally satisfactory in view of the width and pavement of the road. Since there are some crossings where a vehicle should be turned right angle (90°), some traffic signals and other facilities should be removed tentatively.

The bridge (Sri Lanka - Japan Friendship Bridge) across the Kerani River is a PC bridge between seven (7) girders with a road width of 7.5 m. As a result of hearing from the Road Development Authority (RDA) in charge of road management (for formulating the heavy equipment/component transportation plan), the axial load to be applied to the bridge across the Kerani River during transportation of heavy equipment/components was instructed to be 15 ton in maximum.
Meanwhile, the RDA is in charge of management of only the national roads.

(3) Transportation from Route A3 to the proposed project site
From the Route A3 to the proposed project site, two routes are deemed available. One is the route along the Hamilton Canal after crossing the Kerani River and turning to the left, and another is that going north from the Route A3 and entering the proposed project site from the east side of the site. Since the width of the road along the Hamilton Canal is roughly 4 m and the road materials are soft, this road is very dangerous. Moreover, the concrete bridge (about 5 m long and about 4 m wide) existing halfway along this road should be repaired.

The length of the route from the east side of the site to the entrance on the reclaimed land is about 1.9 km and the road width ranges from 4 m to 5.5 m under the present conditions. Moreover, the area halfway along this route is dotted with houses (Refer to Figure 5-5-2).

Based on the results of studying the results of site reconnaissance and discussions with the CEB regarding the above two routes, the CEB has determined to select the route entering from the east side of the site according to the following reasons:

(4) Transportation distance of heavy/large equipment and materials

The heavy/large equipment and materials transportation distance from the Colombo Port to the proposed project site is roughly 18 km including the roads in Colombo City, National Route A3, access way from the east side of the plant site and road within the site.

4.5.2 Study of the Road Width to be Expanded for Transporting Heavy/Long Equipment and Materials to the Site

The existing road from the Route A-3 to the east side of the reclaimed power project site should be expanded and rehabilitated over a distance of about 1.9 km.

According to the results of discussions with Shell Gas Lanka Limited, this road is scheduled to be used for construction of its LPG terminal and transportation of LPG (propane gas) after completion of this terminal. For this purpose, Shell Gas Lanka Limited intends to expand this road to a 6m wide paved road.

Therefore, the width of the existing road should be expanded to 10 m even after expansion to 6 m by Shell Gas Lanka Limited in advance.

Figure 4-1 PLANNING DRAWING FOR INTAKE HEAD AND SUBMARINE INTAKE PIPE

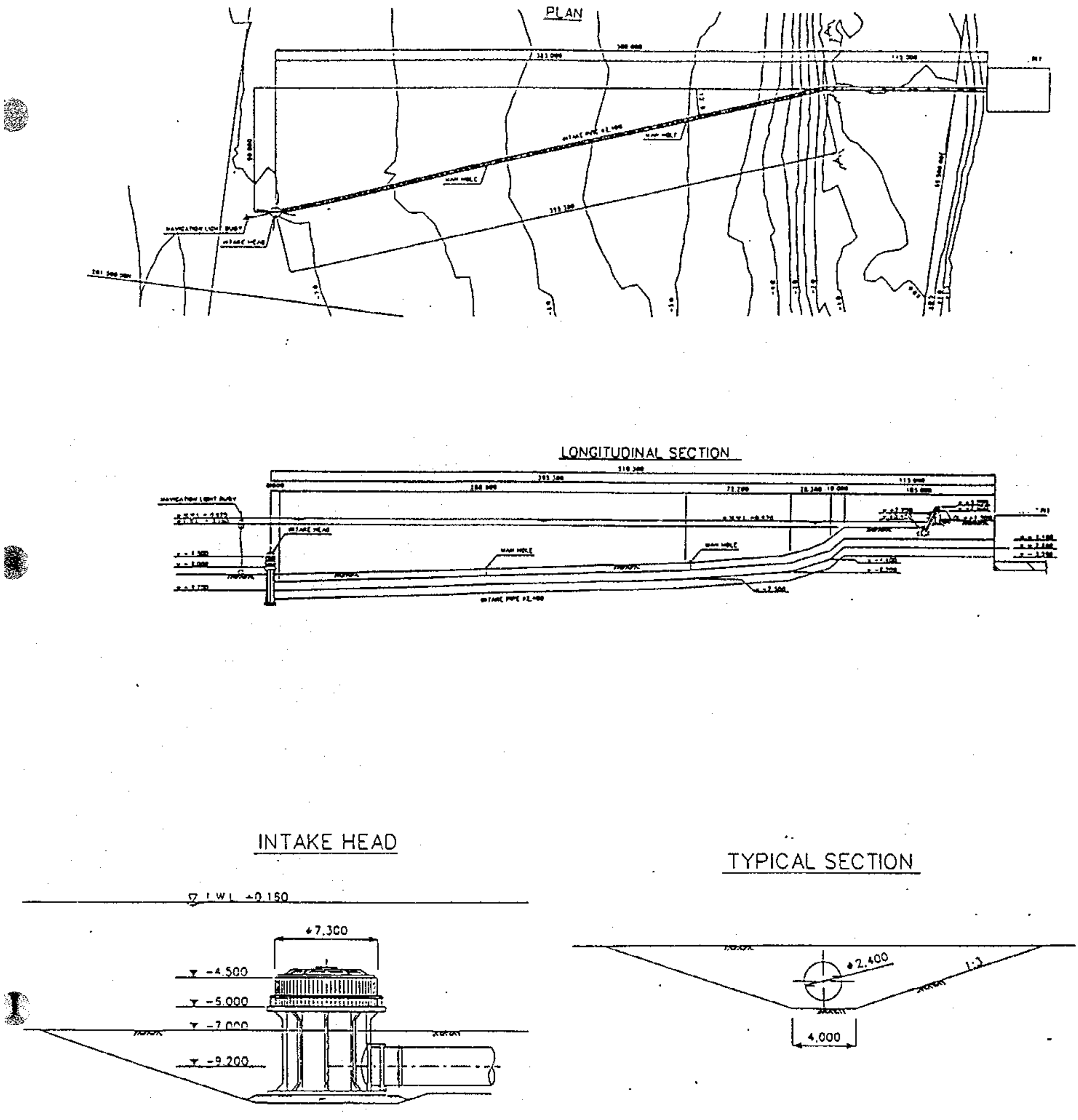


Figure 4-2 PLANNING DRAWING FOR INTAKE & DISCHARGE WATERWAY ROUTE

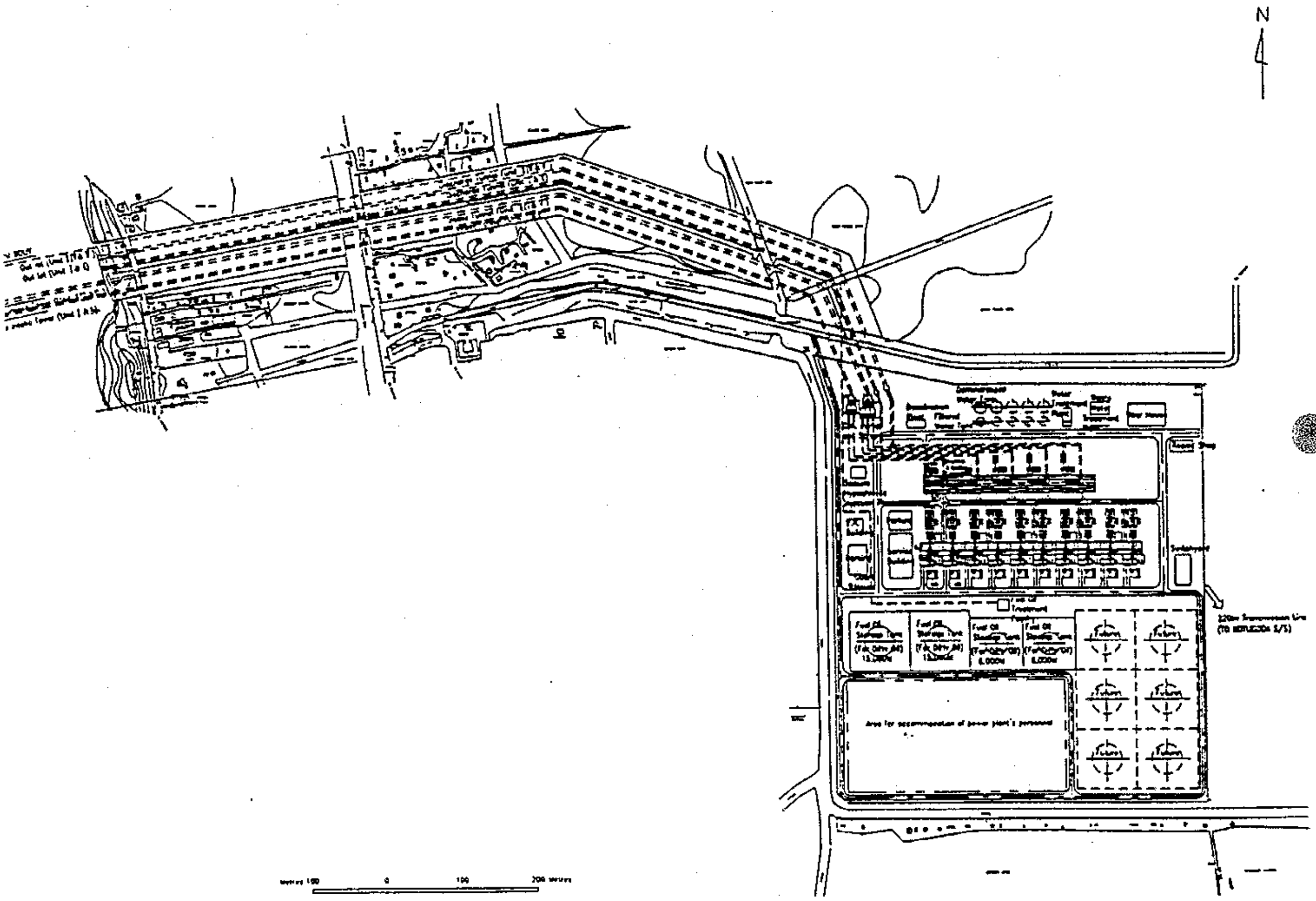
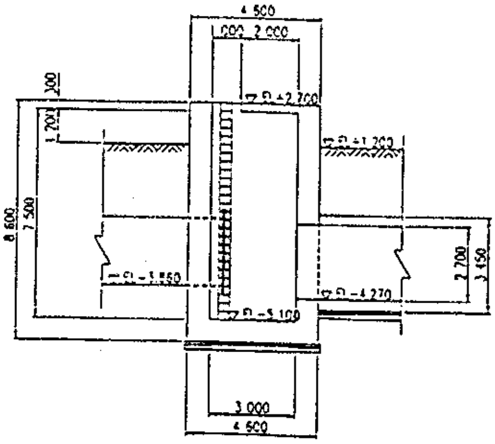


Figure 4-3 PLANNING DRAWING FOR INTAKE & DISCHARGE CULVERT

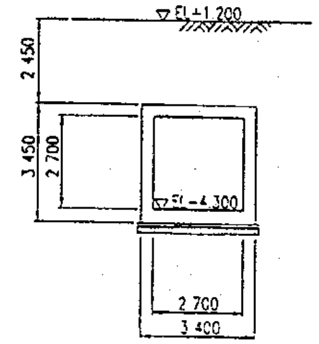
CONNECTION PIT
(SUBHARINE PIPE & INTAKE CULVERT)



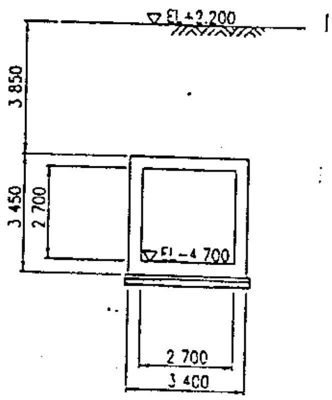
SECTION

INTAKE CULVERT

TYPICAL SECTION
(OUTSIDE OF PLANT AREA)

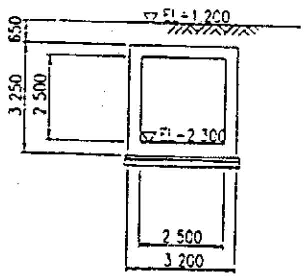


TYPICAL SECTION
(POWER PLANT AREA)



DISCHARGE CULVERT

TYPICAL SECTION
(OUTSIDE OF PLANT AREA)



TYPICAL SECTION
(POWER PLANT AREA)

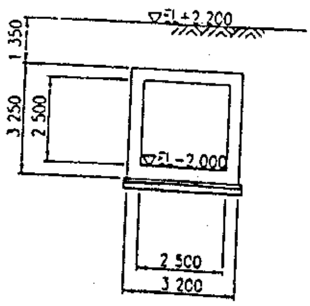
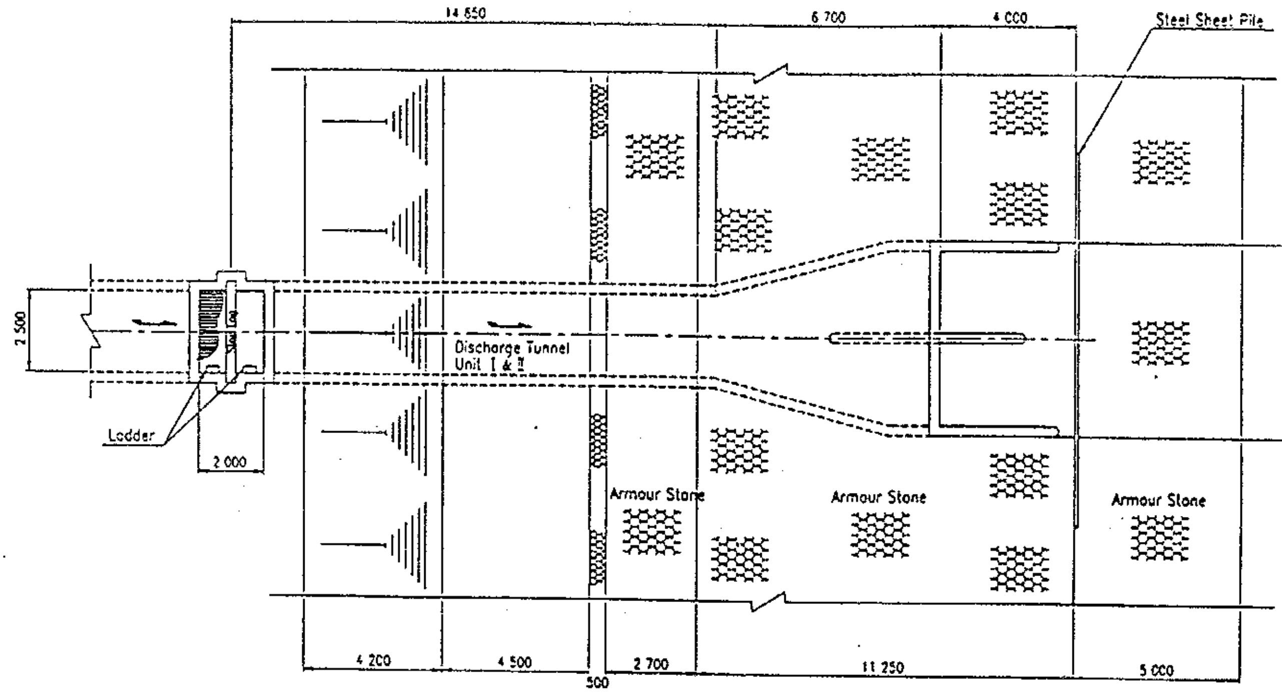
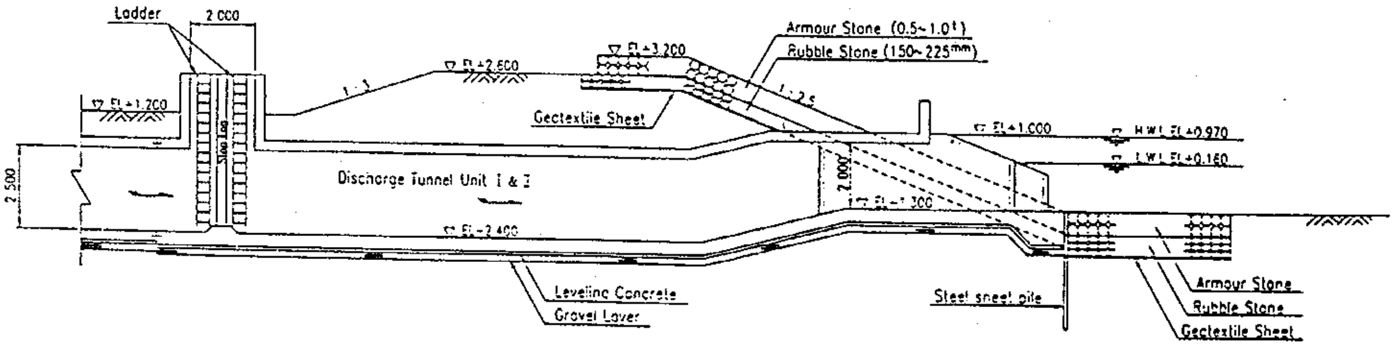


Figure 4-4 PLANNING DRAWING FOR OUTLET

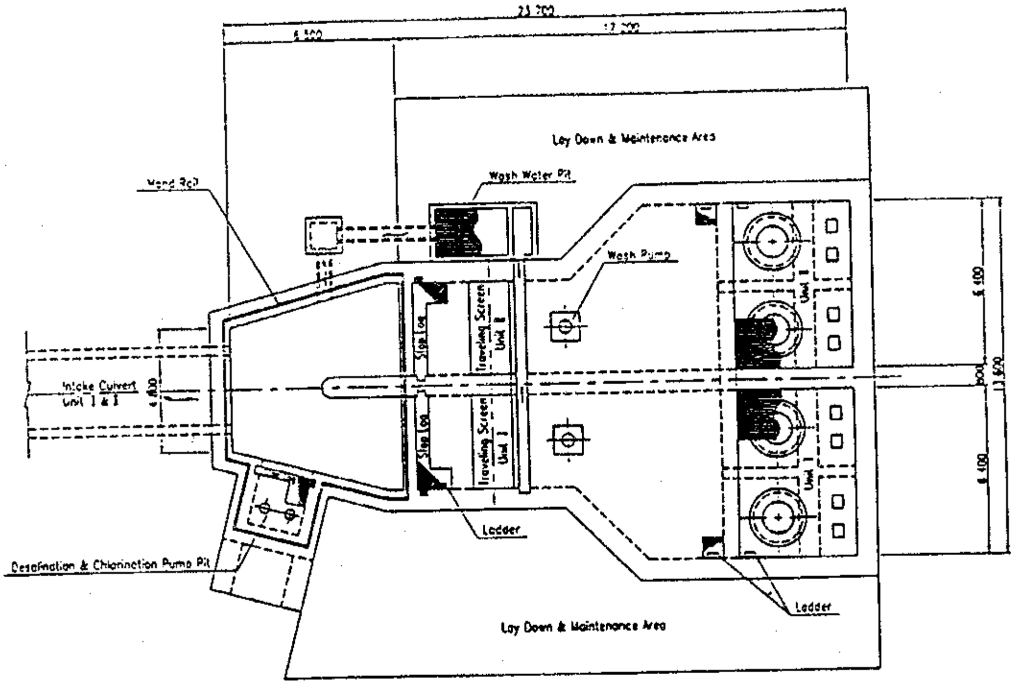


PLAN

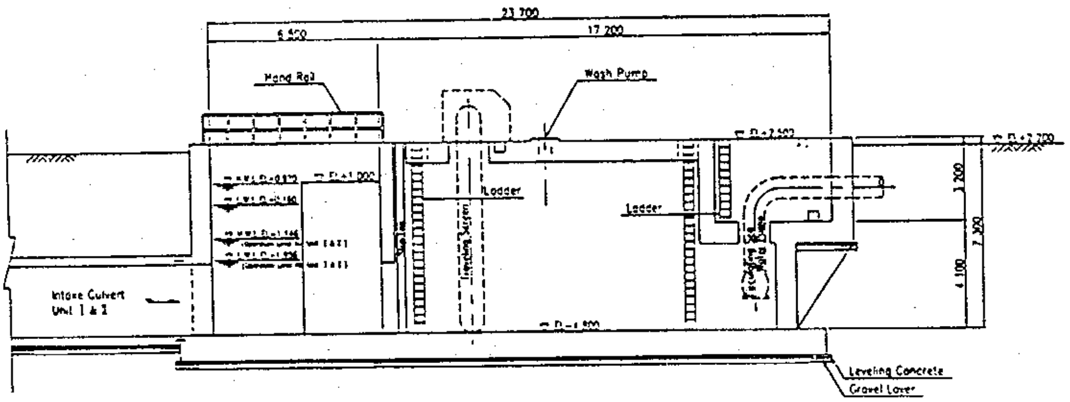


SECTION

Figure 4-5 PLANNING DRAWING FOR SCREEN & CIRCULATING SEAWATER PUMP PIT



PLAN



SECTION

Figure 4-6 PLANNING DRAWING FOR OIL STORAGE TANKS

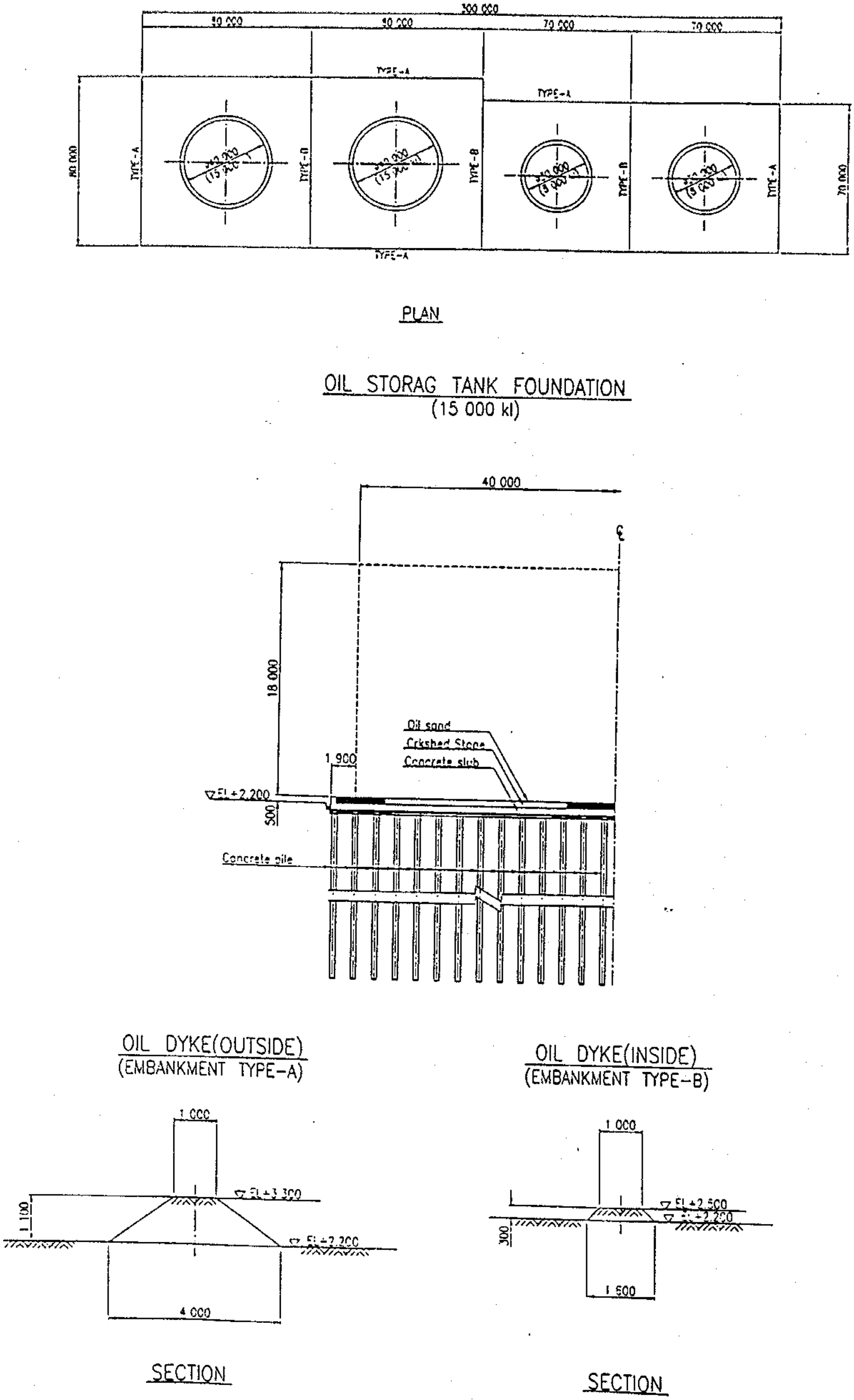
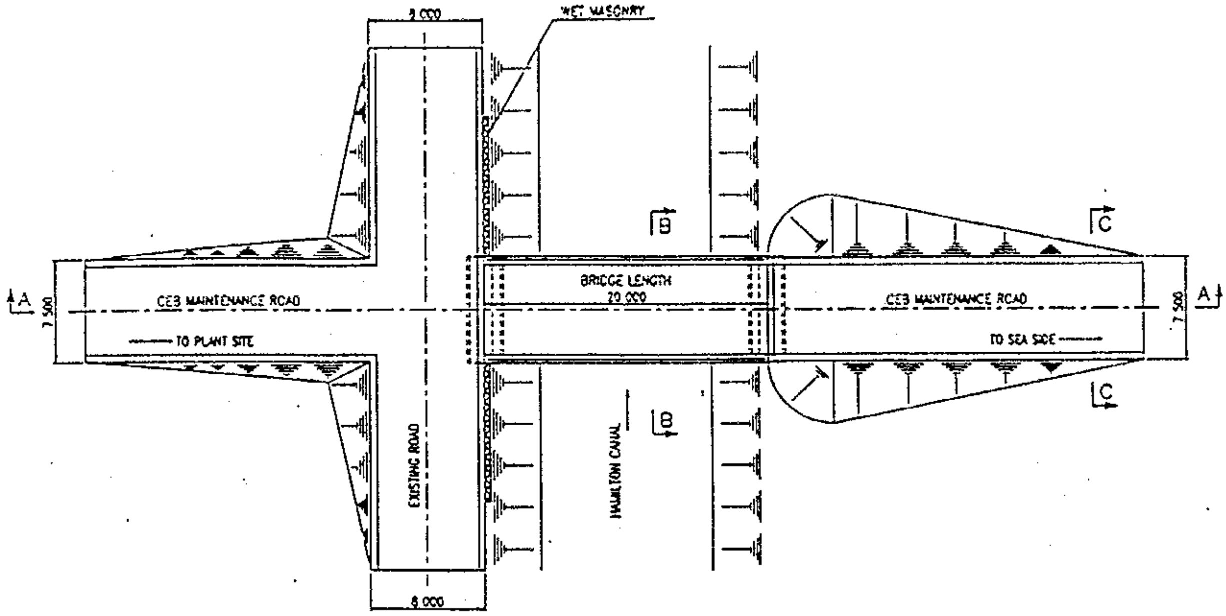
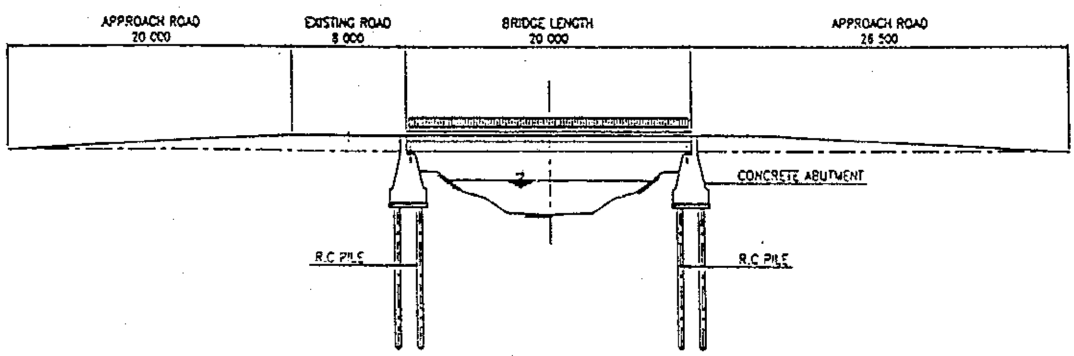


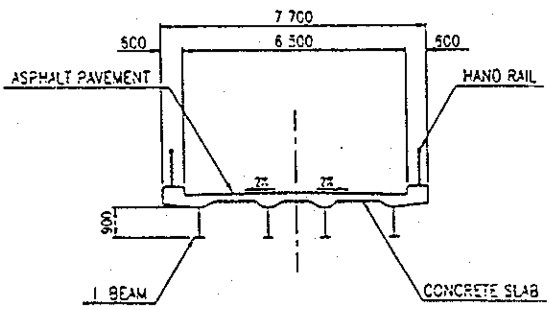
Figure 4-7   PLANNING DRAWING FOR CEB MAINTENANCE BRIDGE



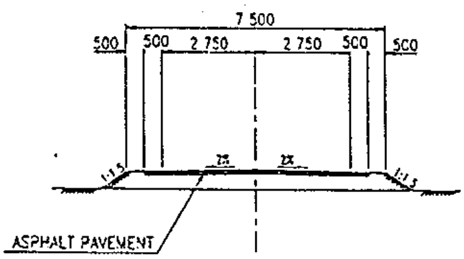
PLAN



SECTION A–A

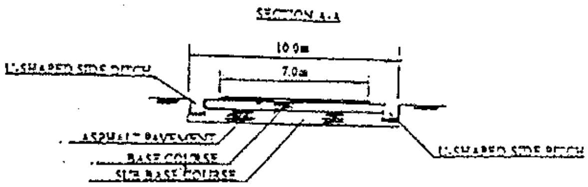


SECTION B–B

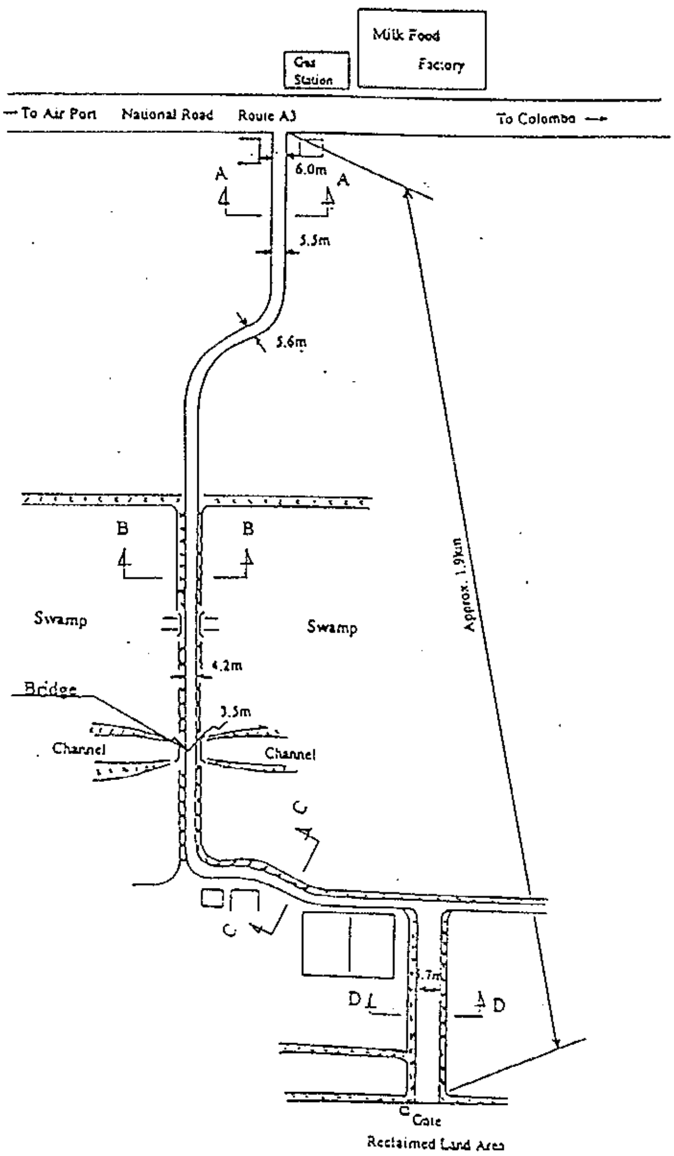


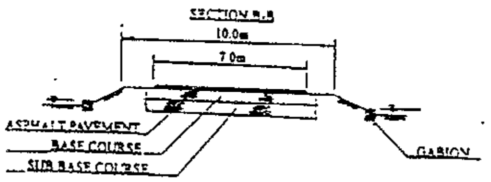
SECTION C–C

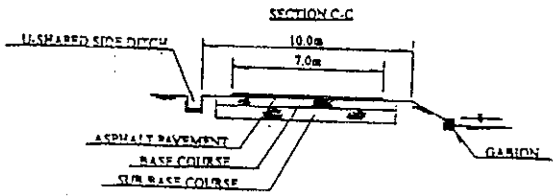
Figure 4-8 PLANNING DRAWING FOR REHABILITATING OF ACCESS ROAD

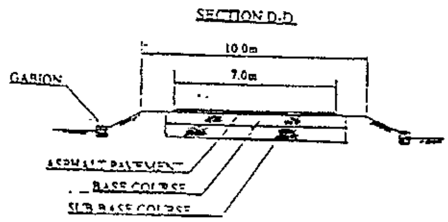


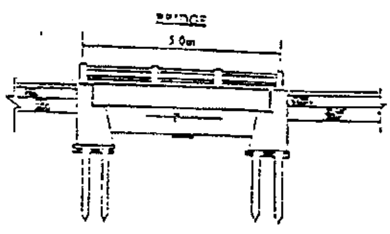
SURVEY MAP FOR EXISTING ACCESS ROAD

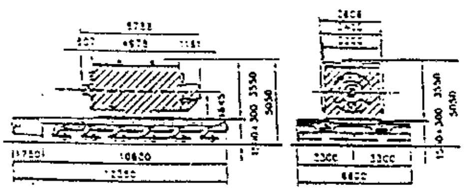












HEAVY EQUIPMENT TRANSPORTATION PLAN
(GENERATOR)

5. ENVIRONMENTAL IMPACT ASSESSMENT

5. ENVIRONMENTAL IMPACT ASSESSMENT

The proposed Kerawalapitiya Combined Cycle Power Plant will make an important contribution in meeting urgent needs of the power requirement in the country by providing relatively clean thermal energy. As a result of careful evaluation of entire range of alternatives for generating electricity, it is concluded that the proposed Combined Cycle Power Plant would form an integral part of the least cost generation plan.

The construction and operation of Kerawalapitiya Combined Cycle Power Plant will have the following positive benefits.

- Proposed electrical power system would provide approximately 960 GWh of electrical energy per annum.
- Ensure sustained economic growth in the country.
- Absence of significant environmental impacts.

The following environmental and economical aspects will be anticipated by the project implementation.

Environmental Aspects

- Emission of SO_2, NO_2 and SPM will clear the permissible level for ambient air quality of the Sri Lanka Standards.
- Noise level by construction machinery and plant facility operation will clear the proposed standards at the boundary of the site.
- Quality of effluent from the site will clear the Sri Lanka Standards.
- The increasing of water temperature by cooling water to be discharged to the coastal sea is not more than 10℃ higher than the ambient water temperature. The area susceptible to temperature rise will be minimized by rapid mixing with the large volume of ambient water body. Therefore, no significant impacts are expected.

- Transmission line will be constructed along the boundary of conservation zone. Careful survey for local living fauna and flora will be carried out before construction, to minimize the impacts due to transmission tower construction work.
- Monitoring on ambient air quality and the effluent to the environmental water body will be carried out and reported to the authorities concerned.
- Reasonable compensation will be made to people related to land acquirement, removal of housing or modification of housing or associated fixed assets.

Economical Aspects

- Meeting the growing electricity demand with an efficient power plant. (The expected thermal efficiency will be approximately 46%)
- Enhancement of local employment
- Production of electricity, that is vital for the expected electricity demand growth and greater reliability which would enhance the foreign investment in Sri Lanka.
- Ensuring the expected economic growth in the country.

The potential impacts on the environment will be insignificant since the predicted emission and effluent level will be within the standards specified by the regulatory authorities. The project site locates on the land already reclaimed and categorized into industrial and commercial zone by the authorities concerned.

The project conforms to the National Environmental Standards and is recommended to be implemented.

6. FEASIBILITY GRADE DESIGN OF KERAWALAPITIYA COMBINED CYCLE POWER PLANT

6 FEASIBILITY GRADE DESIGN OF KERAWALAPITIYA COMBINED CYCLE POWER PLANT

6.1 Combined Cycle Plant

6.1.1 Optimization of Combined Cycle Plant Configuration

A unit of combined cycle power generation plant consists of gas turbine(s), heat recovery steam generator(s), a steam turbine and electric generator(s), and many plant configurations could be considered depending upon the number and the unit capacity of the gas turbine(s) to be applied to form the plant with a nominal capacity of 150 MW. Therefore, it is an important process for the fruitful accomplishment of this study to select the optimum plant configurations for this project, taking the site conditions into account.

The optimum plant configuration must be scrutinized from such many viewpoints as the operability, the maintainability and the performance of the plant, the influence on the net work in a case of the unit trip, the plant construction cost, the marketability and the future power expansion capability of Kerawalapitiya power station.

However, it is not practical from the major viewpoints mentioned above to employ a large number of gas turbine units for the plant, so that the optimum configuration was investigated provided that their maximum number is assumed to be three(3) for this study. The investigation results are as mentioned below :

(1) The gas turbine shaft should be separated the steam turbine shaft taking the plant operability into account.

(2) Generally, the thermal efficiency of the combined cycle power plant increases as the unit capacity of the gas turbine increases. However, there is no distinct difference among the plant thermal efficiencies of combined cycle power as far as the unit capacity of the gas turbine is in a range of 50~100MW. The plant thermal efficiency is 44 – 46 % when the gas turbine is operated on oil fuel and steam is injected for NOx control.

(3) It is foreseen that the net work frequency is lowered less than 47.75 Hz when the plant of 150 MW consisting of one(1) 100 MW gas turbine and one(1) 50 MW steam turbine trips suddenly on an off-peak load condition. As the results, the load of approximately 100 MW connected with the net work will be shed.

(4) In the configuration of the plant of 150 MW consisting of one(1) 100 MW gas turbine and one(1) 50 MW steam turbine, any electric power is can not be dispatched from this power station until the next plant will be completed in the future.

(5) The construction cost of the plant of 150 MW consisting of two(2) 50 MW gas turbines and one(1) 50 MW steam turbine is higher. However, there are advantages that the influence on the net work does not occur, nor is the power station in a complete power

influence on the net work does not occur, nor is the power station in a complete power failure even if one(1) gas turbine suddenly trips.

(6) The number of gas turbine(s) should not be specified to make market competition more open. Therefore, the both plant configurations consisting of one(1) gas turbine and two(2) gas turbines should be taken up as candidates for bidding. Such a consideration as the plant configuration consisting of two(2) gas turbines will not be disadvantageous from the cost competition point of view should be paid at the bidding stage.

Table 6-1 presents candidate models of gas turbines suitable for this project which are available in the current market.

Table 6-1 Candidate Models of Gas Turbines

ISO conditions, Natural Gas

Model No.	Maker	Capacity (MW)	Rotating Speed(rpm)	Efficiency (LHV %)	Exhaust Gas Temp.(℃)	Exhaust Gas Flow(t/h)
GT 8C	ABB	53	3,000	34.4	517	508
GT 13D	ABB	96	3,000	32.0	490	1,120
V64.3	Siemens	63	3,000	36.5	531	538
F 9EA	GE	123	3,000	33.8	538	1,140
MW701D	Mitsubishi	131	3,000	33.9	513	1,260

Remarks : Cited from Gas Turbine World 1997 Handbook

6.2 Design Concept of Plant Main Components

The combined cycle plant comprises three(3) main components of gas turbine(s), heat recovery steam generator(s) and a steam turbine. Described here is the design concept of these components, taking the given site conditions into account. The design results are as summarized below.

(1) Gas Turbine

The gas turbine is the most important component which plays a role as a center core of the combined cycle plant and the highest reliability is necessary for the purpose. The gas turbine is developed, designed and standardized by manufacturers in advance different from a steam turbine which is specifically designed and manufactured every time when it is ordered. Because it is much costly and takes a longer time to develop and design upon request of order. Therefore, it is a practical process to select candidate models suitable for the project among standard models which are in a lineup for production at the time when they are required. Furthermore, it is an essential condition that more than three(3) units are possessed of an operating experience of 24,000hours at least for each selected model at the time when it is selected. Recently, the gas turbines of which turbine inlet temperature to make their performance determinate is around 1,300 ℃ have been commercialized. However, it is difficult to say that they have been so matured and reliable that they are satisfied with the said conditions. Therefore, it is thought desirable to make a candidate the models of which turbine inlet temperature is up to 1,200℃.

(2) Heat Recovery Steam Generator

The heat recovery steam generator(to be referred to as HRSG hereinafter) is a component to convert the heat energy of the gas turbine exhaust gas into the heat energy of the steam. The heat energy recovery is characterized with main four(4) parameters of the number of pressure levels, steam pressure value(s), steam temperature value(s) of the generated steam and the outlet gas temperature of the HRSG on the given gas turbine exhaust gas temperature. For this project, a dual-pressure non-reheat type cycle is employed considering the capacity of the steam turbine and the exhaust gas temperature of the gas turbine. The outlet temperature of HRSG is specified at 170℃ to protect heating tubes in a low temperature area from a low temperature corrosion. As for the type of construction, a gas vertical flow type is adopted as the type is slightly advantageous in total compared with a gas lateral flow type.

(3) Steam Turbine

A single steam turbine is employed for this project irrespective of the number of gas turbines used, taking the operability of the plant into account. The steam turbine is of a single cylinder construction type considering its capacity, experience and economy. The cost effect extends to not only the turbine itself, but also the concrete foundation and the turbine building. The steam turbine is designed at 3,000rpm without a reduction gear giving rise to mechanical loss and noise. As for the cooling system of the condenser, an one-through cooling system using sea water is employed as the results of comparison with a mechanical draft wet cooling system and a direct air cooling system.

6.3 Brief Specification of Main Components

6.3.1 Design Condition

Design conditions of the power plant were decided through the discussion between CEB and the Study Team during the third site survey, as described below.

(1) Atmospheric temperature	: 30°C (Dry bulb), 27°C (Wet bulb)
(2) Relative humidity	: 78%
(3) Atmospheric pressure	: 1.033 bar
(4) Condenser inlet cooling water temperature	: 27.5°C
(5) Type of condenser cooling	: One through flow direct cooling by sea water
(6) Applied standards and codes	: Internationally authoritative standards and codes should be applied.
(7) NO_X control	: Below 70 ppm (15% O_2) at gas turbine outlet by applying steam injection (during combined cycle operation) or water injection (during simple cycle operation)
(8) Altitude	: Sea water level
(9) Noise level	: SPL 1m distant from equipment 85dB(A) SPL on the power station battery limit 60dB(A)
(10) Temperature rise across the condenser	: 10°C
(11) Operation mode	: Each gas turbine generator will be operated in an isolated and open cycle mode. For this purpose, a bypass stack will be installed between the gas turbine exhaust and the HRSG.
(12) Stack height	: 80m (both main stack and bypass stack)
(13) Site area	: As shown below;

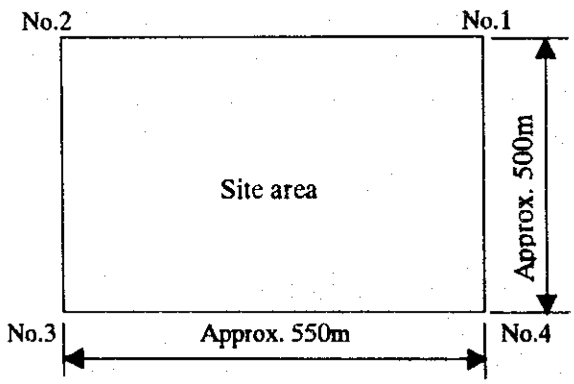


Figure 6-1 Site Drawing

6.3.2 Brief Specification of Main Components

Brief specifications of main components based on the conceptual design are as described below.

(1) Gas Turbine Assembly

a. Number	One(1) or two(2) sets depending upon the plant configuration
b. Unit capacity	50MW class or 100MW class on ISO conditions depending upon Models of manufacturers
c. Type	Simple open cycle heavy duty single shaft type

(2) Heat Recovery Steam Generator

a Type	Dual pressure non-reheat type
b Direction of gas flow	Vertical direction
c No. of boiler	One(1) or two(2) sets, depending upon the number of gas turbines
d Steam conditions	
- Steam pressure	High pressure : 5 to 7 Mpa Low pressure : 0.5 to 0.7 Mpa
- Steam temperature	High temperature : 480 to 500 ℃ Low temperature : 150 to 200 ℃

(3) Steam Turbine

a. Type	Mixed pressure single cylinder single flow condensing type
b. Number	One(1) set
c. Capacity	Approximately 50MW
d. Rotating speed	3,000rpm
e. Steam conditions :	
- Steam pressure	High pressure : 5 to 7 Mpa Low pressure : 0.5 to 0.7 Mpa
- Steam temperature	High temperature : 480 to 500 ℃ Low temperature : 150 to 200 ℃
f. Steam flow	High pressure steam : 95 to 120 t/h Low pressure steam : 50 to 60 t/h
g. Vacuum	Approximately 8 kPa
h. Exhaust direction	Axial flow

(4) Generator

	Gas Turbine	Steam Turbine
a. Type	Totally enclosed air cooled cylindrical rotor synchronous type	
b. Number	One(1) or two(2) sets	One(1) set

c. Apparent capacity	118 MVA or 59 MVA	59 MVA
d. Effective capacity	100 MW or 50 MW	50 MW
e. Voltage	11 kV	
f. Power factor	0.85	
g. Rotating speed	3,000 rpm	
h. Number of poles	2	
i. Short circuit ratio	0.58 ~ 0.64	
j. Insulation class	F class(Temperature rise : B class)	
k. Exciter type	Static type	

(5) Seawater desalination plant

a. Number	1set
b. Type	Multiple-effect distillation
c. Capacity	1,500t/day

(6) Raw water Tank

a. Number	3 sets
b. Type	Steel made cylindrical tank (of dome roof type)
c. Capacity	1,600ton

(7) Demineralizer

a. Number	2 sets
b. Type	Mix bet type with polisher
c. Capacity	55ton/h

(8) Demineralized water

a. Number	1 set
b. Type	Steel made cylindrical tank (of inner roof type)
c. Capacity	1,500ton

(9) Waste water storage pond

a. Number	1 set
b. Type	Pit
c. Capacity	300m^3

(10) Waste water treatment equipment

a. Number	1 set
b. Capacity	17m^3/h

(11) Fuel unloading system 1set

(12) Untreated oil tank

a. Number	2 set
b. Type	Fixed cone roof cylindrical type
c. Capacity	15,000ton

(13) Fuel oil treatment plant

a. Number	3 sets
b. Type	Centrifugal separators (Self-Cleaning Type)
c. Capacity	15ton/h

(14) Treated oil tank

a. Number	2 sets
b. Type	Fixed cone roof cylindrical type
c. Capacity	8,000kl

(15) Fuel feed pump

a. Number	2 sets
b. Capacity	35kl/h

(16) Dike

a. Number	1 set
b. Type	Banking type
c. Capacity	17,741m^3

(17) Fire extinguishing equipment

a. Water source	Raw water tank
b. Fire service pump	
(a) Number	2 sets
(b) Type	to be started up with a motor or a diesel
c. Fire protection system	1 set
d. Air foam and dry chemical fire extinguisher	
(a) Type	Compact movable or portable type

6.4 Power Plant and Equipment Arrangement Plans (Design)

6.4.1 Conditions of Study

The arrangement of the power plant for this project has been planned/studied based on the following conditions:

a. The power plants layout shall be arranged so that as many units as possible can be accommodated in the given site area shown in the page 6-3.

b. The power plant fuels and condenser cooling water will be supplied from the seaside northwest of the plant site.

c. Since the transmission line to be constructed is scheduled to be extended in the southeast direction from the power plant, the switchyard will be arranged on the side a little south and east of the proposed power plant site.

d. The gas turbine(s), a steam turbine and generators will be installed in the main power house.

e. The power plant will be of either of the following two types:

Type A: [(Two gas turbines) + (Two heat recovery steam generators) + (One steam turbine)]

Type B: [(One gas turbine) + (One heat recovery steam generator) + (One steam turbine)]

6.4.2 Power Plant Arrangement Plan

The power plant arrangement planned based on the above conditions are presented in Figures 6-2 and 6-3.

(1) Type A

Presented in Figure 6-2 is the arrangement plan prepared based on : [(Two gas turbines) + (Two heat recovery steam generators) + (One steam turbine)]. In this case, the total output of the power plant will ultimately become 750MW.

(2) Type B

Presented in Figure 6-3 is the arrangement plan prepared based on : [(One gas turbine) + (One heat recovery steam generator) + (One steam turbine)].
In this case also, the total output of the power plant will ultimately become 750MW.

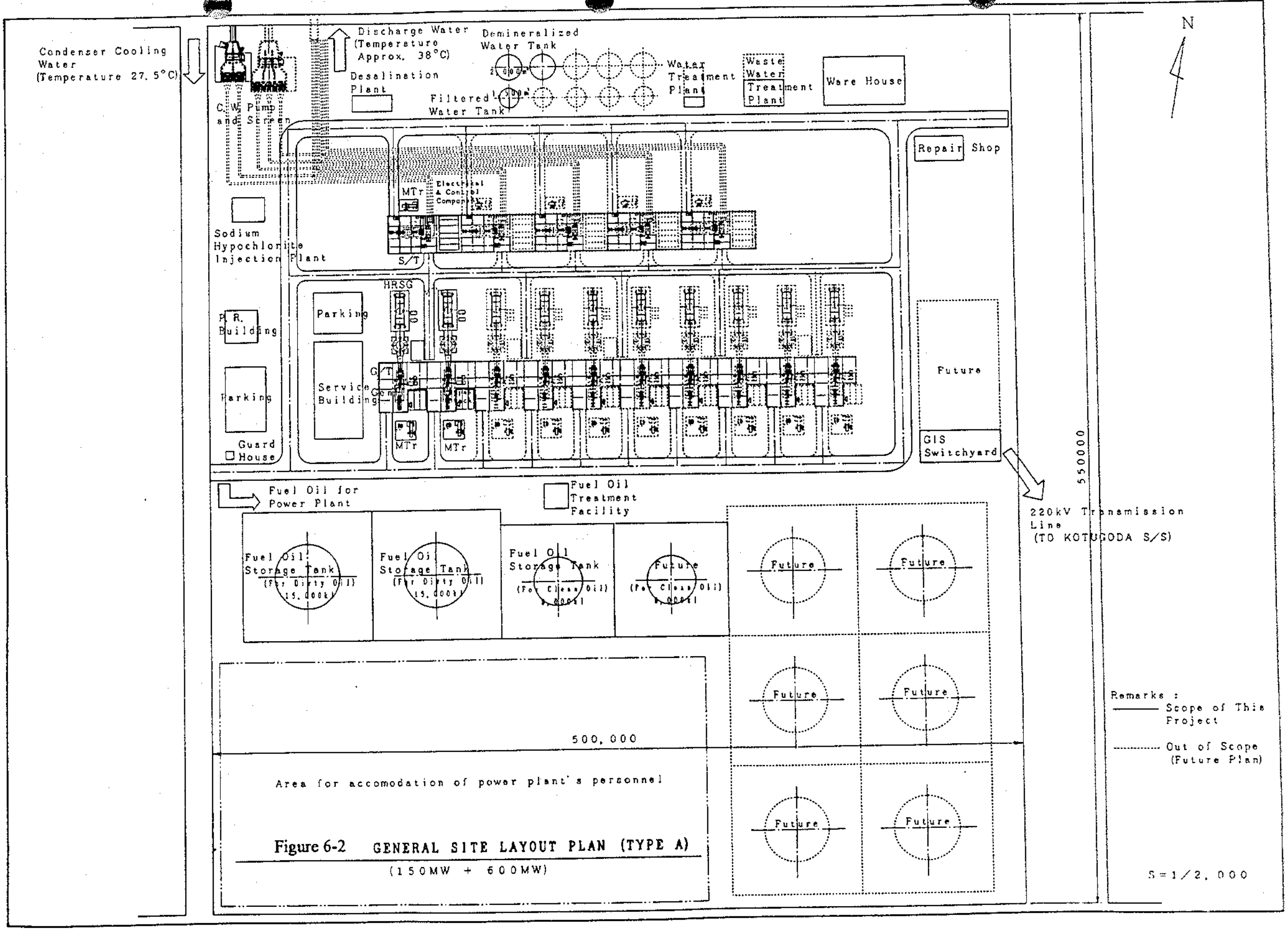


Figure 6-2 GENERAL SITE LAYOUT PLAN (TYPE A)
(150MW + 600MW)

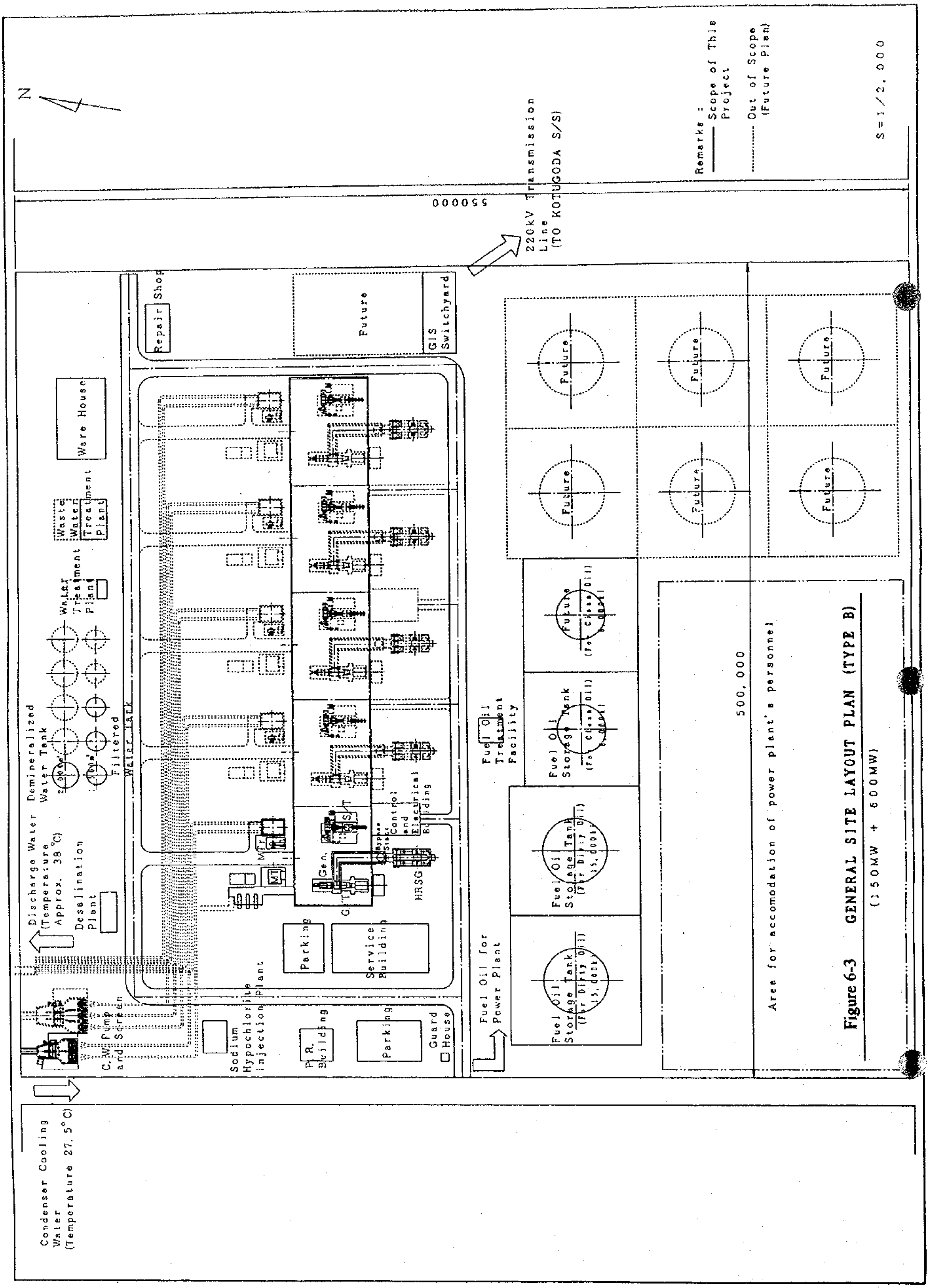


Figure 6-3 GENERAL SITE LAYOUT PLAN (TYPE B)

(150MW + 600MW)

6.5 Operation and Maintenance

The combined cycle power plant is composed of gas turbine(s), heat recovery steam generator(s) (hereinafter called HRSG(s)) and a steam turbine. The HRSG is of an unfired type and its maintenance is far easier differently from the existing combustion type boilers. The steam turbine is a machine historically matured and its maintenance technique is thought to be familiarized with existing steam turbines. From such reasons as described above, mentioned here is the consideration for the operating and maintenance of the gas turbine. And analyzed is past operating and maintenance results of the existing gas turbine generators. Recommendations to elevate the operating reliability and availability of this combined cycle power plant are proposed based on the analyzed results. The cost required for implementation of the recommendations is included in the project cost. The proposed recommendations are as described below.

- Provision of the spare parts to be required for the initial five-year operation in the scope of supply of EPC contractor.
- Provision of the maintenance shop accommodated with a field balancing equipment, TIG and MIG welding machines, boring machines, lathes, an electric furnace, a milling machine, various kinds of flaw detector, various kinds of testing equipment and so on for repair of damaged parts and check of soundness of equipment and facilities.
- Training of operation and maintenance staff at the EPC contractor's factories and site.
- One year stay of a mechanical engineer and an electrical engineer familiar with control equipment to mature the operation and maintenance techniques.
- Introduction of the Information Management System providing historical records of troubles and operating data, the performance degradation status of gas turbines, a steam turbine and HRSGs, status of equivalent operating hours of them for periodical inspections and parts replacements and having the function to diagnose the operating status.

Table xxxx shows the operating experience with the existing gas turbines(unit NO. 1 ~ 6) of Keranittesa Power Station.

Table 6-2 Operating Record Details of Keranitessa Gas Turbines

GT	1992				1993				1994			
NO	POH	FOH	OH	Total	POH	FOH	OH	Total	POH	FOH	OH	Total
01	583.0	501.5	2,759.2	3,843.7	0.0	5,107.8	2.5	5,110.3	744.0	4,636.0	6.5	5,386.5
02	2,184.0	4,824.5	1,375.6	8,384.1	744.0	199.5	328.2	1,271.7	1,425.0	246.0	2,104.7	3,775.7
03	1,464.0	751.5	3,579.7	5,795.2	1.0	5,061.5	321.2	5,383.7	0.0	3,814.5	1,659.6	5,474.1
04	1,761.5	34.5	3,869.4	5,665.6	0.0	255.0	164.6	419.6	617.0	1,635.5	826.8	3,079.3
05	336.8	2,823.5	3,469.1	6,629.4	0.0	8,759.5	0.1	8,759.6	8,740.0	0.0	19.3	8,759.3
06	972.5	1,687.0	2,315.5	4,975.0	8,760.0	0.0	0.0	8,760.0	4,169.5	1,397.0	1,781.0	7,347.5
Total	7,301.8	10,622.5	17,368.7	35,293.0	9,505.0	19,383.3	816.6	29,704.9	15,695.5	11,729.0	6,397.9	33,822.4
GT	1995				1996				1997(up to October)			
NO	POH	FOH	OH	Total	POH	FOH	OH	Total	POH	FOH	OH	Total
01	3,360.0	453.5	1,927.6	5,741.1	559.0	2,083.0	5,844.7	8,486.7	1,498.0	256.0	3,687.0	5,441.0
02	1,967.5	3,316.5	997.8	6,281.8	808.0	879.0	5,821.9	7,508.9	408.0	364.0	4,664.0	5,436.0
03	592.0	4,016.5	1,928.6	6,537.1	1,733.0	1,806.0	3,753.2	7,292.2	1,398.0	343.0	3,847.0	5,588.0
04	134.5	1,291.5	2,090.5	3,516.5	86.0	3,487.0	3,981.2	7,554.2	211.0	363.0	4,723.0	5,297.0
05	3,597.0	4,416.0	13.3	8,026.3	559.0	2,768.0	4,444.6	7,771.6	299.0	417.0	4,493.0	5,209.0
06	9.0	1.166.5	1,068.0	2,243.5	1,777.0	769.0	6,077.0	8,623.0	1,473.0	69.0	3,403.0	4,945.0
Total	9,660.0	14,660.5	8,025.8	32,346.3	5,522.0	11,792.0	29,922.6	47,236.6	5,287.0	1,812.0	24,817.0	31,916.0

The averaged reliability and availability factors of each year are obtained as shown using the above figures.

Year	1992	1993	1994	1995	1996	1997
Reliability factor	79.8	63.0	77.7	72.1	77.6	95.4
Availability factor	66.0	45.0	47.8	53.7	67.7	82.0

Where the reliability and availability factors are defined as follows:

Reliability factor = 1 – (Total FOH) / (Number of GTs × Period Hours)

Availability factor = 1 – (Total FOH + Total POH) / (Number of GTs × Period Hours)

6.6 Construction Schedule of Kerawalapitiya Combined Cycle Power Plant

6.6.1 Construction schedule of Kerawalapitiya Combined Cycle Power Plant

The construction schedule of Kerawalapitiya Combined Cycle Power Plant as shown in Figure 6-4 is assumed to be forty-nine (49) months from Loan Agreement to the Commercial Operation. The following are the period between each key milestone.

● Loan Agreement to Decision of the Consultant	: Five (5) months
● Preparation of Tender Documents, etc.	: Six (6) months
● Tender Announcement to Decision of Bidder	: Seven (7) months
● Award of Successful Bidder to Commissioning	: Thirty one (31) months
● Total (Loan agreement to Commissioning)	: Forty nine (49) months

6.6.2 Items to be considered for the construction schedule

(1) The off-shore work periods of the fuel oil receiving facilities and intake water channel

The off-shore work can not be done from April to November because of severe monsoon. Therefore, it is necessary to review the allover construction schedule so that the off-shore work may be started from October or November.

(2) Access road

Improvement of access road for which around eight (8) months will be required should be completed prior to transportation of large equipment and components to the site.

(3) Intake and discharge channel works (on land)

It will take twenty four (24) months for the construction period of the intake and discharge channel works including the associated reclamation and leveling works of lands.

(4) It is necessary to plan the schedule of the engineering stage I, carefully taking account of the monsoon season, because around thirty (30) days are required for the survey works in the sea area.

Figure 6-4 Construction Schedule of Kerawalapitiya Combined Cycle Power PLant