No. 2

APPENDIX

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

# ENVIRONMENTAL IMPACT ASSESSMENT REPORT

JANUARY 1999



TOKYO ELECTRIC POWER SERVICES CO., LTD.

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## ABBRVIATIONS USED

| | | |
|---|---|---|
| $\mu$ m | - | Micro meter |
| BOD | - | Biochemical Oxygen Demand |
| ℃ | - | Degrees Celsius |
| CEA | - | Central Environmental Authority |
| CEB | - | Ceylon Electricity Board |
| CO | - | Carbon Monoxide |
| COD | - | Chemical Oxygen Demand |
| EIA | - | Environmental Impact Assessment |
| GWL | - | Ground Water Level |
| ha | - | Hectare |
| HRB | - | Heat Recovery Boiler |
| HRSG | - | Heat Recovery Steam Generator |
| JICA | - | Japan International Cooperation Agency |
| kg/s | - | Kilograms par Second |
| km | - | Kilo Meter |
| kV | - | Kilo Volt |
| LPG | - | Liquefied Petroleum Gas |
| m | - | Meter |
| mg/l | - | Milligrams per Liter |
| mm | - | Millimeter |
| M.S.L. | - | Mean Sea Level |
| MVA | - | Mega Volt Amperes |
| MW | - | Mega Watts (1,000 kilo watts) |
| $NO_X$ | - | Nitrogen Oxides |
| OECF | - | Overseas Economic Co-operation Fund of Japan |
| PAA | - | Project Approving Agency |
| Pb | - | Lead |
| pf | - | Plant Factor |
| RDA | - | Road Development Authority |
| $SO_2$ | - | Sulfur Dioxide |
| SPM | - | Suspended Particulate Matters |
| SPMB | - | Single Point Mooring Buoy |
| SS | - | Suspended Solid |
| t | - | Ton |
| t/hr | - | Tons pre Hour |
| TOR | - | Terms of Reference |

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# EXECTIVE SUMMARY

## EXECUTIVE SUMMARY

**The Project**

The Ceylon Electricity Board (CEB), a public corporation, is responsible for the generation, transmission and most of the distribution electricity in Sri Lanka. The CEB is planning to expand Sri Lanka's generation capability in order to meet future demands for electricity. The Long Term Generation Expansion Study 1995 - 2009 prepared by the CEB has identified the need for a number of small thermal plants between 1996 and 1999 to meet the increase in demand.

A 150 MW combined cycle facility on the reclaimed land of the Kerawalapitiya north of the City of Colombo will form part of the least cost solution to meet the projected demand.

**The Environmental Impact Assessment Report**

The preparation of the Environmental Impact Assessment report of this project has been coordinated by the Ceylon Electricity Board (CEB) and the Study Team of Japan International Cooperation Agency (JICA).

**The Development**

The proposed power plant to be located in an area of approx. 28.0 ha where additional four (4) units of the same can be accommodated in the future and will provide around 150 MW of electrical power ; 100MW from a or two gas turbine(s) and 50 MW from a steam turbine.

The fresh water for make-up is supplied from the sea water desalination plant during the first couple of years and then from a pipeline of the National Water Supply and Drainage Board in the future. The quantity will be around 55 tons per hour.

There are two options possible regarding the cooling water supply for the steam turbine. One is a Direct Sea Water Cooling System, the other is Wet Cooling Tower System. The sea water of approx. 3,700 kg/sec. will be required in the former case and the fresh water of approx. 100 kg/sec. will be required in the latter case.

Auto Diesel Oil will be applied as fuel for this plant. Fuel of approximately 184,000tons per year will be required for this plant.

Two (2) 15,000 and two (2) 8,000 tons fuel oil storage tanks will be constructed at the site.

The 220 kV switchyard will be installed at the plant site. The electric power generated from the plant will be transmitted to the existing Kotugoda Sub-station through the new 220kV overhead transmission line with the least disturbance to the environment.

The proposed plant will be operated at the base load to meet electricity requirements in the medium to short term and is identified in the least cost solution to expansion of generation capacity. The Government has accorded high priority to implementation of this project which is expected to be financed by the Government of Japan under very concessionary terms.

**Alternatives**

An alternative power plant to be compared with a C/C (combined cycle) power plant in economical and financial analyses is nominated of a oil-fired conventional (Rankin cycle) type for the following reasons.

1. One of the most reliable types of power plant.
2. The same unit capacity is available.
3. Fuel oil and seawater cooling condenser system are applicable. Therefore, the same facilities for fuel supply and seawater circulation are applicable, hence less cost difference in civil works.
4. Such additional facilities and installation areas as seen on a coal-fired power plant are not required.
5. Environmental impact on the same is expected.
6. A construction period is almost the same because a lengthy construction period for civil works is required.

Specifications of an alternative power plant are as follows.

| | |
|---|---|
| 1. Capacity | ; 150 MW |
| 2. No. and main equipment of unit | ; One(1) unit consisting of one(1) boiler, one(1) steam turbine and one(1) FGD(flue gas desulfurization plant) |
| 3. Fuel | Heavy oil having a sulfur content of 2.0 % |
| 4. Fuel consumption | 33,100 kg/h at 150MW |
| 5. Plant efficiency(HHV basis) | 38% on a power generation basis<br>35% on a power transmission basis |
| 6. Emission | SOx 265ppm<br>NOx 200ppm ($O_2$=4%) |

**Existing Environment**

The proposed power plant site is located about 10 km north ward from the City of Colombo, at Indian Ocean side in Ganpaha District, Western Province. It is the part of the land reclaimed by Kerawalapitiya land reclamation project to become industrial and residential districts located in the southern part of a marsh area named Muthurajawela.

An elevation of the area where was filled up with the sea sand is approximately 1.5 to 1.8 m higher than mean sea level (M.S.L.). The thickness of the sea sand is 2 to 3 m on the stratum. The upper layer of the conventional marsh area is formed by soft peat and a comparatively excellent sand layer appears roughly around 9 m below the ground level.

On the west side of the proposed power plant site, Hamilton Canal flowing from north to south along the coast connects Kelani River and Negombo Lagoon. On its east side is Old Dutch Canal connected to Hamilton Canal by small waterways.

The coast runs approximately 1 km to the west of the proposed site, where the sea is shallow for some distance with seabed inclination of 1/120. The mouth of Kelani River is approximately 8 km south to this coast, and Colombo Port is located approximately 2 km south to the mouth of the river.

The climate is equatorial with 2,000 to 2,500 mm of rainfall per annum, and around 28℃ temperature. The relative humidity is high.

The study area for the purpose of the EIA study is considered to be 10 km from the project site for air quality and oceanography, and 2 km from the project site for other studies. Study area for the transmission line is 100 m (50 m either side from the centerline) wide corridor along the line route. The study area within 2 km radius from the proposed power plant site, comprise of 17 Grama Niladari divisions, has an estimated population of 66,000 people. Many of these people have attended school and have received reasonable education. One third of households in this area are under financial support of the government. During the construction phase of this project many of casual employees would be able to find temporary employment in the project site.

**Anticipated Environmental Impacts**

**(1) Air Quality**

Particulate $NO_X$, $SO_2$ and $CO_2$ are the predominant emission of all fossil fuel fired thermal power plant. Combined cycle power plants have the highest thermal efficiencies and hence the emission of the effluents would be the lowest of all thermal power plants per unit of electricity produced. Auto diesel oil will be used as a fuel and sulfur content is maximum 0.5%. Emission control for NOx steam and water injection system will be introduced.

A series of survey carried out in the study area indicate that the ambient air quality is within the National Standards gazetted by the Central Environmental Authority.

During the construction phase dust from construction activities is expected and, mitigatory measures such as watering the area is recommended to minimize the nuisance caused by dust.

The impacts on air quality due to operation of the power plant was done using computer models developed by United States Environmental Protection Agency. The results show that $NO_X$, $SO_2$ and SPM concentration are all below the stipulated standards of the CEA.

**(2) Noise**

Noise would emanate during the construction phase of the project as well as during operation phase. The existing noise at peak hours have been monitored and found to be within the standards gazetted by the CEA.

During the construction phase, increasing of noise level due to the activity of construction machinery is estimated by equations used in world wide. The results show that the noise level from construction activities is attained the maximum permissible noise level at boundary of the power plant site.

The noise generated during operation will be minimized as the turbine is to be placed in an acoustic enclosure. The estimation of noise level at the boundary of the site will be below the standard of maximum permissible noise level.

**(3) Liquid and Thermal Effluent**

The types of liquid effluent from a power plant during construction and operation phase are waste water from construction activities, from the plant facilities, from the sanitation facility and rain water. The effluent from the construction activities will be discharged to canal after treating appropriately with water quality control measures such as siltation pond. During operational phase, liquid effluent will be discharged to the sea after treated below the standard limits by waste water treatment system. Therefore the effects on surrounding environment is insignificant.

The thermal effluent from the power plant will be discharged at the coast line of Dickowita area. The difference temperature of the cooling water is proposed to be 10 ℃ up. The discharge rate will be 3.6 $m^3$/sec with about 0.5 m/sec of speed at the discharge point. The result of estimation by EPA model shows that the 1 ℃ up of thermal effluent is reached about 800 m from the coast line and covered 0.06 $km^2$ of the area at the case of 10 cm/sec ambient velocity. It is also estimated that the cooling water is mixed rapidly with surrounding sea water just after discharging and is decreased its temperature quickly within a short distance. Considering enough small of discharging speed, rapid decreasing of the temperature in a short distance from the discharge point and temperature difference caused due to natural factors, it is expected that thermal effluent from the power plant will not have a serious effect on the living species and fisheries in the area.

(4) Socio Economic Aspects

The study area in particular has variety land use pattern such as marsh, water bodies and distributed houses especially along side of the A3 route.

In this project, resettlement and/or land acquisition will be necessary at the area related to transmission line, cooling water intake and discharge pipeline and access road. The resettlement and /or land acquisition will be done with appropriate compensation and carefully concerned resettlement plan in order to avoid any dissatisfied feelings by residence.

The positive aspect during construction could be sited as creation of temporary employment for the large number of casual workers in the study area.

Therefore it is necessary that resettlement and land acquisition should be done with maximum concern, but in general no significant impacts on the socio economic well being of the people surrounding the power plant is expected.

**Mitigatory Measures**

Following is a list of mitigatory measures for eliminating, minimizing or reducing adverse impacts on various environmental components.

| ITEMS | PHASE | MITIGATION MEASURES |
|---|---|---|
| Air quality | Construction | Frequent watering for minimizing the impact by generated dust by construction activity. |
| | Operation | Exhaust pollutants are dispersed by the use of effective stack arrangements |
| Noise | Construction | Limitation of the construction activities during night in order to minimize the noise generation. |
| | Operation | Carrying out a regular plant inspection and maintenance program to prevent generation of noise due tear, alignment fault, etc.<br>Providing ear plugs/muffs to contain any impairment of hearing to employees |
| Water Quality | Construction | Installation of appropriate water quality control measures such as siltation pond |
| | Operation | Installation of waste water treatment system which include a neutralizing, hardening and sedimentation system and oil separator system |
| Contingency Plan | Operation | Installation of fire protection equipment and facilities<br>Installation of banking type oil dike and tank partition dike around oil tanks in order to prevent running out oils to the outside |

**Conclusion**

The proposed Combined Cycle Power Plant will make a major contribution in meeting immediate power requirements in the country by providing relatively clean thermal energy. The negative environmental impacts will be mitigated using state of the art techniques in the design. The impacts during the construction is expected to be minimum and wherever necessary mitigatory measures will be undertaken. The positive impacts far out weigh the negative impacts and the project is therefore recommended for implementation.

## SUMMARY SCHEDULE OF LEVEL OF POLLUTANTS AND PROPOSED MITIGATION MEASURES

| Environmental Component & Pollutant | Existing Ambient Level | Maximum Contribution from Power Station | Predicted Ambient Level | Standard Specified | Proposed Mitigation & Monitoring |
|---|---|---|---|---|---|
| **Air Quality**** (mg/m³) | | | | | - Frequent watering<br>- Effective stack arrangements<br>- Regular monitoring for $SO_2$, $NO_X$, SPM will be done to ensure compliance with the required standard. |
| $SO_2$ (1 hr) | 0.051 | 0.135 | 0.186 | 0.20 | |
| $NO_2$ (1 hr) | 0.059 | 0.060 | 0.119 | 0.25 | |
| SPM (24 hr) Weekday | 0.266 | 0.006 | 0.272 | 0.50 | |
| Day of weekend | 0.287 | 0.006 | 0.293 | 0.50 | |
| **Noise** (dB(A)) | | | | | - Designed acoustic enclosure<br>- Limited construction work during night time<br>- Ear protection worn by workers<br>- Regular monitoring will be done to ensure compliance with the required standard. |
| Day | 44 | +7 | 51 | 70 | |
| Night | 42 | +9 | 51 | 60 | |
| | Average Noise Level at the boundary | | Predicted Noise Level at the boundary during the operational phase | | |
| **Effluent Water Quality** | | | Effluent from waste water treatment system will discharge into the sea with following the water quality standard. Waste water (5 l/sec) will be mixed and discharged with cooling water (3,600 l/sec). | Effluent Limits | - Installation of waste water treatment system.<br>- Regular monitoring will be done to ensure compliance with the required standards. |
| pH | 8.0 | 6.0 -8.5 | | 6.0 - 8.5 | |
| COD (mg/l) | (3.4 - 7.9)* | 0.3 | | 250 | |
| $BOD_3^{30}$ (mg/l) | - | 0.1 | | 100 | |
| SS (mg/l) | < 10 | 0.2 | | 150 | |
| Oil & Grease (mg/l) | 3 | < 0.1 | Area of 1℃ up will be about 800 m from the discharge point. | 20 | |
| Thermal Pollution (℃) | 32.7℃ | $\Delta T = 10$℃ | | 45 | |
| Ecology Biodiversity | Contribution to overall biodiversity is small | Impact on biodiversity is insignificant | | | - Detail study at the base of transmission towers will be done before constructing, in order to minimize the impact on biodiversity. |

NOTICE * : These data were obtained from the reference, "The Study Report on the Development of New Port of Colombo (1996)" [ 4 ].

**: Following emission condition was used on the prediction work. : Two point sources (keeping 50 m off) ; Gas flow rate (wet, $m^3N$/sec) - 148, respectively ; Concentrations - $SO_2$ 98 ppm, $NO_X$ 61 ppm, SPM 13 $mg/m^3N$ ; Stack height above ground 80 m ; Gas exit temperature 170 ℃; Diameter of stack inside 3.2 m.

# CHAPTER 1 INTRODUCTION

# CHAPTER 1: INTRODUCTION

## 1.0 General

Ceylon Electricity Board (CEB) is the statutory body which is responsible for Generation, Transmission and Distribution of electricity in Sri Lanka.

At present CEB owns and operates 15 hydro power plants of installed capacity 1135 MW hydro and 2 thermal power stations of installed capacity of 405 MW.

The long term generation expansion planning studies of CEB has identified the need for thermal generation capacity of 300 MW to be added to the system in the year 2001. The proposed 150 MW Combined Cycle Power Plant at Muthurajawela has been identified as one of the plants to be commissioned to meet the projected demand .

## 1.1 Objective of The Project

At present Sri Lanka meet its power requirement form hydro, diesel and gas turbine electrical power generating plants. Sri Lanka has already developed most of the economical hydro potential and the development of remaining hydro potential entails excessive cost and environmental impacts. Therefore expansion of thermal generating capacity is considered as the best to meet the projected demand.

The proposed combined cycle power plant will generate 1110 GWh per year at plant factor of 85%.

## 1.2 Objective of The EIA Report

Under the provision of part IV C of Sri Lanka National Environment Act No 47 of 1980, as amended by Act No. 56 of 1588 (NEA) has determined the projects and undertakings for which approval should be necessary (prescribed projects).

The proposed 150 MW Combined Cycle Power Plant can be regarded as a prescribed project for which approval is necessary, because :

I It is a thermal power plant having generation capacity exceeding 25 MW.

II It consist of installation of transmission line of length exceeding 10 km and voltage above 50 kV.

III It consists of laying of liquid (excluding water) transfer pipeline exceeding 1 km.

IV Part of the project is located within coastal zone.

CEB submitted the preliminary information of the proposed project to the Central Environmental Authority (CEA), in accordance with the National Environmental (Procedure for approval of projects) regulation No. 1 of 1993. The CEA has determined the Ministry of Irrigation & Power as the appropriate Project Approving Agency (PAA) for this project.

The present EIA report has been based on the terms of reference (TOR) assigned to this project by the PAA under the regulations and they will therefore be the recipient of this EIA report.

This draft report forms a part of the planning application and public consultation procedure. Once comments and input from the public have been made, they will be addressed in a separate Addendum.

### 1.2.1 Aims of the EIA Report

The main aims of the EIA are:

- to describe the prevailing situation in the project area in its present state, including aspects of development not in relation with the project itself, but likely to change environmental conditions;
- to identify environmentally sensitive or especially valuable aspects of the project area
- to identify all major impacts caused by the project;
- to identify environmental no-goes or impacts of such importance that they might lead to a recommendation not to realize the project for environmental reasons, if any;
- to proposed measures for preventing mitigating or compensating project impacts;
- to propose, where feasible, additional mitigation and compensation measures;
- to propose monitoring and environmental management measures;
- to establish an environmental monitoring plan.

This EIA Report deals with potential impacts of the combined cycle power Plant at Muthurajawela i.e. with a geographically and technically well defined, specific project.

## 1.3 Government Policy Regarding Power Development

The elements of the overall energy development strategy accepted by the government of Sri Lanka is as follows:

- Providing the basic energy needs for Sri Lanka.
- Choosing the optimum mix of energy resources to meet the energy requirements at the minimum costs the national economy.
- Optimisation of available energy resources to promote socio-economic development for the country.
- Conserving energy resources and elimination of wasteful consumption in the production and use of energy.
- Developing and managing forest and non-forest wood fuel resources.
- Reducing dependence on foreign energy resources and diversifying the sources of energy imports.
- Adopting a pricing policy which enables the financing of energy sector development.
- Ensuring continuity of energy supply and energy price stability.

Establishing the manpower capability to develop and manage the energy sector.

## 1.4 Consistency With Muthurajawela Master Plan Development

Development of Muthurajawela Master Plan is a result of sequence of events began from 1964, when a cabinet sub- committee decided that paddy cultivation at Muthurajawela was no longer feasible .

In 1989 Greater Colombo Economic Commission (GCEC, presently BOI Sri Lanka) was directed to prepare a master plan for Muthurajawela with the assistance of Government of Netherlands for ecological survey. Report on this study is "Environmental Profile of Muthurajawela and Negombo Lagoon".

In accordance with the government's decision of 25th January 1989, general objective of the masterplan is the development of " Muthurajawela marshes" on an environmentally sound and sustainable basis.

Muthurajawela land reclamation (hydraulic landfill with sea sand) is an integral part of whole master plan which create an urban district, to incorporate an industrial area within the landfill which provides infrastructure to other development and create employment.

The proposed project will provide infrastructure for socio-economic development with concern for ecology in the area and therefore the project will meet the objectives of the masterplan.

## 1.5 Extent and Scope of The Study

The scope of the EIA is generally covered by the TOR issued by the PAA.

### 1.5.1 General Consideration on the Environment

In a very general manner, three groups of environmental parameters have to be taken into consideration, namely abiotic, biotic and human or socio-economic aspects. The description of the environment has to cover all the aspects that can be affected in any noticeable way by the project. This means that in the choice of the parameters to be considered, in the methods used, and especially in the depth of analysis for a given parameter, the nature, extent and potential effect of the project itself has to be considered. Therefore, to ensure that environmental issues are duly incorporated into project planning in order to minimize undesirable effects as far as possible, close collaboration of environmental specialists with the engineers involved in project planning and design is essential.

#### 1.5.1.1 Abiotic Environment

The abiotic components comprise the physical and non-living parts of the environment such as the atmosphere (climate, air), lithosphere (geology, soils) and hydrosphere (surface water and groundwater). Some of these may themselves be affected by the project, as for instance the water used in the cooling process, or air quality, while others simply form the basis for the biotic and human aspects.

#### 1.5.1.2 Biotic Environment

The biotic components comprise the animal (fauna) and the vegetation (flora). It is not possible to identify and list in detail all the existing animal and plant species within a given area. Rather, studies have to concentrate on those groups that can serve as biological indicators and/or that are most likely to be affected by the project. Vegetation and fauna depend largely on the abiotic conditions and are influenced by human activities. For the purpose of the present study, terrestrial as well as marine biological resources have to be addressed, with a special emphasis on those that form an essential resource for the human population, especially marine fish.

#### 1.5.1.3 Human Environment

The questions in relation to the human population of the study area will be treated here. This also includes the utilization of the natural resources by the human population (agriculture, fisheries etc.) as well as any need for compensation of the population directly affected by the project.

### 1.5.2 Impact Mitigation

The EIA has to identify all major potential impacts of the project, and mitigation measures have to be proposed. In general there are three possibilities for mitigation of impacts, namely.

- Avoidance: the best mitigation measure consists in preventing an impact from happening; sometimes, this can be achieved by specific project adaptations which prevent a given impact.

- Minimization: where not avoidable, an impact will have to be reduced in extent as far as possible by applying specific technology, corresponding project layout and design etc.

Compensation: if an impact which is considered to be important cannot be prevented or minimized to an acceptable level, adequate compensation has to be provided.

### 1.5.3 Limitations

It should be borne in mind that the present EIA Report, as is normally the case in projects of this importance, was prepared in parallel with the feasibility study. Consequently, it is an essential part of the Feasibility Study and should not be considered in isolation.

## 1.6 Brief Outline of The Contents

The Executive Summary give, in a very concise manner, all the major findings of the EIA Report, namely important aspects of the existing environment, main impacts to be expected, main mitigation measures, main aspects of the monitoring and environmental management plan, and main conclusions. It provides a rapid overview of main issues and solutions, and can be used as a guide to Chapters that may be of particular interest to the individual reader.

Chapter 2 contains a short description of the project. The description focuses only on those aspects of the project that are likely to impact the environment, and the discussion avoids making reference to unnecessary technical details.

Chapter 3 gives a description of the existing environment. For practical purposes the chapter has been divided in four main parts; the first three deal with the abiotic (physical), biotic (biological) and human (socio-economic) aspects of the project area, i.e. with the main parts of the environment

In Chapter 4, impacts likely to happen as a consequence of project implementation are identified. In a first part of this Chapter, impacts of the construction phase are dealt with; as impacts due to construction normally are completely different form those resulting from operation of a plant, this distinction is important. The following parts of this chapter then treat impacts of the operation phase of the project, considering the main parts of the environment as described above.

The same general structure is maintained in Chapter 5, where mitigation measures are described. For every potentially important impact identified in Chapter 4, the corresponding mitigation measure is described here. It is self evident that in cases where the conclusion in Chapter 4 was that no or no significant impact will result from the project, no mitigation measure has been formulated.

The environment is a highly complex structure, and in constant change due to various processes, natural and man made. In order to be able to identify certain impacts when they happen, but mainly in order to be able to control the appropriateness and effectiveness of the mitigation measures, monitoring of certain aspects has to be carried out. In certain cases, where the prevailing state prior to the start of project implementation must be documented monitoring has to start well before the beginning of construction works. The corresponding Monitoring programmes are described in Chapter 6.

Specific aspects which need an institutional set up or which are of special importance in the long run are formulated as Environmental Management Plan in Chapter 7.

Finally, the main conclusion drawn from the findings in the report are provided in Chapter 8. It has to be pointed out that these are the conclusion of the Consultant, and should not be confounded with the decision on the EIA which will have to be made by the Competent Authority.

## 1.7 The Approval Necessary for This Development

### 1.7.1 Coast Conservation Department (CCD)

Part of the proposed project (fuel pipeline and cooling water pipeline) will be constructed within the coastal zone defined by Coast Conservation Act, Number 57, of 1981 as follows:

"That area lying within a limit of three hundred metres land wards of the Mean High Water line and a limit of two kilometres seawards of the Mean Low Water line and in the case of rives, streams, lagoons, or any other body of water connected to the sea either permanently or periodically, the land ward boundary shall extend to a limit of two kilometres measured perpendicular to the straight base line between the natural entrance points [defined by the mean low water line] thereof and shall include the waters of such rivers, streams and lagoons or any other body of water so connected to the sea". The mean high water line is taken to be 0.6 meters above mean sea level. The mean low water line is taken to be 0.6 m below the mean sea level.

Under the terms of Conservation Act, Number 57, of 1981 permission of the Director is necessary is necessary. Accordingly CEB made an application to the CCD to Develop the said part of the 150 MW combined cycle power plant within the coastal zone of Kerawalapitiya area, giving necessary information.

Permit is issued by the Director CCD if the development activity:

a./ is consistent with Coastal Management Plan.

b/. will not have any adverse effect on the stability, productivity and environmental quality.

### 1.7.2 Marine Pollution Prevention Authority (MPPA)

The MPPA is regulated by the Marine Pollution prevention Act, Number 59, of 1981. The Act requires that all ships entering Sri Lanka territorial waters comply with appropriate measures for preventing and controlling pollution of the seas from oils, petrochemicals, organic liquids, organic and inorganic compounds, sewage and garbage. The Act enables the international Convention for the Prevention of Pollution from Ships (the MARPOL 1973 / 1978 Convention). All ships, barges and tugs supplying the proposed power station with supplies are required to comply with the Act's provision.

CEB and the study team consulted the officials of MPPA and their concern on the development is as follows.

(a) The Pipeline should be the double Casing type and buried two meters under the sea bed from the shore access point to the S.P.B.M.

(b) The minimum contingency Equipment should be available as a part of the project itself consisting of the following :-

1. A reasonable length of flexible Booms to be discussed and agreed.
2. A quantity of dispersants which will be recommended and quantified by the MPPA.
3. A medium sized Surface Oil skimmer to be approved by the MPPA in consultation with you.

**1.7.3 Wild Life Conservation Department**

The Fauna and Protection Ordinance (Chapter 469; as amended by Act Numbers 44 of 1964 and Act 1 of 1970) and the Fauna and Flora Protection (Amendment) Act, Number 49, of 1993 make provisions for the conservation of animal and plant species, and of their habitats. The Acts define restrictions concerning entry into and the conservation of wild life conservation areas, including marine protected areas such as coral reefs.

Muthurajawela Sanctuary has been declared by extraordinary gazette dated 31st October 1996, under the provision of Fauna and Flora Protection (Amendment) Act, Number 49, of 1993. The southern boundary of the sanctuary is approx. 2 km. north of the site boundary. The proposed project site does not contain any protected animals or plants, and it is not directly adjacent or close to any protected habitat. The construction site is therefore not impeded by the provisions of the Act, but the operations of the power plant must refer to the marine environment and its resources.

The proposed transmission line to transmit power from proposed power station to Kotugoda substation will traverse proximity to the boundary of the sanctuary.

CEB and the study team has consulted the Wildlife Conservation Department and their Concerns will be addressed.

**1.7.4 Sri Lanka Port Authority (SLPA)**

Proposed fuel pipeline and mooring buoy will be located outside the area of jurisdiction of SLPA. CEB consulted SLPA and their comments on this development will be incorporated.

### 1.7.5 Urban Development Authority (UDA)

The Urban Development Authority (UDA), established under act no. 41 of 1978 provides for promoting integrated planning and implementation of economic Social and Physical Development, development of certain areas declared by the minister, as urban development area. UDA has gazette Muthurajawela as a special project area under their jurisdiction. In this scenario the SLLRDC would then have to carryout plans and proposals of UDA. Reclamation would be just one part of the master plan for Muthurajawela prepared by the UDA.

Under section 8J of part II of Act. The CEB will have to obtain a permit for this development activity.

### 1.7.6 Sri Lanka Land Reclamation and Development Corporation (SLLRDC)

The Kerawalapitiya land fill site is at present under the Sri Lanka Land Reclamation and Development Corporation (SLLRDC). Therefore any activity that comes must be approved by SLLRDC.

### 1.7.7 Local Authority

The relevant Local Authority is Wattala Pradesiya sabha Since the Kerawalapitiya reclaimed site falls within its jurisdiction.

It is therefore necessary to obtain the concern of Wattala Pradesiysabha for this development.

### 1.7.8 Department of Fisheries and Aquatic Resources

Fisheries and Aquatic Resources Act No. 2 of 1996

Section 36

Section 36 of the act relates to the declaration of fisheries reserves. Where such an area is declared, a permit is required from the Director of Fisheries and Aquatic Resources or any person authorised by the director for the following purposes in relation to such reserve.

a) Engaging in any fishing operation in any reserve
b) Mining
c) Collection or otherwise gathering or processing coral or any other Aquatic Resources
d) Dredging or extracting sand or gravel
e) Discharging or depositing waste or any other polluting matter.

f) In any way disturbing, interfering with or destroying fish or other Aquatic Resources or their natural breeding grounds or habitat in such reserve

g) Constructing or erecting any building or other structure on or over any land or waters within such reserve.

Such activities would also be subject to any regulations made under setion 61(o)

### 1.7.9 Road Development Authority (RDA)

The project construction will involve transport of heavy equipment and machinery along A3 route specially during construction. Transportation of heavy load over the new Kelani Bridge will require permission from RDA.

### 1.7.10 Environmental Licensing of Project

Part IVA of the 1988 Act makes provisions for licensing emissions made to water, land and air. It is an offence to release effluents without a license (an Environmental Protection License issued by the CEA. Part IVB of the 1988 Act makes provision for the CEA to define emission standards for effluents released to water all and land. The National environmental (Protection and Quality) Regulations, Number 1 of 1990 (Gazetted on 2nd February 1990 - Gazette Number 595/16) specifies standards and licensing conditions for effluents released to water. Noise control regulations and licensing conditions are specified in Gazette Number 924/12 of 23rd May 1996. Ambient air quality standards and the license requirements for effluent releases are prescribed in the National environmental (Ambient Air Quality) Regulation of 1994 (Gazetted on 20th December 1994).

The National environmental (Protection and Quality) Regulations on waste (Gazetted on 23rd May 1995 - Gazette Number 924/13) specify conditions for licensing the collection, transport, storing, recycling and disposal of waste. The regulations make provision for hazardous waste, and waste that is dangerous to human health and the environment. The waste includes metal compounds, metalloids and a range of organic chemicals.

Under the terms of the 1988 Act and its corresponding legislation, the CEB has a statutory obligation to apply to the CEA, on the project completion and commissioning, for a license to realizing liquid effluents to water, gaseous effluents to air (including noise), and for the disposal of solid waster (including litter) and any hazardous substance or substances.

### 1.7.11 Ministry of Defence

Ministry of defence has consented for the proposed single point mooring buoy at approximately 4.6 Km away from the coast at Kerawalapitiya.

# CHAPTER 2 THE DESCRIPTION OF THE PROJECT

# CHAPTER 2: THE DESCRIPTION OF THE PROJECT

## 2.1 Aim and Scope of the Project

CEB carries out least cost generation expansion planning studies to analyze the possibility of meeting the increasing electric power requirement in Sri Lanka. The study usually covers a period of 15 years and is a rolling plan updated every year. The results of the latest of such studies are published in the report on Long Term Generation Expansion Planning Studies 1996-2010 of July 1996. According to it, CEB needs to install several new thermal power plants to meet the increasing demand. The proposed 150 MW Combined Cycle plant is one plant to be implemented in the years 2000/2001 for this purpose.

The main beneficiaries of this project would be the consumers of CEB, Lanka Electricity Company (Pvt.) Ltd. (LECO) and Local Authorities consisting of residential, commercial and industrial consumers. With rapid industrialization and rapid growth in the residential sector, the CEB would have to be geared up for meeting meet the increasing demand. The number of residential consumers of CEB alone is in the region of 1.5 million as compared with 0.5 million a decade ago.

The expansion of the electricity sector is vital for the expected growth of the industrial sector. All foreign investors who would be willing to invest in Sri Lanka would have to be assured at least of the continuity of power supply (without power cuts). Economic development of the country for which power development is a pre-requisite will ensure a better standard of living and employment opportunities for the people as well.

Power shortages would result in a reduction in the industrial production badly affecting the growth of the economy of the country in addition to the inconvenience caused to the electricity consumers.

It has to be mentioned here that in unelectrified rural areas, people spend more money on Kerosene as compared with electricity users in lighting their homes. Therefore, rural electrification programs which could be implemented with the availability of more generating capacity would provide greater socio-economic benefits to rural people.

Further, load sheddings or power cuts would be inevitable in case this project is not implemented in proper time. These would cause immense harm to the national economy, by way of loss of production which can be many times the cost of revenue lost due to loss of sales of electricity. Any power shortage would be highly detrimental to such an effort as inviting foreign investors for new investments in Sri Lanka.

After 1998 it is imperative that in the years of less than average rain-fall, CEB will have to depend heavily on its thermal plants to supply the electricity demand, to avoid such serious power cuts as seen in 1982 and 1992. Therefore, commissioning of this Combined Cycle power plant at Kerawalapitiya in Gampaha District has become an absolute necessity. It is also recognized that Combined Cycle Power Plants have higher efficiencies and relatively short construction times making them the ideal choice to meet the base load thermal generation requirement.

## 2.2 Nature of Project

### 2.2.1 Project Location

The proposed Combined Cycle power plant is located in the reclaimed land at Kerawalapitiya in Gampaha District 12 km north of the City of Colombo. (Figure 2.1)

The reclaimed land used to be a marsh land and was developed to use as industrial estate and residential area.

### 2.2.2 Design Overview and Plant Layout

The proposed power plant will provide around 150 MW of electrical power from a 100MW gas turbine or two 50 MW ones ; will be each being connected to its own heat recovery steam generator (HRSG). Auto diesel will be used as fuel for the gas turbine. Steam produced by the HRSG will be used to drive a 50 MW steam turbine generator. The exhaust gases from the plant will be discharged to the atmosphere through a dedicated main stack or a by-pass stack.

The proposed plant site will be located in an area of approximately 2.75 hectares (500m × 550m) which can accommodate additional four (4) units of the same capacity for future expansion The main features of the plant consisting of the following components are shown in the conceptual site layout drawing (Figures 2.2 and 2.3).

(a) Gas Turbines (1 or 2)
(b) Heat Recovery Steam Generators (1 or 2)
(c) Steam Turbine (1)
(d) Cooling Water System
(e) Oil Supply, Handling and Storage System
(f) Water Treatment Plant
(g) Plant Electrical Equipment
(h) High Voltage Electrical Equipment
(i) Control and Instrumentation System

(j) Environmental Emission Monitoring System

(k) Balance of Electrical and Mechanical Equipment

(l) Administration Block, Control Room, Workshop and Stores

The basic power plant configuration will, however, depend on the final choice of equipment. The number and type of gas turbine will depend on the selection of the final turnkey contractor.

### 2.2.3 Combustion Turbine Generators (Gas Turbines)

A gas turbine of hot end drive or cold end drive type with a rating ranging from 50 or 100 MW will be applied for this project.

Each gas turbine will be provided with a bypass damper and a bypass stack path, to allow for simple cycle operation.

The typical layouts for arrangements 1:1:1 and 2:2:1 are shown in Figures 2.2 and 2.3, respectively.

(Note : 1:1:1 and 2:2:1 denote to the 1GT:1HRSG:1ST and the 2GT:2HRSG:1ST, respectively. )

### 2.2.4 Heat Recovery Steam Generators

The Heat Recovery Steam Generators (HRSG) will be of a lateral or vertical type, generating dual pressure steam.

The final selection of the type of HRSG will depend on the selection of turnkey contractor.

Each Gas Turbine and HRSG system will be provided with both a by-pass stack and a main stack. An approximately 80 m high by-pass stack will be provided for release of flue gas from gas turbine when the HRSG is not available, out of service or during start up period.

An approximately 80 m high main stack will be provided for release of flue gas from the HRSG. No flue gas comes out from a bypass stack during normal operation.

Makeup water will be obtained from a sea water desalination plant until water from the National Water Supply Drainage Board becomes available. This water will be treated and refined by such facilities as chemical filtration.

### 2.2.5 Steam Turbine

The Combined Cycle Plant will be provided with one steam turbine regardless of the number of gas turbines. Both high pressure steam and low pressure steam from each boiler will be admitted to the steam turbine. The steam turbine should be so designed as to accept full output of the boilers under average ambient conditions at site. The typical auto diesel fired Combined Cycle performance figures for various options and configurations are given in Table 2.1.

### 2.2.6 Cooling Water System

There are two options possible regarding the cooling water supply for the steam turbine.

Direct Sea Water Cooling

A quantity of water up to 3,700 kg/s (approximately) will be pumped up from the bottom of the Arabian Sea and introduced to the condenser. The pump house will be constructed at the power plant site. The cooling water with approximately 10°C of temperature rise from the condenser will be discharged to the Arabian Sea with no loss in quantity.

Wet Cooling Tower

The wet cooling tower system cools the circulating water by making its small portion evaporate with mechanical draft fans. Therefore, the evaporated portion must be made up and its quantity is normally said to be some two (2) to four (4) percent of the circulating blow including a carry-over water. Besides, some additional make-up water shall be allowed for blow down to protect the circulating water from being condensed. In total, the make up water is estimated to be some 100 kg/s.

But, there is no natural fresh water supply source for the above available at Kerawalapitiya area. Therefore, this type cooling water supply system is not feasible for the Kerawalapitiya combined cycle power plant.

### 2.2.7 Fuel to be Applied for This Plant and Fuel Supply System

Fuel Selection for the Project

Considering the domestic conditions and experiences of Sri Lanka, the following are candidates of fuel for the Project.

- Liquefied natural gas(hereinafter referred to as LNG)
- Liquefied petroleum gas(hereinafter referred as to LPG)
- Naphtha
- Heavy diesel oil

- Auto diesel oil

Characteristics of each fuel are as follows.

(a) As for receiving LNG, CEB or CPC must participate in the LNG project from the very beginning stage because of no flexibility in LNG trading and the LNG consumption of the Project is too smaller to establish practical LNG trading, compared with the capacity of the existing LNG projects.

(b) Since LPG market in the world is controlled by one company, there is anxiety about the stable procurement and reasonable price. LPG supply from Shell Gas Lanka Limited is not expected, because of limited capacity of their facility in Sri Lanka.

(c) Gas turbine manufacturer whose gas turbine can fire naphtha is limited. Since a naphtha fired gas turbine requires another fuel during start up period because of high volatility of naphtha, it is common manner to prepare another fuel for stating up.

(d) Heavy diesel oil is applicable to gas turbine but is not circulated in common market and CPC have stopped supplying this fuel since 1996.

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

As mentioned above, since LNG, LPG, naphtha and heavy diesel oil have their own specific problems, it is concluded that auto diesel oil is the most suitable fuel for the Project.

The properties of auto diesel are given in Table 2.2.

<u>Fuel Supply System</u>

Fuel for the gas turbines is unloaded from oil tanker connected to a SPMB (single point mooring buoy) at off shore and is transferred to the Fuel Oil Storage Tanks through the fuel oil pipeline installed on the sea bed.

A greater storage capacity would be recommended to allow for additional lead time for imported Auto Diesel. It is recommended that two (2) 15,000 ton and two (2) 8,000 ton tanks to be installed.. The oil system would also include a pumping station together with necessary filtering, metering and conditioning equipment.

### 2.2.8 Water Treatment Plant

A water treatment plant and water storage facility will be installed to treat and store fresh water to be used for make up water and NOx control steam injection. The fresh water for make-up is supplied from the sea water desalination plant during the first couple of years and then from a pipeline of the National Water Supply and Drainage Board in the future. The quantity will be around 55 tons per hour.

The mix bed with polisher type water treatment plant will be adopted for this plant.

### 2.2.9 Electricity Generating Equipment and High Voltage Switch Gear

The number and design of electricity generators will depend on the number and size of gas turbines and the steam turbines. The gas turbine generator will be of 50 MVA or 100 MVA class, while the steam turbine generator will be of 50 MVA class. 220 kV busbars and a 6.6 kV busbar will have to be installed for gas turbine and steam turbine start up. An electrical single line diagram of a 2:2:1 configuration is given in Figure 2.4.

### 2.2.10 Waste Water, Sewage Effluent, Oil Spillage Treatment

The aqueous discharges likely to arise from the proposed development area as follows:

- Waste water arising from regeneration of ion exchange resin with acid and alkali.
- Station sewage discharged from the administration block and temporary site buildings.
- Station surface water drains.
- Boiler blow down.
- Irregular discharges including water and acid boiler washes, and accidental spillage.

The sewage effluent arising from approximately 500 construction workers and about 80 additional operating and maintenance staff would be discharged to the sewage system.

The routing of all drains through oil interceptors will prevent contamination from any oil spillage. The oil interceptors will be inspected and cleaned regularly and any sludge will be taken off site for disposal. The drainage effluent can be tested for oil contamination to ensure Sri Lankan regulations are complied with.

Blowdown of the drum in each boiler would take place for a few hours each week. The blowdown water will be discharged via a pressure reducing flash tank to the station drains. This very pure water only contains traces of ammonia and sodium triphosphate at a concentration of a few ppm and required no treatment before disposal.

Acid cleaning of the boilers will normally occur during commissioning and at irregular intervals of about 5 years. Hydrochloric acid is usually used for this cleaning with the effluent largely containing compounds of Iron as well as smaller amounts of other metals. The effluent from this process would be neutralized with either lime or sodium hydroxide and the precipitated material would be collected and taken off site for disposal in a land fill site while the liquid portion would be safely discharged.

Water washing of the gas side of the boiler is occasionally required to remove deposits.

The danger of spillage of chemicals will be avoided by having proper bunding for the containers of the main chemicals to be stored on site such as Sodium Hydroxide, Hydrochloric (or Sulfuric) acid, Ammonia and Hydrazine.

<u>Oil Spillage Risks</u>

The spillage of fuel oil, lubricating or other oils represents a major risk factor to the aqueous environment. All fuel tanks will be fully bounded, however risks also will occur from oil pipeline leaks, transformer leaks, and handling of drummed and waste oil. The use of oil interceptors will minimize the risk of discharge to the sea.

Waste water will be mixed with the cooling water discharge.

Standard treatment facilities will ensure that effluent standards are met. The quality of effluent from various sources would be maintained as follows.

Water Treatment Plant Effluent

| | |
|---|---|
| - TSS | : < 150 mg/l |
| - Particle size of TSS | : Floatable Solids, Max : < 3 mm |
| | Settlable Solids, Max : < 850 micro m |
| - pH | : 6.0 to 8.5 |
| - BOD | : < 100 mg/l |
| - Oil and Grease | : < 20 mg/l |
| - Temperature | : < 45°C |
| - COD | : < 250 mg/l |
| - Total residual chlorine | : < 1.0 mg/l |

### 2.2.11 Access

The existing road between A3 national road and the site will be improved for the transportation of the new plant components and facilities.

A temporary gate for construction work will be provided at the north-west and east end of the reclaimed industrial area.

### 2.2.12 The Labor Work Force

The construction of the proposed project will take approximately 31 months. During this period, the peak project employment will be approximately 650 skilled and unskilled workers. Approximately 80 staff will be employed during operation comprising engineers, technicians and skilled/unskilled workmen.

### 2.2.13 Construction Schedule

Please see Figure 2.5.

## 2.3 Justification of the project

The proposed 150 MW Combined Cycle Power Plant Project to be installed in the reclaimed land in Gampaha District north of the City of Colombo will form a part of a least cost solution to meet the projected electricity demand.

According to the Long Term Generation Expansion Planning Studies conducted by CEB, it is necessary to install new thermal generating stations to meet the increasing demand for electrical energy and to replace the Plants due for retirement. The paragraphs below describes the past and future demand for electricity, the need for the proposed Project, and the consequences of non-implementation of the project.

### 2.3.1 Demand for Electricity

Studies carried out by CEB indicate an expected average annual demand growth rate of 7.1 % over the next 20 years with the system loss levels reducing to 14.6 % of generation by the year 2013 and the load factor improving 58 % by 2007 [2].

A large proportion of this growth has been attributed to increase in domestic electricity consumption as a result of extensive rural electrification programs and increase use of household appliances. The increased utilization of electricity in light industry, garment, footwear manufacture, and agricultural processing sectors have contributed substantially to this demand growth.

The early years of the 1990's have followed a similar trend with peak demand increases of 12.1 %, 7.7 %, and -1.2 % in the years 94, 95 and 96 respectively. The system peak demand in 1995 was 980 MW whilst in 1996 it decreased to 968 MW showing an increase of -1.2 % due to curtailed power cut. Table 2.3 shows a breakdown of this historical demand.

In 1992, the rainfall was below average, which seriously affected the amount of energy generated by hydroelectric plants. Continuous thermal power plant backup was provided from January to July and power cuts was forced with daily duration ranging from 3 to 4.5 hours during the month of April & May. Hydro reservoirs in both Mahaweli and Kelani Rivers were drawn to minimum operating levels as they were in the case of 1982 drought.

The consumption of energy by sectors in years 1994, 1995 and 1996 are shown in Table 2.4.

Table 2.4 Consumption of Energy by Sectors

| | 1994 | 1995 | 1996 |
|---|---|---|---|
| Industry | 39.6% | 39.0% | 37.9% |
| Commercial | 16.9% | 16.1% | 16.5% |
| Domestic | 25.5% | 25.9% | 28.6% |
| Others | 18.0% | 19.0% | 17.0% |

The share of electricity consumption in industrial and domestic sectors have been increased recently.

#### 2.3.1.1 Future Demand

The CEB uses an econometric forecasting model "Econometric Software Package" (ESP) to predict future electricity demand. This method of forecasting is based on extrapolating relationships between electricity demand and several socioeconomic indicators such as Gross Domestic Product per Capita, Gross National Product per Capita, and population. A correlation between the impacts of these variables and electricity demand is evaluated and then introduced into the model as part of the forecasting methodology. Forecasts for the various socioeconomic indices are obtained from relevant government agencies.

To access the effect of demand variation, three forecasts have been developed by the CEB, namely low, base, and high forecasts. For this justifications, only the base forecast will be considered. The CEB updates the demand forecast annually; the latest forecast was produced in 1996 and the base forecast used is shown in Table 2.5. During the period 1998-2014 the average annual sales growth is predicted to increase by 8.1% per annum.

### 2.3.2 Need for the Proposed Project

The options that may be considered by Sri Lanka to meet future electricity demand will be from hydroelectric resources, fossil-fuel based thermal systems, nuclear based thermal systems and renewable resources. The long term generation expansion plan of CEB has suggested thermal plants for system additions. The CEB's main planning tools in the development and analysis of optimal generation plan is the Wien Automatic System Planning (WASP III) package. This package optimizes the generation expansion sequence to meet the electricity demand at least cost.

The long terms planning studies carried out during the year 1994 envisages the addition of several thermal power plants to meet the electricity demand at least cost. The base case results of the generation expansion planning studies is given in Table 2.6. According to these results a Combined Cycle power plant of 150 MW is needed to be installed during the years 2000/2001.

#### 2.3.2.1 Supply-Demand Balance

The CEB's 1994 forecast for the total installed capacity and energy of the CEB system are presented in Table 2.7 and Table 2.8. It can be seen that the peak demand will exceed the total installed capacity of the hydro plants from 1997 onwards and energy demand is higher than the average hydro energy from the year 1995 onwards. Thermal generation will be required to meet the demand every year from 1994, unless very wet conditions persist. But after the year 1995, increasing amount of thermal generation will be required even during the wet hydro condition.

## 2.4 Evaluation of Alternatives

### 2.4.1 Hydroelectric Options

At present Sri Lanka has 1,115 MW of installed hydroelectric capacity, capable of providing an average annual generation of 3,785 GWh. The CEB is committed to construct the Kukule (70 MW) and Upper Kotmale (150 MW) Hydroelectric plants. Completion of these power plants during the early part of next decade would mean that most of the Sri Lanka's economically viable hydropower potential has been harnessed.

### 2.4.2 Thermal Options

The following thermal power plants have been considered for the long term generation expansion planning studies.

#### 2.4.2.1 Diesel Power Plants

There are variety of diesel plants, primarily operating on residual fuel oil. The diesel units are available in sizes upto about 20 MW in the case of medium speed and upto 47 MW in the case of slow speed. The operating cost of diesel plants are comparatively cheaper as they are running on residual fuel oil, but the capital cost is greater than the Combined Cycle plant.

#### 2.4.2.2 Gas Turbine Power Plants

Gas turbines running on high quality fuel were considered for the long term planning studies. These plants are generally required for peaking and short term operation especially during the drought to supplement the short fall of hydro energy.

#### 2.4.2.3 Combined Cycle Power Plants

These plants consist typically of Gas Turbine (GT) and Steam Turbine (ST). Heat Recovery Steam Generator (HRSG) receives heat from GT exhaust and supplies steam to the ST. This results in high thermal efficiencies upto about 50 %. This is an attractive option in the medium term to meet the base load requirements.

#### 2.4.2.4 Steam Power Plants

The investment cost of steam power plants are higher, compared with other fossil-fuel fired power plants. However, these plants use relatively cheaper fuels (coal and oil). However, the location of these plants is critical because of the need to import large volumes of fuel. For example, coal plants require a coastal location with a jetty to unload the coal. However in the case of coal, cheaper fuel cost offsets the higher investment cost thereby making it an attractive option for base load operations in the long term.

#### 2.4.2.5 Nuclear Power Plants

Nuclear power plants would involve relatively very high investment cost. The lead time for nuclear plants is very long (about 6 to 10 years). In addition, problems may be associated with public acceptability of this option. Furthermore, the size of the Sri Lankan power system is comparatively small to accommodate the commercially available large nuclear power plants, in the near future.

#### 2.4.2.6 Renewable Sources

The potential for the development of renewable energy for electric power exists in Sri Lanka. The most appropriate options would be wind, solar, wave and biomass generation. Wind appears to be the most promising of these options. Renewable energy technologies are still expensive and have not been fully developed. Consequently, this option was not included in the CEB's least cost analysis.

### 2.4.3 Site Choice

Ideally, a new power station should be located near the load center and as close to a fuel supply as possible. The land reclaimed by Land Reclamation Company in northern Colombo is well situated within CEB's greatest load center. Fuel for the new power plant will be supplied from the oil tanker using the newly installed pipe line.

The site is already designated as a "Predominantly Industrial" area and therefore, is suitable for the development of the proposed project. By contrast, establishing a new greenfield site would require more time and money and would cause more environmental impacts than building on the existing power plant site. Therefore, the construction of the Combined Cycle power plant at the corner of the new industrial area is preferable.

### 2.4.4 Consequences of Non-Implementation of Project

In order to assess the "no project option" case, an analysis was undertaken of the alternative forms of energy used instead of grid electricity to meet the growing energy demand in Sri Lanka. The analysis was divided into the four major users of electrical power: residential, commercial, industrial, and LECO and Local electricity distribution authorities.

#### 2.4.4.1 Residential

Domestic consumption of electricity accounted for 28.6% of all electricity supplied by the CEB in 1996. The primary sue of electricity was for lighting and operating electric fans and entertainment equipment, such as TV and radio. If the required generation plants are not built, the following impacts would be encountered:

- New consumers would not receive electricity
- A similar situation would exist as experienced in1982 and in 1992 when the CEB had to resort to blackouts and power cuts in view of drought conditions.
- Existing consumers would e subjected to power cuts during the day peak and night peak, i.e., between 10 a.m. and 12 noon and 6 p.m. and 9 p.m. respectively.
- These power cuts would lead to individual consumers using alternatives for lighting such as Kerosene lamps. This would place additional financial and economic burdens on the Sri Lankan Economy.
- It would also hamper children's studies and would also create security problems due to lack of street lighting.

#### 2.4.4.2 Commercial

The commercial sector consumed 16.5% of all electricity supplied by the CEB in 1996. This sector includes hotels, offices, shops and government buildings.

If the plant is not built, the comments made above for the residual sector also would apply to this sector. This would restrict economic development in Sri Lanka and delay grid connections for new business ventures.

#### 2.4.4.3 Industrial

The industrial sector consumed 37.9% of all electricity supplied by the CEB in 1996. The loss to the economy due to power cuts in the Industrial sector by way of losses in Production is estimated as being about 10 times the loss due to non-sale of energy from the grid. An alternative source of electricity for this sector is the use of privately owned, isolated generators that use liquid fuels such as diesel oil.

Both new and existing consumers that use these generators would not take advantage of "economy of scale" in power generation. Also they would have to find funds to import the generators increasing the cost of their project investments. In addition they should have special staff at each generation point to run and maintain these small generating plants. Furthermore, the relatively low efficiencies of these small generators would lead to increased emissions of sulfur dioxide ($SO_2$), carbon monoxide, carbon monoxide (CO), and Oxides of Nitrogen (NOx).

#### 2.4.4.4 LECO and Local Electricity Distribution Authorities

This sector accounted for 17.0% of all electricity consumed in 1996. During power cuts, no alternative form of electricity would exist. Applications such as street lightning would not be maintained. The loss of street lights could cause additional traffic accidents and possible increase in crime. The local authorities themselves would be hard pressed by consumers to whom they retail, as all categories of consumers in residential, commercial and small industrial sectors will be effected.

### 2.4.5 Energy Conservation

Much can be done to conserve the use of electricity in Sri Lanka. However, the implementation of a large number of energy conservation measures would be required both in the public and the private sectors. Usually some form of inducement would be needed to encourage the initial capital investment.

Even with optimal energy conservation, it would be unrealistic to achieve a saving of 120-150 MW during peak demand. Furthermore, because of power plant retirement and rapid industrial growth, the construction of new plants would be an absolute necessity.

### 2.4.6 Conclusions

Based on project benefits and "no project option" consequences, it is necessary for the project to proceed, in order to meet the peak power as well as Energy demand in Sri Lanka and to sustain growth in the power sector and consequently in all other sectors off the economy, judging that GDP growth rate of about 6% would necessarily require an electric power growth rate of about 9%.

<u>Selection of Alternative</u>

CEB carries out least cost expansion planning studies based on the techno/economic parameters of several power plant candidates such as hydro and thermal. The capital cost, O&M cost and the lead time of such projects are taken into consideration in the least cost expansion planning studies. Among the thermal power plants, typically for peaking i.e. for low plant factor, the least cost planning exercise will result in low capital cost plants with relatively high O&M cost to be included in the expansion planning sequence. Similarly for the base load operation i.e. for high plant factor, plants with high capital cost and low O&M cost will form the least cost plan.

The most optimal plant sequence for implementation resulting in least cost to the economy is derived from this and expected growth in demand. In this case alternatives to any selected plant is considered in respect of its techno/economic merits and its suitability to meet the power system requirement. Based on the above the least cost sequence of generating capacity expansion is concluded. It is therefore clearly seen that any other alternatives to the proposed Combined Cycle Power Plant in the year 2001 would result in an economically inferior solution.

<u>Selection of fuel</u>

The solution of Auto Diesel as the fuel has been taken with due consideration to the environmental effect of emission of $SO_2$ from the proposed power plant and easy procurement. Auto diesel has insignificant amount of Sulphur hence is a superior fuel.

<u>Selection of Site</u>

In the present configuration, the available land at the Kerawalapitiya area is optimally used for the proposed power plant and any other site would require acquisition of land, possible displacement of people, laying of new pipeline for the fuel supply, etc.

## 2.5 Methodology of Construction and Operation

### 2.5.1 The Construction Schedule

The construction schedule for this project is illustrated in Figure 2.5. Works on the site are due to begin during the first quarter of 1999, with the commercial operation of this plant expected at the beginning in 2001. The principal construction components are shown in Table 2.5-1..

Table 2.5-1 Construction needs

| Items | Dimension | Remarks |
|---|---|---|
| Access | 2.0 km | The site access road branches off from the A3 national road, and its 2.0 km length requires upgrading. After upgrading, the access road is suitable for heavy load equipment, etc. The works will commence in the first quarter of 1998. |
| Transportation | | Heavy loads and bulky parts will be transported by large transporter. The small bridge will be replaced with new one in order for the heavy equipment to be transported. The works will start during the first quarter of 1999 as directed by the civil engineering works program, which is to be defined in more detail from mid 1998 to the first quarter of 1999. |
| Sand, gravel, etc. | 800,000$m^3$ | Two options are presently considered, namely: dredging sands offshore, and extracting sands from a dune northwards of the site. A final decision is not as yet made, and the matter is under discussion between the project proponent's engineers and the Coastal Conservation Department. |
| Work camp | | The construction camp will require facilities for about 650 persons. The detailed planning will be made from mid 1998 onwards. The camp will be equipped with sewage disposal facilities for the disposal of solid and liquid wastes. The camp will be demolished after construction is completed. |
| Work force | | Table 2.5-2 shows the peak demand for a labor force during construction period. |
| Temporary construction site facilities | | Detailed requirements for storing construction materials, vehicle parking, etc.. will be planned during 1999. About 25 hectares of site will be reserved for |

| | | |
|---|---|---|
| | | construction and big enough for the temporary storage of construction materials, etc. Land will required for sea water intake and discharge channels, fuel pipelines and transmission lines. |

### 2.5.2 Construction Site Facilities

Storage facilities will be prepared when and where required. All solids and liquids will be stored within the bounded and spillage controlled areas, as described in chapters 4, 5 and 6. Provisions for sewage treatment and other waste disposals are considered in chapter 4. The construction and completion of a sewage treatment works is planned prior to the initiation of the power plant engineering works.

### 2.5.3 Transport of Construction Material

The A3 national road between Colombo and Elapitiwala is in reasonable condition. The weight limitation is 15 tones/axial.(Load bearing capacity is 2.5 $t/m^2$). At Elapitiwala, access road from the A3 and passes westwards to the site.

The access road requires upgrading and surfacing with asphalt pavement, and these matters are discussed in chapter 4.1.2.

### 2.5.4 Sand Excavations

Sand is required to grade and level the construction site, and for mixing cement as described in chapter 4.1.8. Sand can either be dredged from the sea bed or quarried from a sand dune situated to the north of the site. At the present moment a decision on the exact source of the sand has not been made, and the matter is under discussion between the project proponents and the Coast Conservation Department. Mitigation measures for extracting sand from either of these two sources are described in chapter 5.1.3.

### 2.5.5 Foundations

Foundations will reach the local aquifer. Measures to prevent depression of the aquifer and pollution of the groundwater are discussed in detail in chapter 4, and mitigation measures are addressed in chapter 5.

### 2.5.6 Operation

The principal methods to be adopted for operational aspects such as oil transportation and handling, flue gas treatment, water treatment, waste water treatment, etc. are described in chapter 2.2 (Project Description) as they are closely related to the different plan components.

## 2.6 The Work force

The maximum number of workers required throughout the construction phase of the 150MW is shown in Table 2.6-1. The labor force will be drawn from the local population as much as possible. Housing for these personnel will not be required. Workers drawn from more distant towns will be housed in temporary camps, constructed on the site. Other accommodation will be sought from within the existing villages surrounded the site.

Table 2.6-1 The Labor force manning levels

| Year | Numbers of Workers |
|---|---|
| 1998 | 250 |
| 1999 | 400 |
| 2000 | 650 |
| 2001 | 300 |

## 2.7 Financial Commitments

The exact costs to incorporate the recommended mitigation measures, for the compensation required for relocation, and for the improvements to the social infrastructure in the vicinity of the plant was studied by CEB. All costs related to these issues, however, will have to be carefully reviewed and included in the total budget allocated to the power plant by CEB.

## Table 2.1 Typical Combined Cycle Performance Figures for Various Options and Configurations

| Plant Configuration | Cooling Type | Method of NOx Reduction | Estimated NOx (ppm) | Total Fuel Flow kg/s | Total Exh. Flow kg/s | Gas Turbine Exh. Temp. ℃ | HRSG Exh. Temp ℃ | No. of Bypa and HRSG stack | GT Output MW Total Gross | ST Output MW | CC Output MW | Gross Heat Rate (LHV) KJ/kWr | ST Injection ton/hr | Direct River Cooling Cool Flow ton/hr | Direct River Cooling Temp. Rise ℃ | Net Plant Efficiency (LHV,%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant Type 1 | Sea | No | 350 | 7.83 | 358 | 548 | 170 | 2 and 2 | 107 | 48 | 155 | 7,690<br>7,830(net) | 0 | 3.7 | 10 | 46.0 |
| Configuration 2:2:1 | Sea | Steam Injection | 70 | 8.34 | 371 | 551 | 170 | 2 and 2 | 121.73 | 40.57 | 162.30<br>159.45(net) | 7,840<br>7,980(net) | 46.50 | 3.1 | 10 | 45.1 |
| Plant Type 2 | Sea | No | 250 | 7.89 | 385 | 545 | 170 | 1 and 1 | 106 | 52 | 158 | 7,210<br>7,340(net) | 0 | 4 | 10 | 46.4 |
| Configuration 1:1:1 | Sea | Steam Injection | 70 | 8.21 | 395 | 547 | 170 | 1 and 1 | 115.37 | 46.65 | 162.02<br>159.13(net) | 7,740<br>7,880(net) | 34.00 | 3.6 | 10 | 45.7 |

Table 2.2 Properties of Auto Diesel Oil

| Property/Test | Test Method | | Specification |
|---|---|---|---|
| | IP | ASTM-D | |
| Appearance | | | Clear & free from water and impurities |
| Density @15°C kg/m$^3$ | 160 | 1298 | Max.870 |
| Color ASTM | 196 | 1500 | To be reported |
| Marketing Colour | | | Amber |
| Distillation:- | 123 | 86 | |
| I.B.P. | | | To be reported |
| 10% Evaporated °C | | | To be reported |
| 50% Evaporated °C | | | To be reported |
| 90% Evaporated °C | | | Max. 370 |
| Recovery @315°C | | | Min. 50 |
| Recovery @350°C | | | Min. 80 |
| Cetane Index | | 976 | Min. 45* |
| Cetane Number | | 613 | Min. 48 |
| Cloud Point °C(F) | | 2500 | Max. 15.5(Max. 60) |
| CFPP °C(F) | 309 | | Max. 10(Max. 50) |
| Sulphur Content %(w/w) | 61 | 129 or 1552 | Max. 1.0 |
| Flash Point (PMCC) °C(F) | 34 | 93 | Min. 60(Min. 140) |
| Viscosity Kin @37.8°C,cSt | 71 | 445 | 1.5-5.0 |
| Water Content %(w/w) | 74 | 95 | Max. 0.05 |
| Cu-Strip corrosion 3hrs @50°C | 154 | 130 | Max. 1 |
| Ash %(w/w) | 4 | 482 | Max. 0.02 |
| Carbon Residue, Rambottom on 10% residue %(w/w) | 14 | 524 | Max. 0.3 |
| Sediment by Extraction %(w/w) | 53 | 473 | Max. 0.01 |
| Total Acid No.KOH mg/g | 1 | 974 | Max. 0.2 |
| Strong Acid No.KOH mg/g | 1 | 947 | Nil |
| Calorific Value Gross kcal/kg | 12 | 240 | Min. 10500 |

*Not applicable if any Cetane improver additive is present.

Table 2.3 Breakdown of Historical Electricity Sales

| Year | Total Sale (GWh) | Sales Per Capita (kWh/Person) | Percentage of Sales by Tariff Group % | | | |
|---|---|---|---|---|---|---|
| | | | Domes. | Indust. | Commer. | Others* |
| 1975 | 965 | 71 | 9.0 | 54.3 | 12.4 | 24.3 |
| 1976 | 997 | 73 | 9.5 | 51.8 | 13.5 | 25.2 |
| 1977 | 1,041 | 75 | 10.2 | 49.9 | 14.2 | 25.7 |
| 1978 | 1,166 | 82 | 10.2 | 50.9 | 13.9 | 25.0 |
| 1979 | 1,298 | 90 | 11.8 | 48.7 | 15.5 | 24.0 |
| 1980 | 1,392 | 94 | 13.7 | 45.0 | 16.0 | 25.3 |
| 1981 | 1,510 | 101 | 14.3 | 44.9 | 14.6 | 26.2 |
| 1982 | 1,694 | 112 | 15.3 | 43.6 | 15.5 | 25.6 |
| 1983 | 1,797 | 117 | 17.0 | 41.8 | 16.2 | 25.0 |
| 1984 | 1,886 | 121 | 16.8 | 41.3 | 17.0 | 24.9 |
| 1985 | 2,060 | 130 | 16.8 | 41.3 | 17.0 | 24.9 |
| 1986 | 2,232 | 138 | 16.5 | 41.5 | 17.1 | 24.9 |
| 1987 | 2,253 | 138 | 16.9 | 38.5 | 18.6 | 26.0 |
| 1988 | 2,371 | 143 | 16.5 | 38.1 | 19.5 | 25.9 |
| 1989 | 2,353 | 140 | 17.3 | 36.1 | 19.1 | 27.5 |
| 1990 | 2,608 | 154 | 19.0 | 34.9 | 16.2 | 29.9 |
| 1991 | 2,742 | 159 | 23.5 | 34.9 | 19.9 | 21.7 |
| 1992 | 2,916 | 168 | 23.1 | 36.7 | 19.6 | 20.6 |
| 1993 | 3,270 | 186 | 24.6 | 37.4 | 19.6 | 18.4 |
| 1994** | 3,565 | 200 | 25.5 | 39.6 | 16.9 | 18.0 |
| 1995 | 3,915 | 216 | 25.9 | 39.0 | 16.1 | 19.0 |
| 1996 | 3,588 | 204 | 28.6 | 37.9 | 16.5 | 17.0 |

Notes :

* Includes bulk sales to Lanka Electricity Company and Local Authorities, some of which were gradually being taken over by CEB and completely taken over in 1997.

** Consumption by Hotels is included in the Industry from January 1994.

Table 2.5 Energy and Peak Load Forecast – Base Case 1994

| Year | Sales | | System Loss % | Generation | | Load Factor % | Maximum Demand MW |
|---|---|---|---|---|---|---|---|
| | GWh | Growth % | | GWh | Growth % | | |
| 1998 | 4,948 | 8.1 | 17.6 | 6,005 | 7.8 | 56.3 | 1,218 |
| 1999 | 5,363 | 8.4 | 17.4 | 6,493 | 8.1 | 56.5 | 1,312 |
| 2000 | 5,804 | 8.2 | 17.2 | 7,010 | 8.0 | 56.7 | 1,411 |
| 2001 | 6.296 | 8.5 | 17.0 | 7,586 | 8.2 | 56.9 | 1,522 |
| 2002 | 6,843 | 8.7 | 16.8 | 8,225 | 8.4 | 57.1 | 1,644 |
| 2003 | 7,428 | 8.5 | 16.6 | 8,906 | 8.3 | 57.3 | 1,774 |
| 2004 | 8,054 | 8.4 | 16.4 | 9,634 | 8.2 | 57.5 | 1,913 |
| 2005 | 8,742 | 8.5 | 16.2 | 10,432 | 8.3 | 57.7 | 2,064 |
| 2006 | 9,457 | 8.2 | 16.0 | 11,258 | 7.9 | 57.9 | 2,220 |
| 2007 | 10,221 | 8.1 | 15.8 | 12,139 | 7.8 | 58.0 | 2,389 |
| 2008 | 11,036 | 8.0 | 15.6 | 13,076 | 7.7 | 58.0 | 2,574 |
| 2009 | 11,927 | 8.1 | 15.4 | 14,098 | 7.8 | 58.0 | 2,775 |
| 2010 | 12,858 | 7.8 | 15.2 | 15,163 | 7.6 | 58.0 | 2,984 |
| 2011 | 13,851 | 7.7 | 15.0 | 16,295 | 7.5 | 58.0 | 3,207 |
| 2012 | 14,931 | 7.8 | 14.8 | 17,525 | 7.5 | 58.0 | 3,449 |
| 2013 | 16,082 | 7.7 | 14.6 | 18,831 | 7.5 | 58.0 | 3,706 |
| 2014 | 17,290 | 7.5 | 14.4 | 20,199 | 7.3 | 58.0 | 3,975 |
| 2015 | 18,599 | 7.6 | 14.2 | 21,677 | 7.3 | 58.0 | 4,266 |
| 2016 | 19,993 | 7.5 | 14.0 | 23,248 | 7.2 | 58.0 | 4,576 |
| 2017 | 21,492 | 7.5 | 14.0 | 24,991 | 7.5 | 58.0 | 4,919 |

Table 2.6 Base Case Results – Generation Expansion Planning Studies – 1997

| Year | Hydro Add. | Thermal Additions | Thermal Retirement | LOLP |
|---|---|---|---|---|
| 1998 | - | Lakdanavi 22.5MW Diesel Plant(BOO) | - | 8.266 |
| 1999 | - | Sapugaskanda 40MW Diesel Extension(KFW)<br>KHW Plant 51MW (BOO)<br>Kelanitissa 100MW Part of 150MW CC (OECF) | - | 1.002 |
| 2000 | - | Gas Turbine 105MW<br>Steam Turbine 50MW Part of 150MW CC (OECF) | | 0.023 |
| 2001 | | Kerawalapitiya 150MW CC<br>CC Plant 150MW (BOO or BOT) | Kelanitissa 2×22MW Steam Turbine | 0.039 |
| 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

Table 2.7 Capacity Balance

| Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | | | | | | | | | | | | | | | |
| Existing Hydro | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 | 1115 |
| Kukule | | | | | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| Installed Hydro Capacity(MW) | 1115 | 1115 | 1115 | 1115 | 1185 | 1185 | 1185 | 1185 | 1185 | 1185 | 1185 | 1185 | 1185 | 1185 | 1185 |
| Thermal | | | | | | | | | | | | | | | |
| Kelanitissa GT | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 | 235 |
| Kelanitissa ST | 44 | 44 | 44 | - | - | - | - | - | - | - | - | - | - | - | - |
| Sapugaskanda Diesel | 112 | 112 | 112 | 112 | 112 | 112 | 76 | 76 | 76 | 76 | 40 | 40 | 40 | 40 | 40 |
| Lakdanavi Diesel | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 |
| SapugaskandaDiesel(Ext.) | | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 | 40 |
| KHD Plant Diesel | | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |
| Kelanitissa CC | | 100 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
| Kerawalapitiya CC | | | | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| West Coast Coal Fired | | | | | | | 300 | 300 | 600 | 600 | 900 | 900 | 900 | 900 | 900 |
| Trincomalee Coal Fired | | | | | | | | | | | | 300 | 300 | 600 | 600 |
| GT(105MW) | | | 105 | 105 | 105 | 105 | 105 | 210 | 210 | 210 | 210 | 210 | 315 | 315 | 525 |
| Total Thermal Capacity(MW) | 413.5 | 604.5 | 759.5 | 1015.5 | 1015.5 | 1015.5 | 1279.5 | 1384.5 | 1684.5 | 1684.5 | 1948.5 | 2248.5 | 2353.5 | 2653.5 | 2863.5 |
| Total Installed Capacity(MW) | 1528.5 | 1719.5 | 1874.5 | 2130.5 | 2200.5 | 2200.5 | 2464.5 | 2569.5 | 2869.5 | 2869.5 | 3133.5 | 3433.5 | 3538.5 | 3838.5 | 4048.5 |
| Peak Demand(MW) | 1218 | 1312 | 1411 | 1522 | 1644 | 1774 | 1913 | 2064 | 2220 | 2389 | 2574 | 2775 | 2984 | 3207 | 3449 |
| Reserve(MW) | 310.5 | 407.5 | 463.5 | 608.5 | 556.5 | 426.5 | 551.5 | 505.5 | 649.5 | 480.5 | 559.5 | 658.5 | 554.5 | 631.5 | 599.5 |
| Reserve(%) | 25.5 | 31.1 | 32.8 | 40.0 | 33.9 | 24.0 | 28.8 | 24.5 | 29.3 | 20.1 | 21.7 | 23.7 | 18.6 | 19.7 | 17.4 |

Table 2.8 Energy Balance

| Year | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hydro | | | | | | | | | | | | | | | |
| Existing Hydro | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 | 3850 |
| Kukule | | | | | 305 | 305 | 305 | 305 | 305 | 305 | 305 | 305 | 305 | 305 | 305 |
| Total Hydro Energy(GWh) | 3850 | 3850 | 3850 | 3850 | 4155 | 4155 | 4155 | 4155 | 4155 | 4155 | 4155 | 4155 | 4155 | 4155 | 4155 |
| Thermal | | | | | | | | | | | | | | | |
| Kelanitissa GT | 911 | 434 | 161 | 5 | 27 | 113 | 37 | 44 | 10 | 44 | 27 | 16 | 30 | 26 | 30 |
| Kelanitissa ST | 242 | 235 | 187 | - | - | - | - | - | - | - | - | - | - | - | - |
| Sapugaskanda Diesel | 740 | 1006 | 1039 | 860 | 916 | 986 | 677 | 740 | 635 | 712 | 513 | 440 | 501 | 426 | 492 |
| Lakdanavi Diesel | 152 | 151 | 156 | 156 | 156 | 156 | 156 | 156 | 147 | 156 | 141 | 107 | 133 | 97 | 131 |
| KHD Plant Diesel | | 263 | 266 | 266 | 266 | 266 | 266 | 266 | 257 | 266 | 242 | 201 | 236 | 185 | 232 |
| Kelanitissa CC | | 543 | 956 | 354 | 485 | 767 | 339 | 626 | 216 | 434 | 288 | 146 | 300 | 181 | 375 |
| GT(105MW) | | | 393 | 72 | 117 | 274 | 77 | 264 | 100 | 260 | 145 | 55 | 202 | 114 | 364 |
| Kerawalapitiya CC | | | | 2023 | 2102 | 2186 | 1849 | 2100 | 1580 | 1947 | 1329 | 790 | 1305 | 888 | 1386 |
| Coal Fired | | | | | | | 2079 | 2079 | 4158 | 4158 | 6233 | 8184 | 8288 | 10211 | 10342 |
| Total Thermal Energy(GWh) | 2045 | 2631 | 3158 | 3736 | 4069 | 4748 | 5480 | 6276 | 7104 | 7977 | 8917 | 9939 | 10994 | 12128 | 13353 |
| Total Energy Dispatched(GWh) | 5895 | 6481 | 7008 | 7587 | 8224 | 8903 | 9635 | 10431 | 11259 | 12132 | 13072 | 14094 | 15149 | 16283 | 17508 |
| Total Demand(GWh) | 6007 | 6494 | 7008 | 7586 | 8223 | 8905 | 9636 | 10432 | 11260 | 12138 | 13078 | 14099 | 15161 | 16294 | 17523 |
| Deficit(GWh) | 112 | 12 | 0 | 0 | 0 | 2 | 2 | 3 | 2 | 7 | 6 | 6 | 12 | 11 | 16 |

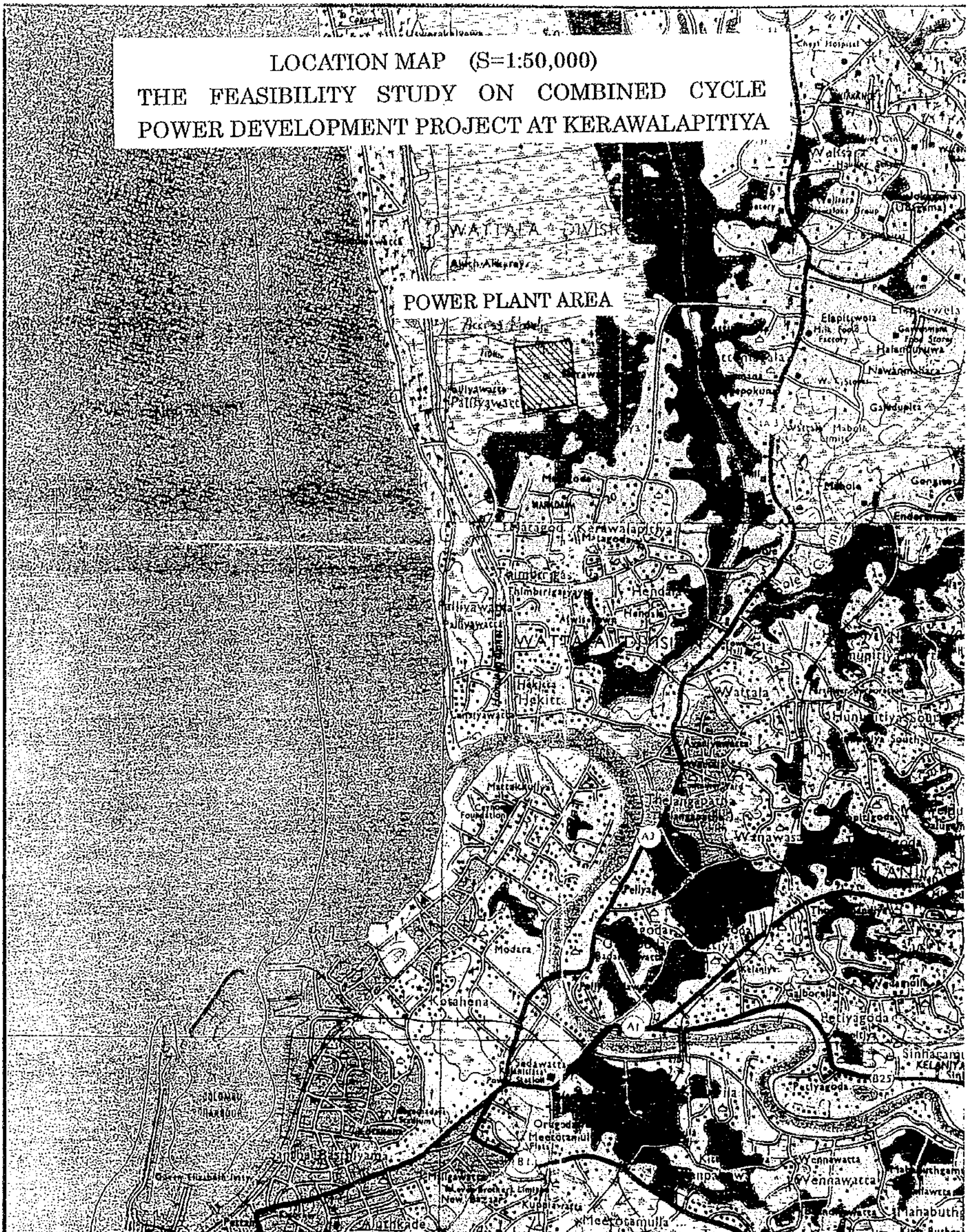


**Figure 2.1(1) Location of Project Site**

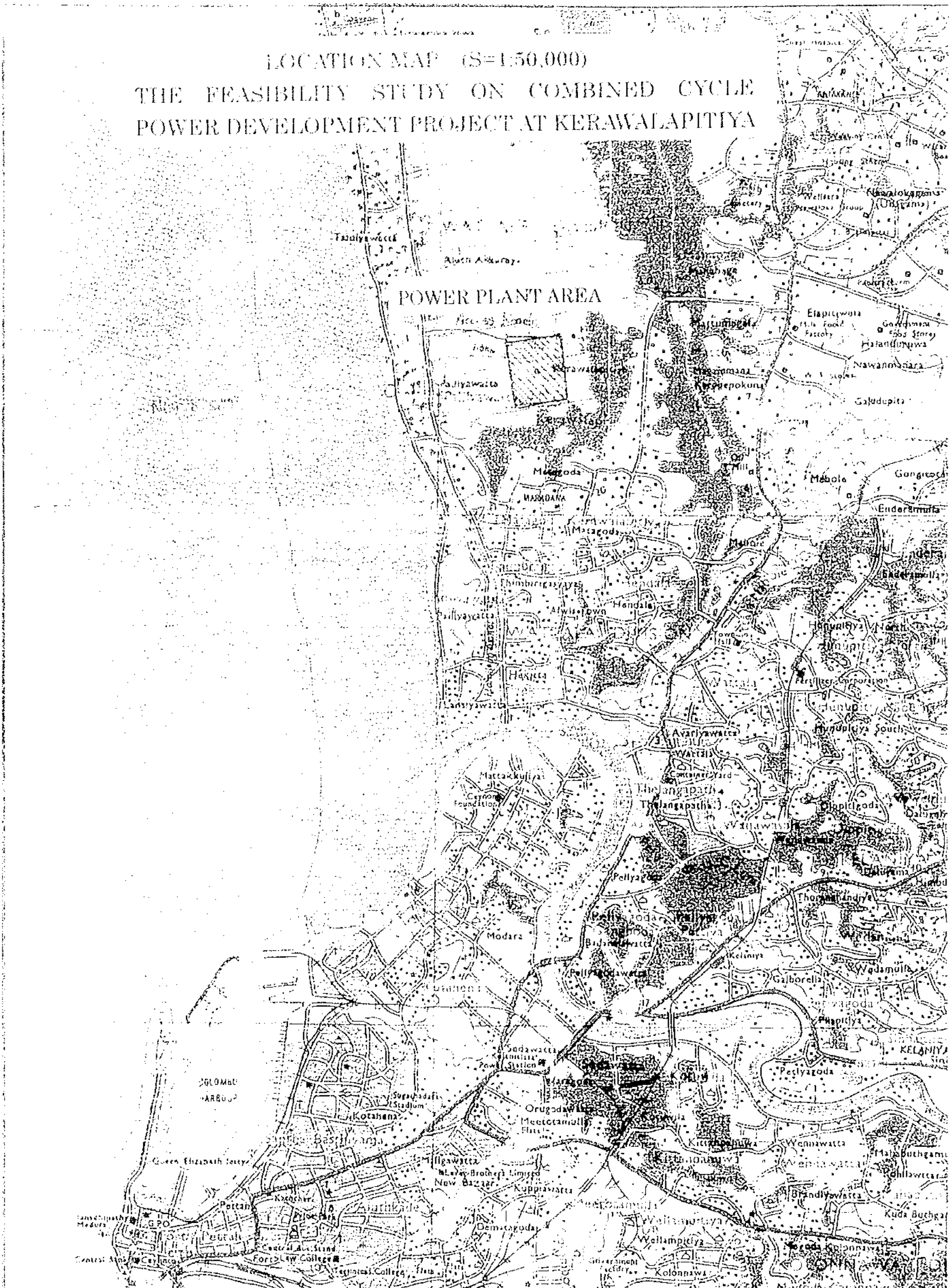


Figure 2.1(1) Location of Project Site