4 AIR QUALITY

4.1 INTRODUCTION

4.1.1 *Background*

This report presents the key findings of an air quality assessment of the proposed 1,800 MW gas-fired power station at Lamma Extension. It is prepared as part of an EIA study carried out under the *Environmental Impact Assessment Ordinance (EIAO)* for the Hongkong Electric Co. Ltd. (HEC).

Following directives from the Executive Council of the Hong Kong SAR Government (ExCo) on 31 March 1998, HEC submitted an application to the Environmental Protection Department (EPD) for the development of a new power station. A new site with a usable area of approximately 22 hectares to be formed to the south of the existing Lamma Power Station was proposed. A *Project Profile* and an application for a *Study Brief* were submitted by HEC on 9 April 1998. In accordance with the *EIAO*, the EPD issued a *Study Brief No. ESB-001/1998* on 20 May 1998 which specifies the following study requirements for air quality issues:

- wind tunnel modelling to study the dispersion of atmospheric emissions from the new power station and relevant premises;
- numerical grid modelling for the assessment of photochemical oxidants and to supplement the spatial scope of the wind tunnel study;
- a regional air quality review;
- a greenhouse gas assessment (which deals with HEC's *overall* operations in future years, so no separate assessment is provided in Part C of this Report of greenhouse gas impacts for the proposed transmission system for the Lamma Extension project); and
- a construction dust assessment (a separate assessment of dust impacts from construction of the transmission system, especially the landing points on Lamma Island, is provided in Part C).

All five areas of assessment are covered in this Report. Also included are the findings of a *5 Year Meteorological Data Review* and a *5 Year Episodes Analysis,* which serve to supplement the results of the wind tunnel study.

4.1.2 *Purpose and Objectives*

This Section of the Report aims to satisfy the requirements in *Clauses 3.1(i), (ii)(a), (ii)(b), (ii)(c) and (ii)(d)* of the *Study Brief*. It has taken into account relevant comments made by the EPD on the *Inception Report*. The primary objectives are:

- to identify existing and planned air sensitive receivers potentially affected by atmospheric emissions from the new power station;
- to review the baseline air quality at key sensitive receivers;
- to present the operating scenarios of the planned facilities and the emissions inventory;
- to describe the assessment methodology and the predicted impacts;

- to consider the cumulative air quality impacts of HEC's proposed and existing power station and the proposed *Waste-to-energy Incineration Facility (WEIF);*

- to evaluate the predicted impacts on air quality against recognised criteria; and

- to recommend mitigation measures where necessary to achieve acceptable air quality.

It has been concluded in two preceding studies entitled *Site Search for a New Power Station: Detailed Site Selection* and *Stage I EIA for a New Power Station, Volumes 1 & 2* that a new gas-fired 1,800 MW combined cycle power station at Lamma would not result in any insurmountable environmental constraints to the Hong Kong SAR and the Pearl River Delta region. This study seeks to investigate the site specific issues and impacts caused by identified plant operating scenarios. Mitigation measures will be recommended wherever applicable to ensure that the environmental impacts during the operational and construction phases will be rendered within acceptable levels.

4.1.3 *Scope of Study*

The proposed project as described in the *Project Profile* consists of two main components: a new 1,800 MW gas-fired combined cycle power station and a dedicated submarine gas pipeline which connects the gas supply from Shenzhen to the new power station site. A transmission system to supply electricity to Hong Kong Island has also been assessed in the current Study. This chapter, however, focuses on the air quality impacts of the gas-fired power station only.

The *Study Brief* requires the modelling of operational air quality impacts within the territory of the Hong Kong SAR and the review of potential impacts in the regional context. Also included in the *Study Brief* are requirements on the assessment of dust impacts during the construction phase.

For the operational air quality assessment, a comprehensive air quality impact assessment for the proposed new power station has been carried out covering the following 3 domains:

- near-field within 9.3 km of the site and inside the Hong Kong SAR territory, for which physical modelling will be carried out in a wind tunnel;

- mid-field covering the Hong Kong SAR territory, for which numerical photochemical grid modelling will be conducted using the PATH air quality modelling system; and

- far-field reaching outside the territory of Hong Kong SAR into the Pearl River Delta region, for which previous regional air quality modelling work will be reviewed.

In addition to the local and regional scale issues, the *Study Brief* stipulates the requirement for a greenhouse gas assessment which is a global issue covered in two previous working papers.

4.1.4 *Relevant EIA Reports*

In accordance with the *Technical Memorandum* issued under *Section 16* of the *Environmental Impact Assessment Ordinance (Cap. 499) (EIAO TM),* the Consultants refer to the following two EIA studies:

- *Stage I EIA for a New Power Station, Volumes 1 & 2* (EIA-130/BC)
- *Environmental Impact Assessment of Units L7 & L8 Lamma Power Station Final Initial Assessment Report* (EIA-012/BC)

4.1.5 *Structure of the Report*

This chapter is organised into the following key areas:

- *Section 4.1* outlines the background, objectives and scope of this study;
- *Section 4.2* highlights the key legislative requirements and standards to be considered;
- *Section 4.3* examines the baseline air quality and meteorological data;
- *Section 4.4* presents the wind tunnel modelling results;
- *Section 4.5* provides the PATH modelling results;
- *Section 4.6* reviews and updates the findings of the previous regional air quality review;
- *Section 4.7* assesses greenhouse gas emission issues for HEC's future operations with the new power station;
- *Section 4.8* evaluates the potential dust impacts during construction;
- *Section 4.9* summarises the mitigation measures identified in the air quality assessment;
- *Section 4.10* recommends environmental monitoring and audit requirements for the power station development; and
- *Section 4.11* summarises the findings and conclusions of the assessment.

4.2 LEGISLATION AND STANDARDS

4.2.1 Air Pollution Control Ordinance

Overview

The principal legislation for air quality is the *Air Pollution Control Ordinance (Cap. 311) (APCO)*. Subsidiary legislation has been made under the *APCO* on specific areas of concern. The two areas that are most relevant to power station development are the ambient air quality standards to be met at receptors and the emission standards to be achieved at source. These are covered by the *Air Quality Objectives* and the *Best Practicable Means Notes* issued under *Cap.311.*

Moreover the operation of the power station, once commissioned, will be subject to the licensing control of the *Air Pollution Control Ordinance (Cap 311).*

On construction dust control, the *Air Pollution Control (Construction Dust) Regulation (Cap. 311)* stipulates the mitigation measures for construction sites. Under the *Air Pollution Control Ordinance,* a licence is required for the operation of concreting batching plant at any construction site. In addition, the *Technical Memorandum on Environmental Impact Assessment Process (EIAO TM)* stipulates that an hourly Total Suspended Particulate (TSP) concentration of 500 μg m^{-3}

measured at 298 K and 101.325 kPa (1 atm) should not be exceeded at any *Air Sensitive Receiver (ASR).*

Air Quality Objectives

There are 10 *Air Control Zones (ACZs)* delineated in the *Air Pollution Control (Air Control Zones) (Declaration) (Consolidation) Order* within the Hong Kong SAR. In each of the *ACZs*, statutory ambient air quality standards known as the *Air Quality Objectives* are defined for seven types of air pollution. The same statutory standards apply to all *ACZs* as stipulated in the *Air Control Zones (Consolidated) Statement of Air Quality Objectives*. These *AQOs* serve as the planning and operational limits for development in Hong Kong.

For the purpose of this study, due to the emission characteristics of the proposed gas-fired plant and the associated construction works, only SO_2, NO_2, O_3 and TSP are of interest. The latter is only of concern during the construction phase. The relevant standards are summarized in the following table.

Table 4.2a ***Hong Kong Air Quality Objectives ($\mu g\ m^{-3}$)***

Pollutant[a]	Averaging Time			
	1 Hour[b]	8 Hours[c]	24 Hours[c]	1 Year[d]
Sulphur Dioxide (SO_2)	800	-	350	80
Nitrogen Dioxide (NO_2)	300	-	150	80
Ozone (O_3)	240	-	-	-
Total Suspended Particulates (TSP)	-	-	260	80

Notes:
(a) Measured at 298 K (25°C) and 101.325 kPa (one atmosphere).
(b) Not to be exceeded more than three times per year.
(c) Not to be exceeded more than once per year.
(d) Arithmetic means.

Best Practicable Means Notes

According to the *Notes on Best Practicable Means for Electricity Works* issued in accordance with *Section 12(1)* of the *APCO*, the emissions standards of the units have to comply with the following limits for new facilities:

Table 4.2b ***Emission Limits Stipulated in the Best Practicable Means Notes***

	Gas-fired Gas Turbines (> 15 MW)
SO_2	10 mg m^{-3} (a)
NO_x (as NO_2)	90 mg m^{-3} (a)
Particulate	5 mg m^{-3} (b)
Exit Temperature (°C)	80 °C
Exit Velocity	15 ms^{-1}

Notes:
(a) hourly average
(b) 2-hourly average

Air Pollution Control Ordinance

The proposed power station is defined as a *Specified Process* in *Schedule 1* of the *APCO (Cap. 311)*. According to the *Air Pollution Control Ordinance*, the operation of a power station requires a *Specified Process Licence*. The licence may contain detailed terms and conditions on the following:

- fuel quality;
- stack height and chimney exit diameter;
- flue gas exit temperature and velocity;
- emissions standards on mass emission rates and concentrations;
- operation and maintenance requirements;
- environmental monitoring requirements at sources; and
- environmental monitoring requirements in the vicinities of the power; station.

4.2.2 *Environmental Impact Assessment Ordinance*

Under the *EIAO*, the criteria for evaluating air quality impacts in *Annex 4* of the *EIAO TM* should be complied with. For the purposes of assessing SO_2, NO_2, O_3 and TSP, the criteria are identical with the *AQOs* given in *Table 4.2a*. The guideline for air quality assessment is laid down in *Annex 12* of the *EIAO TM* and has been followed in this assessment.

4.2.3 *Hong Kong Planning Standards and Guidelines*

The *Hong Kong Planning Standards and Guidelines* provide guidelines for planning development. The relevant requirements have already been covered by the *EIAO* and the *APCO* and hence will not be repeated here.

4.3 BASELINE CONDITIONS

4.3.1 *Scope*

The spatial scope of this air quality study covers the Hong Kong Special Administrative Region (SAR), the Pearl River Delta region and as far as greenhouse gas is concerned, extends to the global scale. As various study methodologies and modelling techniques are involved, some of which have a unique definition of the baseline conditions such as the PATH modelling. Other modelling approach including wind tunnel will utilise measured average background concentration applicable for the urban and rural areas for the purpose of this study.

The assessment of direct and local impacts inside the SAR is addressed by both wind tunnel and the PATH system modelling. As the PATH system is intrinsically capable of evaluating existing and future boundary and background air quality conditions for the SAR, the discussion of baseline conditions will be confined to the area covered by the wind tunnel model (ie within approximately 9 km of the new development).

4.3.2 *Ambient Air Quality*

Overview

Based on annual air quality reports published by the EPD from 1992 to 1996, a detailed review of the baseline air quality data has been carried out. As only one Air Quality Monitoring Station (AQMS) is available inside the study area, the EPD results are augmented by the air quality data monitored at 5 stations in the HEC network. The HEC stations are operated to the standards agreed with the EPD and results obtained are scrutinised monthly by the EPD as part of the

Specified Process Licence requirements.

The stations are shown in *Figure 4.3a*. Each station in the EPD and the HEC network is equipped with continuous monitors for SO_2 and NO_2 except the station at Chung Hom Kok which has monitor for SO_2 only. Results are available in the form of hourly, daily and annual averages. A detailed *Review on Baseline Air Quality* is presented in *Annex B4-1* and a summary is presented below.

Annual Air Quality Trend

Figure 4.3b illustrates annual trends of SO_2 and NO_2. It is observed that the long term SO_2 trend is decreasing. This is expected to continue in view of the ongoing EPD initiatives to improve ambient air quality by introducing vehicle diesel oil with a maximum sulphur content of 0.05% since 1 April 1997 and the diminishing industrial activities in the traditional urban industrial areas. Ambient NO_2 levels were fairly constant in the 5 year period from 1992 to 1996. As higher vehicle design standards are being introduced in Hong Kong through the *Air Pollution Control (Vehicle Design Standards) (Emission) Regulations (Cap. 311)*, it is expected that the ambient levels should stabilise around the existing levels if growth of vehicular traffic can be controlled.

Seasonal Variations

Monthly patterns of ambient SO_2 and NO_2 levels have been examined in order to assess whether potential air quality impacts due to power station peak load operations in summer would coincide with any significantly raised ambient concentrations of SO_2 and NO_2 and thus warrant special treatment for the estimation of background air quality during summer months. *Figure 4.3c* gives a general idea of the typical seasonal variations. No such correlations have been observed. The data, which will have included the effects of the existing Lamma Power Station, suggest that the existing units have not caused any noticeable impacts at receptors in the vicinity of the Central/Western stations during the summer months.

Diurnal Variation in Hourly Concentrations

Based on data in the *1993, 1995* and *1996 issues* of the *Air Quality in Hong Kong,* hourly SO_2 levels normally reach their maximum at Central/Western during the day at either 10 am or 3 pm. Typical levels were 21-33 $\mu g\ m^{-3}$. It was commonly reported that the ambient SO_2 levels were highly associated with human activities. Minimum levels were observed at around 4 am.

For NO_2 levels, the hourly peak concentration usually occurred from 5 pm to 7 pm. The maximum recorded levels ranged from 67-80 $\mu g\ m^{-3}$. The major source of NO_x is vehicle emissions. Again, minimum hourly concentrations were reached at 4 am when human activity is normally at its lowest. *Figure 4.3d* shows the diurnal variations.

Background Air Quality for Years 2002 and 2012

According to the above analysis, it is proposed to adopt the maximum hourly concentrations of an average day as the background for predicting hourly averages in the wind tunnel tests. The background levels chosen for hourly SO_2 and NO_2 are 33 $\mu g\ m^{-3}$ and 80 $\mu g\ m^{-3}$ respectively for the urban areas and 23 $\mu g\ m^{-3}$ and 49 $\mu g\ m^{-3}$ respectively for the rural and new development areas.

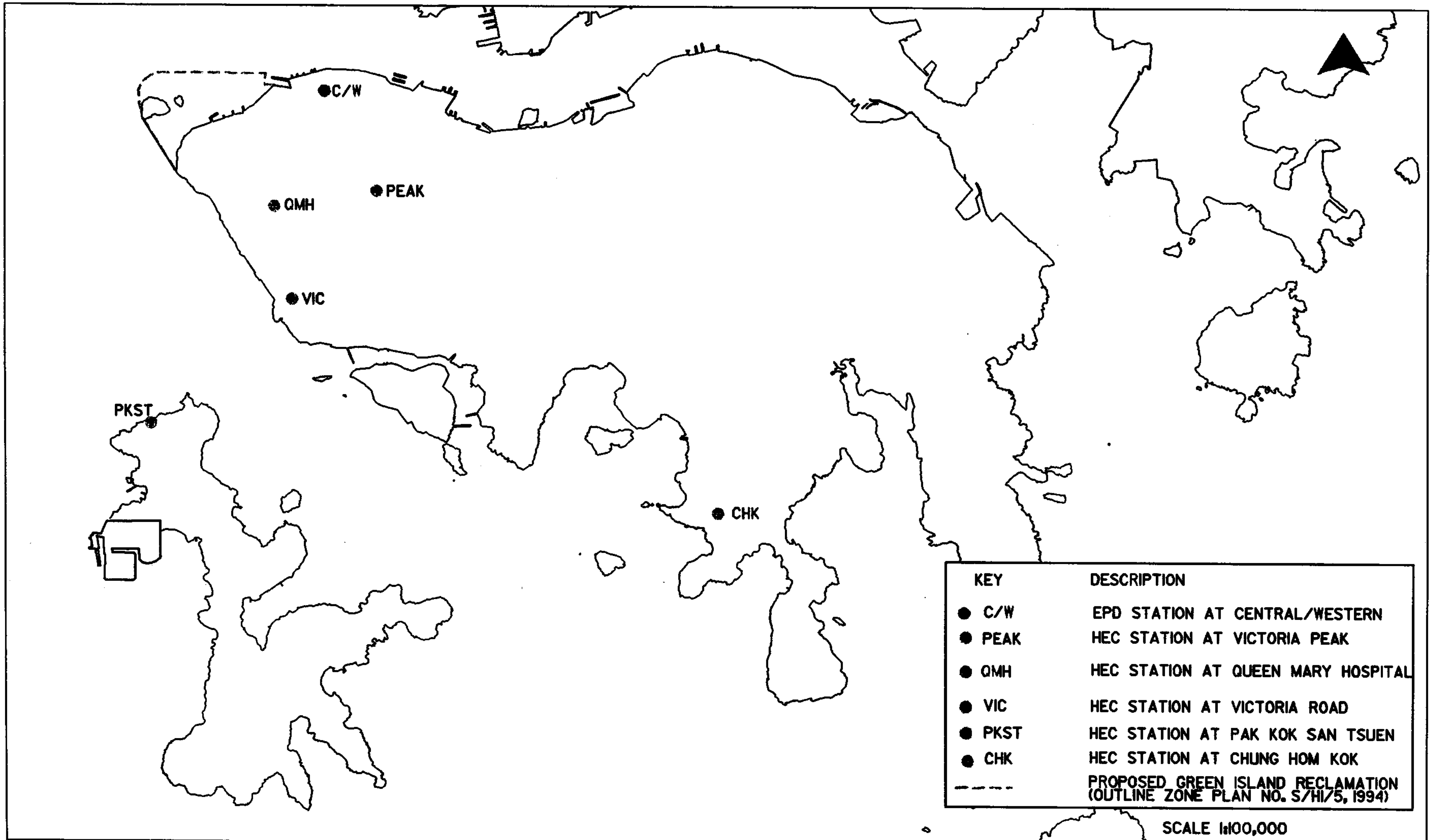

FIGURE 4.3a

AMBIENT AIR QUALITY MONITORING STATIONS

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Figure 4.3bi Trend of Annual Average of SO_2 (1992-1996)

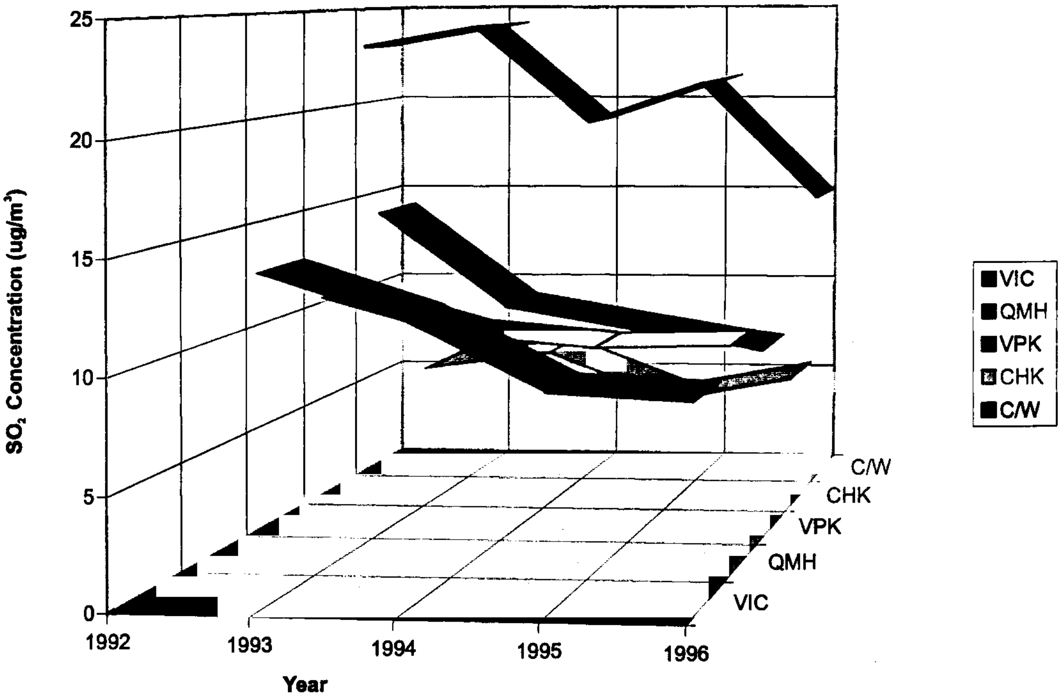
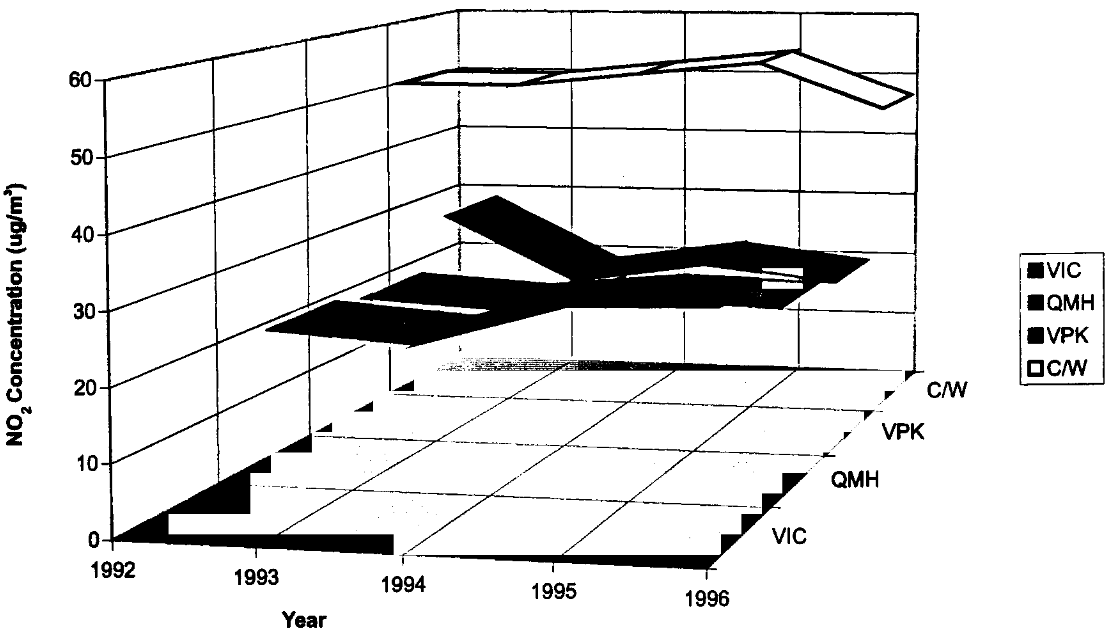


Figure 4.3bii Trend of Annual Average of NO_2 (1992-1996)



FIGURES 4.3b

ANNUAL TREND OF SO_2 & NO_2

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Figure 4.3ci Monthly Variation of SO_2 (1992-1996)

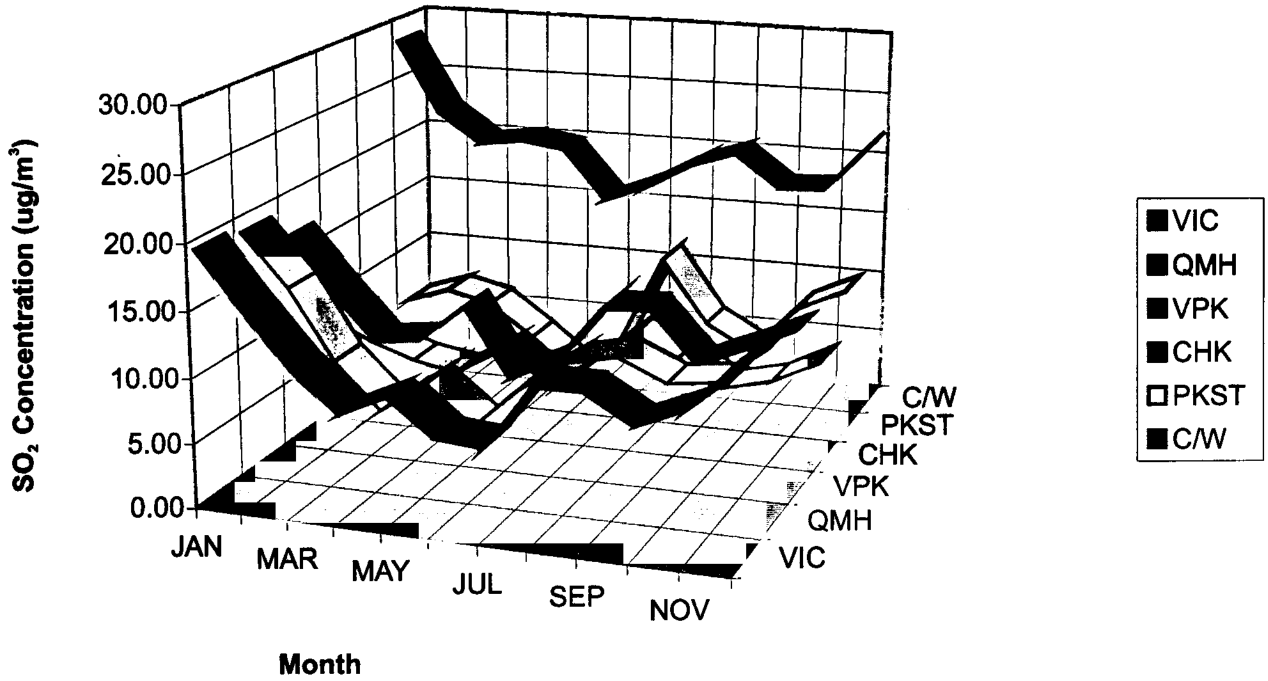
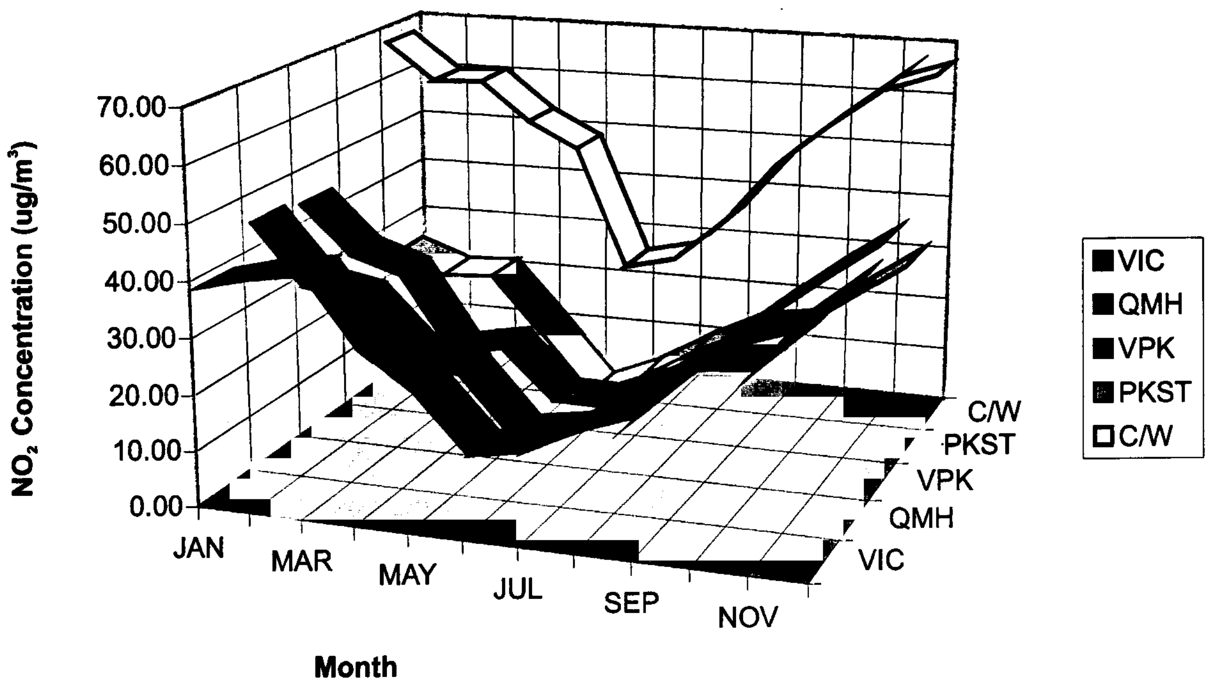


Figure 4.3cii Monthly Variation of NO_2 (1992-1996)



FIGURES 4.3c	MONTHLY VARIATION OF SO_2 & NO_2	Environmental Resources Management ERM
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Figure 4.3di Diurnal Variation of SO_2 (1992-1996)

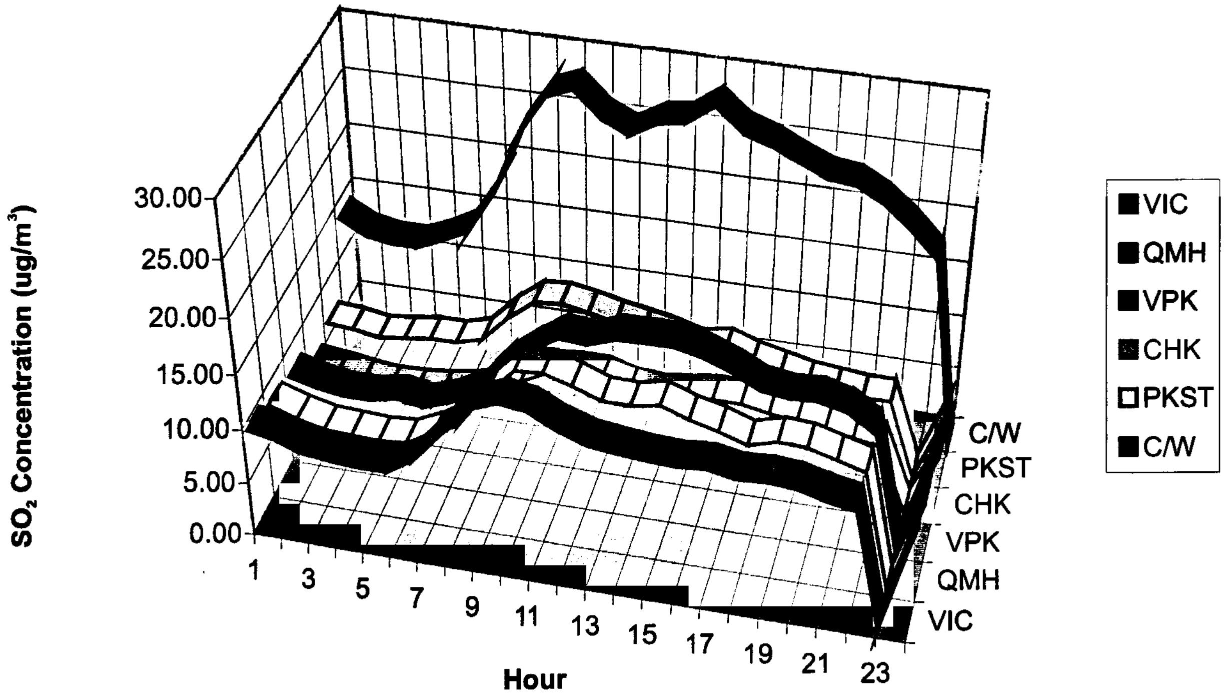
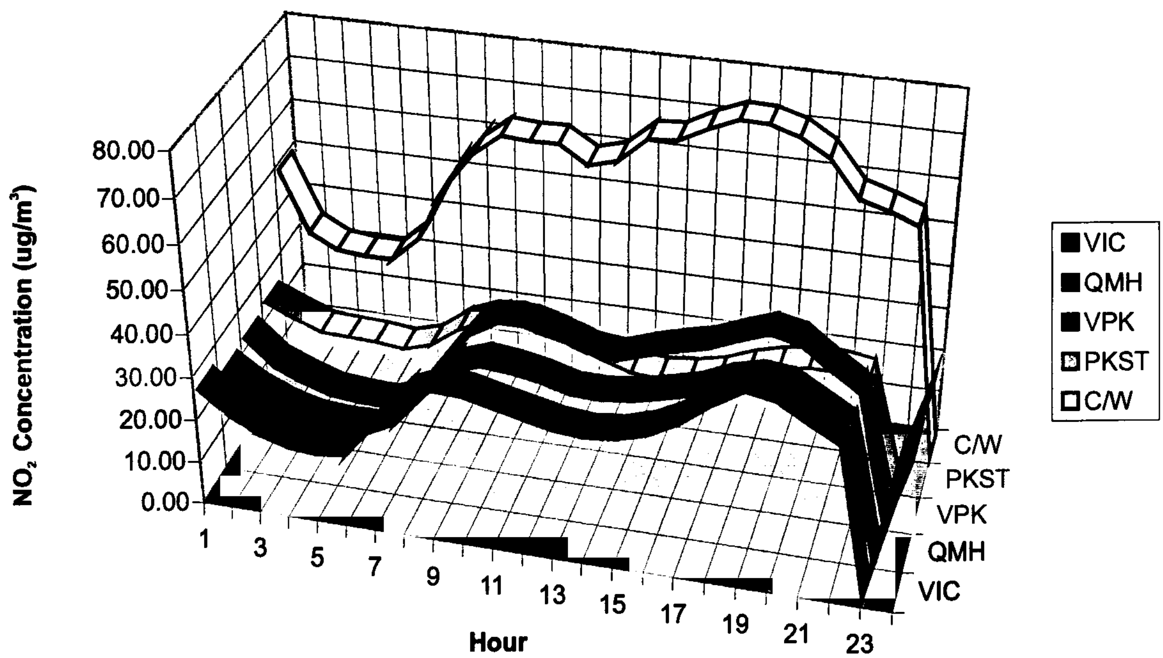


Figure 4.3dii Diurnal Variation of NO_2 (1992-1996)



FIGURES 4.3d

DIURNAL VARIATION OF SO_2 & NO_2 (1992-1996)

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For daily and annual averages, it is considered that average annual means for the 5 year period from 1992 to 1996 should be used (ie the corrections for SO_2 and NO_2 will be 20 $\mu g\ m^{-3}$ and 51 $\mu g\ m^{-3}$ respectively and 10 $\mu g\ m^{-3}$ and 28 $\mu g\ m^{-3}$ respectively for the rural and new development areas). In view of ongoing initiatives to control urban air pollution sources, these levels may represent a slightly conservative estimate for future years. Since the above analysis is independent of the assessment year in the future, the same correction will apply for years 2002 and 2012. Compared with the AQOs, the identified background levels are generally low.

4.3.3 *Meteorology*

The salient meteorological factors that affect atmospheric air dispersion are discussed below. These mainly concern surface winds and precipitation. Of all meterological stations run by the Hong Kong Observatory, the one at Cheung Chau has been considered as the most representative for assessing atmospheric dispersion around Lamma Island. Data on precipitation are based on the station at the Hong Kong Observatory.

A wind rose showing long-term average winds measured at Cheung Chau is shown in *Figure 4.3e*. During the 21 year period of records at Cheung Chau, southwesterly winds blew for 18% of the time from the 180° to 270° sector. Seasonal analysis shows that the southwesterly winds mainly occurred during the summer months between May and September. July recorded the highest frequency of occurrence (54%). For the rest of time, winds from the east and the north predominate. Winds from northwesterly directions are rare throughout the year.

Summer is also the wettest season, with about 80% of the total annual rain falling between May and September. The peak occurs in August, when it rains on average over 50% of the days, with a monthly average of 391 millimetres at the Hong Kong Observatory. January is the driest month with 23 millimetres and rainfall on only about 6 days.

4.4 *WIND TUNNEL MODELLING*

4.4.1 ***Introduction***

This Section presents key findings of the wind tunnel modelling study for the proposed gas-fired power station. Impacts due to the simultaneous operation of the new combined cycle units and the other relevant sources are considered. The air quality impacts due to SO_2 and NO_x emissions during peak load operations have been predicted for the years 2002 and 2012. The spatial scope of the wind tunnel model covers areas defined as the near-field of the power station. Specifically, it includes an area within approximately 9 km of the new power station. *Figure 4.4a* depicts the spatial scope of the wind tunnel study.

The 9 km range is based on consideration of physical similarity laws, dimensions of the wind tunnel, size of the study area and similar project experience. Consideration during the model design stage revealed that the optimum size of the wind tunnel should extend up to 9.3 km to yield representative measurements for receptors further downwind. As stated previously the area outside the 9.3 km range will be addressed by using a mesoscale numerical grid model, the PATH system, to cover the entire territory of Hong Kong and beyond.

The study area covers Lamma Island, the western part of Hong Kong Island from Ap Lei Chau, Wah Fu Estate, Telegraph Bay, Green Island to Kennedy Town, and outlying islands such as Cheung Chau. The key topographical features includes Mt Stenhouse on Lamma Island, Victoria Peak, High West, Mt Davis and Mt Kellet on Hong Kong Island. It is the presence of these mountains and the associated complex terrain that has led to the requirement for wind tunnel testing instead of the conventional dispersion modelling approach.

4.4.2 *Source Descriptions*

Overview

It is envisaged that the proposed 1,800 MW power station will consist of 6 units of 300 MW combined cycle gas-fired power plant. The units will be commissioned in stages from the year 2003 to 2012. *Figure 4.4b* shows the proposed site layout plan for 2012.

Existing Lamma Power Station

The Lamma Power Station is located to the northwest of Lamma Island. There are 8 units of coal-fired plants with a total installed capacity of 2,500 MW. These units operate for most of the year except during maintenance. For peak lopping purposes and for emergency operations, 7 units of open cycle gas turbines are installed. Six of the gas turbines are of 125 MW rating and one is 55 MW. All gas turbines operate on light gas oil. A general plant layout plan is presented in *Figure 4.4c.*

Coal Units

From its inception in the late 1970s, the existing Lamma Power Station has been viewed as a modern pulverised coal power station. The first 3 units are of 250 MW rating, while units 4 to 8 are 350 MW. All 8 units are equipped with high efficiency electrostatic precipitators for particulate control. Units 6 to 8 are further fitted with Flue Gas Desulphurisation (FGD) plant and Low NO_x Burners (LNB).

The coal used is transported to the power station by vessels and stored on site in an open coal stockyard. Only bituminous coal that contains a maximum sulphur content of 1% by weight is used. Typically 99.5% of particulates in the flue gas are removed by the electrostatic precipitators. The FGD plants for Units 6 to 8 operate at a minimum sulphur dioxide (SO_2) removal efficiency of 90%. NO_x removal efficiencies for the LNB for Units 6 and Units 7 & 8 are typically 50% and 60% respectively compared to Units 1 to 5 which are equipped with conventional burners.

Flue gases from the exhausts of the boilers are released through tall stacks after treatment. There are 3 stacks each of 215 mPD for the 8 coal units. Stack 1 serves Units 1, 2 and 3 while Stack 2 contains flues of Units 4, 5 and 6. Exhaust gases from Units 7 & 8 are discharged through Stack 3. Each unit has an independent flue inside each stack. The coal units are shown as L1 to L8 respectively for Units 1 to 8 in *Figure 4.4c.*

Gas Turbine Plants

The 6 units of 125 MW gas turbines are located to the west of the main plant area where the 8 coal units reside. The plants are normally on standby mode. It is only during emergencies or for peak lopping that the gas turbines will be

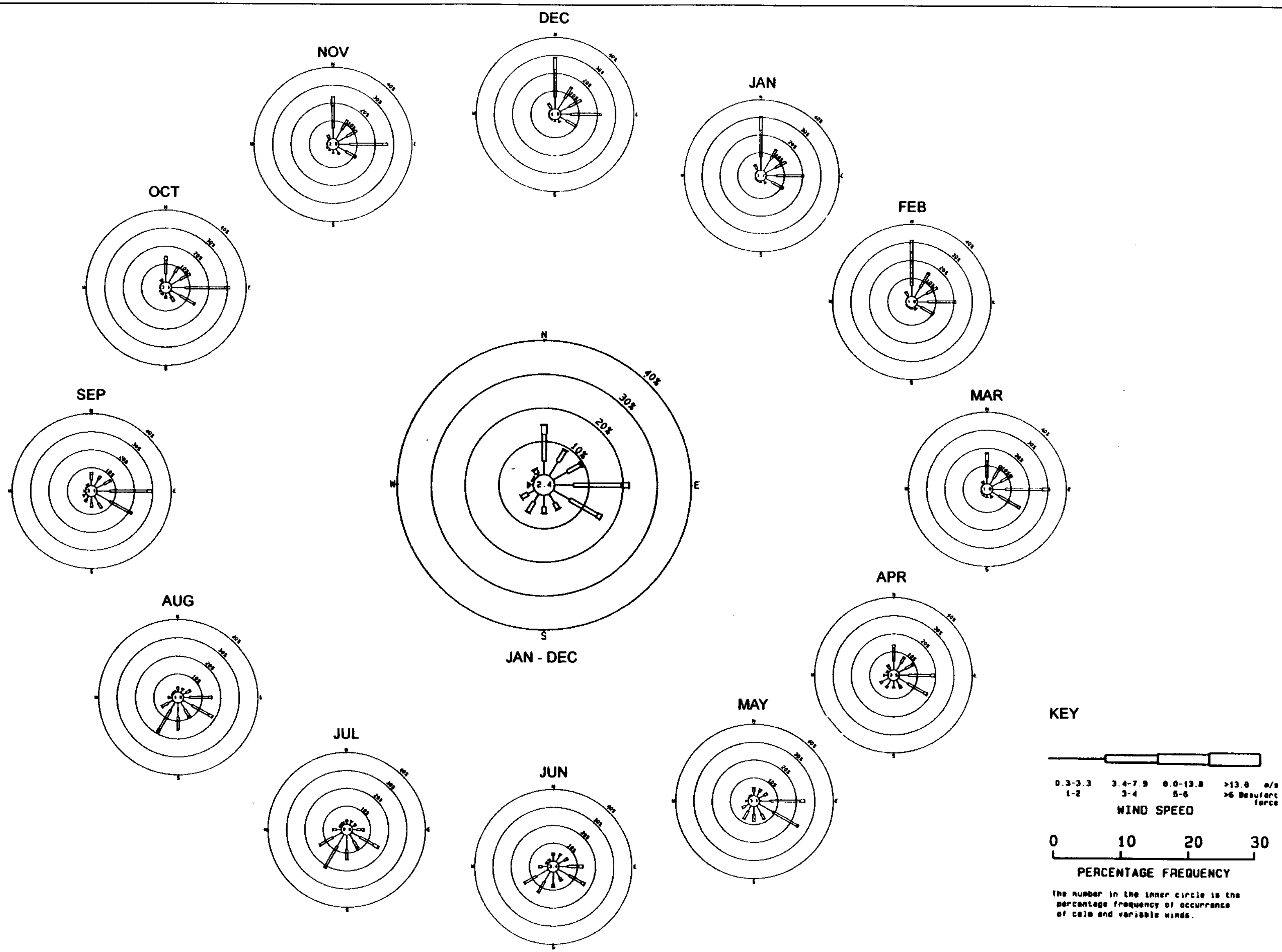

FIGURE 4.3e

WIND ROSE FOR CHEUNG CHAU MET. STATION (1971 - 1991)

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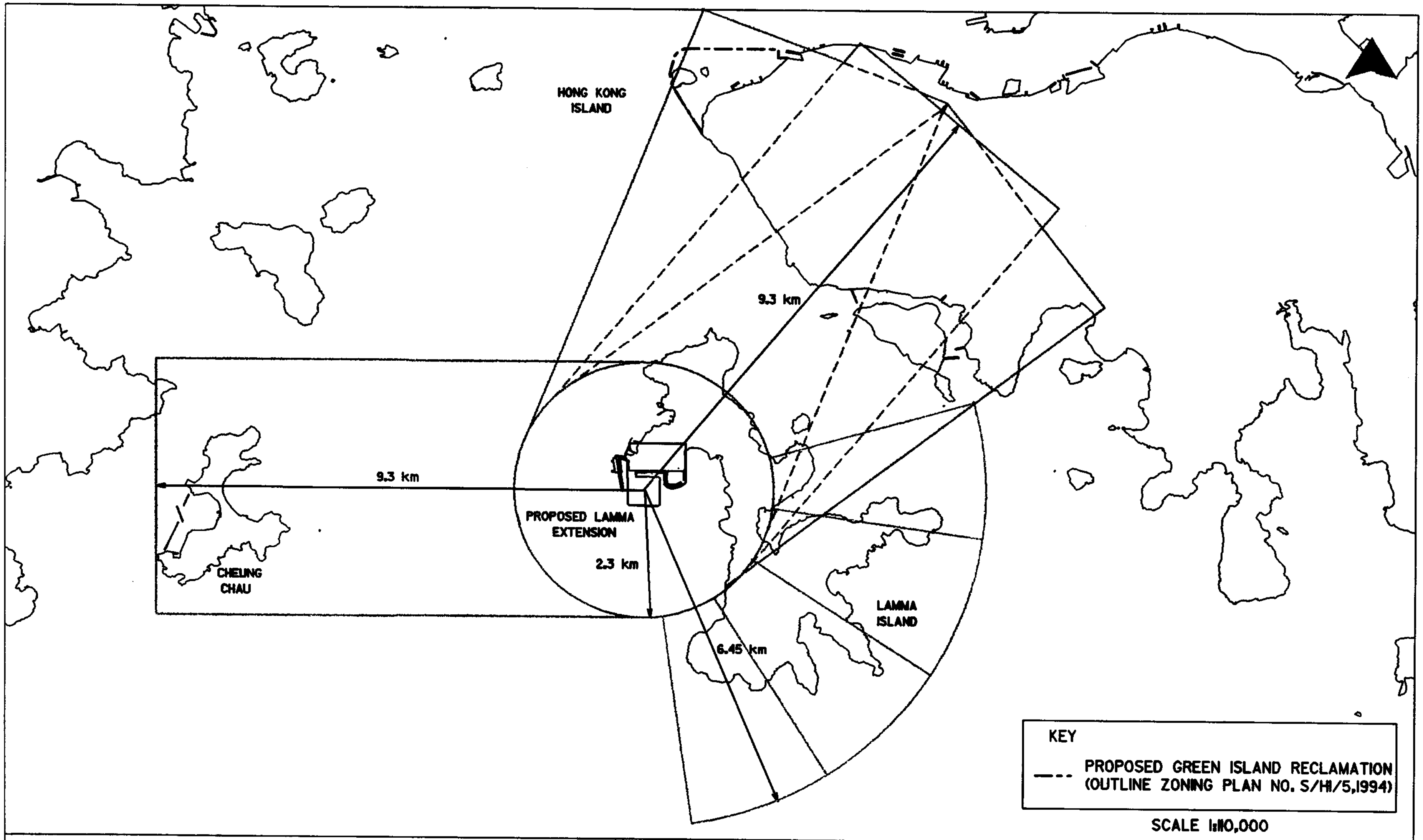

FIGURE 4.4a

SPATIAL SCOPE OF WIND TUNNEL STUDY

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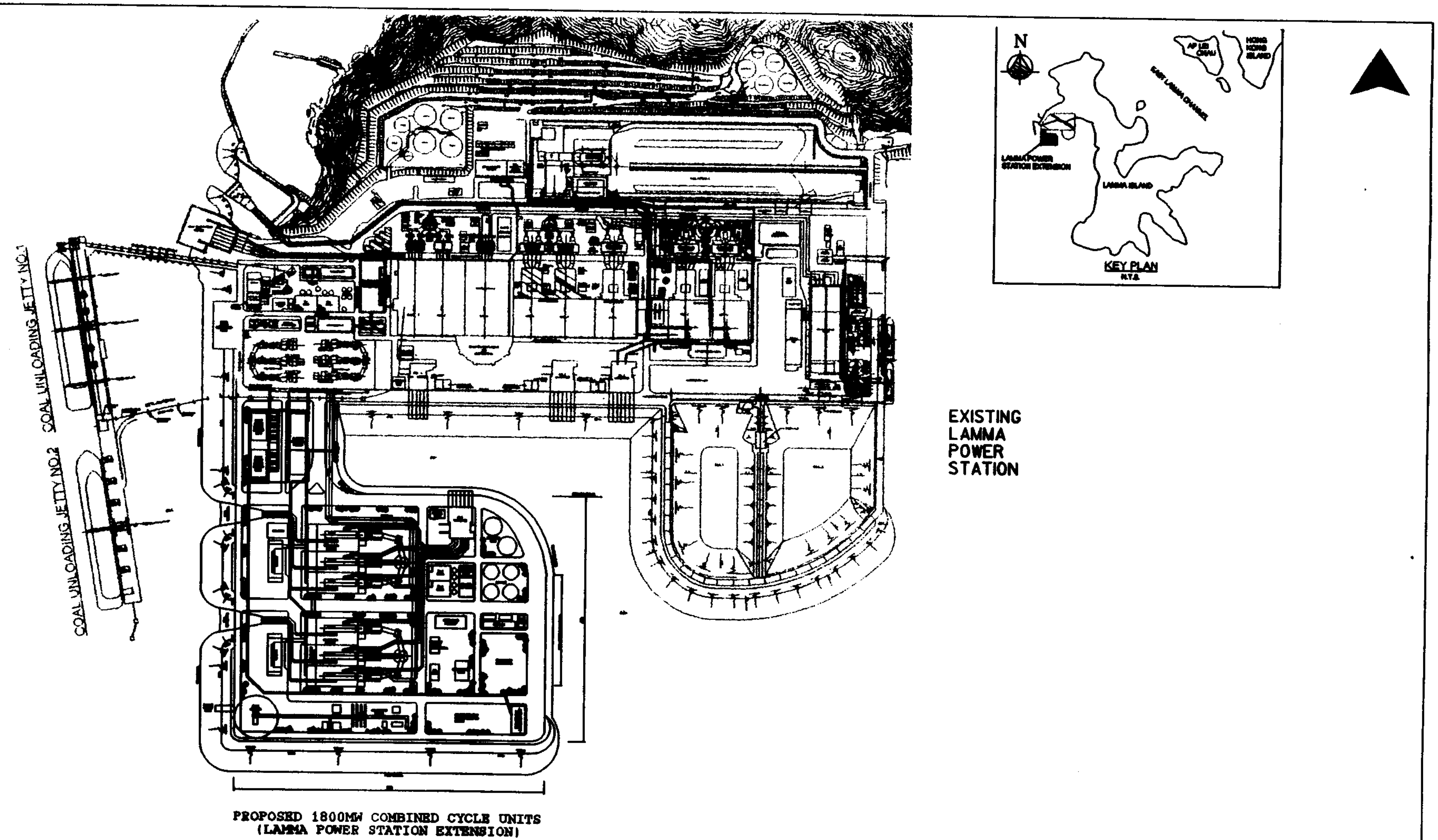

FIGURE 4.4b

PROPOSED SITE LAYOUT PLAN OF LAMMA POWER STATION IN YEAR 2012

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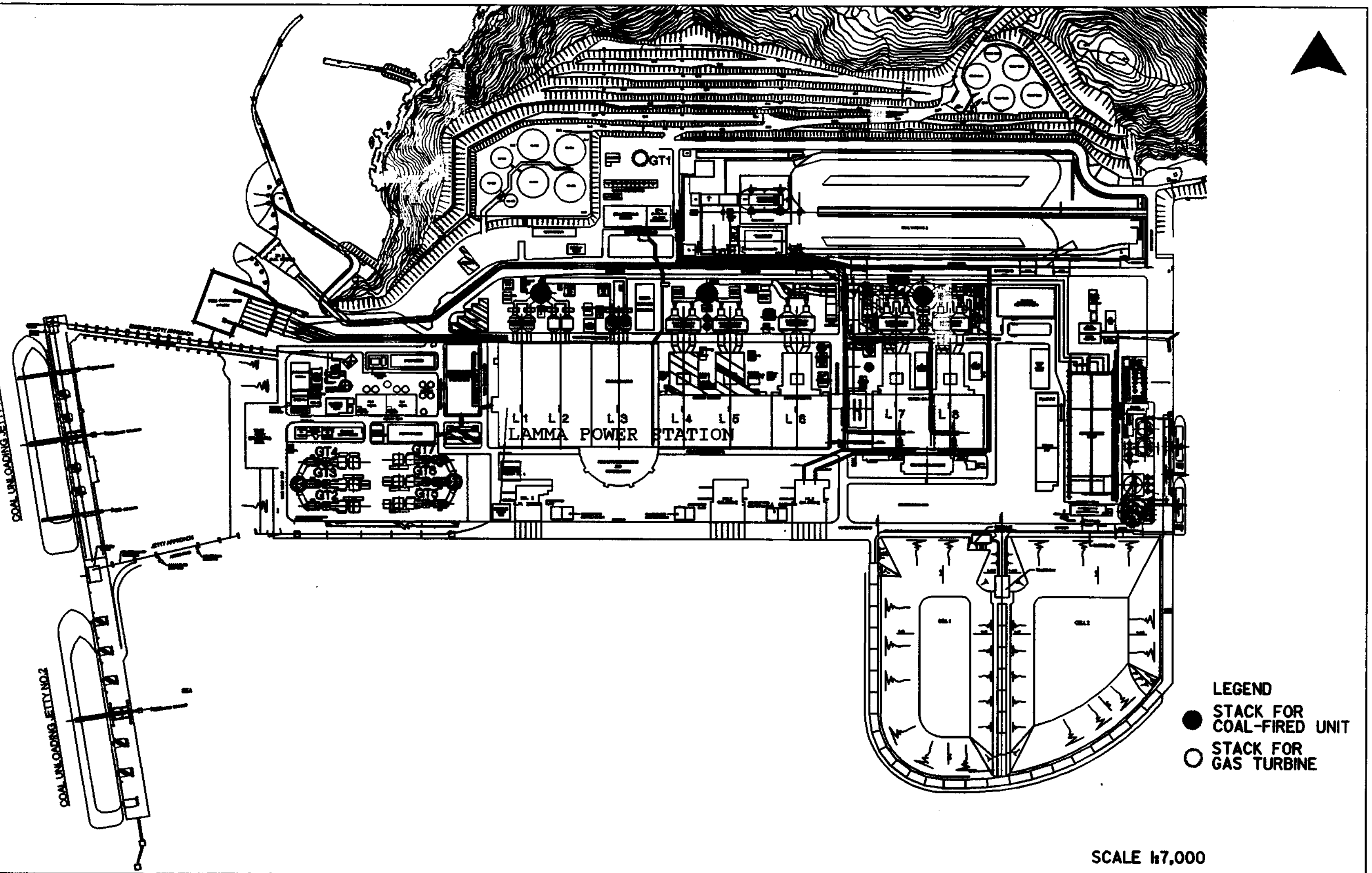

FIGURE 4.4c

EXISTING LAMMA POWER STATION SITE LAYOUT PLAN

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brought into operation. In this connection, the gas turbines mostly operate during the daytime in the summer months although there is no limit to their operating time.

The gas turbines are of open cycle design (ie the hot exhaust gases from the gas turbines are released directly to the atmosphere without passing through any heat recovery devices). Light gas oil of a maximum sulphur content 0.5% by weight is used as the fuel. Stacks are arranged in 2 groups of 3 and are 86 mPD high. The 6 gas turbines are shown as GT2 to GT7 in *Figure 4.4c.*

There is a relatively small gas turbine located to the north of the main coal-fired units, shown as GT1 in *Figure 4.4c.* GT1 is of 55 MW output and operates on light gas oil. It is also of open cycle design and has a stack discharge point at 15.75 mPD.

Proposed New Power Station

- General Description

The new 1,800 MW combined cycle power station will be situated to the south of the existing Lamma Power Station. A new site will be formed with a usable area of approximately 22 hectares. The 6 units of 300 MW combined cycle gas turbines (CCGTs) are arranged from north to south as shown in *Figure 4.4d.* Natural gas will be delivered to the site via a dedicated submarine pipeline that runs from Shenzhen. After treatment and pressure regulation in the on-site Gas Receiving Station, the gas will be piped to the individual units for use.

The new site will be formed by reclamation. Whilst site formation works will be completed in 2001, phased development of the 6 units and the auxiliary plants will occur from 2003 to 2012 .

- Combined Cycle Gas Turbines

The new power station will employ Combined Cycle Gas Turbine (CCGT) technology. A CCGT unit can in fact be considered as two independent power plants operating in series. The first power plant is a modern high efficiency gas turbine plant that powers a generator. Instead of discharging its hot exhaust gases into the open atmosphere, the hot gases are diverted into a heat recovery steam generator. It is through the heat recovery steam generator (HRSG) that the gas turbine plant interfaces with a steam cycle unit through heat transfer.

The steam cycle unit functions in a similar manner to a conventional steam turbine, except that it has a heat exchanger instead of a boiler. It takes up the heat energy of the hot gases from the gas turbine by circulating treated water through the heat recovery steam generator. As water passes through the HRSG, superheated steam is produced which enters a steam turbine and drives a second generator. The combined use of a gas turbine and a steam turbine through a HRSG is the key to the high thermal efficiency of a CCGT unit which is over 50, in comparison with around 40% for a conventional coal unit that operates on a steam cycle only. *Figure 4.4e* shows a schematic of a combined cycle power plant.

The proposed combined cycle units will operate on gas. Natural gas is a premium fuel that contains virtually no sulphur and results in almost zero discharges of particulates. The flues of the 6x300 MW units will be arranged into two groups of stacks. The proposed stack height will be tested in the wind tunnel and overall compliance with the *Air Quality Objectives (AQO)* will be checked with other relevant sources in operation.

Emission Characteristics

The emission characteristics of each source in the existing and future Lamma Power Station are presented in *Table 4.4a*. It should be noted that the commissioning of the proposed new power station and the progressive introduction of generating capacity will shift the base load from the existing Lamma Power Station to the new power station. As the new power station will utilise gas as fuel, there will be a net reduction in the overall aerial emission from HEC.

For completeness, the emissions for a *WEIF* are also included. However, it should be noted that the *WEIF* is not part of the project proposed by the HEC. It is included only to allow the worst case cumulative assessment of air quality impacts.

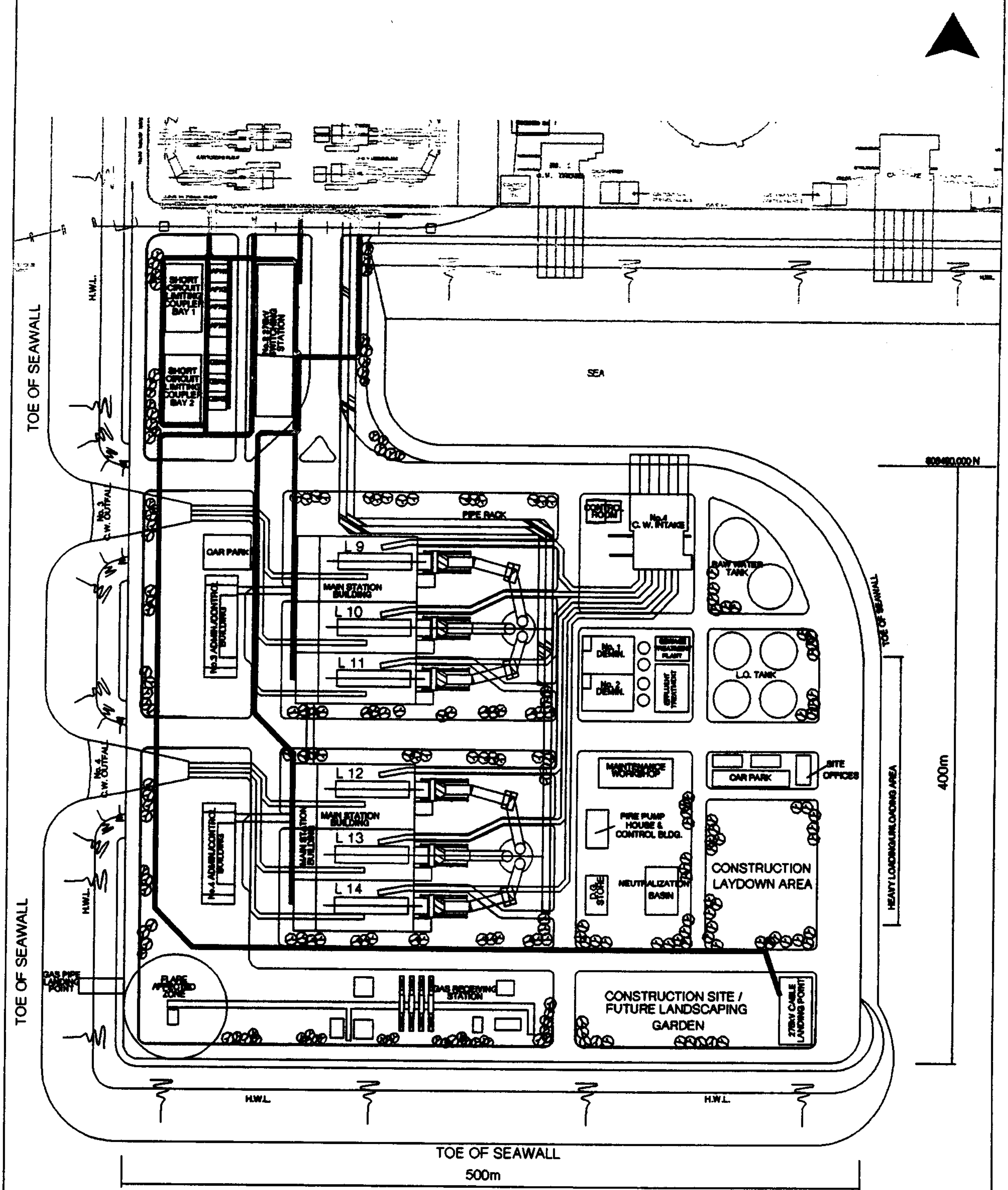
Table 4.4a ***Full Load Emission Characteristics and Stack Parameters for Each Unit***

Units	SO_2 (kg h^{-1})	NO_x (kg h^{-1})	SO_2 (mgNm^{-3})	NO_x (mgNm^{-3})	Min Efflux Temp (°C)	Min Efflux Velocity (m s^{-1})	Stack Height (mPD)	Stack I.D. per flue (m)
L1 -L2 *250 MW*	1900	1230	1910	1200	120	15	215	5.11
L3 *250 MW*	1930	1230	1910	1200	120	15	215	5.11
L4 & L5 *350 MW*	2540	1600	1910	1200	110	15	215	5.62
L6 *350 MW*	254	880	191	660	80	15	215	5.62
L7 & L8 *350 MW*	254	493	200	411	80	15	215	5.54
GT2 - GT7 *125 MW*	1430	1320	290	185	390	32	86	5.6
CCGT *300 MW*	20	179	10	90	80	15	110	5.9
WEIF *600 tpd*	37.3	74.6	200	400	143	22.3	130	5 x 2.15

Notes:
(i) Data for L1-L8 and GT2-GT7 are based on the Specified Process Licences issued under the Air Pollution Control Ordinance. Data for the CCGT are based on the current Best Practicable Means Notes requirements for gas turbines.
(ii) Data are cited at full load conditions for all units except for GT2 - GT7, the emission values of which are based on limits in the Specified Process Licence under normal operating conditions with a total generation output not exceeding 435 MW.
(iii) The concentration of the air pollutants emitted from L1 to L6 are expressed at dry, 0°C, 101.325 kPa and 12% CO_2 concentration conditions. The concentration of the air pollutants emitted from L7 to L8 are expressed at dry, 0°C, 101.325 kPa and 6% O_2 concentration conditions. The concentration of the air pollutants emitted from GTs and the new CCGT units are expressed at dry, 0°C, 101.325 kPa and 15% O_2 concentration conditions.
(iv) NOx concentrations are reported as NO_2.

4.4.3 *Air Sensitive Receivers*

According to the *EIAO TM*, domestic premises, hotel, hostel, hospital, clinic, nursery, temporary housing accommodation, school, educational institution, office, factory, shop, shopping centre, place of public worship, library, court of law, sports stadium or performing arts centre are classified as *Air Sensitive Receivers (ASRs).*



SCALE 1:4,000

FIGURE 4.4d

THE NEW 1,800MW GAS-FIRED POWER STATION SITE LAYOUT PLAN

USTN FILE: usr2/ermhk/c1630/fig0.dgn
DATE: 10/98

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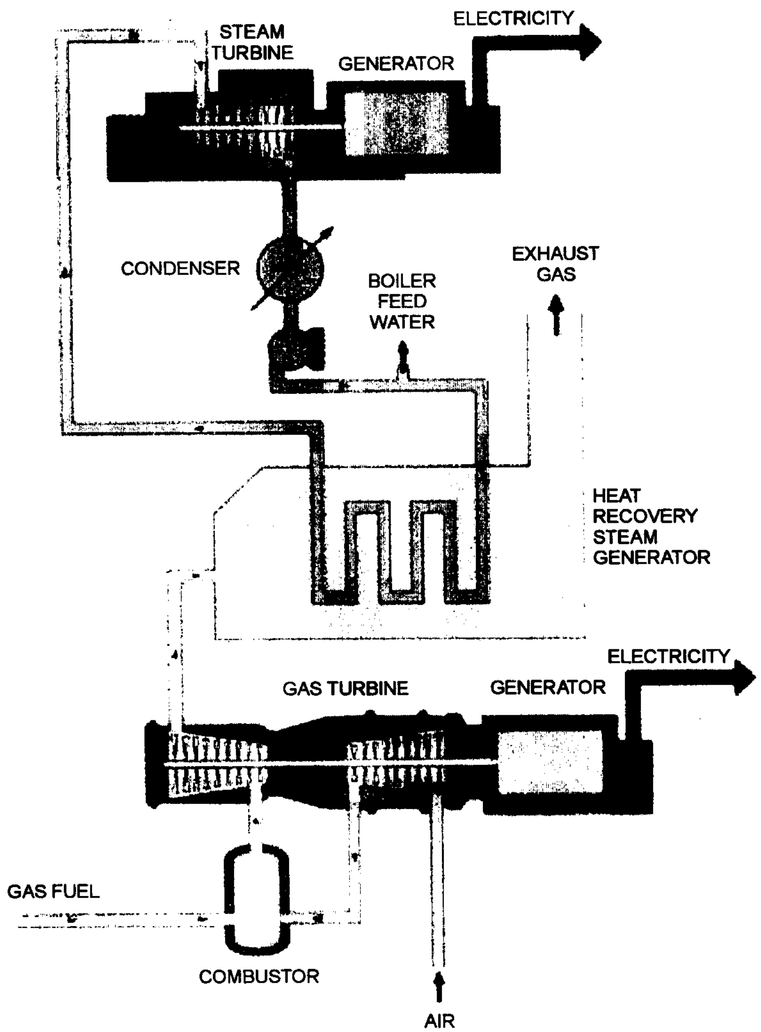


FIGURE 4.4e

A SCHEMATIC REPRESENTATION OF A COMBINED CYCLE GAS-FIRING PLANT

Environmental Resources Management

FILE: C1784/C1784t5
DATE: 21/10/98

For the purpose of identifying representative locations for wind tunnel measurements, both existing and planned *ASRs* have been considered.

Existing Air Sensitive Receivers

Existing air sensitive receivers were determined from aerial photographs. *Figure 4.4f* shows an image of the Lamma Island and part of Hong Kong Island inside the study area.

For prudence, all existing buildings were considered as ASRs, and representative locations at existing ASRs were chosen for measurement in the wind tunnel.

Planned Air Sensitive Receivers

Based on the current Outline Zoning Plans and Outline Development Plans, future ASRs have been reviewed. The most significant planned land uses include the proposed Green Island Reclamation and the Telegraph Bay Reclamation site. Both areas are delineated by a dotted line in *Figure 4.4f.*

As planning and landuse in Hong Kong Island South including Lamma Island is currently under review, so an even distribution of measurement locations in those areas is assumed in order to obtain general information for planning purposes.

4.4.4 *Study Methodology*

General

A wind tunnel creates a neutral atmospheric stability condition for simulating plume dispersion behaviour in complex terrain. The most refined model widely recognised for this particular application was employed for this study. A detailed modelling methodology is presented in *Annex B4-2* and key elements are summarised as follows.

A 1:1000 scale model of the proposed gas-fired power station and all surrounding terrain was used. The range covers a distance of 9.3 km from the centre of the site of the new power station. To accommodate the entire model inside a 4.9 m x 2.4 m boundary layer wind tunnel, the model was split into major sectors as illustrated in *Figure 4.4a*. The area within a radius of 2.3 km was constructed on a circular disk. Extensions stretching up to an additional 7 km beyond the circular disk were provided for measurements at Hong Kong Island, Cheung Chau and the outer parts of Lamma Island.

Representative measurement locations were based on existing ASR locations and consideration of possible future ASRs. Measurements were carried out at each location shown in *Figure 4.4g* at five full scale wind speeds i.e. 2.7 m s^{-1}, 6 m s^{-1}, 9 m s^{-1}, 12 m s^{-1} to 15 m s^{-1}. During the measurements, the model was rotated at 5 degree intervals through the various sectors to cover the entire study area. Carbon monoxide (CO) was used as the tracer gas. Gas sampled at receptors was analysed by infrared analysers stationed outside the tunnel.

Physical Scaling

In order to accurately simulate the exhaust plume from each source, detailed scaling of the full scale exhaust parameters and approaching wind was performed. A combination of both momentum and buoyant scaling was implemented for each of the modelled exhausts. The aim is to provide an optimal combination of exaggerated momentum term and underestimated buoyancy term, so that the non-dimensional plume rise is matched reasonably well over the distances and wind speeds of interest.

Modelling Approach

A two phase approach was used. Phase 1 involves flow visualisation and interactive tracer gas testing. Smoke was added to the atmospheric emissions from the proposed stacks in order to identify the areas of concern. The flow visualisation tests involved the emission of smoke at a scaled flow rate from the different exhaust sources for numerous combinations of wind directions and wind speeds.

Phase 2 consists of detailed tracer gas measurement with all sources in operation. The overall contribution from all sources was determined at all receptor locations for each scenario. Wind speeds remained constant during the tests for each wind speed while wind directions were tested in 5 degree increments.

Meteorological Data

Data for hourly wind speed and wind direction for an entire year were used for the analysis of the frequency of occurrence of meteorological conditions and for the prediction of maximum hourly concentrations at surrounding receptors.

Modelling Scenarios

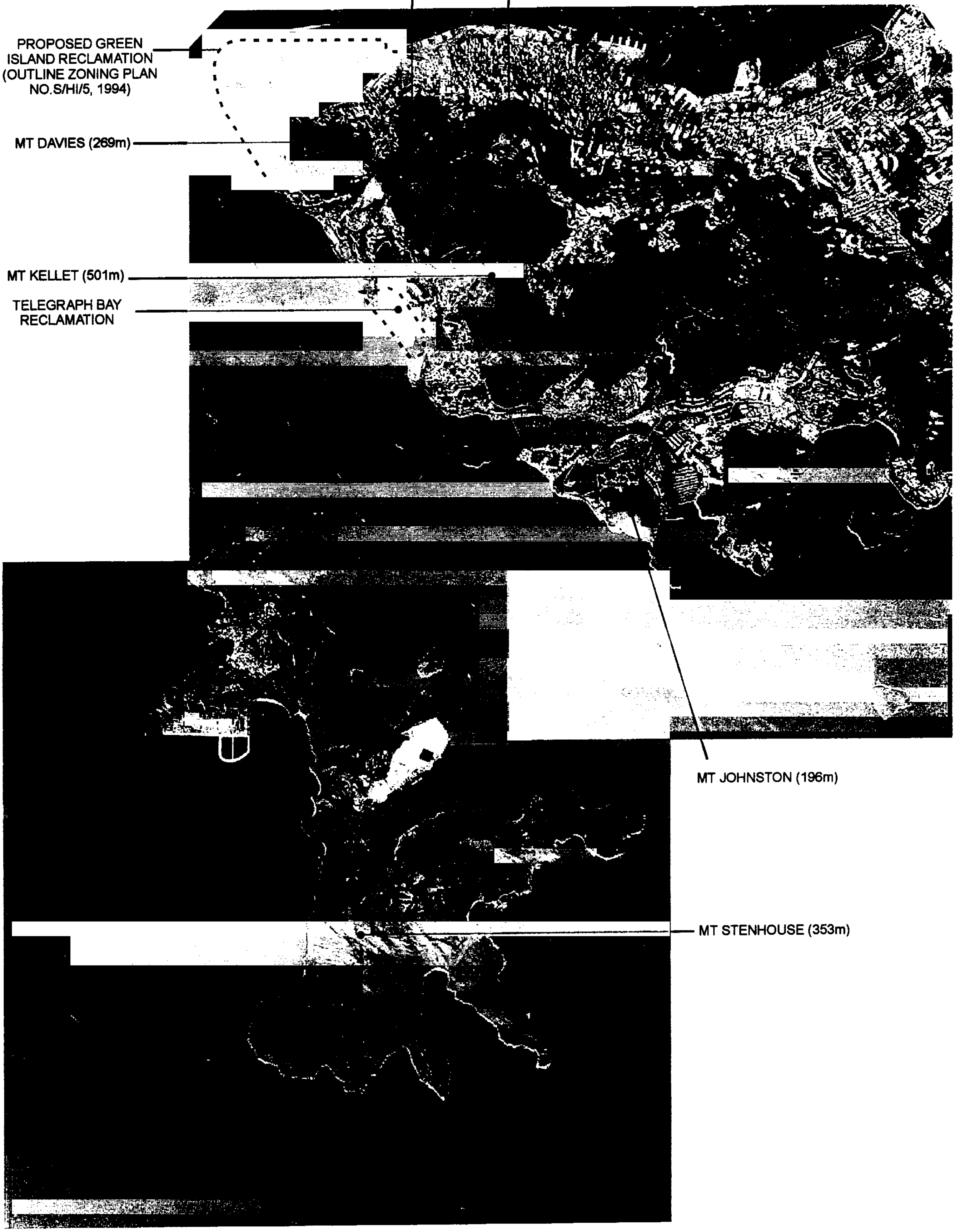
The following 3 scenarios were studied:

Scenario 1: Baseline scenario with existing Lamma Power Station fully operating in 2002 (i.e. before the first new CCGT unit begins operation in 2003).

Scenario 2: 1,800MWGas-fired power station will operate as base load units and the balance of 2,116MW will be delivered from the existing coal-fired units with the most efficient units (Units 4-8) operate first in 2012.

Scenario 3: Gas-fired power station fully operating with existing Lamma Power Station and *WEIF* in 2012.

The forecast HEC system loads for years 2002 and 2012 are 2,794 MW (*Scenario 1*) and 3,916 MW (*Scenarios 2 & 3*) respectively. Although the system load for year 2012 is higher than in 2002, the use of gas-fired units for base load operation and the use of more efficient units from the existing Lamma Power Station result in a reduction of the overall emission from HEC.



AS AT 16.1.97 ORIGINAL TAKEN FROM 20,000 FEET

FIGURE 4.4f

EXISTING TOPOGRAPHY & PLANNED LAND USE

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FILE: C1784/c1784d

DATE: 13/10/98

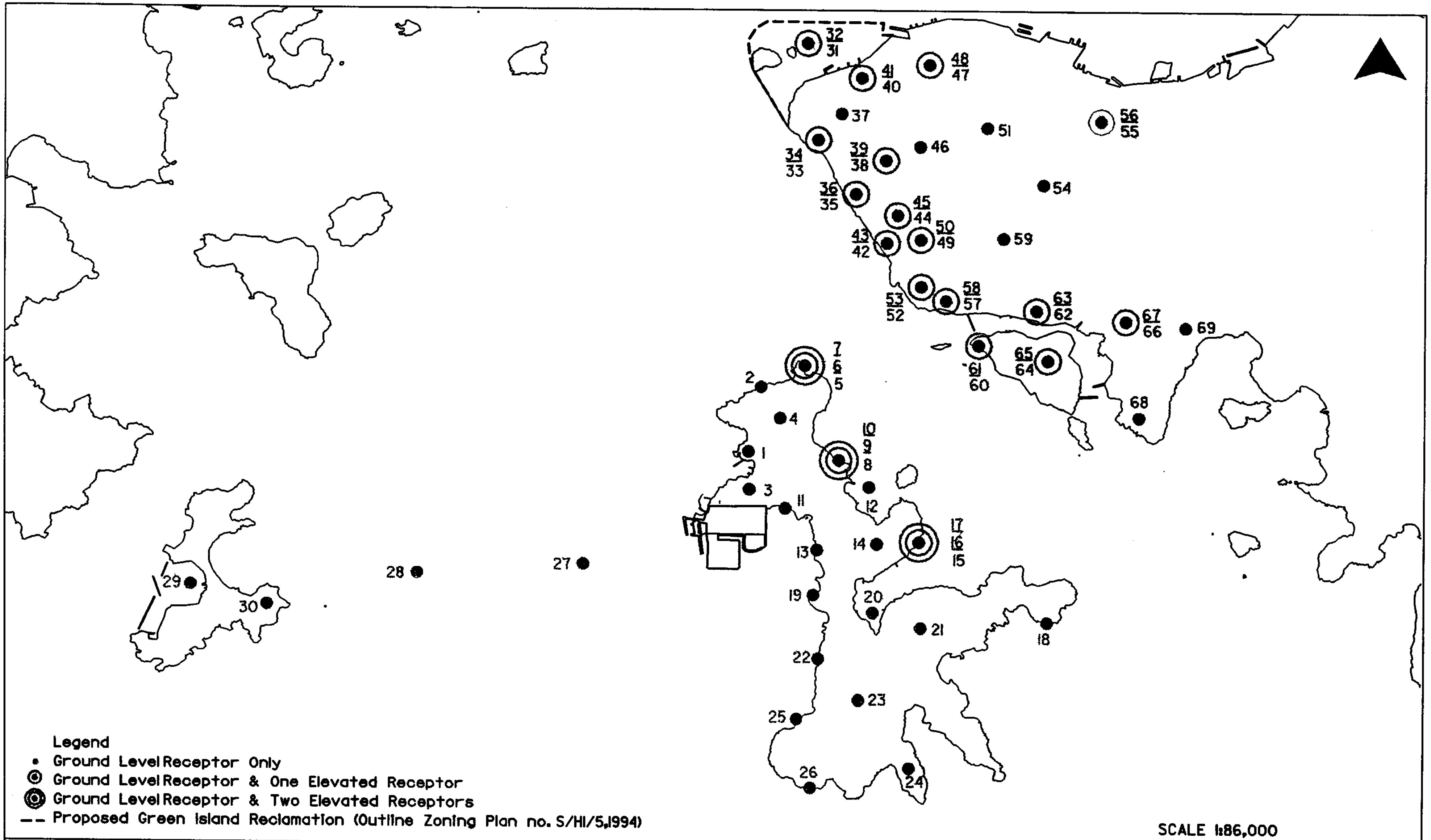

FIGURE 4.4g

WIND TUNNEL MEASUREMENT LOCATIONS

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USTN FILE: ermhk/c1784/st3.dgn
DATE: 27/07/98

Consideration of Background Air Quality

A complete analysis of the air quality impacts requires information regarding the background air quality. Predicted SO_2 and NO_2 levels determined in the wind tunnel will be corrected to include the background concentrations identified in *Section 4.3.2.*

Model Predictions for Nitrogen Dioxide

Nitrogen oxides (NO_x) emitted in the flue gas of a power station consist of approximately 95% of nitrogen monoxide (NO); however, NO is rapidly oxidised to nitrogen dioxide (NO_2) by ozone (O_3). The NO oxidation rate in the atmosphere depends on the interaction of chemical kinetics and the conversion can be estimated based on the Janssen equation using distance from the source, wind speed and O_3 concentration.

Emergency Operation using Light Gas Oil

In the unlikely event of an interruption in gas supply, the gas-fired combined cycle units can operate on light gas oil (0.5% S). A seven-day supply will be available on site. A high level availability analysis was carried out to assess the likelihood of occurrence of such an event, based on preliminary engineering data. *Annex B4-5* gives an account on the assessment of gas supply to Lamma Extension.

4.4.5 *Predicted Air Quality Impacts*

Overview

Results of the model predictions are presented in detail in *Annex B4-2* and summarised below. The receptor reference is provided in *Figure 4.4g* and described in detail in *Annex B4-2.*

Qualitative Assessment

Figure 4.4h shows the physical model in the wind tunnel. Views of the new power station from the highest receptors on Lamma Island, Hong Kong Island and Cheung Chau are shown in *Figures 4.4i, 4.4j* and *4.4k* respectively.

Flow visualisation smoke tests generally indicated that the biggest impacts would occur under high wind speeds (around 12 to 15 $m\ s^{-1}$), as shown in *Figures 4.4l* and *4.4m.* The tests also suggested that impacts would be greatest on or near Lamma Island when compared to Hong Kong Island or Cheung Chau. It was noted that the plumes from the taller stacks (L1 to L8) tend to overshoot the local terrain on Lamma Island. However, the plumes emitted from the shorter gas turbine stacks (L9 to L14) were observed to directly impinge on the hilly terrain of Lamma Island and should therefore produce greater impacts on and near Lamma Island than on Hong Kong Island. It was also observed that wake effects caused by the hilly terrain on Lamma Island had the potential to influence plumes emitted from the shorter stacks, thereby causing the most significant impacts in the immediate vicinity of the facility.

Stack Height Optimization

Based on the results of the flow visualisation experiments, quantitative tracer gas measurements were made for all 5 wind speeds at receptors 1 to 26 on Lamma Island only. *Table 4.4b* presents the worst-case measured SO_2 and NO_2 levels for each stack height tested. It was noted that the worst case concentrations occurred consistently for all 3 stack heights at 15 m s^{-1} when the wind direction was from 200°. Data obtained for the gas-fired CCGTs are shown in *Table 4.4b*.

Table 4.4b ***Worst-Case Air Quality Impacts due to New Stacks of CCGT Units***

Source	Stack Height (mPD)	SO_2 ($\mu g\ m^{-3}$)	NO_2 ($\mu g\ m^{-3}$)
6x300 MW CCGT	90	28	51
6x300 MW CCGT	110	19	35
6x300 MW CCGT	130	16	29

For stack height determination, the "worst case" scenario of emergency oil firing was used. The data suggest that a significant reduction in predicted impacts can be achieved with the 110 mPD stack when compared to the 90 mPD stack. Likewise, predicted impacts were further reduced by extending the stack height to 130 mPD, however a much smaller benefit was observed. As can be seen in *Figure 4.4p*, an exceedance of the one-hour objective concentration of 800 $\mu g\ m^{-3}$ for SO_2 was predicted with the 90 mPD stack height for the oil-firing (0.5% S) scenario under emergency situation. Based on this analysis, the 110 mPD stack height was recommended as the optimum stack height for the new gas-fired power station. Overall air quality impacts due to the combined operation of other sources will be tested in the quantitative tracer gas measurements.

Combined Air Quality Impacts in Years 2002 and 2012

Tables 4.4c and *4.4d* summarise the maximum hourly, daily and annual average concentrations predicted at each receptor for SO_2 and NO_2 respectively. Background concentrations have been included in the presented pollutant concentrations to show cumulative impacts for all 3 operating scenarios. Oxidation of NO to NO_2 in the atmosphere has been incorporated in the assessment using Janssen's oxidation rate[(1)]. Detailed discussions of the model results and other information such as the meteorological conditions associated with each maximum predicted level and contributions from individual sources are available in *Annex B4-2*.

In summary, it can be concluded that no potential breach of the AQO would result from the peak load operations of the new power station in year 2012. Significant improvements in the ambient air quality would result from the commencement of operations of the new gas-fired power station compared with base case in year 2002. Long-term impacts as measured by the annual averages at each receptor are close to zero, which confirms the observations made in the baseline air quality review (*Section 4.3)* that no observed impacts at the ambient air quality monitoring stations were revealed by the monthly variations of recorded SO_2 and NO_2 levels. Generally, the predicted SO_2 and NO_2 concentrations are within the AQOs for all modelled receptors.

Table 4.4c ***Maximum Predicted Cumulative SO_2 Concentrations ($\mu g\ m^{-3}$)***

Receptor	Scenario 1			Scenario 2			Scenario 3		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
1	187	35	11	29	12	10	57	18	10
2	151	39	11	34	13	10	66	21	10
3	84	20	10	32	12	10	41	15	10
4	267	42	12	45	18	11	69	24	11
5	208	32	11	47	15	10	86	26	11

(1) A Classification of NO Oxidation Rates in Power Plant Plumes based on Atmospheric Conditions, L. H. J. M. Janssen *et al*, Atmospheric Environment, Vol. 22, No. 1, 1988.

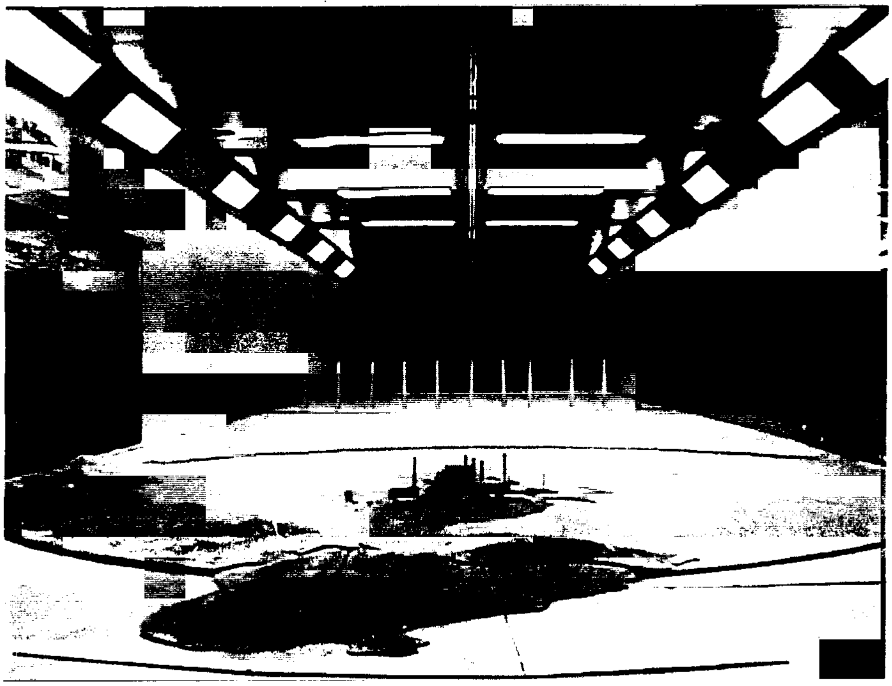

FIGURE 4.4h - APPROACH FLOW CONDITIONS IN WIND TUNNEL

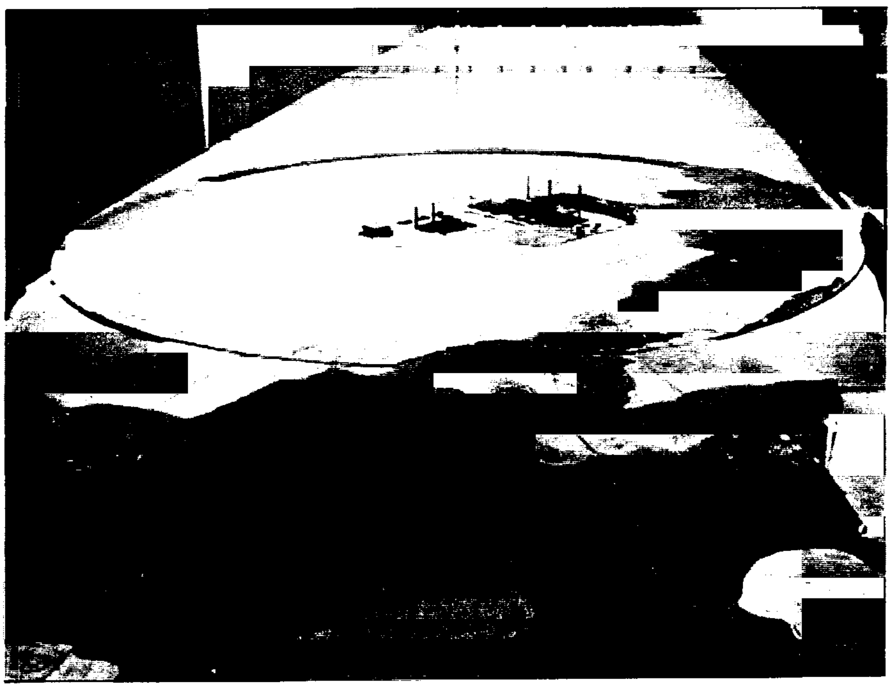

FIGURE 4.4i - A VIEW FROM MT. STENHOUSE, LAMMA ISLAND

FIGURES 4.4h & 4.4i

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DATE: 08/10/98

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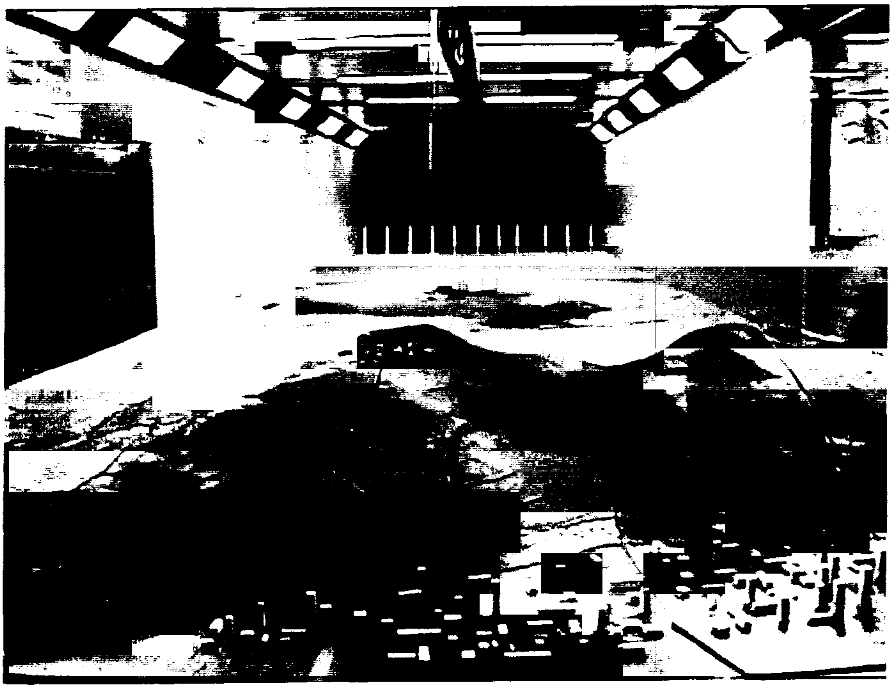

FIGURE 4.4j - A VIEW FROM THE VICTORIA PEAK, HONG KONG ISLAND

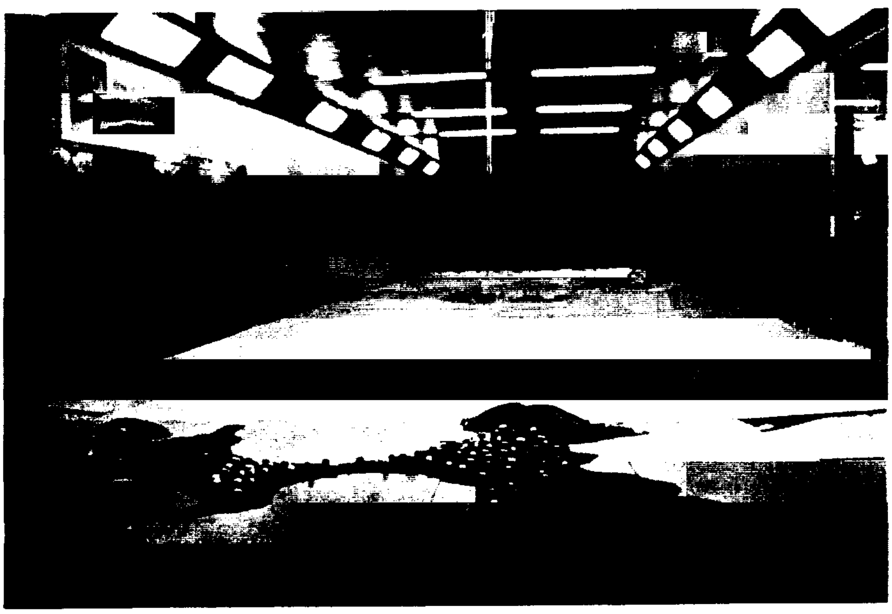

FIGURE 4.4k - A VIEW FROM CHEUNG CHAU

FIGURES 4.4j & 4.4k

FILE: C1784/C1784c2
DATE: 08/10/98

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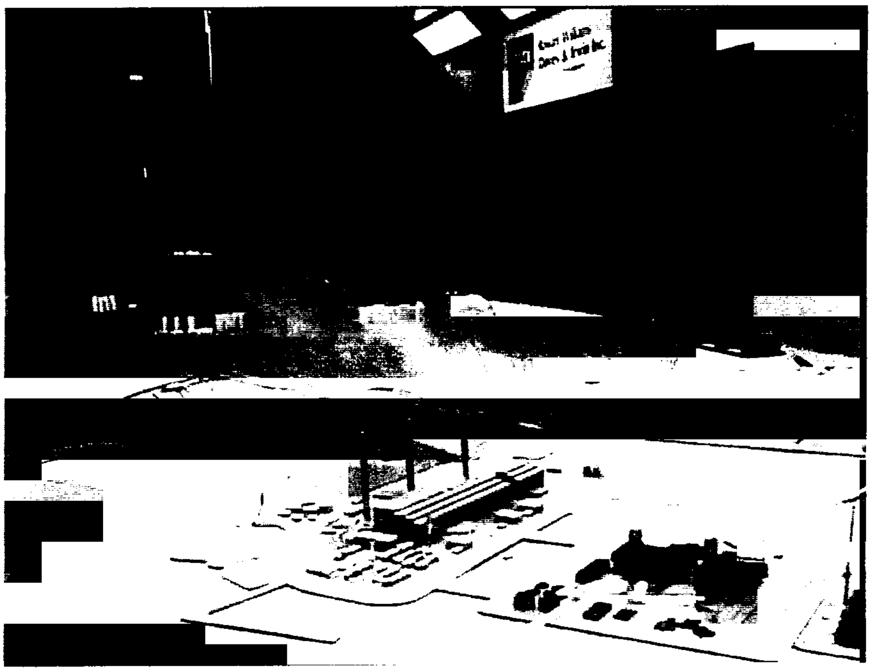

FIGURE 4.4l - FLOW VISUALIZATION OF EMISSIONS FROM NEW STACK
(HIGH WIND SPEED CONDITIONS, APPROX 15m/s)

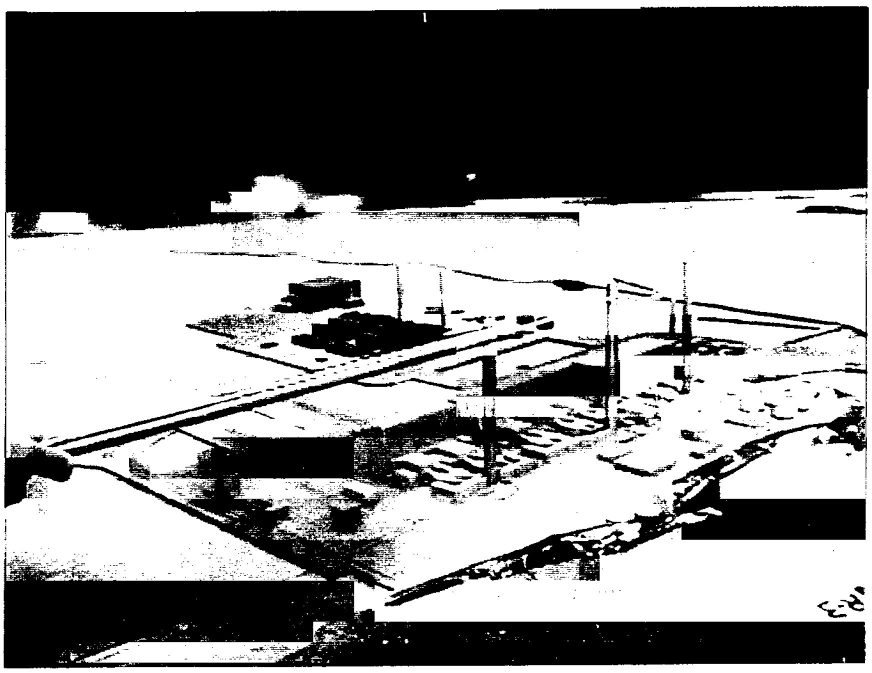

FIGURE 4.4m - FLOW VISUALIZATION OF EMISSIONS FROM EXISTING STACK
(HIGH WIND SPEED CONDITIONS, APPROX 15m/s)

FIGURES 4.4l & 4.4m

FILE: C1784/C1784c3
DATE: 08/10/98

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FIGURE 4.4n - TRUE SIZE OF PHYSICAL MODEL

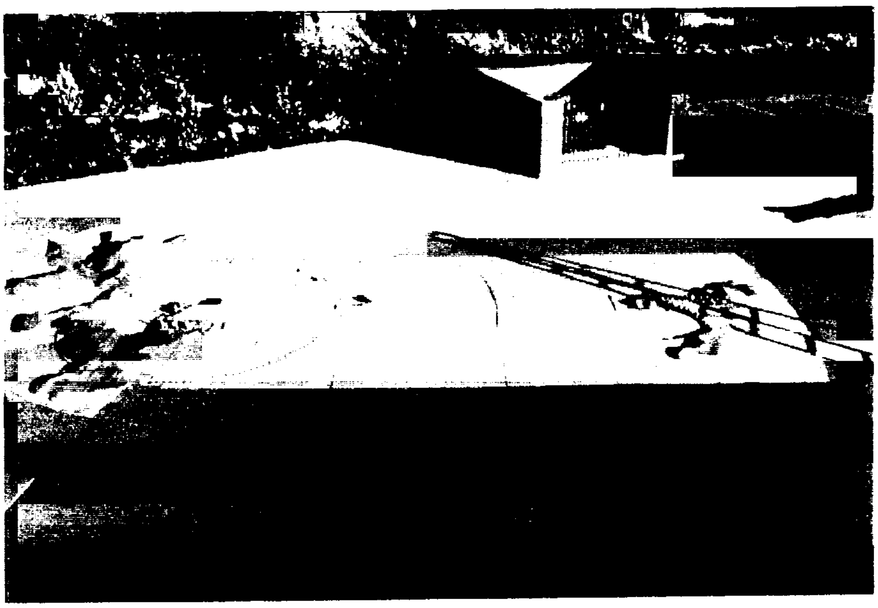

FIGURE 4.4o - TRUE SIZE OF PHYSICAL MODEL EXCEPT HONG KONG ISLAND

FIGURES 4.4n & 4.4o

FILE: C1784/C1784c4
DATE: 08/10/98

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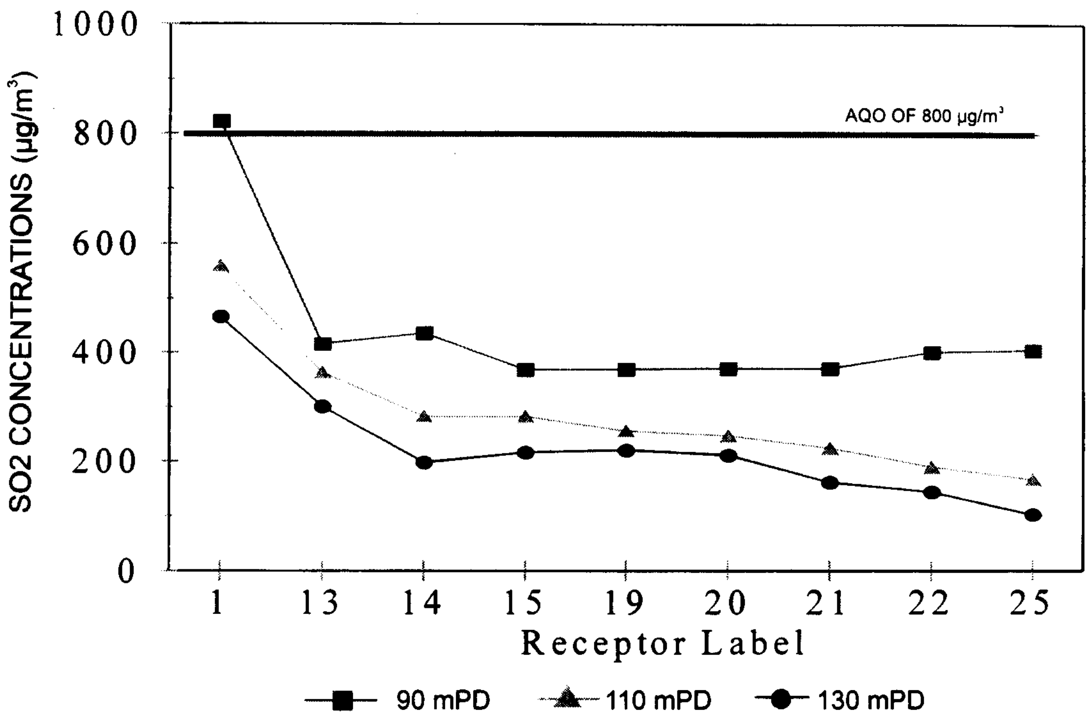

NOTE:

SENSITIVITY TEST OF STACK HEIGHT AT WORST CASE METEOROLOGICAL CONDITIONS FOR EMERGENCY OIL-FIRING OPERATION. TYPICAL SO2 CONCENTRATIONS DUE TO NORMAL GAS-FIRING OPERATION ARE 3.5% OF THE EMERGENCY SITUATION.

FIGURE 4.4p

S02 CONCENTRATIONS AS A FUNCTION OF STACK HEIGHT
(EMERGENCY OIL-FIRING SCENARIO)

FILE: C1830/C1830_21
DATE: 11/12/98

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Receptor	Scenario 1			Scenario 2			Scenario 3		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
6	225	35	11	63	16	10	94	26	10
7	386	57	11	153	24	10	158	32	11
8	217	41	11	39	14	10	69	15	10
9	250	46	11	52	13	10	76	15	10
10	470	70	12	149	20	10	149	20	10
11	120	34	11	46	16	10	46	16	10
12	138	23	10	33	13	10	57	15	10
13	58	17	10	31	11	10	31	12	10
14	79	16	10	28	11	10	42	12	10
15	124	25	10	55	16	10	61	18	10
16	131	21	10	52	13	10	74	17	10
17	177	24	10	76	14	10	105	23	10
18	147	22	10	84	15	10	176	33	11
19	84	19	10	36	12	10	318	47	11
20	118	28	10	38	12	10	263	49	11
21	167	38	10	76	19	10	202	37	11
22	158	19	10	123	16	10	123	17	10
23	256	34	10	195	23	10	195	25	10
24	488	51	10	239	31	10	239	31	10
25	288	28	10	235	26	10	235	26	10
26	332	56	11	220	37	11	220	37	11
27	311	45	12	54	16	10	67	26	11
28	446	92	18	208	43	13	209	50	14
29	732	169	26	461	90	17	461	95	18
30	397	54	13	224	31	11	225	38	12
31 *	197	53	21	152	39	20	154	39	20
32 *	207	55	21	164	40	21	169	41	21
33	136	37	11	75	20	10	88	26	11
34	178	47	12	101	25	11	117	32	11
35	334	59	12	204	30	11	232	37	11
36	395	70	12	244	35	11	268	42	11
37	207	63	12	134	33	11	141	39	11
38	271	40	11	127	21	11	127	24	11
39	209	48	11	144	25	11	169	31	11
40 *	308	83	23	218	51	21	244	59	22
41 *	163	51	22	112	34	21	126	39	21
42	380	60	12	217	29	11	252	35	11
43	281	44	11	166	24	11	196	30	11
44	164	36	11	98	18	10	126	23	11
45	298	56	12	182	28	11	218	34	11
46	369	53	12	222	28	11	239	31	11
47 *	228	64	22	145	39	21	164	46	21
48 *	204	53	21	128	34	21	144	38	21
49	158	35	11	66	17	10	108	27	11
50	258	54	12	138	27	11	189	37	11
51	318	58	11	202	31	11	212	35	11
52	213	46	11	108	25	10	126	31	11
53	281	57	11	144	32	11	159	38	11
54	631	102	13	411	68	12	425	77	12
55 *	208	57	21	141	42	21	175	49	21
56 *	258	71	22	179	51	21	209	58	21
57	267	52	11	141	30	11	159	36	11
58	284	56	11	166	34	11	185	41	11

Receptor	Scenario 1			Scenario 2			Scenario 3		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
59	304	56	11	181	35	11	206	44	11
60	324	42	11	145	22	10	150	23	11
61	403	45	12	233	27	11	237	28	11
62	310	42	11	163	24	11	164	25	11
63	261	34	11	124	19	10	124	20	11
64	456	50	12	226	25	11	226	27	11
65	413	47	12	195	24	11	195	26	11
66	442	51	12	261	30	11	261	33	11
67	369	41	11	212	25	11	212	26	11
68	223	27	11	91	17	10	109	35	11
69	511	82	12	304	50	11	308	51	11

Note:* denotes urban areas, otherwise landuse is considered to be rural/new development.
For rural/new development area, background SO_2 levels for hourly, daily, annual averages are 23 $\mu g/m^3$, 10 $\mu g/m^3$ and 10 $\mu g/m^3$ respectively. Such levels have been included in the above table.
For urban area, background SO_2 levels for hourly, daily, annual averages are 33 $\mu g/m^3$, 20 $\mu g/m^3$ and 20 $\mu g/m^3$ respectively. Such levels have been included in the above table.

Table 4.4d ***Maximum Predicted Cumulative NO_2 Concentrations ($\mu g\ m^{-3}$)***

Receptor	Scenario 1			Scenario 2			Scenario 3		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
1	60	30	28	55	30	28	60	31	28
2	62	31	28	61	31	28	72	34	28
3	52	28	28	55	29	28	55	30	28
4	71	31	28	65	33	28	71	32	28
5	72	31	28	67	33	28	83	37	28
6	74	32	28	70	33	28	83	37	28
7	95	35	28	81	35	28	94	39	28
8	67	31	28	54	29	28	66	29	28
9	71	32	28	55	29	28	68	29	28
10	93	34	28	64	29	28	76	31	28
11	54	29	28	50	28	28	51	28	28
12	60	30	28	57	30	28	65	30	28
13	51	29	28	51	28	28	51	29	28
14	54	29	28	56	29	28	57	29	28
15	62	30	28	60	30	28	67	31	28
16	63	30	28	61	29	28	70	31	28
17	69	30	28	66	30	28	83	33	28
18	75	31	28	64	29	28	135	40	28
19	53	29	28	50	28	28	109	36	28
20	58	30	28	54	29	28	122	40	28
21	68	32	28	58	29	28	120	39	28
22	67	29	28	63	29	28	63	29	28
23	94	32	28	83	31	28	83	31	28
24	150	37	28	103	33	28	103	34	28
25	82	31	28	76	31	28	85	31	28
26	100	37	28	85	33	28	85	35	28
27	72	31	28	59	31	28	61	32	29
28	125	43	29	87	41	29	88	44	29
29	248	75	34	184	56	32	184	62	32
30	148	40	30	107	37	30	109	42	30
31 *	130	61	51	120	59	51	122	61	51
32 *	132	62	51	124	59	51	128	61	51
33	76	35	28	69	33	28	82	38	28

Receptor	Scenario 1			Scenario 2			Scenario 3		
	Hourly	Daily	Annual	Hourly	Daily	Annual	Hourly	Daily	Annual
34	86	36	28	76	35	28	86	40	28
35	120	39	28	114	39	28	133	42	28
36	134	42	28	123	40	28	137	43	28
37	95	42	28	84	37	28	93	42	28
38	108	36	28	78	31	28	81	35	28
39	94	38	28	91	35	28	108	38	28
40 *	157	69	51	141	64	51	159	71	53
41 *	115	60	51	108	57	51	119	60	51
42	124	38	28	110	35	28	130	40	28
43	104	35	28	97	35	28	114	38	28
44	80	30	28	77	33	28	94	36	28
45	111	39	28	100	36	28	123	39	28
46	138	40	28	118	37	28	129	38	28
47 *	136	64	51	124	61	51	140	66	51
48 *	128	61	51	118	59	51	132	63	51
49	77	32	28	71	32	28	100	37	28
50	100	37	28	94	35	28	124	43	28
51	130	43	28	112	37	28	119	41	28
52	87	35	28	84	36	28	92	39	28
53	101	38	28	92	38	28	101	40	28
54	214	53	28	169	46	28	180	53	28
55 *	132	63	51	122	59	51	150	67	51
56 *	146	67	51	134	63	51	164	73	51
57	98	36	28	83	34	28	95	39	28
58	102	38	28	90	35	28	101	39	28
59	117	40	28	95	36	28	117	41	28
60	110	35	28	82	32	28	84	32	31
61	127	36	28	102	34	28	104	34	28
62	116	36	28	90	33	28	90	34	28
63	104	34	28	80	31	28	80	34	28
64	143	37	28	99	33	28	99	34	28
65	134	36	28	93	33	28	93	34	28
66	158	39	28	118	35	28	118	37	28
67	139	37	28	104	33	28	101	33	28
68	96	31	28	73	33	28	110	46	28
69	184	49	28	137	41	28	139	43	28

Note:* denotes urban areas, otherwise landuse is considered to be rural/new development.
For rural/new development area, background NO_2 levels for hourly, daily, annual averages are 49 $\mu g/m^3$, 28 $\mu g/m^3$ and 28 $\mu g/m^3$ respectively. Such levels have been included in the above table.
For urban area, background NO_2 levels for hourly, daily, annual averages are 80 $\mu g/m^3$, 51 $\mu g/m^3$ and 51 $\mu g/m^3$ respectively. Such levels have been included in the above table.

4.4.6 *Evaluation of Impacts*

The wind tunnel model results concluded that there were no potential breaches of the AQOs modelled for all three scenarios, even when estimates of typical background air quality were included . This conclusion is applicable to conditions in the wind tunnel which resemble the neutral atmospheric stability conditions, commonly known as Stability Classes C and D according to the Pasquill-Gifford Classification Scheme. It has been widely accepted that such atmospheric conditions are most representative for modelling worst case impacts during the full load operating conditions of the power station. However, at the request of the EPD, this premise was reviewed with a five-year data set obtained from the Hong Kong Observatory for the period from 1993 to 1997.

Based on the surface observations at Cheung Chau and the upper air measurements at King's Park, it was found that the occurrence of stable conditions is so insignificant as not to warrant a detailed air quality assessment. Only 24 morning or evening stable cases were identified with southwest winds over the 5 year period. Of these, only a small number would be expected to coincide with the high load power plant conditions. It was estimated that the total number of hours with high load coinciding with southwesterly winds and stable conditions may be as low as three hours over 5 years. Full details of the meteorological data analysis are presented in *Annex B4-3* for reference.

Notwithstanding the fact that occurrences of stable conditions are considered to be rare during conditions of high power station loads, a supplementary 5 year episodes analysis was undertaken to address air quality impacts during periods of stable or unstable atmospheric conditions to confirm the wind tunnel results are representative of the worst case impacts. Details of the *5 Year Episodes Analysis* are presented in *Annex B4-4* for reference.

Concerning the emergency oil firing scenario using 0.5 % S fuel, a high level availability analysis indicated that based on preliminary engineering details, the availability of gas supply is 99.65%. It should be noted that the remaining 0.35% does not necessarily mean that there is an average outage of approximately 1.3 days per year. A simple analysis using the ratio of emissions from oil and gas-fired scenarios per stack groups in *Tables 12* and *13* of *Annex B4-2* shows that, even in the unlikely event of emergency oil firing, the relevant AQOs should not be exceeded. Details of the availability analysis of gas supply are presented in *Annex B4-5*.

Table 4.4e shows the estimated electricity consumption and the annual emissions of SO_2 and NO_x in years 2002 and 2012. Due to the shifting of base load from the existing coal-fired units to the new gas-fired combined cycle units, the impacts to local Hong Kong air quality from HEC sources will be much reduced following the full commissioning of the Lamma Extension despite the total electricity generation in 2012 is higher than that in 2002.

Table 4.4e ***Estimated Emissions of SO_2 and NO_x in Future Years***

	2002	2012	% Change
GWh	13,351	19,142	+43%
SO_2 (Tonne/Yr)	47,687	18,426	-61%
NO_x (Tonne/Yr)	41,068	24,669	-40%

4.4.7 *Conclusions*

This wind tunnel modelling study concluded that:

- a stack height of 110 mPD is adequate for the gas-fired combined cycle units proposed for the new power station, as confirmed by detailed tracer gas measurements at key locations identified in the flow visualisation study;

- the net and cumulative impacts of the operation of the new 1,800 MW power station with the existing Lamma Power Station in 2012 will not result in any predicted exceedances of the relevant AQOs for SO_2 and NO_2 at identified receptors in the near-field of the power station;
- the operation of the *WEIF* will not cause any constraints to the proposed development of the 1,800 MW new power station and vice versa;

- an improvement in air quality is predicted in year 2012 compared to year 2002 due to the shifting of power station loads from the coal-fired units to the gas-fired units, despite an overall increase in electricity output from 2,794 MW to 3,916 MW; and

- in the unlikely situation of emergency oil firing, the estimated air quality impacts are still predicted to be within the relevant AQOs.

4.5 *PATH MODELLING*

4.5.1 *Introduction*

Emissions from the proposed CCGT units, and indeed the other power plant units operated by HEC on Lamma Island, may have impacts on receptors in the Hong Kong SAR when the southwesterly wind brings the pollutants from the power station towards the receptors. The Study Brief requires air quality impacts to sensitive receivers in the following geographical areas of the SAR to be assessed:

- Victoria Peak;
- the urban centres of Hong Kong and Kowloon;
- Lamma Island; and
- Hong Kong Island South.

A number of these locations are outside the near-field domain addressed in the wind tunnel studies. In order to complete the assessment, the PATH Modelling System has been applied to generate predictions for air quality in the mid-field (ie within the SAR). PATH is a mesoscale model and hence is well-suited to applications of this nature and furthermore has been set up specifically for Hong Kong.

4.5.2 *The PATH Modelling System*

The modelling system incorporates the following components:

- a multi-scale, non-hydrostatic numerical meteorological model (MM5);

- a multi-scale, multi-species air quality model (SAQM);

- a state-of-the-art emission modelling system (EMS-95) coupled to a two-tiered comprehensive emissions inventory for Hong Kong and, at lower resolution, for southern China;

- a relational database and pre-processor system for storing and managing data and generating databases for model operation and validation;

- a post-processing module for analysis, interpretation and display of model outputs, including visualisation capabilities; and

- an intelligent, user-friendly interface with an on-line help system, which makes extensive use of Graphical User Interface (GUI) and GIS technology.

Modelling Grids

Both the meteorological and air quality models employ the same five-level hierarchy of nested grids and the emissions model is set up to compute appropriate emissions for every cell of each grid. The use of grid-nesting enables higher resolution simulations to be embedded in the larger-scale flows generated by the model run with the coarse resolution. The horizontal resolutions are 40.5, 13.5, 4.5, 1.5, and 0.5 km. The largest grid (40.5 km) extends over a wide area of South-East Asia and the 1.5 km grid covers the whole SAR. The smallest 0.5 km domain covers Hong Kong Island, Kowloon and parts of the New Territories. It should be noted that the 0.5 km grid was not used for this application. All modelling domains have the same vertical structure with 26 unequally spaced levels ranging from 10 m to 20,870 m above the ground.

Emissions Model

The emissions modelling system used in PATH is the Emissions Modelling System version 1995 (EMS-95). EMS-95 is a publicly available, state-of-science modelling system which is maintained and distributed by Alpine Geophysics. EMS-95 has gained a growing acceptance and an installed base including the Lake Michigan Air Directors Consortium, the California Air Resources Board Technical Support Division, United States Environmental Protection Agency (US EPA) Atmospheric Research and Exposure Assessment Laboratory, the Texas Natural Resource Conservation Commission (TNRCC), the Michigan Department of Natural Resources and the Carnegie Mellon University. EMS-95 has been adopted for the MODELS 3 air quality modelling system, which is being developed by USEPA and, most importantly, is currently being used in connection with MM5 and SAQM in the Southern California Air Quality Study (SCAQS-97).

The emission modelling system is coupled in PATH with a two-tiered, comprehensive emissions inventory, dealing with all of the key primary pollutants. Depending on the modelling grid in use, emissions can be determined for a region of southern China at resolutions of 13.5 or 4.5 km and for Hong Kong, at resolutions of 1.5 or 0.5 km. The former allow the air quality model to predict regional background concentrations of both primary and secondary pollutants. The latter are used for the prediction of territory-wide and urban-scale air quality.

Meteorological Model

A state-of-the-art, multi-scale, non-hydrostatic numerical meteorological model (MM5) has been selected for the PATH system. A *two-way* nesting mode is used for all nested grids, except between the 40.5 and 13.5 km grids where one-way nesting is employed. The initial conditions for the largest grid are derived from analyses of European Centre for Medium Range Weather Forecasts (ECMWF). The necessary geophysical data for all model domains have been assembled and included in the system data base. The meteorological fields predicted by MM5 form one of the primary inputs to the air quality model.

Air Quality Model

A multi-scale, multi-species air quality model (SAQM) has been incorporated in PATH for running air quality simulations at regional, SAR-wide and urban scales. The intention of the regional-scale modelling is to provide estimates of the background concentrations of photochemical smog species and smog precursors, and sulphate and nitrate aerosols arising from emissions in mainland China. This methodology has been selected in preference to explicitly prescribing boundary conditions for the model because the latter is likely to be based on a small number of measurements for a limited set of meteorological conditions and hence, likely to lack reliability. The intention of the local-scale modelling is to provide air quality predictions for Hong Kong. Thus, the model is able to consider both the transport and production of photochemical smog within a regional background generated from emissions within southern China, and the urban build-up of primary and secondary air pollutants within the SAR.

4.5.3 *Methodology and Assumptions*

Introduction

Underlying the approach to the assessment is the principal objective of identifying the *incremental* impact on air quality attributable to the operation of the new CCGT units at Lamma Island. In addition to the assessment of the incremental effects, the evaluation will also provide an indication of the cumulative impacts. In order to make this evaluation, the PATH model has been used to assess impacts with and without the emissions from the proposed facilities. The outputs from the model are a true cumulative assessment of emissions from the existing and proposed units at Lamma, the proposed Waste-to-energy Incineration Facilities (WEIF), motor vehicles, area sources, industrial facilities, and marine vessels etc.

Methodology

Two basic emissions scenarios were developed for the year 2012, as follows:

- *Scenario A*: all emissions excluding the emissions from the new CCGT units at Lamma;
- *Scenario B*: all emissions including the emissions from the new CCGT units at Lamma.

The year 2012 was chosen for the assessment as it represents the first year in which all six of the proposed 300 MW CCGT units will be in operation.

For each scenario, a total of six model runs were made using PATH. Each run generated an hour-by-hour prediction of air quality for the whole of the Special Administrative Region (SAR).

One of the key concerns addressed in the assessment, was the potential for impacts due to the CCGT units when the prevailing winds are in a south westerly direction. Under these conditions any plume emitted from the proposed facility would be directed towards Hong Kong Island and the Kowloon urban area. A meteorology simulation for such conditions has already been developed for PATH and is described as a Category E day. The Category E day is one in which stable conditions happened to prevail and is analogous to the Type 5 day described in Haywood (1953). This simulation is considered as the most representative day for assessing impact from the proposed new power plant. Further details of the Category E day are to be found in Working Paper B1 of the Territory-wide Air Quality Modelling System Study.

In addition to the Category E day, five additional days have been simulated and together they characterise the majority of the meteorological conditions that prevail in Hong Kong over the course of a year. By combining the results of these simulations using a weighted average approach, the annual average ground level concentrations of the pollutants may be estimated. The following formula was used for the calculation of annual averages:

$$C_{ann} = \frac{\Sigma w_i c_i}{\Sigma w_i}$$

Where c_i denotes the 24 hr average concentrations computed from model results for a typical day belonging to a meteorological category i, and w_i are the weighting factors reflecting the frequency with which the category i prevails over Hong Kong. More details on the meteorological categories and days selected are provided in *Table 4.5d*. Weighting factors assumed in the evaluation are listed in *Annex B4-6*.

Assumptions

As the PATH emissions inventory reflects the 1995 conditions, in order to simulate air quality in future years, all of the other emissions sources in the SAR need to be adjusted to reflect factors such as vehicle and population growth and the implementation of new controls or emission standards. The following table documents the assumptions used in making these adjustments to the emissions inventory.

Table 4.5a ***Modifications to the Emissions Inventory***

Source Category	Modifications
Area sources	Area sources were scaled in accordance with land use planning scenarios based upon the Territorial Population and Employment Data Matrices, prepared by the Planning Department. The lower growth scenario (Scenario I) were employed to make the projections. This assumes an average GDP growth of 4% per annum over the period 1997 to 2016. Where a projection has not been published for a particular year, a linear extrapolation between the years on each side of the study date was employed. For example, the population forecast for 2012 will be based upon and extrapolation of the projections for 2011 and 2016. The assumed 2012 scaling factor of PATH baseline (1995) emissions is 1.27 for all types of pollutants.
Vehicles	Motor vehicle emissions were scaled in accordance with the interim projections arising from the CTS III study. Data for the CTS III Main Model runs were used as the basis for the evaluation. The Low Growth Scenario was assumed. Another set of data used were the EPD projections of the fleet averaged emission factors for various classes of vehicles, resulting from the imposition of the EURO-3 emission standards. As with the scaling of population estimates, since no data were available for 1995 and 2012, the estimated changes in emissions were based upon a linear extrapolation of the traffic and emission factors data from 1997 and 2011. The traffic and emission standards data were combined into two scaling factors for 2012: 0.98 for NO_x and 1.34 for hydrocarbons.
WEIF	It was assumed that a waste-to-energy incineration facility with a capacity of 2 million tonnes of MSW per annum was operating on a site adjacent to the HEC facilities for the year 2012. Emissions were assumed to be continuously at the limits of the probable license conditions.
Marine vessels	Emissions from ocean going vessels were scaled up in accordance with the projected capacity of the container terminals operating in the SAR. Scaling factors of 1.55 have been adopted for 2012. For the other types of shipping a scaling factor of 1.27, based on the projected population growth was used. The combined effect of these modifications can be estimated as 1.44 for NO_x and 1.38 for hydrocarbons.

Emissions from HEC's facilities were based upon the emissions data presented in *Table 4.4a* of *Section 4.4*, which characterise emissions under full load conditions. The emissions profile was modified to reflect the system peak day load pattern anticipated by HEC.

4.5.4 *Results*

Worst Case Day - 2012

As described in *Section 4.5.3*, the prevailing wind direction on this day has a southwesterly component, which will tend to disperse the emissions from the HEC facilities at Lamma towards the urban areas of Hong Kong Island and Kowloon. Although the maximum cumulative and incremental concentrations predicted under these conditions may not be the highest, the proximity of these maxima to sensitive receptors is a matter of concern and was identified for further investigation.

The prevailing meteorological conditions on this day are described as follows:

"A trough parallel to the coastline lies to the northwest of Hong Kong. A day of generally southwesterly monsoonal flow, with total rainfall of 9.3 mm and 85% cloud cover. The southwesterly flow extends to at least 700 mb with speeds greater than 10 m s^{-1} above 950 mb. Stability is strong throughout from the surface to 700 mb."

The following table presents the maximum one hour ground level concentrations of nitrogen dioxide, sulphur dioxide and ozone for Scenarios A and B. The columns headed *Scenario A* and *Scenario B* show the maximum predicted concentrations due to emissions from all sources within the SAR and hence show the worst case cumulative impact hour. This is not necessarily the same hour as that in which the proposed CCGT units have their maximum impact (the peak impact hour) and in most cases the two do not coincide.

Table 4.5b ***Maximum One-hour Concentrations***

Pollutant	Concentration ($\mu g\ m^{-3}$) (b)		
	Scenario A	Scenario B	CCGT Increment(a)
SO_2	192 (Deep Bay)	192 (Deep Bay)	3.8 (Kowloon)
NO_2	104 (NW Kowloon)	105 (NW Kowloon)	19.5 (Western)
O_3	117 (Mirs Bay)	117 (Mirs Bay)	4.4(Aberdeen)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not coincident either temporally and/or spatially with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

The following points are of note from this assessment:

- Under Scenario B all of the estimated concentrations are at least 50% below the respective Air Quality Objectives.

- As a percentage of the AQOs, the maximum one hour concentrations of NO_2, SO_2 and O_3 attributable to the proposed CCGT units are 6.5%, 0.5% and 1.9% respectively.

Figures 4.5a, b and *c*(2) show the predicted one hour concentrations of NO_2, SO_2 and O_3 corresponding to the hour on which the maximum impact attributable to the proposed CCGT units is predicted. As the ground level concentrations result from complicated interactions between emissions, meteorology and chemistry, the timing of the maximum CCGT impact may not necessarily coincide with the peak in emissions. It should be noted that the *Figures 4.5a, b* and *c* present the cumulative impacts of all sources in the SAR for the peak impact hour and do not display the maximum impacts attributable to the proposals, which are presented in *Figures 4.5d, e* and *f*. *Figure 4.5d* presents the incremental effects of the emissions from the CCGT units on ground level concentrations of nitrogen dioxide. It is evident that the maximum impact of the CCGT emissions is predicted to arise in the Western area. Reductions in concentrations are predicted

(2) The legend for the colours in all plots presented in this section means the lower limit of the range., e.g. in *Figure 4.5a* yellow represents areas with nitrogen dioxide concentrations between 50 and 60 μgm^{-3} and dark red with concentrations exceeding 80 μgm^{-3}. Also note that all plots represent ground level concentrations. The label "@ 1.5 km" refers to the PATH grid resolution used in this study.

to arise in two areas extending from Tsuen Wan to Tai Po and Kwun Tong to Sai Kung. The incremental impact of the CCGT units on ground level concentrations of SO_2 are presented in *Figure 4.5e* and it is evident that the area of maximum impact extends in a narrow band from Western to Kowloon and the Eastern NT. *Figure 4.5f* shows the incremental impacts on ozone concentrations. Although minor increases in ozone levels (less than 2% of the AQO) are predicted in some areas, the main effect of the emissions is to reduce ambient levels of ozone in the Pokfulam and Western areas of Hong Kong Island and in some areas of the Eastern NT.

The maximum 24 hour concentrations of SO_2 and NO_2 are presented in *Table 4.5c*

The reported concentrations under Scenario B are well within the 24-hour AQOs. The incremental effects of the CCGT units are identified in the fourth column in the table and are 0.4% and 3.7% of the AQOs for SO_2 and NO_2 respectively.

Figures 4.5g and *h* present 24-hour ground level concentrations of NO_2 and SO_2 under Scenario B. The area of the peak daily average concentrations of NO_2 extends from the Western Harbour to Sha Tin, with the maximum concentration predicted in NW Kowloon. The peak concentrations of SO_2 are less evenly distributed and as shown in *Figure 4.5h,* three areas are predicted to have daily average concentrations greater than 40 $\mu g\ m^{-3}$.

Table 4.5c ***Maximum 24-hour Concentrations***

Pollutant	Concentration ($\mu g\ m^{-3}$) [b]		
	Scenario A	**Scenario B**	**CCGT Increment**[a]
SO_2	63(Tsuen Wan)	63 (Tsuen Wan)	1.4 (Tai Wai)
NO_2	81 (NW Kowloon)	81 (NW Kowloon)	5.5 (Pokfulam)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily spatially coincident with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Figures 4.5i and *j* show the predicted incremental impacts of the CCGT emissions on the daily average concentrations of SO_2 and NO_2, respectively.

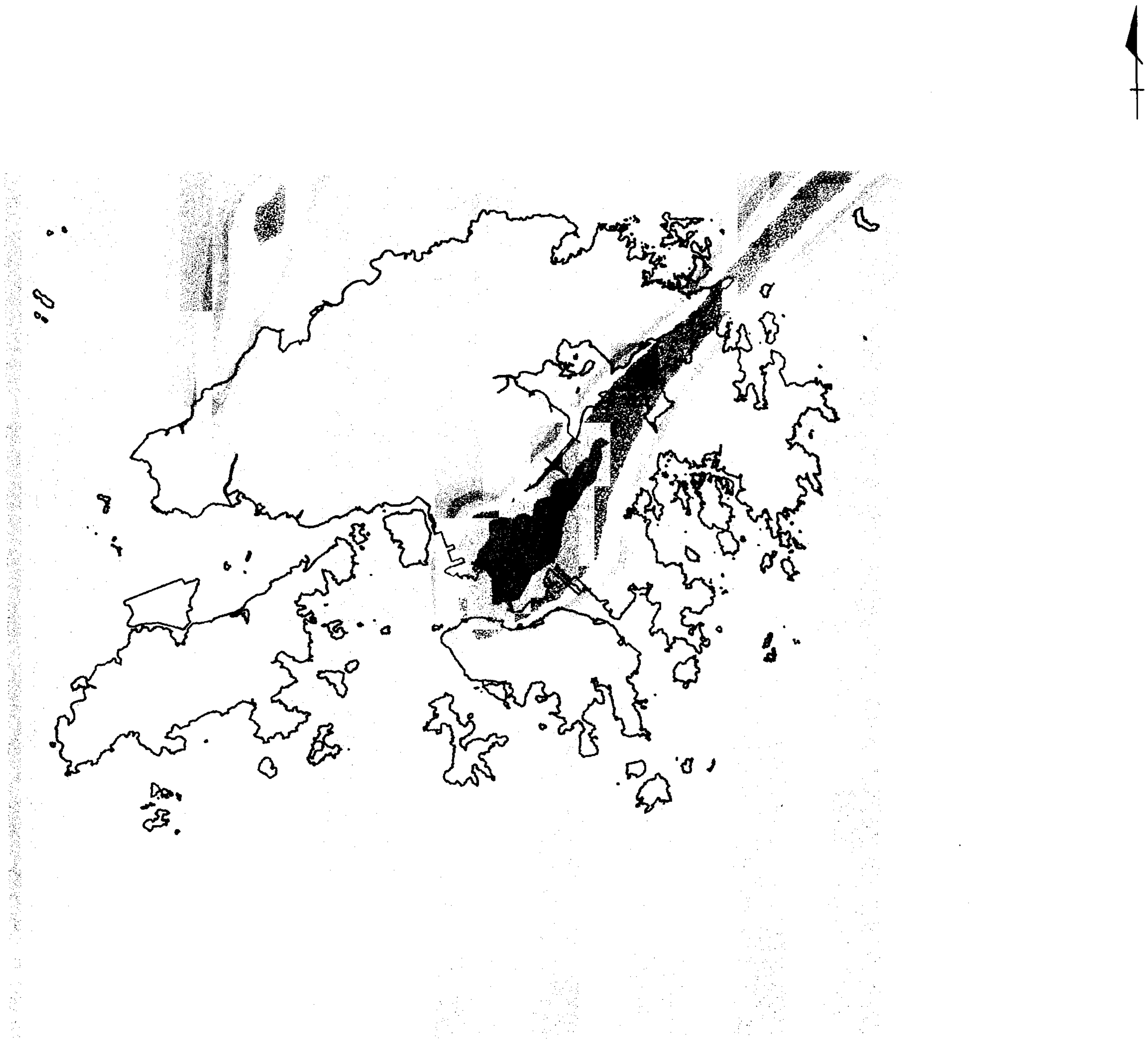
It can be concluded from this evaluation that the cumulative impacts of the proposed CCGT units during the worst case prevailing wind direction are well within the relevant AQOs. The impacts attributable to the proposals have also been identified and are considered negligible in the locations where those maxima are predicted to occur.

Additional Days

Table 4.5d summarises the prevailing meteorological conditions on the additional days that were modelled to allow an estimation of the annual average impact to be made. For each of these days, two scenarios were simulated and the results of these simulations are presented in the following tables.

1Hr Average (B)

Hr 4, 28 June 95



Coast

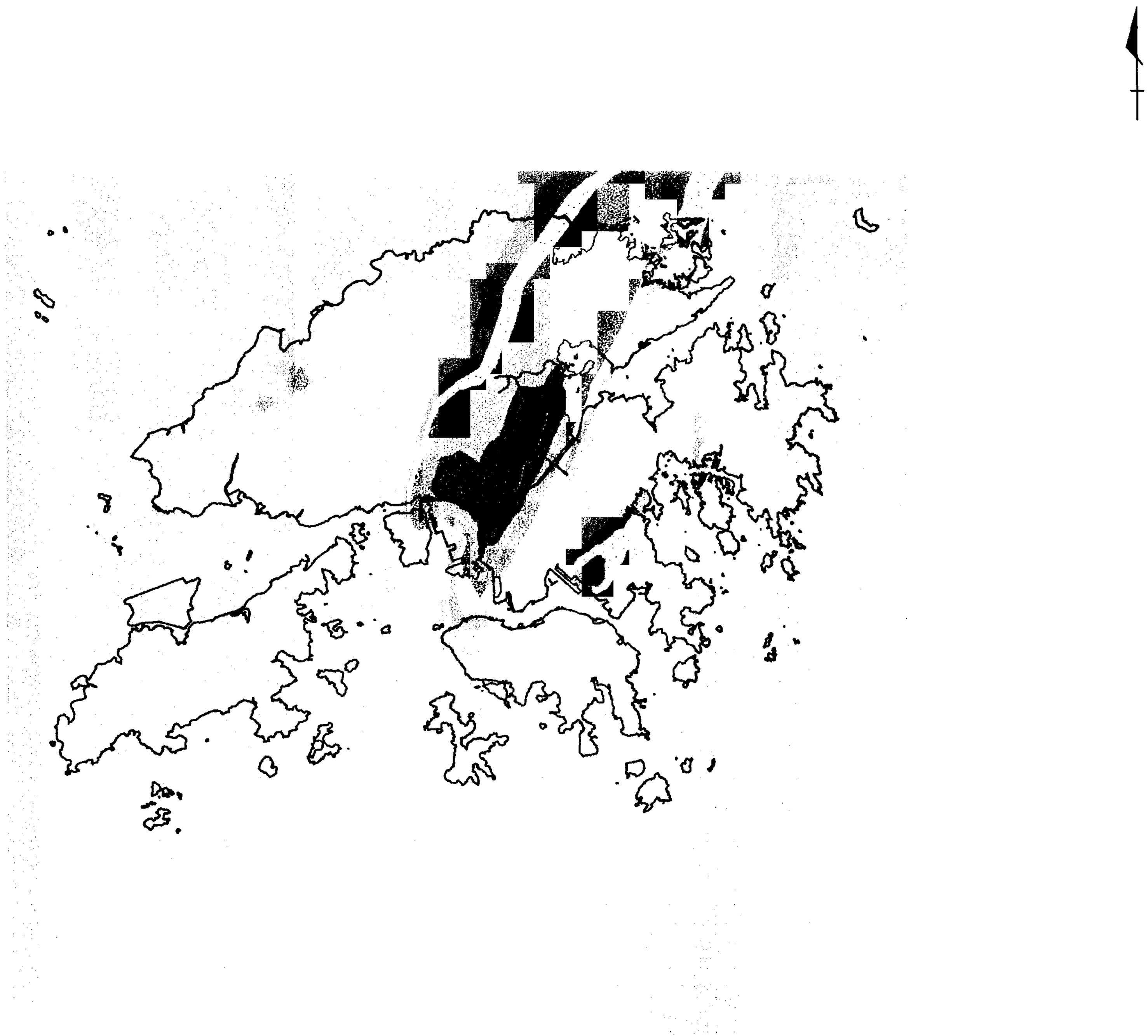
Nitrogen Dioxide @1.5km

0
10
20
30
40
50
60
70
80

Figure 4.5a

Compiled by:
Date: 08 December 98
Reference:

Scale 1:450000

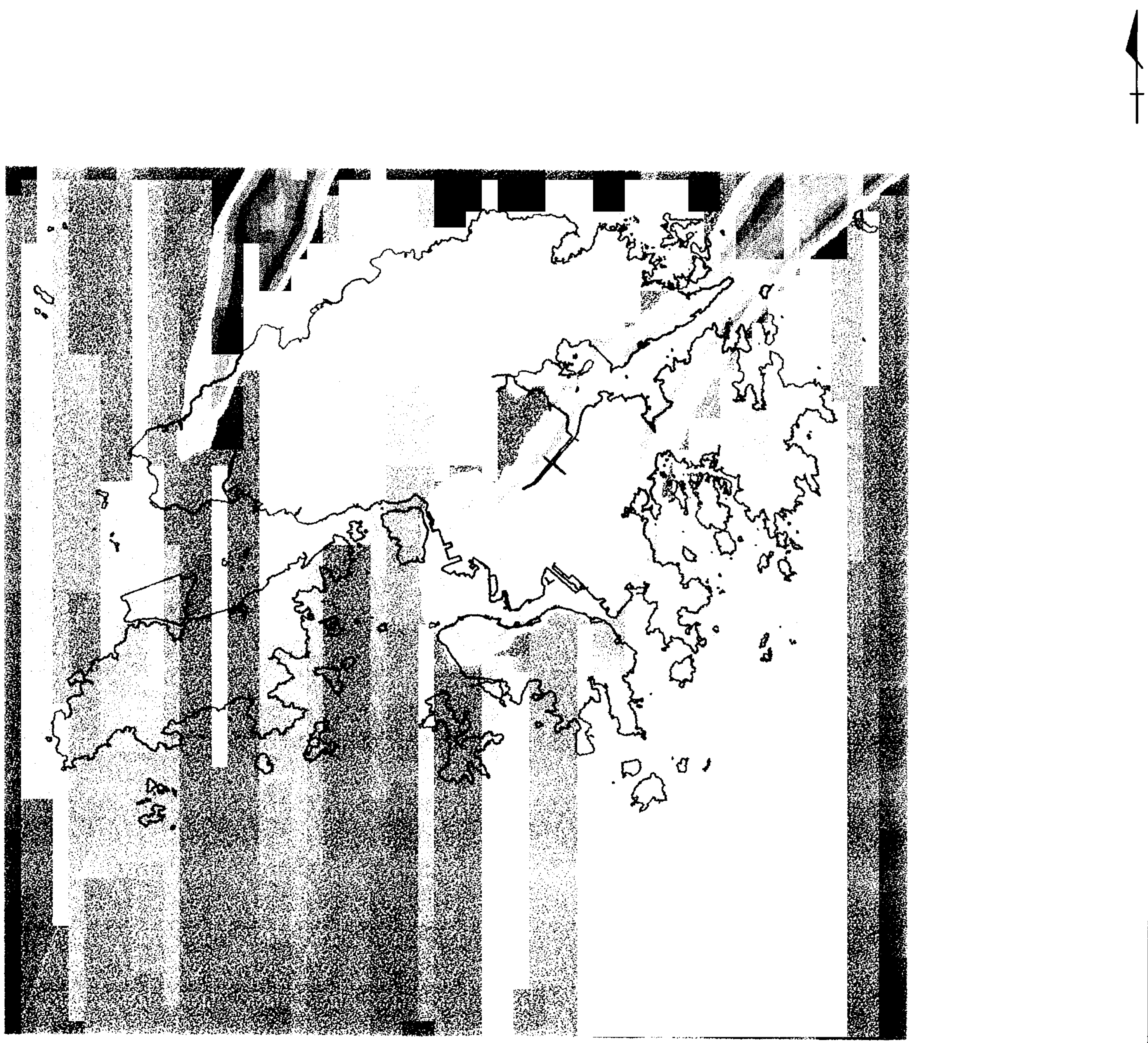


1 Hr Average (B)

Hr 20, 28 June 95

Figure 4.5b

Compiled by:	
Date:	08 December 98
Reference:	
Scale	1:450000



1 Hr Average (B)

Hr 4, 28 June 95

Coast

Ozone

@1.5km

10
20
30
40
50
60
80
100

Figure 4.5c

Compiled by:
Date: 08 December 98
Reference:

Scale 1:450000

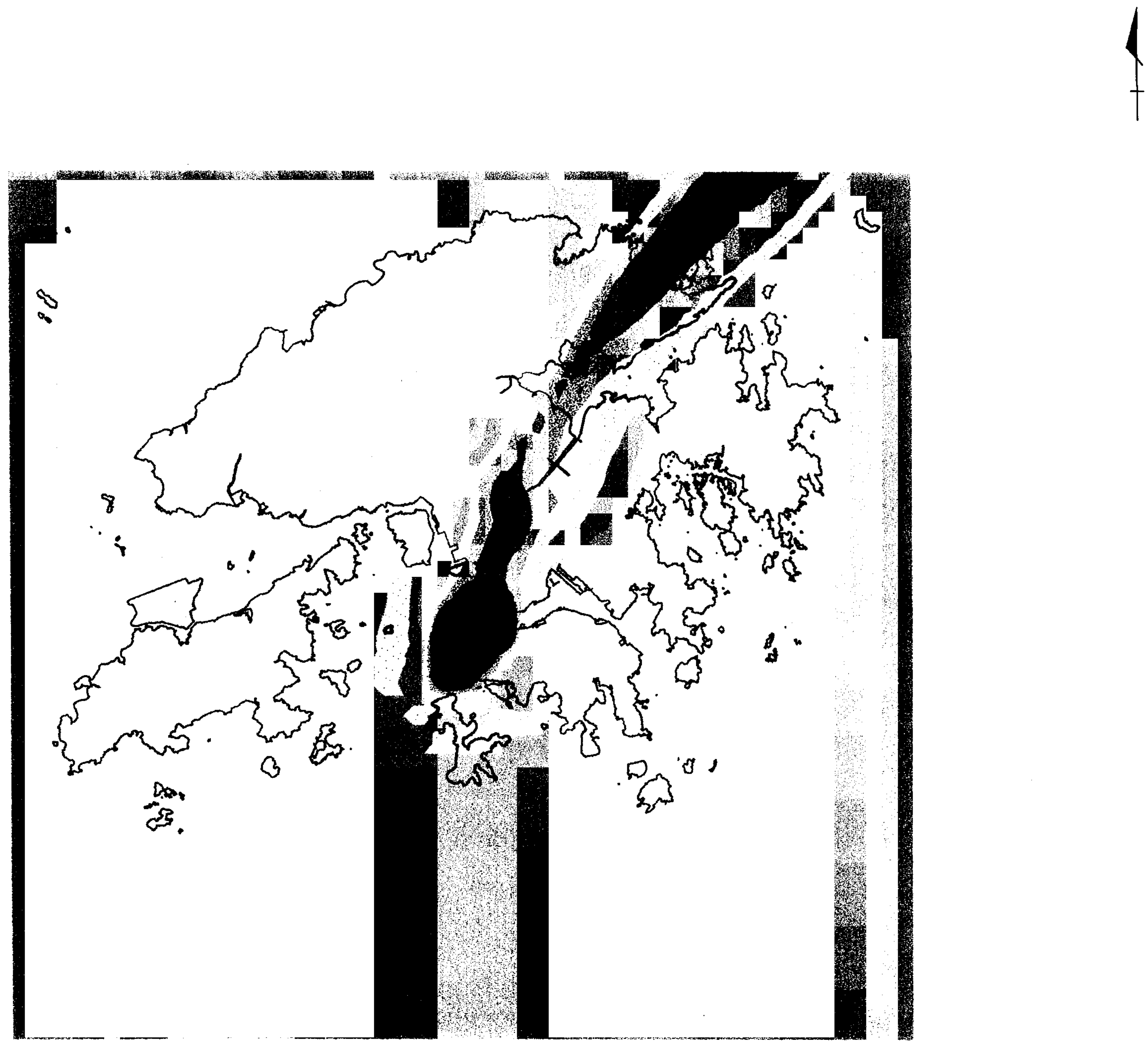
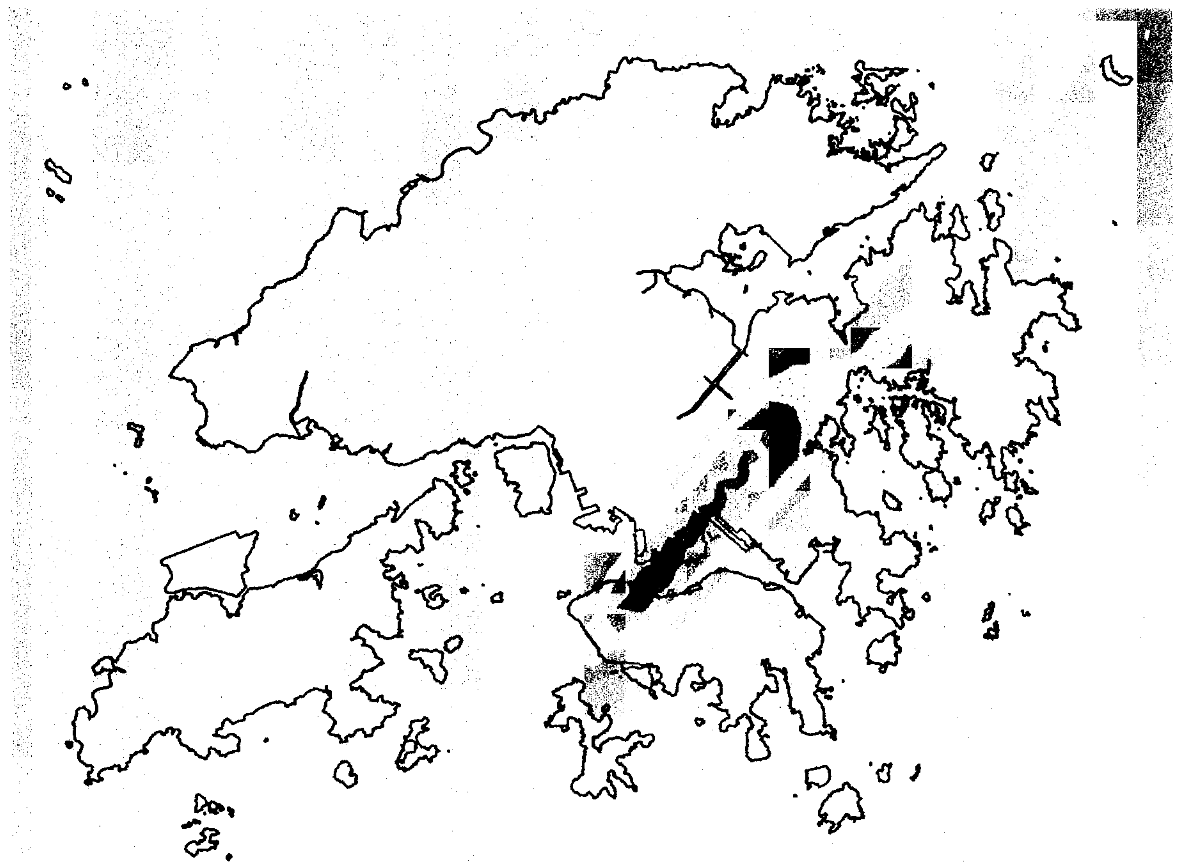


Figure 4.5d

Compiled by:
Date: 25 January 99
Reference:

Scale 1:450000



1 Hr Avg, B - A

Hr 20, 28 June 95

Coast

Sulfur dioxide

@1.5km

-1
0
0.5
1
2
3

Figure 4.5e

Compiled by:
Date: 09 December 98
Reference:

Scale 1:450000

1 Hr Avg, B - A

Hr 4, 28 June 95

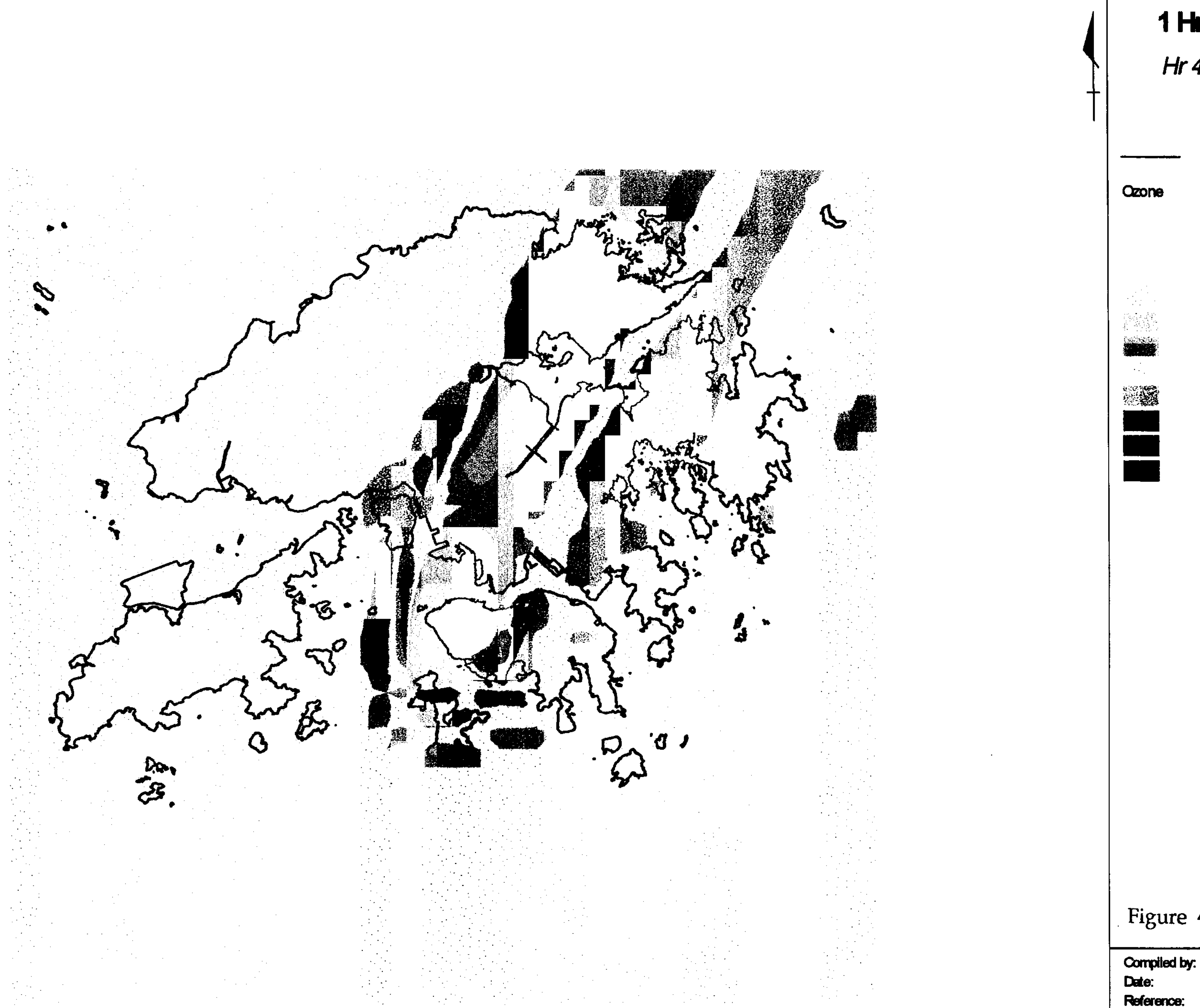
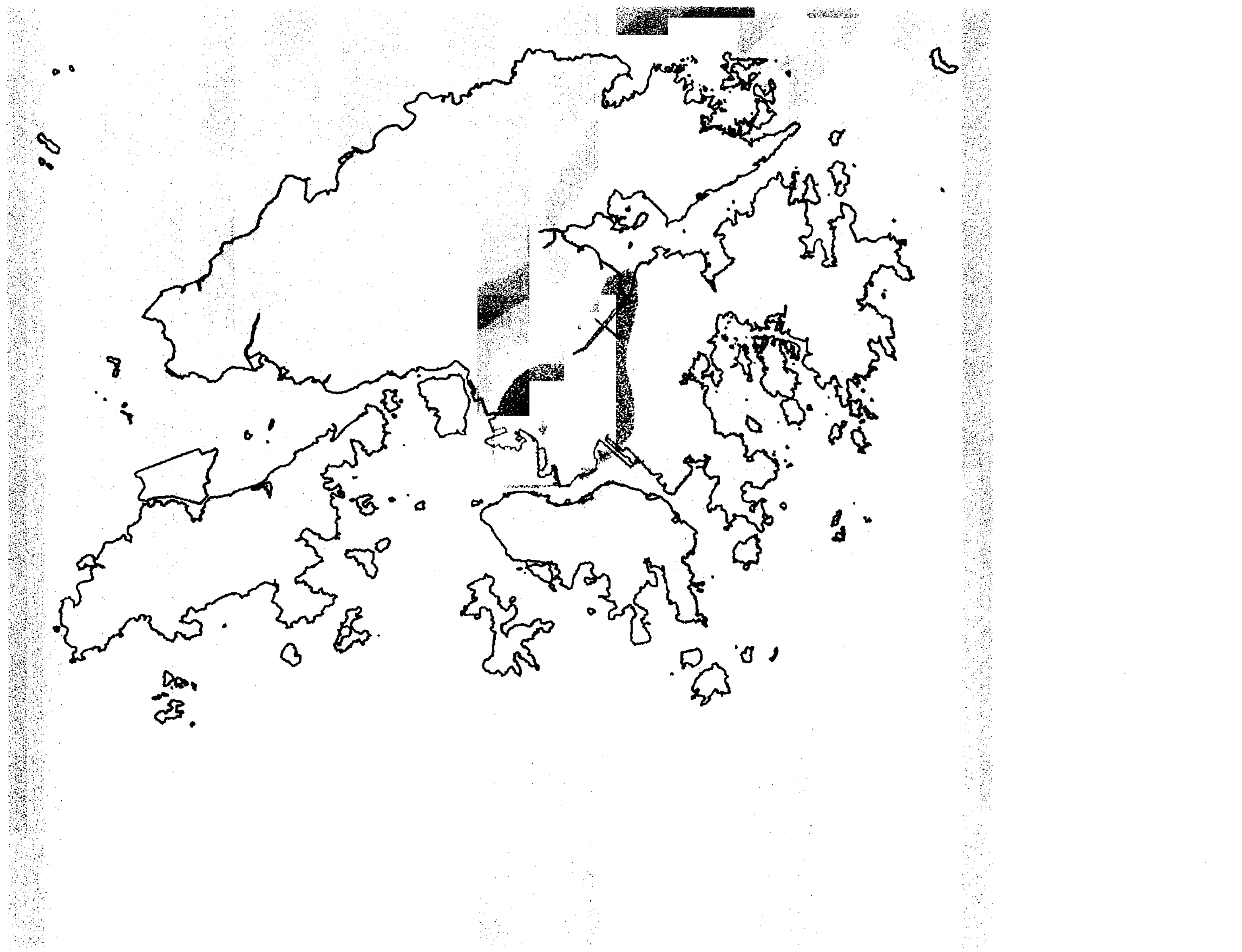


Figure 4.5f

Compiled by:
Date: 25 January 99
Reference:

Scale 1:450000



24 Hr Average (B)

26 June 95

Coast

Nitrogen Dioxide

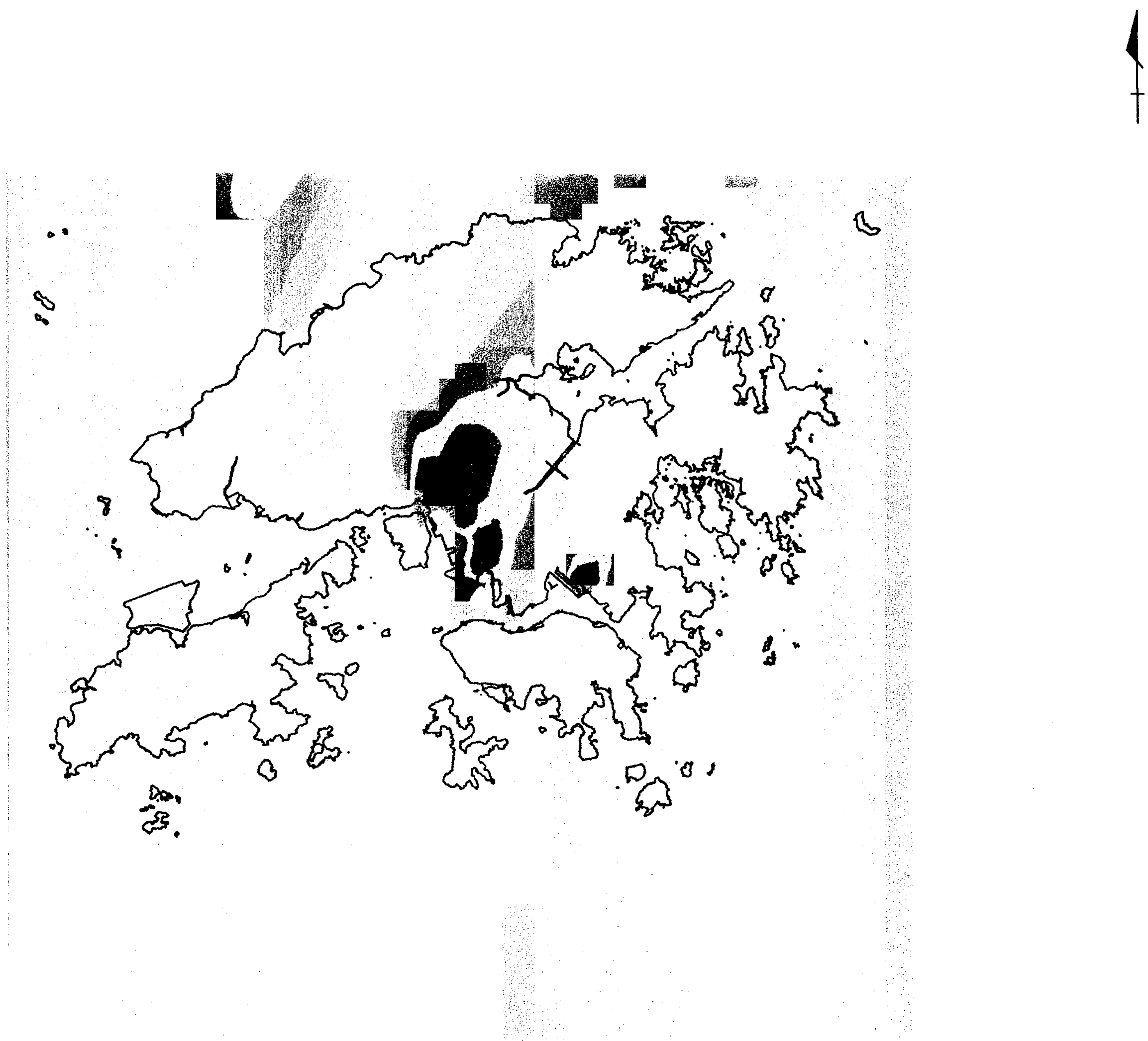
@1.5km
Hr 4, Jun 26, 95
(Scenario)

0
10
20
30
40
50
60
70
80

Figure 4.5g

Compiled by:
Date: 08 December 98
Reference:

Scale 1:450000



24 Hr Average (B)

28 June 95

Coast

Sulfur dioxide

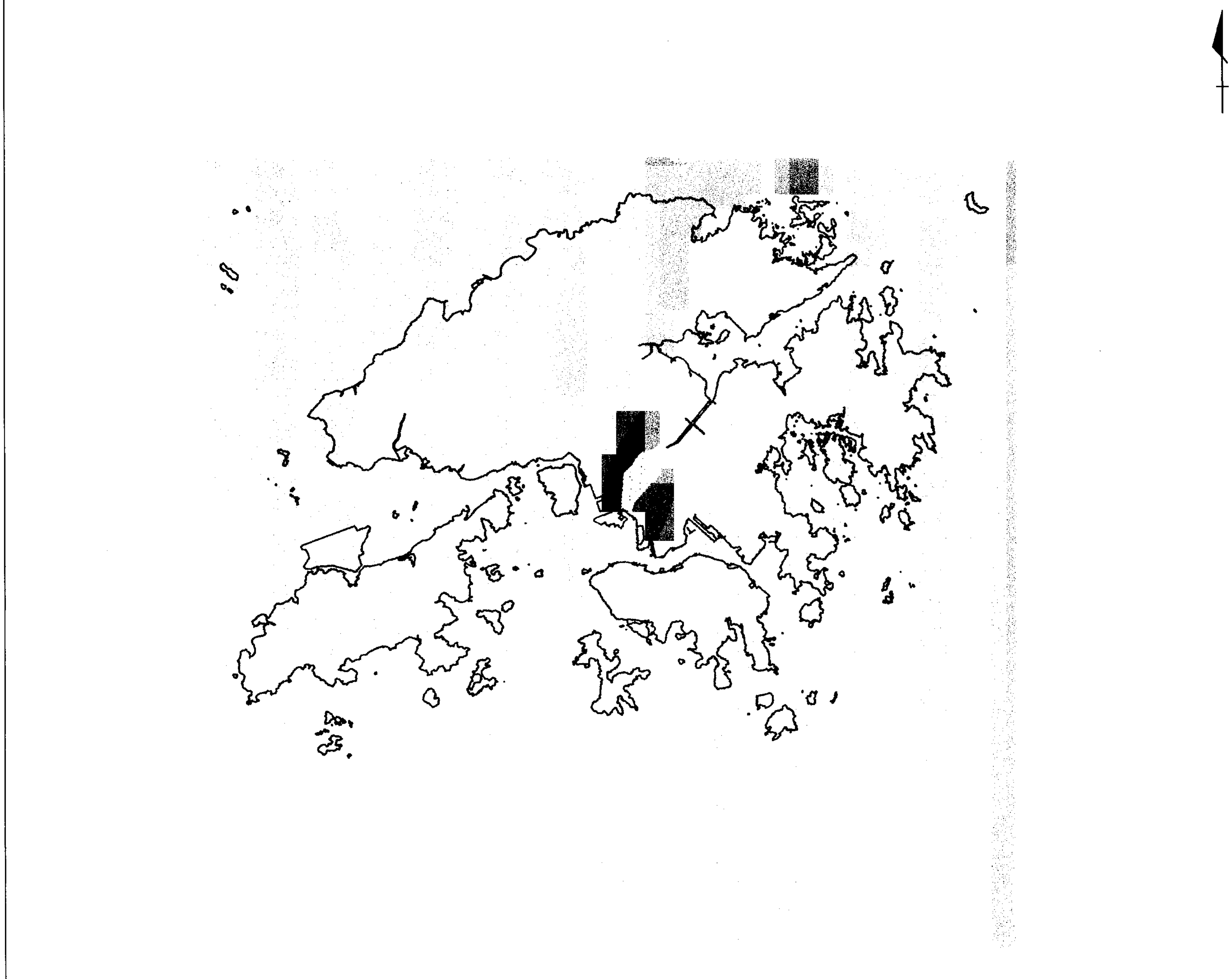
@1.5km

0
10
20
30
40
50

Figure 4.5h

Compiled by:
Date: 08 December 98
Reference:

Scale 1:450000



24 Hr Average
B - A

28 June 95

Coast

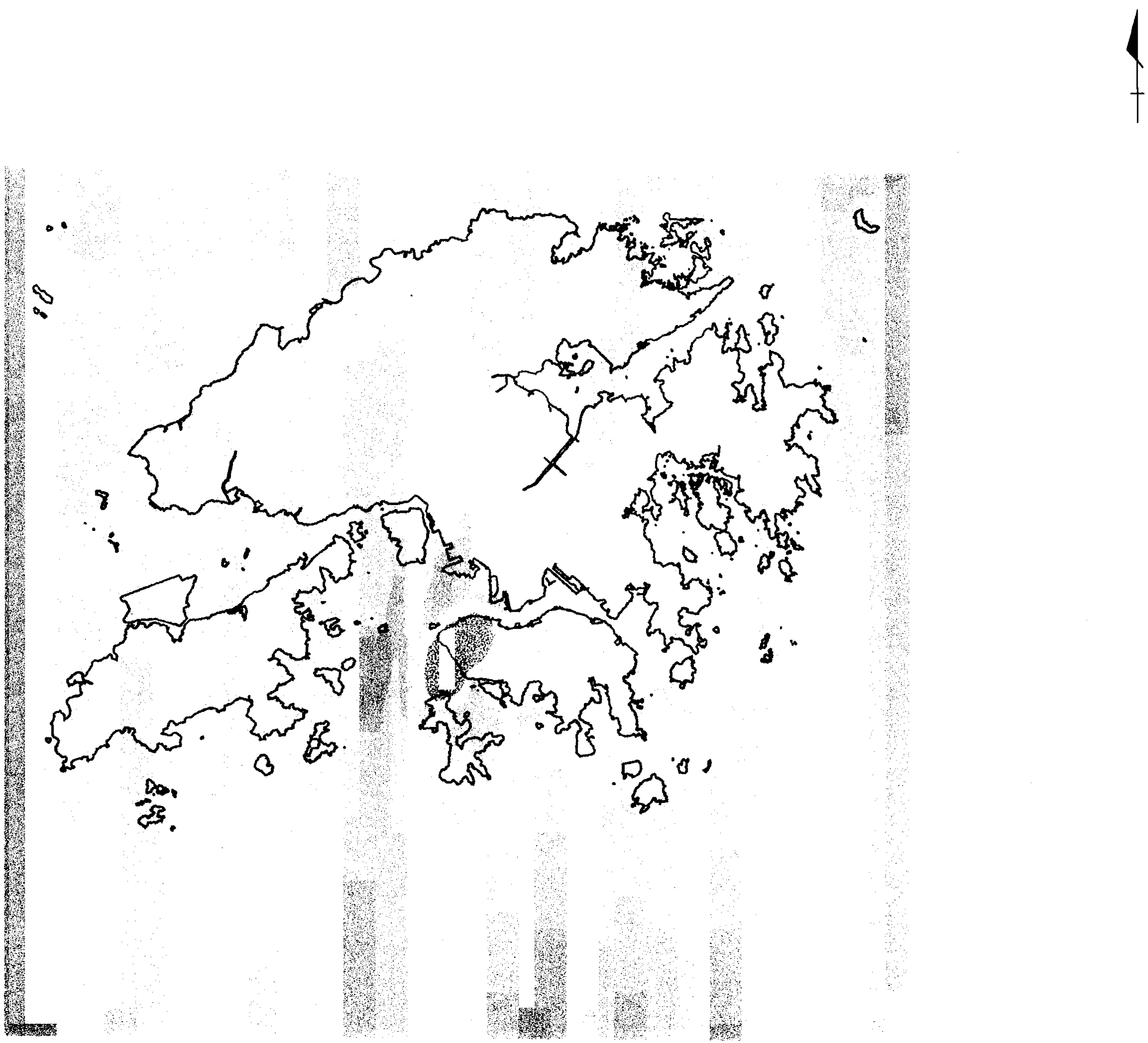
Sulfur dioxide

@1.5km

-1
0
0.5
1

Figure 4.5i

Compiled by:	
Date:	09 December 96
Reference:	
Scale	1:450000



24 Hr Average
B - A

28 June 95

———	Coast
Nitrogen Dioxide	
	@1.5km
	-99
	-2
	-1
	0
	1
	2
	5

Figure 4.5j

Compiled by:
Date: 09 December 98
Reference:

Scale 1:450000

Table 4.5d ***Meteorology***

Day	Date	Description
A	24/11/95	This day is typical of a cold outbreak from the continent to the north of Hong Kong (the maximum temperature was 4° lower than the previous day), leading to north to northeast winds at most stations all day. This direction prevailed throughout from the surface to 850 mb, with a nocturnal and morning jet of 15 m s^{-1} at 900 mb weakening to less than 5 m s^{-1} by 1400 h. Morning and evening temperature profiles showed a slightly stable layer up to 900 mb, capped by a strongly stable layer to at least 700 mb.
B1	23/11/94	Surface winds on this fine and sunny winter monsoon day start out from north to northeast but become northwesterly in the western part of the Territory and southeasterly in the east as the day progresses. Upper winds veer from east to north-northeast between 0200 h and 1400 h, but return to an easterly direction below 850 mb by 2000 h. Morning and evening temperature profiles indicate relatively stable layers from the ground to 900 mb, but it is not possible to speculate as to whether conditions have been stable all day. This day seems to be a winter's day with typical secondary circulations (sea breezes etc.), as described by Wai *et al.* (1996).
B2	20/01/95	Surface winds are mostly east to northeast on this day with some coastal perturbations in the afternoon. Upper winds are steady in direction from east-southeast up to 850 mb in the morning ascents, with a backing towards south in the afternoon and evening. A strongly stable layer exists between 950 and 900 mb throughout, with fairly strong stability between the ground and 900 mb as well, indicating that stable conditions may have prevailed throughout the day.
C	19/11/95	An interesting day on which surface winds are generally northeasterly, but on which a southeasterly sea breeze seems to penetrate halfway across the Territory before nightfall. Winds with a westerly component develop at coastal sites in the west for a short period. Over the 18 hours, winds between 1000 and 800 mb veer from northeast towards north, with a jet at 900 mb present at all times, although its speed at 1400 h is only half as much as at other times. There is more warming on this day below 950 mb than on any of the previous winter days and the evening temperature profile indicates that a mixed layer developed to this level during the day.
F	31/08/93	Surface winds generally easterly during the morning, but by mid-afternoon a western and a southern sea breeze have become well-established with a convergence line running approximately north-south somewhere through the Territory. East-northeasterly winds up to 850 mb in the morning have attained a westerly component by 1400 h and have veered even further to the west by 2000 h. As with most of the days from other categories, a morning low-level jet has disappeared by 1400 h, only to return by 2000 h. The potential temperature profiles indicate a stable profile above 950 mb throughout the period, but also show that the early-morning mixed layer between 1000 mb and 950 mb becomes quite stable under the influence of the sea breeze.

Table 4.5e ***Category A - Maximum One-hour Concentrations***

Pollutant	Concentration ($\mu g\ m^{-3}$) [b]		
	Scenario A	Scenario B	CCGT Increment[a]
SO_2	282 (W of Lantau)	282 (W of Lantau)	6.6 (SW of Lamma)
NO_2	88 (Pokfulam)	88 (Pokfulam)	24.6 (SW of Lamma)
O_3	91 (SW of Lantau)	91 (SW of Lantau)	3.8 (SW of Lamma)

Notes:

(a) The maximum incremental impact attributable to the proposed CCGT units is not coincident either temporally and/or spatially with the maximum reported concentrations under Scenarios A and B.

(b) Location of peaks shown in corresponding cells in the table.

Table 4.5f *Category A - Maximum 24-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) (b)		
	Scenario A	Scenario B	CCGT Increment(a)
SO_2	126 (W of Lantau)	126 (W of Lantau)	3.0 (SW of Lamma)
NO_2	49 (SW of Lamma)	54 (SW of Lamma)	11.6 (SW of Lamma)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not spatially coincident with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5g *Category B1 - Maximum One-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) (b)		
	Scenario A	Scenario B	CCGT Increment(a)
SO_2	206 (W of Lantau)	206 (W of Lantau)	5.1 (SW of Lamma)
NO_2	93 (Aberdeen)	93 (Aberdeen)	21.1 (SW of Lamma)
O_3	91 (Deep Bay)	91 (Deep Bay)	3.8 (SW of Lamma)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily coincident either temporally or spatially with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5h *Category B1 - Maximum 24-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) (b)		
	Scenario A	Scenario B	CCGT Increment(a)
SO_2	67 (Tsing Yi)	67 (Tsing Yi)	1.4 (SW of Lamma)
NO_2	57 (NW of Lamma)	57 (NW of Lamma)	4.0 (SW of Lamma)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily spatially coincident with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5i *Category B2 - Maximum One-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) (b)		
	Scenario A	Scenario B	CCGT Increment(a)
SO_2	166 (N of Green Island)	166 (N of Green Island)	2.0 (S of Lantau)
NO_2	101 (Western Harbour)	101 (Western Harbour)	12.0 (S of Lantau)
O_3	82 (Mirs Bay)	82 (Mirs Bay)	1.1 (S of Lantau)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily coincident either temporally or spatially with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5j *Category B2 - Maximum 24-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) [b]		
	Scenario A	Scenario B	CCGT Increment[a]
SO_2	96 (N of Green Island)	96 (N of Green Island)	0.5 (S of Lantau)
NO_2	78 (N of Green Island)	78 (N of Green Island)	3.9 (S of Lantau)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily spatially coincident with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5k *Category C - Maximum One-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) [b]		
	Scenario A	Scenario B	CCGT Increment[a]
SO_2	146 (S of Lantau)	146 (S of Lantau)	3.7 (SW of Lamma)
NO_2	124(Western Harbour)	124 (Western Harbour)	18.9 (SW of Lamma)
O_3	90 (Deep Bay)	90 (Deep Bay)	1.7 (S of Lantau)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily coincident either temporally or spatially with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5l *Category C - Maximum 24-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) [b]		
	Scenario A	Scenario B	CCGT Increment[a]
SO_2	60 (N of Green Island)	60 (N of Green Island)	0.4 (SW of Lamma)
NO_2	85 (Western Harbour)	85 (Western Harbour)	3.5 (SW of Lamma)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily spatially coincident with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5m *Category F - Maximum One-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) [b]		
	Scenario A	Scenario B	CCGT Increment[a]
SO_2	502 (NW Lantau)	502 (NW Lantau)	7.5 (S of Lantau)
NO_2	152 (Western Harbour)	152 (Western Harbour)	31 (S of Lantau)
O_3	153 (SW of Lantau)	153 (SW of Lantau)	2.8 (SW of Lamma)

Notes: (a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily coincident either temporally or spatially with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Table 4.5n *Category F - Maximum 24-hour Concentrations*

Pollutant	Concentration ($\mu g\ m^{-3}$) [b]		
	Scenario A	Scenario B	CCGT Increment[a]
SO_2	76 (W Lantau)	76 (W Lantau)	0.6 (SW of Lamma)
NO_2	68 (Western Harbour)	68 (Western Harbour)	2.7 (SW of Lamma)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily spatially coincident with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

Based on the results of these model runs, which represent the cumulative effects of emissions from the HEC's sources, including both the new and existing units, and other emission sources contained in the modified PATH emission inventory, the following conclusions can be drawn on the mid-field air quality impacts related to the proposed new power station.

- The predictions demonstrate that the cumulative impacts will not exceed the relevant one-hour AQOs for SO_2, NO_2 and O_3 under the simulated meteorological condition i.e. when winds from the southwest prevail. As southwesterly winds tend to occur during the summer, it has been assumed that HEC's sources were operating under system peak conditions, corresponding to a peak output of 3,916MW in 2012. Under this meterological condition, the maximum predicted levels are well within the relevant AQOs.

  The maximum incremental impacts of emissions from the CCGT units on one-hour average concentrations are typically very low. The maximum one-hour incremental concentrations of SO_2, NO_2 and O_3 are approximately 1%, 10% and 2% of the AQOs respectively due to HEC sources.

- Twenty four hour maximum concentrations are all in compliance with the relevant AQOs for SO_2 and NO_2 under the scenario with southwesterly winds and peak system load. The maximum predicted 24-hour SO_2 and NO_2 concentrations are well within the AQOs.

  The maximum 24-hour incremental concentrations of SO_2 and NO_2 due to HEC sources are approximately 1% and 8% of the AQOs respectively .

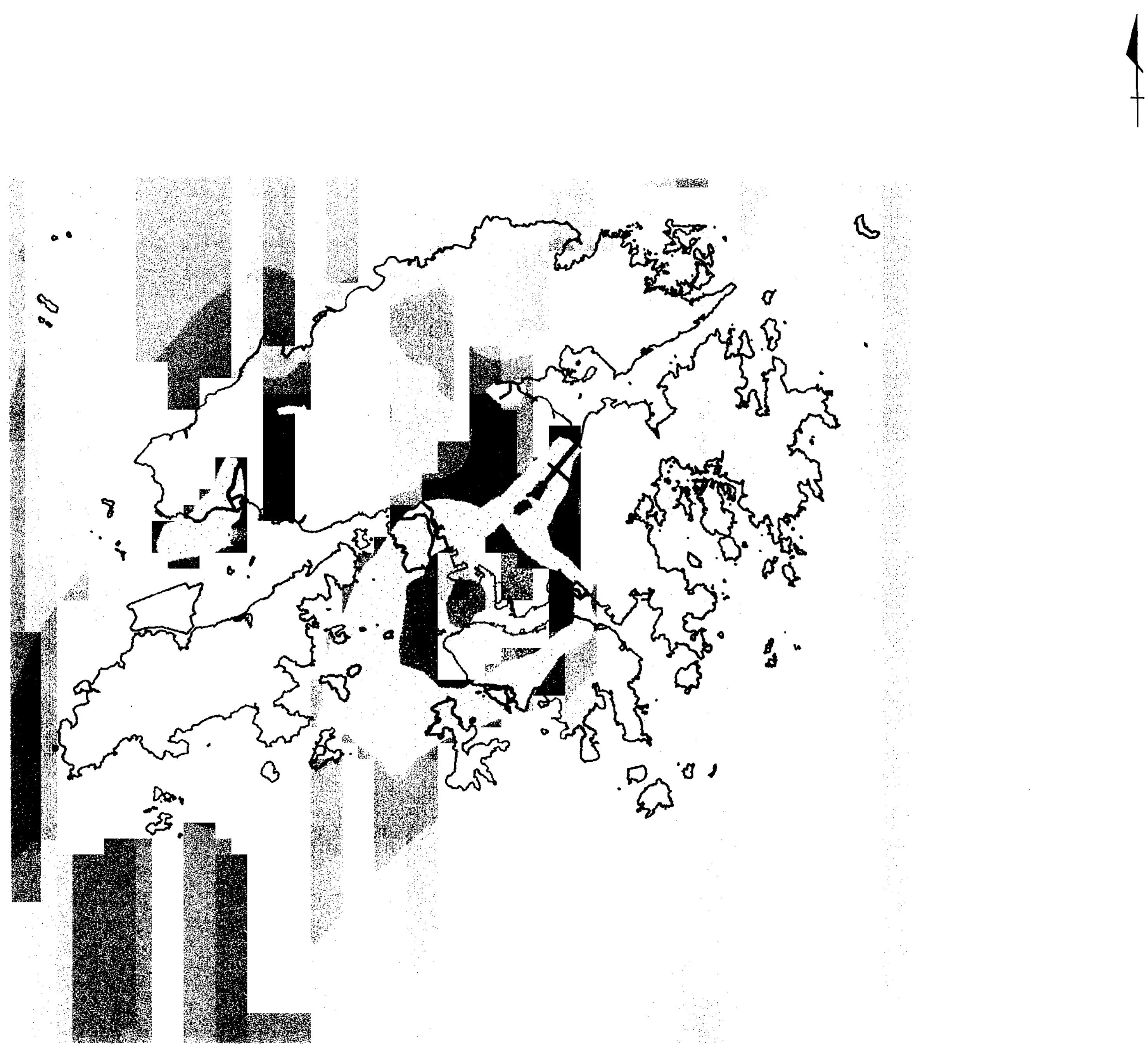
- Annual average concentrations of SO_2 and NO_2 were estimated by combining the simulation results of 6 typical days available in the PATH system. The results of this calculation are presented in *Table 4.5o*. The predicted concentrations of SO_2 and NO_2 are within the relevant AQOs. *Figures 4.5k & 4.5l* show the annual average concentrations of NO_2 and SO_2 respectively.

  The incremental annual average concentrations due to emissions from the CCGT units is less than 0.8% and 3.3% of the AQOs for SO_2 and NO_2 respectively. Figures are included in Annex B4-6.

  In conducting the simulation runs for "other days" when winds from directions other than southwest were modelled, the emissions from the HEC's sources have been assumed to be operating at maximum system load. Hence the annual average computed with respect to HEC's emissions tends to be over estimated.

Annual Average

Scenario B



Coast

Nitrogen Dioxide

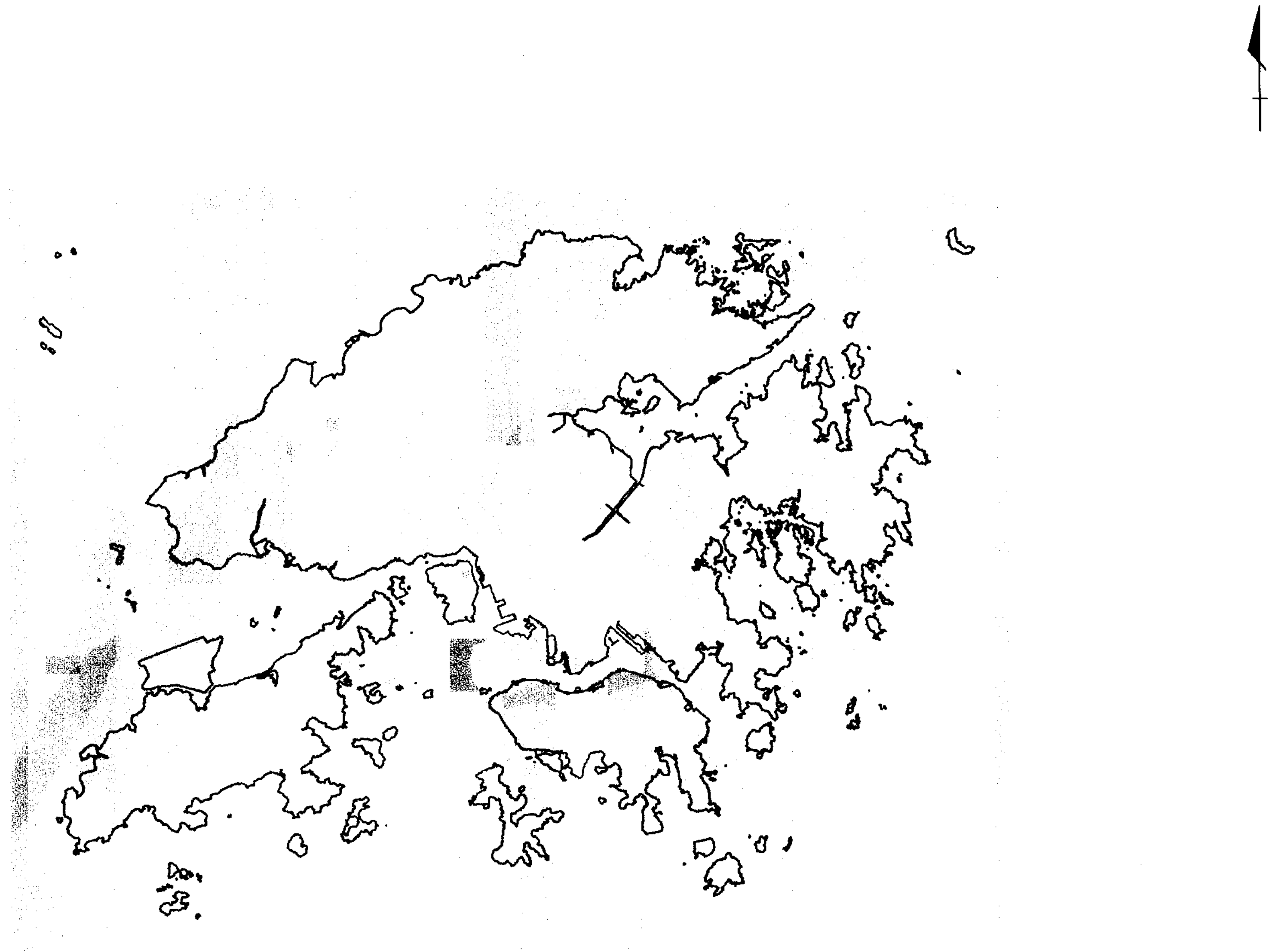
@1.5km

	0
	10
	20
	30
	40
	50
	60

Figure 4.5k

Compiled by:
Date: 07 December 98
Reference:

Scale 1:450000



Annual Average

Scenario B

Coast

Sulfur dioxide

@1.5km

0
10
20
30
40

Figure 4.51

Compiled by:
Date: 07 December 98
Reference:

Scale 1:450000

- It is concluded that the proposed new power plant will not cause exceedance of the relevant AQOs in the mid-field when it is fully developed in 2012, based on the model results of PATH presented above.

Table 4.5o ***Maximum Annual Average Concentrations***

Pollutant	Concentration ($\mu g\ m^{-3}$) [(b)]		
	Scenario A	Scenario B	CCGT Increment[(a)]
SO_2	44.0 (Tsing Yi)	44.0 (Tsing Yi)	0.6 (West Lamma Channel)
NO_2	63.4 (Western Harbour)	63.4 (Western Harbour)	2.6 (West Lamma Channel)

Notes:
(a) The maximum incremental impact attributable to the proposed CCGT units is not necessarily spatially coincident with the maximum reported concentrations under Scenarios A and B.
(b) Location of peaks shown in corresponding cells in the table.

4.6 REGIONAL AIR QUALITY REVIEW

4.6.1 *Background*

Due to the rapid economic developments in Asia, the resulting air pollution in the region has become a growing concern. In particular, the issue of 'transboundary' pollution, ie air pollution from one country or region affecting the air quality in another. To address these concerns, HEC contracted ERM to conduct a quantitative assessment on the regional air quality impacts of a new power station in the Stage 1 EIA, the results of which are documented in the *Stage 1 EIA: Pearl River Delta Air Quality Assessment* Technical Paper.

4.6.2 *Objective of the Study*

The purpose of this EIA is to review and update the findings of the previous assessment, as required by the Study Brief.

4.6.3 *Review of the Pearl River Delta (PRD) Air Quality Assessment*

Objectives of the Pearl River Delta (PRD) Air Quality Assessment

The aim of the Pearl River Delta Air Quality Assessment was to provide a broad evaluation of the potential regional impacts of atmospheric emissions from the proposed new power station. The Study provided information on the nature and extent of regional (the Pearl River Delta area) air quality impacts arising from the proposed new power station operating under two alternative fuel options (coal and gas) and different emission control technologies for nitrogen oxides. Aerial emissions and their effects at the regional level were addressed in this Study, including sulphur dioxide, nitrogen dioxide, acid deposition and photochemical reactions.

Background on Power Station Development in the PRD Region

As one of the fastest growing provinces in China, Guangdong's energy demand has risen sharply in the past decade. The majority of this demand is met by large capacity thermal power stations using coal or oil as a primary fuel. Many of these power plants are located in the PRD region, including:

Shajiao A	Coal	3x200MW + 2x300MW	1987-1993
Shajiao B	Coal	2x350MW	1987
Shajiao C	Coal	3x660MW	1995-1996
Zhujiang I&II	Coal	2x300MW + 2x300MW	1992-1997
Huangpu III	Coal	2x300MW	1989-1990
Huangpu Riming	Coal	1x125MW	1995
Mawan	Coal	2x300MW	1996-1997
Zhuhai I	Coal	2x700MW	1999-2000
Huangpu	Oil	1x125MW	1995
Nanhai I	Oil	2x200MW	1997
Zhongshan	Oil	2x125MW	1997-1998

These power stations represent the major fossil-fuelled power plants either recently built or still under construction. There are additional power stations commissioned in parts of Guangdong Province outside of the PRD, such as at Zhangjiang and Shantou. The total capacity derived from fossil-fuelled power plants and added to the Guangdong grid over the past decade is more than 10,000MW with more stations to be constructed within the next decade, eg Zhuhai Phase II (4x600MW coal) and Taishan (8x660MW coal). Plans for these new power stations have already been approved by the State Planning Committee but the construction schedules have yet to be fixed, dependant as they are upon system demand and the availability of funds.

It should be noted that none of the existing power plants in the province have flue gas desulphurisation (FGD) or NO_x control facilities; these factors influence the high level of concern expressed regarding the development of coal-fired power stations in the province, particularly in the PRD region where the majority of the power plants are located. The total acid deposition in Guangzhou in the early 1990's was more than five times that of Hong Kong. Retrofitting FGD to the existing power plants is considered to be too capital intensive to be implemented on a large scale, although one or two power plants may be retrofitted with FGD in the near future. Hence, there are no plans to modify existing power plants in the region.

The interim measure adopted by the Guangdong Power Bureau and the Environmental Protection Bureau is, therefore, to limit the future development of coal or heavy oil fired power plants, unless suitable emission control facilities are specified. According to the Guangdong Environmental Protection Bureau[(3)]:

> *"In principle, no coal-fired power plants shall be built in the PRD region. Starting from this year no thermal power plants of unit capacity 125MW or less shall be built. New power plants of capacity 200MW or above shall be equipped with FGD... Emphasis shall be placed on developing hydro power and nuclear power; some developments on oil firing; and to create conditions for development of gas firing."*

The Guangdong Power Bureau is also implementing similar planning guidelines for future power station development. Since they presently have surplus capacity in the grid, and there are substantial coal-firing facilities already approved for development within the next decade, the Guangdong Power Bureau is now shifting to gas-firing as well as nuclear technology for future developments.

(3) The 7th Guangdong Provincial Environmental Protection Conference (November 1996)

Assessment Methodology

A three-dimensional prognostic mesoscale meterological model, the *Lagrangian Atmospheric Dispersion Model* (LADM) was used to model the air quality impacts from the proposed new power station. LADM consists of two main components: a mesoscale windfield model which predicts the diurnal cycle of winds and turbulence at many levels and gridpoints in the atmosphere, and a Lagrangian particle dispersion model which uses the winds and turbulence to predict the pathways of pollutants released from the identified sources. This provides a more accurate prediction methodology than the Gaussian dispersion models as the model is able to simulate the effects of rugged terrain, sea breezes, and interaction of complex wind flows such as drainage winds.

The assessment first identifies typical meteorological conditions, for air quality modelling purposes, which are conducive to poor dispersion and photochemical production of smog in the Pearl River Delta. The Integrated Empirical Rate (IER) equations of smog formation were used to evaluate the impact of power station emissions on the regional air quality. Major sources in Hong Kong were included in the emission inventory to simulate hourly NO_2 and O_3 concentrations over the wider Region during daylight hours.

Two worst-case meteorological scenarios in which the urban pollution sources to mix with the emissions from the new power station were chosen after some preliminary test runs. The meteorology of *Scenario 1* was specified as surface synoptic winds of 3 m s^{-1} from the east turning with height to southeasterly by 500 m above ground level with an initial temperature profile of 3K km^{-1} from the surface to 1,000 m and 5K km^{-1} above. *Scenario 2* has a slightly northerly component with surface winds of 3 m s^{-1} from about east-northeast (70°) turning with height to southeasterly from 500m above ground. The temperature profile maintains the same as *Scenario 1*. These two scenarios together with emissions from the pollution sources, warm temperatures and relatively cloud-free skies, would result in smog formation, such as that found to be more prevalent in the autumn months.

Major existing and future pollution sources that are conducive to photochemical reactions were first identified for inclusion in the simulations. Existing sources included elevated point sources such as Castle Peak Power Station, Black Point Power Station and the Lamma Power Station; area sources from the airport at Chek Lap Kok and the urban emissions; and a line source from the North Lantau Expressway. A Waste-to-energy Incineration facility (WEIF) and the proposed new power station were also included in the assessment. A background ozone (O_3) concentration of 67 μg m^{-3} was assumed in this study.

Simulations for the identified worst-case scenarios were carried out initially on a 2 km grid covering 100 km x 100 km and then on a 5 km grid to provide a 250 km x 250 km coverage. The 5 km grid results were the point of focus due to the regional context of this assessment.

Simulations were performed for the following cases:

- existing sources in 2002, before the commissioning of the new power station,
- existing sources in 2012 with a new coal-fired power station;

- existing sources in 2012 with a new coal-fired power station utilising APC and De-NO_x technology; and

- existing sources in 2012 with a new combined cycle gas-fired power station.

Now that the proposed new 1,800 MW power station has been confirmed to be gas-fired, a review of the findings focusing on the gas-fired option, will be carried out.

Concentrations of NO_2, O_3 and SO_2 were modelled as having photochemistry interactions.

Modelling Results

The 5 km grid modelling results are similar for the two worst-case meteorological scenarios. However, the slightly northerly surface wind component in *Scenario 2* was able to split the urban plume in the morning, whereby a portion travels southwards between Lantau Island and Hong Kong Island. This suggests that *Scenario 1* has a higher potential to cause photochemical reaction in the PRD region and hence this report only discusses the modelling results from *Scenario 1*.

Plume Dispersion

For the gas-fired option in 2012, emissions from the Lamma Power Station Extension behaved in a very similar manner to those from the current Lamma Power Station. The plumes stretched from the northern tip of Lantau Island to the PRD at about 1600 LT. At 1700 LT, emissions from the large existing urban sources seemed to have combined over the PRD region, thus creating peak concentrations. By 1800 LT, the plumes had progressed inland and by 1900 LT, the maximum concentrations had declined.

O_3 and NO_2 Simulations

From 2002 to 2012, the O_3 plumes began to enter and concentrate in the PRD at about 1600 LT. At 1700 LT, the plumes from the various sources seemed to have combined over the PRD region, thus creating a peak concentration (about 21% above the 2002 level). However, within the next hour, maximum concentrations in 2012 drop to about 10% below 2002 maximum concentrations. O_3 contributions from the new power station were roughly estimated for 2012 and the findings for O_3 indicated that the new power station would actually reduce O_3 concentrations (about 1%). The minor effects of the new power station suggest that most of the O_3 originates from other existing sources.

From 2002 to 2012, there is an increase of approximately 15% in the highest maximum NO_2 concentrations due to the increase in the emissions from the urban sources. The new gas-fired power station only contributes to less than 1% increase in the maximum NO_2 concentration in 2012 at 1700 LT.

In summary, from the regional perspective, the new gas-fired station would contribute minor reductions to the maximum O_3 concentrations and negligible NO_2 contributions to maximum NO_2 concentrations, under the worst-case scenario modelled. Maxima in the region would not be affected as the emissions from an additional power station, when compared to the existing emissions in the PRD region, are extremely small.

SO_2 Simulations

Assessments for SO_2 was also performed although they are considered as less relevant in the regional context.

No significant SO_2 contribution was registered from the new gas-fired power station in 2012 as the power station contributed negligible SO_2 impact. From 2002 and 2012, maximum SO_2 concentrations decrease significantly due to the reduction in SO_2 emission, with the largest reduction of over 30% occurring at 1800 LT.

It can be therefore be concluded that the existence of a new gas-fired power station would contribute negligible amounts to maximum SO_2 concentrations.

Acid Deposition

Background

Acid deposition refers to the process of wet and dry deposition of acidic material through precipitation or gravitational settling and by direct contact with the ground, vegetation and buildings. Dry deposition of SO_2 and NO_2 and wet deposition of sulphate (SO_4^{2-}) and nitrate (NO_3^-), which are oxidation products of SO_2 and NO_2, are the main constituents of the acid deposition from a power station.

Monitoring by the EPD over the past ten years has established that wet deposition is widespread and relatively uniform across Hong Kong. Dry deposition is mainly due to urban activity and Ayers and Yeung (1996) estimated a background total acid deposition of the order of 160 meq m^{-2} yr^{-1}.

Assessment Approach

The approach to assess the effect of acid deposition in the region can only concentrate on the acid deposition fluxes as it is very difficult to estimate the acid deposition impact from existing sources due to the uncertainty that exists in acid deposition research in the Asian region. A simplified approach was adopted to assess the expected deposition before and after the commissioning of the HEC's new power station using the projected emissions for the year 2002 and 2012 with reference to the 1995 base case. It should be noted that baseline conditions for PRD cities other than Guangzhou could not be established since acid deposition data for these cities were not available. In fact, thus far, Guangzhou has been the only city reported to have collected any extensive acid deposition data.

The most recent total wet deposition data (140 meq m^{-2} yr^{-1}) collected by the EPD in 1993 were used for this assessment. Dry deposition is measured as the product of a deposition velocity and the annual average concentrations of the acidic gases. Using a deposition velocity estimate of 0.36 cm s^{-1} (Ayers and Yeung, 1996) for dry deposition of both SO_2 and NO_2 gives the sum of 220 meq m^{-2} yr^{-1} for 1993. Total wet deposition measured in Guangzhou in 1993 was reported as 720 meq m^{-2} yr^{-1}. Dry deposition of 270 meq m^{-2} yr^{-1} was estimated using the annual average concentration for SO_2 and NO_2. Total acid deposition was therefore estimated as 990 meq m^{-2} yr^{-1} in 1993.

Emissions from the various sources were estimated as shown in *Table 4.6a*.

Table 4.6a ***Estimated NO_X and SO_2 Emissions in Hong Kong and the Pearl River Delta (with the New Power Station Operating in 2012)***

Source	1995		2002		2012 Gas-fired	
	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr
HK International Airport	3,037	1	-	-	-	-
New International Airport Lantau	-	-	7,204	465	7,204	465
Vehicle/Domestic/ Industrial Surface	46,106	16,745	46,106	16,745	46,106	16,745
Town Gas Production Plant	1,366	1,638	1,366	1,638	1,366	1,638
Waste-to-Energy Incineration Facility	-	-	4,503	2,810	4,503	2,810
HEC Total (coal for future)	30,000	25,100	60,234	76,065	33,807	31,347
CLP Total (coal for future)	58,676	92,967	33,483	57,379	66,654	125,337
Total Hong Kong Emissions	139,185	136,451	152,896	155,102	159,640	178,342
PRC Emissions in the PRD Region[d]	232,500[a]	336,300[a]	1,040,000[b]	1,840,000[b]	1,450,000[c]	2,550,000[c]

Notes:
a - figures are for the year 1993
b - figures are for the year 2000
c - figures are for the year 2010
d - *Researches on Perspective Plan for the Pearl River Delta Economic Region*, Guangdong Province Planning Committee (1995)

Assessment Results

By 2002, emissions of acid gases in Guangzhou are estimated to increase by 450% for SO_2 and by 350% for NO_X, combustion-related total acid deposition is expected to increase to a significant 4,500-5,000 meq m^{-2} yr^{-1}. By 2012, the levels in Guangzhou may be as high as 6,200-6,900 meq m^{-2} yr^{-1}.

Acid deposition in the region and the contribution from HEC has been estimated based on a projected emission from HEC and summarised in *Tables 4.6b* and *4.6c*.

Table 4.6b ***Estimated Maximum Percentage Contribution by HEC Operations to Total Combustion-related Acid Deposition in Pearl River Delta.***

Contribution from HEC	Mass-ratio Method	
	2002	2012 Gas Option
Total Acid Deposition (meq m^{-2} yr^{-1})	164	79
Percentage Contribution	3	1

Dry deposition fluxes of SO_2 and NO_2 can also be estimated from the hourly-averaged concentrations calculated by LADM to assess the contribution to changed HEC operations in 2002 and 2012 to acid deposition in the PRD.

The maximum wet deposition in the PRD due to HEC operations in 2012 under the gas-fired option will be no more than that in Hong Kong, viz 28 meq m^{-2} yr^{-1}.

To estimate the HEC contribution to acid deposition, prognostic modelling results of NO_2 at distances up to Guangzhou (PRD) due to HEC emissions, reach 40 ppb for no more than two hours of the modelled day and the winds with an easterly to southerly direction occur only 33% of the time. So the annual average ground level concentrations in 2012 in PRD due to HEC emissions are expected to be $70 \times 2 \times 0.33 / 24 = 1.1$ ppb. Then the dry deposition of NO_2 is expected to be 5 meq/m^2/yr. Similarly for SO_2 the estimated dry deposition is expected to be 9 meq/m^2/yr. So the dry deposition in PRD due to HEC operations with new gas- fired power station in 2012 is expected to be no more than 14 meq/m^2/yr. The total acid deposition is then no more than 42 meq/m^2/yr with the fractional contribution of about 1% to the projected acid deposition in Guangzhou.

Table 4.6c ***Derivation of Maximum Percentage Contribution by HEC Operations to Total Combustion-related Acid Deposition in Pearl River Delta***

	Worst-case Modelling Method	
	2002	2012 Gas Option
Max wet deposition (meq/m^2/yr)	59	28
Max annual average NO_2 (ppb)	2.5	1.1
Max annual average SO_2 (ppb)	3.1	1.0
Max dry deposition (meq/m^2/yr)	40	14
Total acid deposition (meq/m^2/yr)	99	42
Max HEC contribution to total acid deposition	2%	1%

Future acid deposition in the region was estimated based on the projected emissions for the assessment years and the likely contribution from HEC's power stations. The results indicated that the large emissions within the whole PRD have a high potential to cause acid deposition problems. However, it should be noted that the contribution from HEC is relatively minor in the year 2012. The proposed new power station will help to reduce the overall acid deposition to the region by about 1% and the contribution of the new power station is negligible in the context of the emissions from the whole PRD region.

Summary of PRD Assessment Findings

The Pearl River Delta Air Quality Assessment has provided a broad evaluation of the potential regional impacts of atmospheric emissions from the proposed new power station and concluded that additional emissions of nitrogen oxides would contribute insignificantly to regional surface ozone (O_3) and nitrogen dioxide (NO_2) concentrations under the worst-case scenario modelled. Maximum concentrations in the region would not be affected. Regional concentrations and dispersion patterns of sulphur dioxide (SO_2) is also not influenced by the addition of a new gas-fired power station.

The results of the assessment of future acid deposition indicated that the contribution from HEC is relatively minor in the year 2012. The proposed new power station will help to reduce the overall acid deposition to the region by about 1% and the contribution of the new power station is negligible in the context of the emissions from the whole PRD region.

The assessment has also identified the increase in air emissions within the region. As shown in *Table 4.6a,* although NO_X and SO_2 emissions from Hong Kong have been projected (between 2002 and 2012) to increase at a maximum rate of approximately 13% for NO_X and 18% for SO_2, PRC emissions in the PRD region have been projected to increase at a maximum rate of 28% for both NO_X and SO_2 (between 2000 and 2010).

4.6.4 *Assessment Revisions*

Since the previous assessment, a few of the data parameters have been updated. Therefore, in this *Section*, these revisions and their impacts are discussed.

Information Update

Table 4.6d shows the revised projected NO_x and SO_2 emissions for the gas-fired option.

Table 4.6d ***Amended NO_X and SO_2 Emissions in Hong Kong and the Pearl River Delta (with the New Gas-fired Power Station Operating in 2012)***

Source	1995		2002		2012 Gas-fired	
	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr
HK International Airport	4,074	273	-	-	-	-
New International Airport Lantau	-	-	5,235	337	6,651	429
Marine Shipping & Pleasure Craft	16,953	5,221	20,024	6,167	24,412	7,518
Vehicle + Domestic + Industrial Surface	66,020	9,642	65,702	9,633	65,248	9,621
Town Gas Production Plant	559	117	808	169	1,164	244
Waste-to-Energy Incinerator Facility	-	-	-	-	7,842	3,921
HEC Total (gas for future)	20,510	27,690	41,068	47,687	24,669	18,426
CLP Total (gas for future)	39,746	128,408	34,557	58,329	24,301	10,693
Total Hong Kong Emissions	147,862	171,352	167,395	122,323	154,286	50,852
Total PRC (in PRD)[d] Emissions	232,500[a]	336,300[a]	1,040,000[b]	1,840,000[b]	1,450,000[c]	2,550,000[c]
Total PRD Emissions	380,362	507,652	1,207,395	1,962,323	1,604,286	2,600,852

Notes:
a - figures are for the year 1993
b - figures are for the year 2000
c - figures are for the year 2010
d - *Researches on Perspective Plan for the Pearl River Delta Economic Region*, Guangdong Province Planning Committee (1995)

HK International Airport

The airport emissions for NO_x were updated for 1995 according to the data presented in EPD's Territory-wide Air Quality Modelling System (PATH) emissions inventory (Working Paper D2). The SO_2 emissions were derived from a combination of the PATH inventory and the New Airport Master Plan. Projections for both pollutants into 2002 and 2012 were derived also from these two data sources.

Marine Emissions

In light of Hong Kong's position as a leading port in Asia, emissions from marine vessels has been inserted to reflect the contributions of the various major sources more accurately. The 1995 data was obtained from PATH, while the scaling factors used to project the emissions from this category for 2002 and 2012, were those adopted by the PATH modelling section of this Study, as discussed in *Section 4.5, Table 4.5a*.

Vehicle/Domestic/Industrial Emissions

The 1995 vehicle, domestic and industrial emissions have been revised according to the PATH inventory. For 2002 and 2012, vehicle and domestic fuel combustion emissions have been projected utilising the area emission scaling factors for the PATH modelling section of this Study, while industrial point source activities have been assumed to remain constant as many industries have moved across the border to the PRC. The scaling factors used to project the 'vehicle/domestic/industrial' emissions for 2002 and 2012 were adopted as discussed in *Section 4.5, Table 4.5a*. The scaling factor for vehicle activities was based on CTS-3 Main Model runs and the domestic area sources were scaled in accordance with the land use planning scenarios from the Territorial Population and Employment Data Matrices prepared by the Planning Department.

Town Gas

The 1995 emissions from Town Gas operations have been updated according to the PATH inventory. Projections of emissions in 2002 and 2012 were derived via extrapolation from historic Town Gas consumption data (available in Energy Statistics publications).

Waste-to-Energy Incinerator Facility (WEIF)

The emissions from the WEIF were updated to reflect that it will not be in operation until after 2002. The emissions were calculated based on the assumption of operation at full capacity.

HEC Total Emissions

Previous calculations of HEC emissions were based on preliminary calculations utilising generic emission rates for power stations as a whole. This method was used to yield worst-case or more conservative emissions estimates. In this *Review*, the HEC emissions were therefore updated using more detailed emission rates, specific to each individual power generation unit in operation at HEC, as well as the emission control specifications mandatory under Government legislation.

CLP Total Emissions

Previous calculations of CLP emissions were based on preliminary calculations utilising generic emission rates for power stations as a whole. In this *Review*, the CLP emissions were therefore updated using fuel consumption rates and the IPCC methodology for estimating NO_X and SO_2 emissions. More importantly, was the assumption of the use of coal for additional future electricity generation in the previous assessment, thus in this *Review*, it is assumed that gas is used for future additional electricity generation.

PRC Emissions in the PRD Region

The emissions from the PRD region have not been revised since the previous assessment, hence there are no changes to these figures.

Results

Table 4.6e shows the revised emission contributions of HEC operations to the PRD region.

Table 4.6e ***Summary of the Estimated NO_X and SO_2 Emissions from HEC and the Pearl River Delta***

Emissions	**1995**		**2002**		**2012 Gas-fired**	
	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr	NO_X tonnes/yr	SO_2 tonnes/yr
HEC	20,510	27,690	41,068	47,687	24,669	18,426
Total PRD Emissions	380,362	507,652	1,207,395	1,962,323	1,604,286	2,600,852
HEC Contribution to PRD Region	*5.4 %*	*5.5 %*	*3.4 %*	*2.4 %*	*1.5 %*	*0.7 %*

In terms of the PRD region, the total Hong Kong emissions of NO_x and SO_2 predicted for 2012 are respectively only about 9.6% and 2% of the total emissions from the PRD region. HEC contributions to regional NO_x and SO_2 concentrations in 2012 have been estimated to be approximately 1.5% and 0.7% respectively.

4.6.5 *Conclusion*

In conclusion, the new gas-fired station would contribute negligibly to maximum regional concentrations of O_3, NO_2 and SO_2, since the emissions from an additional power station, compared to the existing emissions in the PRD region, are extremely small. There will be a reduction of less than 2% in the predicted O_3 and less than 1% increase in the predicted NO_2 concentration from the new gas-fired power station.

With the introduction of the gas-fired station, HEC's contributions to the PRD regional NO_x and SO_2 concentrations amount to only 1.5% and 0.7% respectively in 2012. The proposed new power station will also help to reduce the overall acid deposition to the region by about 1%. Hence, it could be concluded that the contributions of the new gas-fired station to regional NO_x and SO_2 are negligible in the context of the emissions from the whole PRD region.

4.7 *GREENHOUSE GAS*

This *Section* presents the methodology and findings of the Greenhouse Gas Study carried out by Environmental Resources Management (ERM) for the Hongkong Electric Co. Ltd. (HEC) as part of the Environmental Impact Assessment (EIA) of a 1,800 MW Gas-fired Power Station at Lamma Extension. The Study Brief of the EIA requires HEC to carry out an assessment of the greenhouse gas (GHG) emissions from all HEC activities and to investigate and quantify possible measures to mitigate HEC GHG emissions.

4.7.1 *Background*

International Concerns

The issue of the potential impact on climate change of greenhouse gases (GHGs) is the second major environmental issue to be addressed in a global convention, the first being the Montreal Protocol that sought to phase out the use of ozone depleting substances (ODSs) which are associated with the depletion of the atmospheric ozone layer.

The Montreal Protocol brought to light the difficulties inherent in seeking to achieve global agreement to basic principles and commitments, even where there is a high level of scientific agreement regarding the causes and effect as was the case with the linking of CFC release with the continued depletion of the ozone layer.

For the issue of GHGs, there is a far wider spectrum of opinions regarding the potential influence on climate patterns of the so-called GHGs and hence more difficulties encountered when convincing countries to agree to a reduction in their emission levels of GHGs. For many of the identified GHGs, the actual global warming potentials have yet to be discerned from further research and only preliminary estimates are available. In fact, the actual mechanisms and probabilities of some of these effects are not yet clear and require more research. Consequently, these uncertainties in scientific fundamentals has led to the reluctance of some countries to commit to sharp reductions in their emissions of GHGs, particularly as it is feared that sharp reductions in GHGs may damage economic growth.

The Framework Convention on Climate Change (FCCC) is the primary international agreement on the control of GHGs, was endorsed by 166 countries in 1992 at the Earth Summit in Rio de Janeiro, Brazil. Among the signatories were the People's Republic of China (PRC) and the United Kingdom, both ratifying the Convention in 1993. Hong Kong, however, was not included in the signatory commitments given by either the PRC or the United Kingdom.

The main commitment of the FCCC is summarised in the following extract from Article 4:

"... each of these Parties shall communicate ... detailed information on its policies and measures, ... as well as on its resulting projected anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol, ... ***with the aim of returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases*** not controlled by the Montreal Protocol (emphasis added)."

At the Kyoto Conference held in Kyoto, Japan, on 10 December 1997, 160 nations reached an agreement to further limit GHG emissions. The Kyoto Protocol calls for the industrialised nations (the so-called Annex I countries) to reduce their average national emissions over the period 2008-2012 to about 5% below 1990 levels. The Protocol permits some nations listed in Annex I (those undergoing the process of 'transition to a market economy') to modestly increase their emissions. Special provisions have been made for the members of the former Soviet Bloc, while none of the developing countries, such as India and China, are required to limit their emissions.

Local Concerns

Hong Kong is presently not a signatory to the Convention as it was not included under the commitment made by the United Kingdom in 1992. In addition, it is unclear whether, under the sovereignty to China, Hong Kong is covered under China's participation in the FCCC.

To date, the only official reference to Hong Kong Government's policy on the FCCC can be inferred from paragraph 9.13 of *The Hong Kong Environment: A Green Challenge for the Community - Second Review of the 1989 White Paper on Pollution in Hong Kong - A Time To Act*, November 1993. In this review, the Hong Kong SAR Government states that its "view is that the immediate need is to assess and improve Hong Kong's performance in line with the principles of the Conventions." From this, it can only be assumed that the Hong Kong SAR Government has adopted the goal of returning Hong Kong GHG levels back to the 1990 GHG level, as stipulated under the FCCC.

A recent Greenhouse Gas Study that was undertaken in the Stage 1 EIA which was an integral part of the Site Search for a New Power Station for HEC, produced a GHG emissions inventory estimate for the whole of Hong Kong. Relative emission contributions from various sectors and fuel sources were studied and the most crucial of the conclusions of the study were that by the year 2012, aggregate Hong Kong CO_2 levels would surpass 1990 levels by over 9 Mt of CO_2 (26% more than the 1990 level) under the lowest scenario with HEC utilising gas, and that the electric utilities sector was one of the major contributors of CO_2 emissions. It was also found that the use of gas instead of coal for the proposed station would reduce CO_2 emissions by approximately 5.8 million tonnes.

4.7.2 *Objectives of the Study*

In fulfilment of the requirements of the EIA Study Brief, the objectives of the HEC Greenhouse Gas Study are:

- to assess the GHG emissions arising from all HEC operations; and
- to assess the possible measures for mitigating HEC GHG emissions.

The Study comprises of two components:

- compilation and projections of a GHG emissions inventory for the HEC system; and
- quantification and assessment of possible measures for mitigating emissions from the HEC system.

4.7.3 *Emissions Inventory*

Introduction

The following section presents the GHG emissions inventory compiled for the HEC system and details the methodology, data and assumptions used for the compilation and the projections of the HEC GHG emissions for the years 1990, 1995 (for HFCs and SF_6), 2002 and 2012.

It should be noted that the data utilised for this assessment may be slightly different from that used in the previous greenhouse gas assessment, as this assessment will focus on a new gas-fired station (6 x 300MW) rather than a coal-fired one (3 x 600MW). In addition, HEC's electricity demand forecast has recently been updated, therefore slightly changing the projected fuel consumption data. However, the changes are of a very small magnitude, hence the emissions estimated from this assessment were similar to those from the previous study.

Methodology

GHGs As Defined by the Kyoto Protocol

The six GHGs as defined by the Kyoto Protocol (1997) are as follows:

- carbon dioxide (CO_2);
- nitrous oxide (N_2O);
- methane (CH_4);
- hydrofluorocarbon gases (HFCs);
- perfluorocarbons (PFCs); and
- sulphur hexafluoride (SF_6).

In relation to the HEC system, use of PFC-containing substances has not been recorded. Hence, PFC emissions will not be assessed.

Quantification of GHG Emissions

The methodology adopted for compiling the HEC greenhouse gas emissions inventory was that detailed in the *Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories, Revised 1996*. The Hong Kong Environmental Protection Department (EPD) has indicated that like other countries, these Guidelines have been utilised in their calculations of GHG emissions.

The IPCC member organisations include:

- United Nations Environment Programme (UNEP);
- the Organisation for Economic Co-operation and Development (OECD); and
- the International Energy Agency (IEA).

The Guidelines are internationally accepted and are designed to allow all countries to determine their GHG emissions. As data availability varies significantly between countries, the Guidelines have been designed with a Tier system to allow for estimations under various levels of data sophistication. The Tiers generally describe a suite of methodologies that increase in complexity and accuracy. The complexity of the Tiers is usually consistent for the same gas and source sector, however, they may be different between different gases and sectors. For example, the Tier 2 method for estimating CO_2 from fuel combustion is more complex than the Tier 1 method for estimating CO_2, but the Tier 1 method for estimating CH_4 may be more complex than the Tier 1 method CO_2. Hence, it is common practice to use the most sophisticated level the available data allows.

The IPCC Guidelines classifies GHG emissions according to six major source categories: energy; industrial processes; solvent and other product use; agriculture; land-use change and forestry; and waste. Of these categories, only energy and industrial processes are of relevance to HEC operations. The energy module was utilised to calculate CO_2, CH_4 and N_2O emissions, while the industrial processes module was used to assess HFC and SF_6 emissions.

$\underline{CO_2}$

CO_2 emissions are assumed to be derived mainly from fuel combustion. As a result, the Tier 1 Method in the Energy Module for 'CO_2 Emissions from Fuel Combustion by Source Categories' was used.

$\underline{CH_4 \text{ and } N_2O}$

CH_4 and N_2O emissions are assumed, in the case of electricity generation, also to be produced mainly by fuel combustion, hence the Tier 1 Method for 'Non-CO_2 Emissions from Fuel Combustion by Source Categories' was utilised. Fugitive CH_4 emissions from the gas transmission system and related operational and maintenance processes, were estimated using the Tier 1 Method for 'Methane Emissions from Oil and Natural Gas Activities'.

$\underline{\text{HFCs and } SF_6}$

Emissions of HFCs and SF_6 from HEC are assumed to be solely from the consumption or use of these chemicals as they are not produced from electricity generation. In the HEC system, only two types of HFCs are utilised: R134a (HFC-134a), which is found in the air-conditioning systems of buildings and mobile equipment; and HFC-227ea, which is employed in the FM200 fire services system. The Tier 2 Methods of estimating HFC and PFC Emissions from 'Refrigeration and Air Conditioning Equipment' and 'Fire Extinguishers - Total Flooding Systems' were adopted accordingly, while SF_6 used in gas insulated switchgears (GIS) and transformers was estimated under the category of 'SF_6 Emissions'.

Global Warming Potential

In order to assess the potential climate effects of the various GHGs and the aggregate potential climate effect from HEC operations, global warming potentials (GWPs) were calculated and presented in CO_2 equivalents.

Each GHG may have different GWPs according to different reference time periods. The most common reference period is the 100-year equivalent basis, which reflects how significant the impact will be over a 100-year period. *Table 4.7a* presents the different GWPs for individual gases relevant to HEC operations, in units of CO_2 equivalents ($CO_{2\text{-}e}$).

Table 4.7a ***Numerical Estimates of 100-Year Global Warming Potential Relative to Carbon Dioxide (ie GWP of CO_2 = 1)***

Gas		GWP
carbon dioxide	CO_2	1
methane	CH_4	21
nitrous oxide	N_2O	310
hydrofluorocarbons	HFC-134a	1300
	HFC-227ea	2900
sulphur hexafluoride	SF_6	23900

Source: Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change* (Cambridge, UK: Cambridge University Press, 1996) p121.

Data and Assumptions

As directed by the IPCC Guidelines, local or specific data is used where possible and IPCC default values are employed only when such data is unavailable.

Reference Years

The HEC emission inventories of the five relevant GHGs will be compiled for three years: 1990, 1995 (base year for HFCs and SF_6, as directed by the Kyoto Protocol), 2002 and 2012. As stipulated by the Kyoto Protocol, the base year for CO_2, CH_4 and N_2O will be 1990, while 1995 is the recommended base year for HFCs and SF_6.

In this study, both HFC and SF_6 emissions from HEC for the year 1990 were also assessed in order to give an indication of the percentage contribution of the various GHGs to the total HEC GHG emissions for that year, as shown in *Table 4.7l*.

The year 1990, was established by the FCCC as the reference year by which all future years will generally be assessed. However, the Kyoto Protocol has stated that halogenated substances ie. HFCs, PFCs and SF_6, can be assessed with 1995 as the base year, due to the nature of their existence. 2002 is the year just before the first unit of the new power station is scheduled to become operational and 2012 is the year the new power station is scheduled to be fully operational.

Fuels

Data for HEC's consumption of coal, heavy fuel oil, light fuel oil and natural gas, were provided by HEC. The fuel categorisations assumed equivalent to the IPCC Guidelines are shown in *Table 4.7b*.

Table 4.7b ***Fuels Utilised in HEC Operations***

Fuel	IPCC Description	Hydrogen Content (%)	Carbon Content (%)
Coal	bituminous	4.0	68.0
Heavy Fuel Oil	residual fuel oil	11.0	85.5
Light Fuel Oil	gas/diesel fuel oil	10.5	86.0
Natural Gas	gaseous - dry	22.9	76.0

Source: Fuel suppliers and actual measurements by the Hongkong Electric Co. Ltd. in-house laboratory.

The Gross Calorific Values (GCVs) of the fuels were also provided by HEC. Manufacturer specifications of the fuels only included GCVs and gave no indications of the Net Calorific Values (NCVs). The GCV for each type of fuel is an average across the different brands or sources of the same type of fuel consumed. It is assumed that these average GCVs will not change through time, since the choice of fuel is restricted by the equipment utilising the fuels and it is envisioned that the equipment will not be replaced before 2012. Thus the GCVs used for 1990 were also applied to 2002 and 2012.

For CO_2 emissions calculations, GCVs were therefore used instead of NCVs, since the 'HEC-specific' carbon emission factors (CEFs) were calculated directly from the GCVs. This was considered to be more accurate than using NVCs derived from the GCVs in conjunction with CEFs that were in turn based on these derived NCVs. *Table 4.7c* shows the calculations of the HEC-specific CEFs for the various fuels utilised in the HEC system. IPCC default values were used for the 'fraction of carbon oxidised', as detailed in Table 1-6, IPCC Guidelines (Revised 1996), Volume 3: Reference Manual.

Table 4.7c ***Calculations of Carbon Emission Factors***

Fuel	GCV (TJ/kt)	GCV (t/TJ)	Carbon Content (%)	Carbon Emission Factor (t C/TJ)
Coal	26.38	37.91	68.0	25.78
Heavy Fuel Oil	42.32	23.63	85.5	20.20
Light Fuel Oil	46.29	21.60	86.0	18.58
Natural Gas	54.68	18.29	76.0	13.90

Source: Hongkong Electric Co. Ltd.

Consequently, to maintain consistency, GCVs were also used in the CH_4 and N_2O emissions calculations. The default IPCC CH_4 and N_2O emission factors were adjusted to account for the use of GCVs instead of NCVs, via 'correction values' which were calculated as shown in *Table 4.7d*.

Table 4.7d ***Calculations of CH_4 and N_2O Emission Factors***

Fuel	C/H Ratio (by weight)	GCV (TJ/kt)	NCV (TJ/kt)	Correction Value for IPCC Values
Coal	17.00	26.38	25.20	0.96
Heavy Fuel Oil	7.77	42.32	39.90	0.94
Light Fuel Oil	8.19	46.29	43.98	0.95
Natural Gas	3.32	54.68	49.77	0.91

Note:

(i) The conversion of GCV to NCV is based on the formula: NCV = GCV - [21.2 / (1+C/H)] (Source: "Combustion Calculations", E.M. Goodger)

(ii) The Correction Values are multiplied with the IPCC emission factors for CH4 and N2O to give the required emission factors from GCV.

Source: Hongkong Electric Co. Ltd.

The consumption of fuel in 1990 was based on the actual coal and oil consumed by HEC during the year and the projections of fuel consumption for 2002 and 2012 were based on the forecast of electricity demand. The HEC system load forecast adopted in this EIA study is in line with that recently submitted to Government, which is currently being reviewed by the ESB and its appointed consultants. HEC will update and advise EPD the revised inventory if the figures of the load forecast are adjusted after the review. In addition, the projected CO_2 reduction under the DSM Agreement corresponds to 4% of HEC's total CO_2 emissions by 2012.

CH_4

CH_4 emissions from the HEC operating system originate basically from two sources: combustion of fossil fuel; and fugitive emissions from the natural gas transmission and distribution system.

For emissions from fuel combustion, CH_4 emission factors were calculated by multiplying the IPCC default values (Table 1-7, IPCC Guidelines, Revised 1996, Volume 3: Reference Manual) by the correction values as shown in the last column of *Table 4.7d*. *Table 4.7e* lists the HEC estimates of CH_4 emission factors, adjusted for GCV values.

Table 4.7e ***Calculation of HEC Estimated CH_4 Emission Factors***

Fuel	IPCC Default CH_4 Emission Factor (kg/TJ)	Correction Factor	HEC Estimated CH_4 Emission Factor (kg/TJ)
Coal	1	0.96	0.96
Heavy Fuel Oil	3	0.94	2.82
Light Fuel Oil	3	0.95	2.85
Natural Gas	1	0.91	0.91

Fugitive emissions (or leakage) from the natural gas system are classified by the IPCC Guidelines into three categories: operational, maintenance and accidental. Operational leakage is defined as that arising from normal operation such as emissions associated with chronic leaks from pipe joints and gas receiving stations or discharges from process vents. Maintenance leakage refers to the leakage resulting from repair and maintenance processes (ie pigging inspection and (GRS) pipe section blowdown), while accidental leakage pertains to CH_4 released during pipeline failure or system upsets or accidents.

The HEC system is designed such that, with good operational and maintenance practices, there is minimal leakage from operational processes. However, there will be some operational CH_4 emissions from the HEC system due to a small continuous flow of natural gas (7.22m^3/hr) in the system, used to prevent oxygen accumulation in the venting/flare system. To provide a 'conservative' estimate, it has been assumed that these emissions will not be flared and as a result, they form the largest source of fugitive CH_4 emissions from the HEC system. However, it should be noted that HEC will actively pursue the possibility of flaring the continuous emissions. The possibility of flaring the continuous gas will be reviewed during detail engineering design, taking into consideration the operational and risk requirements. This will be included in the report to be reviewed by EPD as mentioned in *Section 4.7.5*. No occurrences of accidents are predicted, since HEC will be installing a state-of-the-art pressure relief system and precautions will be taken to prevent any construction or excavation activities from occurring near the gas transmission and delivery system. There will be some maintenance leakages from pigging and pipe blow-down processes. Both maintenance and accidental leakages, if they should occur, will be flared, thereby preventing the CH_4 from being released into the atmosphere (assuming 95% efficiency, within the IPCC suggested values, p1.116, Vol. 3).

Data for fugitive CH_4 emissions from the HEC system were provided by HEC and are presented in *Table 4.7f* below. It should be noted that HEC data is most appropriate in this situation as the IPCC Guidelines point out that the IPCC default values have been derived from a very small number of studies and the accuracy of these emission estimates are very uncertain (p.1.128, Vol.3) and so the use of local values are encouraged.

Table 4.7f ***Fugitive Emissions of CH_4 from HEC Operations***

Leakage Type	Process	Emission Rate - not mitigated (kg/year)
Operational	gas transmission & delivery	46,159
Maintenance	pigging & GRS pipe section blowdown (assuming 24" pipe)	3,625
Accidental	system upsets	negligible
Mitigation	flaring	95% efficiency
Source: Hongkong Electric Co. Ltd.		

N_2O

Similar to CH_4, N_2O emission factors were derived by multiplying the IPCC default values (Table 1-8, IPCC Guidelines, Revised 1996, Volume 3: Reference Manual) by the correction values in *Table 4.7d*. *Table 4.7g* shows the HEC estimates of N_2O emission factors, adjusted for GCV values.

Table 4.7g ***Calculation of HEC Estimated N_2O Emission Factors***

Fuel	IPCC Default N_2O Emission Factor (kg/TJ)	Correction Factor	HEC Estimated N_2O Emission Factor (kg/TJ)
Coal	1.4	0.96	1.34
Heavy Fuel Oil	0.6	0.94	0.56
Light Fuel Oil	0.6	0.95	0.57
Natural Gas	0.1	0.91	0.09

HFCs

The only two HFC substances currently utilised in the HEC system are: R134a (HFC-134a) as the refrigerant in the air conditioning systems of both mobile machines (scraper and cat loaders) at the Lamma Power Station and some stationary air cooling systems; and HFC-227ea, found in the FM200 fire suppression equipment (that operates by 'flooding'). There are no HFC chemicals in HEC's current window and split-type air-conditioning systems as they use mostly CFCs (either CFC-12 or HCFC-22).

HFC emissions due to the assembly of the air conditioning systems were not assessed since the systems were imported from overseas and emissions due to their assembly would have been accounted for by the manufacturing country. As for disposal, it should be noted that HEC has a policy of employing disposal contractors that carry out proper HFC disposal procedures which include recovery and reuse, and prevention of HFC leakage into the atmosphere. Hence, the IPCC default value adopted for the recovery rate at disposal is 80%.

Since HFC-134a is proven to be a reliable alternative refrigerant for HCFC chemicals (which are to be phased out in Hong Kong by the year 2030), HFC-134a will be used in HEC's future centralised air-conditioning plant (eg chiller units) in addition to the mobile machines. Two HEC multi-storey buildings, one newly commissioned in 1998 and another scheduled for operation in 1999 have also adopted HFC-134a as refrigerant in the air conditioning system. For future buildings adopting centralised air conditioning systems, it is expected that HFC-134a will also be used as refrigerant. For small air conditioning units such as window and split type units, R-22 (HCFC) will be still used as the refrigerant before any better alternatives are available commercially. Since a lifespan of 15 years for the stationary air conditioning equipment has been assumed and the related equipment installed between 1998 and 1999, disposal of the equipment will not be occurring before the year 2012. Hence, zero disposal activity for HFC-134a from the stationary equipment has been assumed.

It was projected that HEC will not be acquiring any additional mobile HFC air-conditioning equipment as all the mobile equipment (which is used for coal handling) will be decommissioned by 2012. However, the existing equipment will be kept in operation until the end of their lifespan (about 15 years), which means that disposal activities will start to take place in 2005. Therefore, by 2012, there will be no HFC-134a used or stored for mobile equipment, in the HEC system.

Table 4.7h lists the assumptions relevant to the calculations of HFC-134a emissions. Data for the consumption of HFC-134a by HEC operations were provided by HEC.

Table 4.7h ***Assumptions for HFC-134a Emissions***

Input	Value	Comment
Annual leakage rate	30 % (mobile) 17 % (stationary)	IPCC default value IPCC default value
Annual stock leakage rate	30 % (mobile) 17 % (stationary)	IPCC default value IPCC default value
Average equipment lifetime	15 years	IPCC default value
Amount of HFC in systems at time of disposal in% of initial charge	75 % (mobile) 90% (stationary)	IPCC default value IPCC default value
Amount of HFC recovered in % of actual charge (recovery efficiency)	80 %	IPCC default value assuming use of recovery practices (HEC confirmed use of recovery practices at disposal)

Consumption of HFC-227ea used in the FM200 fire services equipment, was projected according to forecasts on the development of rooms such as control, equipment storage and computer rooms.

The annual leakage rate for HFC-227ea emissions calculations was assumed to be 35%, as recommended in the IPCC Guidelines. It should be noted that periodic inspection of the FM200 fire services system and weighing of the gas cylinders is carried out by HEC. However, the Fire Services Department's (FSD) cylinder retest requirement of hydraulic testing, stipulated to be carried out within every 5 years, is performed outside of Hong Kong, therefore, any leakage occurring during product transfer should not be counted in the Hong Kong or HEC emissions inventories.

For disposal activities, it is assumed that 65% of the original amount of HFC-227ea would be present in the FM200 system at disposal time, if the losses are replenished periodically and the new stock and existing bank loss rates are assumed to be equal, as recommended by the IPCC (Reference Manual, p.2.61). Again, recovery practices will be implemented in the event of any FM200 disposal. Since, the FM200 system is assumed to have a lifetime of 30 years (by HEC, as there are no IPCC default values) and it is presently less than 10 years old, there will be no disposal of the system before the year 2012. Hence, the amount of HFC-227ea disposed has been assumed zero for all three case years.

Since 1997, HEC has been storing spare stocks of HFC-227ea, thus emissions calculations have included the potential leakage from these stocks. The IPCC default value of an annual leakage rate of 35% has been assumed.

Table 4.7i lists the assumptions relevant to the calculations of HFC-227ea emissions. Data for the consumption of HFC-227ea by HEC operations were provided by HEC.

Table 4.7i ***Assumptions for HFC-227ea Emissions***

Input	Value	Comment
Annual leakage rate	35 %	IPCC default value
Annual stock leakage rate	35 %	IPCC default value
Average equipment lifetime	30 years	HEC recommended
Amount of HFC in systems at time of disposal in % of initial charge	65 %	IPCC recommended
Amount of HFC recovered in % of actual charge (recovery efficiency)	80 %	IPCC default value assuming use of recovery practices (HEC confirmed use of recovery practices at disposal)

SF_6

In the HEC system, SF_6 is utilised in gas insulated switchgears (GIS) and transformers. Potential emissions can be divided into two main categories: operational and disposal. Emissions from operations include natural leakage as well as consumption from O&M processes. The natural loss factor of 0.1% was used in light of a report compiled by the Technical Committee in Japan for "Handling Rules of Electric Power Use of SF_6 Gas", 31 March 1998, on over 40 pieces of equipment, which recorded an annual leakage rate of less than 0.05%. Thus, assuming an annual leakage rate of 0.1% is considered on the conservative side. SF_6 is also released during the O&M process of arc quenching, with an estimated annual SF_6 consumption rate of approximately 0.6%. As with HFCs, HEC employs contractors that recover and reuse, as much as possible, the SF_6 remaining in disposed equipment. SF_6 gas is inert and is usually in good enough condition for recycle or reuse, which results in a high recovery rate and therefore less emissions. The forecast of SF_6 consumption in HEC is based on the scheduled installation programme of the equipment utilising SF_6 as insulating gas.

Table 4.7j lists the assumptions relevant to the calculations of SF_6 emissions. Data for the consumption of SF_6 by HEC operations were provided by HEC.

Table 4.7j ***Assumptions for SF_6 Emissions***

Input	Value	Comment
Annual loss factor	0.1 %	HEC recommended
Annual stock leakage rate	0.1 %	HEC recommended
O&M consumption rate	0.6 %	HEC recommended
Average equipment lifetime	35 years	HEC recommended
Amount of SF_6 in systems at time of disposal in% of initial charge	70 %	IPCC default value
Amount of SF_6 recovered in % of actual charge (recovery efficiency)	80 %	IPCC default value assuming use of recovery practices (HEC confirmed use of recovery practices at disposal)

HEC Greenhouse Gas Emissions Inventory

Absolute Emissions

An inventory of HEC GHG emissions was compiled and the results are summarised in *Table 4.7k*. Projections of the emissions for 2012 already take into account the mitigation measures that HEC have committed to.

Table 4.7k ***HEC Greenhouse Gas Emissions (in tonnes)***

Year	CO_2	CH_4	N_2O	HFC	SF_6
1990	6,317,058	67.03	90.86	0.001	0.659
1995	-	-	-	0.688	1.214
2002	11,355,533	127.79	161.97	7.688	1.877
2012	10,208,105	190.94	87.06	12.794	2.528

By 2012, CO_2 emissions from HEC operations will amount to approximately 10.2 million tonnes, thereby exceeding 1990 emissions by about 3.9 million tonnes (which translates into a 62% increase over the 1990 level, bearing in mind the total

HEC electricity generation in 2012 will be about 257% of that in 1990). This increase is deemed inevitable since the absolute amount of electricity that needs to be generated will increase and as long as fuel combustion-based technologies are used for power generation, carbon emissions will increase with the amount of fuel consumed. Based on historical data, it is expected that the electricity consumption is not directly proportional to population growth, as illustrated by the present estimates. It should be noted that 6.32 million tonnes of CO_2 for 1990 is higher than the 6.26 million tonnes estimated in the previous greenhouse gas assessment, due to the inclusion in the present assessment, the burning of oil, which is mainly used during start-up of the coal units.

HEC's decision to use gas over coal has aided in decreasing the gap between the 2012 and 1990 emission levels, as gas can provide more energy per tonne of fuel consumed (therefore less fuel needed) and has a carbon emission factor that is almost half that of coal. It has been estimated that if coal had been used instead, emissions in 2012 would be at about 10.3 million tonnes more than the 1990 level (as identified in the Stage 1 EIA Study), as opposed to the 3.9 million projected in this study (see also *Table 4.7m*).

As a result of it being a carbon-related emission, CH_4 emissions from fuel combustion in 2012 have also been predicted to surpass 1990 emissions, but only by about 124 tonnes. Again, the increase in electricity generation inevitably leads to an increase in carbon emissions. The use of gas instead of coal may have decreased the actual amount of fuel necessary for power generation, however, the use of gas in place of coal, leads to an increase in fugitive CH_4 emissions from the gas transmission and delivery system. HEC has plans for a flaring system with the capacity for flaring a total blowdown of the submarine pipeline, but for this assessment, only maintenance leakages are assumed to be flared, in order to yield more conservative estimates.

For N_2O, emissions in 2012 have been predicted to fall below the 1990 level by approximately 4 tonnes (amounting to a 4% decrease). This decrease is fundamentally due to the use of gas, which has a N_2O emissions factor that is only 6.7% of that for coal (ie coal's N_2O emission factor is about 15 times greater than that of gas). The large difference in emission rates between the two types of fuels has allowed an offset of the fact that the total amount of fuel consumed in 2012 will still be more than in 1990.

HFC emissions have been projected to increase to 12.8 tonnes by the year 2012, which is approximately 18 times that of the 1995 level (about 0.7 tonnes). The main reason for this increase is the switch from using ODSs (CFCs are banned while HCFCs are being phased out), which are not defined as greenhouse gases, to using HFCs as refrigerant in cooling systems. Unless alternatives to HFCs, that are also not ODSs, can be developed, this increase can not be avoided as cooling systems are essential for power station and associated operations.

SF_6 emissions in 2012 have been predicted to surpass 1995 emissions by 1.3 tonnes. The reason for this increase is the need for more SF_6 containing equipment, such as circuit breakers and transformers, to support the expansion of HEC's operations and activities, as a consequence of meeting the increasing electricity demand.

Global Warming Potential

The GWPs resulting from HEC emissions were calculated by multiplying the GHG emissions with the relevant GWP values as shown earlier in *Table 4.7a*. *Table 4.7l* shows the results of the GWP calculations as well as the relative contributions of the various GHGs (expressed as percentages) to the total HEC GHG emissions. *Figure 4.7a* graphically presents the GWP of the HEC GHG emissions by GHG and *Figure 4.7b* shows the trend of the total GWP of the HEC GHG emissions over time. Again, it should be noted that the results include the effect of implementing the mitigation measures committed to by HEC.

It is apparent that for the HEC system, absolute emissions of some GHGs are very small in comparison to others. For example, CO_2 emissions were in the order of millions of tonnes, while the next largest components, CH_4 and N_2O, are only in the order of tens or hundreds of tonnes.

However, it is acknowledged that the much higher GWPs of the "minority" GHGs, may render them very significant. Hence, the GWPs of the various GHGs were calculated. But as shown in *Table 4.7l*, even after considering the GWP effects of all the GHGs emitted by the HEC system, CO_2 still emerged as, by far, the largest contributor to HEC's total GWP. For all assessed years, CO_2 invariably accounted for at least 98% of the total HEC GWP. The next largest contributors to HEC's total GWP were N_2O, HFCs and SF_6, each contributing a little less than half a percent, while CH_4 emissions contributed a maximum of only 0.04%.

Table 4.7l ***Global Warming Potential of HEC Greenhouse Gas Emissions (in tonnes of CO_2 equivalents)***

Year	CO_2	CH_4	N_2O	HFC	SF_6	Total Emissions
1990	6,317,058 *99.29 %*	1,408 *0.02 %*	28,166 *0.44 %*	2 *0.00 %*	15,747 *0.25 %*	6,362,381 *100 %*
1995	-	-	-	1,990	29,006	-
2002	11,355,533 *98.96 %*	2,684 *0.02 %*	50,209 *0.44 %*	21,418 *0.19 %*	44,870 *0.39 %*	11,474,714 *100 %*
2012	10,208,105 *98.77 %*	4,010 *0.04 %*	26,988 *0.26 %*	35,842 *0.35 %*	60,415 *0.58 %*	10,335,360 *100 %*
Note: GWP	1	21	310	1,300/2,900	23,900	

Conclusion

It can be concluded that CO_2 forms the single largest component of HEC's GHG emissions. This suggests that future mitigation measures should focus, as a first priority, on decreasing CO_2, although it is recognised that implementing measures to decrease the other GHGs, should not be neglected.

The amount of CO_2 emitted per MWH produced by HEC over time, is shown in *Table 4.7m* and *Figures 4.7c* and *4.7d*. It can be seen that although the amount of GHGs emitted and electricity generated generally increase through the years, the GHG emissions per MWH drops dramatically after the commissioning of the first unit of the new station after 2002.

Table 4.7m ***HEC Greenhouse Gas Emissions per MWH for Case Years***

Year	HEC GHG Emissions (in tonnes of CO_2 eq.)	HEC System GWH	GHG Emission t/MWH
1990	6,362,380	7,447.4	0.854
2002	11,474,714	13,351.0	0.859
2012	10,335,359	19,142.0	0.540

This means that with the full commissioning of the new gas-fired station in 2012, HEC will be able to reduce its CO_2 emissions per unit of electricity generated, to 37% below the 1990 level.

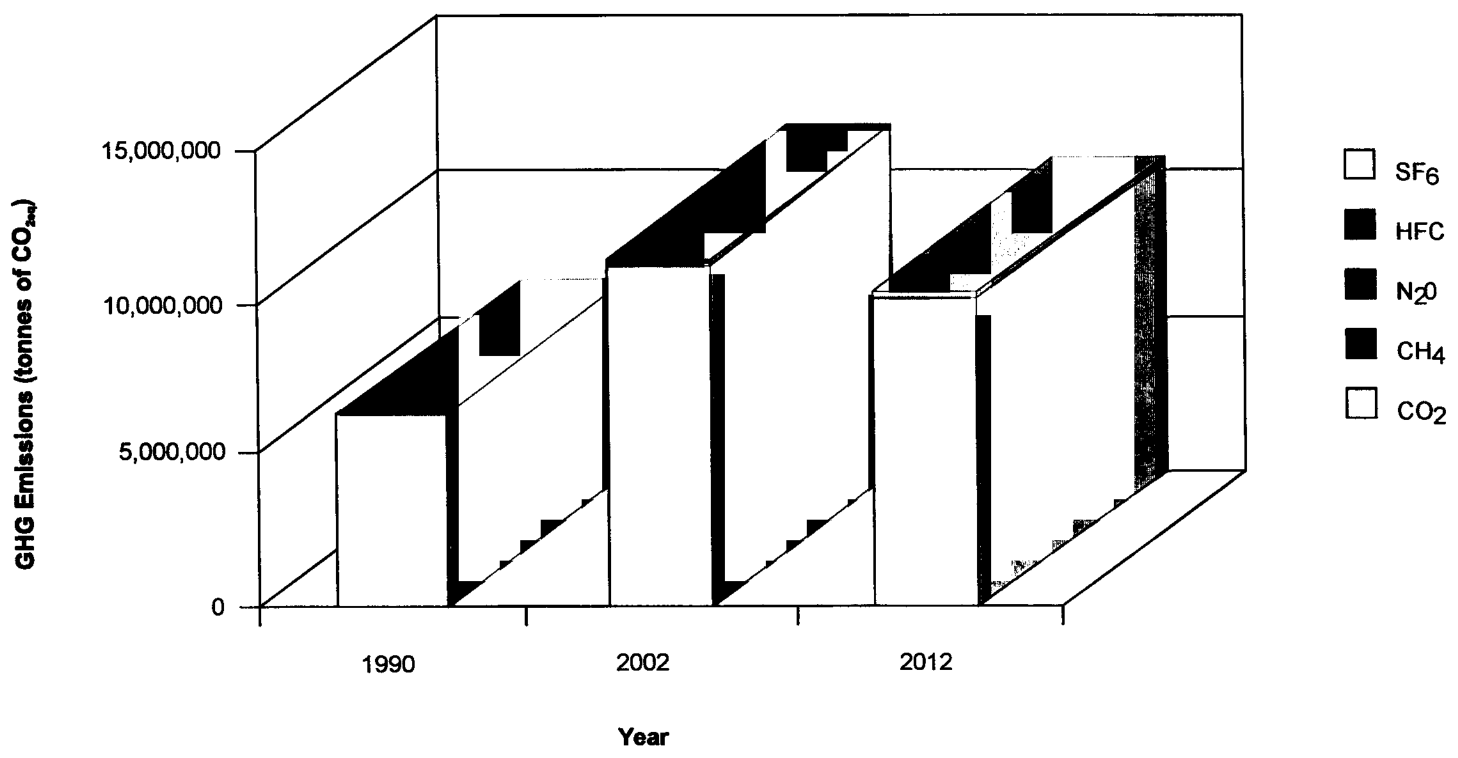


FIGURE 4.7a

HEC GREENHOUSE GAS EMISSIONS BY GHG

Environmental Resources Management

ERM

FILE: C1830/1830_4
DATE: 20/11/98

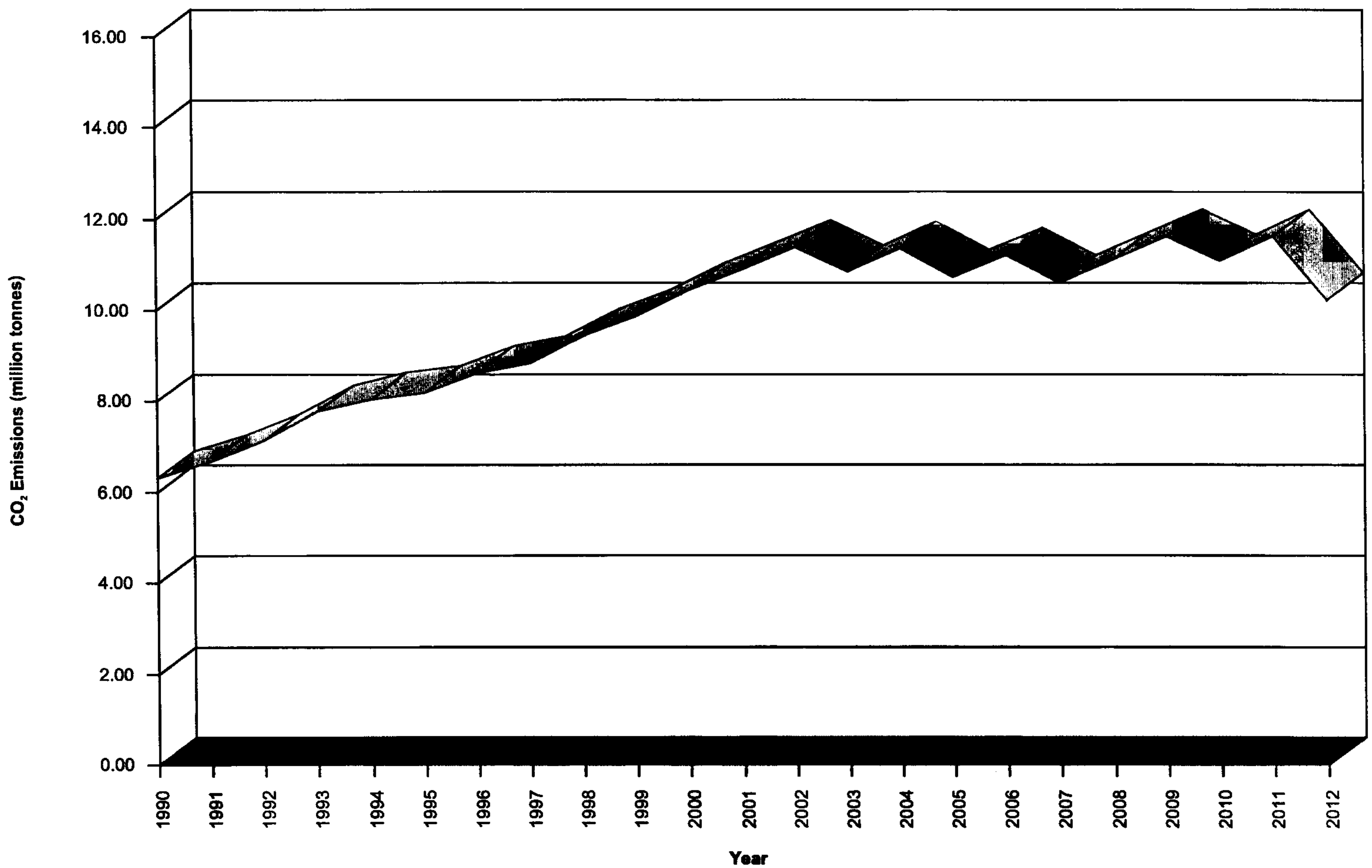


FIGURE 4.7b

HEC's CO_2 EMISSION TRENDS

FILE: C1830/1830_5
DATE: 20/11/98

Environmental Resources Management

ERM

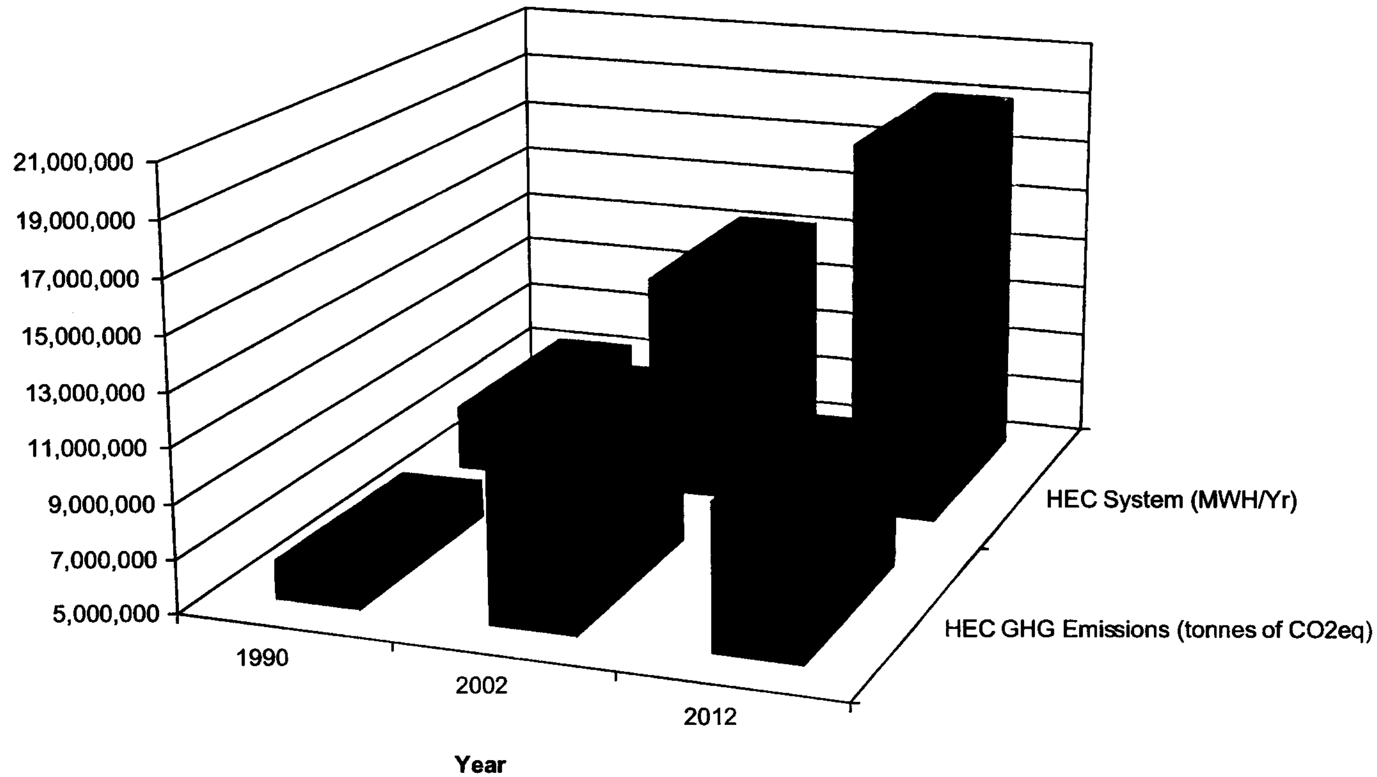


FIGURE 4.7c

TOTAL HEC GREENHOUSE GAS EMISSIONS AND ELECTRICITY GENERATION

FILE: C1830/1830_6
DATE: 20/11/98

Environmental Resources Management

ERM

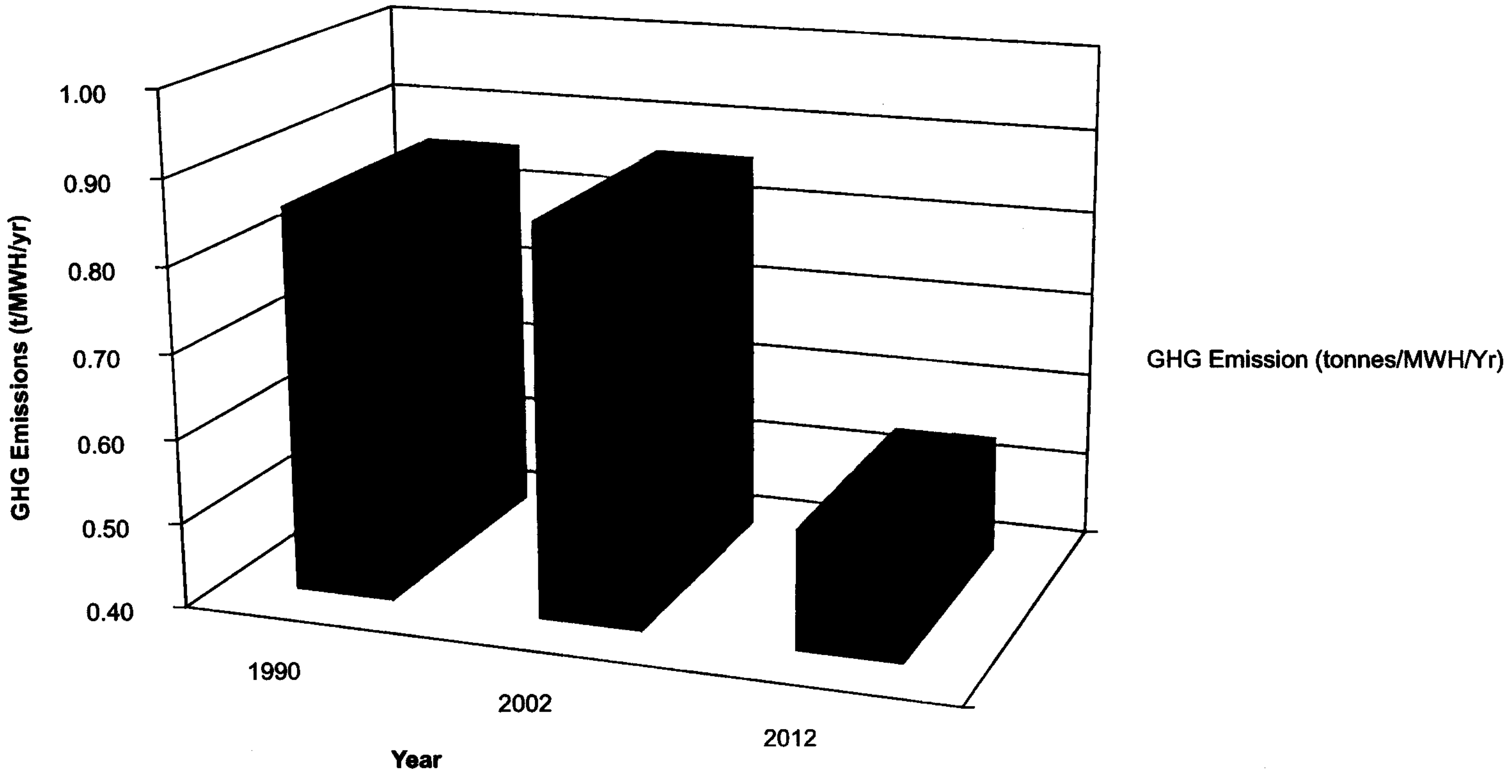


FIGURE 4.7d

HEC GREENHOUSE GAS EMISSIONS PER MWH

FILE: C1830/1830_7
DATE: 20/11/98

Environmental Resources Management

ERM

4.7.4 *Mitigation Measures*

Introduction

There are a number of options for the mitigation of GHG emissions from the electric utility sector which are generally classified into the following categories:

- increasing the efficiency of electricity production from conventional fossil fuels (eg coal and gas);
- switching to fuels that have lower GHG emissions than those currently in use (eg gas instead of coal);
- increasing the efficiency of electricity consumption through improved lighting, air conditioning, insulation, motors, etc;
- reducing fugitive GHG emissions and leakage; and
- sequestering carbon emissions.

Examples of options classified under these categories are discussed briefly in the following sections.

In addition, HEC's present tendering practices already taken into consideration, equipment efficiency and historic environmental records. HEC is constantly keeping an open mind to adopting any proven technologies of higher plant efficiency and better environmental performance systems in the design and equipment selection of the Lamma Extension project.

Improving the Efficiency of Electricity Production and Distribution

The total emissions from power stations can be reduced by increasing the efficiency of electricity production and distribution. Measures that improve electricity generation efficiency include:

- efficiency improvements; and
- cogeneration (capturing unused energy for use in other applications).

Measures that improve the efficiency of electricity transmission and distribution include:

- high efficiency transformers;
- reconductoring; and
- voltage distribution upgrades.

Increasing the Use of Low GHG-Emitting Fuels

Another approach is reducing the use of high GHG-emitting fuels. This includes the engagement of options such as:

- switching to fuels with lower GHG emissions (ie using gas instead of coal);
- preferential operation of the power units; and
- the use of renewable energy.

Increasing the Efficiency of Electricity Consumption

The approach of increasing the efficiency of electrical appliances and equipment is generally referred to Demand Side Management (DSM). Although this category is not within the scope of this study, a rough calculation will be performed for this assessment.

Reducing Fugitive GHG Emissions and Leakage

If applicable, CH_4 emissions from the transmission system could be reduced by:

- improving the maintenance and repair of seals on the gas transmission system to prevent leakage;
- good housekeeping practices to prevent accidental releases; and
- flaring of any fugitive emissions.

Fugitive HFC emissions and leakages can be minimised by:

- improving the maintenance and repair of seals on the HFC-containing equipment to prevent leakage;
- good housekeeping practices including regular inspection and maintenance; and
- implementing recovery practices for reusing HFCs from disposed equipment.

Since the largest consumers of SF_6 belong to the electricity generation sector, SF_6 emissions could be reduced via the following methods:

- improving the maintenance and monitoring the SF_6 gas pressure in the electrical equipment to prevent leakage;
- gas leakage detection by sensitive detection equipment;
- recycling and reuse in electrical equipment; and
- general good housekeeping practices.

Carbon Sequestration

GHG sequestration encompasses two main categories of methods:

- emissions removal from sources followed by appropriate storage and treatment procedures, to prevent or minimise GHG emissions into the atmosphere; and
- increasing the number or capacity of carbon sinks by planting and maintaining green plants or trees (eg. afforestation/reforestation programmes).

Assessment Methodology

The quantification of the reduction in GHG emissions due to the implementation of certain mitigation measures generally requires a certain amount of detail in the assumption of a 'base case' and the 'improved case'. The merits of a particular measure can vary greatly according to how rigorously implemented the measure was and the magnitude of the changes introduced. The experience of some overseas utility companies has shown that it is often difficult to assess the mitigation benefits until after the options have been implemented. Due to the lack of prior historic mitigation experience in Hong Kong, finding an appropriate base case for comparison is often difficult without utilising an arsenal of assumptions. It is acknowledged, however, that some measures may be easier to assess, like the effects of mitigation involving fuel combustion and efficiency, especially the reductions in CO_2.

For this study, possible mitigation measures to reduce GHG emissions related to the HEC system, as categorised in the *Introduction* of *Section 4.7.4*, were reviewed and the achievable GHG emissions reduction through these mitigating options, were quantified as far as possible, based on available information.

For consistency, the IPCC Guidelines or values that were calculated using the methodology outlined within the IPCC Guidelines, were used to quantitatively assess the emissions reductions possible for various mitigation measures. The same data used for the emissions inventory were also used for these assessments.

Assessment Results

Improving Electricity Generation and Distribution Efficiency

Electricity Generation

One of the most effective ways of reducing greenhouse gas emissions is to increase the efficiency of electricity production. A "Power Generation Technology Review" was conducted in the Stage 1 EIA Study which concluded that for electricity production by fossil fuel, gas-fired combined cycle technology is by far the most efficient method among all the commercially available or under development technologies.

Table 4.7n shows representative efficiencies for various types of power plants, as detailed in *Annex B* of *Technical Paper: Power Generation Technology Review* in the Stage 1 EIA Study.

Table 4.7n ***Efficiencies for Various Types of Power Plants***

Type of Power Plant		Fuel	Efficiency	Higher/Lower Heat Value
Advanced Pulverised Coal	APC	coal	40%	HHV
Integrated Gasification Combined Cycle	IGCC	coal	43%	HHV
Pressurised Fluidised Bed Combustion	PFBC	coal	42%	HHV
Circulating Fluidised Bed Combustion	CFBC	coal	36%	HHV
Gas Fired Combined Cycle	GFCC	gas	50%	HHV
Gas Fired Simple Cycle,	GFSC	gas	37%	HHV

It can be seen that gas plant efficiencies were found to range from 37% to 50%, while coal plant efficiencies ranged from 36% to 43%. For possible gas plant technologies, utilising GFCC over simple cycle GFSC resulted in a 13% difference in efficiency.

The inventory calculations were based on HEC's proposed use of GFCC technology. By utilising the percentage efficiencies as shown in *Table 4.7n* with the inventory results, a rough comparison could be quantified. Estimated CO_2 emissions from the various technologies are shown in *Table 4.7o*.

Table 4.7o ***Estimated CO_2 Emissions for Various Types of Power Plants in 2012***

Type of Power Plant		Fuel	Efficiency (%)	Estimated CO_2 Emissions (Mt)
Advanced Pulverised Coal	APC	coal	40%	16.3
Integrated Gasification Combined Cycle	IGCC	coal	43%	15.5
Pressurised Fluidised Bed Combustion	PFBC	coal	42%	15.7
Circulating Fluidised Bed Combustion	CFBC	coal	36%	17.5
Gas Fired Combined Cycle	GFCC	gas	50%	10.2
Gas Fired Steam Cycle	GFSC	gas	37%	11.9

In comparison to the presently proposed gas (GFCC) technology, it was projected that the amount of CO_2 emissions would be approximately 6.1 million tonnes more if the most feasible option of coal technology (APC) was used, while there would be about 1.7 million tonnes more if the gas technology, GFSC, was used.

Cogeneration

During the combustion process, only a portion of the fuel burned is converted into electrical energy - the rest is normally not captured. Cogeneration is the implementation of a category of technologies that aim to recover the portion of thermal energy that is normally not captured during fuel combustion and to divert it for use in subsequent applications.

Most cogeneration technologies that are currently considered as 'mature' are for the cogeneration of electricity and steam for use in district heating and/or industrial processes. As there is little large-scale industry in Hong Kong and no infrastructure in place for the bulk use of steam, such cogeneration technologies are not considered suitable for implementation in Hong Kong and were therefore not quantitatively assessed. Furthermore, the consumption of HEC's internal system (eg for hot water supply or air conditioning) is also too small to justify the construction of a cogeneration system from an economic point of view.

Electricity Transmission and Distribution

Efficient transmission and distribution of electricity can also reduce GHG emissions, as this would ultimately lead to less fuel being required to generate electricity for the enduser. Measures that increase the efficiency of electricity transmission and distribution include: the use of high efficiency transformers; reconductoring; and voltage distribution upgrades.

In general, the quantification of implementing these measures would require a 'base case', such as an old plant (with the same power generation technology) without any of these efficiency features and then a comparison of the old plant with the upgraded plant. In the case of HEC, all the technology and equipment to be utilised at the new plant will be the most practically efficient to date. To transmit power from Lamma Extension to Hong Kong Island, 275kV submarine cables will be utilised and advanced, high voltage transformers and associated transmission and distribution equipment, will also be employed to minimise transmission losses.

In this particular case, a quantitative assessment of the benefits of these measures was not carried out, since the benefits would vary depending on the 'base case' chosen and as mentioned earlier, the data for an appropriate base case were not available at the time of the study. The variability of the benefits of increasing electricity transmission and distribution efficiency is illustrated by some US electrical utility companies, which have seen GHG reductions ranging from hundreds of tonnes of CO_2 equivalents to over a hundred thousand tonnes.

According to HEC's statistics, the overall transmission and distribution (T&D) losses in HEC system in 1997 was 4.23%, which is already among the best in the world. This will be further improved with the advancement of the T&D technologies in future.

Increasing the Use of Low GHG-Emitting Fuels

Fuel Switching

Switching to fuels with lower GHG emissions is one of the most effective, and often least expensive, ways to reduce GHG emissions. The principle of this group of options is to use fuels that produce less carbon emissions. For instance, for the fuels utilised by HEC, coal has a carbon emission factor (in tonnes/TJ) that is approximately 30% higher than that of gas. Switching to fuels with no GHG emissions, such as nuclear or hydro power generation, would obviously have an even larger impacts. However, the feasibility of the safe application of non-GHG emitting technologies within Hong Kong, has yet to be demonstrated. Hence, the current electricity generation options in Hong Kong, that are both feasible and safe, are limited to fuel combustion-related technologies.

In its decision to utilise the GFCC technology, HEC has already committed the new power station to using gas. *Table 4.7n* indicates that the use of gas over coal, has resulted in CO_2 reductions of at least 6.1 million tonnes ie. assuming use of the most feasible coal technology (APC) and gas (GFCC).

In addition, HEC will be converting existing peak lopping oil-fired gas turbines to gas-firing ones, which will lead to a shift in the use of oil to gas. Not only does oil have a lower energy capacity (ie can provide less energy per unit mass of fuel), but it also has a higher carbon emission rate than gas. Both of these factors combine to render natural gas as a lower GHG-emitting fuel than oil. Therefore the shift from oil to gas will decrease GHG emissions from turbine operations. It has been estimated that such a conversion can result in a reduction of approximately 1,700 tonnes of CO_2 emissions in 2012.

Preferential Operations of Power Units

Preferential operation of power units refers mainly to the shifting of the base load to units with lower emitting capacities eg. switching the base load to gas-fired units from the coal-fired ones.

Other than the day time periods in the summer season, during which nearly all of the existing coal-fired units plus the additional gas-fired combined cycle will have to be operated to meet the electricity demand, HEC will have the option of exercising preferential operation. That is, the operation of a certain number of units for base load operation while shutting down the remaining units or leaving them on stand-by. With the commissioning of Lamma Extension, there will be two major types of machines in HEC System: coal-fired units in the existing power station and gas-fired combined cycle units in Lamma Extension.

It is estimated that in 2012 when Lamma Extension is fully developed, shifting of the base-load operation to the gas-fired combined cycle units, which is the assumption for the calculations in the inventory, can reduce the CO_2 emissions by up to 4.2 million tonnes compared to the case of base load operation of existing coal-fired units.

Use of Renewable Energy

Renewable energy is often cited as a potential alternative to the use of fuels for electricity generation. However, requirements, such as space and the presence of certain energy elements, as well as the maturity of the related technologies is often questioned. HEC recognises the potential for renewable energy and it is their policy to support research in this field, in the hope that one day, renewable energy will become a viable option for the SAR.

The Hong Kong University is presently carrying out research on Building Integrated Photovoltaic (BIPV) technology. This entails the use of Photovoltaic (PV) panels, or more commonly known as solar panels, as building components (cladding, roofing etc) and simultaneously generate electricity for powering the building services system. The objective of the study is to monitor the performance of a wide range of advanced thin-film PV module types such that a performance database can be established and made accessible to the building professionals for their application of PV in future development. HEC has offered sponsorship to support the next phase of research, which is to establish the daily and annual yield from diverse PV technologies in large arrays in different orientations in typical Hong Kong climates of high humidity and temperatures.

The Hong Kong Federation of Youth Groups intend to build a wind-powered and human-powered irrigation system in the Lamma Island Youth Camp. The purpose of the irrigation system is to provide water for the plants within the camp and to act as an educational demonstration of the application of wind energy. HEC has offered sponsorship for The Hong Kong University to carry out the engineering design of the irrigation system which primarily comprises of a windmill, driven unit and water conveyor belt. Furthermore, HEC is also planning to commence a separate field survey to investigate whether there is a suitable site on Lamma Island or Po Toi that has adequate wind energy potential for the development of a commercial-scale wind turbine.

Increasing the Efficiency of Electricity Consumption

It should be noted that in forecasting the future load demand for electricity, HEC has already taken into account the positive impacts arising from the promotion of DSM by HEC and the HKSAR Government. HEC made a DSM Agreement with the Government in November 1997 and has since signed and submitted a 3-year DSM Resource Plan to the Government for future implementation. Discussions with the Government on HEC's proposed DSM programme are ongoing.

It has been estimated that the electricity savings arising from the implementation of DSM is approximately 485 GWH in 2012. Assuming the additional 485 GWH of electricity is generated by the coal-fired units since the gas-fired ones will be used as base-load, it is estimated that DSM measures can result in a reduction of about 409,000 tonnes of CO_2 in 2012.

Reduction of Fugitive GHG Emissions and Leakage

Since the volumes of fugitive GHG emissions are usually small compared to GHG emissions from fuel combustion, the efficiency of related mitigation measures is sometimes questionable. However, emitters are still encouraged to implement such measures, if possible, as reductions in absolute emissions is the key to minimising the global climate effects of GHGs.

CH_4 Emissions

In electricity generation, fugitive CH_4 emissions are usually anticipated only from the gas delivery system and receiving stations. If the gas delivery pipes and joints are well-sealed and the receiving stations are well-maintained, minimal CH_4 leakage would be ensured. Related activities include: a change in operation and maintenance practices, such as reducing pipeline blowdown; directed inspection; and maintenance of controllers at gate or receiving stations. From US experience, possible CH_4 emissions reductions from this group of measures can range from a few tonnes to just over 1000 tonnes, although most registered reductions have been between 100 to 1000 tonnes.

The practice of flaring could be employed to further reduce CH_4 emissions, transforming the gas into CO_2, which has a lower GWP than CH_4.

For the HEC system, other than a few joints at the onshore section where flange connections will be used to facilitate maintenance, the whole pipeline from the Shenzhen LNG terminal to Lamma Extension will be of welded joint design. Hydrostatic testing will be carried out to confirm no leakage prior to the commissioning of the gas pipeline and receiving stations.

Pipeline failures causing leakage of natural gas are generally attributed to: corrosion, mechanical failure or third party activities. Considering HEC's use of advanced technologies and the installation of a certain number of measures at the design stage, it is envisioned that the chance of gas pipeline failure is remote. The gas pipeline for Lamma Extension will be made of steel that is specially designed for gas transmission (API 5L). Corrosion protection coatings will be applied on the internal and external surfaces of the pipeline and since LNG is moisture-free, gas leakage due to corrosion attack is not anticipated For protection against mechanical and third party damages, detailed surveys and feasibility studies have been carried out to identify areas where protection of the pipeline is required. Burial under seabed and mattress protection will be proposed and adopted to protect against pipeline damage or failure. Hence, CH_4 leakage from the actual pipeline is not expected. Periodic inspection of the pipeline by intelligent pigging will also be performed.

During normal operations, however, a small continuous flow of natural gas at 7.22 m^3/h (corresponding to 46,159 kg/yr CH_4) is required to prevent oxygen from accumulating in the venting/flare system. Since it is assumed that these CH_4 emissions will not be flared, they will constitute the largest portion of fugitive CH_4 emissions from the HEC system.

The emissions from maintenance work, such as pigging and pipe blowdown, will be flared. As a consequence of flaring, the total reduction in fugitive CH_4 emissions has been estimated to be approximately 3.4 tonnes in the year 2012. The net reduction in GWP will be approximately 62.8 tonnes of CO_2 equivalents.

It is the intention of HEC to flare any maintenance and accidental leakages, turning the gas into CO_2, which has a lower GWP than CH_4. The flaring efficiency has been assumed to be 95%.

HFC Emissions

General HFC mitigation measures include: improving the maintenance and repair of seals on the HFC-containing equipment to prevent leakage; good housekeeping practices including regular inspection and maintenance; and implementing recovery practices for reusing HFCs from disposed equipment.

In the HEC system, HFCs are used mainly as coolants or fire suppression gases. The best way of ensuring minimal leakages from the equipment containing the HFCs, is to implement regular maintenance and inspection of the equipment. In addition, the HFCs should be recovered and recycled as much as possible at the time of the equipment's disposal. Two types of HFCs are found in the HEC system: HFC-134a for cooling purposes, and HFC-227ea (FM-200) as a fire extinguishing gas. It is HEC's policy to engage disposal contractors that recover or reuse the HFCs after decommissioning of the equipment. The contractor's work will be monitored and managed to follow strictly the designated procedures as stipulated in HEC's specifications and work quality system, which includes requirements for the certification of workers and documentation.

For R-134a (HFC-134a) refrigerant, the leakage during operation is minimised by plant management system. In the chiller units adopting R-134a, the plant will be maintained by reputable contractors who will carry out preventive and remedial measures as necessary and provide 24-hour on-call services for emergencies. Again, the contractor's work will be monitored and managed to follow strictly the designated procedures as stipulated in HEC's specifications and work quality system. In case of overhaul work and plant disposal, the refrigerant will be recovered and recycled by appropriate equipment in accordance with the instructions issued by the equipment manufacturers. For HFC-134a in mobile equipment, regular inspection and routine maintenance of the mobile cooling systems will take place to ensure minimal leakage or fugitive emissions. In fact, all related mobile equipment will be decommissioned in 2010 because they will no longer be needed as coal-related activities will decrease with the commissioning of the new gas-fired units. Consequently, there will not be any HFC-134a emissions from mobile equipment sources in the HEC system from that year onwards.

For the FM-200 (HFC-227ea) system, regular testing and maintenance work will be performed by HEC staff and registered contractors in accordance with the statutory requirements and the accepted procedure stipulated in the operation manuals. The procedure includes both the preventive and remedial measures to ensure proper function of the system. The testing and maintenance work comprises visual inspection, functional test, gas quantity check and hydraulic test for gas containers. The test and maintenance reports will be documented and filed for future reference.

Quantification of the HFC emissions mitigated by the adoption of good recovery and reuse practices for disposal activities is not possible for this assessment as disposal activities have not been projected for the years prior to 2012. It is envisioned that disposal activities will be relevant after that year but its exclusion allows for a more conservative estimate of HEC's emissions.

SF_6 Emissions

It has been estimated that globally, 80% of SF_6 is used in gas-insulated switchgear and circuit breakers, making the electricity generating sector the largest consumers of SF_6. Although the amounts of absolute emissions are small, the amount of GWP reduction could prove substantial.

Similar to HFC mitigation, fugitive emissions of SF_6 from HEC can be reduced by: improving the maintenance and monitoring of the gas within the system to prevent leakage; employing gas leakage detection by sensitive detection equipment; and general good housekeeping practices. In addition, recycling of SF_6 and reuse in the electrical equipment can also contribute to emissions reductions.

HEC currently adopts a number of measures to minimise SF_6 gas emission to the atmosphere. Every gas zone of the SF_6 gas insulated plants in HEC is equipped with pressure gauges to monitor the gas pressure and is installed with a pressure low alarming system to detect any abnormal gas leakage. The alarm is relayed back to HEC's System Control Centre which is manned on a round-the-clock basis such that the responsible engineer can be called out to site to take the appropriate action to rectify the leakage. With this alarm system, although abnormal gas leakage is not normally expected, appropriate action can be taken in the rare event that it is detected.

Gas leakage inspections are carried out at regular intervals, every 3 to 5 years, using sensitive detection equipments. SF_6 gas insulated equipment are hermetically sealed. The gas insulated parts require minimal inspection and maintenance. From an operational and reliability point of view, it is HEC's policy to discourage opening up a SF_6 gas insulated equipment. SF_6 gas should not be released into the atmosphere during any installation and maintenance work. Only in exceptional conditions will the gas insulated parts will be opened up. Under such circumstance, the gas shall be reclaimed, purified, temporarily stored and reused. HEC possesses a large number of gas treatment plant/equipment for those purposes. SF_6 gas is inert, therefore its properties will not deteriorate with time. Consequently, when a piece of gas insulated equipment is coming to the end of its normal service life, the SF_6 will still be in good condition and can easily be recycled or reused. However, since the longevity of gas insulated equipment is about 35 years, disposal of SF_6-containing equipment will not take place before 2012.

From HEC's past experience, it is expected that the loss of gas during the transfer is minimal. HEC is currently discussing with the equipment manufacturers, methods to minimise the loss during gas transfer between gas insulated equipment and gas treatment plants. Records of the transfer efficiency are presently unavailable.

It has been estimated that with the implementation of the above measures, the amount of SF_6 reduction that can be achieved by HEC in 2012 is approximately 1.2 tonnes of SF_6, which amounts to a reduction of over 28,000 tonnes of CO_2 equivalents.

Carbon Sequestration

Carbon sequestration refers mainly to the 'storage' of carbon, which can reduce the amount of GHG in the atmosphere. Sequestration can be accomplished through either the removal of CO_2 from smoke stacks and the subsequent storage of the gas or carbon, or forestry programmes that increase the amount of carbon absorbed and stored in the biomass.

Removal From Smokestacks

The removal of CO_2 from smokestacks is still in the conceptual stage and has not yet been tried on a large scale basis. Some of the different theories put forth include:

- low temperature (cryogenic) separation;
- polymeric membrane separation;
- ceramic absorption; and
- absorption in chemicals such as aqueous amine.

Once the CO_2 has been removed by one of these methods, it must be stored in such a way that it is not released back into the atmosphere or used for other applications. Some of the proposed methods of storage include:

- deep saline aquifers;
- depleted oil and gas reservoirs; and
- underground cavities.

Current estimates of the cost of removing CO_2 by each of these methods are significant, requiring high capital cost investment, and possibly considerable amounts of energy to run the systems (eg liquefying the CO_2 by cooling it as it leaves the smokestack). Some novel methods are currently being researched or tested in the demonstration stage. Given the present level of technology, none of the above options should be considered feasible on a large scale basis.

Afforestation and Reforestation

A number of utility companies worldwide currently have programmes to sequester carbon in trees through a number of methods, including:

- paying logging companies to modify the way in which they manage their forests to preserve non-harvested biomass;

- purchasing land and turning it into park land which will never be developed; and

- planting trees.

However, it should be noted that in general, massive areas of forestation are usually required to provide enough carbon capacity to totally offset the emissions from a typical power station. Although different species of plants in different climates and geographical areas will have different sequestration rates, it is often not practical to count on carbon sequestration as the major means of mitigation. Furthermore, other major challenges with afforestation programmes include the development of mechanisms for monitoring implementation and maintenance, the lack of benchmarks to determine the contribution of the afforestation programme to GHG levels and the need to manage the programme in perpetuity.

Nevertheless, in seeking to take practical approaches to offset GHG emissions, particularly CO_2 emissions, HEC is committed to implementing compensation programmes. HEC will strive to explore the feasibility of the afforestation scheme in partnership with the Hong Kong based green groups and the local authorities through: providing funding to local activities such as those organised by the green groups and Government organizations involving tree planting and/or preservation; and taking a pro-active approach in searching for participation opportunities in forestry improvement programmes, especially in the area of the Pearl River Delta, due to the limitation of area available for forestation in the HKSAR territory.

HEC is a sponsor of the *Corporate Afforestation Scheme* launched by the Agriculture & Fisheries Department (AFD) in 1998. It is a three-year (1998-2000) planting and forestry management project aimed at accelerating the greening process of the countryside with degraded slopes caused by hill-fires and soil erosion. Details of HEC's involvements in the Corporate Afforestation Scheme are shown in *Table 4.7p*.

Table 4.7p ***HEC's Involvements in the Corporate Afforestation Scheme***

Particulars	Tai Lam Country Park	Tai Tam Country Park
Location	Tsuen Wan	Quarry Bay
Period	1998 - 2000	1998 - 2000
Area of Woodland	2 ha	1 ha
No. of Trees	min. of 10,000	min. of 4,000
Project Agent	Friends of the Earth	Conservancy Association
Representative Species	*Acacia spp.*	*Acacia spp.*
Estimated CO_2 Sequestered	55 tonnes	27.5 tonnes

Due to the lack of information at the present time, the *Acacia spp.*, which is very common in Hong Kong, was assumed as the representative species for local plantation, for the purpose of this assessment.

In terms of non-local projects, HEC has committed to a tree planting expedition at Ho Yuen in the Guangdong Province, which commenced in March 1998. This land greening activity, as part of the "Green Gift to Home Country Project", was organised by the Conservancy Association of Hong Kong and sponsored by HEC. The Project consists of a series of tree plantation and land conservation activities at different locations at the mainland sites for the coming three years. It involves greening and conservation work in the Xin Feng Jiang National Forest Park beside the Xin Feng Jiang Reservoir at Ho Yuen. The sponsorship targets a tree seeding of more than 22,100, with 22 species in about 20 hectares within a three-year period. *Table 4.7q* shows the assumptions made for calculating the afforestation efforts by HEC in the PRC.

Table 4.7q ***HEC's Involvement in a PRC Afforestation Scheme***

Particulars	Guangdong Province
Location	Xin Feng Jiang Reservoir, Ho Yuen
# of Sites	3
Period	1998 - 2001
Area of Woodland	20 ha
No. of Trees	22,100
No of Species	22
Project Agent	Conservancy Association
Representative Species	Loblolly Pine
Estimated CO_2 Sequestered	146.7 tonnes

To facilitate a general calculation of the CO_2 sinks formed as a result of HEC's commitment to the "Green Gift to Home Country Project", a representative species with an IPCC default value was chosen.

Using IPCC methodology and default values for the representative species, it has been estimated that the total amount of CO_2 emissions sequestered by HEC's afforestation commitments amount to approximately 229 tonnes per year. This illustrates the magnitude of area required to generate more substantial sinks. Although it is a fact that the actual CO_2 sequestration potential for a specific area varies according to the plant species, as well as the climate and geology of the area, it can generally be assumed that thousands of hectares can sequester in the order of tens of thousands of tonnes of CO_2.

The HEC's afforestation schemes currently in progress, are for pilot purpose only. HEC will continue to actively explore opportunities of afforestation and forest conservation in Hong Kong and mainland areas. Potential project(s) include the woodland conservation and reforestation programme in mainland, supported by the local Environmental Protection Bureau and State Forestry Bureau. These are long term projects which are scheduled to last for 5 to 10 years.

Summary of Findings

Table 4.7r summarises the findings of the mitigation assessment. All calculated figures are based on the IPCC method of calculation. IPCC default values were used to generate the low and/or high estimates of mitigated emissions, while the HEC estimates are based on HEC data.

Figures 4.7e and *4.7f* show the amount of GHG emissions reduced by HEC's implementation of various mitigation measures, while *Figure 4.7g* shows the trend of the total HEC GHG emissions reductions.

Summary of Findings for Mitigation Assessment for 2012

Category of Mitigation Measures	Mitigated Annual Emissions - Low Estimate (tonnes of CO_{2-e})	Mitigated Annual Emissions - High Estimate (tonnes of CO_{2-e})	HEC Estimated Mitigated Annual Emissions (tonnes of CO_{2-e})
Electricity Generation Improvement	5,300,000 IGCC - GFCC	7,250,000 CFBC - GFCC	6,060,000 APC - GFCC
Cogeneration [a]	≤ 100 US experience	≥ 350,000 US experience	not applicable
Electricity Transmission [a]	≤ 100 US experience	≥ 100,000 US experience	data not available
Fuel Switching - station	5,300,000 IGCC - GFCC	7,250,000 CFBC - GFCC	6,060,000 [b] APC - GFCC
Fuel Switching - gas turbines	-	-	1,700 oil- to gas-fired
Preferential Operations	-	-	4,236,000 [b] APC - GFCC
DSM Measures	≤ 1 US experience	≥ 1,000,000 US experience (but usually less than 100,000)	409,000 485 GWH saved, gas as base-load & coal as topping
Fugitive CH_4 Emissions	52.9 80% flaring efficiency	66.2 100% flaring efficiency	62.8 95% flaring efficiency
Fugitive HFC Emissions	-	-	data not available
Fugitive SF_6 Emissions	-	-	28,000 HEC annual loss factor of 0.7%, IPCC default for stock leakage of 1%
GHG from Smokestacks	-	-	not applicable
Afforestation / Reforestation	≤ 1 per ha assuming 'other forests' in IPCC	~ 27.5 per ha assuming *Acacia spp.* in IPCC	229 IPCC default - *Acacia spp.* (HK), Loblolly pine (PRC)
Total			6,498,992

Notes: (a) Only a qualitative review was carried out with reference to US experience.
(b) The measure assessed in this category was not calculated in the Total as it is already covered in the Electricity Generation category.

It can be seen that the use of natural gas as fuel and the preferential operation of the CCGT units as base-load units, will significantly reduce HEC's annual CO_2 emissions by over 6 million tonnes. Combined with the other measures, the total mitigated CO_2 emissions in 2012 would be approximately 6.5 million tonnes, which is more than HEC's total CO_2 emissions in 1990.

The following is a summary of the mitigation measures that will be implemented by HEC to reduce GHG emissions from its operations:

- adoption of high efficiency combined cycle units;
- use of natural gas instead of coal;
- converting existing peak lopping oil-fired gas turbines to gas-firing ones;
- actively pursuing the development of renewable energy potential in Hong Kong, such as the photovoltaic cell and wind energy;
- promotion of Demand Side Management (DSM); and
- participation in afforestation schemes.

4.7.5 *Recommendations*

Improving Electricity Generation and Distribution Efficiency

In terms of electricity generation, the most efficient technology available are recommended. As discussed earlier in this Study and from the results of the previous Stage 1 EIA, given the present situation, the use of the GFCC technology would be best. However, care needs to be taken as to whether the generation or version of the technology adopted has been thoroughly tested and proven to have reached maturity. In response, HEC has already committed to the use of the GFCC technology for the new proposed power station and the generation of the technology to be used will be the second generation turbines with a turbine inlet temperature (TIT) of 1,300°C, which have been fully researched, redesigned and tested for troubleshooting previous problems.

For electricity transmission and distribution (T&D), it is recommended that the use of the most efficient transformers and high voltage cables feasible, to which HEC has already made a commitment. A loss rate of 4.23% was recorded in 1997, amongst the lowest in the world and HEC will aim to improve or maintain this rate.

Increasing the Use of Low GHG-Emitting Fuels

In terms of fuel use, it is recommended that if only fuel combustion technology is feasible at this stage in time, any additional power units should be gas-fired rather than coal-fired. In response, HEC has already clarified that the proposed power station will be gas-fired, which is an improvement on coal. It has been estimated that the use of gas over coal for the new power station will result in a CO_2 emissions reduction of about 6 million tonnes.

It is also recommended that equipment utilising high GHG-emitting fuels be replaced with those using low-emitting GHG fuels or that equipment be altered to achieve the same effect. To this end, HEC will be converting existing peak lopping oil-fired gas turbines to gas-firing ones, which will lead to a shift in the use of oil to gas. This will decrease GHG emissions from turbine operations. Any schemes or plans of such conversions will be submitted to EPD prior to the commencement of the works.

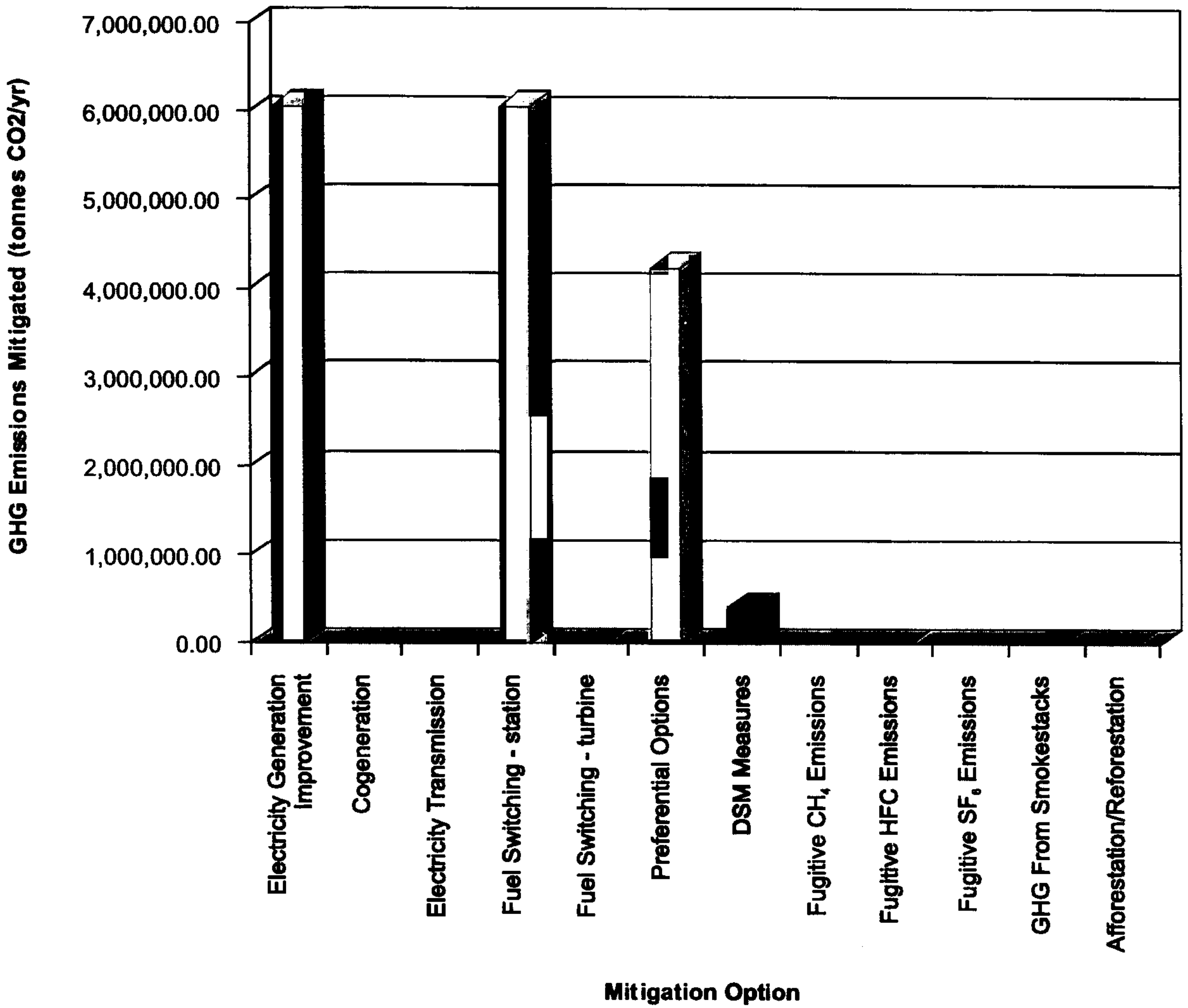


FIGURE 4.7e

GHG MITIGATED BY EACH CATEGORY

FILE: C1830/1830_8
DATE: 20/11/98

Environmental Resources Management

ERM

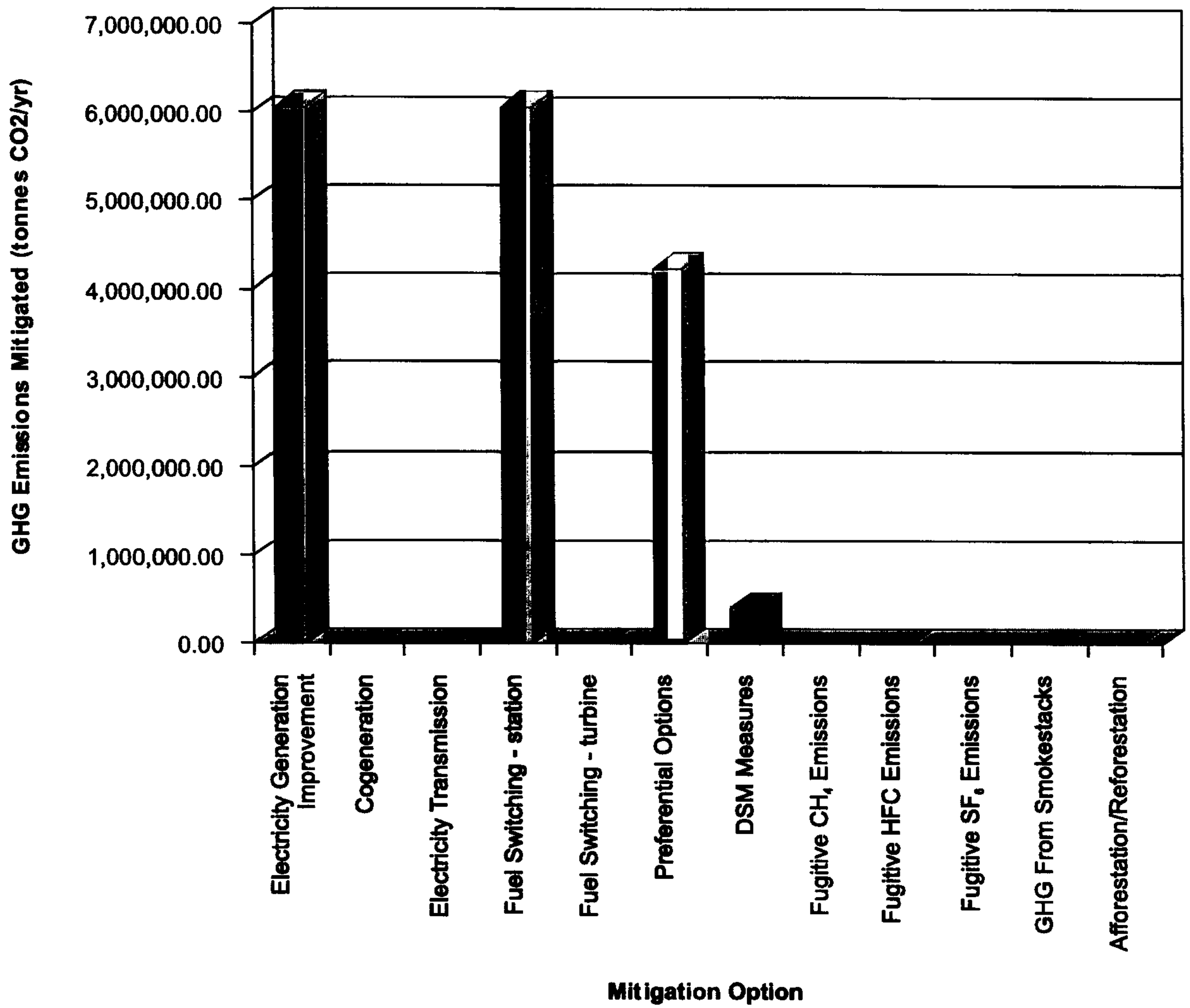


FIGURE 4.7e

GHG MITIGATED BY EACH CATEGORY

FILE: C1830/1830_8
DATE: 20/11/98

Environmental Resources Management

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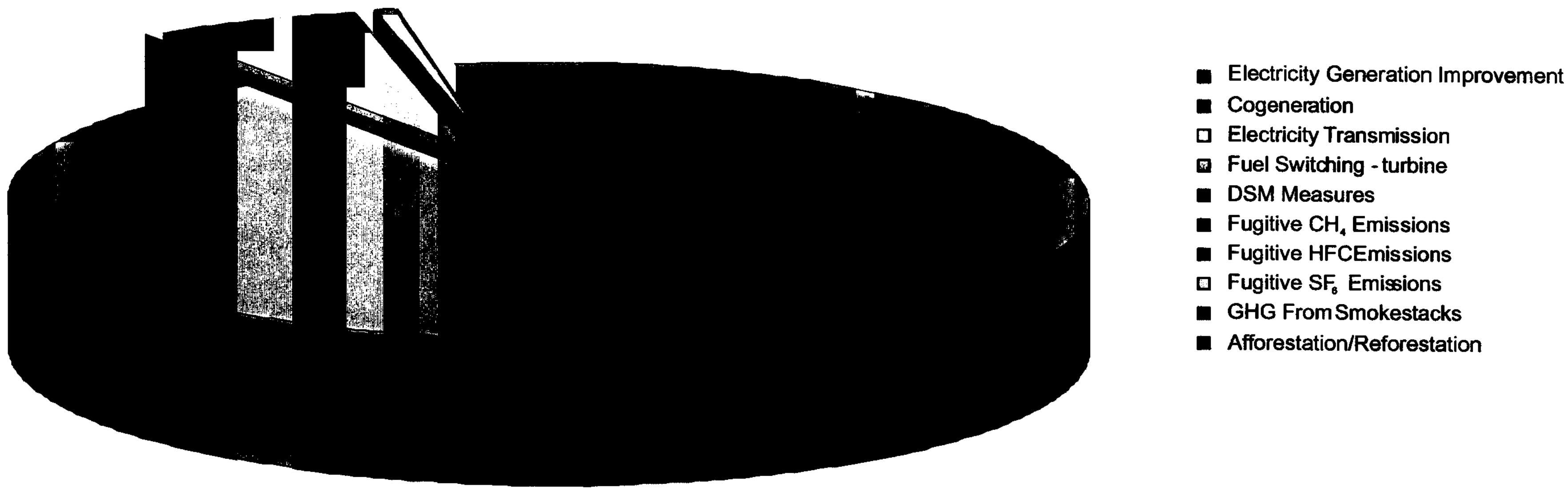


FIGURE 4.7f

CONTRIBUTION TO TOTAL HEC MITIGATED GHG EMISSIONS
(note that 'Fuel Switching-station' and 'Preferred Operations' are omitted as they are covered by 'Electricity Generation')

FILE: C1830/1830_9
DATE: 20/11/98

Environmental Resources Management
ERM

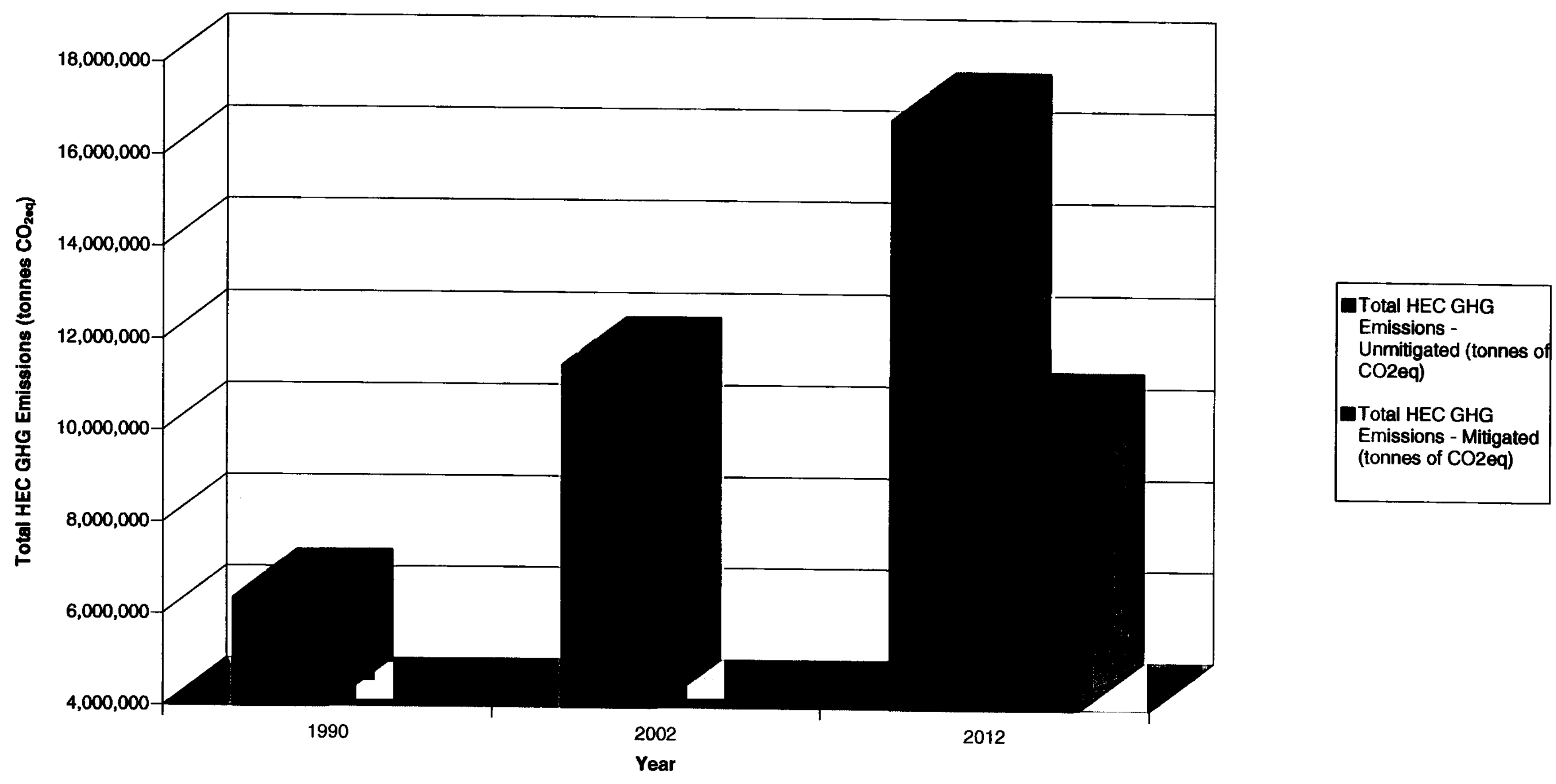


FIGURE 4.7g

TOTAL HEC GREENHOUSE GAS EMISSIONS IN 2012 FOR MITIGATED AND UNMITIGATED OPTION

FILE: C1830_26
DATE: 04/02/99

Environmental Resources Management

ERM

If non-combustion technologies ever become feasible in Hong Kong, such technologies should be given due consideration for future power generation development. To this effect, HEC has been funding research on the development of renewable energy potential in Hong Kong, such as the photovoltaic cell and wind energy. HEC will continue to actively pursue and aid in developing this potential.

For base-load shifting, it is recommended that the gas units be utilised as the base-load with the coal units as peaking units. As recommended, HEC intends to implement the gas-fired units as base-load. It has been estimated that shifting the base-load to gas-fired units could result in CO_2 reductions of approximately 4 million tonnes.

Increasing the Efficiency of Electricity Consumption

The implementation of DSM is also recommended. From overseas experience, it has been demonstrated that this category of measures can, if widely implemented, yield large and more long-term reductions in comparison to other measures. Recognising this, HEC made a DSM Agreement with the Government in November 1997 and has since signed and submitted a 3-year DSM Resource Plan to the Government for future implementation. Discussions with the Government on HEC's proposed DSM programme are ongoing and it is HEC's intention to continue to explore DSM-related possibilities. The expected GHG reduction achievable due to the DSM programme, once approved by the Government, will be reflected in the annual inventory report for continuous monitoring.

It has been estimated that the electricity savings arising from the implementation of DSM is approximately 485 GWH in 2012, translating to a reduction of a possible 409,000 tonnes of CO_2.

Reduction of Fugitive GHG Emissions and Leakage

Voluntary Reduction of HFC, PFC and SF_6 Emissions

It is recommended that general good housekeeping be implemented to ensure that the systems or equipment containing the gas, will not 'leak' out. Associated measures include:

- routine maintenance and inspections;
- minimising emissions during the installation, operation, maintenance, repair, disposal, and decommissioning of systems and equipment containing HFCs, PFCs and SF_6;
- requiring leak monitoring on a regular basis, via detection equipment and inspections;
- requiring leak testing and repair prior to top up of systems that have lost HFCs, PFCs or SF_6;
- requiring the practice of recovering and recycling to the maximum extent feasible using appropriate recycling equipment; and
- having a disposal plan which will eliminate the release of HFCs, PFCs and SF_6 into the ambient environment.

HEC will explore the feasibility of adopting a comprehensive Life Cycle Management Program for SF_6 and the utilisation of SF_6 reclaiming and HFC/PFC recycling technologies. HEC will submit to EPD for review, a detailed proposal for the above voluntary emissions reduction programme before the commissioning of the first 300 MW gas-fired unit.

Reducing CH_4 Emissions

For the gas transmission and distribution system, equipment should be chosen and measures taken, so as to prevent CH_4 leakage from the delivery system. In accordance with this recommendation, HEC will be implementing the following:

- corrosion-preventing coatings on the pipeline;
- welded pipe joints; and
- conducting or sponsoring studies to designate areas of the pipeline that require protection and to ensure that no activities that may pose a threat to the integrity of the gas delivery system will be allowed.

Emissions from maintenance activities, such as CH_4 from pigging and pipe blowdown, should be minimised by changing the maintenance practices to result in smaller or less frequent emissions. HEC will be designing procedures for maintenance operations that will cater to this objective.

Flaring of operational, maintenance or accidental CH_4 emissions, is recommended, as the transformation to CO_2 results in lower GWP emissions. All remaining emissions will be flared, assuming an efficiency rate of 95%. The flaring system must be designed with a capacity that can at least accommodate gas blow down of the entire pipeline, in case of an emergency.

Target reduction and achieved results of the above procedural controls will be reported in the annual inventory reports.

HEC will also submit to EPD for review, a report of the above actions, including procedures to reduce emissions from maintenance, operations and emergencies, and other possible upgrading of CH_4 reduction, before the commissioning of the first 300 MW gas-fired unit.

Carbon Sequestration

Increasing carbon sequestration through afforestation and reforestation, is also recommended, as is research on any available land or resources that would allow the use of vast plots of land, with a suitable climate. The species of trees for planting can have a large impact on the amount of CO_2 that can be sequestered. It is therefore advised that those which are most resilient to the relevant weather and environmental conditions and have the highest mass accumulation rate, be selected. Examples of such species are *Acacia spp.* and *Eucalyptus spp.* The higher mass accumulation rates are usually found in tropical forests with warm temperatures and damp conditions.

Locally, HEC is currently an avid sponsor of the *Corporate Afforestation Scheme* launched by the Agriculture & Fisheries Department (AFD) in 1998. It is a three-year (1998-2000) planting and forestry management project involving a total of 3 ha of land in the Tai Lam and Tai Tam Country Parks.

In terms of non-local projects, HEC has committed to a tree planting expedition at Ho Yuen in the Guangdong Province, which commenced in March 1998. This land greening activity, as part of the "Green Gift to Home Country Project", was organised by the Conservancy Association of Hong Kong. The Project consists of a series of tree plantation and land conservation activities in 3 sites within the Xin Feng Jiang National Forest Park at Ho Yuen. The sponsorship targets a tree seeding of more than 22,100, with 22 species in about 20 hectares.

The current HEC afforestation schemes are at this stage, for pilot purpose only. HEC will continue to actively explore opportunities of afforestation and forest conservation in Hong Kong and mainland areas. Potential project(s) include the woodland conservation and reforestation programme in mainland, supported by the local Environmental Protection Bureau and State Forestry Bureau. These are long term projects which are scheduled to last for 5 to 10 years.

Furthermore, HEC has proposed that the new extension be landscaped with trees and other suitable vegetation. This will not only increase the surrounding carbon sinks and thereby decrease GHG concentrations, but will aid in preventing the occurrence of adverse visual impacts.

It is also recommended that the option of obtaining carbon credit certificates under a recognised carbon accounting system (for carbon emissions trading), be pursued. The possibility of employing qualified independent auditors for this purpose (as stipulated by UNFCCC/IPCC present and future guidelines), will be explored by HEC.

The latter is important in view of the need to maintain the carbon sink established under the above afforestation and reforestation scheme. HEC will submit to EPD for review, a progress report on the above actions for a carbon accounting and monitoring programme before the commissioning of the first 300 MW gas-fired unit. These efforts may pave the way for future carbon emissions trading with the PRC and overseas.

Additional Recommendations

Annual Inventory Reporting

HEC has volunteered to undertake annual revisions and update of its GHG emissions inventory. The greenhouse gas emission inventory will cover at least the six GHGs specified under the Kyoto Protocol (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6). The inventory shall be established and maintained in accordance with the latest IPCC Guidelines, with details documented for regular reviews and updates. The inventory will be reported on an annual basis, including actual figures and targets for the previous and current years, as well as the next year's forecast. Discrepancies for actual versus target figures and actions for improvement or enhancement should be discussed. HEC will update the inventory according to the figures of the electricity load forecast, upon every subsequent review by the Government. This will also be reported in the annual report.

4.7.6 *Conclusion*

This component of the air quality assessment included the compilation of a greenhouse gas emissions inventory for all HEC operations, and an investigation of the impacts of proposed greenhouse gas mitigation measures.

The inventory was compiled and projected to 2002 and 2012, based on proposed operating parameters and mitigation measures for HEC operations over the estimation period. Total emissions were projected to increase from 1990 levels by 80% (5.11 Mt) and 62% (3.97 Mt) in 2002 and 2012 respectively, illustrating the beneficial impact of using gas-fired units for base-load operation after 2002 despite total electricity generation in the year 2012 being 2.57 times that of 1990. Estimated greenhouse gas emissions *per unit of energy produced* were predicted to fall from 1990 levels by 37% in 2012.

The impacts of mitigation measures in the areas of increased production and distribution efficiency, use of fuels with intrinsically low greenhouse gas emissions, improved consumption efficiency, reduced fugitive emissions, and carbon sequestration, were quantified in the assessment. A total of 6.5 million tonnes of emissions of CO_2 equivalent will be avoided in 2012 as a result of these measures (a 39% reduction in overall emissions), leaving an estimated total of 10.3 million tonnes for HEC operations in that year. The total mitigation achieved in 2012 will be more than HEC's total emissions in 1990.

CO_2 is the single largest component of HEC's GHG emissions, with amounts in the order of millions of tonnes, while the next largest components, CH_4 and N_2O, are only in the order of tens or hundreds of tonnes. For all assessed years, CO_2 invariably accounted for at least 98% of the total HEC GWP. This suggests that future mitigation measures should focus, as a first priority, on decreasing CO_2, although it is recognised that implementing measures to decrease the other GHGs, should not be neglected.

Although the amount of GHGs emitted and electricity generated generally increase through the years, the GHG emissions per MWH drops dramatically after the commissioning of the first unit of the new station after 2002.

Most of the mitigation measures discussed in this Study, have already been addressed by HEC and in most cases, actions have been taken.

In the Stage 1 EIA Study, the use of non-combustion technologies for power generation had already been assessed and it was concluded that the use of these technologies would not be technically feasible in the context of Hong Kong, due to the lack of the required resources and geographical constraints.

It seems that as long as combustion technologies are utilised, decreasing electricity demand or consumption would be a very attractive option and to this end, HEC has made due commitments.

In conclusion, all mitigation options that are both feasible and practical at the present time in Hong Kong, have been considered in this Study and all options have been addressed by HEC.

HEC is committed to adopting all practical measures for reducing its GHG emissions, especially from the proposed 6 x 300 MW gas-fired power station. Measures such as base-load shifting to gas units, gas flaring and participation in afforestation programmes will be employed. With all these measures implemented, HEC is able to reduce the CO_2 emissions per unit electricity generated by 37% below the 1990 level in 2012. However, since both Hong Kong's population and economy will continue to grow substantially into the next decade, such reductions will still fall short of the Kyoto Protocol perceived objectives for developed countries. HEC will nevertheless continue to explore and implement all feasible and practical mitigation options to further reduce its GHG emissions in line with the Government policy.

Perhaps a more strategic view on how Hong Kong should address the issue of GHGs, would be to begin by researching more appropriate options for GHG reductions. Hong Kong is a very unique place and sometimes trying to categorise its development is a difficult task. Its phenomenal population and economic growth has resulted in it being labelled as one of the richest developed countries in the world. Hence, blindly adopting the UNFCCC or IPCC goals without researching the feasibility and reasoning behind such feasibility, may not be appropriate. Conventions such as the UNFCCC are developed with a global context in mind (with the assumption of similarities between countries) and so some fine-tuning of the stipulated goals and methodologies may be needed to aid the various countries or cities in reducing GHG emissions.

Hong Kong should explore what it can achieve, how and why. The objective of reducing GHG emissions, as much as possible, lies in the same vein as the UNFCCC or Kyoto Protocol. Whether Hong Kong is able to meet the target and deadlines should not be the issue, but rather has Hong Kong made maximal effort to achieve these goals. Hong Kong's present endeavors to achieve the goals set out by the UNFCCC and Kyoto Protocol leaves much to be applauded and admired. It could well be that Hong Kong may be able to achieve these international target GHG emission levels and maybe even improve on them, but only at a later date than proposed. In any case, more research is needed to address the issue of Hong Kong's strategy towards GHG emissions reduction.

4.8 *Construction Dust*

4.8.1 *Introduction*

This section describes the potential air quality impacts arising from the construction of the extension of HEC Lamma Power Station. Dust emission is expected to be the major air pollutant source.

Air Sensitive Receivers have been identified for the construction of the Power Plant Extension. Air quality impacts affecting the ASRs will be assessed and suitable mitigation measures, where necessary, will be recommended to limit the dust emission from the site to within relevant criteria.

4.8.2 *Baseline Conditions*

The air quality of Lamma Island is mainly affected by the existing HEC Lamma Power Station. The emission from the chimney has been controlled by good engineering practice with tall stacks. With the pollutant discharged from the 215mPD chimney, dispersion of pollutants has been enhanced and its impact on the surrounding area is low and well within the criteria.

The fugitive emission from the ash lagoon and coal yard are the major dust sources. Three TSP monitoring stations are operated by HEC at Reservoir Area, East Gate and Tai Yuen Village to record the ambient dust concentrations as shown in *Figure 4.8a*. The samplers at the Reservoir Area and the East Gate are for compliance checking at the perimeter of the power station. The sampler at Tai Yuen Village is remote from the Power Station and hence data obtained are representative of the baseline levels at surrounding villages. The monitored annual average TSP level at the Reservoir Area, East Gate and Tai Yuen Village stations were 73, 74 and 54μgm^{-3} respectively in 1997. As Tai Yuen Village is characteristic of the rural villages in the vicinity of the power station, the baseline concentration at surrounding ASRs has been taken as 54μgm^{-3}.

4.8.3 *Air Sensitive Receivers*

The land use of the surrounding areas from HEC Lamma Power Station are mainly open area and low-rise village house of 2-3 storeys. The nearest villages to the Power Station are Ko Long, Tai Wan To and Hung Shing Ye.

According to the *EIAOTM*, domestic premises, hotel, hostel, hospital, clinic, nursery, temporary housing accommodation, school, educational institution, office, factory, shop, shopping centre, place of public worship, library, court of law, sports stadium or performing arts centre are classified as ASRs. The identified representative ASRs are listed in *Table 4.8a* respectively and their locations are shown in *Figure 4.8b*.

Table 4.8a ***Location of Identified Representative Air Sensitive Receivers***

ASRs	Location	Distance from the Site boundary (m)
A1	Village House at the south of Ko Long	850
A2	Scattered Village House at the south of Wang Long	1000
A3	Village House at the north of Hung Shing Ye	1350
A4	Hung Shing Ye Beach	1300
A5	Scattered Village House at the southeast of Hung Shing Ye Beach	1325

4.8.4 *Potential Sources*

Dust emission from the various construction activities is the major pollutant source. The extension of the Lamma Power Station will be constructed in 2 stages:

- Stage 1: Dredging & Site Formation; and
- Stage 2: Civil and E&M Work.

The construction programme of the extension work is shown in *Figure 4.8c*.

Stage 1 construction will last for 21 months between November 1999 and end of July 2001. It is identified that the major activities are dredging, rock and sand-filling works and site formation. The materials generated during Stage 1 construction are summarized in *Table 4.8b* below.

Table 4.8b ***Material Handling Rate for Stage 1 Construction***

Material	Volume handled (m^3)	Material Handling Rate (m^3/day)	Remarks
Soft marine mud from dredging	5,200,000	21,667	• working period: 8 months
Marine Sand for filling work	8,700,000	30,526	• working period: 9.5 months
Rock	1,400,000	6,222	• working period: 7.5 months
Concrete Blocks	25,000	278	• working period: 3 months

Note:
(i) Working hours are 24 hours a day and 7 days a week.

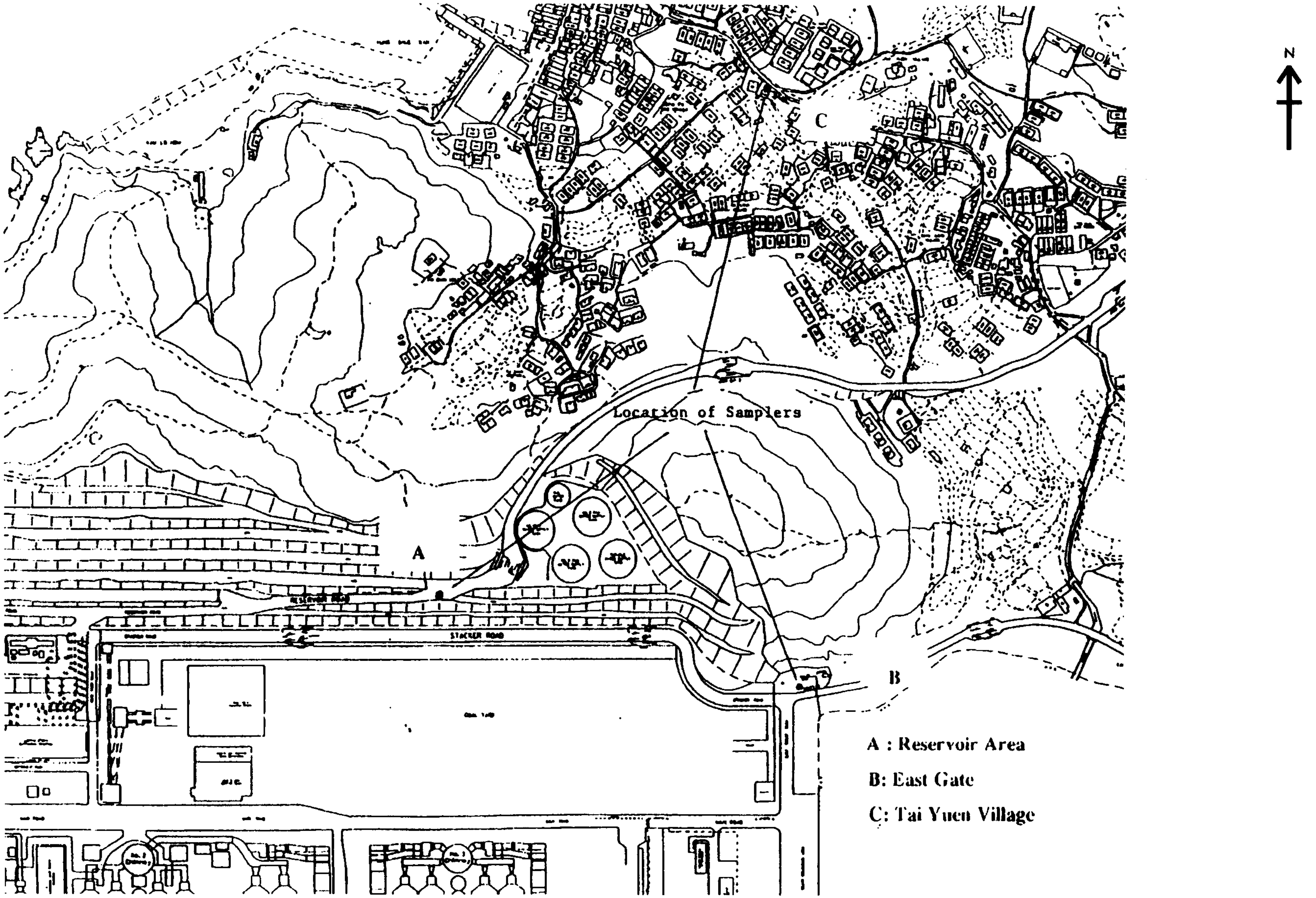


FIGURE 4.8a

LOCATION OF TSP SAMPLERS

FILE: C1830/C1830z14
DATE: 07/12/98

Environmental Resources Management

ERM

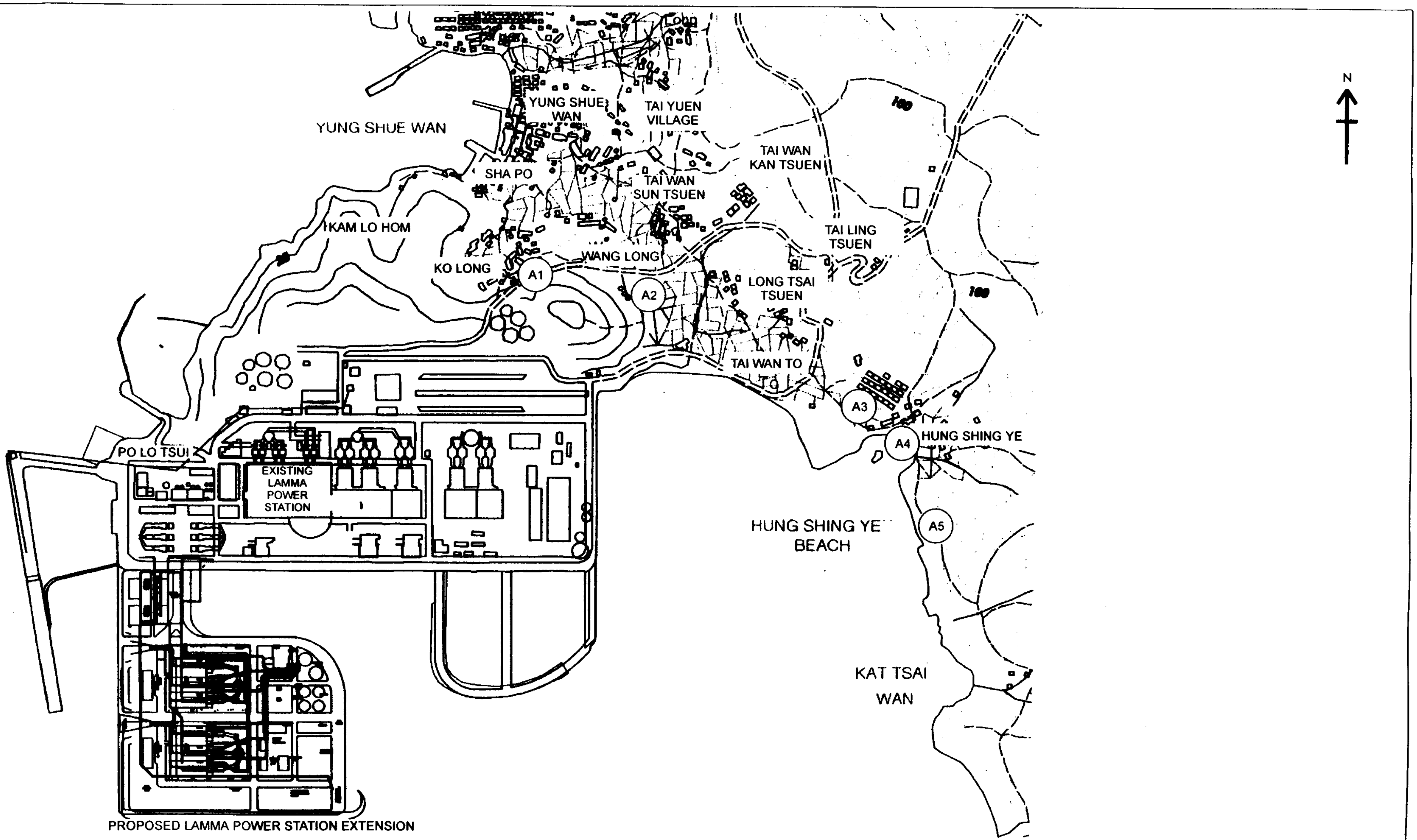


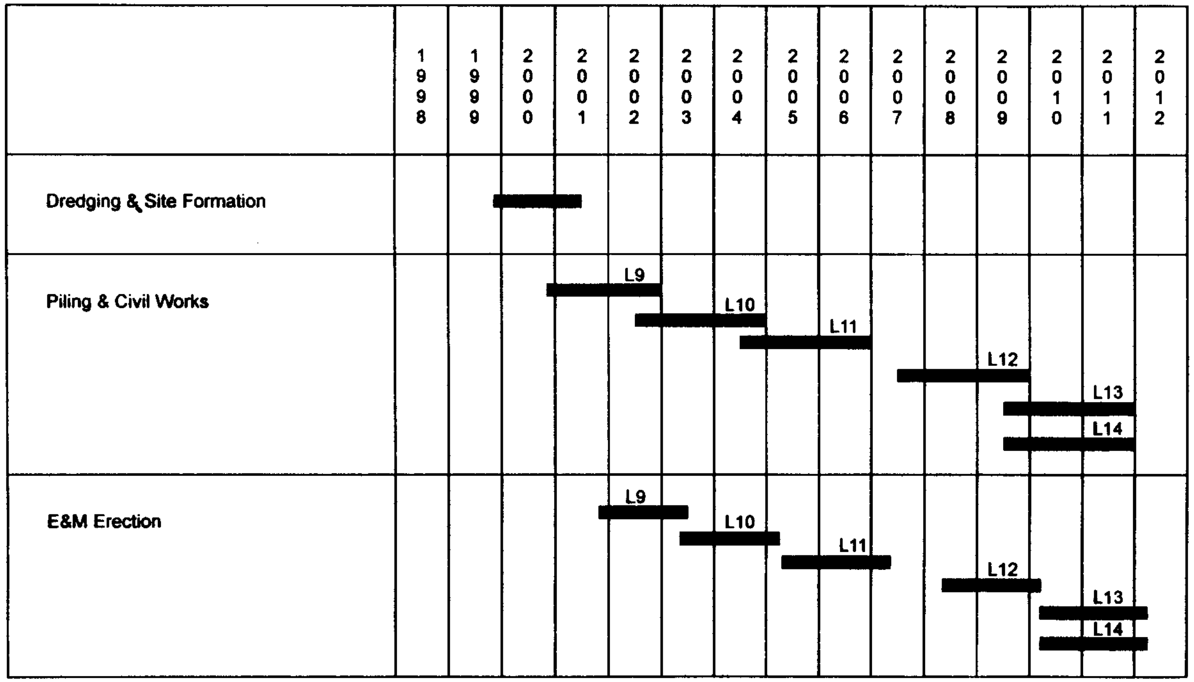
FIGURE 4.8b

LOCATION OF IDENTIFIED AIR SENSITIVE RECEIVERS

FILE: C1830/c1830s4
DATE: 07/12/98

Environmental Resources Management

ERM



Dredging & Site Formation	L9-L14	01/11/1999 - 31/07/2001
Piling & Civil Works	L9	01/12/2000 - 31/12/2002
	L10	01/07/2002 - 31/12/2004
	L11	01/07/2004 - 31/12/2006
	L12	01/07/2007 - 31/12/2009
	L13	01/07/2009 - 31/12/2011
	L14	01/07/2009 - 31/12/2011
E&M Erection	L9	01/12/2001 - 30/06/2003
	L10	01/04/2003 - 31/03/2005
	L11	01/04/2005 - 31/03/2007
	L12	01/04/2008 - 31/03/2010
	L13	01/04/2010 - 31/03/2012
	L14	01/04/2010 - 31/03/2012

FIGURE 4.8c

CONSTRUCTION PROGRAMME FOR 1,800MW GAS-FIRED COMBINED CYCLE PLANT AT LAMMA EXTENSION (6x300MW)

FILE: C1830/C1830x
DATE: 07/12/98

Environmental Resources Management

ERM

For the Stage 2 construction (civil and E&M work), the work is expected between December 2000 and early 2012 and the construction materials will be delivered by barge and transferred to the site by truck. The major dust generating activities are wind erosion, infrastructure works, truck movement on unpaved haul road and concrete batching plant. A maximum haulage of 6 trucks per hour is expected.

Moreover, the following control measures have been taken in the existing station to prevent fugitive dust emissions:

- maximum/total enclosure of all coal and ash conveyors and transfer points;
- storage of the limestone/gypsum/extracted fly ash in sealed silo before removal;
- spraying of water (more than 45 tonnes/day) and dust suppressant onto the coals for reducing coal dust emissions; and
- procedures to minimize drop height of the coal.

4.8.5 *Assessment Methodology*

Dust emission from the construction activities is the main pollutants during construction phase. Potential dust impacts were predicted by the USEPA approved air dispersion model, *Fugitive Dust Model* (FDM). Meterological data for 1997 from Cheung Chau weather station, operated by Hong Kong Observatory, was employed for the model run. Dust emission rates and associated particle size distributions for the assessment were determined based on the *Compilation of Air Pollutant Emission Factors, 5th Edition, USEPA* (AP-42) (see *Table 4.8c*). The construction works are expected to be conducted 30 days a month and 24 hours a day for Stage 1 work and 26 days a month and 12 hours a day for Stage 2 work.

Table 4.8c ***Emission Factors for Stage 1 & 2 Construction Activities***

Construction Activities	Emission Factor (i)	Remarks
Handling of sand	$0.14u^{1.3}g/Mg$	• moisture content : 50%
Heavy Construction (building construction)	2.69 Mg/hec/month of activity	
Concrete Batching Plant	0.164 kg/Mg	• 100 m^3/hr
Wind erosion	0.85 Mg/hec/yr	
Truck movements on unpaved haul road	2.77 kg/VKT	• 6 truck/hr • silt content of road surface: 10% • vehicle speed: 8 kph • vehicle weight: 25 tonnes • vehicle with 10 wheels

Note:
(i) From *Compilation of Air Pollutant Emission Factors* (AP-42), 5th Edition, USEPA

It is expected that the moisture content of dredged material is high and dust emission from the activity will be suppressed. Moreover, marine sand is expected for sand filling and the process will be done by hydraulic means, therefore, no emission from this activity is expected. In addition, the particle size of rock is large (≥100 mm), the emission for rock handling is limited and negligible.

The dust emission rate at Stage 2 will be used in the modelling to predict the worst scenario of the air quality impact.

4.8.6 *Evaluation of Impacts*

The potential daily and hourly dust impacts for the Study on the ASRs at ground level and 10 m above ground for the construction of Stage 2 works were modelled and the results are presented in *Table 4.8d*. A background concentration of 54μgm^{-3} has been included in the results based on the baseline conditions identified in *Section 4.8.2*.

Table 4.8d ***Predicted Cumulative Hourly and Daily TSP Level for Identified ASRs (μgm^{-3})$^{(i)}$***

ASRs	Hourly Cumulative TSP Level		Daily Cumulative TSP Level	
	Ground Level	10 m Above Ground	Ground Level	10 m Above Ground
A1	178	167	61	60
A2	141	135	58	58
A3	104	103	56	56
A4	147	145	58	57
A5	124	122	57	57
Criteria	500	500	260	260

Note:
(i) Background TSP level of 54*μgm*$^{-3}$ at Tai Yuen Cheun has been included in the results.

The above results show that, the predicted hourly and daily TSP levels at all identified ASRs are within the criteria of 500 μgm^{-3} and 260 μgm^{-3} respectively. The hourly TSP levels at ground and 10 m above ground are in range of 104 - 178 and 103 - 167 μgm^{-3} respectively. The daily TSP levels at ground level and 10 m above ground were broadly similar and ranged between 56 - 61 μgm^{-3}. The highest hourly and daily TSP levels at ground level and 10 m above ground are predicted at A1 (Village House at the south of Ko Long). However, even at the worst affected location, the cumulative impacts are well within the criteria.

Isopleths of hourly and daily TSP at ground level and 10 m above ground are presented in *Figures 4.8d -g* and they confirm that the TSP levels at all sensitive receivers will satisfy the dust criteria. Mitigation measures and environmental monitoring are recommended to limit the emission from the site to ensure the air quality will be satisfied within the site boundary.

4.8.7 *Mitigation Measures*

The following control measures are recommended according to the *Air Pollution Control (Construction Dust) Regulation* to minimise dust emissions for the Stage 1 & 2 construction:

- the haul roads should be sprayed with water to keep the entire road surface wet;

- the load carried by vehicle should be covered by impervious sheeting to ensure no leakage of dusty materials from the vehicle; and

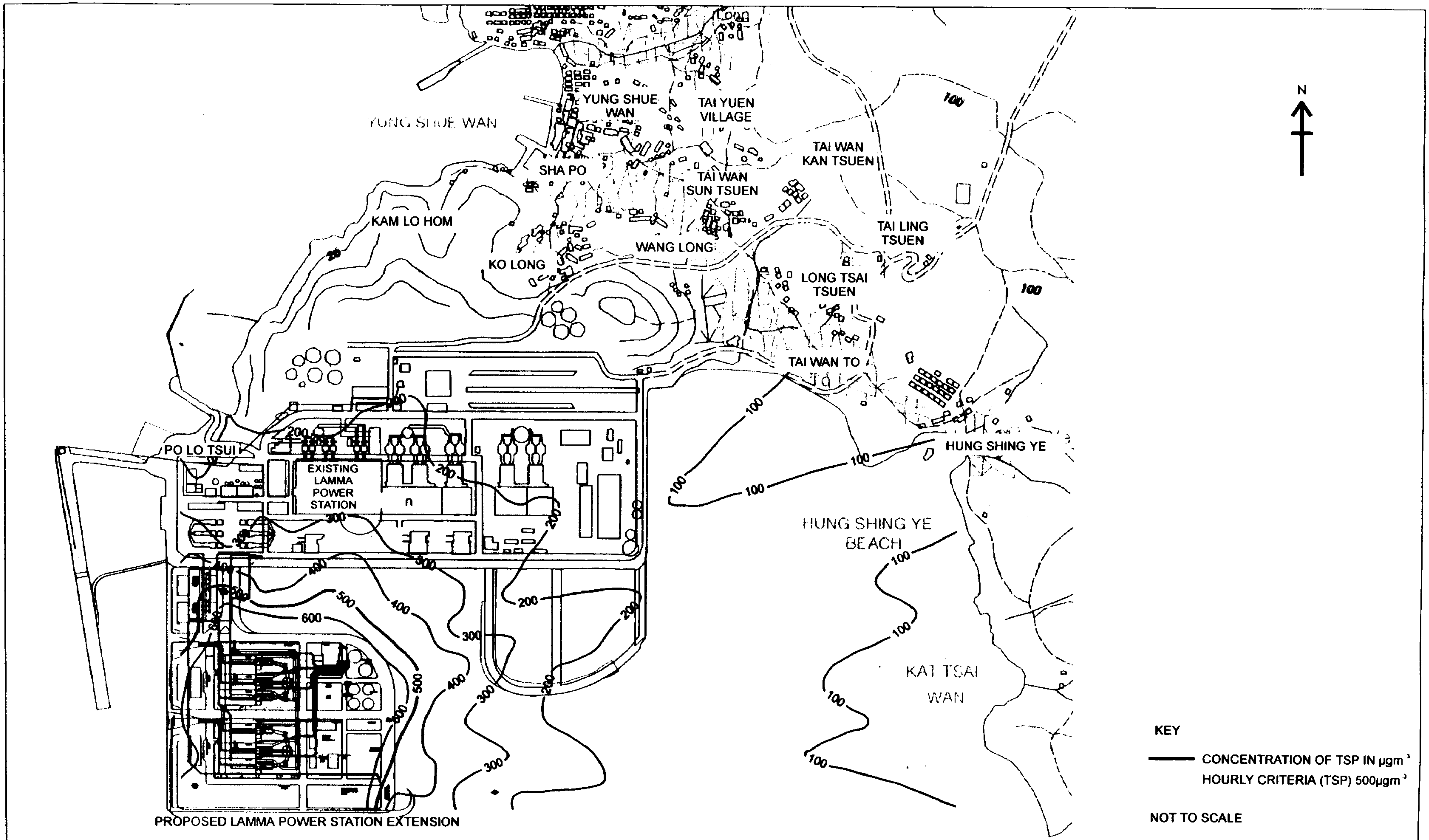


FIGURE 4.8d

ISOPLETHS OF HOURLY TSP AT GROUND LEVEL

FILE: C1830/C1830z23
DATE: 07/12/98

Environmental Resources Management
ERM

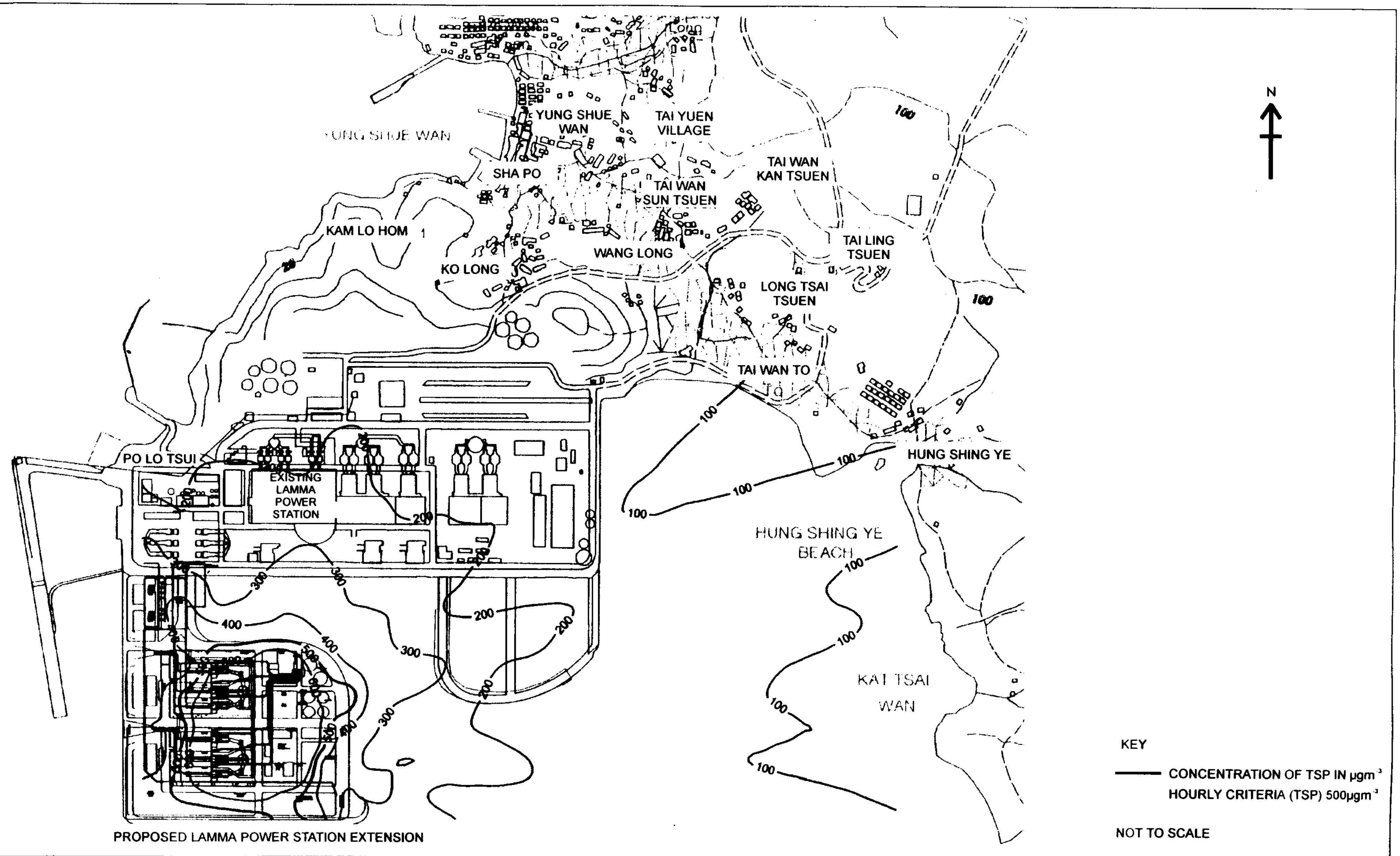
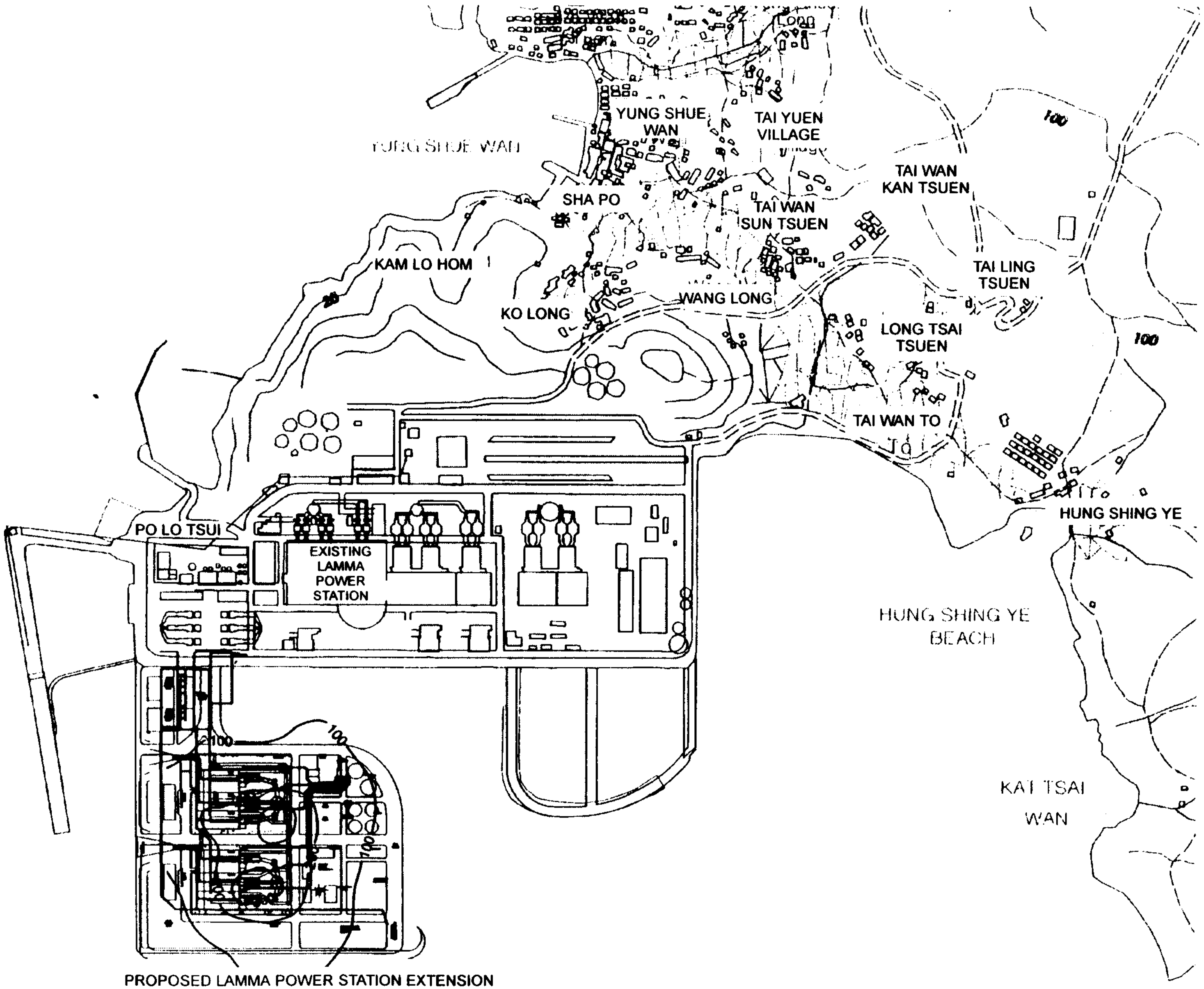


FIGURE 4.8e

ISOPLETHS OF HOURLY TSP AT 10m ABOVE GROUND LEVEL

FILE: C1830/C1830z24
DATE: 07/12/98

Environmental Resources Management
ERM



KEY

CONCENTRATION OF TSP IN μgm⁻³ DAILY CRITERIA (TSP) 260μgm⁻³

NOT TO SCALE

FIGURE 4.8f

ISOPLETHS OF DAILY TSP AT ABOVE GROUND LEVEL

Environmental Resources Management

ERM

FILE: C1830/C1830z25
DATE: 07/12/98

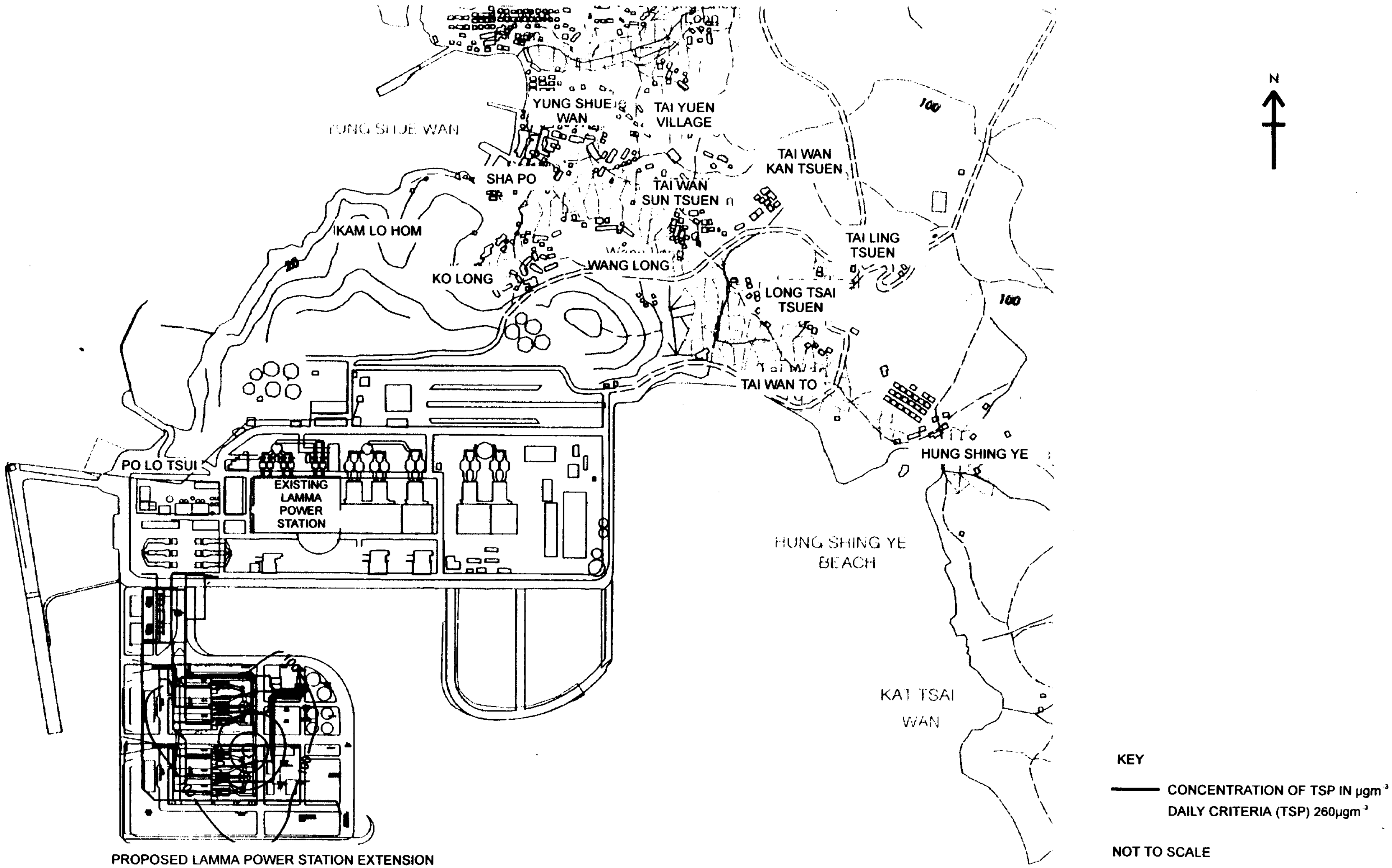


FIGURE 4.8g

ISOPLETHS OF DAILY TSP AT 10m ABOVE GROUND LEVEL

FILE: C1830/C1830z26
DATE: 07/12/98

Environmental Resources Management

ERM

- the heights from which fill materials are dropped should be controlled to a practical level to minimise the fugitive dust arising from unloading.

In addition, for the concrete batching plant good housekeeping practice and the following control measures recommended under the *Best Practicable Means Requirements for Cement Work (Concrete Batching Plant)* should be adopted to prevent fugitive dust emissions:

- loading, unloading, handling, transfer or storage of any dusty materials should be carried out in a totally enclosed system;
- the materials which may generate airborne dust emissions should be wetted by water spray system;
- all receiving hoppers should be enclosed on three sides up to 3 m above unloading point; and
- all conveyor transfer points should be totally enclosed.

4.8.8 *Environmental Monitoring and Audit Requirements*

The construction work will inevitably lead to dust emissions, mainly from heavy construction, truck haulage, concrete batching and wind erosion. It is predicted that the dust level will satisfy the dust criteria at all ASRs.

Mitigation measures have been recommended in *Section 4.8.7* to limit the dust emission and dispersion. Should significant ambient TSP levels be detected during construction, HEC will take appropriate control measures to ensure that the dust criteria at all ASRs are satisfied. With the implementation of the recommended dust control measures, the TSP levels will comply with the dust criteria.

4.8.9 *Conclusions*

Dredging, site formation, civil work and E&M work are the major works during the whole construction of the HEC Lamma Power Station Extension. Construction activities such as material handling, heavy construction, wind erosion, truck movement on the unpaved haul roads and concrete batching will be the main dust generating activities.

The predicted cumulative hourly and daily TSP levels at ASRs are within the dust criteria under the worst case scenario. Mitigation measures and EM&A requirements have been recommended to limit the dust emission from the site to ensure that the actual dust emissions will be controlled within the criteria.

4.9 SUMMARY OF MITIGATION MEASURES

The mitigation measures identified in *Sections 4.4* through *4.8* are summarised below:

4.9.1 *Operational Phase*

For the control of local and regional air quality impacts, and greenhouse gas emissions, the following measures are recommended:

- LNG shall be used as the primarily fuel with light gas oil as standby fuel only.
- Combined cycle technology or other proven technology with higher efficiency shall be used.
- CCGT emission characteristics shall comply with the criteria stipulated in the *Notes on Best Practicable Means Requirements for Electricity Works.*
- Stack height for each unit shall not be less than 110mPD.
- Stacks shall be arranged in groups and located in the identified positions.
- Detailed engineering study shall be conducted to improve the availability of gas supply to Lamma Extension to be better than 99.65% so as to further minimize the need for emergency oil firing.
- the gas-fired combined cycle units shall be used as the base load units to minimize the operation of coal-fired units.
- the more efficient units which are fitted with FGD and LNB in the existing coal-fired Lamma Power Station will be operated first under normal situation to meet system demand.
- The existing oil-fired gas turbines shall be converted into gas-fired units as soon as possible.
- Stringent operation and maintenance procedures shall be imposed to prevent any fugitive emissions of greenhouse gases into the atmosphere.
- High efficiency transmission and distribution apparatus shall be employed.
- Participation into the afforestation schemes shall continue.
- Promotion of demand side management shall continue.

4.9.2 *Construction Phase*

For general construction works, the dust control measures stipulated under the *Air Pollution Control (Construction Dust) Regulation* shall be complied with, such as:

- the haul roads shall be sprayed with water to keep the entire road surface wet.
- the load carried by vehicle shall be covered by impervious sheeting to ensure no leakage of dusty materials from the vehicle.
- the heights from which fill materials are dropped shall be controlled to a practical level to minimise the fugitive dust arising from unloading.

For the concrete batching plant, the following control measures are recommended according to the *Best Practicable Means Requirements for Cement Work (Concrete Batching Plant)*:

- loading, unloading, handling, transfer or storage of any dusty materials shall be carried out in a totally enclosed system.

- the materials which may generate airborne dust emissions shall be wetted by water spray system.

- all receiving hoppers shall be enclosed on three sides up to 3 m above unloading point.

- all conveyor transfer points shall be totally enclosed.

4.10 *EM&A REQUIREMENTS*

4.10.1 *Operational Phase*

The following monitoring and audit requirements are recommended:

- ambient air quality monitoring (for NO_2 and SO_2) at the existing HEC network shall continue to provide ongoing indicators of the general air quality in the surroundings of the new power station up to year 2012 and beyond.

- fuel quality shall be regularly inspected to ensure a low residual sulphur level.

- stack gas monitoring for NO_x (NO and NO_2), CO, oxygen and stack temperature shall be conducted.

- greenhouse gas inventory shall be updated annually.

- records to demonstrate compliance with the operations plan for minimising GHG emissions shall be maintained and kept on-site (operations include conversion program of existing peak lopping oil-fired gas turbines to gas-firing ones, shifting the base-load from coal-fired to gas-fired, and operations and maintenance practices to result in smaller or less frequent CH_4 emissions).

- records to demonstrate compliance with the comprehensive life cycle management program for HFC/PFC/SF_6 containing equipment, shall be maintained and kept on-site.

- records of carbon sinks under a carbon accounting system for afforestation or reforestation schemes, shall be maintained and kept on-site.

4.10.2 *Construction Phase*

The following are recommended to ensure effective control of dust emissions:

- continuous surveillance of the implementation of dust mitigation measures shall be carried on a day to day basis.

- baseline conditions at the existing monitoring sites at the Reservoir Area, East Gate and Tai Yuen Village shall continue in order to provides indicators on the general air quality at site boundary and receptor.

- continuous monitoring at surrounding receptor sites shall be carried out should complaint be received or exceedance be found at any one of the sites at the Reservoir Area, East Gate and Tai Yuen Village until no exceedance is recorded.

4.11 SUMMARY AND CONCLUSIONS

The operational air quality impacts on the local, regional and global scale of the proposed power station development has been studied. It is concluded that:

- the full load operation of the new 1,800MW gas-fired combined cycle power station will not cause any potential exceedance of the AQOs for SO_2 and NO_2 in year 2012. The results were obtained under the combined operation of the existing Lamma Power Station and the *WEIF*. The provision of a 110mPD stack for the new units is adequate to ensure compliance of the AQOs, even when the emergency oil-firing scenario is considered. An improvement in the air quality and annual emission loading are expected from year 2002 to 2012 as loads are increasingly transferred to the gas-fired power plant from the existing coal units, despite an increase in annual peak system demand from 2,794MW to 3,916MW.

- the contribution of the new CCGT to the ambient concentrations of SO_2 and NO_2 are predicted to be small in year 2012. The predicted hourly, daily and annual average levels of SO_2, NO_2 and O_3 are within the AQO limits.

- with increasing total installed capacity of fossil fuel power stations in the Pearl River Delta, it is found that the contribution of NO_x and SO_2 from the new gas-fired power station at Lamma extension will only represent 1.5% and 0.7% of the regional total respectively. With the adoption of natural gas and the combined cycle technology, it is considered that any residual regional air quality impacts are controlled within practicable limits.

- despite the absence of any numerical targets to achieve from the Hong Kong SAR Government and the uncertainty of its status in the major international treaties, mitigation measures have been proposed and results for some of the quantifiable control measures have been presented. It has been concluded that maximum effect in controlling greenhouse gas can be achieved by the use of the new gas-fired units to replace the existing coal units, once they are available.

During the construction phase, it is envisaged that with the adoption of the proper dust control measures, no potential exceedances of the statutory criteria for dust are expected even under the worst case scenario. An effective environmental monitoring and audit programme will prove indispensable in ensuring that the site construction activities are controlled within acceptable levels.