CONTENTS

ANNEX

4 AIR QUALITY ASSESSMENT

4.1 INTRODUCTION

This section presents the assessment of potential air quality impacts from the construction and operation of the proposed LNG terminal at South Soko. Dust generated from the construction activities and gaseous emissions from construction plant are potential concerns during the construction phase. Air emissions from LNG terminal equipment, LNG carrier and the gas heaters of the new Gas Receiving Station (GRS) located at Black Point are the principal concern during the operational phase. Representative Air Sensitive Receivers (ASRs) and emission inventories have been identified and a quantitative assessment of the air quality impacts has been conducted.

4.2 LEGISLATION REQUIREMENT AND EVALUATION CRITERIA

The principal legislation for the management of air quality in Hong Kong is the *Air Pollution Control Ordinance* (*APCO*) (Cap. 311). Under the *APCO*, the *Hong Kong Air Quality Objectives* (AQOs), see *Table 4.1*, stipulate the statutory limits for air pollutants and the maximum allowable number of exceedances over specific periods.

Table 4.1 Hong Kong Air Quality Objectives ($\mu g\ m^{-3}$) [(a)]

Air Pollutant	**Averaging Time**				
	1 Hour [(b)]	**8 Hour [(c)]**	**24 Hour [(c)]**	**3 Months [(d)]**	**1 Year [(d)]**
Total Suspended Particulates (TSP)	-	-	260	-	80
Respirable Suspended Particulates (RSP) [(e)]	-	-	180	-	55
Sulphur Dioxide (SO_2)	800	-	350	-	80
Nitrogen Dioxide (NO_2)	300	-	150	-	80
Carbon Monoxide (CO)	30,000	10,000	-	-	-
Photochemical Oxidants (as ozone (O_3)) [(f)]	240	-	-	-	-
Lead (Pb)	-	-	-	1.5	-

Notes:
(a) Measured at 298K (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
(e) Suspended airborne particulates with a nominal aerodynamic diameter of 10 micrometres or smaller
(f) Photochemical oxidants are determined by measurement of ozone only

A maximum hourly TSP concentration 500 μgm^{-3} at ASRs is also stipulated in the *Technical Memorandum on Environmental Impact Assessment Process* (*EIAO-TM*) to control potential construction dust impacts.

The measures stipulated in the *Air Pollution Control (Construction Dust) Regulations* should be followed to ensure that any dust impacts are reduced.

In accordance with the *Air Pollution Control (Furnaces, Ovens and Chimneys) (Installation and Alteration) Regulations*, an installation of a chimney/flue which consumes more than 1,150 megajoules of gaseous fuel per hour or 25 litre of conventional liquid fuel per hour requires an approval from the *Environmental Protection Department* (EPD) prior to the commencement of the installation work. Engineering plans showing the elevations and plan views of the chimney/flue together with the specification should be submitted for approval not less than 28 days prior to the commencement of such work.

Should a process listed in *Table 4.2* exceed the respective regulatory thresholds under the *Air Pollution Control (Specified Process) Regulations*, it is classified as a Specified Process and hence, a licence should be obtained from the EPD prior to their operation.

Table 4.2 Specified Process and Its Regulated Capacity under the Air Pollution Control (Specified Process) Regulations

Specified Process	Regulatory Threshold for Licence from the EPD
Concrete Batching Plant	• Works in which the total silo capacity exceeds 50 tonnes
Rock Crushing Plant	• Works in which the processing capacity exceeds 5,000 tonnes per annum
Gas Turbine Generator	• Works in which fossil fuel is burnt either wholly or as part of the process of electricity generation where the installed generation capacity of such works exceeds 5 MW

During the operation of these processes, the air/dust control measures in the *Guidance Note on the Best Practicable Means for Cement Works (Concrete Batching Plant) (BPM 3/2), Electricity Works (Coal-fired Plant, Gas-fired Gas Turbine and Oil-fired Gas Turbine (Peak Lopping Plant)) (BPM 7/1)* and *Mineral Works (Stone Crushing Plants) (BPM 11/1)* should be implemented to meet the respective emission limits.

4.3 BASELINE CONDITIONS AND AIR SENSITIVE RECEIVERS

4.3.1 Baseline Conditions

The proposed LNG terminal is located on the South Soko Island. The North Soko Island is located approximately 1 km away from the site. The island has no population and there are no major sources of atmospheric emissions in the vicinity.

The proposed GRS is located to the west of the BPPS (see *Figure 4.3b*). The Black Point Headland is located to the west of the GRS. The Black Point area has a very low population density. Air emissions from the BPPS and the Castle Peak Power Station (CPPS) are major sources of air emissions in the vicinity.

There is currently no Air Quality Monitoring Station (AQMS) operated by the EPD in the immediate vicinity. The nearest EPD AQMS is located in Tung Chung (TC), which is to the north of Sunset Peak and Lantau Peak. The air quality data from the AQMS at Tung Chung in 2004 are adopted as the background in this Study. These data are summarized in *Table 4.3*.

Table 4.3 Background Air Quality at Tung Chung

Air Pollutant	Background Concentration (μg m^{-3})
Total Suspended Particulates (TSP)	72 (a)
Respirable Suspended Particulates (RSP)	62 (a)
Nitrogen Dioxide (NO_2)	52 (a)
Sulphur Dioxide (SO_2)	27 (a)
Carbon Monoxide (CO)	799 (a)
Ozone (O_3)	108 (b)

Notes:

(a) Annual Average Concentrations measured at EPD's Tung Chung AQMS in 2004

(b) The ozone concentration is the annual average of the daily hour maximum concentration measured in 2004

Contribution of Emissions from BPPS and CPPS

Air quality in the vicinity will also be influenced by local emission sources, including BPPS and CPPS during the operation of GRS.

An *EIA of the Proposed 6,000 MW Thermal Power Station at Black Point: Key Issue Assessment – Air Quality* (hereafter referred to as the *BPPS EIA Study*) has been used as the basis for quantifying the contribution of emissions from BPPS and CPPS to local air quality.

The *BPPS EIA Study* included wind tunnel testing to assess the near-field air quality impacts of six gas-fired units, each with a design generating capacity of 800 MW (Phases I and II) (i.e., a total generating capacity of 4,800 MW) for BPPS and the CPPS "A" and "B" Units (CPA and CPB). The findings of the wind tunnel tests indicated that nitrogen dioxide (NO_2) is the major air pollutant and that higher NO_2 impacts occur at higher wind speeds (refer to *Annex D* of *BPPS EIA Study*) [(1)]. NO_2 concentrations under different averaging times at Lung Kwu Tan were calculated based on the wind tunnel testing results, the reported ozone level (i.e. 70 μgm^{-3}) and the NO_x/NO_2 ratio estimation approach as described in "*A Classification of NO Oxidation Rates in Power Plant Plumes based on Atmospheric Conditions*", by Janssen, 1983.

Since the assessment was completed, there have been a number of changes to both the installed generating capacity and the regional air quality.

(1) In accordance with the *EIA of the Proposed 6000MW Thermal Power Station at Black Point: Key Issue Assessment – Air Quality, Part A – Complex Terrain Wind Tunnel Tests, Section 2.3.3*, September 1993, the wind tunnel testing was conducted at wind speeds ranging from 3 ms^{-1} to 15 ms^{-1}. However, it should be noted that the higher wind speeds of 12 ms^{-1} and 15 ms^{-1} occur very rarely (about 4% of the time across all wind directions and 1% for directions towards land, based on Chek Lap Kok data for 1980 – 90). In fact, 12 ms^{-1} is only applicable for a few wind directions and receptors and 15 ms^{-1} is unlikely ever to occur for durations of one hour or more.

Compared to the ozone level in 1993 (70 μgm^{-3}), the annual average of the daily one-hour maximum concentrations has increased to 108 μgm^{-3} in 2004 (see *Table 4.3*).

For assessing the contribution of the BPPS, an adjustment was made to account for the current generating capacity which is 2,500 MW. There is no confirmed programme for the Phase II expansion, as was assumed in the *BPPS EIA Study*.

For assessing the contribution of the CPPS, an allowance was made for the fact that low NO_x burners are now operating in the CPA and CPB. A further NO_x reduction is anticipated for CPB and the indicative date of the implementation of the further NO_x reduction measures will be over the period of 2009 to 2011 according to the approved *EIA for Emission Control Project to CPPS "B" Units*.

Taking into consideration the latest information for BPPS and CPPS as well as the higher ozone level of 108 μgm^{-3}, the adjusted NO_2 concentrations are summarized in *Table 4.4* and were utilised in the assessment of the cumulative air quality impacts in the Lung Kwu Sheung Tan area.

Detailed calculations are provided in *Annex 4-A*.

Table 4.4 Adjusted Maximum Hourly, 2nd Highest Daily and Annual NO_2 Concentrations in 2004 based on Wind Tunnel Test Results

Location	Adjusted NO_2 Concentration in 2004 (μgm^{-3}) (a)		
	Maximum Hourly	Daily (c)	Annual (c)
Lung Kwu Tan	54 (b)	22	0.6

Notes:

(a) Adjustment is based on the annual average of the daily hourly maximum ozone concentration (108 μgm^{-3}) in 2004.

(b) Only the BPPS contribution is considered. A factor of 0.5 is applied to adjust for the current power generating capacity of BPPS to current capacity.

(c) Both BPPS and CPPS contributions are considered, no adjustment has been made to account for the reduced power generation capacity of BPPS, existing licence limit requirement or the future NO_x reduction at CPB due to the implementation of the Emission Control Project.

4.3.2 *Air Sensitive Receivers*

In accordance with the Study Brief, the study area for the air quality assessment is generally defined by a distance of 500 m from the boundary of the Project site. Air Sensitive Receivers (ASRs) were identified in accordance with the criteria in *EIAO-TM Annex 12*.

No ASRs were identified on the South Soko Island. The nearest ASR is the Staff Quarters of Shek Pik Prison (A1), which is approximately 6.4 km away. In the Lung Kwu Sheung Tan area, six ASRs were identified by site visit. A description of the identified ASRs is summarized in *Table 4.5* and their locations are shown in *Figures 4.1a* and *4.1b*.

Table 4.5 Identified Air Sensitive Receivers

ASR	Location	Approximate Distance from LNG Emission Source (m)	Type of Uses	Maximum Height (m above ground)
Soko Island				
A1	Staff Quarters of Shek Pik Prison	6,400	Prison	10 m
Black Point				
A2	Black Point Power Station – Administration Building	510	Office	6
A3	Karting Track	1,800	Recreational	1.5
A4	Open Storage – Site Office	1,390	Site Office	6
A5	Concrete Batching Plant – Site Office	1,440	Site Office	1.5
A6	Hong Kong Oil – Site Office	1,550	Site Office	6
A7	Open Storage – Site Office	1,680	Site Office	1.5

4.4 *POTENTIAL SOURCES OF IMPACT*

4.4.1 *Construction Phase*

Nuisance from dust generating activities and gaseous emissions from diesel-driven plant has the potential to arise during construction. The major construction works include slope cutting, site clearance, dredging, reclamation, gas pipeline installation works and civil works. Excavation and filling, materials handling, wind erosion of open areas and blasting are the major dust generating activities during the construction of the LNG terminal.

Site Clearance and Blasting

Site clearance and blasting are planned to be undertaken within the first year of the works. Due to the limited space available onsite, excavated soil will be temporarily stockpiled offsite for reuse within the project or other concurrent construction projects. Excavated rocks will be taken to a quarry in Mainland China for processing and the processed rock will be subsequently reused within the project for protection of the submarine pipeline or within the reclamation. Suitable stockpile sites are currently being sought. Details of the disposal arrangements for the excavated materials are presented in *Section 7 (Waste Management)*.

Blasting works will be carried out during the site formation works. During the blasting works, the control measures stipulated in the *Air Pollution Control (Construction Dust) Regulations* will be implemented to reduce the dust impacts. Mobile rock crushers will be employed onsite to crush the excavated rock into a suitable size for transportation. During the rock crushing activities, the dust control measures recommended in the *Guidance Note on the Best Practicable Means for Mineral Works (Stone Crushing Plants) (BPM 11/1)* will be implemented to meet the emission limit in *BPM 11/1*.

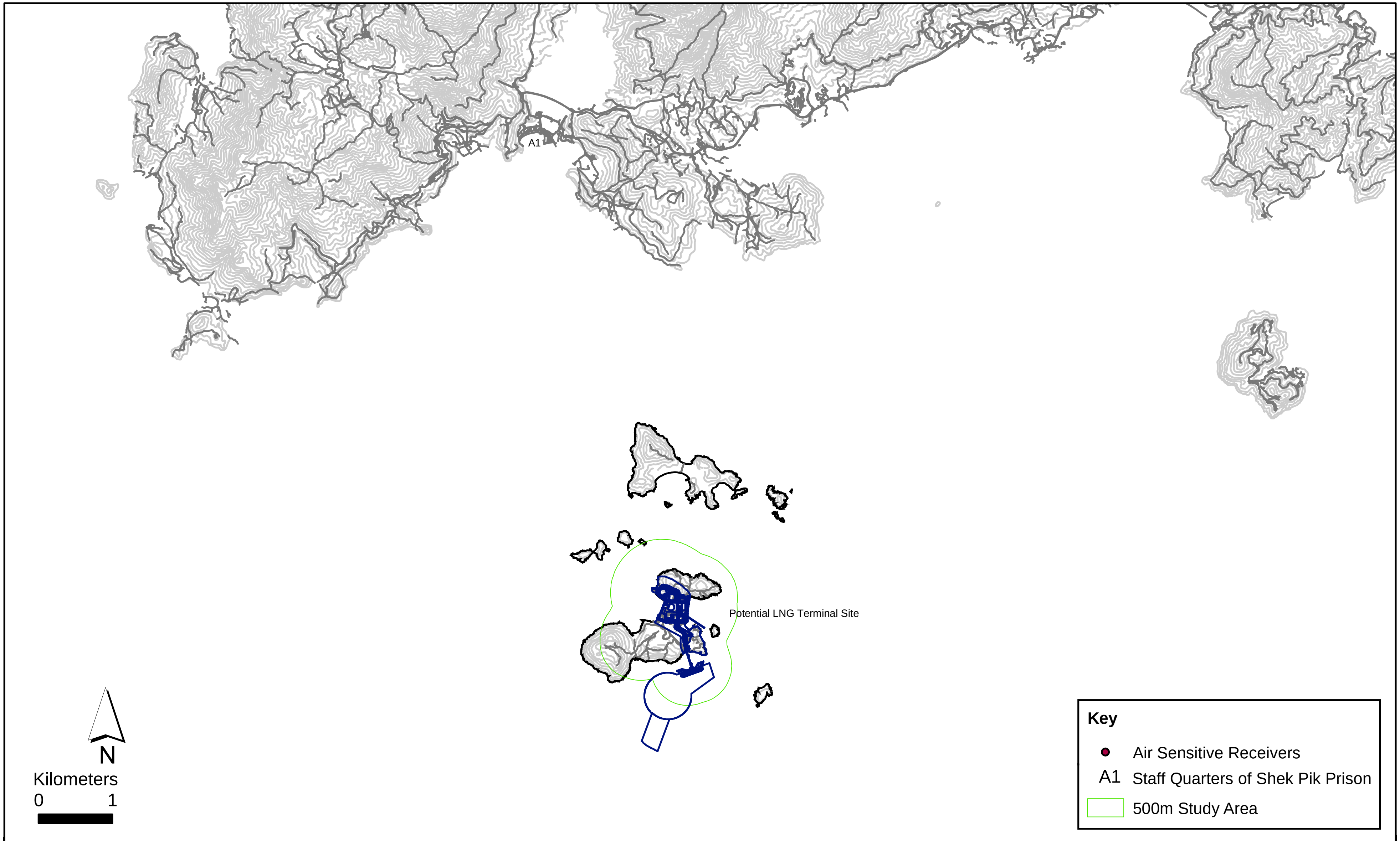

Figure 4.1a

Location of Nearest Air Sensitive Receiver

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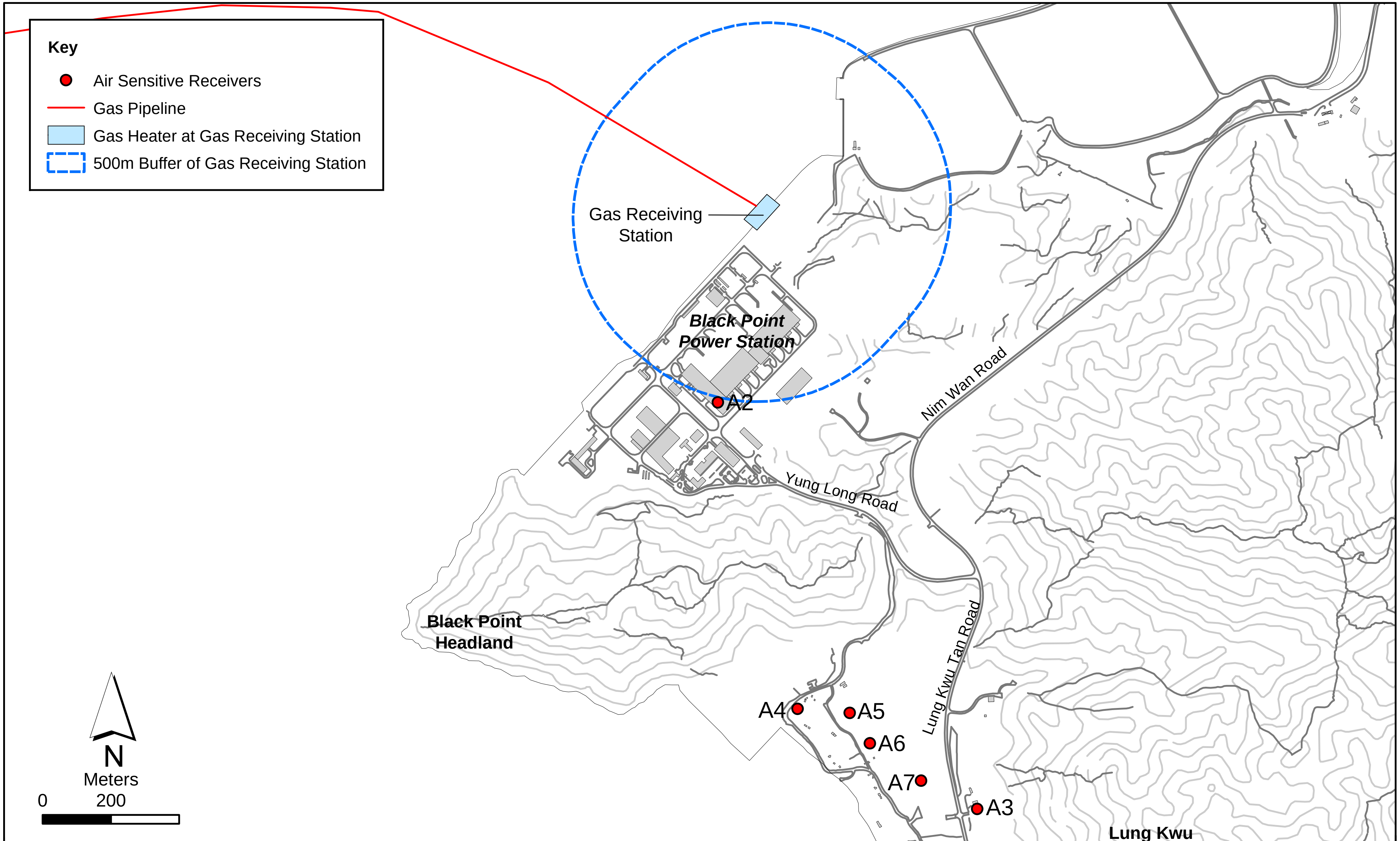

Figure 4.1b

Location of Air Sensitive Receiver at Black Point (GRS)

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Any dust impact during site clearance and blasting is expected to be localized. The separation distance between the identified ASR and the construction site is approximately 6.4 km, which satisfies the HKPSG recommended buffer distance of 100 m. Together with the implementation of the dust control measures stipulated in the *Air Pollution Control (Construction Dust) Regulations* and in the *Guidance Note on the Best Practicable Means for Mineral Works (Stone Crushing Plants) (BPM 11/1)*, the potential dust impact arising from site clearance and blasting works at the ASR is predicted to be minor and within the dust criteria.

Dredging and Reclamation Works

Dredging works will be required for construction of seawall, approach channel and turning basin, submarine water main, gas pipeline, cabling and gas receiving station. Such dredging is planned to be undertaken within the first two years of the works depending on the programme for the *Foreshore and Seabed (Reclamations) Ordinance (FSRO)* approval. Marine sediment will be dredged and disposed of at designated marine disposal sites by barge. The moisture content of dredged materials is very high, therefore, no fugitive dust emissions are anticipated during the works.

During the reclamation works, rocks will be imported for seawall construction from the designated stockpile site or quarries whereas soil will also be imported from the designated stockpile site or public filling area for filling works. No fugitive emissions are expected from rock filling; however, fugitive dust emissions are possible from the handling of public fill. In accordance with the construction method, the filled area will be compacted immediately after filling and therefore, fugitive dust emissions will be reduced. Furthermore, due to the large separation distance from the ASR and with the implementation of the dust control measures stipulated in *Air Pollution Control (Construction Dust) Regulations*, no dust impact is anticipated.

Terminal Facility Construction Works and Civil Works

Terminal facility construction works and civil works will be carried out. Two concrete batching plants with concrete production rates of 110 m^3hr^{-1} and 60 m^3hr^{-1} (as backup) each, are proposed on site for the concreting work and fugitive dust emissions are expected. However, during the concreting activity, the dust control measures recommended in the *Guidance Note on the Best Practicable Means for Cement Works (Concrete Batching Plant) (BPM 3/2)* will be implemented to meet the respective emission limits. With the implementation of the dust control measures recommended in the *BPM 3/2* and large separation from the ASR, an adverse air quality impact is not anticipated at the ASR.

On-site Sewage Treatment Works

The sewage generated from the workforce during the construction phase will be either conveyed to a public sewage treatment works (STW) or treated onsite. The daily generation rate of sewage is about 240 m^3, assuming a workforce of up to 1,600 people. If a small STW is proposed on-site it will be designed to meet the Hong Kong standards [(1)] and will minimise the potential of odour nuisance.

Gaseous Emissions from Construction Plant

Gaseous emissions from diesel-driven construction plant will arise during the construction phase. With reference to the construction programme and the powered-mechanical equipment (PME) inventory (see *Section 5.4.1 and Annex 5-B*), LNG terminal facility construction works and civil works will involve the highest number of diesel-driven PMEs (a total of 54 PMEs) including 2 backhoes, 3 drill rigs, 18 engines, 16 air compressors, 15 crawler cranes; 4 trucks and 14 barges/tug boats. The engine power of the engines is about 500 kW. For other diesel-driven PMEs, the average engine power is similar to a truck engine, i.e., 100 kW. The barges/tugboats will normally be berthing for unloading/loading of equipment or materials and therefore, their emissions will not be continuous.

Oxides of nitrogen (NO_x) and respirable suspended particulates (RSP) are the major air pollutants emitted from diesel-driven PMEs. The emission factors for non-road diesel engines, as recommended in the *USEPA Tier 1 Non-road Engine Emission Factors* [(2)], are used to estimate the emission quantities. Assuming that all diesel-driven equipment are operated simultaneously, the estimated emission rates are summarized in *Table 4.6*.

Table 4.6 Emission Factors and Emission Rates for Construction Plant based on the Preliminary Design Estimates

	NO_x	RSP
Total worksite area	230,000 m^2	
Total no. of engines	18	
Average Engine Power of generator (kW) [(a)]	500	
Total no. of diesel-driven equipment (including backhoes + drill rigs + air compressor + crawler crane + trucks)	40	
Average Engine Power of diesel-driven equipment (kW) [(b)]	100	
USEPA Tier 1 Non-road Engine Emission Factor (g/kWh) [(c)]	9.2	0.54
Total emission rate (g/s)	33.2	1.95
Total emission rate per area (g/m²/s)	1.4×10^{-4}	8.5×10^{-6}

Notes:

(a) Reference to the engine power provided by the Design Engineer

(b) Typical engine power of truck is 100 kW and it is assumed that the engine power of stationary source is also about 100 kW.

(c) Reference to *USEPA Non-road Engine Emission Factor (http://www.dieselnet.com/standards/us/offroad.html)*

(1) Environmental Guidance Note for Sewage Pumping Stations which is NOT a Designated Project, by EPD; Guidelines for the Design of Small Sewage Treatment Plants, by EPD; Sewerage Manual - Pumping Stations and Rising Mains, by DSD

(2) http://ww.dieselnet.com/standards/us/offroad.html

Air emissions will disperse very rapidly over the large construction area and the number of construction plant items adopted in the above estimation is the worst case. It should also be noted that not all items of construction plant will be operated continuously. Taking into account the large separation distance between the site boundary and the nearest ASR (see *Table 4.5*), no adverse air quality impacts are anticipated.

Offshore PMEs such as grab dredgers, barges and tugboats will be distributed at the area of dredging, reclamation, turning basin, pipeline works, jetty and other marine works. Referring to the construction plant inventory in *Section 5.4.1 and Annex 5-C*, a total of 9 dredgers/barges/tugboats are required for reclamation; a total of 12 dredgers/barge/tugboats are required for marine works and a total of 5 are required for the installation of water main and cable. These dredgers, barges and tugboats are located at different marine works area, therefore, the air emissions from the offshore PMEs over an overall large marine works area will be low. With the consideration of large separation from the ASR, no adverse air quality impact due to offshore PMEs is anticipated.

4.4.2 *Operational Phase*

During the operation of the LNG terminal, potential sources of air quality impact include:

<u>South Soko Island</u>

- emissions from the submerged combustion vaporizers (SCVs);
- emissions from the gas-turbine generator;
- emissions from the LNG carrier and tugboats during the unloading of LNG;
- emissions from the on-site vehicles;
- emissions from the diesel-driven firewater pumps;
- fugitive hydrocarbon release from boil-off gas (BOG) compressors seal leakage; and

<u>Black Point</u>

- emissions from gas heaters at the Gas Receiving Station (GRS) at the Black Point Power Station.

Emissions from Submerged Combustion Vaporizers (SCVs)

Five submerged combustion vaporizers (SCVs) will be operated in the event that the Open Rack Vaporizers (ORVs) run below their capacity (i.e., the ambient seawater temperature is too cold, breakdown of the seawater intake pump or an increase in gas sendout is required).

Natural gas will be used as fuel for the SCVs. An individual stack is connected to each of the SCVs and has a preliminary design diameter of 1.2 m and a height of 13 m above ground. As the operating frequency of the SCVs is not known at this stage, for the purposes of the assessment, it has been assumed that all five of the SCVs are in continuous operation. Based on the continuous operation of SCVs, the exhaust gas flowrate of each SCV is approximately 26,000 Nm^3hr^{-1} (1). The exhaust gas will be emitted at about 30 to 50°C. Oxides of nitrogen (NO_x) and carbon monoxide (CO) are the principal air emissions and about 51 tonnes of NO_x and 257 tonnes of CO may be emitted from the SCVs a year. It has been conservatively assumed that the exhaust gas will be emitted at 30 °C.

Emissions from Gas-turbine Generators

The on-site gas-turbine generators may be used to generate electric power for the LNG terminal. According the preliminary design, four units of gas-turbine generators are proposed to provide a total capacity of 23 MW. These generators are fuelled by natural gas. An individual stack is connected to each generator and has a preliminary designed exhaust area of 2.3m x 2.3m and a height of 8 m above ground. NO_x and CO are the principal air emissions. Assuming that the gas-turbine generators are operated continuously, about 128 tonnes of NO_x and 156 tonnes of CO will be emitted a year. The total exhaust gas will be emitted at an estimated flowrate of 382,800 Nm^3hr^{-1} and at a temperature of 500 °C.

A specified process licence will be obtained from the EPD in accordance with the *Air Pollution Control (Specified Process) Regulations* and the requirements for operational monitoring, including in-stack, process and ambient monitoring in BPM 7/1 (2) , will be followed.

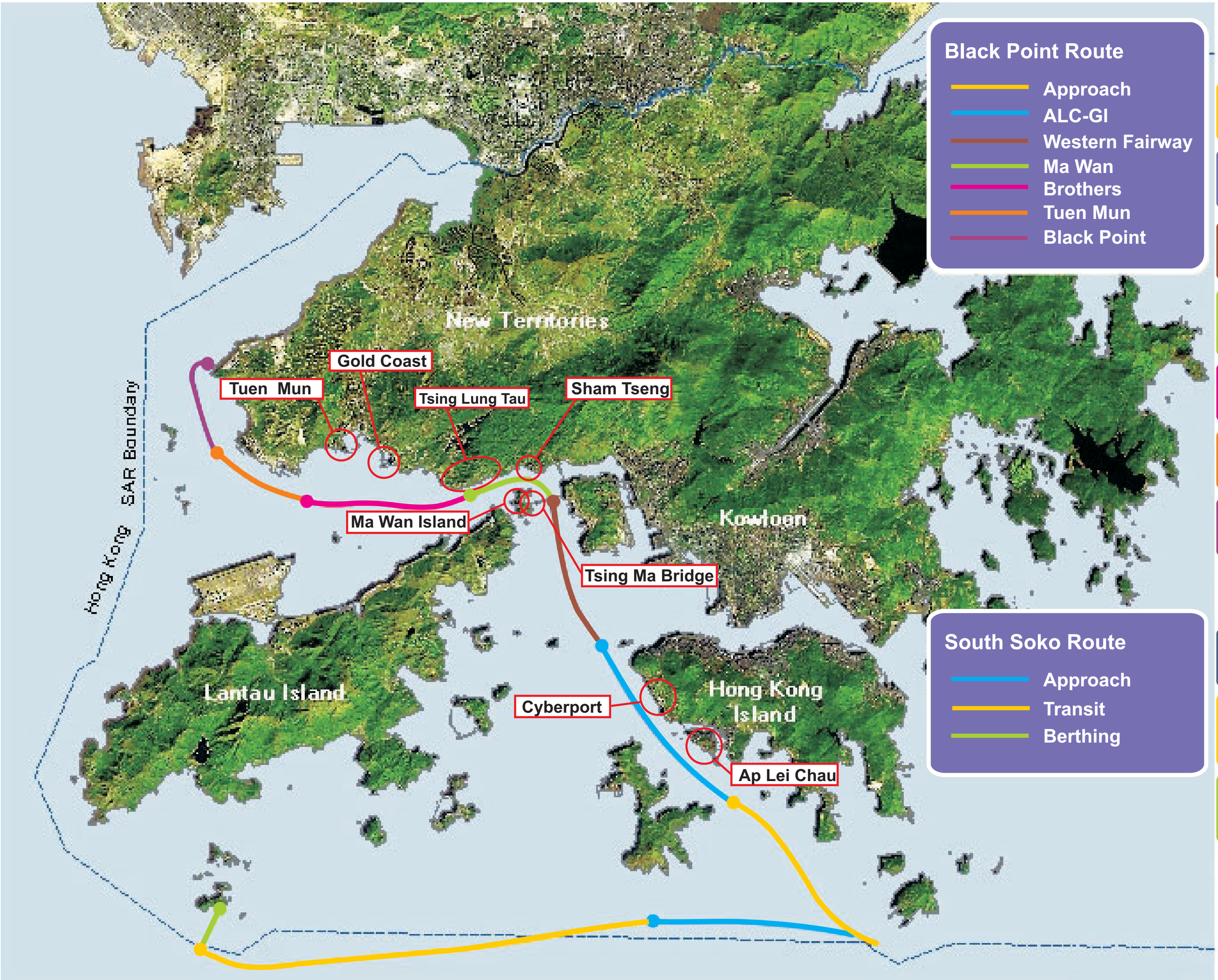
Emissions from LNG Carrier and Tugboats during Unloading of LNG

LNG will be delivered to the LNG terminal by LNG carrier. The LNG will then be transferred from the LNG carrier to the storage tanks at the terminal at a preliminary design rate of 14,000 m^3hr^{-1}. The unloading time will be approximately 18 hours. Approximately 75 LNG carrier deliveries are expected each year (i.e., approximately one LNG carrier transit into and out of Hong Kong waters every 5 days). While within Hong Kong waters, the LNG carrier will be guided by a pilot, with two to four tugboats available to assist as necessary. While the LNG carrier is alongside the jetty, two tugboats will remain in close proximity, but the engines of the tugboats will be shut down.

The proposed LNG carrier transit route (refer to *Figure 4.2*), is very short in Hong Kong waters and the LNG carrier will be travelling slowly due to the speed limitation stipulated by the Marine Department. In addition, the frequency of LNG carrier transits into and out of Hong Kong is very low (i.e., approximately 6 carriers per month) when compared with the frequency of

(1) "Nm^3s^{-1}" denotes the gas flowrate measured at a reference condition of 0°C and 101.3kPa.

(2) A Guidance Note on the Best Practicable Means for Electricity Works (Coal-fired Plant, Gas-fired Gas Turbine and Oil-fired Gas Turbine), BPM 7/1, by EPD



Black Point

- **Approach**
  Approach From entry to Hong Kong waters through pilot boarding to AP Lei Chau(10km)
- **ALC-GI**
  South of Ap Lei Chau to Green Island along East Lamma Channel (11km)
- **Western Fairway**
  Western Fairway up to SW Tsing Yi (8km)
- **Ma Wan**
  Ma Wan approach west of Tsing Yi under bridge and around Ma Wan Island to location south of Brothers Point at Tai Lam Chung (5km)
- **Brothers**
  Brothers Point Channel south up to Urmston Road south of Tuen Mun River Trade Terminal (RTT) (9km)
- **Tuen Mun**
  Urmston Road from south of Tuen Mun River Trade Terminal to west of Castle Peak (5km)
- **Black Point**
  Around Castle Peak up to Black Point, Including turning basin, berthing operation and carrier at berth (7km)

South Soko

- **Approach**
  From entry to Hong Kong waters, approach to pilot boarding at South Lamma DG Anchorage (13km)
- **Transit**
  From pilot boarding area at South Lamma DG Anchorage, transit through PRC waters south of the South Cheung Chau disposal ground to re-entry to Hong Kong waters (23km)
- **Berthing**
  Transit approach channel, with tug assistance turn carrier 180 deg and then berth the carrier to the Soko Island Terminal jetty (2km)

Figure 4.2

LNG Carrier Transit Routes for Black Point and South Soko Option

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ocean-going cargo/passenger vessels (i.e., in 2005, an average of about 3,300 ships per month) [(1)]. Hence, the impact due to its emissions will be transient and would not cause adverse air quality impact.

When moored in required position alongside the jetty, the main engine will be switched off and the auxiliary engines will operate for LNG unloading and to provide power for other ship services. Three auxiliary engines with a total generator capacity of approximately 9.35 MW running at 75% load will be operated to pump the LNG to the terminal's storage tanks. The auxiliary engines are assumed to be fuelled by Marine Diesel Oil (MDO) or Heavy Fuel Oil (HFO) and NO_x, SO_2 and CO are the principal air emissions. The MDO or HFO has been assumed to contain a maximum of sulphur content of 1.5%. Approximately 13.88 g/kWh of NO_x, 6 g/kWh of SO_2 and 0.6 g/kWh of CO will be emitted from the auxiliary engine at 75% load [(2)]. The exhaust gas velocity is estimated to be 25.0 ms^{-1} through a stack of approximately 41 m above sea level. The stack diameter is about 0.45 m. The three individual stacks of the auxiliary engines are enclosed in a single chimney, therefore the three individual emission sources are modeled as an equivalent source with an equivalent diameter of 0.78 m.

For the worst case assessment and to allow for the flexibility in the LNG carrier unloading process, it has been assumed that exhaust emissions from the auxiliary engines are emitted continuously.

Emissions from On-site Vehicles

As the delivery of diesel, LNG and materials are marine-based, the number of on-site vehicles will be limited to those required for staff transportation and maintenance works only. The emissions from on-site vehicles will therefore, be negligible and no adverse air quality impact from this source is anticipated.

Emissions from Diesel-driven Firewater Pumps

Four firewater pumps (two diesel-driven and two electric-driven) will be provided and located besides the utility area. They will be used in emergency situations and during routine testing only, i.e., an average of 1.5 hours per week on average. The fuel consumption rate of each diesel-fired firewater pump is about 0.108 m^3hr^{-1}. NO_x, SO_2 and CO are the principal air emissions. The air emissions are infrequent and minor and hence, adverse air quality impacts are not anticipated.

An approval for the chimney installation for diesel-driven pumps will be obtained from the EPD, in accordance with the *Air Pollution Control (Furnaces, Ovens and Chimneys) (Installation and Alteration) Regulations*.

(1) Reference to Port and Maritime Statistics, by Hong Kong Marine Department http://www.mardep.gov.hk/en/publication/pdf/portstat_1_m_a1.pdf

(2) Reference to IMO MARPOL Annex 4 and 75% load of each generator

Fugitive Hydrocarbon Release from Boil-off Gas (BOG) Compressors Seal Leakage

Fugitive hydrocarbon may be released from a leakage of the boil-off gas (BOG) compressors seal, releasing a quantity of boiled-off vapours of about 53 tonnes of hydrocarbon per annum. Typically about 90% of the hydrocarbon will be methane. This is equivalent to only 0.02% of the total annual emission of methane in Hong Kong [1]. Emissions will be minimised through the design process and the ongoing maintenance programme, which will incorporate a leak detection and repair monitoring programme.

The safety implications of accidental leaks are discussed in *Section 13*.

Emissions from Gas Heaters at Gas Receiving Station at Black Point Power Station

The pipeline from South Soko Island to the BPPS will terminate at a Gas Receiving Station (GRS) located at the existing BPPS (please refer to *Figure 3.11*). The new GRS will include an inlet header, filters, gas meters, gas heaters, pressure control equipment and the associated pipework. The gas from the terminal will be transferred to the GRS and then will be heated up by four gas heaters before sending to the existing BPPS.

Natural gas will be used as fuel for the gas heaters and NO_x and CO are the principal air emissions. Approximately 72 tonnes of NO_x and 45 tonnes of CO will be emitted a year. The total flowrate of the exhaust gas is estimated to be 73,900 Nm^3hr^{-1} and the exhaust gas temperature will be about 280°C. An individual stack is connected to each of the gas heaters. The stack diameter is 1.07 m and the stack height is approximately 15 m above ground.

Summary

In view of the emission characteristics of these sources and the frequency of operation, the SCVs, gas-turbine generators and LNG carrier auxiliary engines on South Soko and gas heaters at new GRS at Black Point are included in the detailed assessment. The other sources have been excluded from the modelling assessment on the basis that they are of a small scale and /or are operated very infrequently. The locations of the major emission sources are shown in *Figures 4.3a and 4.3b*.

4.5 ASSESSMENT METHODOLOGY

4.5.1 Emission Rate Estimation

SCVs and gas-turbine generators at South Soko and gas heaters at GRS at BPPS are operated by natural gas and hence NO_x and CO are the principal air emissions. During the LNG unloading process, the LNG carrier auxiliary

(1) Reference to the total methane (CH_4) of 246,000 tonnes in the *Hong Kong Greenhouse Gas Emission Inventory 2004* in the EPD website (http://www.epd.gov.hk/epd/english/environmentinhk/air/data/files/table_ghg_wtc.pdf)

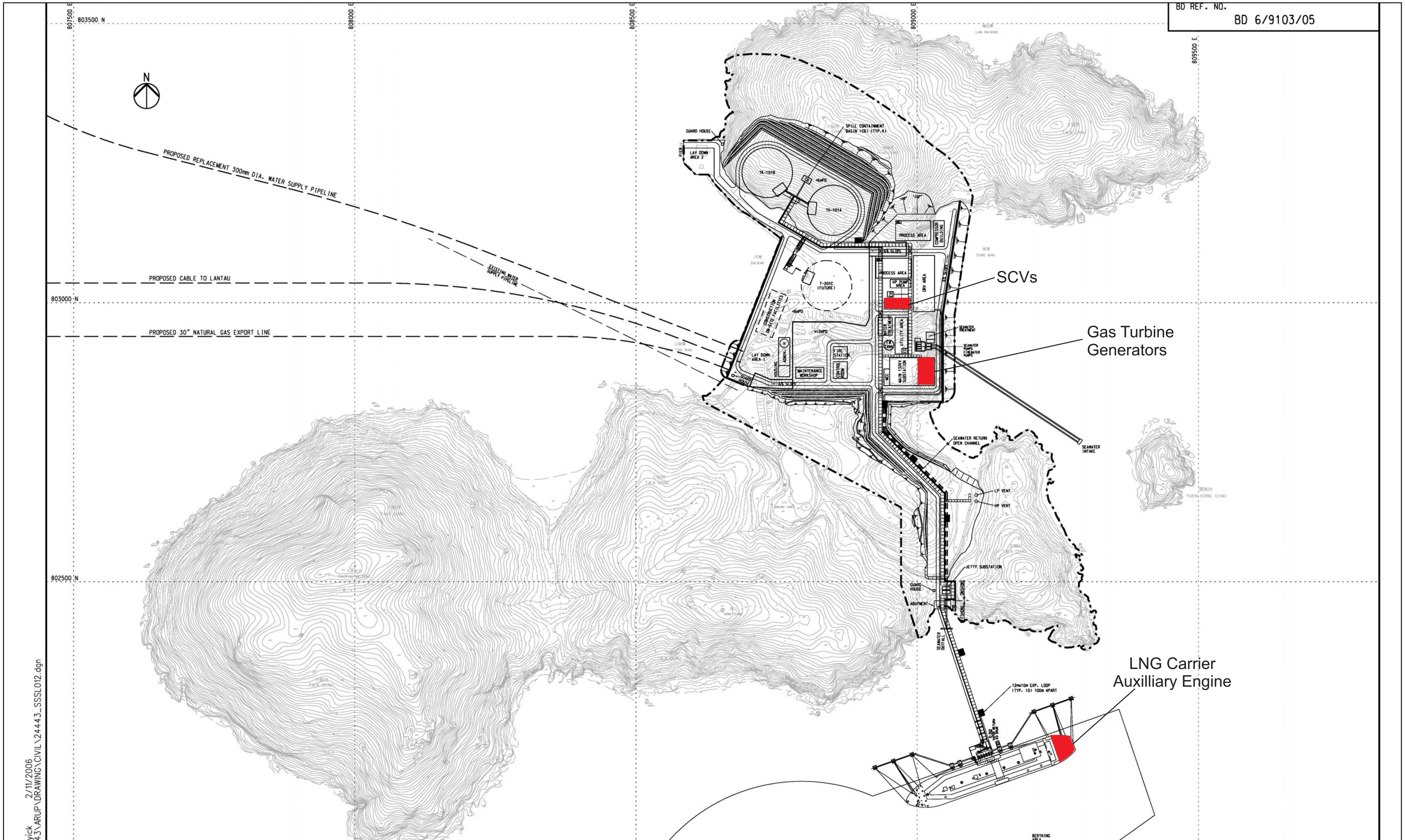

Figure 4.3a

Location of Potential Air Emission Sources On South Soko Island

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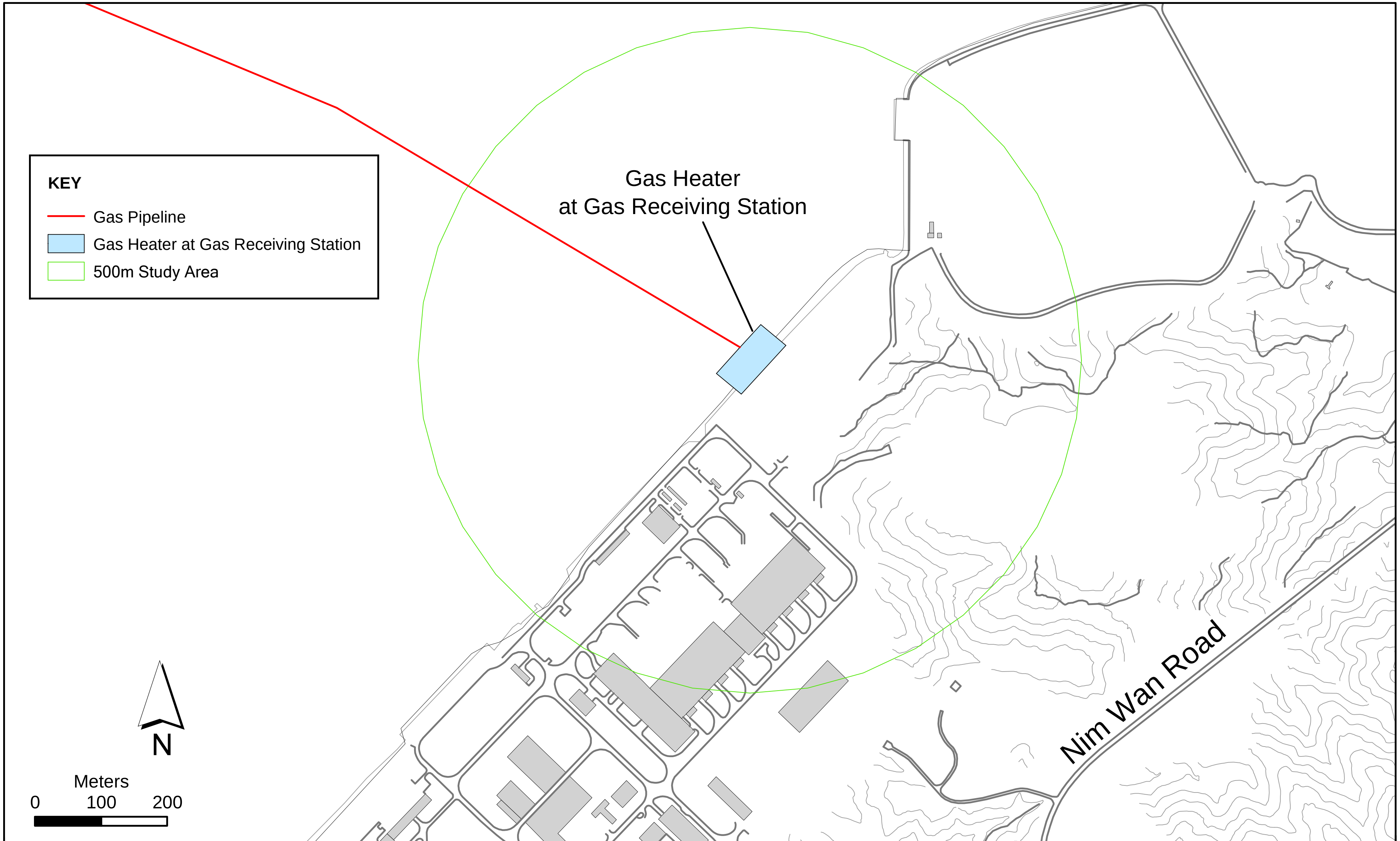

Figure 4.3b

Location of Gas Receiving Station

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Date: 05/10/2006

engines are operated by MDO or HFO and so NO_x, SO_2 and CO are the principal air emissions.

As discussed in *Section 4.4.2*, the SCVs, gas-turbine generators, LNG carrier auxiliary engines and gas heaters at GRS are assumed to be operating continuously throughout 24 hours and 365 days in the modeling assessment as a conservative approach.

The emission rates of NO_x, SO_2 and CO are estimated and summarized in *Table 4.5* and detailed calculations are presented in *Annex 4-B*.

Table 4.7 ***Summary of Emission Rates of NO_x, SO_2 and CO based on Preliminary Design Estimates***

	South Soko			Black Point
	SCV	**Gas Turbine Generator**	**LNG Carrier – Auxiliary Engine [b]**	**Gas Heaters at GRS**
Stack height (m)	13	8	41	15
Stack diameter (m)	1.2	2.6 [a]	0.78	1.07
Exit temperature (°C)	30	500	320	280
Exit velocity (m/s)	7.09	14.2	25	11.56
No. of emission source	5	4	1 [c]	4
NO_x emission rate of each source (g/s)	0.32	1.01	36	0.57
SO_2 emission rate of each source (g/s)	-	-	15.6	-
CO emission rate of each source (g/s)	1.63	1.24	1.56	0.36

Notes:
(a) The stack diameter is an equivalent diameter in which the stack emission area is 2.3 m x 2.3 m.
(b) The total capacity of LNG carrier auxiliary engines is 9,350 kW.
(c) Three individual emission sources are modeled as an equivalent source.

4.5.2 *Modelling Approach*

An air dispersion model, *Industrial Source Complex Short Term* (ISCST3), recommended in the *EPD's Guideline of Choice of Models and Model Parameter*, was employed to predict the air quality impact.

The SCVs, gas-turbine generators, LNG carrier auxiliary engines and gas heaters were assumed to be operated continuously in the modeling assessment for a worst case assessment.

As the site areas of LNG terminal and GRS are classified as "rural" in accordance with the EPD's *Guidelines on Choice of Models and Model Parameter*, the "rural" dispersion mode was used in the model run. In addition, the local terrain has also been incorporated into the model to account for terrain-induced impacts to dispersion.

Due to the high background ozone level as presented in *Table 4.3* (108 μgm^{-3}), the Ozone Limiting Method (OLM) was therefore used to estimate the hourly conversion ratios of NO_x to NO_2.

Since most of the emissions are from elevated sources, air pollutant concentrations were, therefore, predicted at 1.5 m and 10 m above ground level for the identified ASRs.

A worst-case assumption of continuous emissions from all of the identified sources was made and a whole year of meteorological data was used in the air dispersion model. Maximum hourly, daily and annual average NO_2, SO_2 and CO concentrations were predicted at the identified ASRs.

4.5.3 *Meteorological Conditions*

Representative hourly meteorological data from the *Hong Kong Observatory* (HKO) station located at Cheung Chau, for the year 2004, were used for the assessment of the air quality impact in the vicinity of South Soko. Whereas the hourly meteorological data from the HKO station located at Sha Chau for the year 2004 were used for the assessment of the air quality impact in Black Point. The meteorological data included hourly wind speed, wind direction, stability class, air temperature and mixing height information.

4.5.4 *Cumulative Impacts*

Within the vicinity of the South Soko Island, there is no major air emission source and only the background air quality (presented in *Table 4.3*) would contribute to the cumulative air quality impacts during the operation of the LNG Terminal.

Within the vicinity of the GRS at Black Point, the Black Point Power Station (BPPS) is the nearest existing air emission source. In addition, the Castle Peak Power Station (CPPS) also contributes to the local air quality. The cumulative assessment considers the background air quality, as presented in *Table 4.3,* and these two main emission sources.

In the future, atmospheric emissions may arise from additional facilities in the vicinity, including Animal Carcass Treatment Facilities (ACTF), Sludge Treatment Facilities (STF), Waste-to-Energy Facilities (WEF) and the landing point of the Ling Ding Yang Bridge, would also contribute to the cumulative air quality should they be developed. The status and the timeframes of these developments are unknown at this stage and hence they are not be considered in the cumulative air quality impact assessment for this project.

4.6 EVALUATION OF IMPACTS

4.6.1 *Results (Emissions from Operation of LNG Terminal Only)*

The worst case maximum hourly, daily average and annual average concentrations of NO_2 and SO_2 and the worst case maximum hourly and 8-hour average concentrations of CO were predicted due to the operation of the LNG Terminal. The predictions are summarized in *Table 4.8*.

Table 4.8 Predicted Maximum Hourly, Daily Average and Annual Average Concentrations of NO_2 and SO_2 and Hourly and 8-hour Average Concentrations of CO (Emissions from the Operation of the LNG Terminal and GRS)

ASRs	Predicted Concentrations (μgm^{-3}) (a)							
	NO_2			SO_2 (b)			CO	
	Maximum Hourly	Daily	Annual	Maximum Hourly	Daily	Annual	Maximum Hourly	8-hour
1.5 m above ground								
A1	44	10	0.39	13	3	0.12	102	31
A2	6	3.1	0.3	-	-	-	8	6.5
A3	4	1.9	0.1	-	-	-	10	5.6
A4	5	1.2	0.1	-	-	-	8	5.2
A5	4	1.5	0.2	-	-	-	6	4.0
A6	3	1.6	0.1	-	-	-	8	6.4
A7	4	2.1	0.2	-	-	-	13	9.3
10 m above ground								
A1	45	10	0.39	13	3.3	0.12	102	31
A2	6	3.7	0.4	-	-	-	8	6.6
A3 (c)	-	-	-	-	-	-	-	-
A4	5	1.2	0.1	-	-	-	8	5.2
A5 (c)	-	-	-	-	-	-	-	-
A6	3	1.6	0.1	-	-	-	8	6.5
A7 (c)	-	-	-	-	-	-	-	-
AQO	**300**	**150**	**80**	**800**	**350**	**80**	**30,000**	**10,000**

Notes:

(a) No background concentrations are included.

(b) No SO_2 will be emitted from gas heaters at the GRS.

(c) As A3, A5 and A7 are not elevated ASRs and therefore, no assessment was performed at 10 m above ground level at these ASRs.

The predicted worst-case concentrations at all identified ASRs are very low and well within the respective AQOs.

4.6.2 *Cumulative Impacts*

South Soko

Within the vicinity of the South Soko Island, there is no major air emission source and only the background air quality (presented in *Table 4.3*) would contribute to the cumulative air quality impacts during the operation of the LNG Terminal.

Isopleths of cumulative maximum hourly, daily and annual average NO_2 and SO_2 concentrations at 1.5 m and 10 m above ground are plotted (including the background NO_2 and SO_2 concentrations of 52 μgm^{-3} and 27 μgm^{-3}, respectively) and are presented in *Figures 4.4 – 4.15*.

The isopleths indicate exceedances of the NO_2 and SO_2 AQOs at the headlands of South Soko based on the worst case approach assuming that the emissions from the SCVs, gas-turbine auxiliary engines and LNG carrier auxiliary

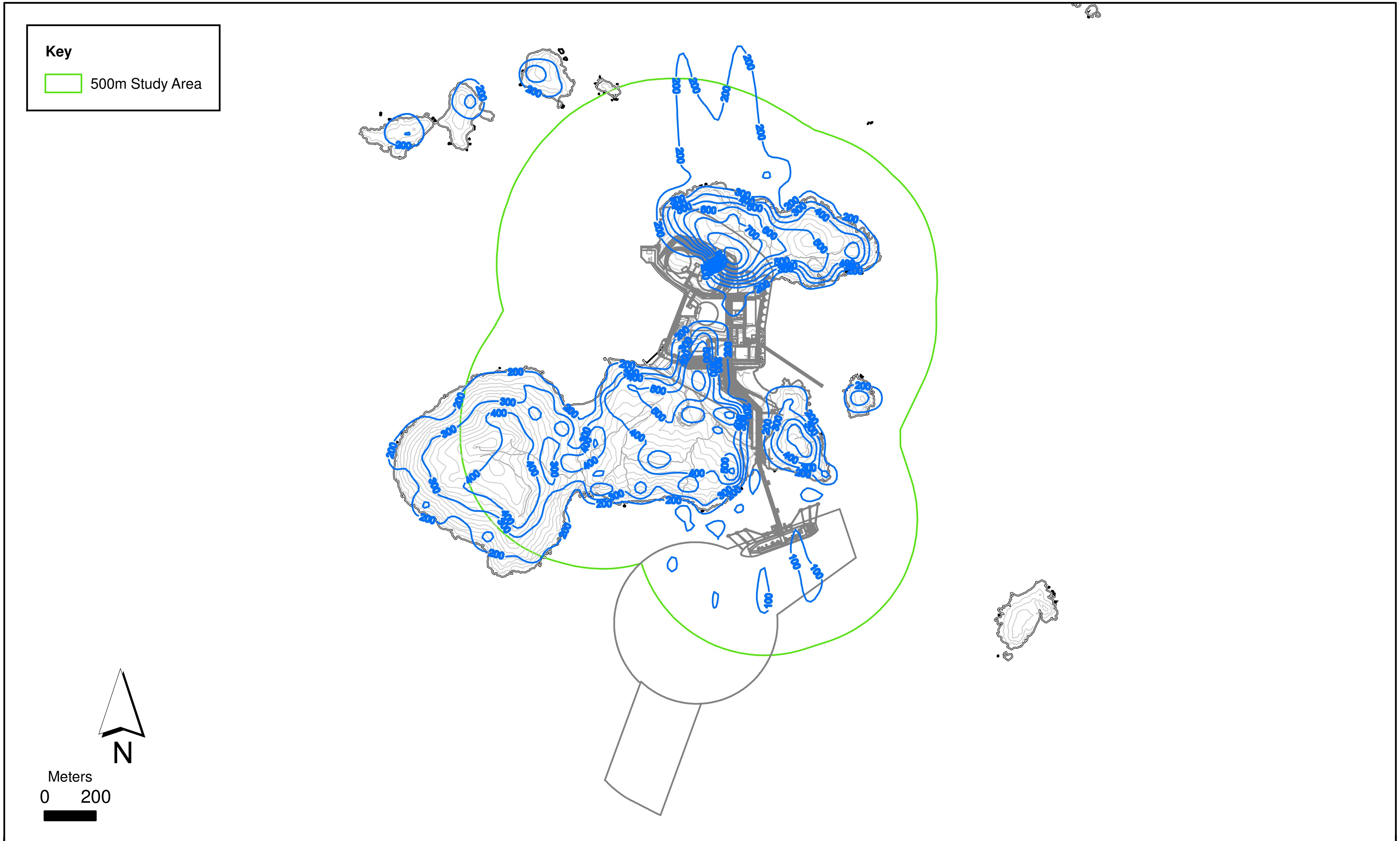

Figure 4.4

Isopleths of Cumulative Maximum Hourly NO2 at 1.5m Above Ground
(Emissions from LNG Terminal + Background)

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Date: 05/12/2006

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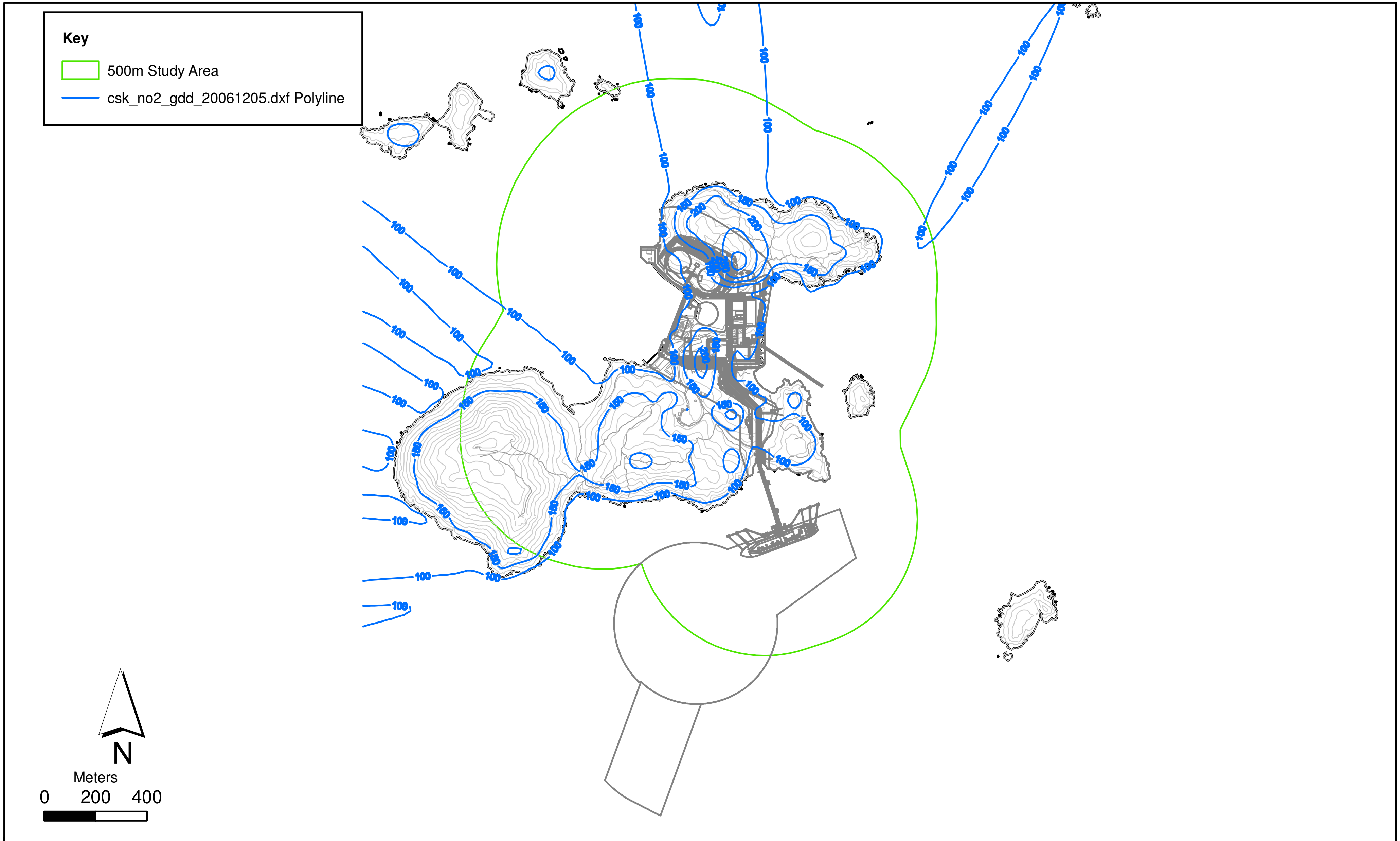

Figure 4.5

Isopleths of Cumulative Daily NO2 at 1.5m Above Ground
(Emissions from LNG Terminal + Background)

File: Report_August/0018180_Air_NO2_GDHC_SK_1.mxd
Date: 05/12/2006

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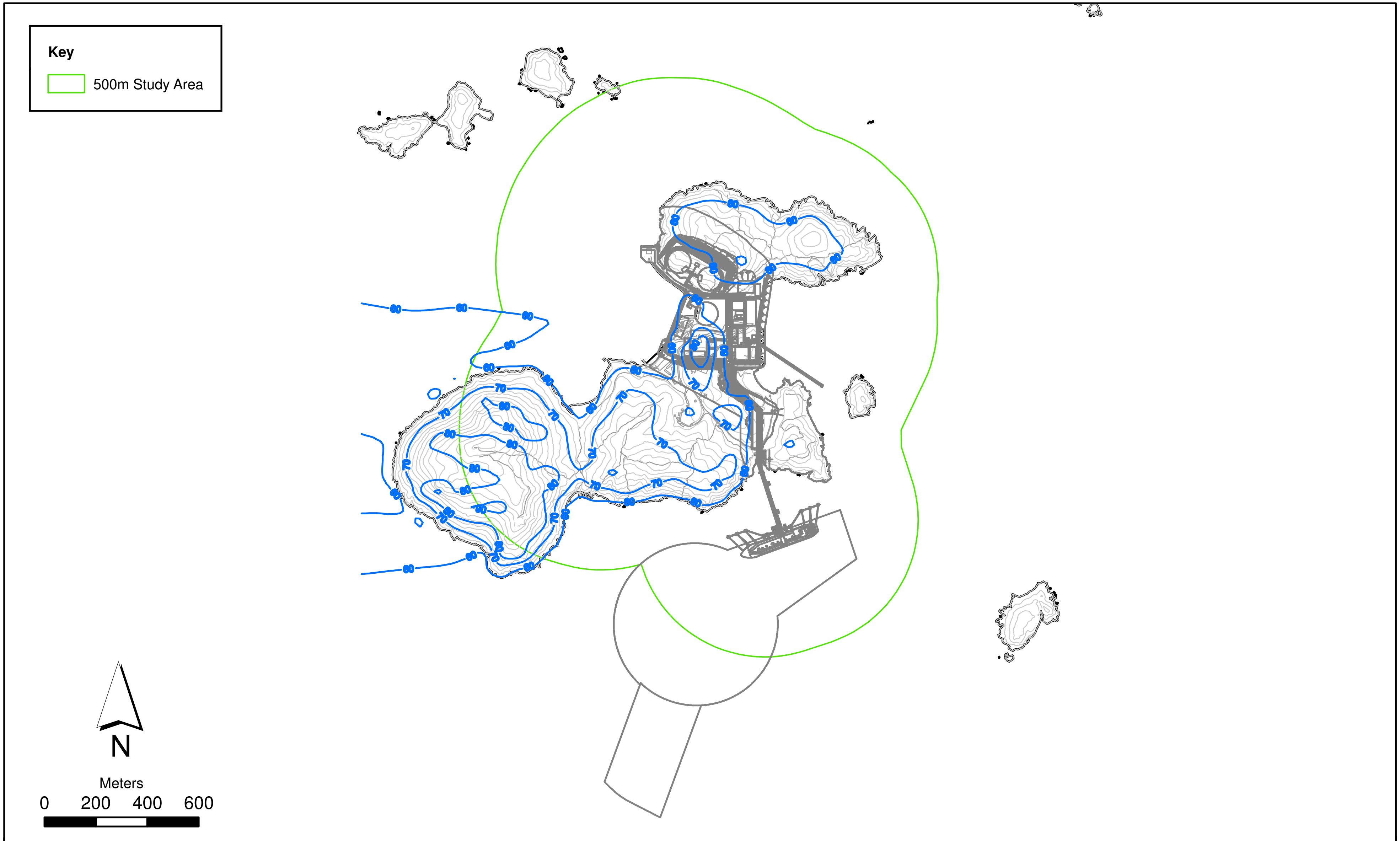

Figure 4.6

Isopleths of Cumulative Annual Average NO_2 at 1.5m Above Ground
(Emissions from LNG Terminal + Background)

File: Report_August/0018180_Air_NO2_GDHC_SK_2.mxd
Date: 05/12/2006

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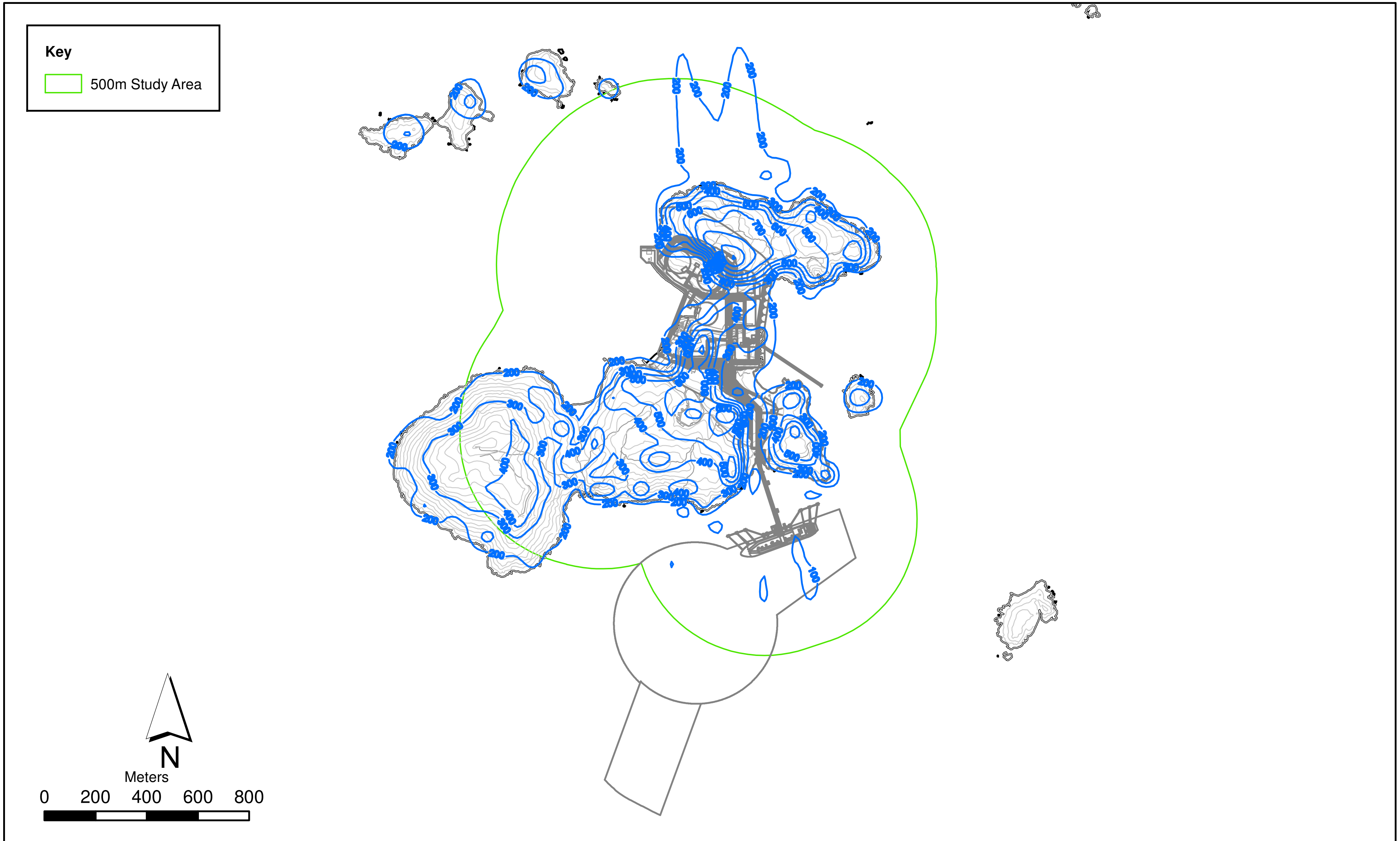

Figure 4.7

Isopleths of Cumulative Maximum Hourly NO2 at 10m Above Ground
(Emissions from LNG Terminal + Background)

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Date: 05/12/2006

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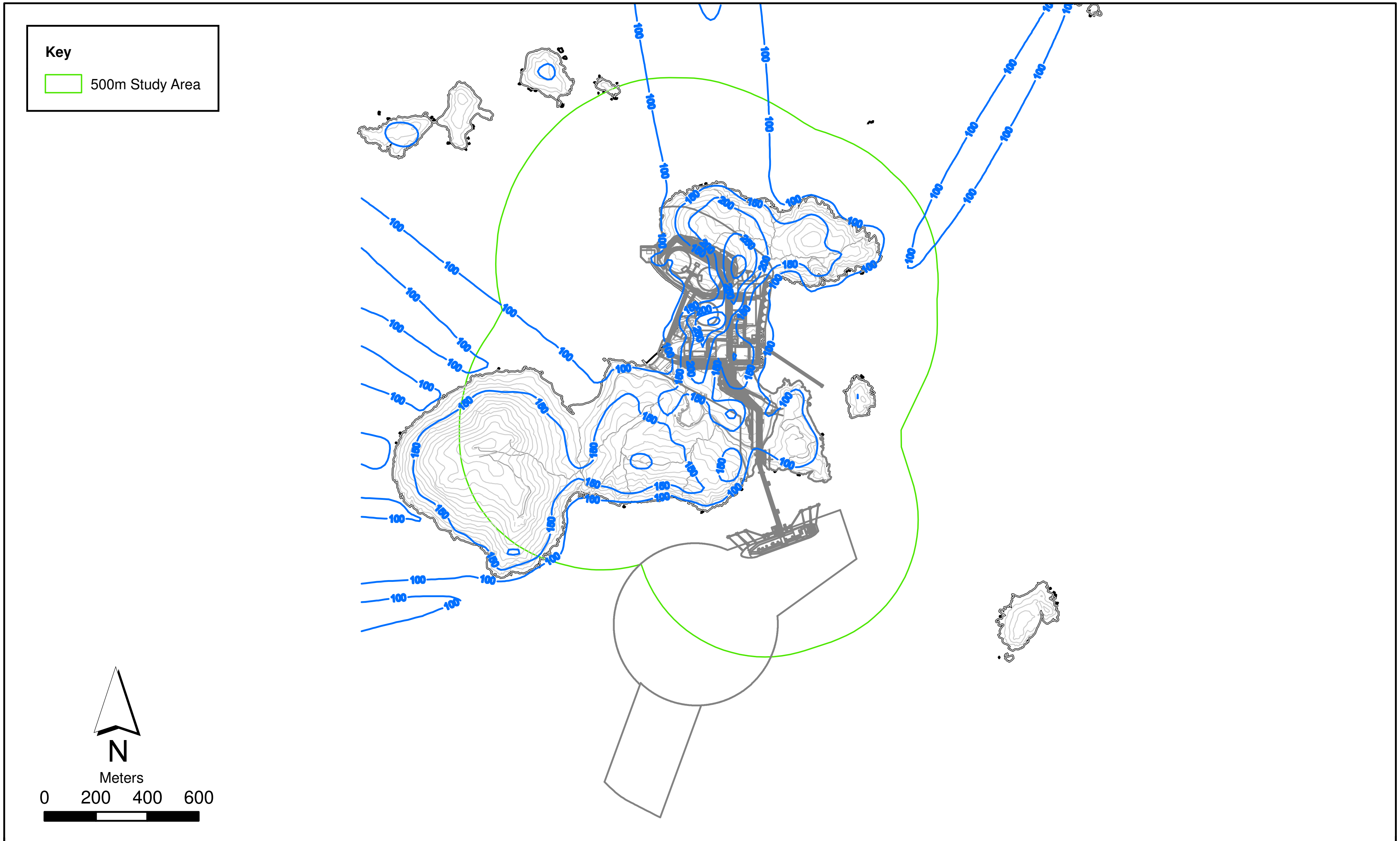

Figure 4.8

Isopleths of Cumulative Daily Averaged NO2 at 10m Above Ground
(Emissions from LNG Terminal + Background)

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Date:05/12/2006

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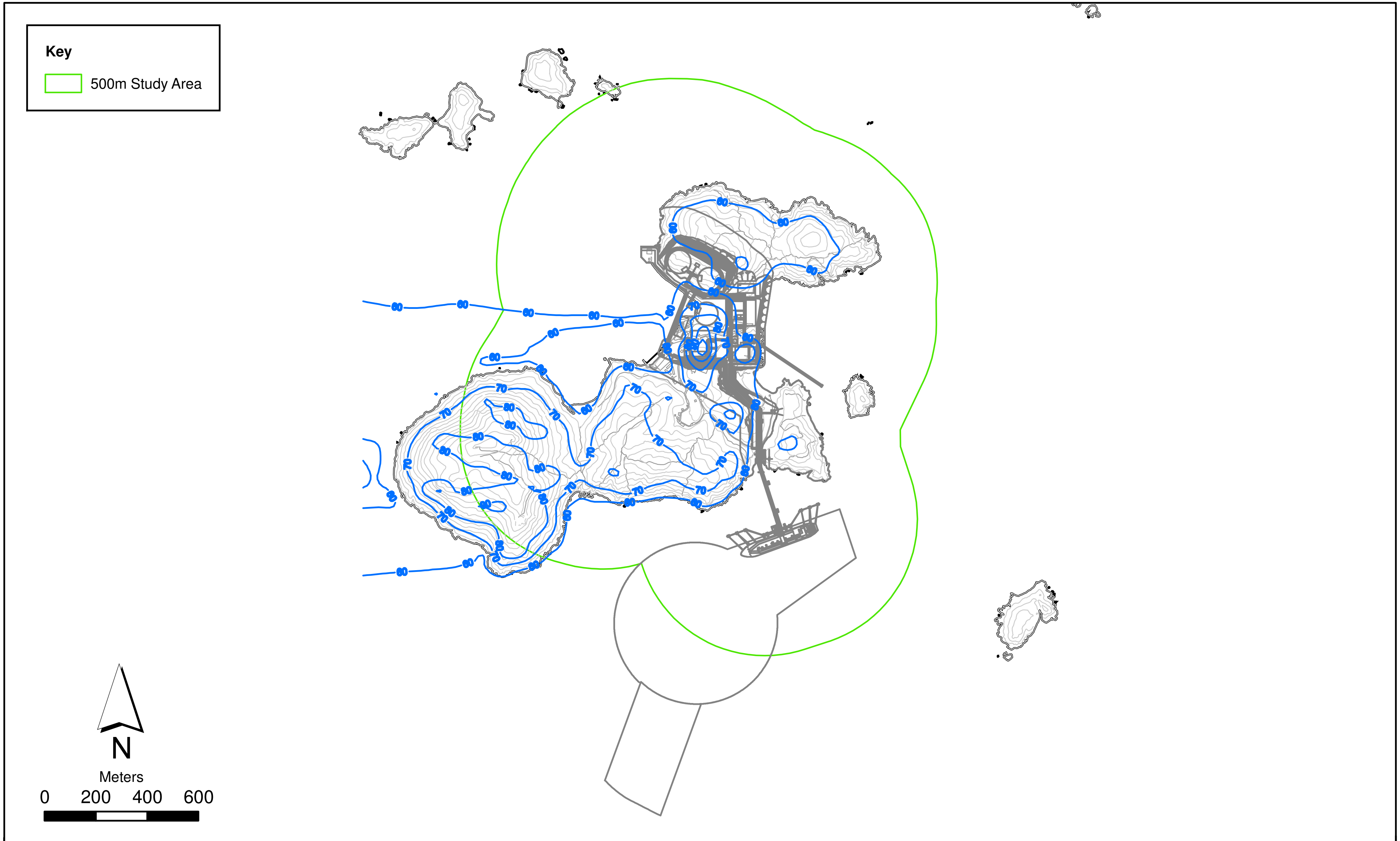

Figure 4.9

Isopleths of Cumulative Annual Averaged NO_2 at 10m Above Ground
(Emissions from LNG Terminal + Background)

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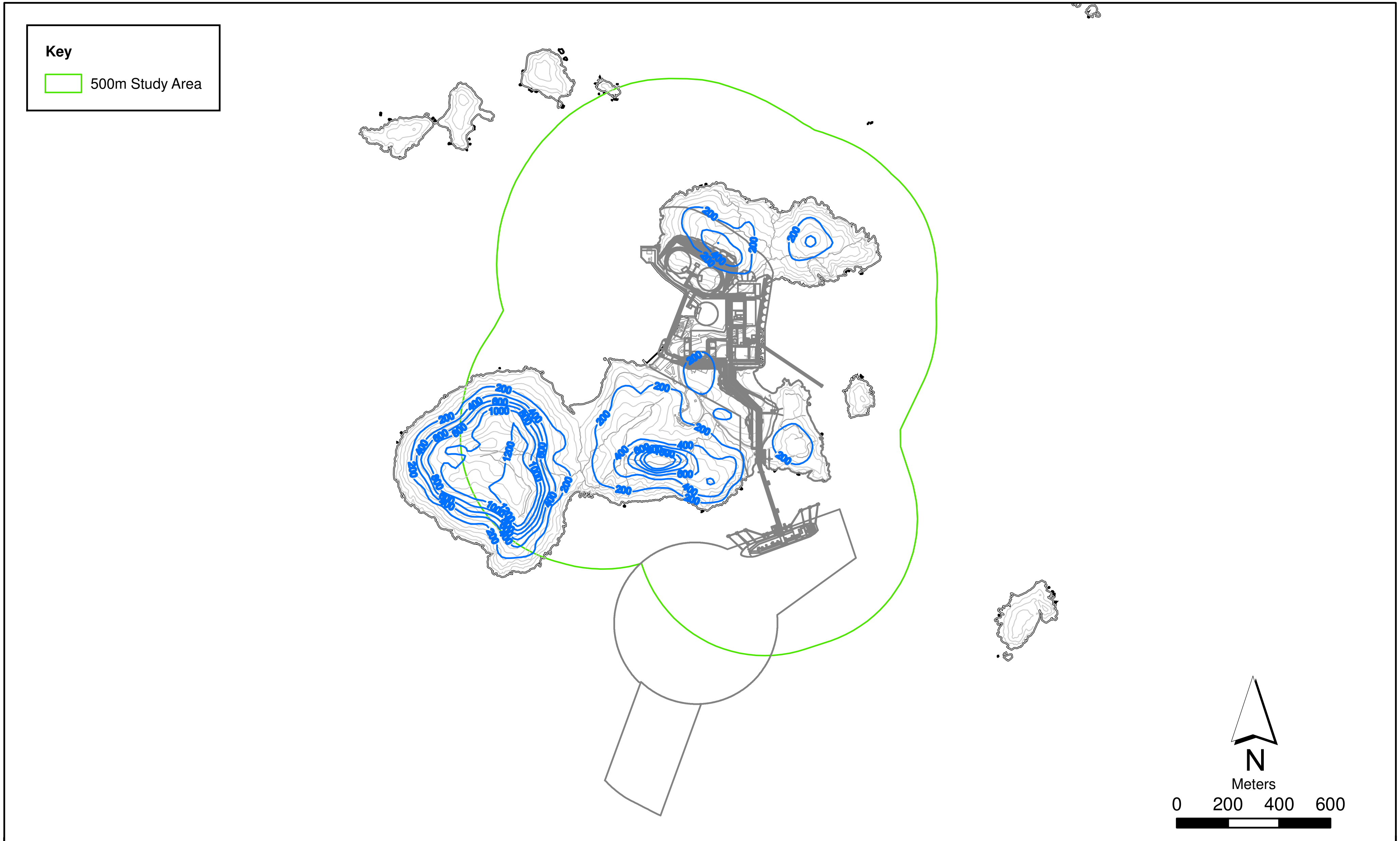

Figure 4.10

Isopleths of Cumulative Maximum Hourly SO2 at 1.5m Above Ground
(Emissions from LNG Terminal + TC AQMS Background)

File: Report_August/0018180_Air_SO2_GDH_SK_1.mxd
Date: 07/12/2006

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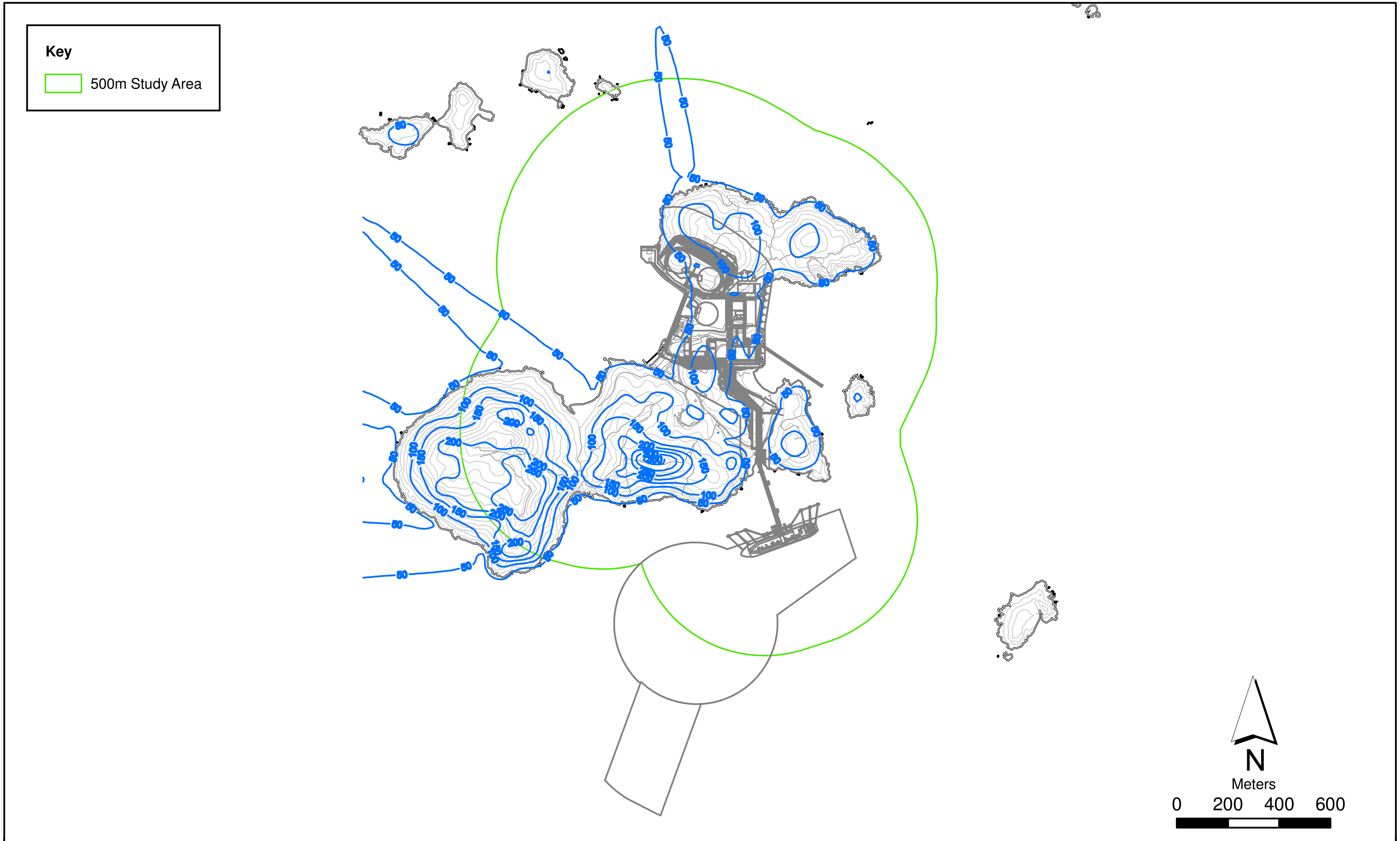

Figure 4.11

Isopleths of Cumulative Daily Average SO2 at 1.5m Above Ground
(Emissions from LNG Terminal + TC AQMS Background)

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Date: 07/12/2006

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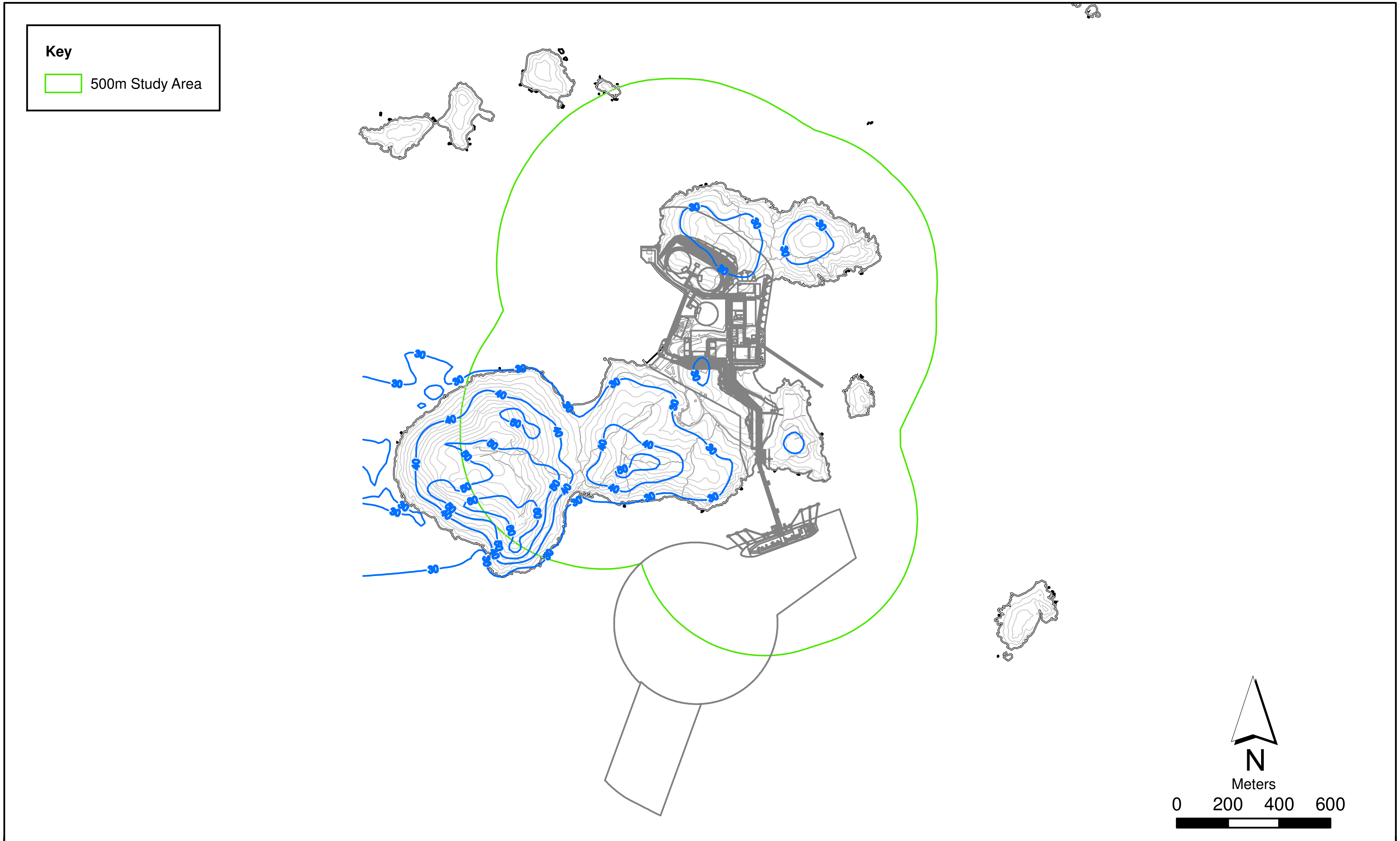

Figure 4.12

Isopleths of Cumulative Annual Average SO2 at 1.5m Above Ground
(Emissions from LNG Terminal + TC AQMS Background)

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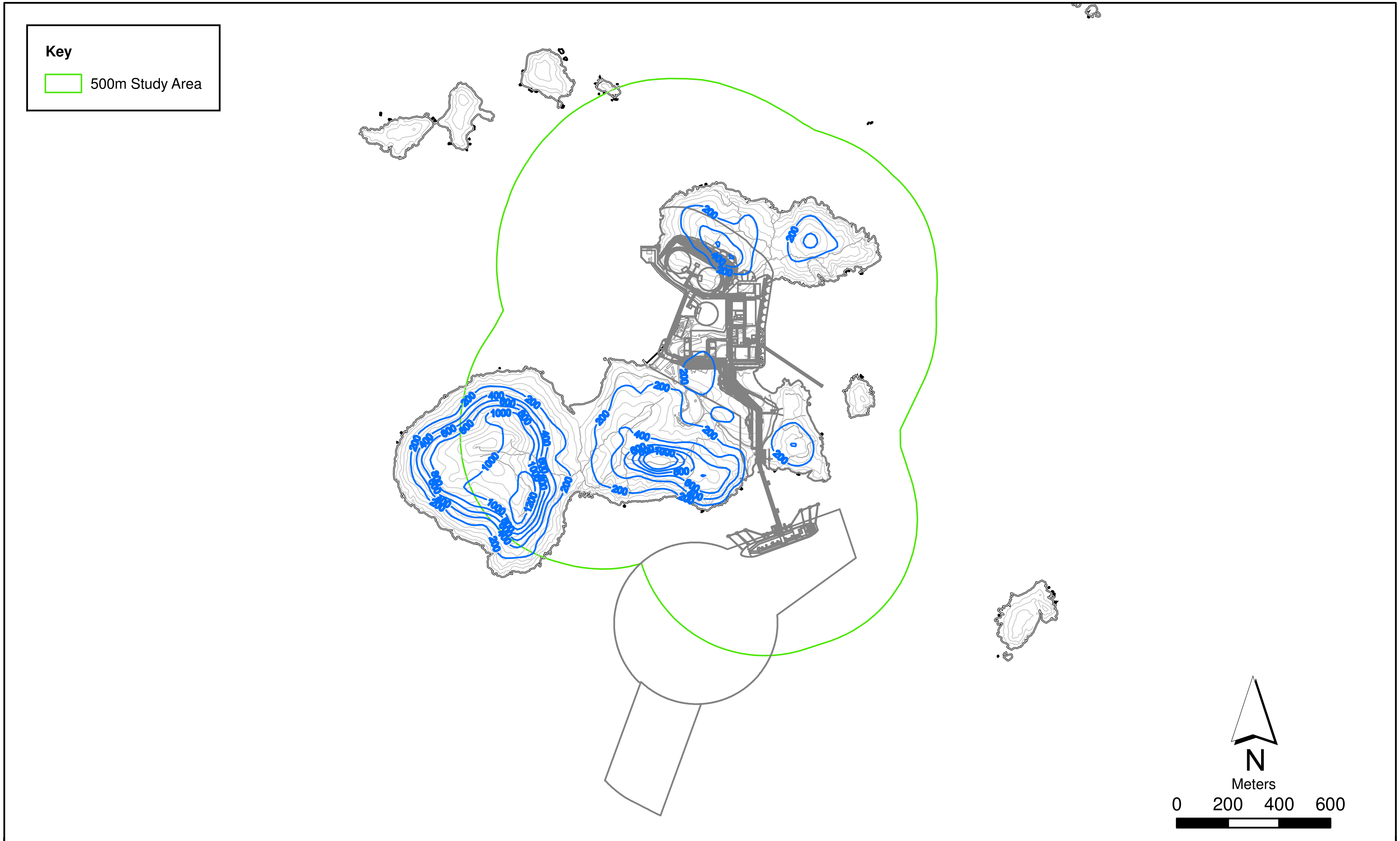

Figure 4.13

Isopleths of Cumulative Maximum Hourly SO2 at 10m Above Ground
(Emissions from LNG Terminal + TC AQMS Background)

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Date: 05/12/2006

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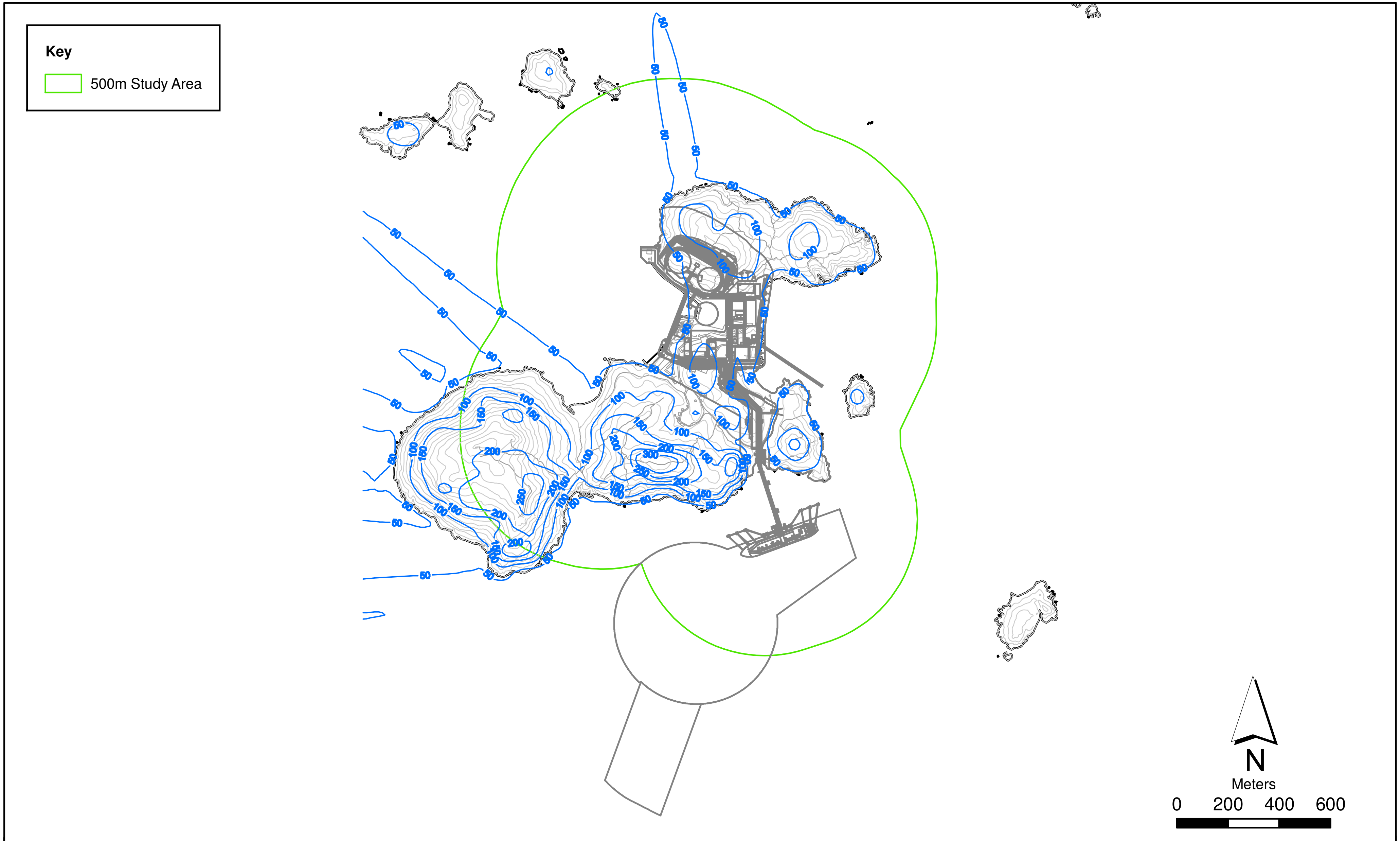

Figure 4.14

Isopleths of Cumulative Daily Average SO2 at 10m Above Ground
(Emissions from LNG Terminal + TC AQMS Background)

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Date: 11/12/2006

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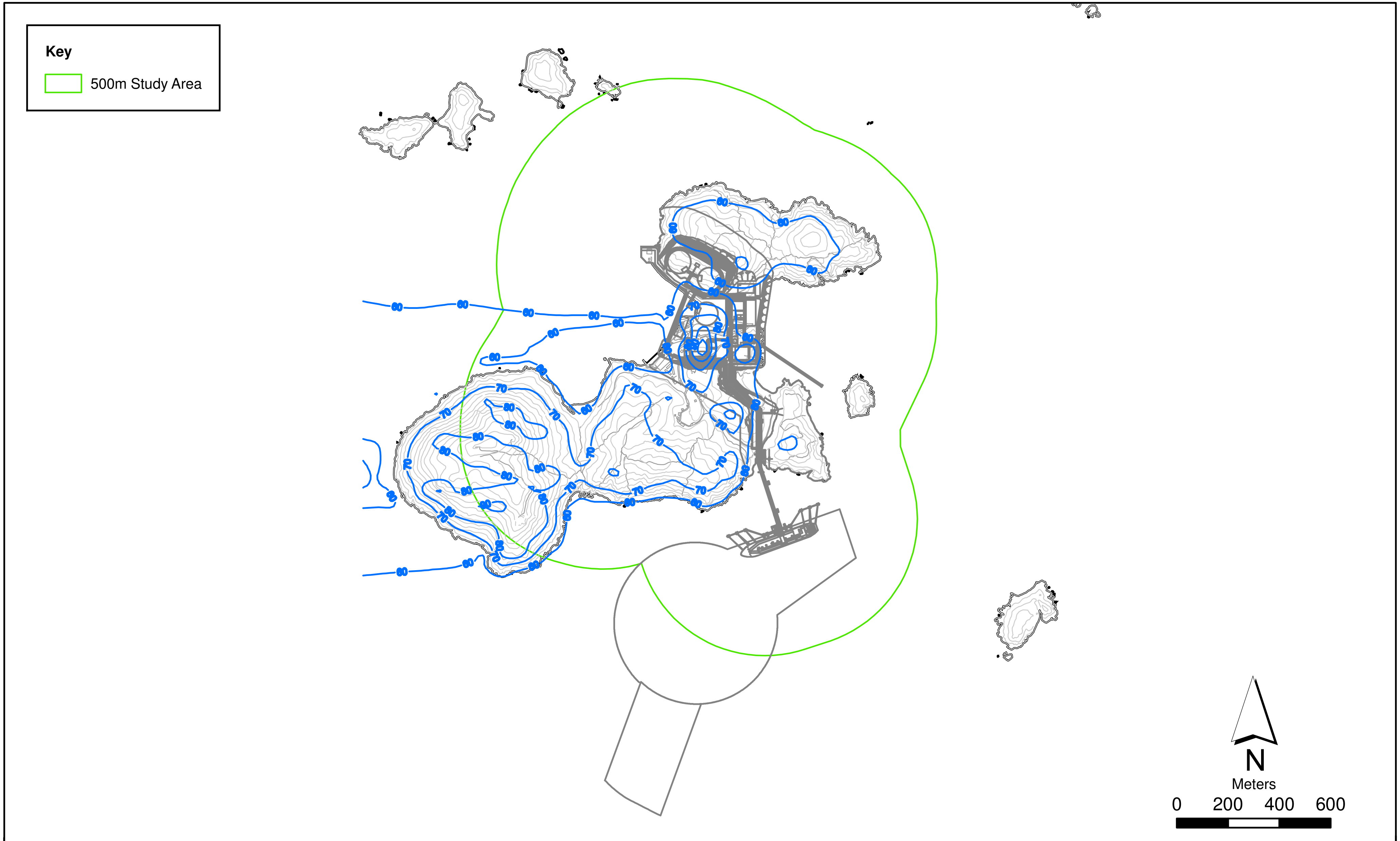

Figure 4.15

Isopleths of Cumulative Annual Average SO_2 at 10m Above Ground
(Emissions from LNG Terminal + TC AQMS Background)

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Date: 11/12/2006

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engines were operating continuously and that high concentrations of ozone were present.

In reality, the frequency of LNG carrier berthing at the LNG terminal is low (i.e., 6 carriers per month) and the SCVs will only be operated in the event that the ORVs run below their capacity. Therefore, the potential impact to this uninhabited area will be lower than that presented in the figures. It should be noted that development in these areas will be constrained by the designation of a Consultation Zone. The area of the Consultation Zone is not yet defined; however, with reference to Consultation Zones for other PHIs, it can be expected to have a radius of not less than 500 m. This would impose development constraints in the area and prohibit the development for Air Sensitive Uses.

Black Point

The air emissions from existing BPPS and CPPS together with the background air quality would contribute to the ambient air quality in Black Point during the operation of the GRS.

Cumulative Short-term (Hourly) Air Quality Impact

The existing Black Point Power Station (BPPS) is the largest single emission source in the Lung Kwu Sheung Tan area. There is a possibility that a north-westerly wind may bring emissions from the GRS and BPPS towards the ASRs in the Lung Kwu Sheung Tan area. No impact from the CPPS is considered due to the opposing worst case wind angle. Therefore, the short term cumulative maximum hourly NO_2 concentrations at the identified ASRs are summarized in *Table 4.9*.

Table 4.9 Cumulative Maximum Hourly NO_2 Impacts (Emissions from GRS + BPPS + Background Air Quality)

ASR	**Predicted Cumulative Maximum Hourly NO_2 Concentration (μgm^{-3}) at Black Point (a)**	
	1.5 m above ground	**10 m above ground**
A2	112	112
A3 (b)	110	-
A4	111	111
A5 (b)	110	-
A6	109	109
A7 (b)	110	-
Hourly NO_2 Criterion	**300**	**300**

Note:

(a) Background NO_2 concentration of 52 μgm^{-3} measured at EPD's AQMS at Tung Chung in 2004 and the adjusted maximum hourly NO_2 concentration attributed to the BPPS (54 μgm^{-3}) are included.

(b) As A3, A5 and A7 are not elevated ASRs and therefore, no assessment was performed at 10 m above ground level at these ASRs.

The results indicate that the contribution of NO_2 from the operation of GRS is very low and the cumulative maximum hourly NO_2 concentrations in the

Lung Kwu Sheung Tan area comply with the respective AQOs. No adverse cumulative short-term air quality is predicted.

Isopleths of cumulative maximum NO_2 concentrations were plotted and are shown in *Figures 4.16* and *4.17*. No offsite exceedance is predicted. Hence, no adverse cumulative short-term air quality impact is anticipated within the Lung Kwu Sheung Tan area due to the operation of the GRS.

Cumulative Long-term (Daily and Annual) Air Quality Impacts

Emissions from BPPS and CPPS together with the background air quality have the potential to cause cumulative long-term air quality impacts during the operation of the GRS. The predicted daily and annual average NO_2 concentrations attributable to the BPPS and CPPS are 22 μgm^{-3} and 0.6 μgm^{-3}, respectively (refer to *Table 4.4*) [1]. The cumulative daily and annual average NO_2 concentrations in the Lung Kwu Sheung Tan area are summarized in *Table 4.10*.

Table 4.10 ***Cumulative Daily and Annual Average NO_2 Impacts (Emissions from GRS + BPPS + CPPS + Background Air Quality)***

ASR	Cumulative Long-term NO_2 Concentration (μgm^{-3}) at Black Point			
	Daily Average [(a) (b)]		Annual Average [(a) (c)]	
	1.5 m above ground	10 m above ground	1.5 m above ground	10 m above ground
A2	77.1	77.7	52.9	53.0
A3 [(d)]	75.9	-	52.7	-
A4	75.2	75.2	52.7	52.7
A5 [(d)]	75.5	-	52.8	-
A6	75.6	75.6	52.7	52.7
A7 [(d)]	76.1	-	52.8	-
NO_2 Criteria	**150**	**150**	**80**	**80**

Notes:

(a) Background of NO_2 concentration of 52 μgm^{-3} measured at EPD's AQMS at Tung Chung is included.

(b) Adjusted daily NO_2 concentration of 22 μgm^{-3} is included (refer to *Table 4.4*).

(c) Adjusted annual average NO_2 concentration of 0.6 μgm^{-3} is included (refer to *Table 4.4*).

(d) As A3, A5 and A7 are not elevated ASRs are therefore, no assessment was performed at 10 m above ground at these ASRs.

Compared to *Table 4.8*, the results indicate that the contribution of NO_2 from the operation of GRS is very low and the cumulative daily and annual average NO_2 concentrations in the Lung Kwu Sheung Tan area comply with the respective AQOs. No adverse cumulative long-term (daily and annual) air quality is predicted.

Isopleths of cumulative daily and annual average NO_2 concentration at 1.5 m and 10 m above ground are plotted and shown in *Figures 4.18* to *4.21*. No off site exceedance is predicted.

(1) It should be noted that these values are the second highest daily averages.

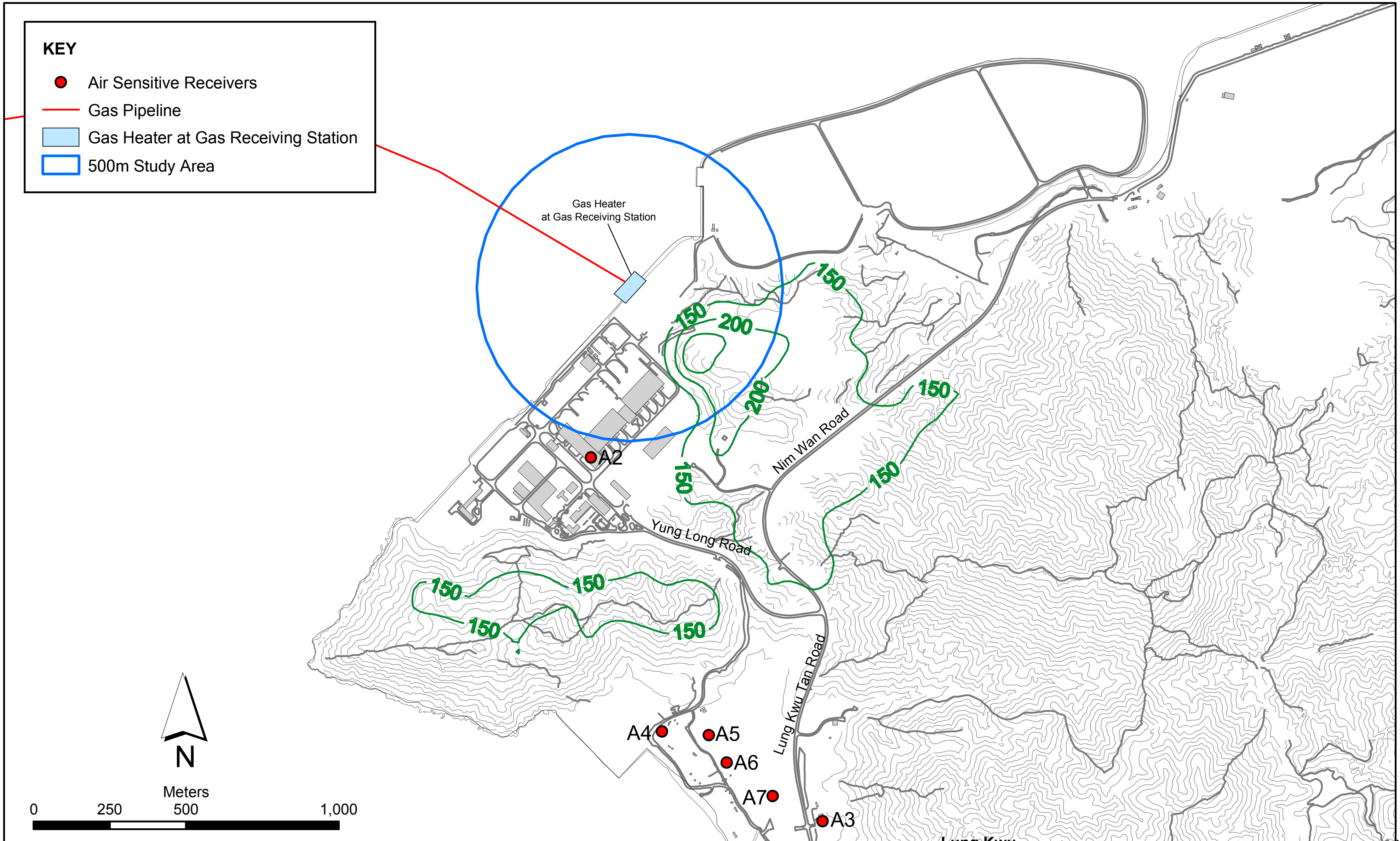

Figure 4.16

Isopleths of Cumulative Maximum Hourly NO_2 Concentration at 1.5m above ground
(Emission from GRS + Background + BPPS)

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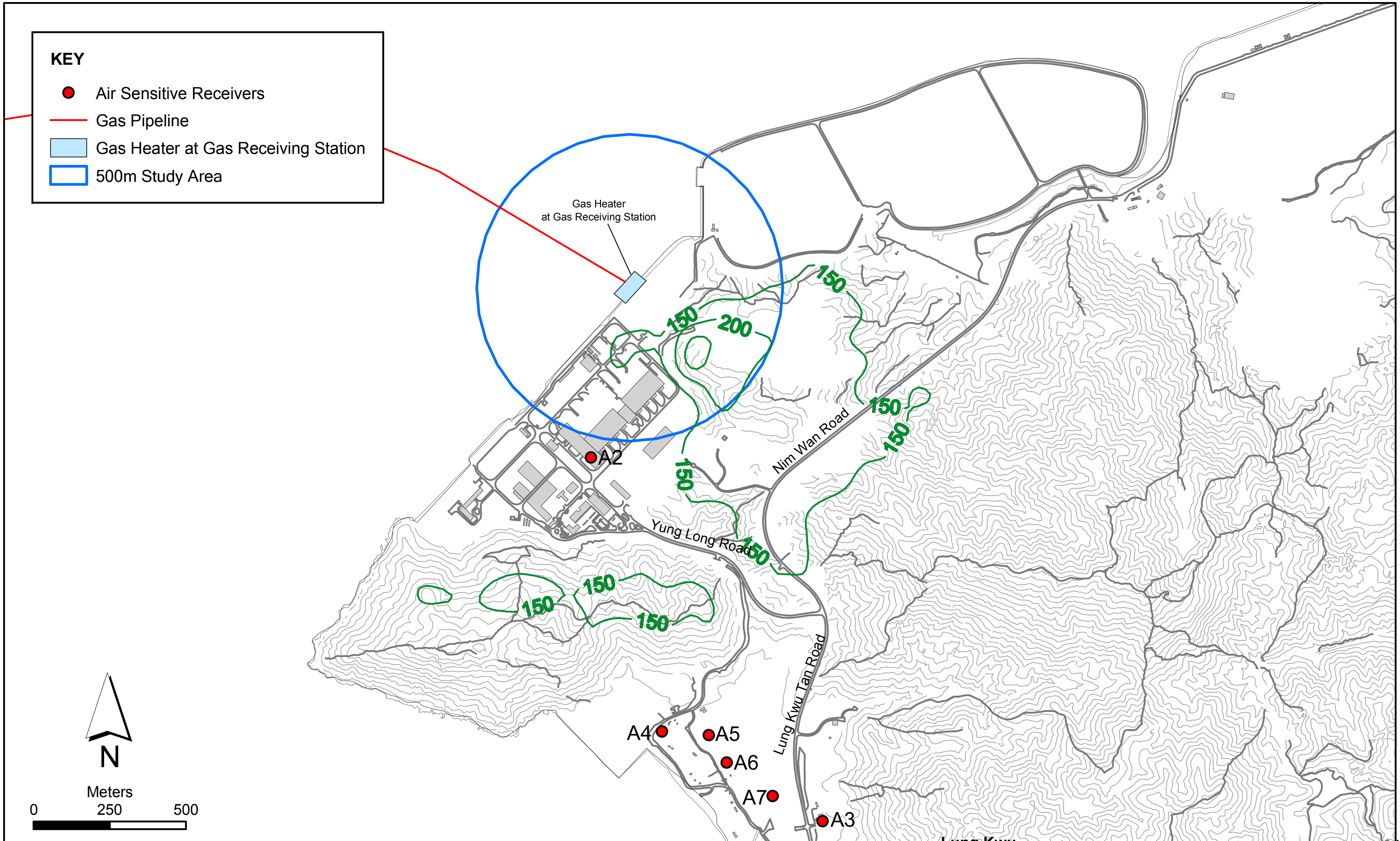

Figure 4.17

Isopleths of Cumulative Maximum Hourly NO_2 Concentration at 10m above ground
(Emission from GRS + Background + BPPS)

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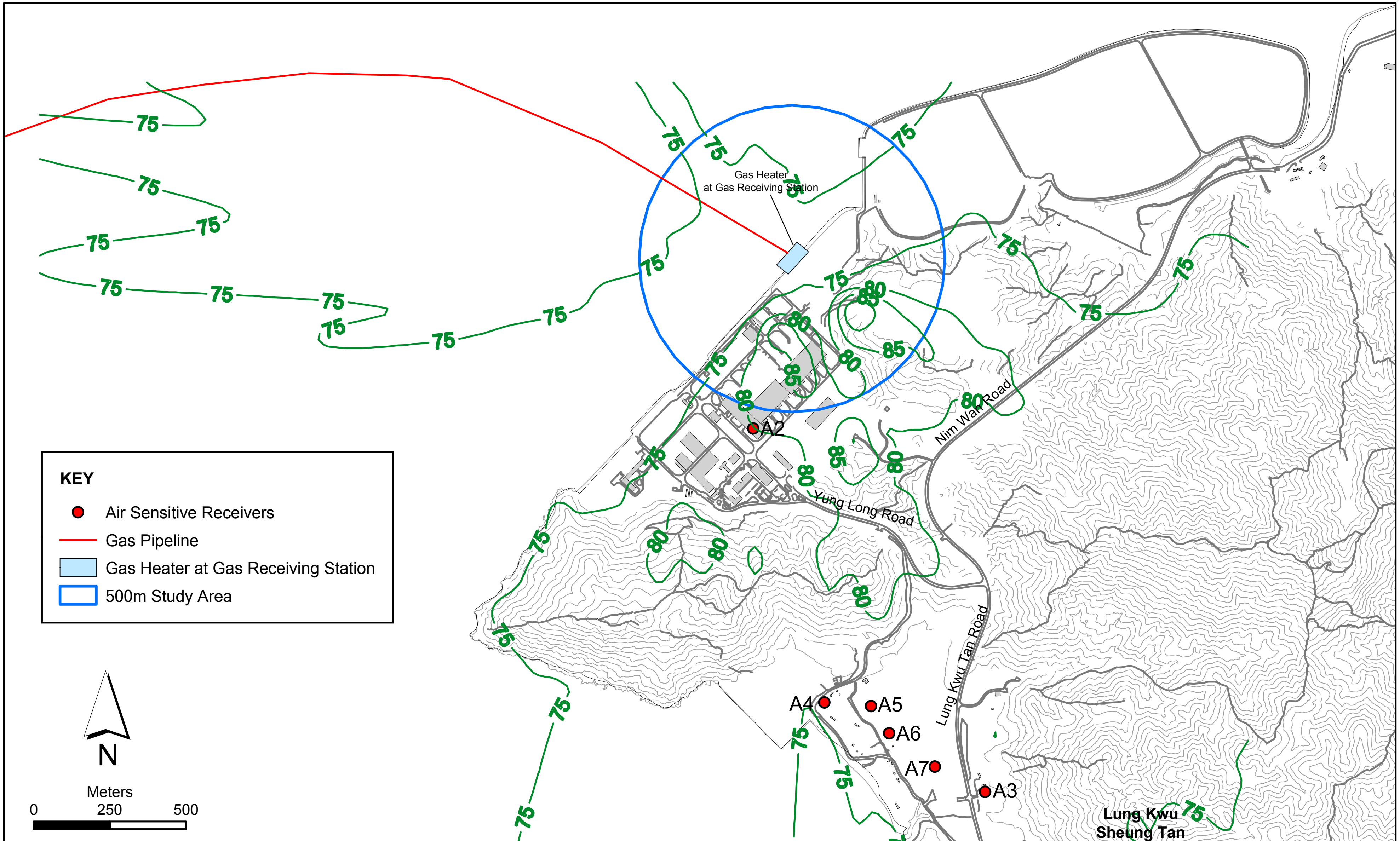

Figure 4.18

Isopleths of Cumulative 2nd Highest Daily NO_2 Concentration at 1.5m above ground
(Emission from GRS + Background + BPPS + CPPS)

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Date: 28/11/2006

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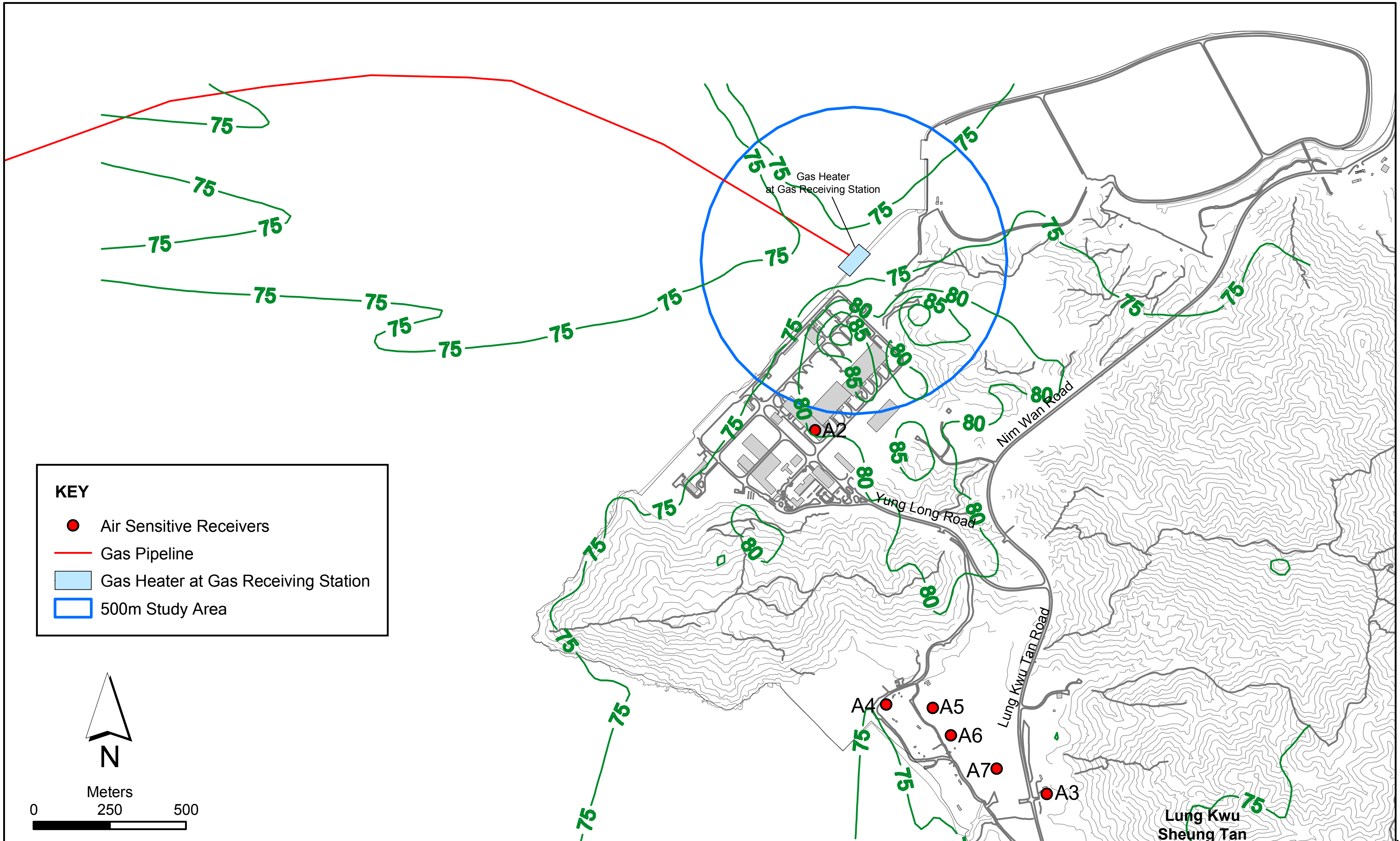

Figure 4.19

Isopleths of Cumulative 2nd Highest Daily NO_2 Concentration at 10m above ground
(Emission from GRS + Background + BPPS + CPPS)

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Date: 28/11/2006

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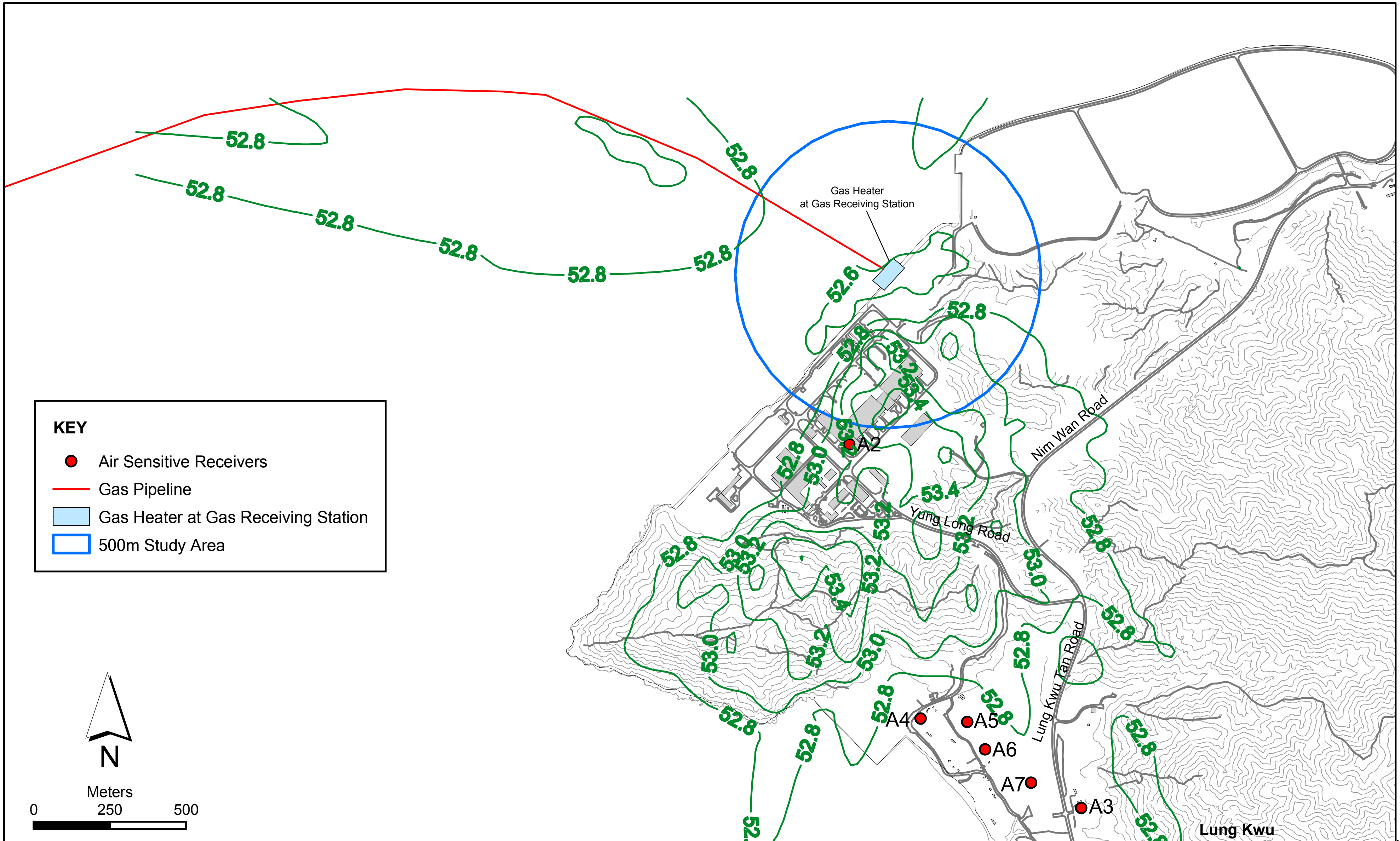

Figure 4.20

Isopleths of Cumulative Annual Average NO_2 Concentration at 1.5m above ground
(Emission from GRS + Background + BPPS + CPPS)

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Date: 28/11/2006

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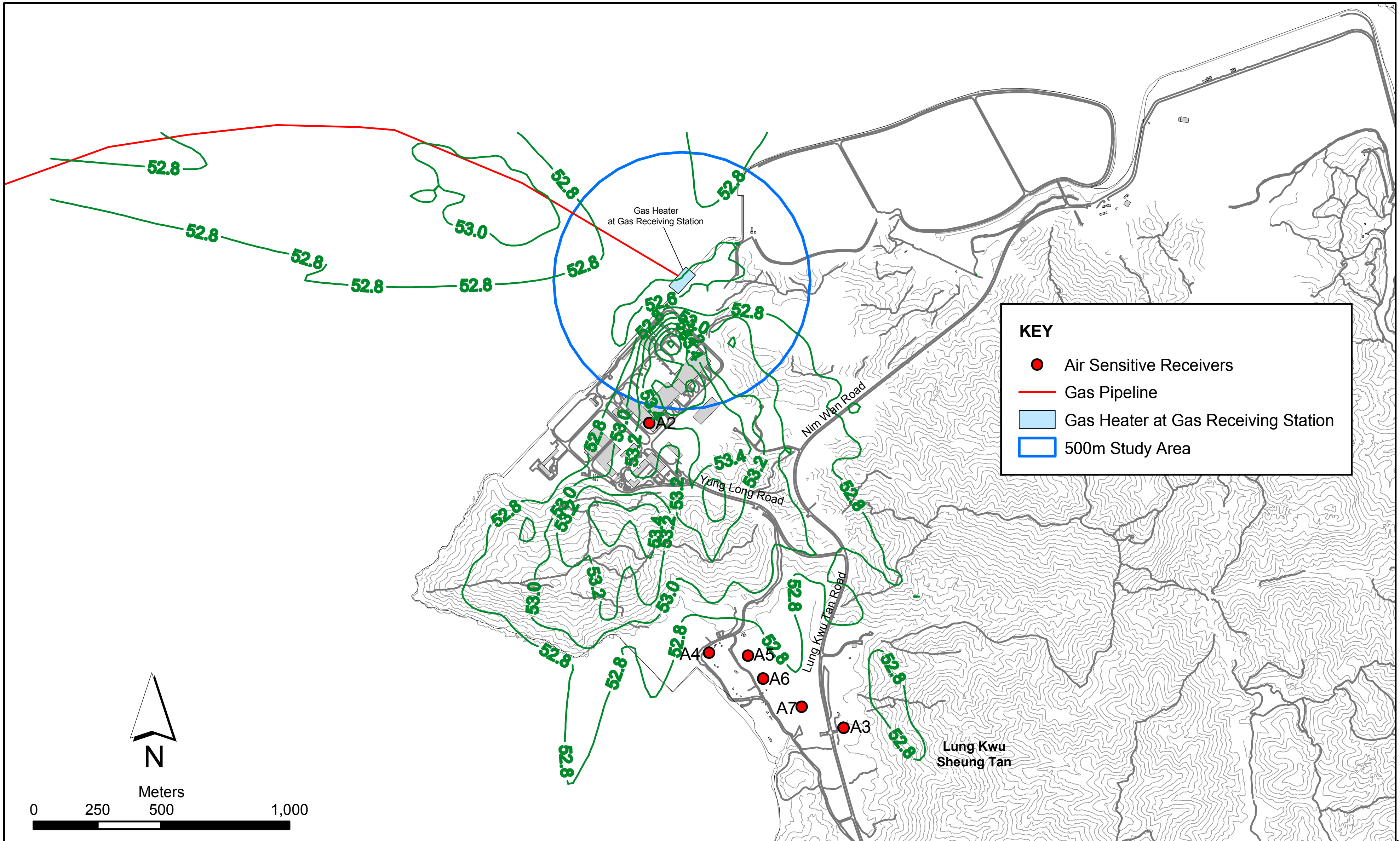

Figure 4.21

Isopleths of Cumulative Annual Average NO_2 Concentration at 10m above ground
(Emission from GRS + Background + BPPS + CPPS)

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Date: 28/11/2006

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It should be noted that the cumulative long-term air quality impact assessment does not account for the fact that CAPCO has obtained an approval for the *Emission Control Project for the Castle Peak Power Station "B" Units* [1] in which the NO_x emissions will be further reduced.

4.7 MITIGATION MEASURES

4.7.1 *Construction Phase*

Dust control measures stipulated in the *Air Pollution Control (Construction Dust) Regulation* will be implemented during the construction of the LNG terminal to control the potential fugitive dust emissions.

Good site practices such as regular maintenance and checking of the diesel powered mechanical equipment will be adopted to avoid any black smoke emissions and to minimize gaseous emissions.

The dust control measures for the operation of the concrete batching plant recommended in the *Guidance Note of Best Practicable Means for Cement Works (Concrete Batching Plant) BPM 3/2* will be implemented

The dust control measures for the operation of the rock crushing plant recommended in the *Guidance Note of Best Practicable Means for Mineral Works (Rock Crushing Plant) BPM 11/1* will be implemented.

4.7.2 *Operational Phase*

No exceedance of the AQO criteria is anticipated at the ASRs but the cumulative maximum hourly, daily and annual NO_2 concentrations and maximum hourly and daily SO_2 concentrations were predicted to exceed the respective AQO criteria at the headlands on South Soko Island (refer to *Figures 4.4* to *4.13*). In reality, the frequency with which the worst case emissions would coincide with the worst meteorological conditions is low. It should be noted that any future developments in the vicinity of the LNG terminal will be tightly controlled following the designation of a Consultation Zone. Should development be proposed in these areas, the air quality constraint would have to be accounted for.

The air control measures for the operation of the gas turbine generator recommended in the *Guidance Note of Best Practicable Means for Electricity Works (Coal-fired Plant, Gas-fired Gas Turbine and Oil-fired Gas Turbine (Peak Lopping Plant)) (BPM 7/1)* will be implemented.

(1) EIA-123/2006, Emissions Control Project at Castle Peak Power Station "B" Units, by CAPCO

4.8 RESIDUAL IMPACTS

4.8.1 *Construction Phase*

With the implementation of the recommended dust control measures, no residual impacts are anticipated.

4.8.2 *Operational Phase*

No adverse residual operational air quality impact is anticipated.

4.9 ENVIRONMENTAL MONITORING AND AUDIT

4.9.1 *Construction Phase*

A weekly site audit will be conducted to ensure the implementation of the dust control measures.

4.9.2 *Operational Phase*

The requirement of the operational monitoring of the gas-turbine auxiliary engines including in-stack, process and ambient monitoring described in BPM 7/1 (1) will be followed.

4.10 CONCLUSIONS

Potential dust nuisance from dust generating activities and gaseous emission from construction plant during construction of the LNG terminal and Gas Receiving Station (GRS) have been considered. With the implementation of standard mitigation measures, no adverse impact is anticipated. The gaseous emissions from the construction plant are also minimal and no adverse impact is anticipated.

During the operation of the LNG terminal, air emissions from submerged combustion vaporisers (SCVs), gas-turbine generators and LNG carrier auxiliary engines during LNG unloading and gas heaters at GRS are potential sources of air quality impacts. As a worst-case assumption, it was assumed that all four sources were operating continuously. With this set of assumptions, the assessment indicated no exceedances of the AQOs at the identified ASRs.

Cumulative maximum hourly, daily and annual average NO_2 and maximum hourly and daily SO_2 concentrations were predicted to exceed the respective AOQ criteria at the uninhabited South Soko headlands based on continuous emissions and the worst case meteorological condition. In reality, the probability of this set of worst case emissions and meteorological conditions

(1) A Guidance Note on the Best Practicable Means for Electricity Works (Coal-fired Plant, Gas-fired Gas Turbine and Oil-fired Gas Turbine), BPM 7/1, by EPD

arising simultaneously is low. Any future developments in the vicinity of the LNG terminal will be tightly controlled following the designation of a Consultation Zone. Should development be proposed in these areas, the air quality constraint would have to be accounted for.

The cumulative NO_2 concentrations due to the operation of the GRS taking into account the BPPS and CPPS contribution and the background air quality are within the AQO criteria and no adverse air quality impact is anticipated.

Annex 4

Air Quality Supporting Document

Annex 4-A

Adjustment of Background NO_2 at Black Point for GRS

4A.1 ADJUSTMENT OF BACKGROUND NO_2 AT BLACK POINT

4A.1.1 Background

An extensive set of wind tunnel tests for the Black Point Power Station was conducted as parte of the *EIA of the Proposed 6000 MW Thermal Power Station at Black Point* in 1993 (hereafter called BPPS EIA Study). Maximum 1-hour average nitrogen dioxide (NO_2) concentrations were modelled for a number of ASRs. However, even that the NO_x emission rates assumed in 1993 for the particular set of wind tunnel tests remain relevant for the present situation, the NO_x to NO_2 conversion rates may have had changed over the years due to the increase in background ozone concentrations. The update of such conversion rates and the re-assessment of NO_2 at the interested ASRs is summarized as below.

4A.1.2 NO_x to NO_2 Conversion in BPPS EIA Study

The methodology for determination of NO_x to NO_2 conversion used was based on the commonly used Janssen's formula (1) that links the conversion rate to the prevailing meteorological conditions, distance to the receptor and the background ozone concentrations:

$$NO_2 / NO_x = A (1 - \exp(-\alpha x)) \quad [1]$$

where A and α are coefficients depending on wind speed, ambient ozone concentration and the season of the year that can be determined.

In the BPPS EIA Study, the values of coefficients used were obtained from Janssen tables for summer conditions using linear interpolation of wind speeds. The ambient ozone concentration was assumed as 35 ppb for A and 50 ppb for α determination. The artificial increase of O_3 concentration assumed for α estimates was substantiated by the higher solar radiation in HK as compared to Holland, where the Janssen's study was conducted.

The value of A was calculated to be 0.74 and the values of α were 0.21 km^{-1} for wind speed of 8 m/s and 0.29 km^{-1} for wind speed of 12 m/s in the BPPS EIA Study.

4A.1.3 Adjustment for NO_x/NO_2 Conversion Rate and NO_2 Concentration

Adjustment of Janssen's Coefficients

The annual average of daily hour maximum ozone concentration measured at EPD AQMS in Tung Chung for the year 2004 is 108 μgm^{-3}, i.e., about 55 ppb. Assuming again the summer conditions, from the *Janssen Table 4*, A will be equal to 0.81 for wind speeds from 5 to 15 m/s.

(1) Janssen L.H.J.M. et al. A Classification of NO Oxidation Rates in Power Plant Plumes based on Atmospheric Conditions. Atmospheric Environment, 22, 43-53, 1988.

For the α estimation, to be consistent with the BPPS EIA Study, the ozone level is increased by 15 ppb, i.e., from 55 to 70 ppb. Using again *Janssen Table 4* and applying interpolation between the 50 and 90 ppb levels in a way consistent with the BPPS EIA Study approach, α will be 0.175 km^{-1} for 70 ppb of ozone and wind speed of 5 m/s and 0.40 km^{-1} for the 15 m/s wind speed.

By linear interpolation for wind speeds, α will be 0.33 km^{-1} for 12 m/s.

Adjustment of NO_2 Concentrations

If C_1 is NO_2 concentration obtained in the BPPS EIA Study and C_2 is the NO_2 concentration in this Study, the adjustment of NO_2 concentrations can obtain from the Janssen's formula (1):

$$C_2 = C_1 [A_2 (1 - \exp(-\alpha_2 x))] / [A_1 (1 - \exp(-\alpha_1 x))] \quad [2]$$

where x is the distance (km) between ASR and the source

The formula [2] using the appropriate values of A and α coefficients is applied to recalculate the maximum hourly and 2nd highest NO_2 concentrations shown in *Table 3.3a and 6.2b of the BPPS EIA Study*, respectively.

Short-term NO_2 Concentration

BPPS Contribution

The maximum hourly NO_2 concentrations, presented in the *BPPS EIA Study, Part A, Table 3.3a*, was predicted based on the generating capacity of 4,800 MW of BPPS.

The current operation of BPPS is about 2,500 MW which is approximately 50% of the *BPPS EIA Study*, therefore, a factor of 0.5 is applied to adjust the NO_2. Using adjusted Janssen coefficient, the maximum hourly NO_2 concentrations at ASRs at Lung Kwu Tan are calculated.

ASRs at Lung Kwu Tan (x=2, C_1 = 30% of AQO, wind speed of 12 m/s):
$C_2 = 30 [0.81 (1 - \exp(-0.33 \times 2))] / [0.74 (1 - \exp(-0.29 \times 2))] \times 0.5$ = 18%of AQO (54 μgm^{-3})

CPPS Contribution

For ASRs A2 to A7 located at Lung Kwu Sheung Tan area, since the wind angles from LNG terminal and from the CPPS are opposite, therefore, no cumulative short-term impact is anticipated.

Long-term NO_2 Concentrations

The 2nd daily and annual average NO_2 concentrations, presented in the *BPPS EIA Study, Part B, Table 6.2b*, had considered the contribution from BPPS as well as CPPS with NO_x reduction of 10% and 50% for CPA and CPB [(1)], respectively. The 2nd daily and annual average NO_2 concentrations in the *BPPS EIA Study, Part B, Table 6.2b* are summarized below.

	Lung Kwu Tan
Worst wind speed adopted in Wind Tunnel Testing (m/s)	12
2nd Highest Daily NO_2 Concentration	12.1% of AQO (18 μgm^{-3})
Annual NO_2 Concentration	0.6 % of AQO (0.33 μgm^{-3})
Note: (a) Reference to Table 6.2b of BPPS EIA Study	

CAPCO considers further reducing the NO_x emission at CPB to meet emission cap in 2010. Therefore, an *EIA for Emission Control Project to CPPS "B" Units* was conducted and approved in November 2006. In the approved *EIA for Emission Control Project to CPPS "B" Units*, new NO_x reduction technology is proposed to further reduce 80% of current NO_x emission. Based on the findings in the approved *EIA for Emission Control Project to CPPS "B" Units*, CAPCO is negotiating with the EPD to obtain a new licence NO_x limit in future and hence the future NO_x limit is not yet confirmed at this stage. However, it is expected that is likely to be tightened to meet the NO_x limit specified in the *Best Practicable Means for Electricity Works (Coal-fired Plant, Gas-fired Gas Turbine and Oil-fired Gas Turbine (Peak Lopping Plant)* (BPM 7/1) which is 670 mgm^{-3}.

Therefore, in view of the current generating capacity of BPPS (2,500 MW) and the further NO_x reduction at CPB, the 2nd daily and annual average NO_2 concentrations at Lung Kwu Tan in the above table will be reduced.

However, since the above results are the cumulative results taking into account the contribution from BPPS and CPPS, therefore, the results could only be adjusted with ozone level of 108 μgm^{-3}, i.e., about 55 ppb in 2004 as worst case assessment.

In accordance with the Equation [1] for adjustment of NO_2 concentrations, shorter distance from the source will give higher NO_2 concentration. Therefore, the distance between the BPPS and Lung Kwu Tan (which is shorter than CPPS to Lung Kwu Tan) is used for the calculation to obtain the worst 2nd highest daily NO_2 concentration.

The detailed calculations are shown as below.

2nd Highest Daily NO_2 Concentration

Lung Kwu Tan
C_2 = 12.1 [0.81 (1 – exp (-0.33 x 2))] / [0.74 (1 – exp (-0.29 x 2))] = 14.5%of AQO (22 μgm^{-3})

(1) Reference to *the BPPS EIA Study, Part A, Section 3.2.3*, 1,100 ppm reduced to 1,000 ppm for CPA (about 10% reduced) and 1,100 ppm reduced to 6,00 ppm for CPB (about 50% reduced).

Annual Average NO_2 Concentration

Lung Kwu Tan

C_2 = 0.6 [0.81 (1 – exp (-0.33 x 2))] / [0.74 (1 – exp (-0.29 x 2))] = 0.7%of AQO (0.6 μgm^{-3})

Summary

A summary of adjusted short-term and long-term NO_2 concentrations are presented as below.

	Lung Kwu Tan
Worst wind speed adopted in Wind Tunnel Testing (m/s)	12
Adjusted Maximum Hourly NO_2 Concentration	54 μgm^{-3} (BPPS ONLY)
Adjusted 2nd Highest Daily NO_2 Concentration (BPPS + CPPS with NO_x mitigation)	22 μgm^{-3}
Adjusted Annual NO_2 Concentration (BPPS + CPPS with NO_x mitigation)	0.6 μgm^{-3}

Of note, in accordance with the indicative commencement programme in the *Emission Control Project to CPPS "B" Units*, the low NO_x reduction technology will be operated in end of 2009 to 2011 which should be earlier than the LNG Terminal operation. Therefore, during the LNG Terminal operation, the 2nd highest daily and annual average SO_2 concentration should be much lower due to the current BPPS power generating capacity and future NO_x reduction programme at CPB.

Therefore, the cumulative short-term and long-term NO_2 impact assessment in this Study will be the worst-case assessments.

Annex 4-B

Detailed Operational Phase Air Emission Rate Estimation

4B.1 EMISSION RATE CALCULATIONS

Submerged Combustion Vaporizers (SCVs)

Total emissions : NO_x = 51 tonnes/yr and CO = 257 tonnes/yr (provided by Vendor's equipment information, emissions are based upon 30 t/hr and fuel gas produced per 100 t/hr LNG vaporization)

No. of SCVs = 5

Emission rate of each SCV:
NO_x = (51 tonnes / 365 days / 24 hours / 3600 s) x $1x10^6$ / 5 = **0.32 g/s**
CO = = (257 tonnes / 365 days / 24 hours / 3600 s) x $1x10^6$ / 5 = **1.63 g/s**

Total flowrate = 130,000 Nm^3hr^{-1} (at 0 °C & 101.3 kPa)
At exhaust temperature of 30 °C, the total flowrate = 144.285.71 m^3hr^{-1}
Stack velocity = 144.285.71 / 3600 / 5 / (π x 0.6^2) = 7.09 ms^{-1}

Gas Turbine Generators

Total emissions : 128 tonnes of NO_x and 156 tonnes of CO a year (based on Solar Turbines Mar-90, by Caterpillar)
Gas turbine generator operation time : continuous
No. of gas turbine = 4 + 1 (spare)

Emission rate of each gas turbine generator:
NO_x = (128 tonnes / 365 days / 24 hours / 3600 s) x $1x10^6$ / 4 = **1.01 g/s**
CO = (156 tonnes / 365 days / 24 hours / 3600 s) x $1x10^6$ / 4 = **1.24 g/s**

Total flowrate = 382,800 Nm^3hr^{-1} (at 0 °C & 101.3 kPa)
At exhaust temperature of 500 °C, the total flowrate = 1,083,899 m^3hr^{-1}
Stack velocity = 1,083,899 / 3600 / 4 / (2.3 x 2.3) = 14.2 ms^{-1}

LNG Carrier – Auxiliary Engines

- Total generator capacity = 9,350 kW (under 75% load factor)
- Generator load factor = 75%
- Burning Marine Diesel Oil (MDO) or Heavy Fuel Oil (HFO)

According to IMO MARPOL Annex VI, NO_x is limited by the formula:
45.0 x $rpm^{-0.2}$ g/kWh

The auxiliary generator will be operating at 720 rpm and therefore, NO_x emission will be 12.07 g/kWh. At 75% load, the NO_x can vary from 7% to 15% and therefore, upper limit of NO_x emission will be 12.07 x 1.15 = 13.88 g/kWh.

NO_x emission factor = 13.88 g / kWh
SO_2 emission factor = 6 g / kWh (based on 1.5% sulphur content)
CO emission factor = 0.6 g / kWh

Emission rate from one chimney:
NO_x = (13.88 g / kWh x 9,350 kW) / 3600 = **36 g/s**
SO_2 = (6 g / kWh x 9,350 kW) / 3600 = **15.6 g/s**
CO = (0.6 g / kWh x 9,350 kW) / 3600 = **1.56 g/s**

As 3 individual stacks are enclosed in a single chimney, therefore, effective diameter = 0.78 m
Exhaust gas velocity = 25 ms^{-1}
Exhaust temperature = 320 °C

Gas Heaters at Gas Receiving Station at Black Point

Total emissions : 72 tonnes of NO_x and 45 tonnes of CO a year (based on Vendor's equipment information, 4.1 MMSCFD for the Design Case)

Total no. of stack = 4

Emission rate of each stack:
NO_x = (72 tonnes / 365 days / 24 hours / 3600 s) x $1x10^6$ / 4 = **0.57 g/s**
CO = (45 tonnes / 365 days / 24 hours / 3600 s) x $1x10^6$ / 4 = **0.36 g/s**

Total flowrate = 73,900 Nm^3hr^{-1} (at 0 °C & 101.3 kPa)
Assuming at exhaust temperature of 280 °C, the total flowrate = 149,695 m^3hr^{-1}
Stack velocity = 149,695 / 3600 / 4 / (π x 0.54^2) = 11.56 ms^{-1}

Summary of Modelling Parameters

	SCV	**Gas Turbine Generator**	**LNG Carrier – Auxiliary Engine**	**Gas Heaters at GRS**
No. of Emission Source	5	4	1	4
Stack Height (m)	13	8	41	15
Stack Diameter (m)	1.2	2.6 (a)	0.78	1.07
Exit Temperature (°C)	30	500	320	280
Exit Velocity (m / s)	7.09	14.2	25	11.56
NO_2 Emission Rate (g / s)	0.32	1.01	36	0.57
SO_2 Emission Rate (g / s)	-	-	15.6	-
CO Emission Rate (g / s)	1.63	1.24	1.56	0.36

Note:
(a) The stack diameter is an equivalent diameter in which the stack emission area is 2.3 m x 2.3 m.