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 Black Point. Dust generated from the construction activities and gaseous emissions from construction plant are potential concerns during the construction phase. Air emissions from the LNG terminal equipment and the LNG carrier are the principal concerns 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 level of TSP of 500 μgm^{-3} at ASRs is also stipulated in the *Technical Memorandum on Environmental Impact Assessment Process* (*EIAO-TM*) to assess potential construction dust impacts.

The measures stipulated in the *Air Pollution Control (Construction Dust) Regulation* 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 for equipment which consumes more than 1,150 megajoules of gaseous fuel per hour or 25 litres 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 should be submitted not less than 28 days prior to the commencement of such work.

Should the processes listed in *Table 4.2* exceed the respective regulatory thresholds under the *Air Pollution Control (Specified Process) Regulations*, a Specified Process (SP) 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 Thresholds for Apply 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

During the operation of these processes, the dust control measures in the *Guidance Note on the Best Practicable Means for Cement Works (Concrete Batching Plant) (BPM 3/2)* 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 site is located to the northwest of the Black Point Headland and to the west of the existing Black Point Power Station (BPPS). The area has a very low population density and the local air quality is influenced by industrial emissions from the existing BPPS, Castle Peak Power Station (CPPS) and other industrial facilities, vehicle emissions from Lung Kwu Tan Road, marine vessels and regional pollutant fluxes.

Background Air Quality

There is currently no Air Quality Monitoring Station (AQMS) operated by the EPD in the immediate vicinity of Black Point. The nearest EPD AQMS is located at Tung Chung (TC). The annual average concentrations of air pollutants measured at EPD's AQMS at Tung Chung in 2004 are summarized in *Table 4.3*.

Table 4.3 Background Air Quality at Tung Chung (2004)

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

Note:
(a) The ozone concentration is the annual average of the daily hourly maximum concentrations measured in 2004.

The measured annual averages at the Tung Chung AQMS give an indication of the regional air quality.

Contribution of Emissions from BPPS and CPPS

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

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 NO_2 and SO_2 emissions from BPPS and CPPS to local air quality. It should be noted that there are no SO_2 emissions from BPPS gas-fired units.

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, Ha Pak Nai/Nim Wan and Sheung Pak Nai 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 installed in 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 measure is over the period of 2009 to 2011, according to the approved EIA for *Emission Control Project to CPPS "B" Units*. In addition, a flue gas desulphurization (FGD) system will be installed to further reduce SO_2 emissions. The indicative date of the FGD implementation is similar to that for NO_x reduction.

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 and SO_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, Ha Pak Nai/Nim Wan and Sheung Pak Nai areas.

Detailed calculations are provided in *Annexes 4-A* and *4-B*.

Table 4.4 *Adjusted Maximum Hourly, 2nd Highest Daily and Annual NO_2 and SO_2 Concentrations in 2004 based on Wind Tunnel Test Results*

Location	Adjusted Concentration in 2004 (μgm^{-3})					
	NO_2 (a)			SO_2		
	Maximum Hourly	Daily (d) (e)	Annual (d) (e)	Maximum Hourly	Daily (d) (e)	Annual (d) (e)
Sheung Pak Nai	99 (b)	22 (f)	0.6 (f)	170	60 (f)	1.5 (f)
Ha Pak Nai / Nim Wan (g)	108 (b)	22	0.6	170	60	1.5
Lung Kwu Tan	54 (c)	22	0.6	- (h)	60	1.5

Notes:

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

(b) BPPS and CPPS contributions are included. Current power generating capacity of BPPS (2,500 MW) has been accounted for. NO_x reduction has been considered for CPA and CPB, respectively (refer to *Annex 4-A*).

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

(d) Both BPPS and CPPS contributions are considered, no adjustment has been made to account for the reduced power generation capacity of BPPS, the existing licence limit requirement or the future NO_x and SO_2 reduction at CPB due to the implementation of the Emission Control Project.

(e) Since the adjusted 2nd highest daily and annual average NO_2 and SO_2 concentrations at Lung Kwu Tan and Ha Pak Nai are similar, the adjusted 2nd highest daily and annual average NO_2 and SO_2 concentrations at Lung Kwu Tan are adopted for the cumulative long-term impact assessment.

(f) Sheung Pak Nai was not included in the wind tunnel testing in BPPS EIA Study; however, the worst wind angle for Sheung Pak Nai is similar to that for Ha Pak Nai. As it is located further away from the BPPS and CPPS than Ha Pak Nai, the Ha Pak Nai predictions were adopted as a worst case assumption.

(g) In accordance with *Figure 2.3a* of the *BPPS EIA Study*, the assessment point in Ha Pak Nai was identified at Nim Wan which is close to ASR A2 (EPD Office at WENT Landfill). Therefore, the wind tunnel testing results at Ha Pak Nai in the BPPS EIA Study will be used directly without any adjustment.

(h) No SO_2 contribution from BPPS due to negligible SO_2 emissions from gas-fired units.

4.3.2 *Air Sensitive Receivers*

In accordance with the Study Brief, the study area for the air quality assessment is defined by a distance of 500 m from the boundary of the Project site. Within 500 m of the Project site boundary, no ASR was identified.

The nearest identified ASRs in the surrounding environment, as identified by site visits, are summarized in *Table 4.5* and shown in *Figure 4.1*.

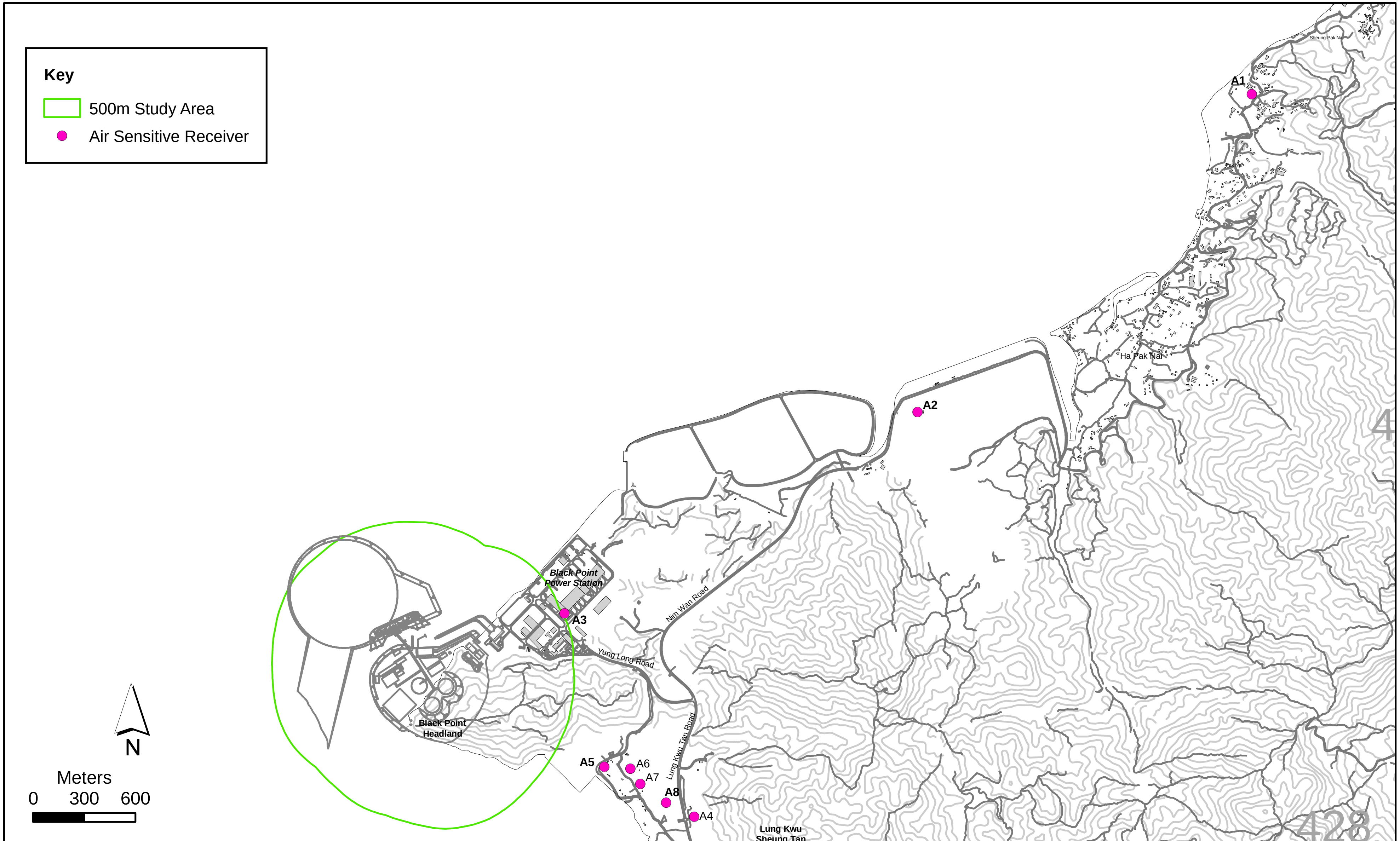

Figure 4.1

Location of Air Sensitive Receiver at Black Point

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Table 4.5 Identified Air Sensitive Receivers

ASR	Location	Approximate Distance from LNG Terminal (m)	Type of Uses	Maximum Height (m above ground)
A1	Sheung Pak Nai	7,500	Residential	10
A2	EPD Office at WENT Landfill	3,200	Office	10
A3	Black Point Power Station – Administration Building	600	Office	6
A4	Karting Track	1,700	Recreational	1.5
A5	Concrete Batching Plant – Site Office	1,050	Site Office	6
A6	Open Storage – Site Office	1,170	Site Office	1.5
A7	Hong Kong Oil - Site Office	1,300	Site Office	6
A8	Open Storage – Site Office	1,500	Site Office	1.5

4.4 POTENTIAL SOURCES OF IMPACT

4.4.1 Construction Phase

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

Site Clearance and Blasting

Site clearance and blasting are planned to be undertaken within the first 18 months 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 the submarine gas pipeline protection works 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 impact. Mobile rock crushers will be employed onsite to crush the excavated rock into a suitable size for transportation. The processing capacity of the mobile rock crushers is not yet confirmed at this stage. 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 the *BPM 11/1*.

Any dust impact during site clearance and blasting is expected to be localized. The separation distance between the nearest identified ASR (A3) and the construction site is approximately 600 m, which satisfies the *Hong Kong Planning & Standards Guideline* (HKPSG) recommended buffer distance of 100 m. Together with the implementation of the dust control measures stipulated in *Air Pollution Control (Construction Dust) Regulation* and the *Guidance Note of Best Practicable Means for Mineral Works (Rock Crushing Plant) BPM 11/1*, the potential dust impact arising from site clearance and blasting works is predicted to be minor and is not anticipated to exceed the dust criterion.

Dredging and Reclamation Works

Dredging works will be required for seawall construction, reclamation, approach channel and turning basin. Dredging is planned to be undertaken within the first 2.5 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 therefore, anticipated during the works.

During reclamation, rocks will be imported for seawall construction. Marine sand and public fill will be imported for the reclamation works. No fugitive emissions are expected from rock and marine sand 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 ASRs and with the implementation of the dust control measures stipulated in *Air Pollution Control (Construction Dust) Regulations*, the dust impact from filling activities is very limited.

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), are proposed at an offsite area. Fugitive dust emissions are expected from the operation of the concrete batching plants. The potential sites of the concrete batching plants include the CLP Ash Lagoon area, within the existing Black Point Power Station (BPPS) or at STT lots outside the BPPS site.

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 emission limits. With the implementation of the dust control measures recommended in the *BPM 3/2*, an adverse air quality impact is not anticipated at the ASRs.

On-site Sewage Treatment Works

A small sewage treatment works (STW) is proposed for on-site sewage treatment during the construction phase. The STW shall be designed to meet the Hong Kong standards [(1)] and reduce the odour nuisance and will comply with the regulatory requirements.

Gaseous Emissions from Construction Plant

Gaseous emissions from 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*), LNG terminal facility construction works and civil works will involve the highest number of diesel-driven PMEs including a total of 39 items of diesel-driven PMEs, including 2 backhoes, 3 drill rigs, 9 generators, 16 air compressor, 9 crawler cranes; 4 trucks and 14 barges/tug boats. The engine power of the generators 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, the emissions from barges/tugboats will not be continuous.

Oxides of nitrogen (NO_x) and respirable suspended particulates (RSP) are the major air pollutants emitted from 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 construction plant items 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 Plant Design

	NO_x	RSP
Total worksite area	230,000 m^2	
Total no. of generators	9	
Average Engine Power of generator (kW) [(a)]	500	
Total no. of diesel-driven equipment (including backhoe + drill rig + air compressor + crawler crane + trucks)	34	
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)	20.2	1.19
Total emission rate per area (g/m^2/s)	8.8×10^{-5}	5.2×10^{-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*) (i.e., 600 m between site boundary and ASR A3), 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, jetty and other marine works. Referring to the construction plant inventory in *Section 5.4.1 and Annex 5-C*, a total of 17 dredgers/barges/tugboats are required for reclamation and a total of 7 dredgers/barge/tugboats are required for marine works. These dredgers, barges and tugboats are located at different marine works areas; 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 impacts include:

- emissions from submerged combustion vaporizers (SCVs);
- emissions from the LNG carrier and tugboats during the unloading of LNG;
- emissions from the pipeline gas heaters;
- emissions from on-site vehicles;
- emissions from the emergency generators;
- emissions from diesel-driven firewater pumps;
- fugitive hydrocarbon releases from Boil-off Gas (BOG) compressors seal leakage.

Emissions from Submerged Combustion Vaporizers (SCVs)

Five submerged combustion vaporizers (SCVs) will be operated in the event that the Open Rack Vaporizer (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. 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 LNG Carrier and Tugboats during Unloading of LNG

LNG will be delivered to the LNG terminal by LNG carrier. The LNG will 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 or 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 *Part 2, 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 ocean-going cargo/passenger vessels (i.e., in 2005, an average of about 3,300 ships per month) (2)). Hence, the impact due to emissions during transits in Hong Kong waters will be temporary and minor and would not cause an 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 during LNG unloading and to provide power for other ship services. Three auxiliary engines with at total capacity of approximately 9.35 MW running at 75% load will be operated to pump the LNG to the terminal's storage tanks. The generators 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 (3). The MDO/HFO has been assumed to contain a maximum 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 (4). The exhaust gas velocity is estimated to be 25.0 ms^{-1} through a stack at 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 flue; therefore the three

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

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

(3) Particulates will also be emitted, although in very small quantities.

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

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 generators are emitted continuously.

CAPCO will ensure that the LNG carriers berthing at the Black Point Terminal will comply with IMO Marpol Annex VI and have the on-board electric generators which have total air emissions equal to or less than those stipulated in this assessment, particularly the fuel quality (1.5% sulphur in MDO or HFO), NO_x emission rate (13.88 g/kWh) and peak hourly engine load (9,350 kW).

Emissions from Pipeline Gas Heaters

Four pipeline gas heaters are proposed for heating the send-out gas to 57 °C. The heaters use pipeline gas as their fuel source. 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.

Emissions from On-site Vehicles

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

Emissions from Emergency Generator

The LNG terminal will be operated by the imported electricity from the existing power plant. The on-site emergency generator (with capacity of 500 kW) will only be used to generate electric power during startup, emergency situations or routine testing, i.e. 3 hours per week on average. The generator will be driven by diesel and NO_x, SO_2 and CO are the principal air emissions. In view of its infrequent operation and the separation distance from ASRs, adverse air quality impacts are not anticipated.

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

Emissions from Diesel-driven Firewater Pumps

Four firewater pumps (two diesel-driven and two electric-driven) will be provided and located beside 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-driven firewater pump is about 0.108 m^3/hr. 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*.

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*.

Summary

In view of the emission characteristics of these sources and the frequency of operation, the SCVs, LNG carrier generators and pipeline gas heaters 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 *Figure 4.2*. CAPCO is willing to accept a permit condition limiting NO_x emission from LNG terminal related onshore combustion sources of SCVs and gas heaters to no more than 3.88 g/s.

4.5 ASSESSMENT METHODOLOGY

4.5.1 Emission Rate Estimation

SCVs and pipeline gas heaters are operated by natural gas and hence NO_x and CO are the principal air emissions. During the LNG unloading process, the LNG carrier generators 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, LNG carrier generators and pipeline gas heaters are assumed to be operating continuously throughout 24 hours and 365 days in the modeling assessment and hence this is the worst-case approach.

(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)

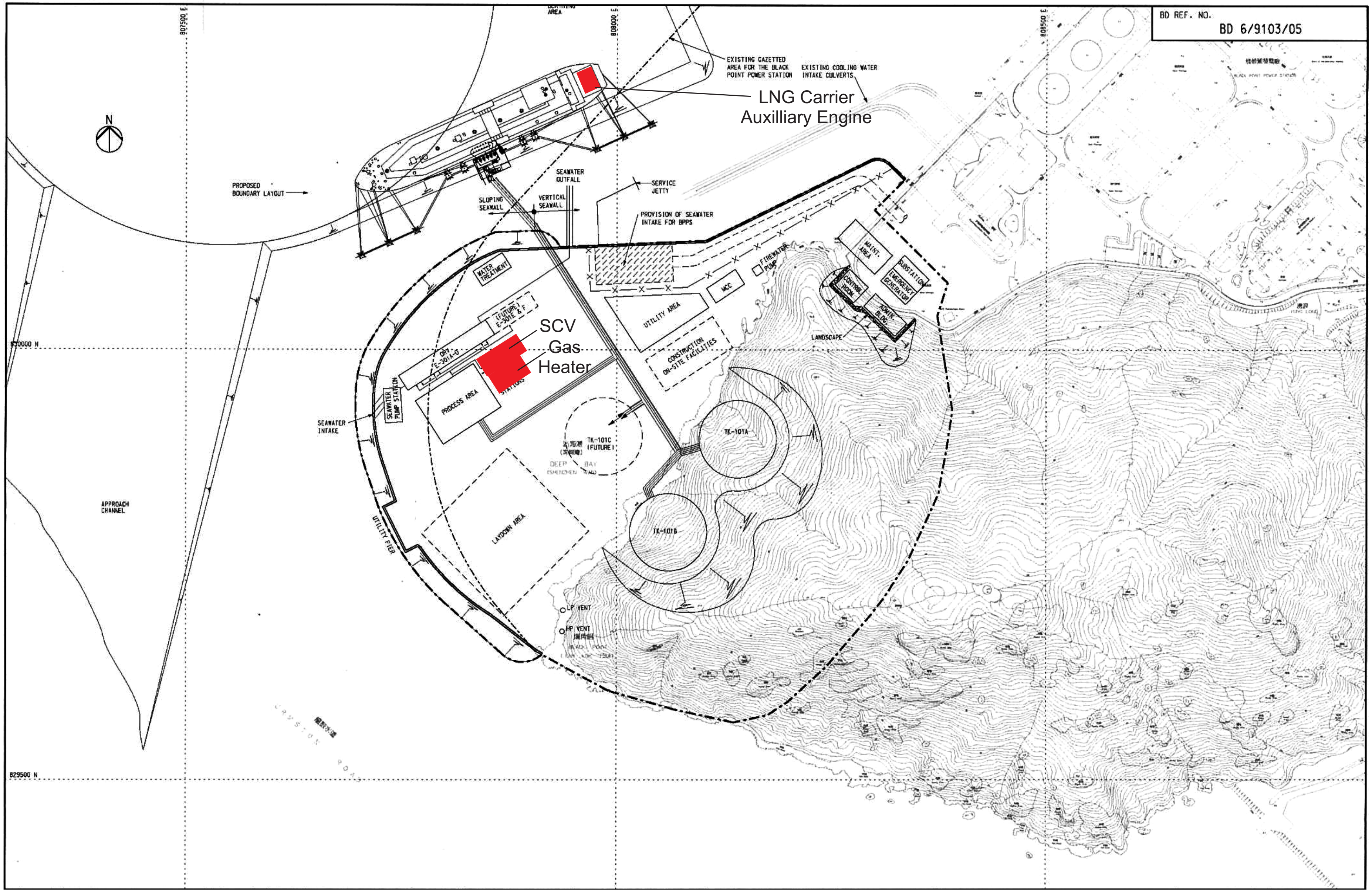

Figure 4.2

Location of Potential Air Emission Sources

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The estimated emission rates of NO_x, SO_2 and CO are summarized in *Table 4.7* and detailed calculations are presented in *Annex 4-C*.

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

	SCV	LNG Carrier – Auxiliary Engine [a]	Pipeline Gas Heater
Stack height (m)	13	41	15
Stack diameter (m)	1.2	0.78	1.07
Exit temperature (°C)	30	320	280
Exit velocity (m/s)	7.09	25	11.56
No. of emission sources	5	1 [b]	4
NO_x emission rate of each source (g/s)	0.32	36	0.57
SO_2 emission rate of each source(g/s)	-	15.6	-
CO emission rate of each source (g/s)	1.63	1.56	0.36

Notes:
(a) The total capacity of LNG carrier generators is 9,350kW.
(b) Three individual emission sources are modelled 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 impacts.

The SCVs, LNG carrier generators and pipeline gas heaters have been assumed to be operated continuously in the modeling assessment for a worst case assessment.

As the site area is 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. In addition, the local terrain has been incorporated into the model to account for terrain-induced impacts to dispersion.

It has been assumed that the background ozone present in the vicinity of the Project site is elevated, and so the Ozone Limiting Method (OLM) was used to estimate the hourly conversation ratios of NO_x to NO_2. As a worst case assumption, the annual average of daily hourly maximum ozone concentrations measured at EPD's Tung Chung AQMS in 2004 (i.e., 108 μgm^{-3}) was utilized.

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

A worst case assumption of continuous emissions from all the identified sources was made, a high background ozone level and a whole year of meteorological data were 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 Condition*

Representative hourly meteorological data from the *Hong Kong Observatory* (HKO) station located at Sha Chau, for the year 2004, were used in the model. The meteorological data included hourly wind speed, wind direction, stability class, air temperature and mixing height information.

4.5.4 *Cumulative Impact*

The Black Point Power Station (BPPS) is considered the nearest existing air emission source, contributing to the air quality within the study area. In addition, the Castle Peak Power Station (CPPS) also contributes to the local air quality. The 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 the 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 time frames of these developments are unknown at this stage and hence they are not 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)*

ASRs	Predicted Concentrations (μgm^{-3}) (a)							
	NO_2			SO_2			CO	
	Maximum Hourly	Daily	Annual	Maximum Hourly (c)	Daily	Annual	Maximum Hourly (c)	8-hour
1.5 m above ground								
A1	76	4	0.03	28	1	0.01	77	10
A2	68	3	0.03	27	1	0.01	23	3
A3	129	6	0.07	49	2	0.01	564	71
A4	103	9	0.71	37	3	0.26	212	32
A5	123	14	1.27	64	6	0.49	291	43
A6	180	17	0.88	64	6	0.30	900	150
A7	116	11	0.96	50	4	0.36	239	34
A8	118	13	1.03	51	4	0.35	581	97
10m above ground								
A1	76	4	0.03	28	1	0.01	77	10
A2	68	3	0.03	27	1	0.01	23	3
A3	169	7	0.09	49	2	0.01	844	105
A4 (b)	-	-	-	-	-	-	-	-
A5	123	14	1.23	64	6	0.50	292	45
A6 (b)	-	-	-	-	-	-	-	-
A7	116	11	0.97	50	4	0.37	238	34
A8 (b)	-	-	-	-	-	-	-	-
AQO	**300**	**150**	**80**	**800**	**350**	**80**	**30,000**	**10,000**

Notes:

(a) No background concentrations are included.

(b) As A4, A6 and A8 are not elevated ASRs and therefore, no assessment was performed at 10 m above ground at these ASRs.

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

Isopleths of predicted maximum hourly, daily average and annual average NO_2 concentrations at 1.5 m and 10 m above ground are presented in *Figures 4.3* to *4.8*, respectively. Exceedance of maximum hourly and daily NO_2 concentrations was predicted at the Black Point Headland, an area in the firing range and in an area of rough terrain between Black Point and Nim Wan due to plume impingement.

4.6.2 *Cumulative Impacts*

The emissions from the existing BPPS and CPPS together with the background air quality would contribute to the cumulative air quality impacts in the vicinity during the operation of the LNG Terminal.

Cumulative Short-Term (Hourly) NO_2 Impact

The existing BPPS is the closest emission source affecting the Nim Wan and Sheung Pak Nai areas. There is possibility that a south-westerly wind may

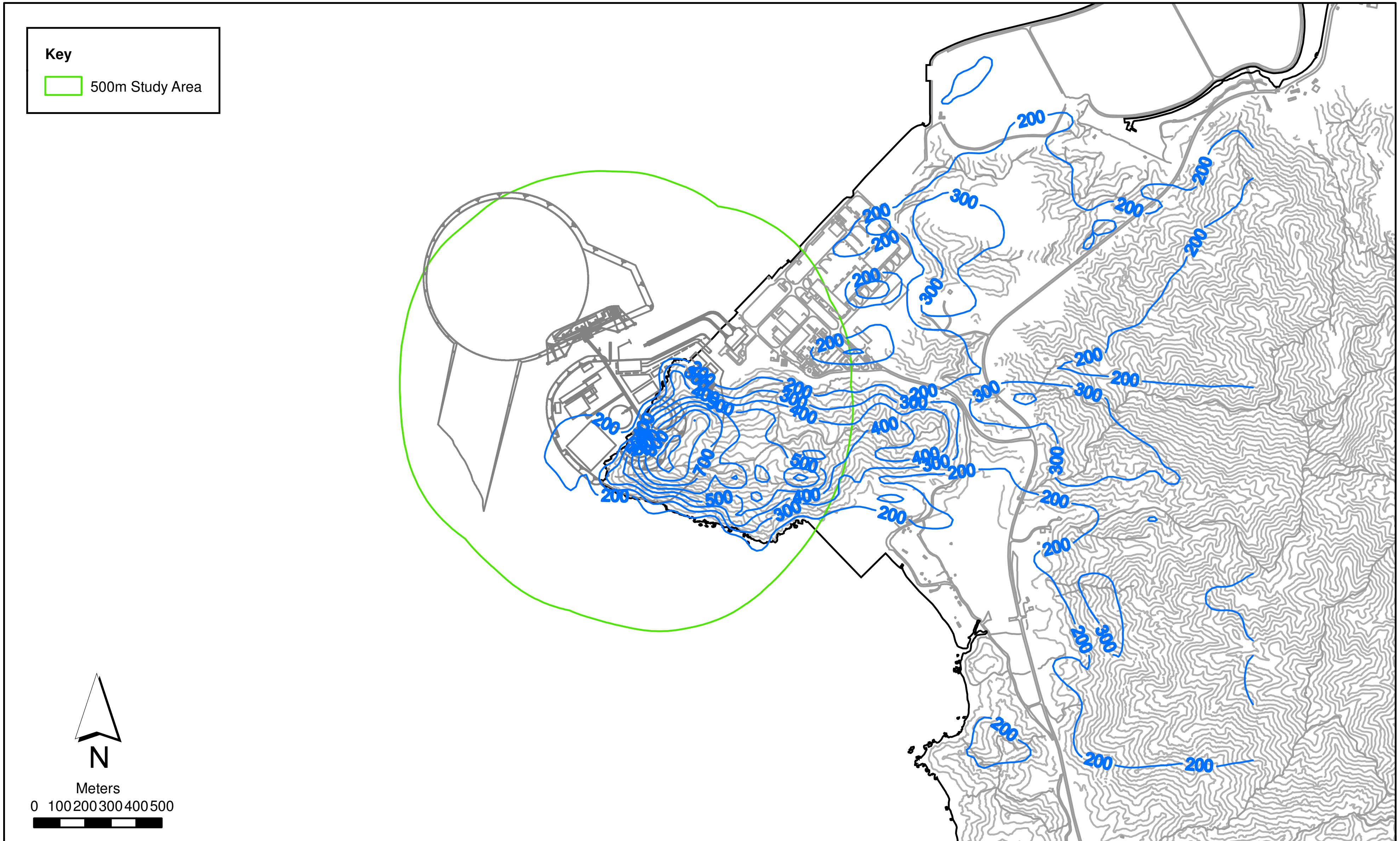

Figure 4.3

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

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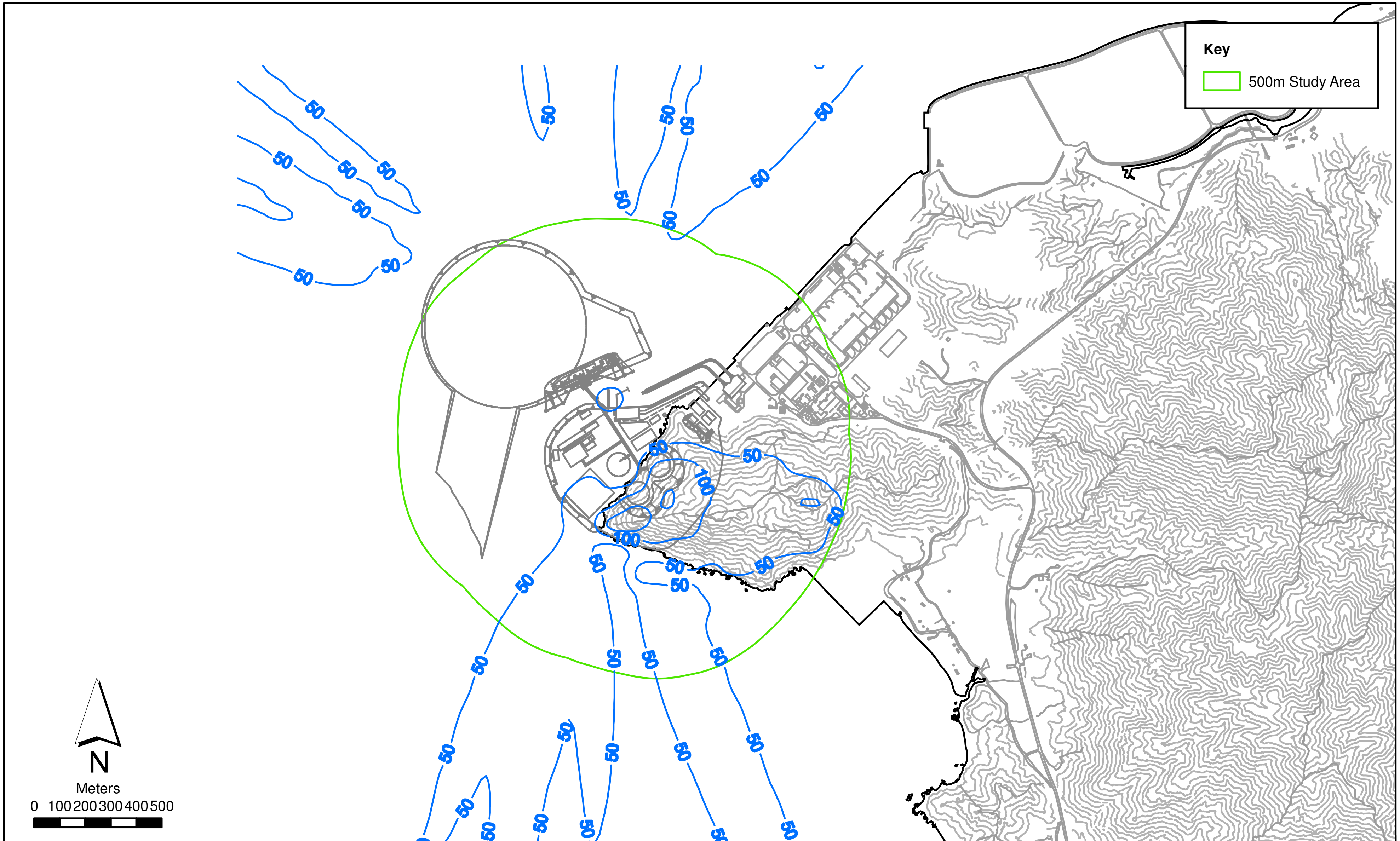

Figure 4.4

Isopleths of Daily Average NO2 at 1.5m Above Ground
(Emissions from LNG Terminal Only)

File: Report_August/0018180_Air_NO2_GDD_BP_1.mxd
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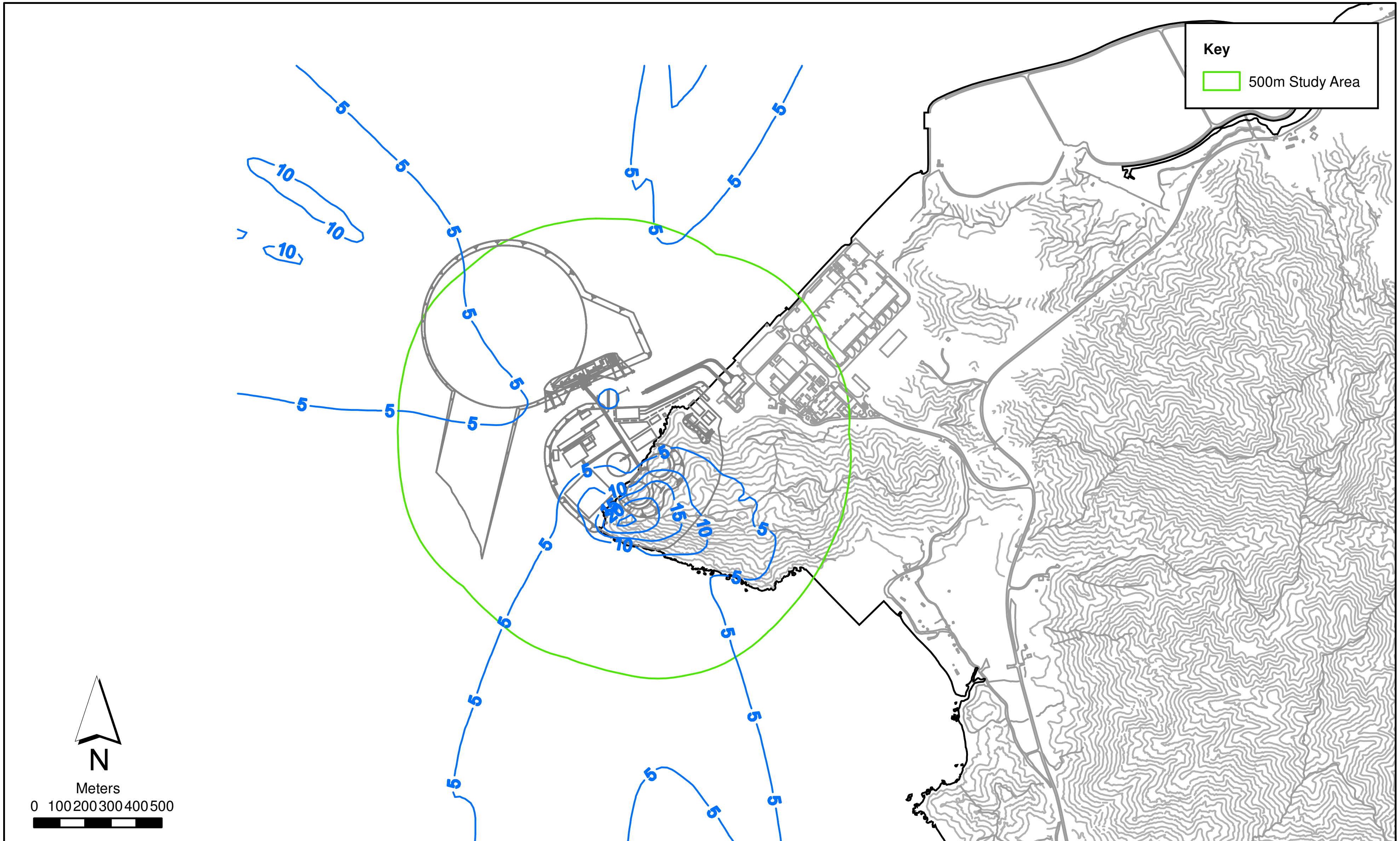

Figure 4.5

Isopleths of Annual Average NO2 at 1.5m Above Ground
(Emissions from LNG Terminal Only)

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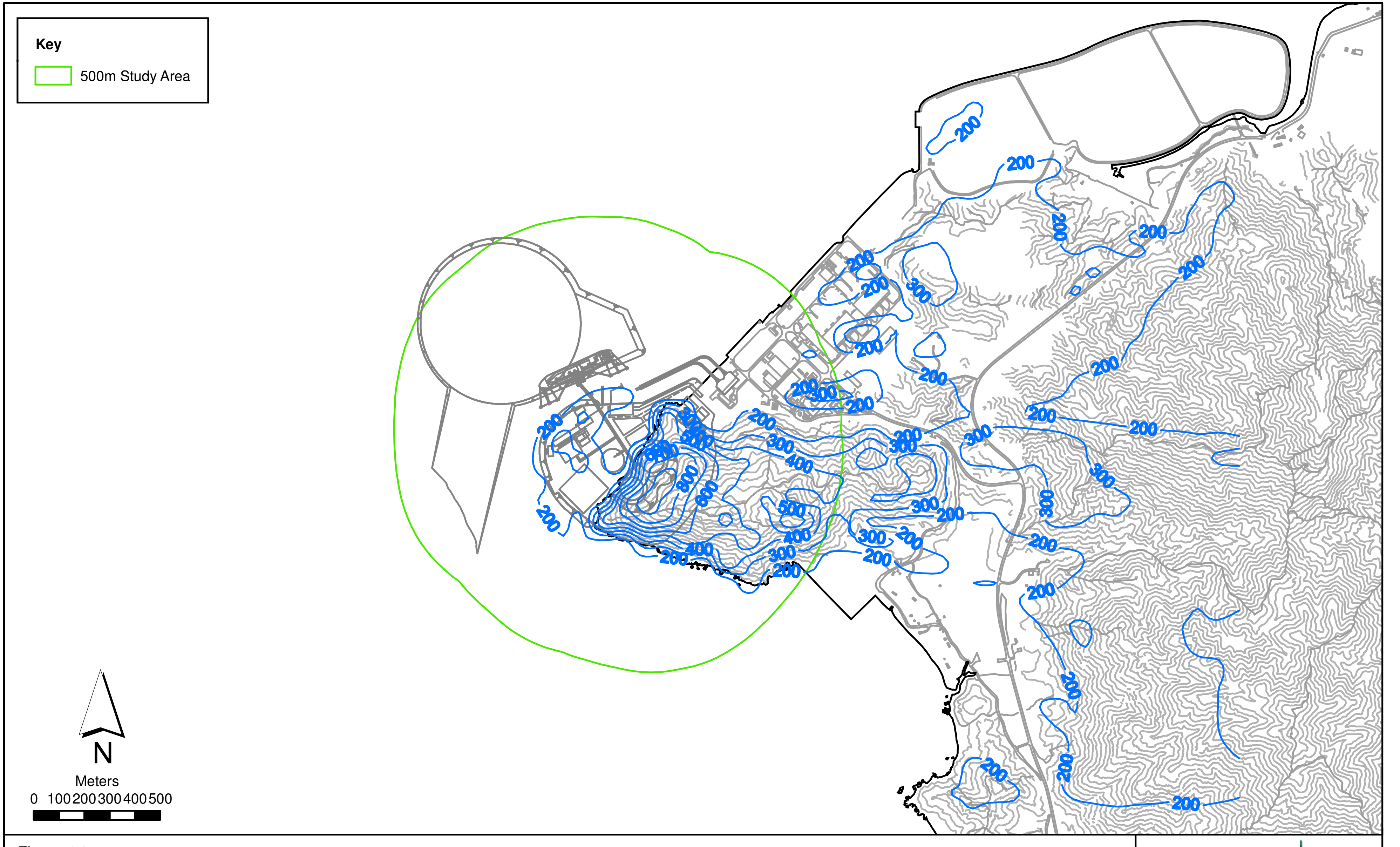

Figure 4.6

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

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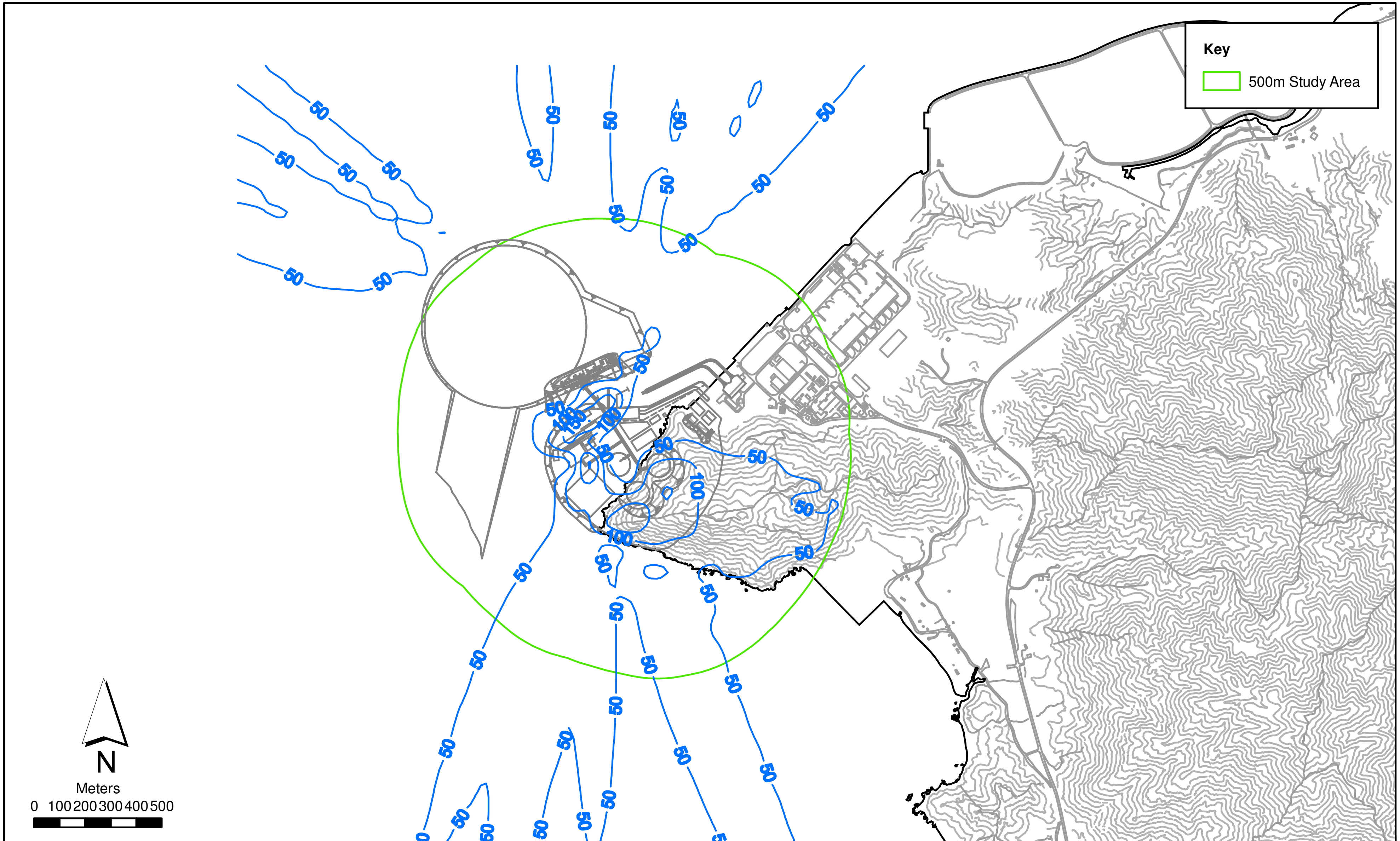

Figure 4.7

Isopleths of Daily Average NO2 at 10m Above Ground
(Emissions from LNG Terminal Only)

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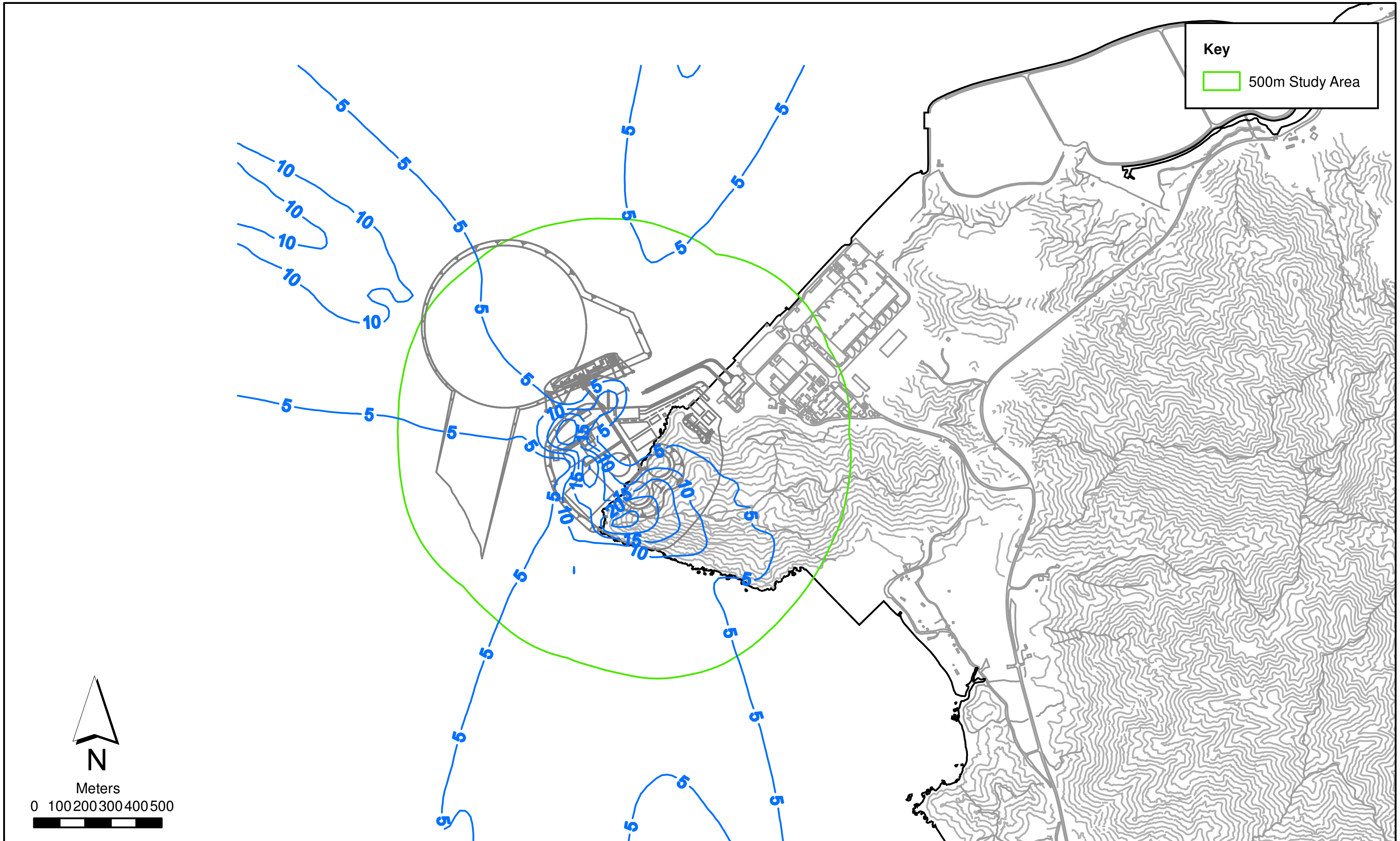

Figure 4.8

Isopleths of Annual Average NO2 at 10m Above Ground
(Emissions from LNG Terminal Only)

File: Report_August/0018180_Air_NO2_10a_BP_1.mxd
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bring emissions from the LNG Terminal and BPPS towards ASRs A1 and A2 and hence cumulative NO_2 impacts may arise [1]. The assessment has also taken emissions from the CPPS into consideration. Cumulative maximum hourly NO_2 and SO_2 impacts at ASRs A1 and A2 were assessed taking into account the background air quality (shown in *Table 4.3*) and the adjusted maximum hourly NO_2 and SO_2 concentrations attributable to the BPPS and CPPS, as shown in *Table 4.4*. The NO_2 and SO_2 concentrations predicted at ASRs A1 and A2 are summarized in *Table 4.9*.

A3 is located within the BPPS site. The emission height of the BPPS is about 100 m and hence due to high efflux temperature and efflux velocity, the plume will not reach ground level at A3. In addition, no impact from the CPPS is considered due to the opposing worst case wind angle. Hence, short-term cumulative NO_2 and SO_2 impacts due to BPPS and CPPS are not expected.

For those ASRs (A4 to A8) located at Lung Kwu Sheung Tan, the worse case wind angles for emissions from the LNG Terminal and the BPPS are similar and therefore the contribution from BPPS is considered. No impact from the CPPS is considered due to the opposing worst case wind angle.

The cumulative maximum hourly NO_2 and SO_2 concentrations at the identified ASRs are summarized in *Table 4.9*.

(1) No SO_2 contribution from BPPS is considered due to very negligible emission from gas-fired units and with reference to the BPPS EIA Study, Annex B – Source Emissions and Characteristics.

Table 4.9 Cumulative Maximum Hourly NO_2 and SO_2 Impacts (Emissions from LNG Terminal + BPPS + CPPS + Background Air Quality)

ASR	Cumulative Maximum Hourly Concentration (μgm^{-3}) (a)			
	NO_2		SO_2 (g)	
	1.5 m above ground	10 m above ground	1.5 m above ground	10 m above ground
A1	227 (b)	227 (b)	225 (f)	225 (f)
A2	228 (b)	228 (b)	224 (f)	224 (f)
A3 (c)	181	221	76	76
A4 (d) (e)	209	-	64	-
A5 (e)	229	229	91	91
A6 (d) (e)	286	-	91	-
A7 (e)	222	222	77	77
A8 (d) (e)	224	-	78	-
Hourly NO_2 Criterion	**300**	**300**	**800**	**800**

Notes:

(a) Background NO_2 and SO_2 concentration of 52 μgm^{-3} and 27 μgm^{-3}, respectively, measured at EPD's AQMS at Tung Chung is included.

(b) Adjusted maximum hourly NO_2 concentration (99 μgm^{-3} for A1 and 108 μgm^{-3} for A2) due to the contribution of BPPS and CPPS is added (refer to *Table 4.4*).

(c) No contribution from CPPS and BPPS.

(d) No contribution from CPPS due to opposing worst wind angle. Adjusted maximum hourly NO_2 concentration (54 μgm^{-3} for A4 to A8) from the contribution of BPPS is also added (refer to *Table 4.4*).

(e) As A4, A6 and A8 are not elevated ASRs and therefore, no assessment was performed at 10 m above ground at these ASRs.

(f) Adjusted maximum hourly SO_2 concentration of 170 μgm^{-3} for A1 and A2 due to the contribution of CPPS is added.

(g) No SO_2 contribution from BPPS is taken into account due to very negligible emission from gas-fired units with reference to the BPPS EIA Study, Annex B – Source Emissions and Characteristics.

The results indicate that the worst case cumulative hourly NO_2 and SO_2 impacts at all ASRs meet the AQOs. It should be noted that the cumulative maximum hourly NO_2 and SO_2 concentrations at all ASRs attributable to the LNG terminal emissions are predicted assuming continuous emissions from all sources. The actual cumulative maximum hourly NO_2 and SO_2 concentrations are expected to be lower than those presented in *Table 4.9*.

Isopleths of cumulative hourly NO_2 and SO_2 concentrations were plotted and are shown in *Figures 4.9 to 4.12*. The predicted worst case cumulative hourly NO_2 and SO_2 concentrations exceeded the respective assessment criteria at the Black Point Headland, the rough terrain area between Lung Kwu Sheung Tan and Nim Wan and at the firing range.

In reality, the frequency of LNG carrier berthing at the LNG terminal is low (i.e., 6 carriers per month) and the SCVs will be operated in the event that the ORVs run below their capacity. Therefore, the potential impact to these uninhabited areas will be lower than that presented in the figures.

It is noted that the designation of a Consultation Zone would impose development constraints. The area of the Consultation Zone is not yet defined; however, with reference to Consultation Zones for other PHIs, it can

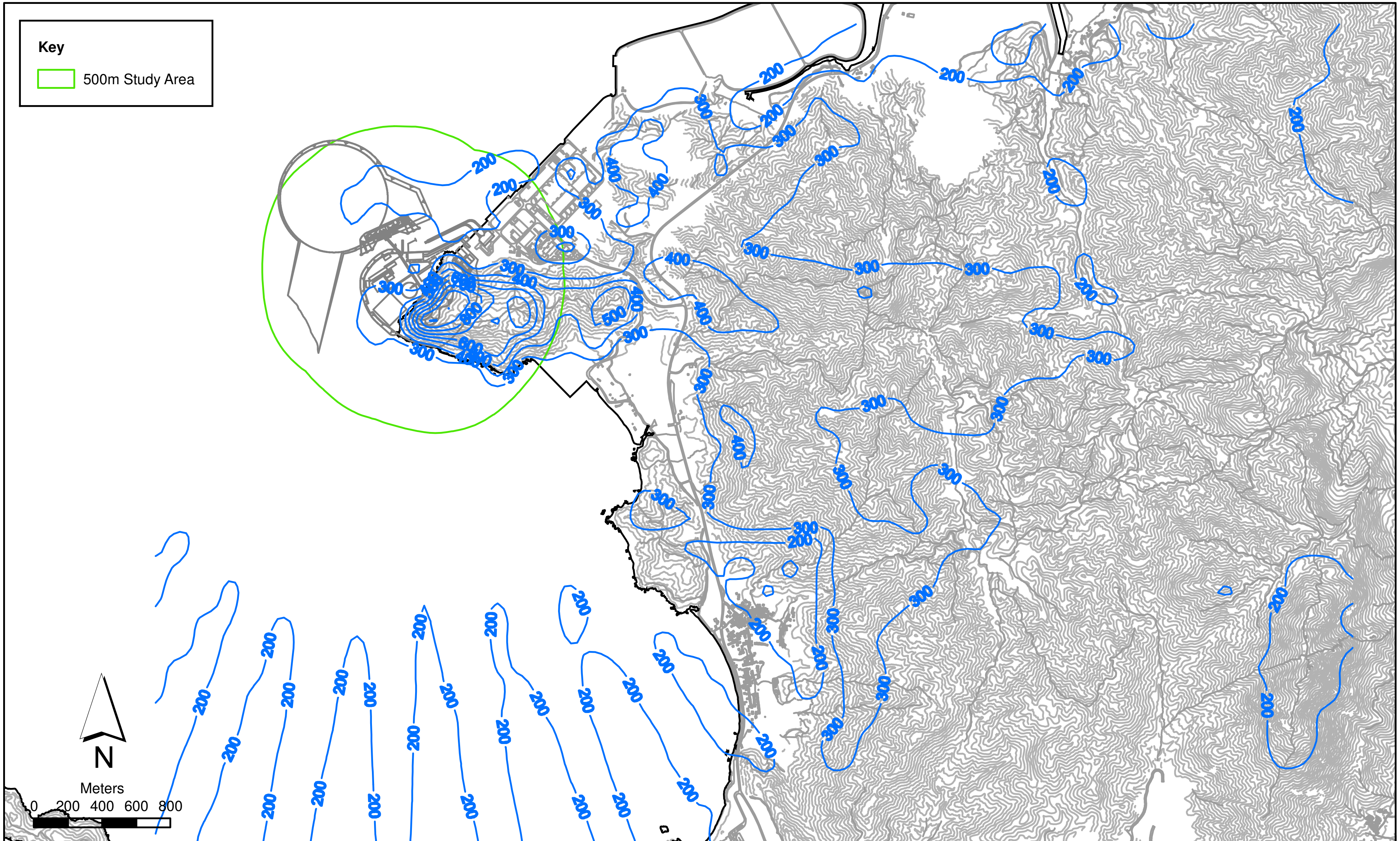

Figure 4.9

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

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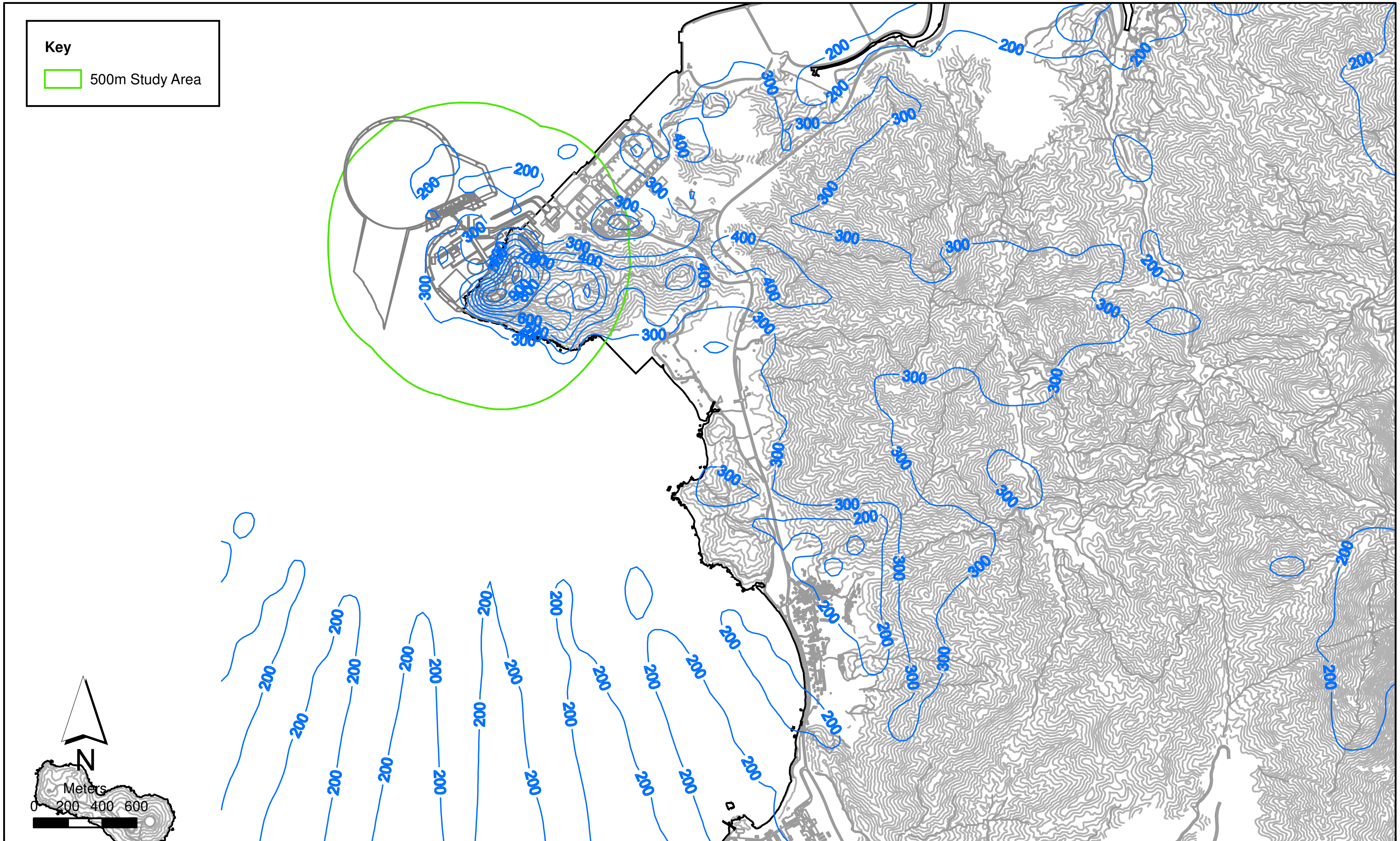

Figure 4.10

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

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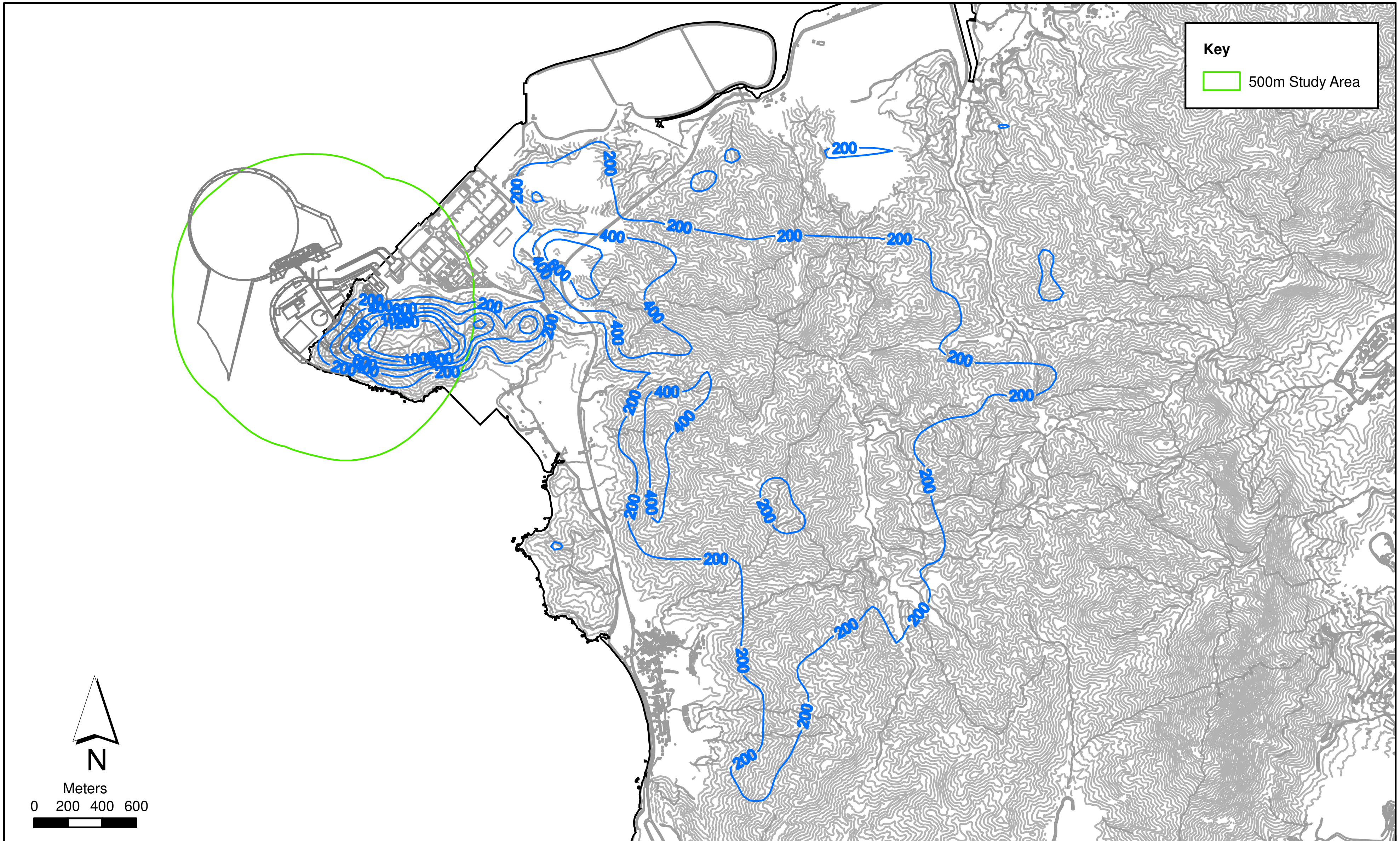

Figure 4.11

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

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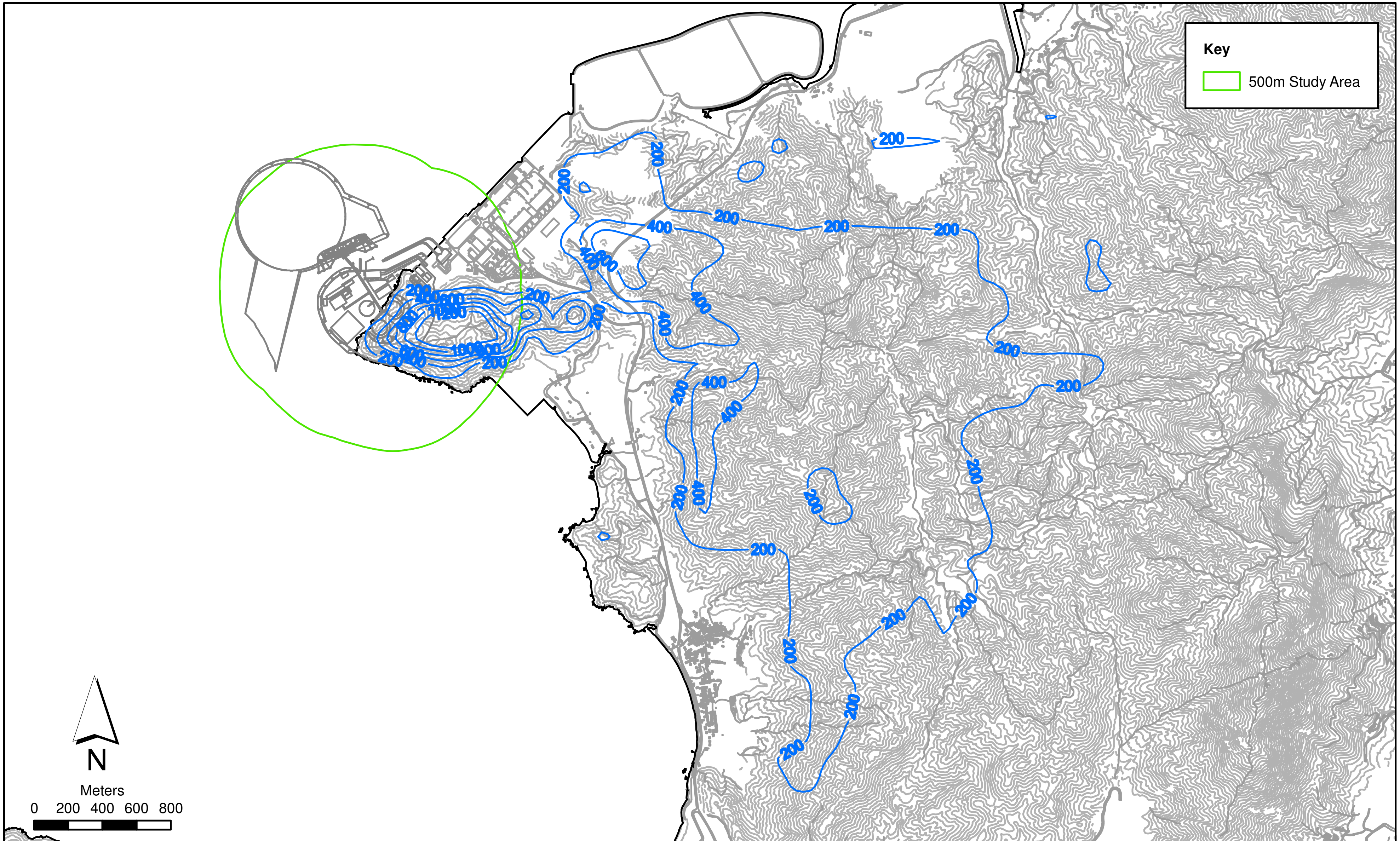

Figure 4.12

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

File: Report_August/0018180_Air_SO2_10h_BP_1.mxd
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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. In addition, no development is allowed within the firing range and no planned or proposed developments are known in the area of rough terrain near Nim Wan.

Nevertheless, should development be proposed in these areas in the future, the air quality constraints would have to be accounted for.

Cumulative Daily and Annual NO_2 and SO_2 Impacts

Emissions from BPPS and CPPS together with the background air quality have the potential to create cumulative daily and annual average air quality impacts during the operation of the LNG Terminal. The predicted daily NO_2 concentrations attributable to BPPS and CPPS are 22 μgm^{-3} and 0.6 μgm^{-3}, respectively. The predicted daily SO_2 concentrations attributable to BPPS and CPPS are 60 μgm^{-3} and 1.5 μgm^{-3}, respectively (refer to *Table 4.4*) [(1)]. The cumulative daily and annual average NO_2 and SO_2 concentrations at the ASRs are summarized in *Table 4.10*.

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

Table 4.10 Cumulative Daily and Annual Average NO_2 and SO_2 Impacts (Emissions from LNG Terminal + BPPS + CPPS + Background Air Quality)

ASR	Cumulative Daily Concentration (μgm^{-3}) (a) (b)		Cumulative Annual Average Concentration (μgm^{-3}) (b)	
	1.5 m above ground	10 m above ground	1.5 m above ground	10 m above ground
NO_2 *(c) (d)*				
A1	77	77	52.6	52.6
A2	76	76	52.6	52.6
A3	79	81	52.7	52.7
A4 (e)	81	-	53.2	-
A5	85	85	53.6	53.6
A6 (e)	89	-	53.3	-
A7	83	83	53.4	53.4
A8 (e)	85	-	53.4	-
NO_2 Criteria	**150**	**150**	**80**	**80**
SO_2 *(f) (g)*				
A1	88	88	28.5	28.5
A2	88	88	28.5	28.5
A3	89	89	28.5	28.5
A4 (e)	90	-	28.8	-
A5	93	93	29.0	29.0
A6 (e)	93	-	28.8	-
A7	91	91	28.9	28.9
A8 (e)	91	-	28.9	-
SO_2 Criteria	**350**	**350**	**80**	**80**

Notes:

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

(b) Background NO_2 and SO_2 concentrations (52 μgm^{-3} and 27 μgm^{-3}, respectively) as presented in *Table 4.3* is included.

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

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

(e) As A4, A6 and A8 are not elevated ASRs and therefore, no assessment was performed at 10 m above ground at these ASRs.

(f) Daily SO_2 concentration of 60 μgm^{-3} is included (refer to *Table 4.4*).

(g) Annual average SO_2 concentration of 1.5 μgm^{-3} is included (refer to *Table 4.4*).

The results indicate that the cumulative daily and annual average NO_2 and SO_2 impacts at all identified ASRs are well within the AQOs. The contribution from the LNG terminal emissions is very minor, even under the worst case scenario.

Isopleths showing the cumulative daily and annual average NO_2 and SO_2 concentrations at 1.5 m and 10 m above ground are plotted and shown in *Figures 4.13* to *4.20*. Although exceedances of the daily NO_2 criterion are predicted at a small area on the Black Point Headland located close to the LNG Storage Tanks, the small affected area will be within the PHI Consultation Zone and development constraints will be imposed.

It should be noted that the cumulative air quality assessment does not account for the fact that CAPCO has obtained an approval for the *Emission Control*

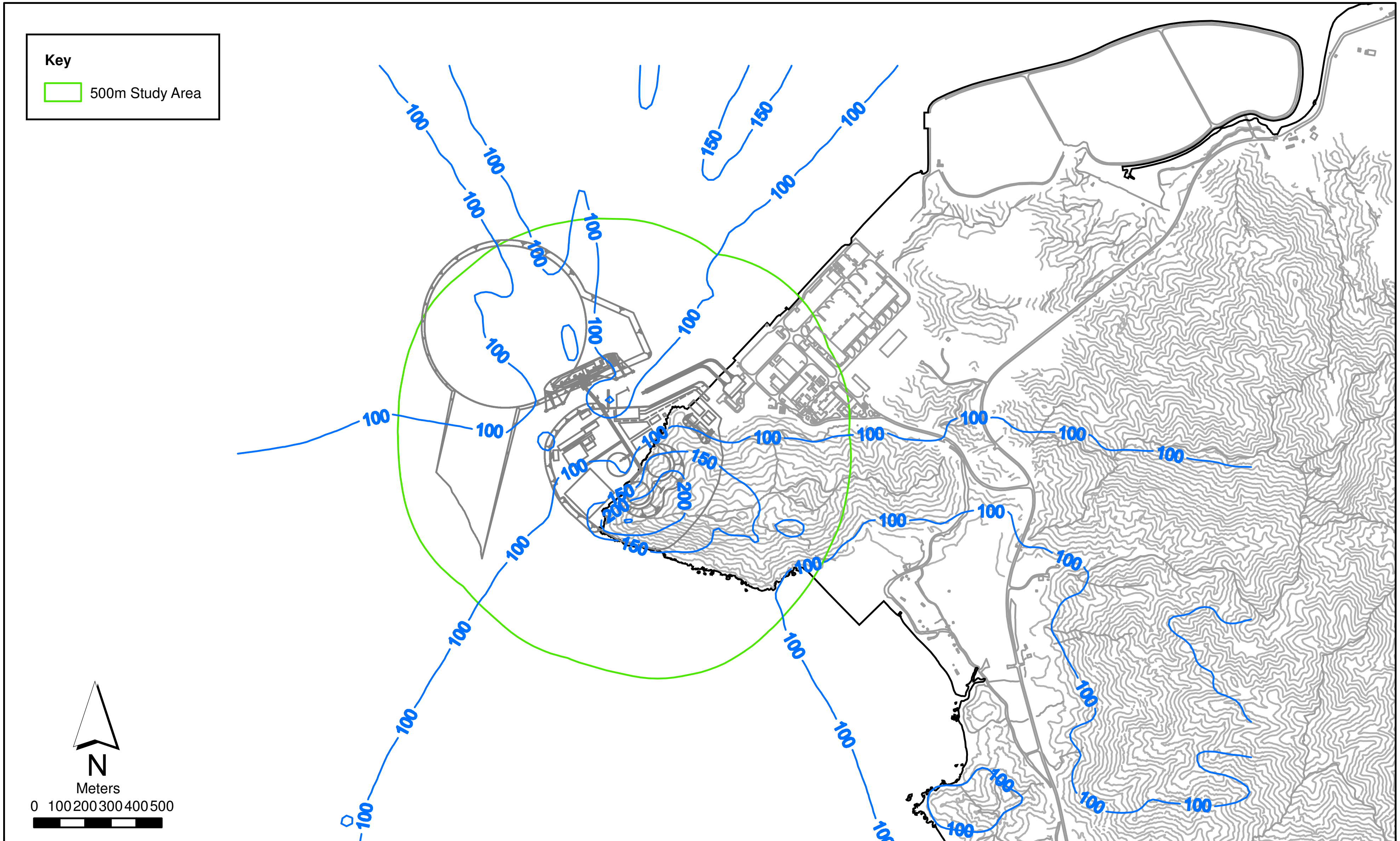

Figure 4.13

Isopleths of Cumulative 2nd Highest Daily Average NO2 at 1.5m Above Ground
(Emissions from LNG Terminal + TC AQMS Background + BPPS + CPPS)

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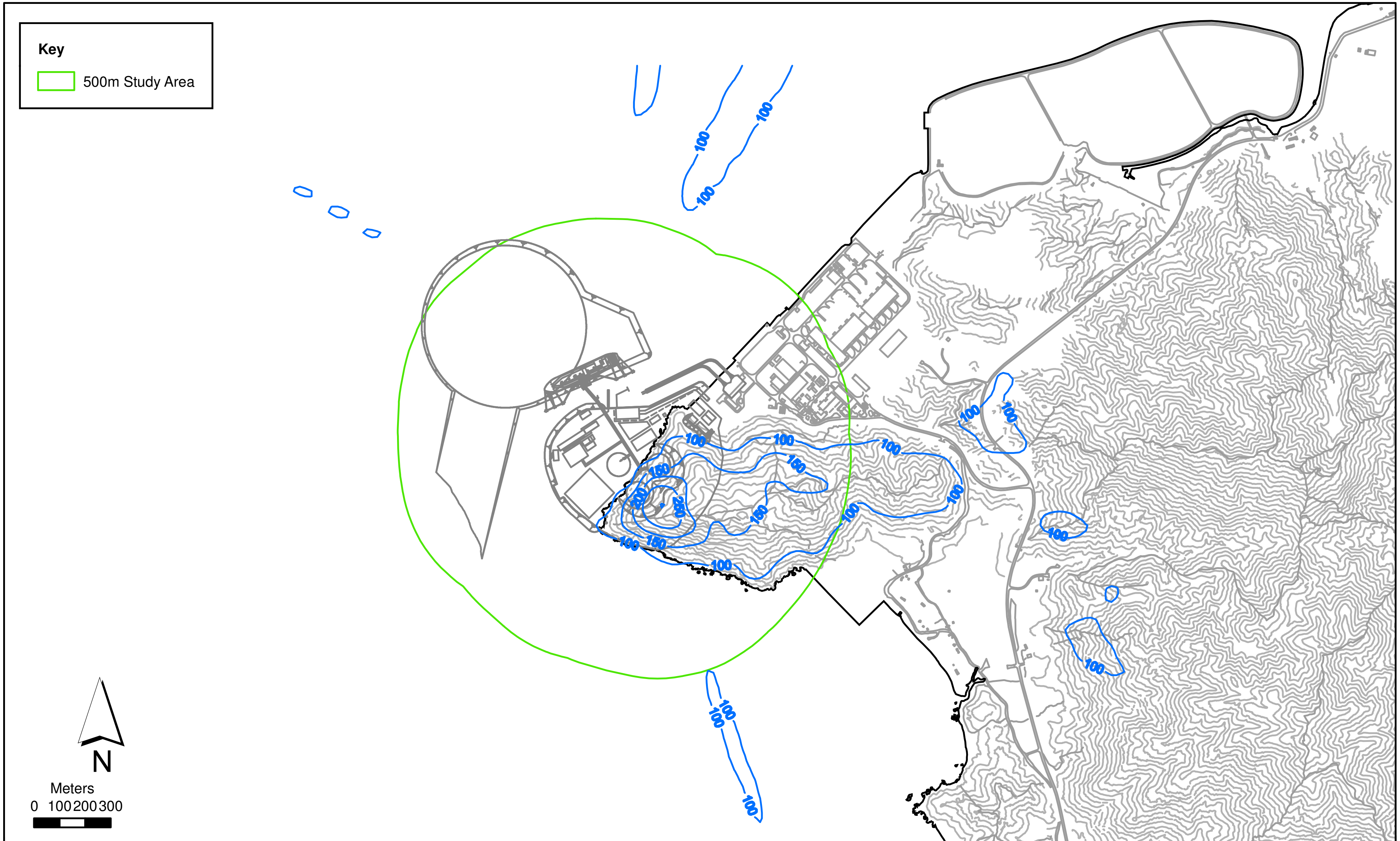

Figure 4.14

Isopleths of Cumulative 2nd Highest Daily Average NO2 at 10m Above Ground
(Emissions from LNG Terminal + TC AQMS Background + BPPS + CPPS)

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Date: 05/12/2006

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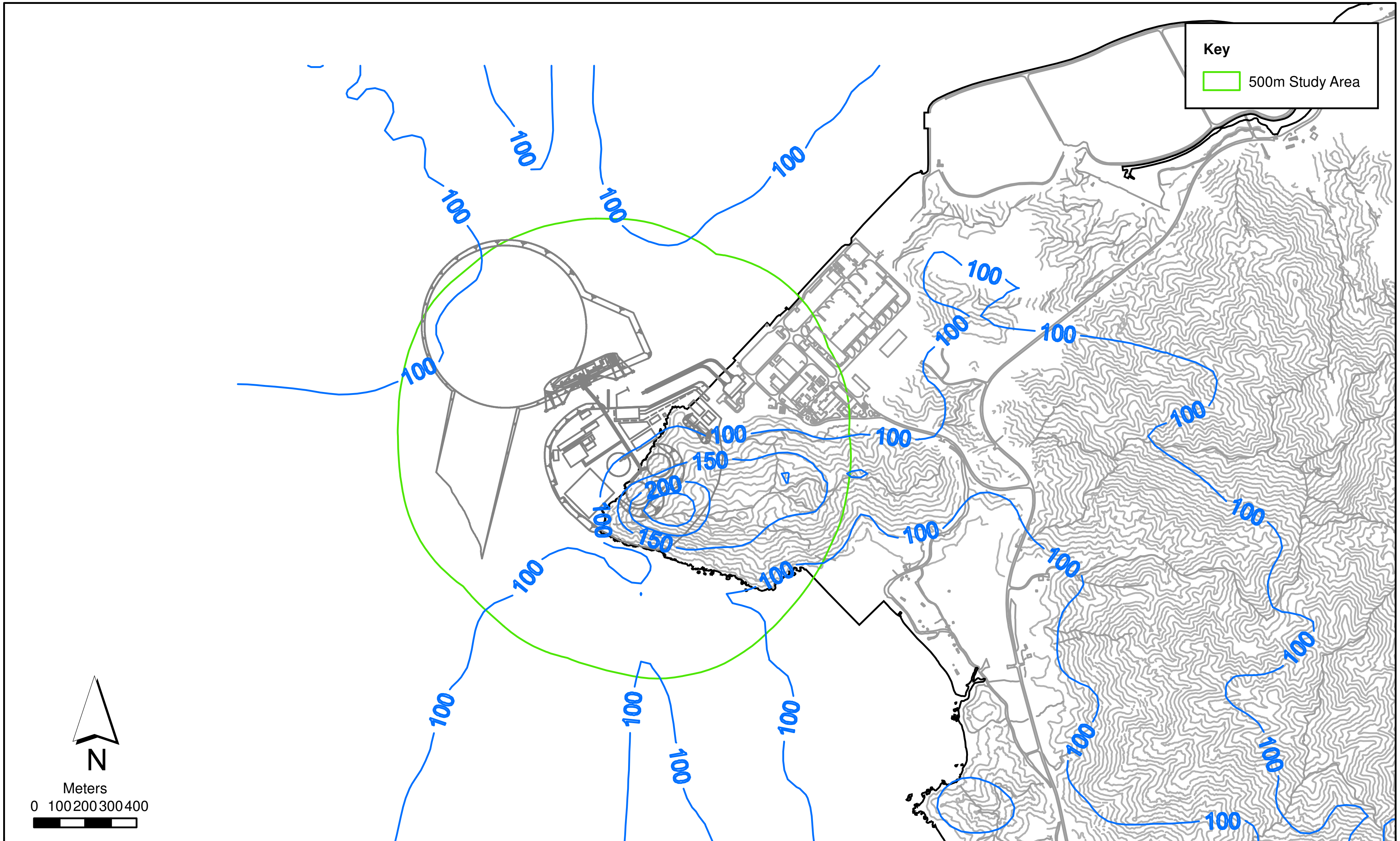

Figure 4.15

Isopleths of Cumulative 2nd Highest Daily Average SO2 at 1.5m Above Ground
(Emissions from LNG Terminal + TC AQMS Background + CPPS)

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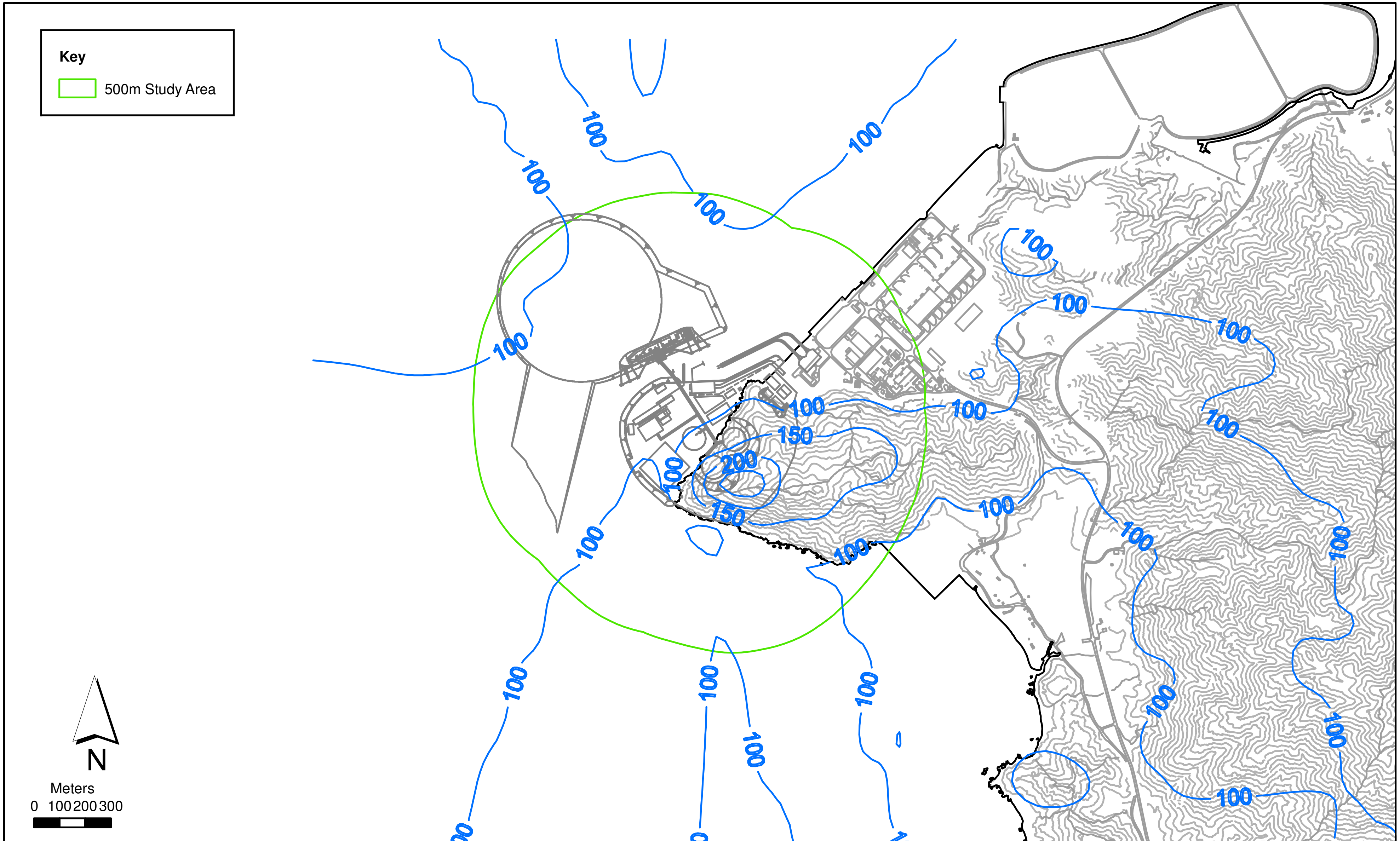

Figure 4.16

Isopleths of Cumulative 2nd Highest Daily Average SO2 at 10m Above Ground
(Emissions from LNG Terminal + TC AQMS Background + CPPS)

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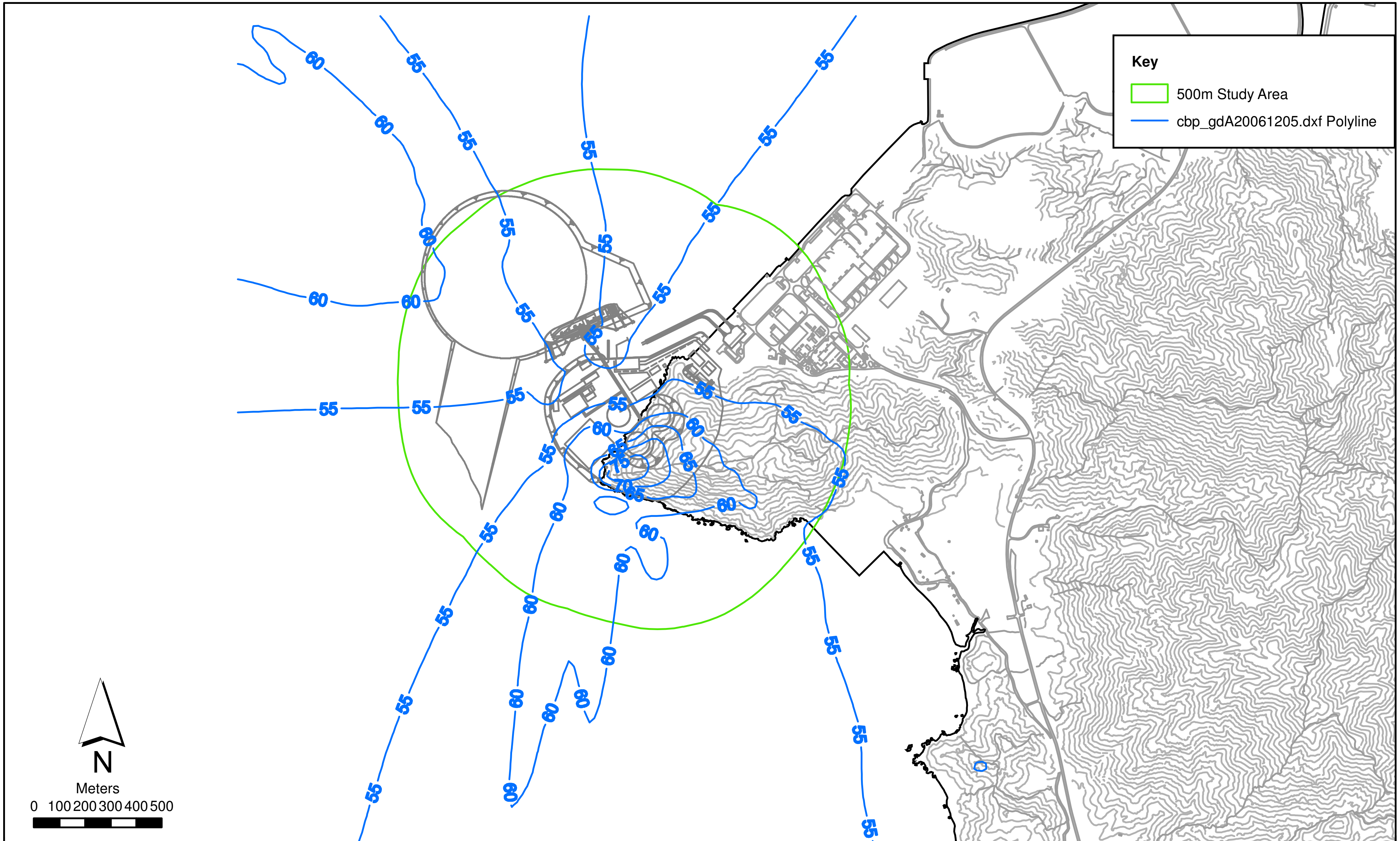

Figure 4.17

Isopleths of Cumulative Annual Average NO2 at 1.5m Above Ground
(Emissions from LNG Terminal + TC AQMS Background + BPPS + CPPS)

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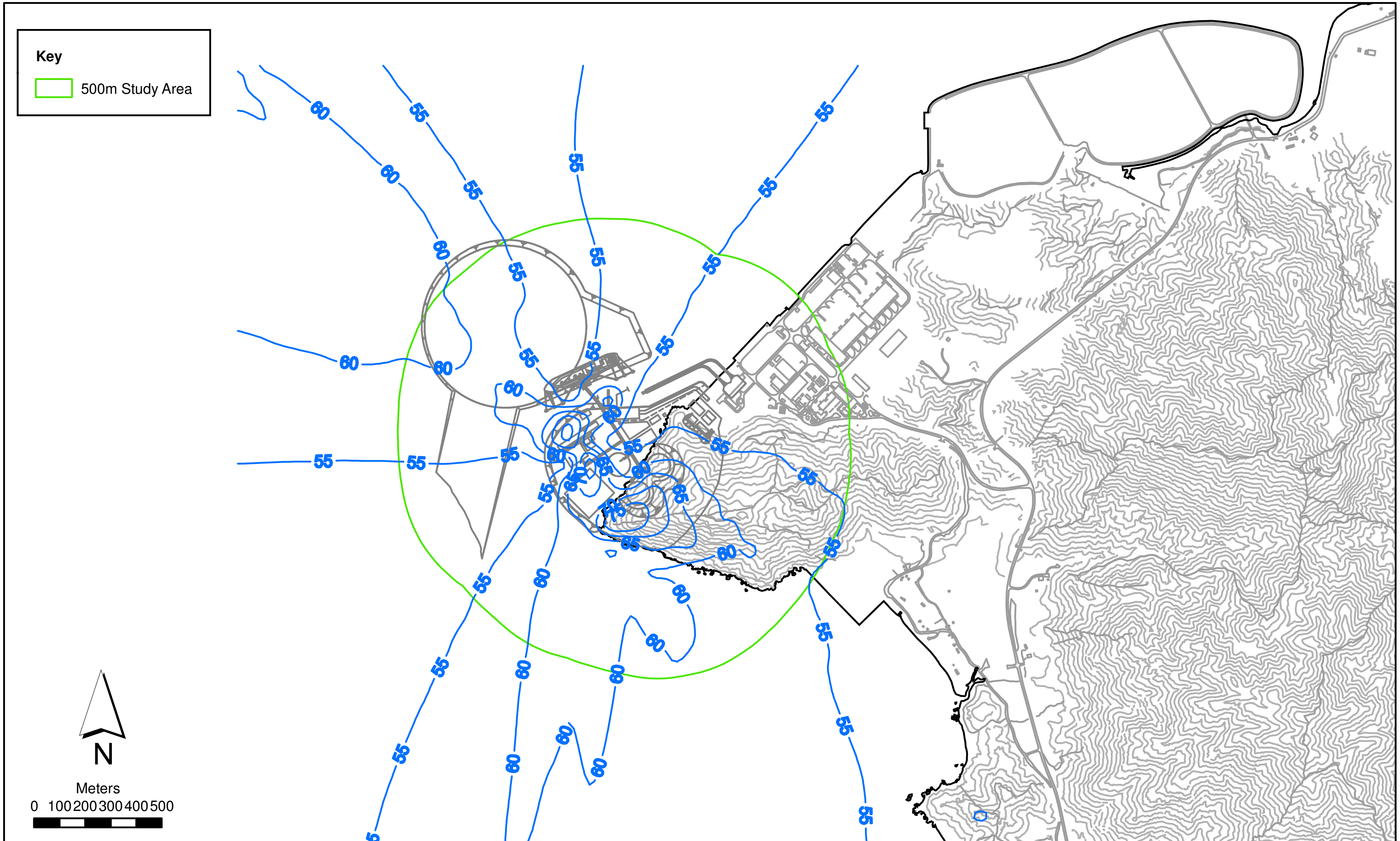

Figure 4.18

Isopleths of Cumulative Annual Average NO2 at 10m Above Ground
(Emissions from LNG Terminal + TC AQMS Background + BPPS + CPPS)

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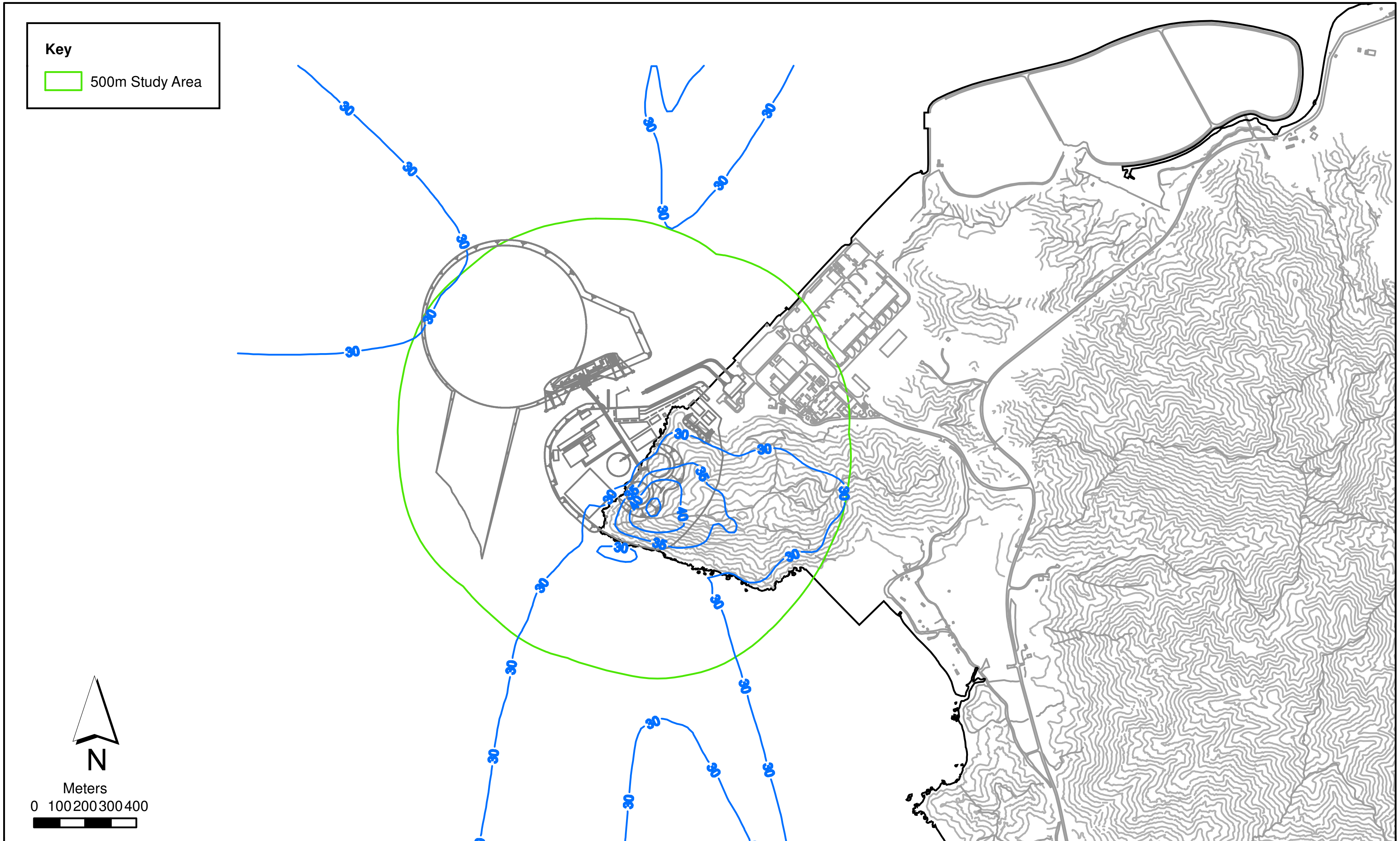

Figure 4.19

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

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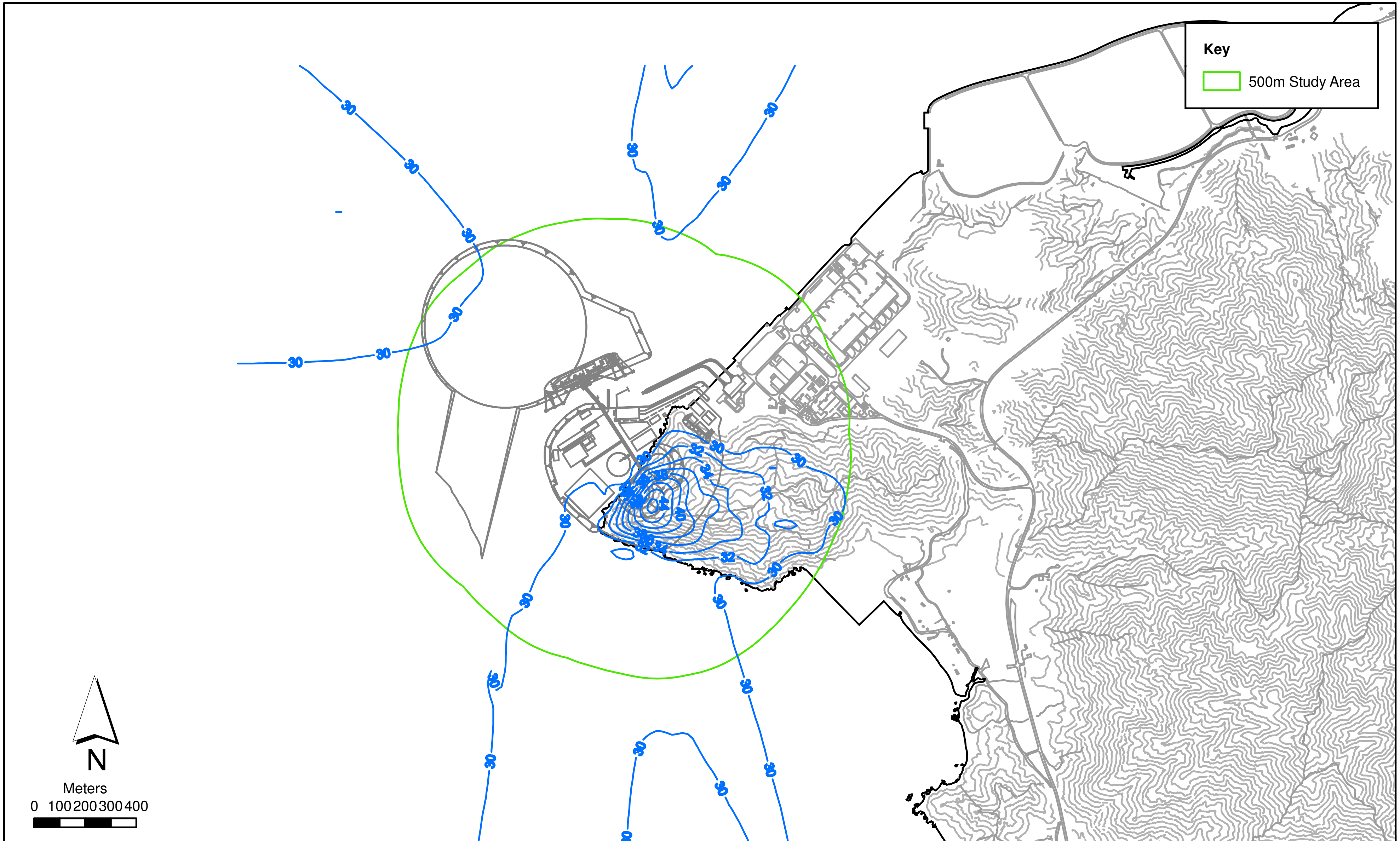

Figure 4.20

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

File: Report_August/0018180_Air_SO2_10a_BP_1.mxd
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Project for the Castle Peak Power Station "B" Units [1] in which the NO_2 and SO_2 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 exceedances of the AQO criteria are anticipated at the ASRs but the hourly NO_2 and SO_2 concentration was predicted to exceed the criterion in some unpopulated areas including Black Point Headland, firing range and the area of rough terrain near Nim Wan . Exceedances of the daily NO_2 criterion are predicted at a small area on the Black Point Headland located close to the LNG storage tanks. 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 constraints would have to be accounted for.

4.8 RESIDUAL IMPACTS

4.8.1 Construction Phase

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

4.8.2 Operational Phase

No adverse residual operational air quality impact is anticipated.

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

4.9 ENVIRONMENTAL MONITORING AND AUDIT

4.9.1 *Construction Phase*

Dust monitoring is recommended at the Administration Building of the existing Black Point Power Station as a counter check to this assessment. 24-hour TSP measurement will be conducted by High Volume Sampling (HVS) once every 6 days throughout the site formation works.

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

4.9.2 *Operational Phase*

No operational air quality monitoring is required.

4.10 CONCLUSIONS

Potential nuisance from dust generating activities and gaseous emission from construction plant during construction of the LNG terminal have been considered. With the implementation of standard mitigation measures, no adverse impact is anticipated. The gaseous emissions from the construction equipment are also minimal and no adverse impact is anticipated. Dust monitoring is recommended at the Administration Building of the Black Point Power Station to ensure no exceedance of the dust criteria (1) is encountered during site formation and reclamation works.

During the operation of the LNG terminal, air emissions from submerged combustion vaporisers (SCVs), LNG carrier auxiliary engines during unloading and pipeline gas heaters are potential sources of air quality impacts. For worst case assessment, it was assumed that all three sources were operating continuously. With this set of assumptions, the assessment indicated no exccedances of the AQOs at the ASRs.

Cumulative maximum hourly NO_2 and SO_2 concentrations were predicted to exceed the respective criteria at the uninhabited Black Point Headland, firing range and the area of rough terrain near Nim Wan (refer to *Figures 4.9* to *4.12*). Cumulative daily NO_2 concentrations were predicted to exceed the criterion at a small area near the LNG storage tanks on the Black Point Headland assuming continuous emissions and the worst case meteorological condition (refer to *Figures 4.13* to *4.14*). In reality, the probability of this set of worst case emissions and meteorological conditions 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

(1) Hourly dust criterion of 500 μgm^{-3} is recommended in the EIAO-TM and daily dust criterion of 260 μgm^{-3} is stipulated in the HKAQOs.

development be proposed in these areas, the air quality constraints would have to be accounted for.

Annex 4

Air Quality Supporting Document

Annex 4-A

Adjustment of Background NO_2 at Black Point

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 part 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:

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

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 0.24 km^{-1} for wind speed of 8 m/s and 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):

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

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 2^{nd} 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 generating capacity of BPPS is about 2,500 MW which is approximately 50%, therefore, a factor of 0.5 is applied to adjust the NO_2 based on the current operation mode. Using adjusted Janssen coefficient, the maximum hourly NO_2 concentrations at ASRs at Lung Kwu Tan, Ha Pa Nai and Sheung Pak Nai are calculated.

Of note, A2 (EPD Office at WENT Landfill) is located at Nim Wan and the distance between BPPS and A2 is about 2.1 km. No assessment point was identified in the wind tunnel testing. But in view of the detailed wind tunnel testing results in the *BPPS EIA Study Annex D (NO_2 results under Option 3 at wind direction of 232°)*, the results at 2.4 km away from BPPS emission sources is lower than that predicted at 3.2 km which is at Ha Pak Nai, therefore, the predicted results at Ha Pak Nai will be used to represent the worst NO_2 concentration attributable to BPPS at A2 (EPD Office at WENT Landfill).

ASRs at Lung Kwu Tan (x=2, C_1 = 30% of AQO, wind speed of 12 m/s), Ha Pak Nai (x=3.2, C_1 = 10% of AQO, wind speed of 8 m/s) and Sheung Pak Nai (x=7.5, C_1 = 5% of AQO, wind speed of 8 m/s):

Lung Kwu Tan
C_2 = 30 [0.81 (1 – exp (-0.33 x 2))] / [0.74 (1 – exp (-0.29 x 2))] x 0.5 = 18%of AQO (54 μgm^{-3})

Ha Pak Nai
C_2 = 10 [0.81 (1 – exp (-0.24 x 3.2))] / [0.74 (1 – exp (-0.21 x 3.2))] x 0.5 = 6%of AQO (18 μgm^{-3})

Sheung Pak Nai
C_2 = 5 [0.81 (1 – exp (-0.24 x 7.5))] / [0.74 (1 – exp (-0.21 x 7.5))] x 0.5 = 2.9%of AQO (9 μgm^{-3})

CPPS Contribution

For ASRs A3 to A8 located at Lung Kwu Sheung Tan area, since the worst wind direction from LNG terminal and from CPPS to ASRs A3 to A8 are opposite, therefore, no cumulative short-term impact is anticipated.

For ASRs A1 and A2 located at Sheung Pak Nai and Nim Wan, respectively, contribution from the CPPS is likely to cause cumulative air quality as well as BPPS with the LNG Terminal contribution.

The CPPS contribution assessed in the BPPS EIA Study is used in the following calculation. In the BPPS EIA Study, no wind tunnel testing was performed at Sheung Pak Nai. However, Sheung Pak Nai (8 km) is located further away from CPPS than Ha Pak Nai (i.e., 5.5 km) and the NO_2 concentration at Sheung Pak Nai should be lower than that at Ha Pak Nai. Therefore, NO_2 concentrations predicted at Ha Pak Nai are used as worst case NO_2 concentration at Sheung Pak Nai.

The worst wind direction of CPPS "A" and "B" Units (CPA and CPB) to Ha Pak Nai is about 195°. With reference to *BPPS EIA Study, Annex H, Table H.1b*, the maximum hourly NO_2 concentration under wind speed of 8 ms^{-1} are 59.9 μgm^{-3} and 46.6 μgm^{-3}, contributed from CPA and CPB, respectively.

CPA is currently operating with low-NO_x burners and the current licence limit of NO_x is 1,500 mgm^{-3}. In the *BPPS EIA Study, Annex B*, the source NO_x concentration at source for CPA in the wind tunnel testing was 1,577 mgm^{-3}. Therefore, about 5% of NO_x is reduced by the operation of low-NO_x burners and hence, a reduction factor of 0.05 will be applied to adjust the NO_2 concentration attributable to CPA at Ha Pak Nai.

The source NO_x concentration at source for CPB in the wind tunnel testing was 1,578 mgm^{-3} in accordance with the *BPPS EIA Study, Annex B*. Currently, CPB is also operating with low-NO_x burners and the current licence limit of NO_x is 1,500 mgm^{-3}. Also, 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 reasonable licence NO_x limit in future and hence the future NOx 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, with the consideration of existing low-NO_x burner and future implementing of new NO_x reduction technology, a NO_x reduction factor of 0.57 (1) will be applied to adjust the NO_2 concentration contributed from CPB at Ha Pak Nai. The indicative commencement date of future low NO_x technology at CPB is in end of 2009 to 2011 in accordance with the approved *EIA for Emission Control Project to CPPS "B" Units* which is likely to be earlier than this Study.

Hence the maximum hourly NO_2 concentration contributed from CPA and CPB will be adjusted by

(a) higher ozone level (108 μgm^{-3}) in 2004;
(b) NO_x reduction by current implementation of low NO_x burners at CPA (a factor of 0.05) and
(c) current low-NO_x burner and future new NO_x reduction technology at CPB (a factor of 0.57).

The calculation is shown as below

Ha Pak Nai

CPA
C_2 = 59.9 [0.81 (1 – exp (-0.24 x 5.5))] / [0.74 (1 – exp (-0.21 x 5.5))] x (1-0.05)
= 67 μgm^{-3}

CPB
C_2 = 46.6 [0.81 (1 – exp (-0.24 x 5.5))] / [0.74 (1 – exp (-0.21 x 5.5))] x (1-0.57)
= 23 μgm^{-3}

Therefore, the total maximum hourly NO_2 concentration at Ha Pak Nai contributed from CPA and CPB is 67 μgm^{-3} + 23 μgm^{-3} = 90 μgm^{-3}

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 (2), respectively. The 2nd daily and annual average NO_2 concentrations in the *BPPS EIA Study, Part B, Table 6.2b* are summarized below.

(1) A factor of 0.57 = (1,578 mg/m³ - 670 mg/m³) / (1,578 mg/m³)
(2) 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).

	Lung Kwu Tan	Ha Pak Nai
Worst wind speed adopted in Wind Tunnel Testing (m/s)	12	8
2nd Highest Daily NO_2 Concentration	12.1% of AQO (18 μgm^{-3})	11.3 % of AQO (17 μgm^{-3})
Annual NO_2 Concentration	0.6 % of AQO (0.33 μgm^{-3})	0.5 % of AQO (0.28 μgm^{-3})
Note: (a) Reference to *BPPS EIA Study, Part B, Table 6.2b*		

As discussed before, the current licence NO_x limit is likely to be further tightened to meet 670 mgm^{-3} 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) for CPB. 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 and Ha Pak Nai in the above table will be reduced.

However, since the above results are the cumulative results taking into account of emissions from BPPS and CPPS in the Wind Tunnel Testing, 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 or Ha Pak Nai (which is shorter than CPPS to Lung Kwu Tan or Ha Pak Nai) is used for the calculation to obtain the worst 2nd highest daily NO_2 concentration.

The detailed calculations are shown as below.

<u>2nd Highest Daily NO_2 Concentration</u>

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})

Ha Pak Nai
C_2 = 11.3 [0.81 (1 – exp (-0.24 x 3.2))] / [0.74 (1 – exp (-0.21 x 3.2))] = 13.6%of AQO (20 μgm^{-3})

<u>Annual Average NO_2 Concentration</u>

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})

Ha Pak Nai
C_2 = 0.5 [0.81 (1 – exp (-0.24 x 3.2))] / [0.74 (1 – exp (-0.21 x 3.2))] = 0.6%of AQO (0.5 μgm^{-3})

Summary

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

	Lung Kwu Tan	Ha Pak Nai	Sheung Pak Nai [(a)]
Worst wind speed adopted in Wind Tunnel Testing (m/s)	12	8	8
Adjusted Maximum Hourly NO_2 Concentration	54 μgm^{-3} (BPPS ONLY)	108 μgm^{-3} (BPPS + CPPS)	99 μgm^{-3} (BPPS + CPPS)
Adjusted 2nd Highest Daily NO_2 Concentration (BPPS + CPPS with NO_x mitigation)	22 μgm^{-3}	20 μgm^{-3}	-
Adjusted Annual NO_2 Concentration (BPPS + CPPS with NO_x mitigation)	0.6 μgm^{-3}	0.5 μgm^{-3}	-

Note:
(a) No wind tunnel testing was performed at Sheung Pak Nai in the BPPS EIA Study; the NO_2 concentrations predicted at Ha Pak Nai is used as worst case assumption.

Since the adjusted 2nd highest daily and annual average NO_2 concentrations at Lung Kwu Tan and Ha Pak Nai are similar, the adjusted 2nd highest daily and annual average NO_2 concentrations (22 μgm^{-3} and 0.6 μgm^{-3}, respectively) at Lung Kwu Tan which is the highest will be adopted for the cumulative long-term impact assessment at all identified ASRs and for plotting the contours to assess the worst case cumulative impacts.

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.

Also, the maximum hourly NO_2 concentration from CPPS contribution at Nim Wan/Ha Pak Nai and Sheung Pak Nai is estimated at 195°. However, the worst wind angle from LNG terminal to Nim Wan/Ha Pak Nai and Sheung Pak Nai is about 232°. According to *Wind Tunnel Tests for Castle Peak "A" and "B Station, by Central Electricity Research Laboratories,* 1981, at the worst wind angle of 232° the NO_2 plume contributed from CPPS is very narrow and will not contribute NO_2 to Nim Wan, Ha Pak Nai and Sheung Pak Nai areas. Therefore, the cumulative short-term NO_2 impact assessment due to LNG terminal and CPPS will rarely occur and therefore, the cumulative short-term NO_2 impact assessment considering the above adjusted maximum hourly NO_2 concentration from CPPS is the worst-case assessment.

Annex 4-B

Adjustment of Background SO_2 at Black Point

4B.1 *BPPS CONTRIBUTION*

Since the BPPS is gas-fired gas turbine power plant, the SO_2 emission is very negligible in accordance with the *BPPS EIA Study, Annex B (Source Emissions and Characteristics – Option 3)*. Therefore, in this Study, no SO_2 concentration attributable to BPPS is considered.

4B.2 *CPPS CONTRIBUTION*

Short-term SO_2 Concentration

For the ASRs A3 to A8, the worst wind direction blowing from LNG Terminal to the ASRs is opposite to the worst wind direction blowing from CPPS to the ASRs, therefore, no short-term cumulative SO_2 concentration is anticipated at ASRs A3 to A8.

For ASRs A1 and A2 located at Sheung Pak Nai and Nim Wan, respectively, contribution from CPPS is likely to cause cumulative SO_2 impact with the LNG Terminal contribution.

The CPPS contribution assessed in the *BPPS EIA Study* is used in the following calculation.

In the BPPS EIA Study, no wind tunnel testing was performed at Sheung Pak Nai. However, Sheung Pak Nai (8 km) is located further away from CPPS than Nim Wan/Ha Pak Nai (i.e., 5.5 km) and the NO_2 concentration at Sheung Pak Nai should be lower than that at Nim Wan/Ha Pak Nai. Therefore, SO_2 concentrations predicted at Nim Wan/Ha Pak Nai are used as worst case SO_2 concentration at Sheung Pak Nai.

The worst wind direction of CPA and CPB to Nim Wan/Ha Pak Nai is about 195°. However, no wind tunnel testing for SO_2 was performed at such wind angle and hence the NO_x concentrations in the *Annex H, Table H.1b* of the *BPPS EIA Study*, (maximum hourly NO_x concentration at 8 ms^{-1} are 118.3 μgm^{-3} and 91.7 μgm^{-3}, contributed from CPA and CPB, respectively), will be adjusted to SO_2 concentrations by using the ratio of existing SO_2 licensed limit (i.e., 2,100 mgm^{-3}) and NO_x concentrations in the *BBPS EIA Study Annex B (Source Emissions and Characteristics*, i.e., 1577 mgm^{-3}). Hence, the source SO_2 concentrations are both 133% of source NO_x concentrations for CPA and CPB and the SO_2 concentrations attributable to CPA and CPB are, therefore, 157 μgm^{-3} and 122 μgm^{-3}, respectively.

There is no flue gas desulphurization system (FGD) applied to the current CPA and CPB operation. For CPB, FGD will be installed to reduce SO_2 emission and about 89% of SO_2 concentration will be reduced at Nim Wan/Ha Pak Nai area in accordance with the *EIA for Emission Control Project to CPPS "B" Units, Annex A, Table A.4*. Therefore, 89% SO_2 reduction will be applied to the adjusted SO_2 concentration attributable to CPB. Therefore, maximum hourly SO_2 concentration attributable to CPB will be 122 μgm^{-3} x (1-0.89) = 13 μgm^{-3}.

Therefore, total maximum hourly SO_2 concentration attributable to CPA and CPB is 157 + 13 = 170 μgm^{-3}.

Long-term SO_2 Concentration

The 2nd daily and annual average SO_2 concentrations presented in the *BPPS EIA Study, Part B, Table 6.2b* had considered the contribution from CPPS (no contribution from BPPS as negligible SO_2 emissions due to gas-fired plant operation). Comparing the existing SO_2 licence limit of 2,100 mgm^{-3} of both CPA and CPB and the source SO_2 concentrations in the *BPPS EIA Study, Part B, Table 6.2b* (1,635 mgm^{-3} for CPA and 1,726 mgm^{-3} for CPB), the 2nd daily and annual average SO_2 concentrations in the *BPPS EIA Study, Part B, Table 6.2b* are adjusted by applying a factor of 1.28 (1) to reflect the current power station operation and the adjusted 2nd daily and annual average SO_2 concentrations are summarized as below.

	Lung Kwu Tan	**Ha Pak Nai**
Worst wind speed adopted in Wind Tunnel Testing (m/s)	12	8
2nd Highest Daily SO_2 Concentration	11% of AQO (39μgm^{-3})	17 % of AQO (60 μgm^{-3})
Annual SO_2 Concentration	1 % of AQO (0.8 μgm^{-3})	1.9 % of AQO (1.5 μgm^{-3})
Note: (a) Reference to *BPPS EIA Study, Part B, Table 6.2b* and a factor of 1.28 is applied.		

As the above long-term SO_2 concentrations are contributed from both CPA and CPB and hence the SO_2 emission from CPB will be adjusted by further reduced due to the implementation of the *Emission Control Project to CPPS "B" Units*.

In the BPPS EIA Study, no wind tunnel testing was performed at Sheung Pak Nai. However, Sheung Pak Nai (8 km) is located further away from CPPS than Nim Wan/Ha Pak Nai (i.e., 5.5 km) and the NO_2 concentration at Sheung Pak Nai should be lower than that at Nim Wan/Ha Pak Nai. Therefore, SO_2 concentrations predicted at Nim Wan/Ha Pak Nai are used as worst case SO_2 concentration at Sheung Pak Nai.

(1) The CPA source SO_2 concentration, i.e., 1,635 mgm^{-3} is used for the adjustment to obtain a conservative factor.

Summary

A summary of adjusted short-term and long-term SO_2 concentrations are presented as below.

	Lung Kwu Tan	**Nim Wan / Ha Pak Nai**	**Sheung Pak Nai** [(a)]
Worst wind speed adopted in Wind Tunnel Testing (m/s)	12	8	8
Adjusted Maximum Hourly SO_2 Concentration	-	170 μgm^{-3} [(b)] (CPPS ONLY)	170 μgm^{-3} [(b)] (CPPS ONLY)
Adjusted 2nd Highest Daily SO_2 Concentration (CPPS)	39 μgm^{-3}	60 μgm^{-3}	60 μgm^{-3}
Adjusted Annual SO_2 Concentration (CPPS)	0.8 μgm^{-3}	1.5 μgm^{-3}	1.5 μgm^{-3}

Note:
(a) No wind tunnel testing was performed at Sheung Pak Nai in the BPPS EIA Study; the SO_2 concentrations predicted at Nim Wan/Ha Pak Nai is used as worst case assumption.
(b) A total SO_2 concentrations of CPA and CPB contributions (i.e., 157 μgm^{-3} + 13 μgm^{-3} = 170 μgm^{-3})

For the worst case assessment, the adjusted 2nd highest daily and annual average SO_2 concentrations at Nim Wan/Ha Pak Nai (60 μgm^{-3} and 1.5 μgm^{-3}, respectively) will be adopted for the cumulative long-term impact assessment at all identified ASRs and for plotting the contours to assess the worst case cumulative SO_2 impacts.

Of note, in accordance with the indicative commencement programme in the *Emission Control Project to CPPS "B" Units*, the FGD 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 based on the future SO_2 reduction programme at CPB.

Similar to short-term NO_2 contribution from CPPS, no contribution of SO_2 from CPPS to Nim Wan/Ha Pak Nai and Sheung Pak Nai areas at 232° (which is the same worst wind angle of LNG terminal to Nim Wan/Ha Pak Nai and Sheung Pak Nai areas. Therefore, the cumulative short-term SO_2 impact considering the SO_2 contribution from CPPS at 195° is a very worst case assessment in this study.

Therefore, the cumulative short-term and long-term SO_2 impact assessment in this Study will be the worst-case assessment.

Annex 4-C

Detailed Operational Phase Air Emission Rate Estimation

4C.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 flue 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 of each SCV = 144,285.71 / 5 / 3600 / (π x 0.6^2) = 7.09 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

Pipeline Gas Heater

Total emissions : 72 tonnes of NO_x and 45 tonnes of CO a year (based on 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 1×10^6 /4 = **0.57 g/s**
CO = (45 tonnes / 365 days / 24 hours / 3600 s) x 1×10^6 / 4 = **0.36 g/s**

Total flowrate = 73,900 Nm^3hr^{-1} (at 0 °C & 101.3 kPa)
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	LNG Carrier – Auxiliary Engine	Pipeline Gas Heater
No. of Emission Sources	5	1	4
Stack Height (m)	13	41	15
Stack Diameter (m)	1.2	0.78	1.07
Exit Temperature (°C)	30	320	280
Exit Velocity (m/s)	7.09	25	11.56
NO_x Emission Rate (g/s)	0.32	36	0.57
SO_2 Emission Rate (g/s)	-	15.6	-
CO Emission Rate (g/s)	1.63	1.56	0.36