PAPUA LNG PROJECT - DOWNSTREAM

Air Quality Impact Assessment

Prepared for:

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BASIS OF REPORT

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DOCUMENT CONTROL

Reference	Date	Prepared	Checked	Authorised
620.31072.00000-R02-v1.0	5 June 2023	K Lawrence	F Rahaman AS, IS, TV, TC, EM, MH, KE, JA, YL, AW	Final

EXECUTIVE SUMMARY

The proposed Papua LNG Project – Downstream (the Project) proposes to expand the capacity of the existing Papua New Guinea Liquefied Natural Gas Plant (LNG Plant) located in Caution Bay (Central Province), approximately 20 km north-west of Port Moresby. New LNG processing trains are proposed, which will expand the capacity of the LNG Plant by an additional 4 million tonnes per annum stream day capacity (Mtpa). Gas for the Project will be supplied from the Elk and Antelope reservoirs in Gulf Province.

SLR Consulting Australia Pty Ltd (SLR) was commissioned by Tetra Tech Coffey PNG Ltd (Tetra Tech Coffey) on behalf of ExxonMobil PNG Antelope Limited (EMPNGA) to prepare an air quality impact assessment to inform the Environmental Impact Statement (EIS) for the Project.

Potential impacts of the Project on the above environmental values were assessed based on a review of the existing air quality in the study area, and through a compliance assessment for the expanded LNG Plant with the ambient air quality guidelines set for the key air pollutants that have been identified as being generated by the new facilities at the site.

Potential Sources of Air Emissions

During the construction phase, the main emissions to air will be fugitive emissions of particulate matter (dust) from earthworks, wind erosion of disturbed areas and stockpiles, and wheel-generated dust. Mechanically generated total suspended particulate (TSP) emitted by construction activities predominately comprises larger size fractions of particles, which have the potential to give rise to off-site nuisance impacts.

During construction there will also be products of combustion from the diesel-powered construction equipment such as trucks, excavators and cranes, and from the transport of workers and equipment. These emissions will include oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), volatile organic compounds (VOCs) and fine particulate matter. These emissions will occur over a relatively large area and are likely to disperse to background levels before reaching any off-site sensitive receptors. No adverse air quality impacts would therefore be expected as a result of these emissions.

The main emissions to air associated with the existing and proposed LNG Plant operations are products of combustion from the burning of fuel gas in gas turbines for power generation and to drive compressors, as well as from flaring. There will also be small quantities of fugitive emissions of VOCs from both the existing plant and the new plant to be installed as part of the proposed expansion.

Emissions associated with commissioning the Project have been included in the estimated emissions for the proposed Papua LNG Plant.

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While the gas currently processed at the existing LNG plant does not contain any appreciable quantities of sulfur, the feed gas produced by the proposed Papua LNG Project is anticipated to contain up to 30 parts per million (ppm) mercaptans (RSH) and 3 ppm hydrogen sulfide (H_2S). As part of gas processing within the Papua LNG plant, the RSH and H_2S will be removed from the main gas stream in a mole sieve bed and then intermittently released to fuel gas system during the bed regeneration process on a 15 hour cycle. The concentrated sulfur-containing gases will form SO_2 when combusted in the Combined Cycle Power Plant (CCPP) and process sludge incinerator, peaking every 15 hours during the regeneration step and then reducing to trace amounts once the mole sieve bed has been regenerated.

The key pollutants considered in the assessment of operational phase air emissions are therefore:

- NO_x
- CO
- SO_2
- Particulate matter
- Benzene

Existing Air Environment

Currently, air emissions from the existing LNG Plant operations are the main source of air pollutants in the area. Two other notable air emission sources have also been identified:

- NiuPower Port Moresby Power Station: A 50 MW gas-fired power station located approximately 4 km to the northeast.
- Dirio Power Plant: A 47 MW gas-fired power station approximately 300 m east of the NiuPower Power Station.

Other potential sources of air emissions in the area include domestic and agricultural activities carried out in and around the villages of Lea Lea, Papa, Boera and Porebada, as well as traffic-related emissions from the roads that service them. These activities would contribute minor emissions of particles, NO_x, SO_2 and hydrocarbons. Natural sources of particulate matter, such as sea salt and smoke from local and remote fires, would also be present from time to time.

Ambient air quality monitoring data recorded at the PNG LNG Plant in 2015-16 was reviewed, including:

- Continuous monitoring of total suspended particulate (TSP), PM_{10} and $PM_{2.5}$ concentrations at three on-site locations using E-BAMs,
- Periodic monitoring of CO using a ToxiRAE Pro.
- Hydrogen sulphide (H_2S), NO_2, ozone (O_3) and SO_2 concentrations using passive diffusion tubes over consecutive two-week exposure periods at each of the three on-site monitoring locations.

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The review concluded the following:

- Particulate levels are normally low and below relevant criteria, however short-term events of slightly elevated levels can be recorded at times. Wheel-generated dust associated with public traffic on Lea Lea Road is likely to have contributed to the events of elevated TSP, PM_{10} and $PM_{2.5}$ levels.
- Ambient concentrations of NO_2 in the area were well below the annual average guideline levels during the monitoring period.
- The two-week average SO_2 concentrations measured on site during the monitoring period were also relatively low at less than 20 µg/m^3. The average concentration recorded over the year across all three monitoring sites was 4.7 µg/m^3, which is well below the current European Council annual average standard of 20 µg/m^3 for the protection of vegetation (EC, 2008).

Assessment Methods

Modelling of dust emissions from construction projects is generally not considered appropriate, as emission rates can vary depending on a combination of the construction activity and prevailing meteorological conditions (e.g., rainfall and wind speed), which cannot be reliably predicted. The potential for adverse impacts has therefore been assessed qualitatively based on the nature and scale of activities to be undertaken, the proximity of sensitive receptors to the main construction areas, and considering the dust mitigation measures that will be implemented during the works.

Potential off-site impacts of air emissions from the Project operations were assessed based on a detailed atmospheric dispersion modelling study. The modelling method conducted for the assessment of the proposed project included meteorological modelling using WRF and CALMET, followed by dispersion modelling using CALPUFF.

Stack and emission data used in the modelling for the existing LNG Plant and proposed Papua LNG plant were compiled based on currently available design data, equipment and feed gas specifications, and published emission factors (as required). Multiple emission scenarios were modelled to enable the off-site pollutant concentrations predicted as a result of both routine and non-routine operating conditions (flaring events) for both the existing and expanded plant. In addition to the LNG plant emissions, all modelling scenarios included:

- Shipping emissions: For the current operational scenarios this includes emissions from tankers and tugboats operating at the jetty, and for the proposed operations, included emissions from tankers and tugboats operating at both the jetty and the CALM buoy.
- Third party power stations: Emissions from the NiuPower and Dirio gas-fired power plants.

As the Government of Papua New Guinea does not currently have any specific statutory air quality requirements, the results of the modelling were compared to relevant ambient air quality criteria identified for use in the study based on a review of:

- Environment Permit EP-L3(210)
- *Environmental Management Plan: LNG Plant and Marine Facilities* (PNG LNG, 2019)
- IFC Environmental, Health and Safety Guidelines
- World Health Organization (WHO) Air Quality Guidelines

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- European Commission (EC) Air Quality Standards
- United States Environmental Protection Agency (US EPA) standards

The criteria adopted for use in this assessment are summarised in **Table ES-1**.

Table ES-1 Ambient Air Quality Criteria Adopted for this Assessment

Pollutants	Averaging Period	Limit (µg/m³)	Source
NO_2	1-hour	200	Environment Permit (EP-L3(210)), WHO 2021
	24-hours	25	WHO 2021
	Annual	40	Environment Permit (EP-L3(210))
		10	WHO 2021
SO_2	10-Minutes	500	Environment Permit (EP-L3(210)), WHO 2021
	1-hour	200	US EPA, 2010
	24-hours	20	Environment Permit (EP-L3(210))
		40	WHO 2021
CO	1-hour	35,000	WHO 2021
	8-hours	10,000	WHO 2021
Benzene	Annual	5.0	EC, 2022, current
		3.4	EC, 2022, proposed
PM_{10}	24-hours	45	WHO, 2021
	Annual	15	WHO, 2021
$PM_{2.5}$	24-hours	15	WHO, 2021
	Annual	5	WHO, 2021

Potential Impacts on Air Quality

Construction Activities

The Papua LNG Plant construction works will involve the construction of both onshore facilities and marine facilities in Caution Bay, and construction of the Project is expected to take approximately four years. The nearest sensitive receptors are scattered dwellings to the north of the LNG Plant site, with the closest houses located within 50 to 200 m of the site boundary. Some of these houses have attached gardens/plantations that could also be adversely affected if dust emissions from the construction works are not appropriately controlled.

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The construction works will occur in previously disturbed areas and earthworks will be relatively limited. Care will be taken during the works to minimise the potential for soil erosion from exposed surfaces, and water trucks, water sprays or dust suppressants will also be used as necessary to manage dust. Stockpiles will be stabilised, and erosion control measures implemented in accordance with the Project's environmental management plan. Emissions to air associated with transport of materials and workers, including exhaust emissions and wheel-generated dust, will be minimised through the Project logistics strategy and by ensuring that designated access routes are appropriately designed, upgraded where required, and maintained to minimise dust emissions.

While there is potential for short-term elevations in dust levels close to the construction areas, particularly during vegetation clearance and earthworks, no long-term air quality impacts would be expected to occur as a result of air emissions during the construction phase. Revegetation of cleared areas will ensure rapid stabilisation of exposed soils and any settled dust is likely to be cleaned off vegetation and other surfaces relatively quickly by rain.

With good practice air quality management, there would be a low risk of adverse dust soiling and human health impacts at the nearest sensitive receptors during the construction phase of the project. Any impacts would be highly localised and are expected to be able to be managed through targeted dust suppression, supported by and consultation with potentially affected sensitive receptors.

Operational Activities

Based on the results of the air dispersion modelling study, the following conclusions were drawn:

- The maximum 1-hour and 8-hour average off-site CO concentrations predicted for both the normal and the upset operating scenarios are far below the relevant WHO ambient air quality criteria and the Project is not predicted to result in any significant changes in the predicted maximum concentrations compared to current operations. No adverse air quality impacts are therefore expected as a result of CO emissions from operations at the integrated LNG Plant.
- NO_X emissions from the site are proposed to increase as a result of the proposed expansion, however the maximum 1-hour, 24-hour and annual average NO_2 concentrations at the sensitive receptors are predicted to remain well below the relevant WHO criteria. In relation to the maximum off-site predictions, the following was noted:
    - For both current and proposed operations, maximum 1-hour average NO_2 concentrations slightly above the current WHO guideline and Environmental Permit limit of 200 µg/m^3 are predicted in a small area off-shore (approximately 400 m north of the jetty and associated with peak emission during ship manoeuvres), with much lower impacts predicted inland at the sensitive receptors. Given the restricted boat access to this area during loading operations and ship movements, no potential exposures would be expected.
    - Under the proposed normal operating conditions, concentrations above the current WHO guideline of 25 µg/m^3 are predicted in an undeveloped area immediately north of the LNG Plant. The area predicted to be impacted has no houses and is a very localised area adjacent to the boundary. In addition, due to the conservative approaches used in the assessment, these predictions are expected to be overestimates of actual concentrations.
    - No exceedances of the current WHO annual average NO_2 guideline of 10 µg/m^3 are predicted anywhere within the modelling domain.

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Given the above, and as no exceedances are predicted at the identified sensitive receptor locations, the risk of any adverse air quality impacts as a result of NO_X emissions from the Project is concluded to be low.

- The off-site 24-hour and annual PM_{10} concentrations are predicted to increase slightly as a result of the Project, however the predicted concentrations are far below the adopted WHO ambient air quality criteria. Based on the results presented, no adverse air quality impacts are expected as a result of PM_{10} emissions from the sole or concurrent operation of the existing LNG Plant and proposed expansion.. On this basis, no adverse air quality impacts are expected as a result of PM_{10} emissions from current or proposed operations at the site.
- Emission estimation and dispersion modelling has not been performed for $PM_{2.5}$, however as the sources of PM_{10} at the LNG Plant are predominantly associated with gas combustion processes, it can be expected that the majority of PM_{10} emitted from the Project will also be in the $PM_{2.5}$ size fraction. The maximum downwind $PM_{2.5}$ concentrations that would be predicted are therefore likely to be slightly lower, but similar to, the predicted PM_{10} concentrations presented above. These concentrations are well below the WHO (2021) $PM_{2.5}$ guidelines adopted for this assessment.
- The maximum predicted 10-minute and 1-hour average SO_2 concentrations are below the relevant criteria of 500 µg/m^3 (Environmental Permit Limit and WHO guideline level) and 200 µg/m^3 (US EPA air quality standard) respectively, for both current and proposed operations, including both normal operating conditions and worst case upset operating conditions. A notable increase in the maximum 10-minute and 1-hour average SO_2 concentrations is predicted at the sensitive receptor locations as a result of the Project, which is due to SO_2 emissions from combustion of RSH and H_2S containing fuel gas in the CCPP.
- The maximum 24-hour average SO_2 concentrations predicted also comply with the current environmental permit limit of 20 µg/m^3 at all sensitive receptor locations included in the assessment, however concentrations above this limit are predicted in a localised, undeveloped area immediately north of the LNG Plant, extending across the coastline into Caution Bay. It is noted that the current PNG LNG environment permit limit is based on the WHO ambient air quality guideline of 20 µg/m^3 current at the time of preparing the PNG LNG EIS. In 2021, WHO revised this guideline to 40 µg/m^3, which the proposed operations easily complies with at all areas beyond the site boundary. A review of the current environmental permit limit for 24-hour ambient SO_2 concentrations to bring it in line with the current WHO guideline would therefore result in compliance.
- For both current and proposed operations, the maximum predicted off-site annual average benzene concentrations are below the current limit of 5 µg/m^3 set by the EU. The predicted concentrations at sensitive receptor locations also comply with the reduced limit of 3.4 µg/m^3 proposed for attainment in the EU by 2030. For the proposed scenario however, there is a localised area to the north of the site where the 2030 limit is predicted to be exceeded, associated with the relatively high estimated fugitive benzene emission rates for the new analyser houses proposed within the Papua LNG Plant. Based on the modelling results at sensitive receptor locations, no adverse air quality impacts are expected as a result of benzene emissions from the current or proposed operations, nonetheless during detailed design, the assumptions used to estimate the emissions will be confirmed and specifications developed to minimise any emissions from these units.

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Mitigation

The air dispersion modelling performed as part of this assessment will continue to inform the detailed design of the Project and be reviewed and updated as more detailed design data becomes available. A priority of the detailed design phase will be to identify and evaluate potential additional mitigation measures to reduce NO_2 and SO_2 emissions further from the Project to achieve compliance with the relevant 24-hour average criteria at all off-site locations.

Air quality management measures covering fugitive dust and other air emission sources and pollutants will be included as part of the project's Construction Environmental Management Plan (CEMP). The mitigation measures adopted to manage air emissions during the PNG LNG construction project are expected to form the basis of the CEMP for the Project. Air quality impacts from the operational phase of the Project will also be managed in accordan Operations Environmental and Social Management Plan (ESMP) that will be developed for the integrated LNG operations, inclusive of reviewing and integrating the existing PNG LNG Plant and Marine Facilities EMP (PNG LNG, 2019).

Monitoring

At this stage, an ambient air quality monitoring program to monitor particulate levels at off-site receptors is not considered to be required for the construction phase of the project. Monitoring of the effectiveness of the dust controls implemented during the works would instead be performed through regular observations of dust levels near potential dust generating activities to confirm that no dust clouds can be visually observed travelling off-site, tracking water usage for dust suppression to ensure that water carts and water sprays are being used regularly, and ongoing consultation with neighbouring land users (e.g. via the ExxonMobil grievance management system with Community Liaison Officers) to confirm that dust nuisance impacts are not being experienced as a result of the works.

Should the Project become aware that dust nuisance impacts are occurring (or have the potential to occur), a site dust monitoring program may be implemented, potentially involving the use of dust deposition gauges or portable dust monitors (or a combination of both), to assist in the effective targeting of increased dust suppression measures and monitoring contractor compliance with expected good practice regarding dust control.

Air emissions and ambient air quality monitoring programs for the operational phase of the Project will be outlined in the Integrated LNG Plant Operations ESMP. Air emissions monitoring for the Integrated LNG Plant will include periodic stack sampling in accordance with standard industry methods and subject to the provisions set out in the stack emissions monitoring procedure.

The need for any continuous emissions monitoring systems (CEMS), or Predictive Emissions Monitoring Systems (PEMS) for the major emission sources will be evaluated during detailed design. This may include continuous monitoring of sulfur in the CCPP fuel gas and the CCPP fuel feed rates to provide suitable data to provide continuous SO_2 emission rate data via a PEMS (or provision to enable retrofitting such systems if deemed necessary based on the actual operation of the plant). Once the detailed design of the plant is completed and the air dispersion modelling study updated, the most appropriate emissions monitoring equipment and systems to meet regulatory requirements and provide the level of risk management needed can be confirmed.

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Monitoring of ambient air quality will also continue to be undertaken periodically in the vicinity of the Project site to validate the predictions of the ambient air quality assessments and evaluate conformance with guideline values. The need for routine ambient monitoring of SO_2 concentrations would be determined once the detailed design of the plant is completed and the air dispersion modelling study updated to confirm the predicted off-site ground level concentrations. Emission testing data collected once the plant operations commence would also inform the decisions regarding the need for, and design of, an ambient air quality monitoring network.

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Abbreviations

%	Percent
°C	degrees Celsius
µg	Microgram
$\mu g/m^3$	microgram per cubic metre
$\mu g/Nm^3$	microgram per normalised cubic metre (273K, 101.3kPa)
CCPP	Combined Cycle Power Plant
CO	carbon monoxide
CO_2	carbon dioxide
EC	European Commission
EIS	Environmental Impact Statement
EMPNGA	ExxonMobil PNG Antelope Limited
EMPNG	ExxonMobil Papua New Guinea Limited
ESL	Effects Screening Level
g	Gram
ha	Hectare
K	degrees Kelvin (273K is equal to 0°C)
kg/hr	kilograms per hour
km	Kilometre
km E	kilometres east
km N	kilometres north
kPa	Kilopascals
kW	Kilowatt
LNG	liquefied natural gas
m/s	metre per second
m^3	cubic metre
MMscfd	Million standard cubic feet per day
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
O_3	Ozone
PM_{10}	particulate matter with an equivalent aerodynamic diameter of 10 microns or less
$PM_{2.5}$	particulate matter with an equivalent aerodynamic diameter of 2.5 microns or less
PNG LNG Project	Papua New Guinea Liquefied Natural Gas Project
ppb	parts per billion (10^9)
ppm	parts per million (10^6)
SO_2	sulphur dioxide
TSP	total suspended particulate matter
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VOCs	volatile organic compounds
WHO	World Health Organization
WRF	Weather Research and Forecast Model

Glossary

air dispersion model	A computer-based software program which provides a mathematical prediction of how pollutants from a source will be distributed in the surrounding area under specific conditions of wind, temperature, humidity and other environmental factors.
ambient	Pertaining to the surrounding environment or prevailing conditions.
atmosphere	A gaseous mass surrounding the planet that is retained by Earth's gravity. It is divided into five layers, with most of the weather and clouds found in the first layer.
atmospheric stability	The tendency of the atmosphere to resist or enhance vertical motion.
background	The existing air quality in the Project area excluding the impacts from the Project.
CALMET	A meteorological model that develops wind and temperature fields on a three-dimensional gridded modelling domain.
CALPOST	A post-processor used to process CALPUFF files, producing tabulations that summarise results for user-selected averaging periods.
CALPUFF	A transport and dispersion model that advects “puffs” of material emitted from modelled sources, simulating dispersion and transformation processes.
climatological	The science dealing with climate and climatic phenomena.
combustion	The process of burning. A chemical change, especially oxidation, accompanied by the production of heat and light.
dust deposition	Settling of particulate matter out of the air through gravitational effects (dry deposition) and scavenging by rain and snow (wet deposition).
dispersion	The spreading and dilution of substances emitted in a medium (e.g., air or water) through turbulence and mixing effects.
diurnal	Relating to or occurring in a 24-hour period; daily.
downwind	The direction in which the wind is blowing.
environmental value	A quality or physical characteristic of the environment that is important to ecological health or public amenity.
fossil fuel	A natural fuel such as coal, diesel or gas, formed in the geological past from the remains of living organisms.
fugitive emissions	Pollutants that escape from an industrial process due to leakage, materials handling, transfer, or storage.
greenhouse gas	A gas that contributes to the greenhouse effect by absorbing infrared radiation, e.g., carbon dioxide.
guideline	A general rule, principle, or piece of advice. A statement or other indication of policy or procedure by which to determine a course of action.
meteorological	The science that deals with the phenomena of the atmosphere, especially weather and weather conditions.

mixing height	The height to which the lower atmosphere will undergo mechanical or turbulent mixing, producing a nearly homogeneous air mass.
modelling domain	The area over which the model is making predictions.
particulate	Of, relating to, or formed of minute separate particles. A minute separate particle, as of a granular substance or powder.
plume	A space in air, water, or soil containing pollutants released from a point source.
point source	A pollution source that is fixed and/or uniquely identifiable, such as a stack, chimney, outlet pipe or vent.
pollutant	A substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource.
prognostic	A prediction of the value of variables for some time in the future on the basis of the values at the current or previous times.
qualitative assessment	An assessment of impacts based on a subjective, non-statistical oriented analysis.
quantitative assessment	An assessment of impacts based on estimates of emission rates and air dispersion modelling techniques to provide estimate values of ground level pollutant concentrations.
receptor	Coordinate locations specified in an air dispersion model where ground level pollutant concentrations are calculated by the model.
sensitive receptor	Locations such as residential dwellings, hospitals, churches, schools, recreation areas etc., where people (particularly the young and elderly) may often be present.
spatial variation	Pertaining to variations across an area.
standard	The prescribed level of a pollutant in the outside air that should not be exceeded during a specific time period to protect public health.
synoptic meteorological data	A surface weather observation, made at periodic times (usually at 3-hourly and 6-hourly intervals), of sky cover, state of the sky, cloud height, atmospheric pressure reduced to sea level, temperature, dew point, wind speed and direction, amount of precipitation, hydrometeors and lithometeors, and special phenomena that prevail at the time of the observation or have been observed since the previous specified observation.
topography	Detailed mapping or charting of the features of a relatively small area, district, or locality.
volatile organic compounds	All organic compounds (substances made up of predominantly carbon and hydrogen) with boiling temperatures in the range of 50 to 260°C, excluding pesticides. This means that they are likely to be present as a vapour or gas in normal ambient temperatures.
wind direction	The direction from which the wind is blowing.
wind erosion	Detachment and transportation of loose topsoil or sand by the wind.
windrose	A meteorological diagram depicting the distribution of wind direction and speed at a location over a period of time.

1 Introduction

ExxonMobil PNG Limited (EMPNG) is the operator of the PNG LNG Project, an integrated development that is commercialising the gas resources of Papua New Guinea. The Papua LNG Project is a gas development project for the Papua LNG Project Joint Venture participants, which are: 1) TotalEnergies EP PNG Limited (TotalEnergies, an affiliate of TotalEnergies SA), 2) ExxonMobil PNG Antelope Limited (EMPNGA) and ExxonMobil PNG Elk Limited, 3) Pac LNG Assets Limited, Pac LNG International Limited, Pac LNG Investments Limited, Pac LNG Overseas Limited and Pac LNG Holdings Limited (affiliates of Santos Limited) and 4) JX Nippon Oil and Gas Exploration Pty Ltd.

ExxonMobil PNG Antelope Limited (EMPNGA) is the ExxonMobil affiliate responsible for the construction of the Project. Once the Project has been constructed and commissioned, the ExxonMobil affiliate Niugini LNG Operating Company Limited (NLOC), will be responsible for operation of the expanded LNG Plant (both new and existing facilities).

The Papua LNG Project involves two components:

- The Papua LNG Project – Upstream (referred to as the Upstream component)
- The Papua LNG Project – Downstream (the Project and the component addressed in this document).

The Papua LNG Project will involve producing and processing the gas and condensate from the Elk and Antelope gas reserves in Petroleum Retention License 15 (PRL-15), located in Gulf Province, Papua New Guinea and piping them overland, then offshore in the Gulf of Papua, to the existing Papua New Guinea Liquefied Natural Gas Project (PNG LNG Project) producing and exporting facility (LNG Plant) located in Caution Bay (Central Province) approximately 20 km north-west of Port Moresby (see Figure 1).

The existing PNG LNG Project commercialises gas reserves in the Hela, Western and Southern Highlands provinces of Papua New Guinea. The gas is extracted and conditioned, then transported to the LNG Plant via pipeline, where it is liquefied and exported by ship to international gas and domestic electricity markets.

Execution of the Upstream component and the Project is delimited in Caution Bay, with the approximate boundary (i.e., the scope break) between the components located near the fence of the LNG Plant, south of the existing jetty.

SLR Consulting Australia Pty Ltd (SLR) was commissioned by Tetra Tech Coffey PNG Ltd (Tetra Tech Coffey), on behalf of EMPNGA to prepare an air quality impact assessment for the Project. The findings of this assessment will inform the Environmental Impact Statement (EIS) for the Project.

1.1 Assessment Objectives

The objectives of the air quality impact assessment were to:

- Evaluate incremental impact of the Project as well as the LNG Plant's performance against relevant criteria in Environment Permit EP-L3(210) (CEPA, 2022) and where guidelines are not provided for in the Environment Permit, relevant international standards and ExxonMobil standards.
- Characterise the ambient air environment.
- Compile an inventory of air emissions from the existing LNG plant, proposed Papua LNG plant and ancillary infrastructure, and other emission sources (i.e., third-party gas-fired power stations in the area and shipping emissions).

- Assess the impacts of cumulative air emissions on sensitive receptors, from construction and the operation of the new facilities, in conjunction with existing air emission sources operating at the LNG Plant and immediate locality.
- Propose measures to manage exceedances of relevant criteria in Environment Permit EP-L3(210) and where not applicable, relevant international standards.

LEGEND

- Papua LNG Project - Downstream
- Papua LNG Project - Upstream
- Existing facility
- Province capital
- PNG LNG pipeline
- Proposed Papua LNG pipelines
- Santos oil pipeline
- Existing and proposed plant layout
- PPFL2 boundary
- APPFL boundary
- Province boundary
- Current navigational channel
- Proposed navigational channel

Proposed CALM buoy components

- CALM buoy
- Naphtha and condensate pipelines
- CALM buoy navigational area

SOURCE
Infrastructure data from EMPNGA and Tetra Tech Coffey (indicative only).
Place names from NGIA.
Provinces from NSO.
Imagery from ArcGIS Online.

0 50 100 km

SCALE **1:3,500,000**
PAGE SIZE: **A4**
PROJECTION: **GCS WGS 1984**

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PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 1

Papua LNG Project – Downstream Project location

TETRA TECH COFFEY

DATE: 28.07.23 PROJECT: 754-MELEN300733 FILE: 300733_SLR_F001_GIS

2 Project Description

2.1 Project Area

The PNG LNG Project is located in the Central Province, approximately 20 km north-west of Port Moresby, between the coastal settlements of Boera and Papa. The LNG Plant occupies three separate lease areas: Portion 2456, Portion 2457 (coastal strip) and Portion 2458 (offshore).

2.2 Project Overview

The Project incorporates the expansion of the LNG Plant's existing onshore and marine facilities in Caution Bay, including the installation of new LNG processing trains (SMR technology).

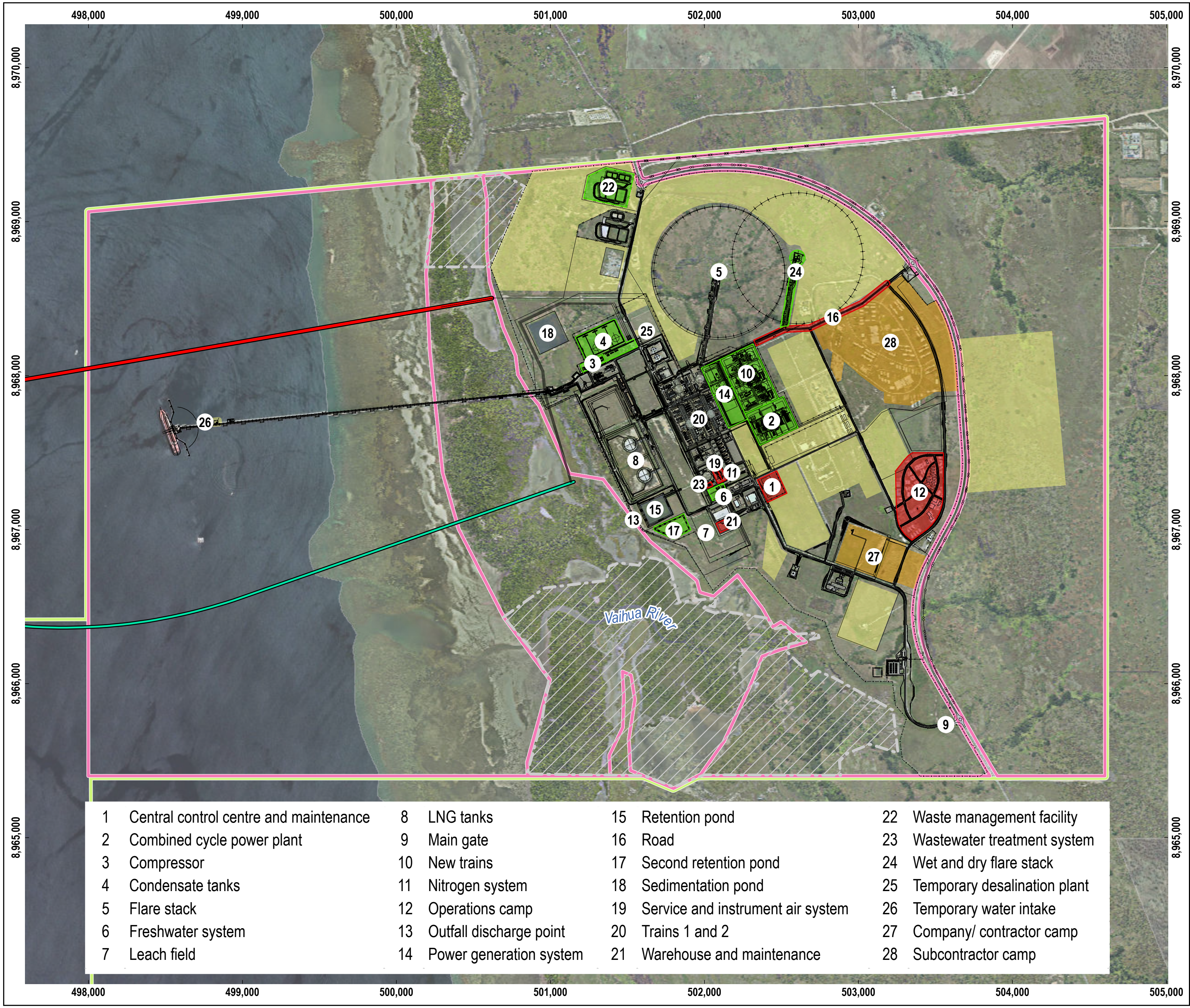
A new Combined Cycle Power Plant (CCPP) will be utilised to provide electric power for the LNG plant. The CCPP will consist of four gas turbine generators (GTGs), four Heat Recovery Steam Generators (HRSGs) and two steam turbine generators (STGs). The CCPP will provide sufficient power to the integrated LNG Plant, therefore three of the seven PNG LNG GTGs will be repurposed as cold standby for the integrated LNG Plant. **Figure 2** shows the proposed areas within the existing LNG Plant lease area where the new onshore facilities will be developed. The proposed marine facilities associated with the Project are shown in **Figure 3**.

A summary of the components of the Project is provided in **Table 1**.

Table 1 Project Components at the LNG Plant

Component	Description
Additional LNG trains	New LNG processing trains and supporting systems including: • Inlet gas receiving and treatment • Dehydration/mercaptan removal • Mercury removal • Heavy-hydrocarbon separation (which contains benzene, toluene, ethylbenzene, and xylenes (BTEX)) • Liquefaction • Stabilisation • Refrigeration system • Fractionation system (naphtha)
Expansion of existing utilities	Existing PNG LNG shared utilities to be expanded include: • Hot oil system • Service and instrument air system • Nitrogen system • Freshwater system • Desalinated water system • Potable water system • Diesel oil storage and distribution system

Component	Description
	• Open and closed drain systems • Sanitary wastewater treatment systems
New utilities	Options for new separate utilities may include: • Integrated fuel gas system and power generation system (CCPP) • Tempered water system • Highly demineralised water system for the Heat Recovery Steam Generators (HRSGs) • Flare system (wet and dry gas) • Thermal oxidizer
Product storage	Product storage will include: • New condensate storage tanks with a total storage capacity of up to 110,000 m^3
New marine facilities	Options for new or expanded marine facilities may include: • Catenary Anchor Leg Mooring (CALM) buoy and associated exclusion zones • Pipeline end manifold (Upstream construction component, Project operations component) • Condensate pipelines (Upstream construction component, Project operations component) • New FEED pipelines including a gas pipeline and a condensate pipeline (Upstream construction component and Project operations component), with landfall and tie-in to the pipelines at the LNG Plant. The pipelines will be located south of the existing LNG Plant jetty. • Alternate shipping channel • Navigation and monitoring systems
Temporary facilities	Temporary construction facilities will be located within the PNG LNG Project's lease boundaries and will include laydown areas, offices, workshops and concrete batching plants.
Waste	Options being reviewed for waste facilities and management being assessed may include: • Temporary onsite storage and segregation of waste, with transport to and disposal at third party waste management facility • New engineered solid waste landfill within existing LNG Plant security fence for disposal of non-restricted waste, with limited disposal of restricted waste by specialised service.
Logistics route	Most construction materials will be transported by truck from Motukea Port in Port Moresby to the LNG Plant site via the Lea Lea Road. Repairs or upgrades to the road, or relocation of overhead cables may be required to allow transport of large, heavy loads.
Workforce	Construction: Approximately 5,000 to 7,000 personnel at peak. Operation: Increase of approximately 50 operations and maintenance technicians with support staff anticipated to increase.
Accommodation	Construction: Up to 6,000 bed construction camps. Operation: Up to 500 beds at the existing operations camp.



1	Central control centre and maintenance	8	LNG tanks	15	Retention pond	22	Waste management facility
2	Combined cycle power plant	9	Main gate	16	Road	23	Wastewater treatment system
3	Compressor	10	New trains	17	Second retention pond	24	Wet and dry flare stack
4	Condensate tanks	11	Nitrogen system	18	Sedimentation pond	25	Temporary desalination plant
5	Flare stack	12	Operations camp	19	Service and instrument air system	26	Temporary water intake
6	Freshwater system	13	Outfall discharge point	20	Trains 1 and 2	27	Company/ contractor camp
7	Leach field	14	Power generation system	21	Warehouse and maintenance	28	Subcontractor camp

SOURCE
Infrastructure, cultural heritage and lease boundary from EMPNGA.
Imagery from EMPNGA and Google Earth.

0 0.5 1 km

SCALE 1:35,000
PAGE SIZE: A4
PROJECTION: WGS 1984 UTM Zone 55S

EXXONMOBIL PNG ANTELOPE LIMITED

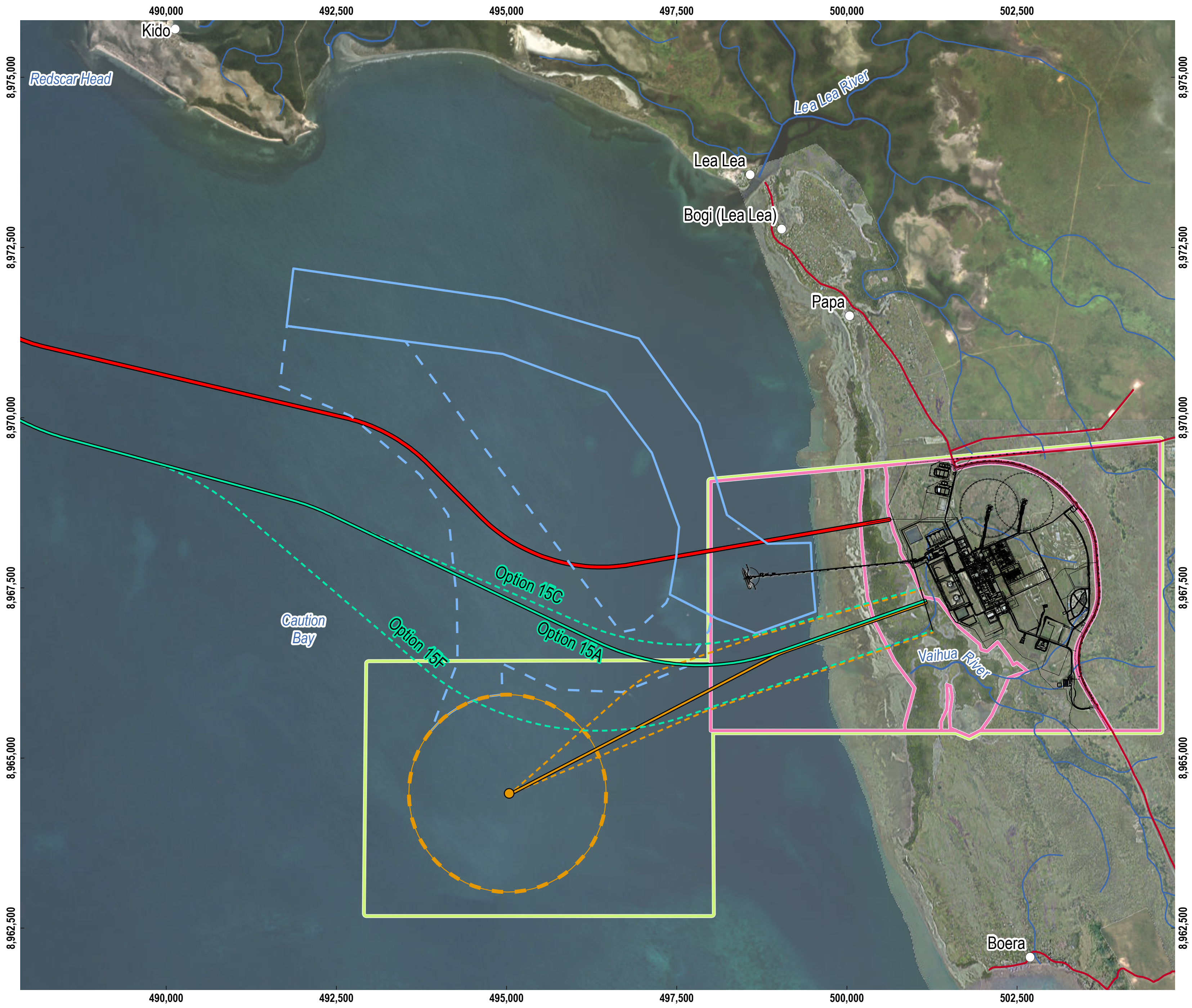
PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 2

Proposed onshore facilities for the Project

TETRA TECH COFFEY

DATE: 28.07.23 PROJECT: 754-MELEN300733 FILE: 300733_SLR_F002_GIS



LEGEND

- Village
- Road
- Watercourse
- PNG LNG pipeline
- Proposed Papua LNG pipelines route
- Proposed Papua LNG pipelines route alternate
- Existing and proposed plant layout
- PPFL2 boundary
- APPFL boundary
- Current navigational channel
- Proposed navigational channel

Proposed CALM buoy components

- CALM buoy
- Naphtha and condensate pipelines
- Naphtha and condensate pipelines alternate
- CALM buoy navigational area

SOURCE
Infrastructure, roads, watercourses and lease boundary from EMPNGA.
Imagery from EMPNGA and Planet Labs.

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SCALE 1:80,000
PAGE SIZE: A4
PROJECTION: WGS 1984 UTM Zone 55S

EXXONMOBIL PNG ANTELOPE LIMITED
PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 3

Proposed marine facilities for the Project

TETRA TECH COFFEY

DATE: 28.07.23 PROJECT: 754-MELEN300733 FILE: 300733_SLR_F003_GIS

DOC REFERENCE: \\TT.LOCAL\COF\S772\S\GIS\300733_EMPNG_PAPUALNGDOWNSTREAM\1_PAPUALNGDOWNSTREAM\GIS\APRX\300733_02_FIGS_A.APRX LAYOUT:300733_02_GIS006_16 SAVED BY: JASON.ORAM 18.07.23 1:49 PM

2.3 Onshore Production Facilities

New liquefaction trains will be located adjacent to the existing trains 1 and 2 (**Figure 2**). As with the existing trains 1 and 2, processing of the gas into LNG requires removal of impurities and hydrocarbons that are heavier than methane, followed by super cooling to form a liquid. The new trains will utilise single mixed refrigerant (SMR) technology to process the gas.

The main steps in LNG processing are shown in **Figure 4** and include the following systems:

- Inlet receiving and treatment
  - These systems receive gas from the pipelines, heat it to prevent hydrate (water) formation, and separate out liquids from the gas.
- Dehydration and mercury removal
  - Gas from the inlet and treatment systems is processed to remove moisture and mercury.
- Heavy Hydrocarbon removal
  - The sweet, dry gas stream is fed to the Heavy Hydrocarbon Removal system, which includes the heavy hydrocarbon removal cold box, scrub column feed separator and scrub column. Heavier hydrocarbons (such as ethane, propane and butane) are separated off at this stage to avoid freezing in the liquification step.
- Liquefaction
  - The gas is cooled to below the methane boiling point of around -161^{o}C. At this temperature, it liquefies to 1/600th of its original volume.
- Refrigeration
  - These systems cool and pressurise the refrigerants used in the liquefaction systems.
- Fractionation and stabilisation
  - The heavier hydrocarbons removed prior to cooling the gas are processed to produce sour naphtha.

The main products produced by the existing LNG Plant include LNG and naphtha. The LNG Plant also supplies gas to the Port Moresby Power Station for the domestic electricity market.

Sour naphtha recovered from the fractionation system will be blended with the Papua LNG field condensate and stored in new storage tanks with a total capacity of up to 110,000 m^3. The blended product is then pumped from the new condensate storage tanks to the CALM buoy, to be loaded onto tankers for shipping.

2.3.1 Supporting Utilities and Offsites

The LNG Plant facilities and infrastructure comprise various systems that support the operation of the plant, such as those for power generation, freshwater supply and wastewater treatment. The existing systems were analysed during the preliminary design process to determine if they had capacity available to support the Project.

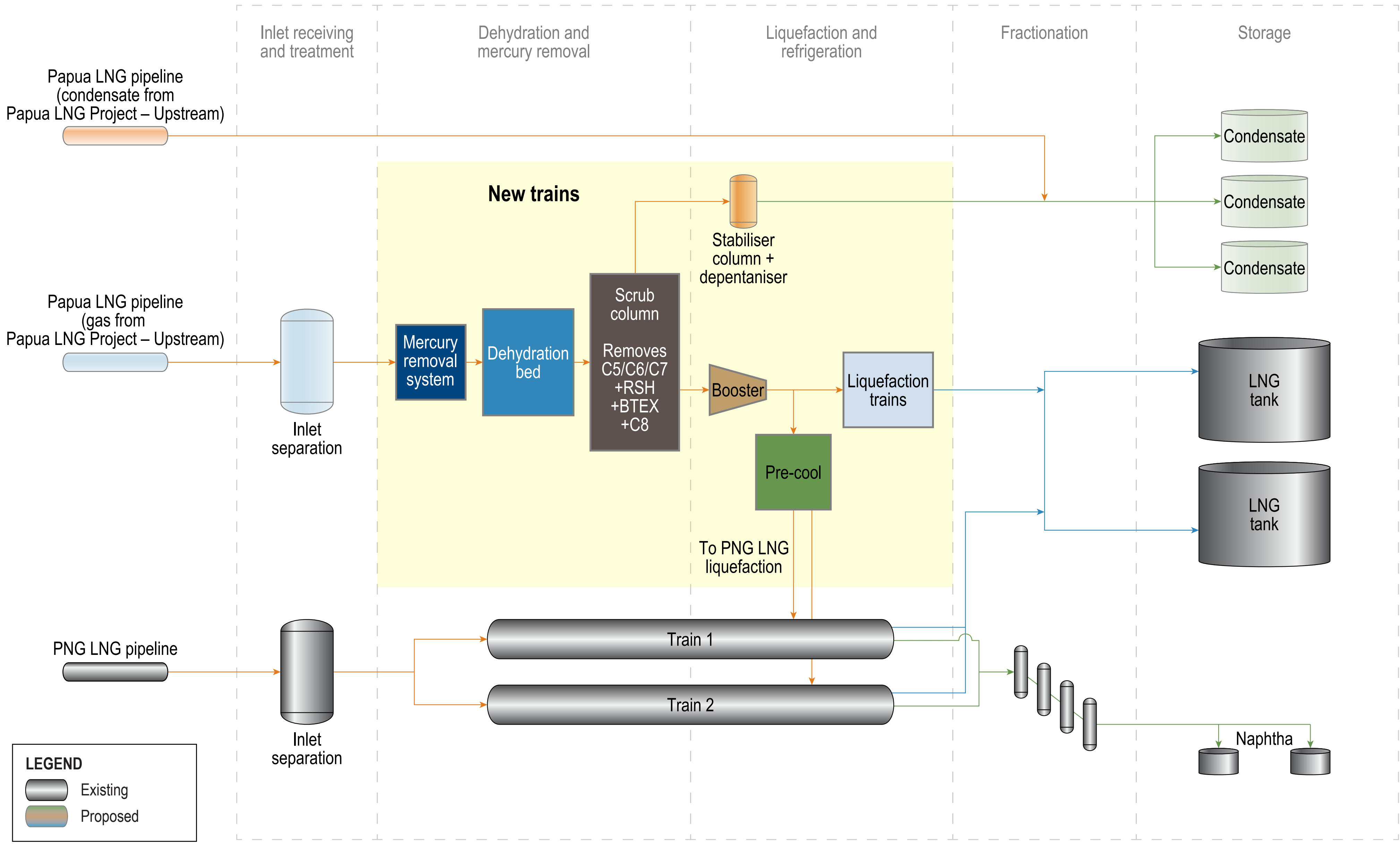
Facilities and infrastructure required to support the operation of the new LNG trains are distinguished by those that are shared facilities and those that are new facilities. The shared facilities will be common to existing and new trains and will utilise the available capacity of the existing LNG Plant systems with some modifications and upgrades to provide expanded capacity where required. New facilities will be for the operation of the new LNG trains.

The existing LNG Plant shared facilities and infrastructure that the Project will tie into, modify or expand include:

- Hot oil system
- Service and instrument air system
- Nitrogen system
- Fresh water system
- Desalinated water system
- Fire water supply system
- Potable water system
- Diesel oil storage and distribution system
- Open and closed drain systems
- Sanitary wastewater treatment systems (sewage treatment plant, STP)

New facilities and infrastructure to be constructed include:

- Integrated fuel gas system
- Power generation system (CCPP)
- Tempered water system
- Highly demineralised water system for the HRSGs
- Wet and dry flare systems
- Thermal oxidizer



EXXONMOBIL PNG ANTELOPE LIMITED

PAPUA LNG PROJECT – DOWNSTREAM

FIGURE 4

Overview of proposed LNG processing systems

SOURCE
EMPNGA

TETRA TECH COFFEY

DATE: 19.07.23 PROJECT: 754-MELEN300733 FILE: 300733_SLR_F004_GRA DOC REFERENCE: \\ETSS772GISFS1\DATA$\GIS\300733_EMPNG_PAPUALNGDOWNSTREAM\2_GRAPHICS\SLR\300733_SLR_GRA001.AI_7

2.3.2 Temporary Facilities

Temporary facilities will be required during construction and include laydown areas, offices, workshops, a temporary desalination facility and concrete batching plants. These facilities will be located within the existing LNG Plant lease boundaries. A temporary construction laydown area will be located outside of the LNG Plant fence line. Temporary laydown and storage areas are required during construction to receive, store and partially assemble project materials and equipment. Large and/or heavier permanent equipment will be directly delivered to its installation site to avoid the inefficiency of double handling.

2.3.3 Marine Facilities

A CALM buoy concept has been selected for the expansion of the existing marine facilities to accommodate the increase in LNG and non-LNG liquids production and subsequent increase in the number of vessels. This concept will delink the non-LNG liquids (naphtha and condensate) from LNG offloading at the existing berth. The concept includes a second shipping channel, additional navigational and monitoring systems, and approximately 7 km of dual subsea pipelines for the naphtha and condensate. The export pipelines will terminate at a pipeline end manifold (PLEM). The PLEM will be designed to have piping for each product and allow for pigging. There will be pig launchers and receivers onshore and four remote actuated valves controlled by the CALM buoy hydraulic power unit. Additional upgrades to the existing berth are being considered to improve maintainability such as the installation of a maintenance crane and replacement of the existing condensate loading arm with an LNG loading arm.

2.3.4 Offshore Pipelines

Two new pipelines, one for feed gas (40-inch diameter pipe) and one for field condensate (10-inch diameter pipe), and including a fibre optic cable line, will be constructed and operated as part of the Upstream component of the Papua LNG Project, to deliver product to the LNG Plant. Combined, this pipeline infrastructure is referred to as the ‘Papua LNG pipelines’. The Papua LNG pipelines are to be located on the southern side of the existing LNG Plant jetty and traverse the existing LNG Plant lease boundaries.

The Papua LNG pipelines will be laid on the sea floor by a pipelaying vessel and pulled ashore by equipment located on land. Depending on seabed conditions, the pipe will be placed in an excavated trench, or laid by ploughing or jetting. The Papua LNG pipelines will be concrete-coated to weigh them down and for protection from external influences.

In addition to the Papua LNG pipelines, two additional export pipelines (24-inch diameter each) will also be constructed, along with the PLEM, as part of the Upstream component. The new export pipelines will convey naphtha and condensate from the LNG Plant to the CALM buoy that will be constructed as part of the Project. The CALM buoy, PLEM and the two export pipelines will be designed and operated as part of Project.

The nearshore portion of these pipelines will traverse the existing LNG Plant lease boundaries and will be assessed within the EIS. The Papua LNG pipelines nearshore route will be to the south of the LNG Plant jetty (see **Figure 3**).

2.3.5 Workforce and Accommodation

A construction workforce of between 5,000 and 7,000 people will be needed to construct the Project over the planned four-year period. The permanent operations and maintenance workforce is expected to increase by approximately 50 technician personnel to support the integrated LNG Plant. Support staff is anticipated to increase and will be evaluated throughout FEED.

The existing operations camp is sufficient to meet increased capacity from the Project and will not be expanded. Camp A is anticipated to meet the capacity of the integrated LNG Plant. The existing Camp A has approximately operational 500 beds, of which approximately 300 personnel represent the steady state requirement on site. This provides approximately 200 beds for overflow capacity for events such as major maintenance programs and unplanned events.

2.3.6 Logistics Route

Most construction material will be imported by ship via Motukea Port and trucked to site along the Lea Lea Road. If materials are shipped to Motukea Port then the Road may require repairs or upgrade, including relocation of overhead cables, to accommodate heavy and/or overweight vehicles and transport of large modules. Transport of construction and operations personnel from Port Moresby will also occur along this road. Smaller sensitive equipment and time constrained shipments may be transported by air to Jacksons International Airport in Port Moresby and trucked to the LNG Plant.

2.3.7 Commissioning and Operation

Commissioning activities will be required to test the modified shared facilities and new facilities at the LNG Plant. These activities are expected to include testing the operation of individual components and systems, including flaring during start-up.

The operational and maintenance procedures are expected to be similar to those in place at the existing LNG Plant.

2.4 Project Schedule

Timeframes for key project development milestones are shown in **Table 2** below:

Table 2 Project Timeframe

Key Milestone	Timeframe
Environment surveys and approval process	2022 to 2023
Front-end engineering design	2023
Detailed engineering design	2024 to 2026
Construction	2023 to 2027
Commissioning and start-up	2027 to 2028

3 Identification of Project Air Emissions

3.1 Construction Phase

The main emissions to air expected to result from project construction activities are fugitive emissions of particulate matter (dust) from earthworks, wind erosion of disturbed areas and stockpiles, and wheel-generated dust. Mechanically-generated total suspended particulate (TSP) emitted by construction activities predominately comprises larger size fractions of particles, which have the potential to give rise to off-site nuisance impacts.

During construction there will also be products of combustion from the diesel-powered construction equipment such as trucks, excavators and cranes, and from the transport of workers and equipment. These emissions will include oxides of nitrogen (NO_x), carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), volatile organic compounds (VOCs) and fine particulate matter. Compared to mechanical sources, the particulate matter emitted by combustion sources has a much higher proportion of fine particulate matter (i.e. particulate matter with an aerodynamic diameter of 10 micrometres or less (PM_{10}) and particulate matter with an aerodynamic diameter of 2.5 micrometres or less ($PM_{2.5}$)).

There will also be other minor air emissions associated with the construction works, such as VOC venting emissions from fuel storage and handling, and odours associated with sewage treatment facilities and from the storage, handling and disposal of municipal waste from the construction camps. These emissions will be similar to, or less than, the levels currently generated by the current PNG LNG Plant operations and would not be expected to give rise to any adverse air quality impacts beyond the PNG LNG Plant Lease Boundary. They have therefore not been considered further.

3.2 Commissioning and Operational Phases

The main emissions to air associated with the existing and proposed operations are products of combustion from the burning of fuel gas in gas turbines for power generation and to drive compressors, as well as from flaring.

While the gas currently processed at the existing LNG plant does not contain any appreciable quantities of sulfur, the feed gas for the Papua LNG Project will contain up to 30 ppm mercaptans (RSH) and 3 ppm hydrogen sulfide (H_2S). As part of gas processing within the Project facilities, the RSH and H_2S will be removed from the main gas stream in a mole sieve bed and then intermittently released to fuel gas system during the bed regeneration process on a 15-hour cycle. The concentrated sulfur-containing gases will then be combusted to form SO_2 when the fuel gas is fed to the CCPP, peaking every 15 hours during the regeneration step and then reducing to trace amounts once the mole sieve bed has been regenerated. This is discussed further in **Section 6.4**

There will also be small quantities of fugitive emissions of VOCs from both the existing plant and the new plant to be installed as part of the proposed expansion.

The key pollutants considered in the assessment of operational phase air emissions are therefore:

- NO_x
- CO
- SO_2
- CO

- Particulate matter (as PM_{10})
- Benzene

As for the construction phase, the Project will result in increases in other minor air emissions associated with the site's operational activities, such as VOC venting emissions from fuel storage and handling, wheel-generated dust and products of combustion from the transport of workers and equipment, and from general maintenance activities (e.g., from sanding, welding and the use of solvents for cleaning equipment parts). The increases in these emissions will be minimal compared to the existing LNG plant operations and would therefore not be expected to give rise to any adverse air quality impacts beyond the PNG LNG Lease Boundaries. They have therefore not been considered further in this assessment.

4 Air Quality Regulatory Requirements and Assessment Criteria

In February 2014, the Papua New Guinea (PNG) Parliament passed an Act to set up a new Conservation and Environment Protection Authority (CEPA). CEPA has replaced the Department of Environment and Conservation (DEC) as the government agency responsible for administering the *Environment Act 2000*.

The *Environment Act 2000* (Environment Act) is the primary legislation in PNG that regulates the environmental impact of development activities and how adverse effects of such activities should be avoided, remedied or mitigated. The Environment Act caters for the sustainable management of the biological and physical components of the land, air and water resources of the country.

Several guidelines have also been published by the then DEC relevant to the assessment of air emissions from proposed developments, including:

- *Guideline for submission of an application for an environmental permit to discharge waste* (DEC, 2004a).[1]
- *Technical Guideline (Additional Information) Air Discharges* (DEC, 2004b)

The *Technical Guideline (Additional Information) Air Discharges* sets out the information that should be provided as part of an application for an Environment Permit where air emissions may be generated. This includes:

- Details of the source, nature, composition and rate of air emissions.
- Information on emissions control equipment and proposed methods to minimise air discharges (specific information for fabric filters, afterburners and wet scrubbers is requested).
- Maintenance procedures and contingency procedures to avoid air discharges from process failure and shut down.
- Stack emission details.
- Calculated ground level concentrations of pollutants proposed to be discharged to air under normal and maximum operating conditions and start up and shutdown conditions.
- An assessment of the impact of the proposal on the environment.

The *Technical Guideline (Additional Information) Air Discharges* also requires that in assessing the potential impacts on air quality the '*effects of existing on-site discharges and existing loadings from neighboring industries*' must be considered.

4.1 Environment Permit EP-L3(210)

Air quality criteria from the existing Environment Permit EP-L3(210) for the LNG Plant are shown in **Table 3**. These criteria are equivalent to those set by the WHO for these pollutants (discussed in **Section 4.3.4**). These criteria "*are applicable near permanent operations facilities*", as stated in EP-L3(210). For the purposes of this assessment, that has been assumed to mean all areas beyond the existing PNG LNG Plant Lease Boundaries.

[1] Noting that CEPA currently only issues one environment permit that addresses both waste discharge and water extraction.

Table 3 PNG LNG Project Environment Permit EP-L3(210), Ambient Air Quality Guidelines

Pollutant	Averaging Time	Guideline Value ($\mu g/Nm^3$)(1)
Nitrogen dioxide (NO_2)	1-hour	200
	1-year	40
Sulphur dioxide (SO_2)	10-minutes	500
	24-hours	20

Source: Table 3-1, Annex 2 of Environment Permit (EP-L3(210))

[1] Concentration presented at $\mu g/m^3$ normalised to 273K and 101.3kPa.

4.2 Environmental Management Plan: LNG Plant and Marine Facilities

The *Environmental Management Plan: LNG Plant and Marine Facilities* (PNG LNG, 2019) is a component of the production Environmental Management Plan (EMP) for the PNG LNG Project. The ambient air quality guidelines set out in this document are reproduced in **Table 4**.

Table 4 PNG LNG Production Environmental and Social Management Plan Air Quality Guidelines

Pollutant	Averaging Period	Air Quality Limit Values ($\mu g/m^3$)	Notes
Nitrogen dioxide (NO_2)	1 hour	200	
	Annual	40	
Sulfur dioxide (SO_2)	10-minutes	500	
	24-Hours	20	
Carbon monoxide (CO)	15-minutes	100,000	
	30-minutes	60,000	
	1-hour	30,000	
	8-hours	10,000	
PM_{10}	24-hours	150	
	Annual	70	
$PM_{2.5}$	24-hours	75	
	Annual	35	
TSP	24-hours	150-230	
	Annual	60-90	
Ozone	8-hours	100	Daily maximum not to be exceeded more than 24 times per year
Hydrogen sulfide	Not specified	5,000	No offensive odour at boundary

Source: (PNG LNG, 2019)

4.3 Review of National and International Air Quality Guidelines

The Government of Papua New Guinea does not currently have any specific statutory air quality requirements. Therefore, to identify appropriate ambient air quality criteria, relevant guidelines set by other agencies have been reviewed, including:

- IFC Environmental, Health and Safety Guidelines
- World Health Organization (WHO) Air Quality Guidelines
- European Commission Air Quality Standards
- United States Environmental Protection Agency (US EPA) standards

4.3.1 IFC General EHS Guidelines: Environmental – Air Emissions and Ambient Air Quality

The International Finance Corporation (IFC) *Environmental, Health and Safety Guidelines: Environmental – Air Emissions and Ambient Air Quality* (IFC, 2007) provides an approach to the management of significant sources of air emissions, including specific guidance for assessment and monitoring of impacts. This guideline states that:

> *'Where possible, facilities and projects should avoid, minimize, and control adverse impacts to human health, safety, and the environment from emissions to air. Where this is not possible, the generation and release of emissions of any type should be managed through a combination of:*
>
> - *Energy use efficiency*
> - *Process modification*
> - *Selection of fuels or other materials, the processing of which may result in less polluting emissions*
> - *Application of emissions control techniques.'*

Projects with significant sources of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimise impacts by ensuring that:

- Emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards or, in their absence, the current WHO Air Quality Guidelines (refer **Section 4.3.4**), or other internationally recognised sources.
- Emissions do not contribute a significant portion to the attainment of relevant ambient air quality guidelines or standards (as a general rule, the guideline suggests 25% of the applicable air quality standards to allow additional, future sustainable development in the same airshed).

The IFC general air quality guidelines require that impacts on air quality of a proposed development be estimated through qualitative or quantitative assessments by the use of baseline air quality assessments and atmospheric dispersion models to assess potential ground level concentrations. Local atmospheric, climatic, and air quality data should be applied when modelling plume dispersion, taking into account atmospheric downwash, wakes, or eddy effects of the source, nearby structures and terrain features. The dispersion model applied should be internationally recognised, or comparable.

4.3.2 IFC Environmental, Health and Safety Guidelines for Liquefied Natural Gas Facilities

The IFC industry sector Environmental, Health and Safety (EHS) guideline document for LNG facilities (IFC, 2017) is designed to be used together with the General EHS Guidelines document and provides general and industry-specific examples of Good International Industry Practice (GIIP). This document applies to LNG base load liquefaction plants; transport (by sea and land); storage; regasification (including floating storage regasification units); peak shaving terminals; and LNG fuelling facilities.

The EHS guideline document for LNG facilities notes that principal air emission sources from LNG facilities include:

- combustion for power and heat generation (e.g., boilers, or for dehydration and liquefaction activities at LNG liquefaction terminals);
- reciprocating and other engines (which may be used to drive large machinery such as compressors and pumps); and
- emissions resulting from flaring and venting, as well as from fugitive sources.

Principal pollutants from these sources are identified as:

- oxides of nitrogen (NO_X);
- carbon monoxide (CO); and
- sulfur dioxide (SO_2).

The EHS guideline document for LNG facilities provides guidance on recommended air emissions mitigation strategies for combustion units, venting and flaring operations, boil-off gas management and fugitive emissions. It states that air quality impacts should be estimated by the use of baseline air quality assessments and atmospheric dispersion models to establish potential ground level ambient air concentrations during facility design and operations planning.

4.3.3 IFC Environmental, Health and Safety Guidelines for Thermal Power Plants

The IFC EHS guideline document for thermal power plants (IFC, 2017) provides general and industry-specific examples of GIIP relevant to combustion, gasification or pyrolysis processes fuelled by gaseous, liquid and solid fossil fuels and biomass, and designed to deliver electrical or mechanical power, steam, heat, or any combination of these. It contains the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs.

The EHS guideline document for thermal power plants notes that principal air emission sources from the combustion of fossil fuels include:

- sulfur dioxide (SO_2);
- oxides of nitrogen (NO_X);
- particulate matter; and
- carbon monoxide (CO).

It identifies that the amount and nature of air emissions depends on factors such as the fuel type, the type and design of the combustion unit (e.g., reciprocating engines, combustion turbines, or boilers), operating practices, emission control measures and the overall system efficiency. Some measures, such as choice of fuel and use of measures to increase energy conversion efficiency, will reduce emissions of multiple air pollutants per unit of energy generation. Optimising energy utilisation efficiency of the generation process depends on a variety of factors, including the nature and quality of fuel, the generation cycle type chosen (e.g., reciprocating engine, single or combined cycle gas turbine, steam turbine), its configuration (e.g., electricity generation or co- or tri-generation of electricity, heating and cooling), the operating temperature of the combustion turbines, the operating pressure and temperature of steam turbines, the local climatic conditions and the type of cooling system used.

The EHS guideline document for thermal power plants provides guidance on recommended air emissions mitigation strategies, including:

- Selection of the best power generation and pollution control technologies for the fuel chosen to balance the environmental and economic benefits;
- Designing stack heights and configurations according to GIIP to avoid excessive ground level concentrations and minimise impacts; and
- Considering use of combined heat and power (CHP) facilities (such as the CCPP proposed as part of the Project). By combining useful heat output with power production, CHP facilities can achieve thermal efficiencies of 70–90%, compared with the 30–60% electrical efficiencies available from thermal power-only plants.

4.3.4 World Health Organization Air Quality Guidelines

The first edition of the WHO air quality guidelines was issued in 1987 and was intended for European countries. By 2000, research concerning health effects of air pollution had significantly advanced to enable the WHO to update its guideline resulting in the publication of *Air Quality Guidelines for Europe, Second Edition* (WHO, 2000). In this edition the guidelines were no longer presented as European-specific, but applied to all countries.

WHO updates the Air Quality Guidelines on a regular basis to assure their continued relevance and to support a broad range of policy options for air-quality management in various parts of the world, especially taking into account the breadth of new health studies that have been published in the meantime (WHO, 2005).

The latest update of the WHO air quality guidelines was released in 2021 (WHO, 2021) and the current guidelines are presented in **Table 5** compared to the current PNG LNG Environment Permit EP-L3(210) (CEPA, 2022) and EMP limits. It is noted that the 2021 WHO guideline for NO_2 (annual average), CO (1-hour) and particulate matter (as $PM_{2.5}$ and PM_{10}) are more stringent than the PNG LNG Project Environment Permit and EMP limits. The current WHO guideline for 24-hour average concentrations of SO_2 is twice that currently set out in the PNG LNG Project Environment Permit EP-L3(210) (CEPA, 2022).

Table 5 Current WHO Air Quality Guidelines for Relevant Pollutants

Pollutant	Averaging Time	Guideline Value (µg/Nm³)	Current PNG LNG Limits (µg/Nm³)	
Nitrogen dioxide (NO_2)	1-Hour	200	200	Environment Permit EP-L3(210)
	24-Hours	25	-	
	Annual	10	40	Environment PermitEP-L3(210)
Sulfur dioxide (SO_2)	10-minutes	500	500	Environment Permit EP-L3(210)
	24-Hours	40	20	Environment Permit EP-L3(210)
Carbon monoxide (CO)	15-Minutes	100,000	100,000	EMP LNG Plant and Marine Facilities
	30-minutes	-	60,000	EMP LNG Plant and Marine Facilities
	1-Hour	35,000	30,000	EMP LNG Plant and Marine Facilities
	8-Hours	10,000	10,000	EMP LNG Plant and Marine Facilities
	24-Hours	4,000	-	EMP LNG Plant and Marine Facilities
PM_{10}	24-Hours	45	150	EMP LNG Plant and Marine Facilities
	Annual	15	70	EMP LNG Plant and Marine Facilities
$PM_{2.5}$	24-Hours	15	75	EMP LNG Plant and Marine Facilities
	Annual	5	35	EMP LNG Plant and Marine Facilities

4.3.5 European Commission Air Quality Limit Values

The European Union has established health-based standards and objectives for a number of pollutants in air. Directive 2008/50/EC of the European Parliament and of the Council adopted on 21 May 2008 (EC, 2008), merged four prior directives and one Council decision into a single directive on air quality that sets out ambient air quality limit values for Europe. On 26 October 2022, as part of the European Green Deal, the Commission proposed to revise the Ambient Air Quality Directives (EC, 2022). The revision aligns the air quality standards more closely with the updated recommendations of the World Health Organization.

The current and proposed European air quality limit values relevant to the Project are summarised in **Table 6**. Similar to the WHO guidelines, the proposed 2030 European limit value of 50 µg/m³ for 24-hour average SO_2 concentrations is less stringent than the limit currently specified in the PNG LNG Project Environment Permit EP-L3(210) of 20 µg/m³. The proposed 2030 European annual average limits for PM_{10} and $PM_{2.5}$ are also more stringent than the EMP limits but less stringent than the 2021 WHO guidelines.

Table 7 presents the current and proposed air quality guidelines for the protection of vegetation and ecosystems. Criteria are provided by the EC for NO_X and SO_2.

Table 6 Relevant European Commission Ambient Air Quality Limit Values

Pollutant	Averaging Period	Current		Proposed to be Attained by 2030	
		Air Quality Limit ($\mu g/m^3$)	Permitted Exceedances Each Year	Air Quality Limit ($\mu g/m^3$)	Permitted Exceedances Each Year
Nitrogen dioxide (NO_2)	1 hour	200	18 hours/year	200	1 hour/year
	24-hour	-	-	50	18 days/year
	Annual	40	-	20	-
Sulfur dioxide (SO_2)	1-Hour	350	24 hours/year	350	1 hour/year
	24-Hours	125	3 days/year	50	18 days/year
	Annual	-		20	-
Carbon monoxide (CO)	8-Hours	10,000	none	10,000	none
	24-hours	-	-	4,000	18 days/year
PM_{10}	24-Hours	50	35 days/year	45	18 days/year
	Annual	40	-	20	-
$PM_{2.5}$	24-Hours	-	-	25	18 days/year
	Annual	25	-	10	-
Benzene	Annual	5	-	3.4	-

Source: (EC, 2008), (EC, 2022)

Table 7 Relevant European Commission Air Quality Criteria for Vegetation Impacts

Pollutant	Averaging Period	Current	
		Air Quality Limit ($\mu g/m^3$)	Comment
Critical levels for the protection of vegetation [1]			
Oxides of nitrogen (NO_X)	Annual	30	-
Sulfur dioxide (SO_2)	Calendar year and winter (1 October to 31 March)	20	
Assessment thresholds for the protection of vegetation and natural ecosystems [2]			
Oxides of nitrogen (NO_X)	Annual	19.5	-
Sulfur dioxide (SO_2)	Average between 1 October and 31 March	8	-

[1] (EC, 2008)
[2] (EC, 2022)

4.3.6 US Environmental Protection Agency National Ambient Air Quality Standards

The US EPA Office of Air Quality Planning and Standards (OAQPS) have set National Ambient Air Quality Standards for seven criteria pollutants: PM_{10}, $PM_{2.5}$, ground level ozone (O_3), CO, SO_2, NO_2 and lead (Pb) (US EPA, 2016). These standards are applicable throughout the USA, and while individual states may have stronger air pollution laws or regulate additional pollutants, they cannot have less stringent pollution limits than those set by the US EPA.

The current US EPA primary and secondary standards relevant to the Project are presented in **Table 8**. The primary standards are set to protect public health, including the health of 'sensitive' populations such as asthmatics, children, and the elderly. Secondary standards are also set for some pollutants, which were developed to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation and buildings. In all cases other than TSP, the secondary standards are either equal to or higher, i.e. less stringent, than the primary standards shown in **Table 8**.

Table 8 USEPA National Ambient Air Quality Standards

Pollutant	Averaging Time	Primary Standard		Secondary Standard	
		ppb	µg/m³	ppb	µg/m³
Nitrogen dioxide (NO_2)	Annual	53	100	53	100
	1-Hour [1]	100	190	-	-
Sulfur dioxide (SO_2)	1-Hour [2]	75	200	-	-
	3-Hours [3]	-	-	500	1,330
Carbon monoxide (CO)	8-Hours [1]	9,000	10,000	-	-
	1-Hour [1]	35,000	40,000	-	-
Ozone (O_3)	8-Hours [4]	70	137	70	137
PM_{10}	24-Hours [5]	-	150	-	150
$PM_{2.5}$	Annual [6]	-	12	-	15
	24-Hours [7]	-	35	-	35

Source: https://www.epa.gov/criteria-air-pollutants/naaqs-table

1 3-year average of the 98th percentile of the daily maximum 1-hour average

2 3-year average of the 99th percentile of the daily maximum 1-hour average

3 Not to be exceeded more than once per year

4 3-year average of the fourth-highest daily maximum 8-hour average

5 Not to be exceeded more than once per year on average over 3 years

6 Annual mean, averaged over 3 years.

7 3-year average of the 98th percentile of 24-hour concentrations

4.4 ExxonMobil Standards

ExxonMobil Environment Policy includes the following commitments:

- *Comply with all applicable environmental laws and regulations and apply responsible standards where laws and regulations do not exist;*
- *Encourage concern and respect for the environment, emphasize every employee's responsibility in environmental performance, and foster appropriate operating practices and training;*
- *Work with government and industry groups to foster timely development of effective environmental laws and regulations based on sound science and considering risks, costs, and benefits, including effects on energy and product supply;*
- *Manage its business with the goal of preventing incidents and of controlling emissions and wastes to below harmful levels; design, operate, and maintain facilities to this end;*

- *Respond quickly and effectively to incidents resulting from its operations, in cooperation with industry organizations and authorized government agencies;*
- *Conduct and support research to improve understanding of the impact of its business on the environment, to improve methods of environmental protection, and to enhance its capability to make operations and products compatible with the environment;*
- *Communicate with the public on environmental matters and share its experience with others to facilitate improvements in industry performance;*
- *Undertake appropriate reviews and evaluations of its operations to measure progress and to foster compliance with this policy.*

In line with the ExxonMobil Environment Policy, this assessment has reviewed air quality criteria from a range of international organisations to identify appropriate criteria in the absence of guidelines being available in PNG for some of the pollutants assessed.

4.5 Ambient Air Quality Criteria Adopted for this Assessment

The ambient air quality criteria adopted for use in this study are summarised in **Table 9**. Priority has been given to the limits set out in the current Environment Permit, however where the source of those limits (WHO ambient air quality guidelines) have been revised since the Permit was issued, the current WHO guidelines are also presented. For those pollutants or averaging periods with no limits set in the current Environment Permit, the air quality criteria were selected based on the following hierarchy:

- Current WHO ambient air quality guidelines
- United States Environmental Protection Agency (US EPA) standards
- European Commission (EC) Air Quality Standards

Table 9 Ambient Air Quality Criteria Adopted for this Assessment

Pollutants	Averaging Period	Limit ($\mu g/m^3$)	Source
NO_2	1-hour	200	Environment Permit (EP-L3(210)), WHO 2021
	24-hours	25	WHO 2021
	Annual	40	Environment Permit (EP-L3(210))
		10	WHO 2021
SO_2	10-Minutes	500	Environment Permit (EP-L3(210)), WHO 2021
	1-hour	200	US EPA, 2010
	24-hours	20	Environment Permit (EP-L3(210))
		40	WHO 2021
CO	1-hour	35,000	WHO 2021
		30,000	EMP (PNG LNG, 2019)
	8-hours	10,000	WHO 2021, EMP (PNG LNG, 2019)
Benzene	Annual	5.0	EC, 2022, current
		3.4	EC, 2022, proposed
TSP	24-hours	150-230	EMP (PNG LNG, 2019)
	Annual	60-90	EMP (PNG LNG, 2019)
PM_{10}	24-hours	45	WHO, 2021
	Annual	15	WHO, 2021
$PM_{2.5}$	24-hours	15	WHO, 2021
	Annual	5	WHO, 2021

5 Existing Environment

5.1 Environmental Values

For the purposes of this assessment, an environmental value is defined as a quality or physical characteristic of the environment that is important to ecological and human health. In relation to air quality, the following environmental values have been identified:

- an air environment that is conducive to human health and wellbeing
- an air environment that is conducive to protecting the health and biodiversity of ecosystems
- an air environment that is conducive to protecting the aesthetics of the environment, including protection against nuisance odour and dust impacts
- an air environment that is conducive to protecting agricultural uses

Potential impacts of the Project on the above environmental values were assessed based on a review of the existing air quality in the study area, and through a compliance assessment for the expanded LNG Plant with the ambient air quality guidelines set for the key air pollutants that have been identified as being generated by the new facilities at the site.

5.2 Climate

PNG has a tropical, monsoonal climate. The coastal and islands regions tend to be hot and humid, with temperature averages ranging between 20°C to 32°C, relative humidity levels ranging from 70% to 90% and high rainfall year-round. The south of Papua New Guinea has a wet season from November to April and a dry season from May to October, while further north rainfall is more consistent throughout the year.

Seasonal climate changes in the study area are controlled by two mass air movements. Typically, the southeasterly trade wind season occurs from April/May to October/November and the northwest monsoon occurs from November/December to March/April. There are transitions at the cross-over of each season.

PNG's climate varies considerably from year to year due to the El Niño-Southern Oscillation (ENSO). This is a natural climate pattern that affects weather across the world. El Niño is a warming of the Pacific Ocean resulting in longer and cooler dry seasons (i.e. periods of drought), and a delay to the start of monsoon season. La Niña, the cold phase of ENSO, typically results in higher than average rainfall and warmer temperatures during the wet season, often leading to flooding events and landslides (BoM,CSIRO, 2014). PNG also experiences neutral phases.

Temperatures are mild and remain relatively consistent throughout the year. They are also altitude dependent, with hot and humid conditions associated with lower altitudes and cooler conditions at higher altitudes.

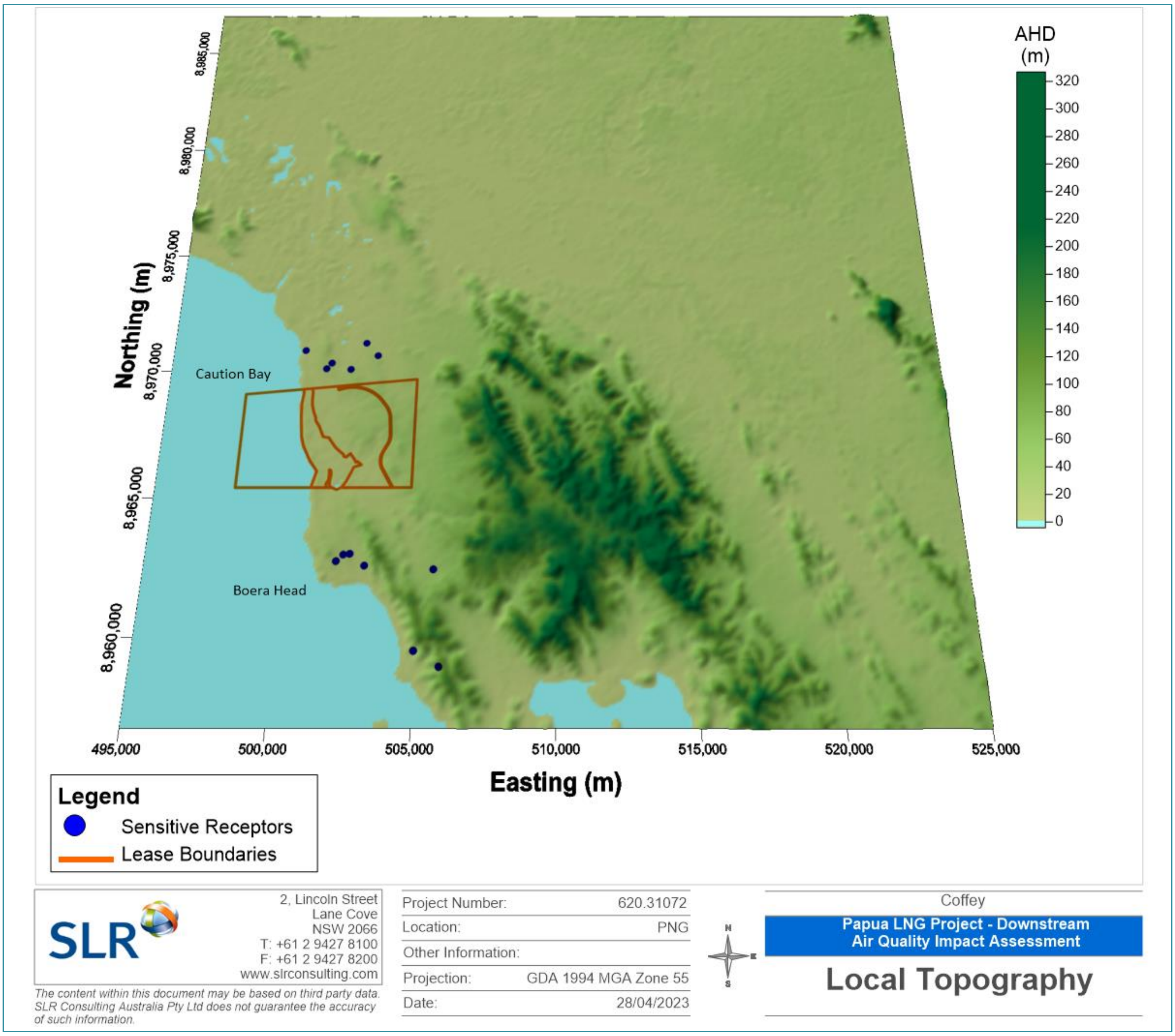
Tropical cyclones affect southern PNG between November and April. In the 41-year period between 1969 and 2010, 23 tropical cyclones passed within 400 km of Port Moresby, an average of less than one cyclone per season. From 1969–2010, cyclones occurred more frequently in neutral phases of the El Niño-Southern Oscillation (BoM,CSIRO, 2014).

5.3 Topography and Surrounding Land Use

The topography and land use of the study area have the potential to impact on the baseline air quality as well as the dispersion of air emissions. Local wind patterns will be influenced by hills and valleys which will act to channel winds. Night-time drainage flows will create downslope winds which will also influence the direction in which emissions will be dispersed. The natural vegetation in the study area also has the potential to affect wind speeds and atmospheric turbulence through changes in surface roughness associated with changes in canopy heights. Ambient particulate levels are also affected by vegetation, which reduces wind erosion but also has the potential to contribute to increased pollen levels.

The LNG Plant is located on the coastal plain at Caution Bay (see **Figure 5**), which is approximately 14 km wide, formed by Redscar Head to the northwest and Boera Head to the southeast. The coastal plain varies in width from 3 km to 5 km.

Figure 5 Surrounding Topography



To the east and southeast of the LNG Plant, the coastal plain transitions into a series of northwest to southeast aligned low hills, typically ranging in height from 300 to 350 m above sea level (ASL). Within 5 km of the site, most of area is less than 50 m ASL.

Primary land uses in the region are agricultural, comprised of grazing and cropping/cultivation. Existing forests are used as a resource for construction materials and firewood. Land to the east of the LNG Plant has been zoned as General Industrial or as Reserve Land for Papa Village, for the purpose of providing land for related industrial activities. Two gas-fired power plants are located to the east of the existing LNG Plant, and a public road runs through the middle of the Lease Boundary. Offshore, the coastal zone is used as a transport route between coastal villages as well as for fishing. The intertidal zone is used for the gathering of food and materials.

5.4 Sensitive Receptors

The four villages closest to the LNG Plant are Lea Lea, Papa, Boera and Porebada. These villages are located within the Hiri Rural Local Level Government (LLG) area, which forms part of Hiri District in Central Province. In the 2011 National Population and Housing Census, the Hiri Rural LLG was reported to have a total population of approximately 47,000 people, with the population in the closest villages to the LNG Plant being (Coffey, 2020):

- Papa - 2,415 people
- Boera - 3,178 people
- Porebada - 7,193 people
- Lea Lea - 4,577 people

In addition to these villages, four residences are identified within 500 m from the northern boundary of the Project site. These residences, along with thirteen representative receptor locations for the villages, were selected to use in the air dispersion modelling study performed as part of this assessment to represent the residential areas closest to the Project.

The receptor locations are shown as pink diamonds in **Figure 6** and their coordinates are listed in **Table 10**.

Figure 6 Representative Sensitive Receptor Locations used in the Air Dispersion Modelling Study

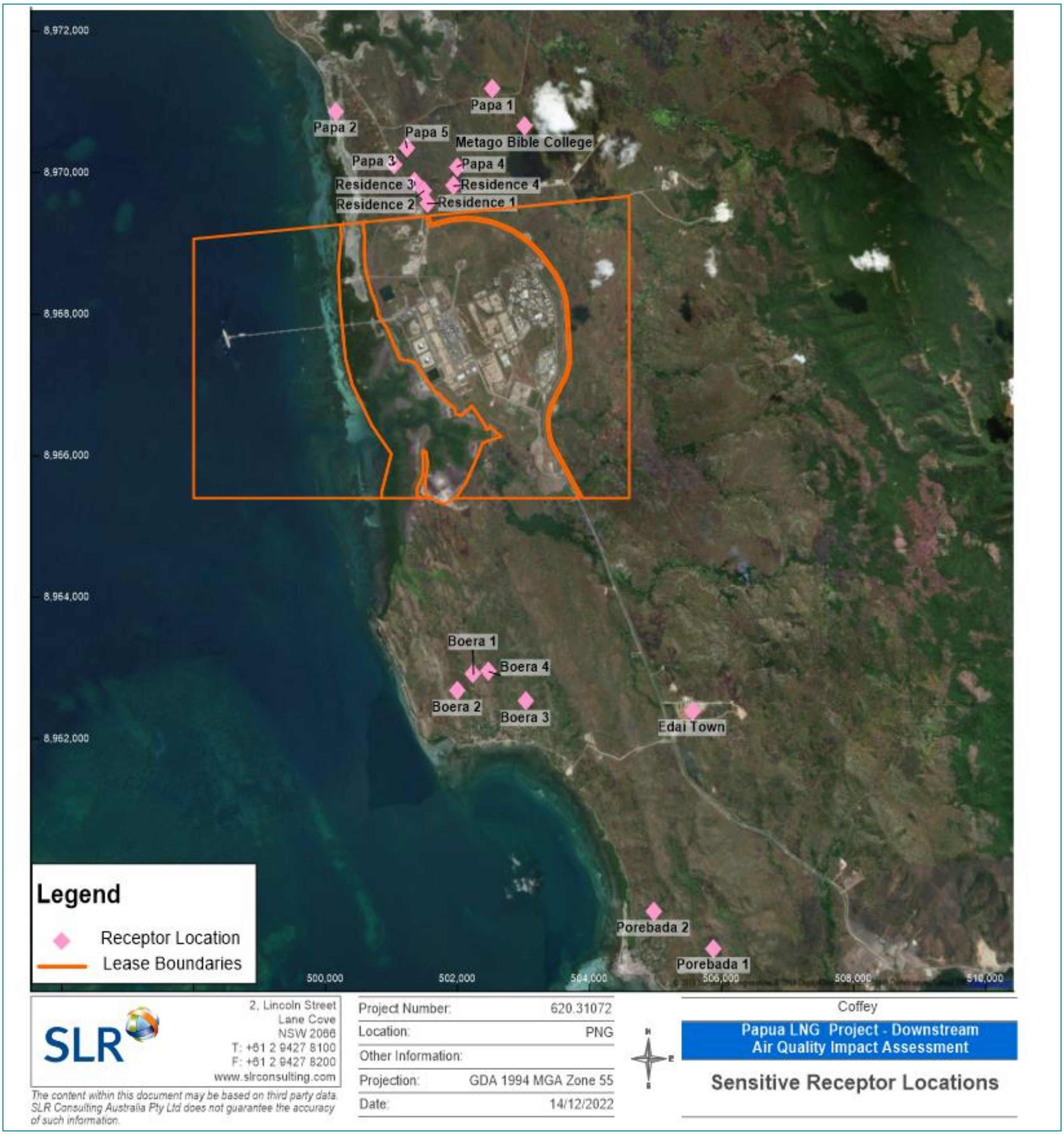


Table 10 Discrete Receptor Locations used in the LNG Plant Air Quality Modelling Study

Receptor Name	Location (MGA 94 Zone 55)	Distance and Direction from LNG Plant Lease Boundary (km)
Papa 1	502,534 mE, 8971,184 mN	1.7, north
Papa 2	500,154 mE, 8,970,865 mN	1.6, north-northwest
Papa 3	501,030 mE, 8,970,105 mN	0.7, north
Papa 4	501,991 mE, 8,970,083 mN	1.0, north
Papa 5	501,231 mE, 8,970,351 mN	0.7, north
Boera 1	502,240 mE, 8,962,912 mN	2.5, south
Boera 2	501,992 mE, 8,962,677 mN	2.7, south
Boera 3	503,026 mE, 8,962,530 mN	2.9, south
Boera 4	502,474 mE, 8,962,950 mN	2.5, south
Porebada 1	505,878 mE, 8,959,040 mN	6.5, south-southeast
Porebada 2	504,964 mE, 8,959,564 mN	5.9, south-southeast
Edai Town	505,553 mE, 8,962,397 mN	3.1, south-southeast
Metago Bible College	503,017 mE, 8,970,657 mN	1.2, north
Residence 1	501,540 mE, 8,969,563 mN	0.2 north
Residence 2	501,491 mE, 8,969,745 mN	0.3 north
Residence 3	501,348 mE, 8,969,874 mN	0.5 north
Residence 4	501,940 mE, 8,969,813 mN	0.4 north

5.5 Existing Air Quality

Air emissions from the existing LNG Plant operations are the main source of air pollutants in the area. Two other notable sources of existing and future air emissions have been identified:

- NiuPower Port Moresby Station: A 50 MW gas-fired power station located approximately 4 km to the northeast of the LNG Plant site. The power station comprises six Wärtsilä 20V34SG gas engines with the exhaust emissions vented through a single stack tower containing six flues.
- Dirio Power Plant: A 47 MW gas-fired power station approximately 300 m east of the existing NiuPower Power Station. There is limited information publicly available on the site layout and air emissions for this facility. For the purposes of this study it has been assumed that the station comprises three Solar Titans identical to the Train 1 and 2 power generation turbines at the LNG Plant site.

Other potential sources of air emissions in the area include domestic and agricultural activities carried out in and around the villages of Lea Lea, Papa, Boera and Porebada, as well as traffic-related emissions from the roads that service them. These activities would contribute minor emissions of particles, NO_x, SO_2 and hydrocarbons. Natural sources of particulate matter, such as sea salt and smoke from local and remote fires, would also be present from time to time.

The proposed Mayur Resources Cement and Lime Project is located approximately 13 km to the northwest of the LNG Plant. The quarrying, processing and wharf operations associated with this project will be located sufficiently far from the LNG Plant site that no cumulative impacts on local air quality would be anticipated. However, if product is transported along Lea Lea Road to Port Moresby, then additional wheel-generated dust and vehicle emissions associated with these truck movements have the potential to impact on air quality in the vicinity of the LNG Plant site and at sensitive receptors along the road. The definitive feasibility study for this project was completed in January 2019 and information on any proposed truck movements along Lea Lea Road is not yet publicly available. Potential cumulative impacts have therefore not been included in this assessment.

ExxonMobil commissioned an air quality monitoring program to monitor ambient air quality at the LNG Plant over a one year period from July 2015 to July 2016. The monitoring program was designed as a screening level air quality monitoring program and included the following:

- Continuous monitoring of TSP, PM_{10} and $PM_{2.5}$ concentrations at three on-site locations (Gate 1, Gate 2 and Gate 3) using E-BAMs, with the different size fractions being measured by changing the sampling heads on a fortnightly basis.
- Monitoring of CO concentrations once a fortnight at each of the three on-site monitoring locations for a period of approximately one hour using a ToxiRAE Pro.
- Monitoring of hydrogen sulphide (H_2S), NO_2, ozone (O_3) and SO_2 concentrations using passive diffusion tubes over consecutive two week exposure periods at each of the three on-site monitoring locations.

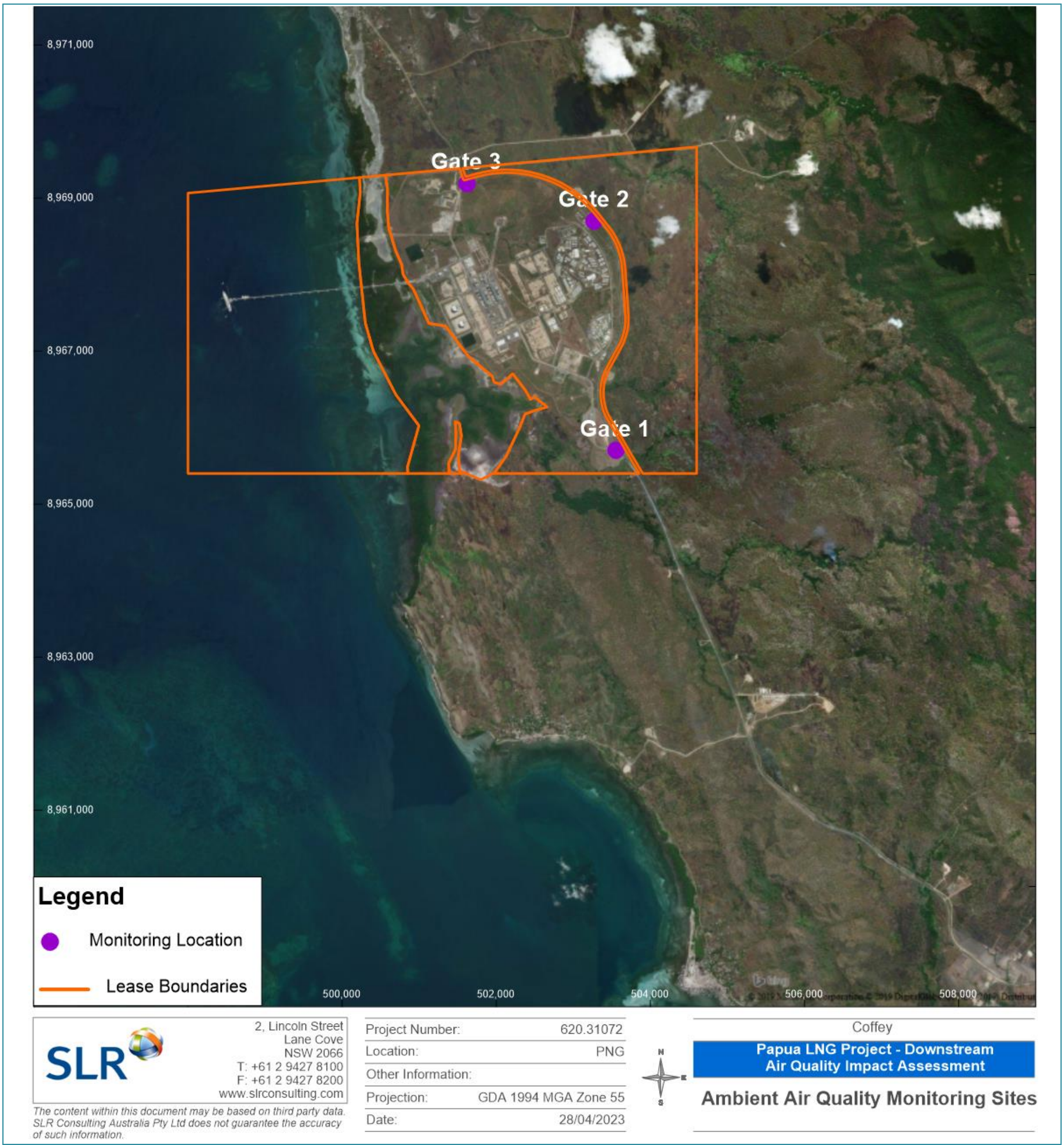
As there have been no changes in site operations since this monitoring was conducted that would have resulted in significant changes in the LNG plant site emissions, the measured on-site pollutant concentrations are expected to still be representative of current site conditions.

The monitoring locations are shown in **Table 11** and **Figure 7**. As shown in **Figure 7**, all three monitoring sites are located close to Lea Lea Road, hence wheel-generated dust and engine exhaust emissions from traffic using this road (e.g. private vehicles, buses and Project-related vehicles) have potential to impact on the air quality measurements recorded at these locations.

Table 11 Ambient Air Quality Monitoring Locations

Monitoring Site	Location (MGA 94 Zone 55)
Gate 1	503,551 mE, 8,965,704 mN
Gate 2	503,273 mE, 8,968,703 mN
Gate 3	501,618 mE, 8,969,196 mN

Figure 7 LNG Plant Ambient Air Quality Monitoring Sites



Particulate Matter

A summary of the ambient TSP, PM_{10} and $PM_{2.5}$ concentrations measured at the LNG Plant site is shown in **Figure 8**.

As shown in **Figure 8**, ambient 24-hour average TSP concentrations measured on site during the monitoring period were consistently below the adopted guideline level of 150 µg/m^3 (EMP limit). Elevated concentrations were recorded by the Gate 3 monitor during the November sampling period, however concentrations recorded at the other monitoring sites during the same period were consistently much lower, indicating that the elevated concentrations recorded at Gate 3 during this period were associated with a temporary, localised source. The average TSP concentration recorded over the year across all three monitoring sites was 20.2 µg/m^3, which is well below the adopted annual average guideline level of 60 µg/m^3.

The 24-hour average PM_{10} concentrations measured on site were also generally below the current WHO guideline level of 45 µg/m^3. Three exceedances of the guideline were recorded over the year; one event at Gate 1 in August 2015 and two at Gate 3 in January and April 2016. All three of these exceedances were only slightly above the guideline, with a maximum concentration of 58 µg/m^3 recorded. The average concentration recorded over the year across all three monitoring sites was 17.6 µg/m^3, which is slightly above the adopted WHO annual average guideline level of 15 µg/m^3.

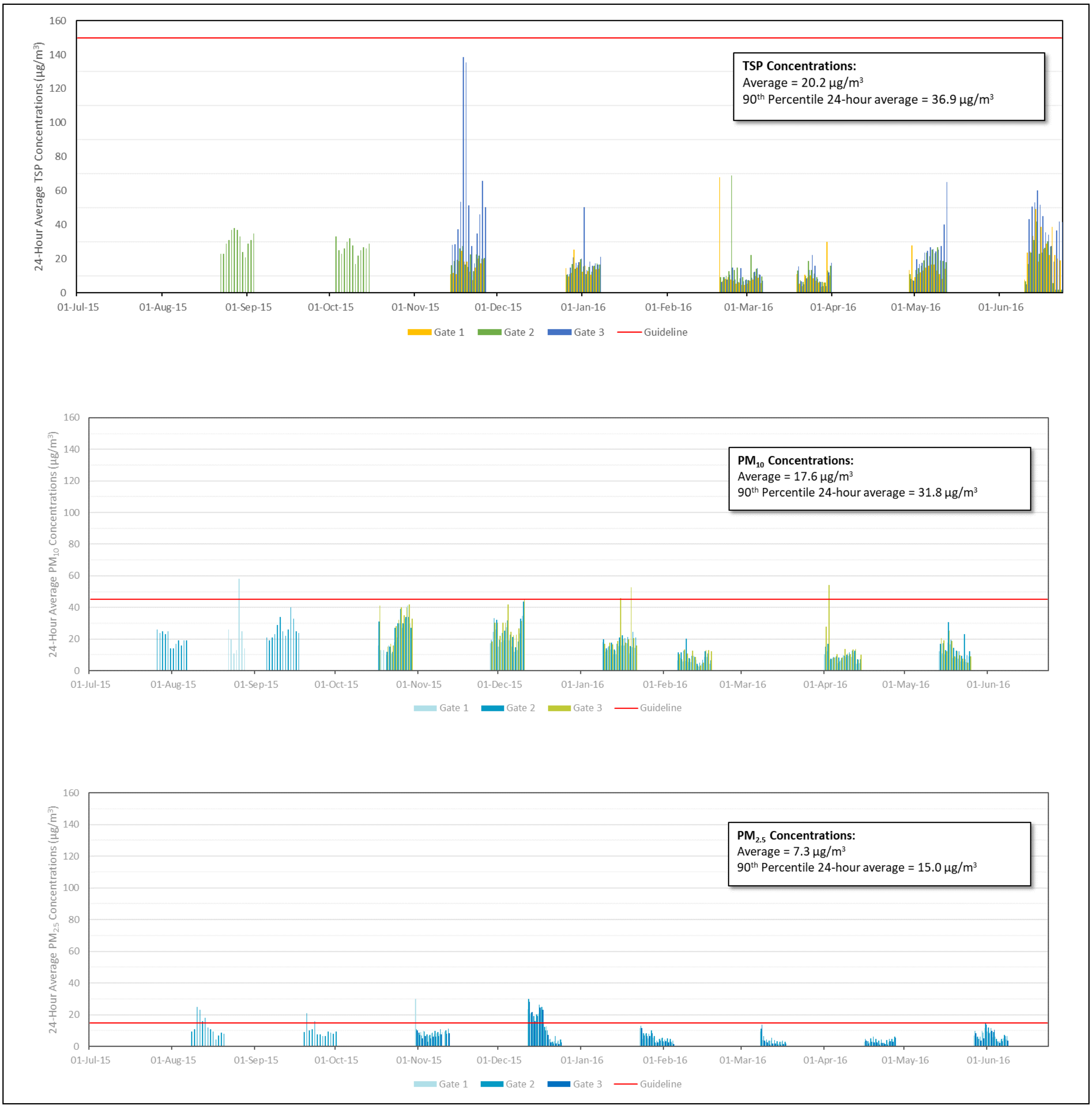
The 24-hour average $PM_{2.5}$ concentrations measured on site were also generally below the current WHO guideline level of 15 µg/m^3. Exceedances of the guideline were recorded at all sites in December 2015. The maximum 24-hour average concentration recorded was 30 µg/m^3. The average concentration recorded over the year across all three monitoring sites was 7.3 µg/m^3, which is above the current WHO annual average guideline level of 5 µg/m^3.

Based on the average TSP, PM_{10} and $PM_{2.5}$ concentrations recorded over the monitoring period, a PM_{10}/TSP ratio of approximately 85% and a $PM_{2.5}$/PM_{10} ratio of approximately 40% can be derived. These ratios would be considered typical for an air environment where suspended particulate levels are dominated by combustion sources, which is as would be expected for on-site locations within the LNG Plant boundary.

While there is no clear seasonal trend in the data, it appears that fine particulate concentrations (PM_{10} and $PM_{2.5}$) were slightly higher in the first 6 months of the monitoring period.

Overall, the results indicate that particulate levels are normally low and below relevant criteria, however short-term events of slightly elevated levels can be recorded at times. The recently reduced WHO guidelines for $PM_{2.5}$ are particularly challenging to meet in many environments. Gates 1-3 are located on Lae Lae Road, which is semi-sealed and in poor condition, with large areas of loose gravel. Wheel-generated dust associated with public traffic is therefore likely to contribute to the events of elevated TSP, PM_{10} and $PM_{2.5}$ levels measured at these locations.

Figure 8 Ambient Particulate Concentrations Measured at the LNG Plant (2015/2016)



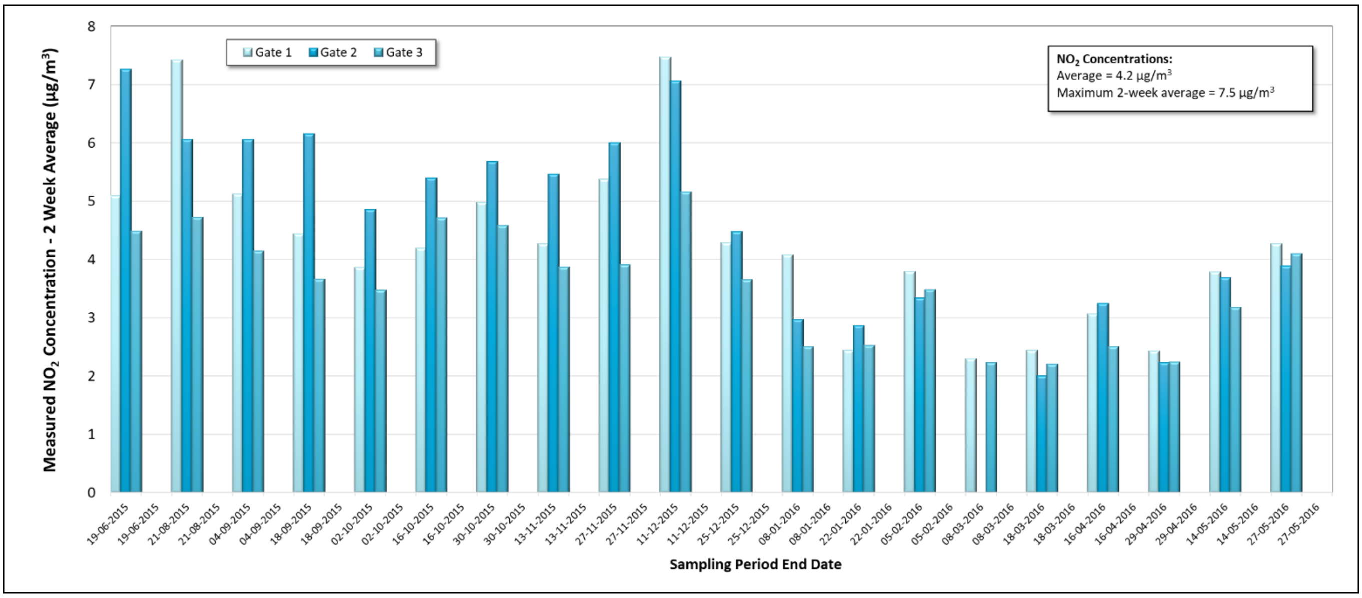
Nitrogen Dioxide

A summary of the ambient NO_2 concentrations measured at the LNG Plant site is shown in **Figure 9**. As these concentrations are measured over two week sampling periods, they are not directly comparable to the short term ambient air quality criterion for NO_2 of 200 µg/m^3 listed in **Table 9**, which relates to a 1-hour averaging period. However, as shown in **Figure 9**, the concentrations measured on site during the monitoring period were relatively low, at less than 8 µg/m^3. The average concentration recorded over the year across all three monitoring sites was only 4.2 µg/m^3, which is approximately 10% of the annual average NO_2 air quality criterion of 40 µg/m^3.

Exhaust emissions from vehicles on Lea Lea Road have potentially contributed to the NO_2 levels recorded at the monitoring sites.

Based on these results it may be concluded that ambient concentrations of NO_2 in the area were well below the annual average guideline levels during the monitoring period.

Figure 9 Ambient NO_2 Concentrations Measured at the LNG Plant (2015/2016)

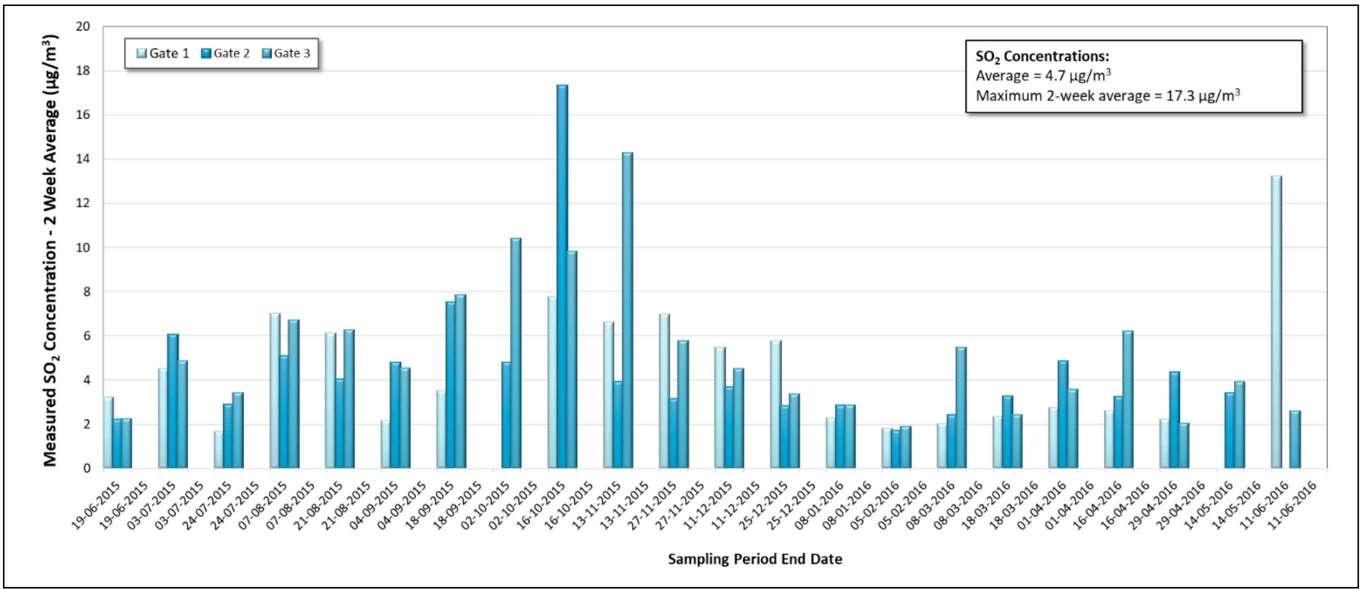


Sulfur Dioxide

A summary of the ambient SO_2 concentrations measured at the LNG Plant site is shown in **Figure 10**. As these concentrations are measured over two week sampling periods, they are not directly comparable to the short term ambient air quality criteria for SO_2 listed in **Table 9** (500 µg/m^3 as a 10-minute average, 200 µg/m^3 as a 1-hour average and 20 µg/m^3 as a 24-hour average). However, as shown in **Figure 10**, the concentrations measured on site during the monitoring period were relatively low, at less than 20 µg/m^3. Exhaust emissions from vehicles on Lea Lea Road have potentially contributed to the SO_2 levels recorded at the monitoring sites, particularly given the relatively high maximum sulfur content of 500 ppm currently specified for PNG.

The average concentration recorded over the year across all three monitoring sites was 4.7 µg/m^3, which is well below the current EC annual average standard of 20 µg/m^3) for the protection of vegetation (EC, 2008).

Figure 10 Ambient SO_2 Concentrations Measured at the LNG Plant (2015/2016)



Carbon Monoxide

All 1-hour average CO monitoring results reported from the ambient air quality screening monitoring program were below 1 µg/m^3. Given the current WHO 1-hour average CO guideline is 35,000 µg/m^3, these results indicate that existing CO concentrations in the vicinity of the LNG Plant operations are negligible.

Ozone

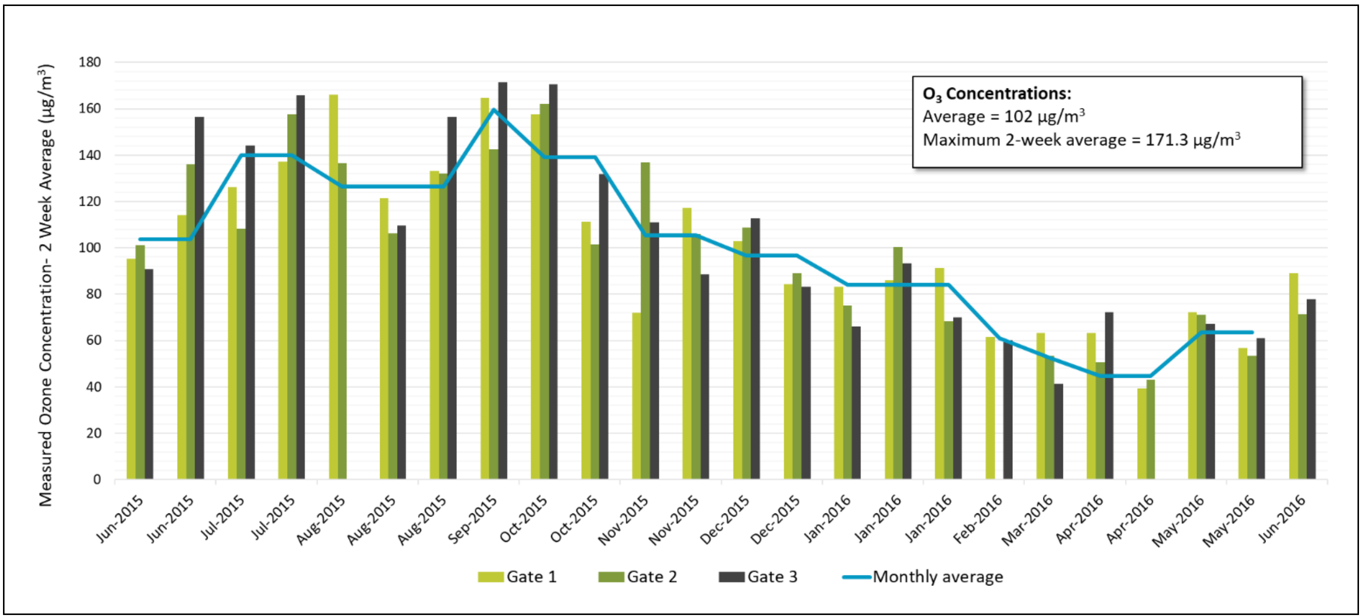
Ozone is a secondary pollutant, which means it is not directly emitted by traffic or industry, but it is formed on warm summer days by the influence of solar radiation on a mixture of airborne pollutants (ozone precursors), primarily NOx and VOCs. Ozone can also be degraded by the compounds (NO_x) from which it is formed. This degradation occurs more extensively in cities than in rural areas, because nitric oxide (NO) concentrations are higher in cities due to traffic emissions. As a result, ozone levels are generally higher during summer than winter, and higher in rural areas than in cities.

Elevated ground-level ozone concentrations can also be associated with long-range windborne transport across state and national borders (CEC, 1997). A study investigating high levels of ozone (up to approximately 160 µg/m^3) recorded over the Western Pacific Ocean in 2014 (Anderson, et al., 2016), identified the source of these elevated concentrations to be fires in tropical Africa (8,000 km away) and Southeast Asia (2,000 km away).

A summary of the ambient O_3 concentrations measured at the site is shown in **Figure 11**. The maximum two week average ozone concentration recorded during the monitoring program was approximately 171 µg/m^3 and the average concentration recorded over the year across all three monitoring sites was 102 µg/m^3. Concentrations were generally higher during the first six months of the monitoring program (particularly during July – October), indicating a possible seasonal trend.

As discussed above, these elevated O_3 concentrations are not due to emissions from the LNG Plant, but are a characteristic of the background air environment. In fact, close to the plant, where sampling was performed, emissions from the LNG Plant can be expected to reduce ambient O_3 levels due to NO within the plumes reacting with the O_3 to form NO_2. Nonetheless, these screening monitoring results do indicate that background O_3 levels in the area can be elevated (see **Section 6.2.3**).

Figure 11 Ambient O_3 Concentrations Measured at the LNG Plant (2015/2016)



6 Assessment Method

6.1 Construction Dust Impacts

Construction works, such as the excavation of foundations and construction of the new trains at the LNG Plant will result in the generation of fugitive dust emissions. These emissions have the potential to result in elevated TSP concentrations and dust deposition rates in the vicinity of the works.

Modelling of dust emissions from construction projects is generally not considered appropriate, as emission rates can vary depending on a combination of the construction activity and prevailing meteorological conditions (e.g., rainfall and wind speed), which cannot be reliably predicted. The potential for adverse impacts has therefore been assessed qualitatively based on the nature and scale of activities to be undertaken, the proximity of sensitive receptors to the main construction areas, and considering the dust mitigation measures that will be implemented during the works (see **Section 7.1**).

6.2 Operational Phase Air Emissions

Potential off-site impacts of operational air emissions from the Project were assessed using atmospheric dispersion modelling. Atmospheric dispersion models are computer programs that calculate the pollutant concentration downwind of a source using information on the:

- Contaminant emission rate;
- Characteristics of the emission source (release height above ground, temperature and upward velocity, plume width etc);
- Local topography;
- Meteorology of the area; and
- Ambient or background concentrations of the pollutant.

The modelling method conducted for the assessment of the proposed project included meteorological modelling using WRF and CALMET, followed by dispersion modelling using CALPUFF.

Stack and emission data used in the modelling for the existing LNG Plant and Project facilities were compiled based on currently available design data, equipment and feed gas specifications, and published emission factors (as required). Multiple emission scenarios were modelled to enable the off-site pollutant concentrations predicted as a result of both normal and upset operating conditions (flaring events) for the existing and proposed integrated plant. In addition to the LNG plant emissions, all modelling scenarios included:

- Shipping emissions: For the current operational scenarios this includes emissions from tankers and tugboats operating at the jetty, and for the proposed operations included emissions from tankers and tugboats operating at both the jetty and the CALM buoy.
- Third party power stations: Emissions from the Niu Power and Dirio gas-fired power plants.

The results of the modelling have been compared to the ambient air quality criteria adopted for use in the assessment as listed in **Table 9**.

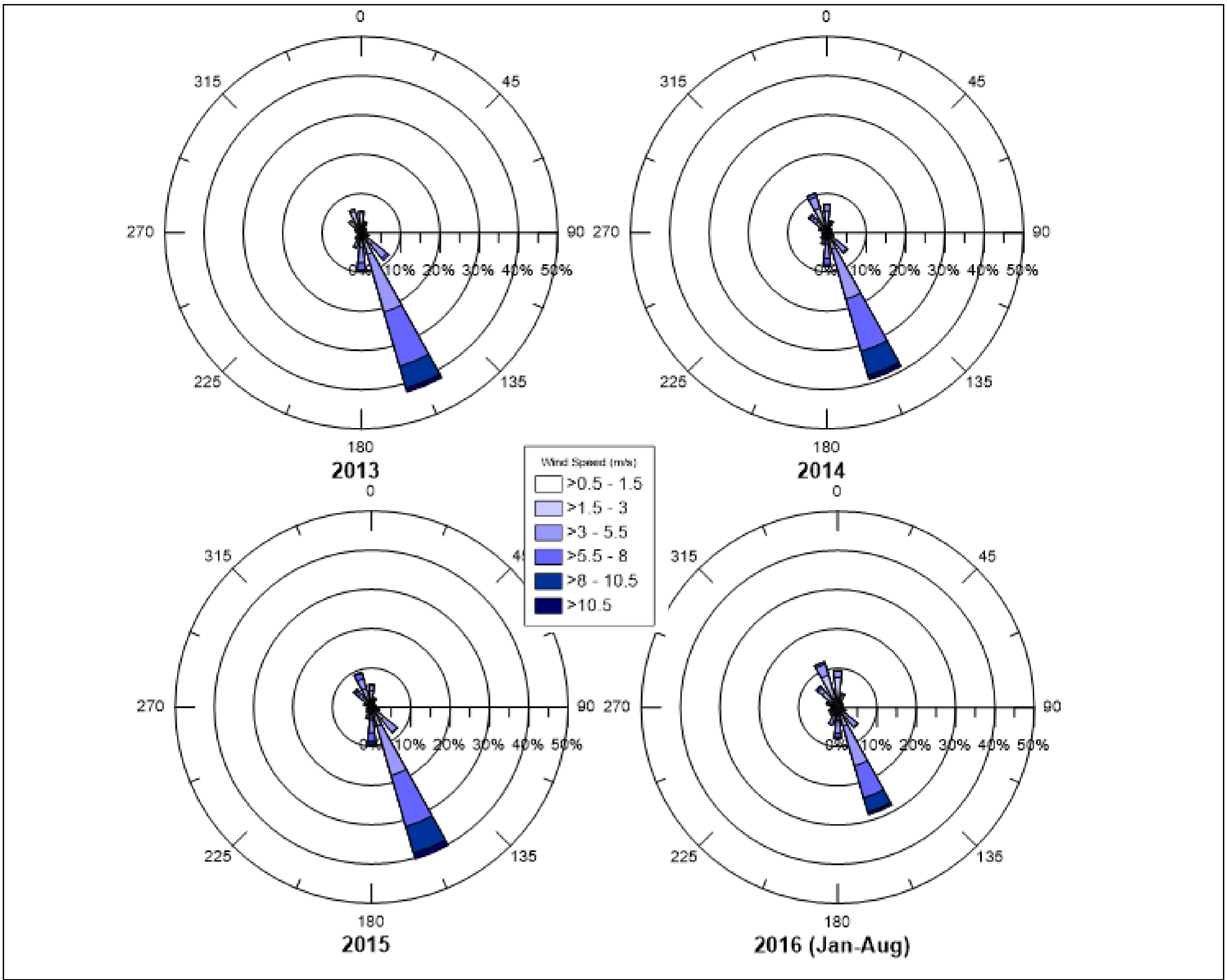
6.2.1 Meteorological Modelling Methodology

Site-representative, three-dimensional meteorological data was generated using a combination of the Weather Research and Forecast (WRF) and CALMET models. Further details on meteorological modelling approach and the setup of these models are provided below.

6.2.1.1 Selection of Meteorological Modelling Period

Air dispersion modelling was performed using a 3-dimensional, one year, hourly meteorological dataset (i.e. containing 8,760 different meteorological conditions at each horizontal and vertical grid point within the modelling domain). A review of meteorological data recorded at Port Moresby Airport was performed to select the year for use in the modelling study. As shown in **Figure 12**, this analysis showed that similar wind patterns were recorded during each year reviewed. In addition, no significant differences in ambient temperatures were identified across the period reviewed. Given that no significant inter-annual variations in the measured meteorology were identified over the period 2013-2016, the 2015 calendar year was selected for use in the modelling as it was the most recent year with a complete dataset from Port Moresby Airport.

Figure 12 Windroses Compiled from Data Recorded at Port Moresby Airport (2013 – 2016)



6.2.1.2 WRF

The Weather Research and Forecast (WRF) model is a next-generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. The model serves a wide range of meteorological applications across scales from tens of meters to thousands of kilometres.

For this assessment, the WRF modelling system was used to produce the meteorological field required to provide the 'initial guess' field for the CALMET meteorological model. Parameters used in the WRF model for this assessment are presented in **Table 12**.

Table 12 Meteorological Parameters – WRF

Parameter	Domain 1	Domain 2	Domain 3
Modelling domain	1,890 km × 1,890 km	225 km × 225 km	93 km × 93 km
Grid resolution	27 km	9 km	3 km
Number of vertical levels	30	30	30
Microphysics	WSM6	WSM6	WSM6
Cumulus parametrization	Kain-Fritsch	Kain-Fritsch	Kain-Fritsch
Shortwave radiation physics	Dudhia	Dudhia	Dudhia
Longwave radiation physics	RRTM	RRTM	RRTM
Planetary boundary layer	YSU	YSU	YSU

6.2.1.3 CALMET

In the simplest terms, CALMET is a meteorological model that develops hourly wind and other meteorological fields on a three-dimensional gridded modelling domain that are required as inputs to the CALPUFF dispersion model. Associated two-dimensional fields such as mixing height, surface characteristics and dispersion properties are also included in the file produced by CALMET. The interpolated wind field is then modified within the model to account for the influences of topography, sea breeze, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field. The final hourly-varying wind field thus reflects the influences of local topography and land uses.

CALMET modelling was conducted using the nested CALMET approach, where the final results from a coarse-grid run were used as the input for a fine-grid run. This has the advantage that off-domain terrain features including slope flows and blocking effect can be allowed to take effect and the larger-scale wind flow provides a better start in the fine-grid run.

The outer domain (centred on the LNG Plant) was modelled with a resolution of 1 km. WRF-generated three-dimensional meteorological data were used as the 'initial-guess' wind field and local topography and land use information were used to refine the wind fields predetermined by the WRF data.

CALMET also allows the use of on-site or nearby meteorological stations to be included in the model run to optimise the performance of the model. On-site meteorological data suitable for use in CALMET are not available for the LNG Plant site. While there is an on-site meteorological station located at the LNG Plant, the data recorded are not suitable for input into a meteorological model as wind directions are only recorded as cardinal directions (north, northwest, west etc.) not in degrees. Instead the data available from the on-site station have been used to assess the performance of the WRF/CALMET modelling in capturing the key features of the local meteorology at this site. Available wind speed, wind direction, temperature and relative humidity data recorded at Port Moresby Airport (located 20 km to the southeast of the LNG Plant site) were used as input to the CALMET model to refine the predicted meteorological data for the LNG Plant. Sea surface temperature data for Port Moresby were also input into CALMET to optimise the model's ability to capture the sea breeze effects associated with the coastal location of the LNG Plant.

The output from the outer domain CALMET modelling was then used as input for the inner domain CALMET modelling. A horizontal grid spacing of 200 m was used in the inner domain to adequately represent local terrain features and land use. Fine scale local topography and land use information were used in the inner domain run to refine the wind field parameters predetermined by the coarse CALMET run.

The parameters used in the meteorological modelling to drive the CALMET model are detailed in **Table 13**.

Table 13 CALMET Modelling Parameters

Parameter	Data
Outer Domain	
Modelling period	1 January 2015 to 31 December 2015
Meteorological grid	50 km × 50 km
Meteorological grid resolution	1 km
Initial guess filed	WRF output
Vertical resolution (cell heights)	10 (0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1200 m, 2000 m, 3000 m, 4000 m)
Data assimilation	Port Moresby Airport (surface data), Port Moresby (monthly sea water temperature data)
Inner Domain	
Meteorological grid	30 km × 27 km
Meteorological grid resolution	200 m
Initial guess field	3D output from outer domain model run

6.2.2 Dispersion Modelling Methodology (CALPUFF)

Emissions from the Project have been modelled using the US EPA's CALPUFF (Version 6.42) modelling system. CALPUFF (Scire, Strimaitis, & Yamartino, 2000) is a multi-layer, multi-species, non-steady state puff dispersion model that can simulate the effects of time and space varying meteorological conditions on emissions transport, transformation and removal. The model contains algorithms for near-source effects such as building downwash, partial plume penetration, sub-grid scale interactions as well as longer-range effects such as substance removal, chemical transformation, vertical wind shear and coastal interaction effects. The model uses dispersion equations based on a Gaussian distribution of substances across the puff and takes into account the complex arrangement of emissions from point, area, volume, and line sources.

The primary output from CALPUFF contains either hourly concentration or hourly deposition fluxes evaluated at selected receptor locations. The CALPOST post-processor is then used to process these data, producing tabulations that summarise results of the simulation for user-selected averaging periods.

CALPUFF was run using the CALMET output for the LNG Plant site using the modelling domains described in **Table 14**. Discrete receptors were also included in the modelling to represent the nearest sensitive receptors as outlined in **Section 0** and the monitoring locations discussed in **Section 5.5**.

Table 14 CALPUFF Grid Parameters

Parameter	Model Domain
Grid size	200 m
Number of grid points	82 x 82 x11
Year of analysis	2015
Southwest corner	495,000 mE, 8,957,400 mS (UTM zone 55S)

6.2.3 NO_X to NO_2 conversion

NO_X emissions from fossil fuel combustion are primarily nitric oxide (NO), with only a few volume percent as NO_2. However, once the gases are discharged into the atmosphere, chemical reactions take place which result in the transformation of NO in the plume to NO_2.

There are various methods for estimating NO_2 concentrations from model predictions of NO_X as the plume is emitted from the emission point. Generally, these methodologies assume a higher NO to NO_2 conversion rate with increasing background ozone concentrations.

The US EPA has developed a procedure known as the Ozone Limiting Method (OLM), which allows a conservative estimate of the NO_2 concentration to be made in a NO_X plume. The calculation requires knowledge of the background ozone (O_3) concentration, which is usually derived from direct measurements. Such data are readily available in urban areas where the method is mostly used.

The OLM method can be summarised by the following equation:

$$[NO_2]_{total} = \{0.1 \times [NO_X]_{predicted}\} + \text{minimum of } \{0.9 \times [NO_X]_{predicted} \text{ or } (46/48) \times [O_3]_{background}\} + [NO_2]_{background}$$

Where:

$[NO_2]_{total}$ = the predicted concentration of NO_2, via OLM, in µg/m^3

$[NO_2]_{predicted}$ = the predicted concentration of NO_2 in µg/m^3 from the dispersion model in µg/m^3

$[O_3]_{background}$ = the background concentration of O_3 in µg/m^3

46/48 = the molecular weight of NO_2 divided by the molecular weight of O_3

$[NO_2]_{background}$ = the background concentration of NO_2 in µg/m^3

For 1-hour and 24-hour average NO_X predictions, if the $[O_3]_{background}$ is taken to be 170 µg/m^3 (the maximum 2-week average concentration recorded by the 2015-2016 ambient monitoring program (see **Section 5.5**) and $[NO_2]_{background}$ is taken to be zero (since there are no significant sources of NO_2 present in the area apart from those included in the model) then the value of NO_2 is estimated to be 10% of the predicted concentration of NO_X plus the minimum of 90% of the predicted NO_X concentration or 159 µg/m^3 (as 159 = 170 x (45/48)).

6.2.4 Sub-Hourly Averaging Period Predictions

The plume dispersion model calculated ground level pollutant concentrations on a minimum 1-hour average timestep, in line with the 1-hour meteorological data used in this study. To provide estimates of 10-minute average ground level SO_2 concentrations for comparison against the 10-minute average assessment criterion for SO_2, the Turner power law was used (Turner, 1994). This method scales the 1-hour average prediction up by a factor of 1.43 to estimate the equivalent 10-minute average prediction.

In addition to the scaling factor above, the predicted ground-level, 10-minute average SO_2 concentrations reported for the proposed operations scenario were also scaled up further to account for the variable SO_2 emission rate from the CCPP and new sludge incinerator. This is discussed further in **Section 6.4.2**.

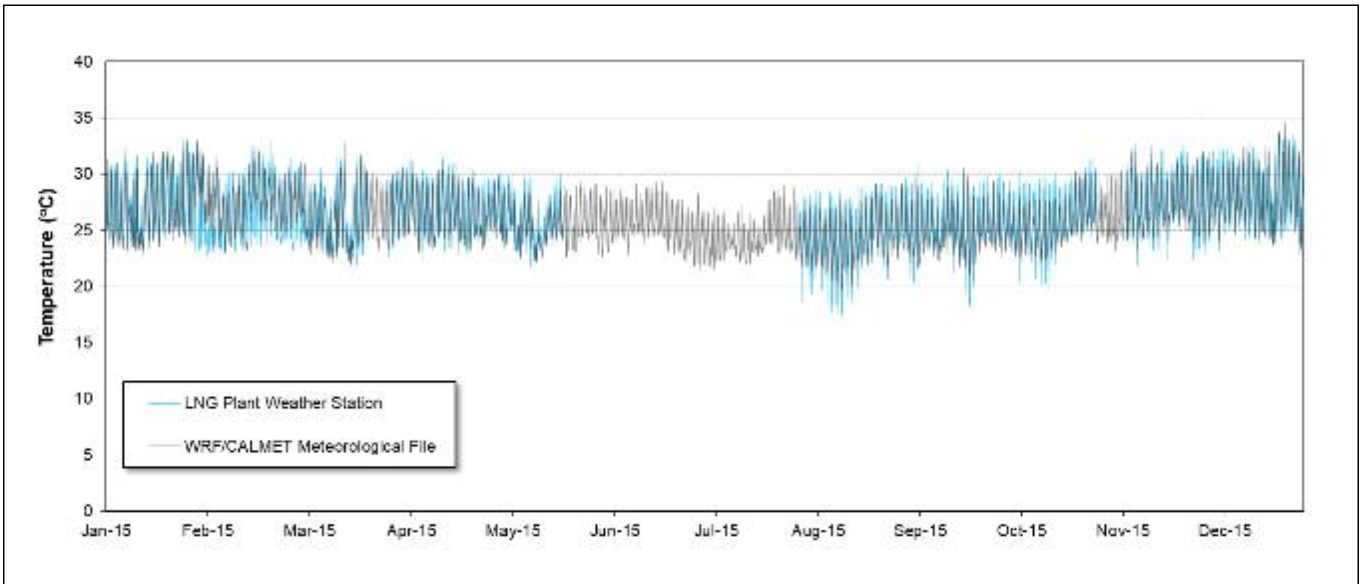
6.3 Meteorological Data Used in the Dispersion Modelling

This section presents a summary of the key meteorological conditions predicted by CALMET at the LNG Plant site for the 2015 calendar year. The meteorological model dataset for the LNG Plant site has been compared to weather data recorded by the on-site meteorological station (where available) to provide an assessment of the representativeness of the model dataset.

6.3.1 Temperature

Figure 13 shows the hourly ambient temperatures predicted for the LNG Plant site for the 2015 calendar year compared to the observational data recorded by the on-site weather station during the same period. As expected, the temperature is relatively consistent throughout the year. The temperatures in the modelling file range between 20°C and 35°C, and compare well with the observational data. There is a slight overprediction in the night-time (cooler) temperatures during August – October when the observed temperatures drop below 20°C, however this is a minor deviation and would not have a significant impact on the accuracy of the modelling. If anything, it is expected to result in conservative predictions of ground level pollutant concentrations as the modelling will tend to underestimate plume buoyancy and overestimate thermal turbulence at these times, resulting in slightly higher ground level concentrations than would otherwise be predicted.

Figure 13 Ambient Temperature at the LNG Plant Site (WRF/CALMET Predictions, 2015)



6.3.2 Wind Speed and Direction

A summary of the annual wind behaviour predicted by CALMET for the LNG Plant is presented in **Figure 14**. **Figure 14** indicates that over the 1-year period used in the modelling (2015 calendar year), the site experienced light to moderate winds (between 1.5 m/s and 8 m/s), predominantly from the southeastern quadrant. Calm wind conditions (wind speeds less than 0.5 m/s) were predicted to occur approximately 3% of the time. The seasonal wind roses indicate that winds are lighter during the wet season compared to the dry season. Winds from the western and northern quadrant occur very infrequently during both the dry and wet seasons.

Wind speed and wind direction measurements are available from the onsite weather station for 2013, 2015, 2019 and 2020 calendar years. A comparison of wind data predicted by WRF/CALMET and available wind data recorded at the onsite meteorological station is presented in **Figure 15**. A comparison of the windroses presented in **Figure 15** shows that the WRF/CALMET wind data for 2015 captures the predominant southeasterly winds characteristic of the site and compares well with the monitoring data recorded by the onsite meteorological station in 2013 and 2015 calendar years. There are some differences between the two sets of windroses however, which may be due to interannual variations as they are for different years. Monitoring data recorded in 2019 and 2020 shows relatively high frequency of light winds and low frequency of high winds compared to that recorded in 2013 and 2015 calendar years.

A wind speed frequency chart is presented in **Figure 16** comparing the available measured (2013, 2019 and 2020 calendar years) and modelled (2015 calendar year) datasets. This plot shows that the frequency of wind speed categories predicted by WRF/CALMET compare well with the available on-site data. The modelling dataset has a noticeably lower frequency of winds in the 0 to 1 m/s range, which is likely to be due to these winds being close to the stall speed of the wind sensor (0.4 m/s). The comparison also showed that frequencies of higher wind speed (>4 m/s) recorded in 2019 and 2020 are significantly lower than that recorded in 2013 calendar year and predicted by WRF/CALMET model for 2015 calendar year.

Given that most of the air emissions associated with the existing and proposed plant will be release via stack and associated high thermal buoyancy of combustion gases, use of meteorological data predicted by WRF/CALMET models, that are in reasonable agreement with meteorological data recorded in 2013 and 2015 calendar year at the onsite meteorological station, as input to the CALPUFF dispersion model is likely to overestimate the potential impacts at the nearfield receptors, more specifically nearest residences located to the north of the site.

Figure 14 Wind Roses for the LNG Plant Site – CALMET Prediction (2015)

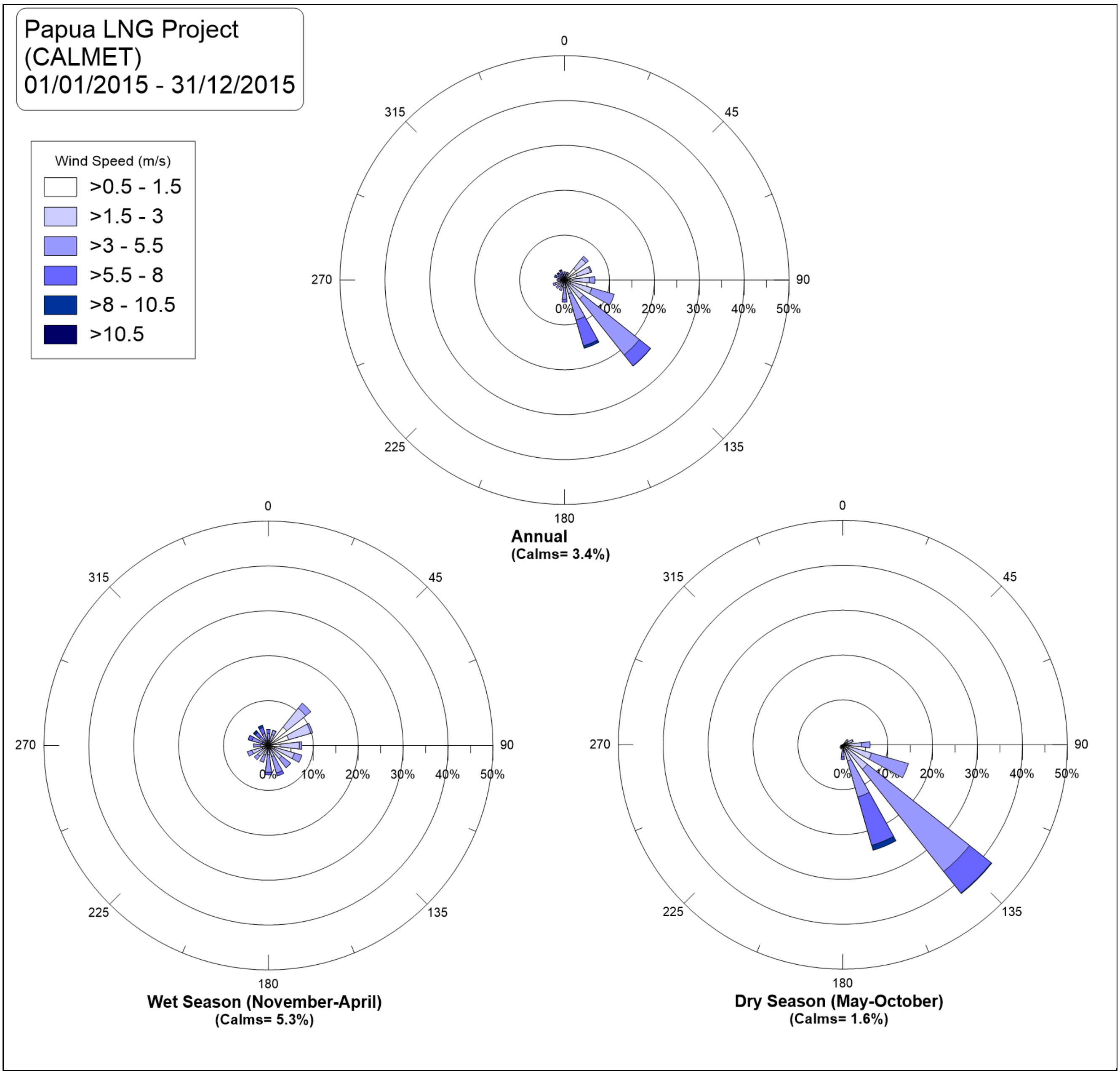


Figure 15 Wind Roses for the LNG Site – Model Prediction and Observations

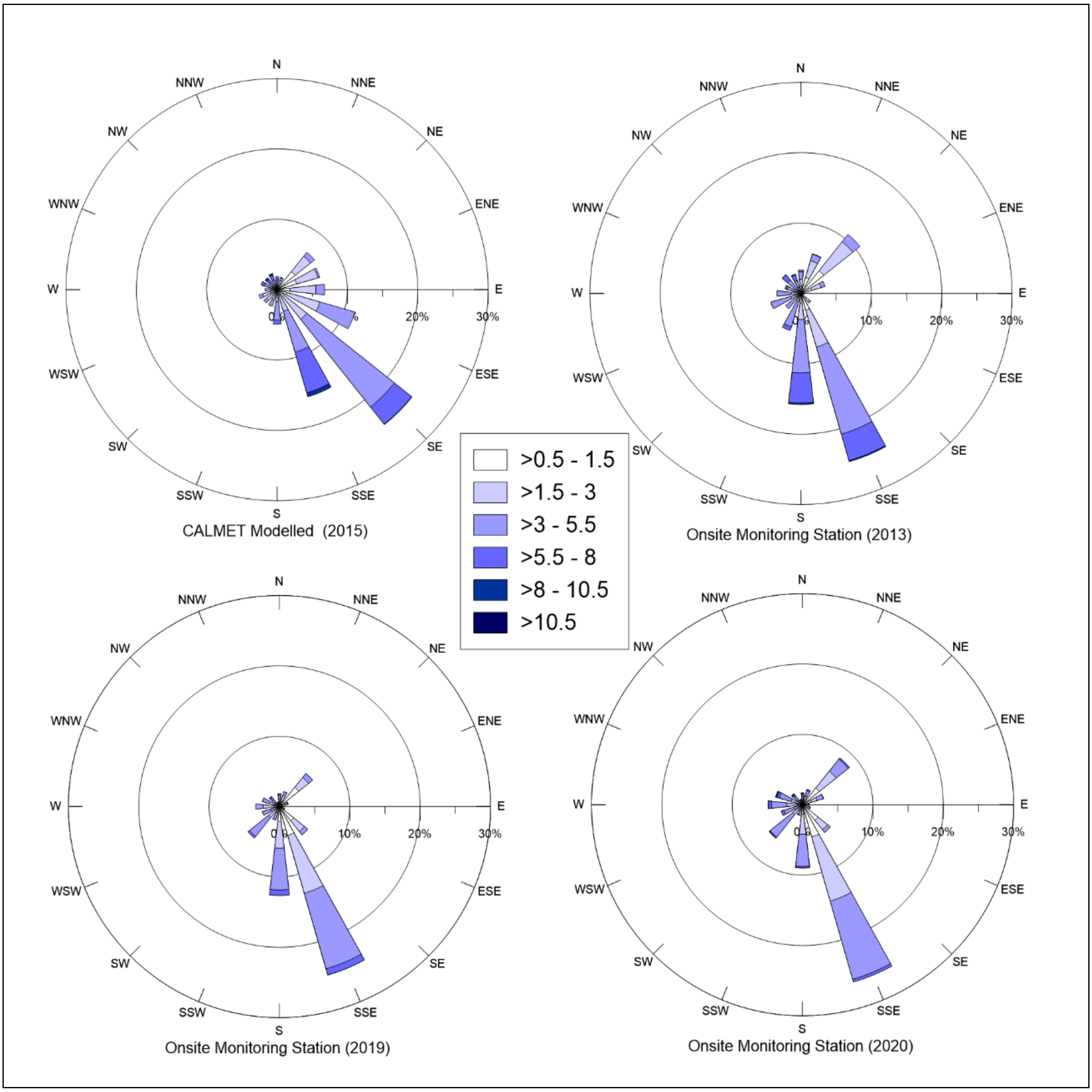
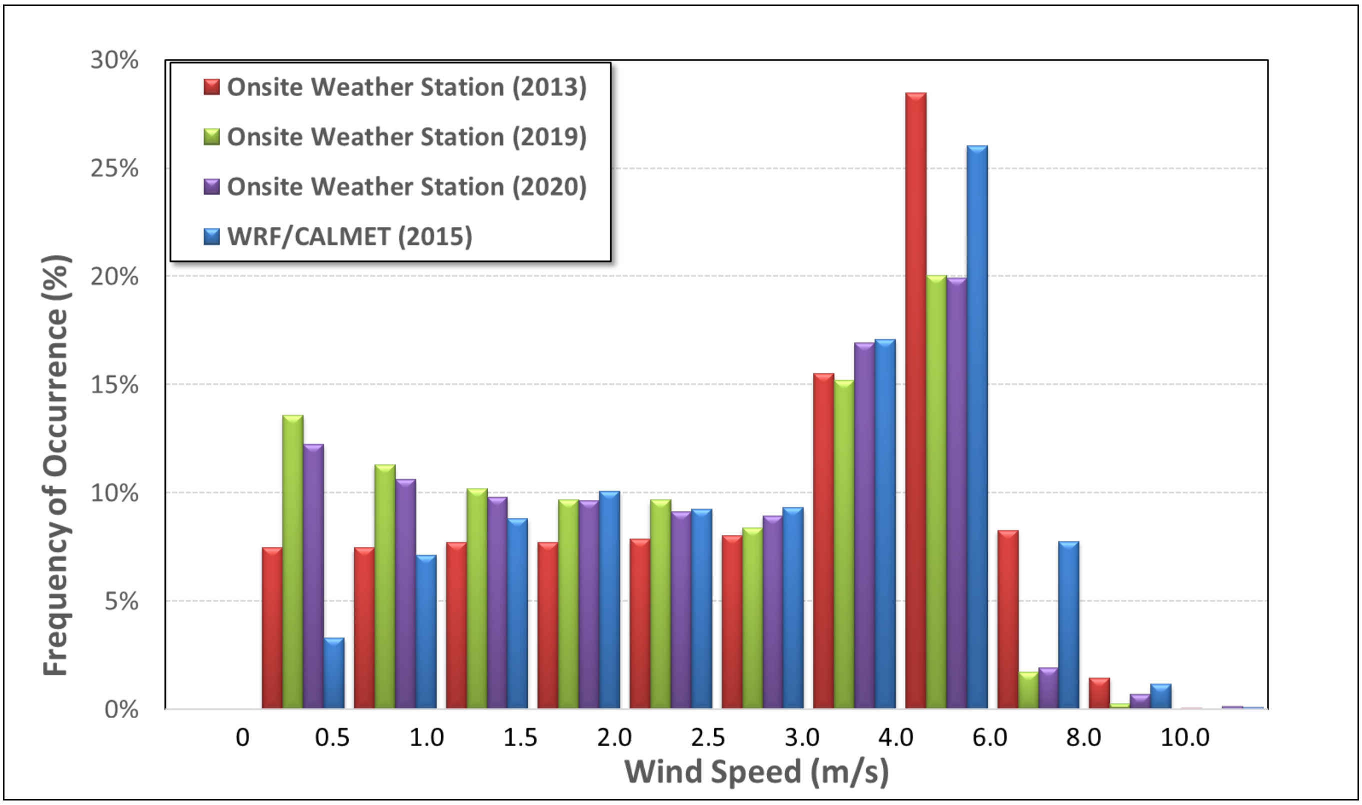


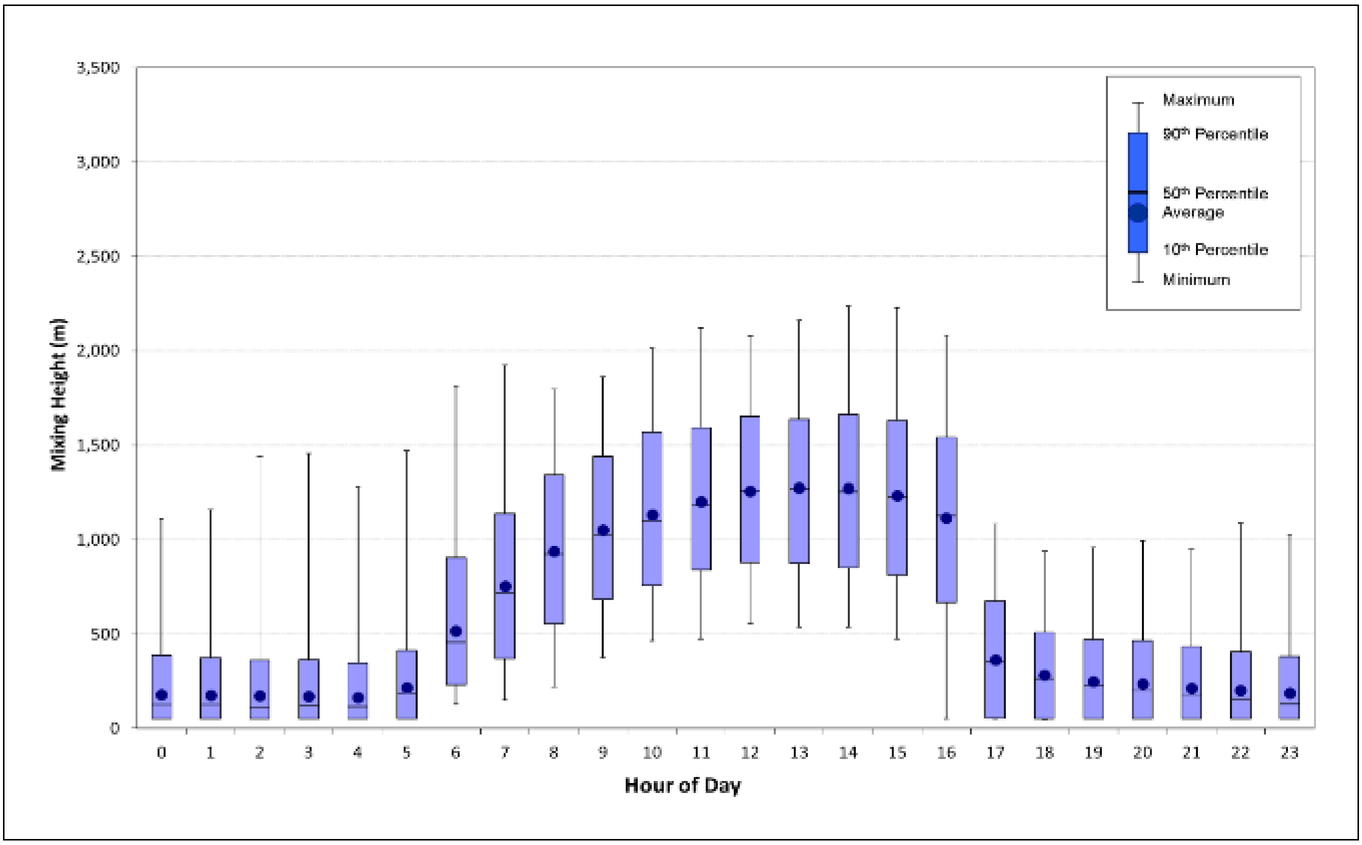
Figure 16 Wind Speed Frequency Plot for the LNG Plant Site – Measured versus Modelled



6.3.3 Mixing Heights

Diurnal variations in maximum and average mixing heights predicted by CALMET at the LNG Plant are illustrated in **Figure 17**. As would be expected, an increase in the mixing height during the morning is apparent, arising due to the onset of vertical mixing following sunrise. Maximum mixing heights occur in the mid to late afternoon, due to the dissipation of ground-based temperature inversions and the growth of the convective mixing layer.

Figure 17 Mixing Heights for the LNG Plant Site (WRF/CALMET Predictions, 2015)



6.3.4 Atmospheric Stability

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Gifford-Turner (PGT) assignment scheme identifies six Stability Classes, A to F, to categorise the degree of atmospheric stability as follows:

- A = Extremely unstable conditions
- B = Moderately unstable conditions
- C = Slightly unstable conditions
- D = Neutral conditions
- E = Slightly stable conditions
- F = Moderately stable conditions

The meteorological conditions defining each PGT stability class are shown in **Table 15**.

Table 15 Meteorological Conditions Defining PGT Stability Classes

Surface Wind Speed (m/s)	Daytime Insolation			Night-Time Conditions	
	Strong	Moderate	Slight	Thin overcast or > 4/8 low cloud	<= 4/8 cloudiness
< 2	A	A - B	B	E	F
2 - 3	A - B	B	C	E	F
3 - 5	B	B - C	C	D	E
5 - 6	C	C - D	D	D	D
> 6	C	D	D	D	D

Notes:

Strong insolation corresponds to sunny midday in midsummer in England; slight insolation to similar conditions in midwinter.

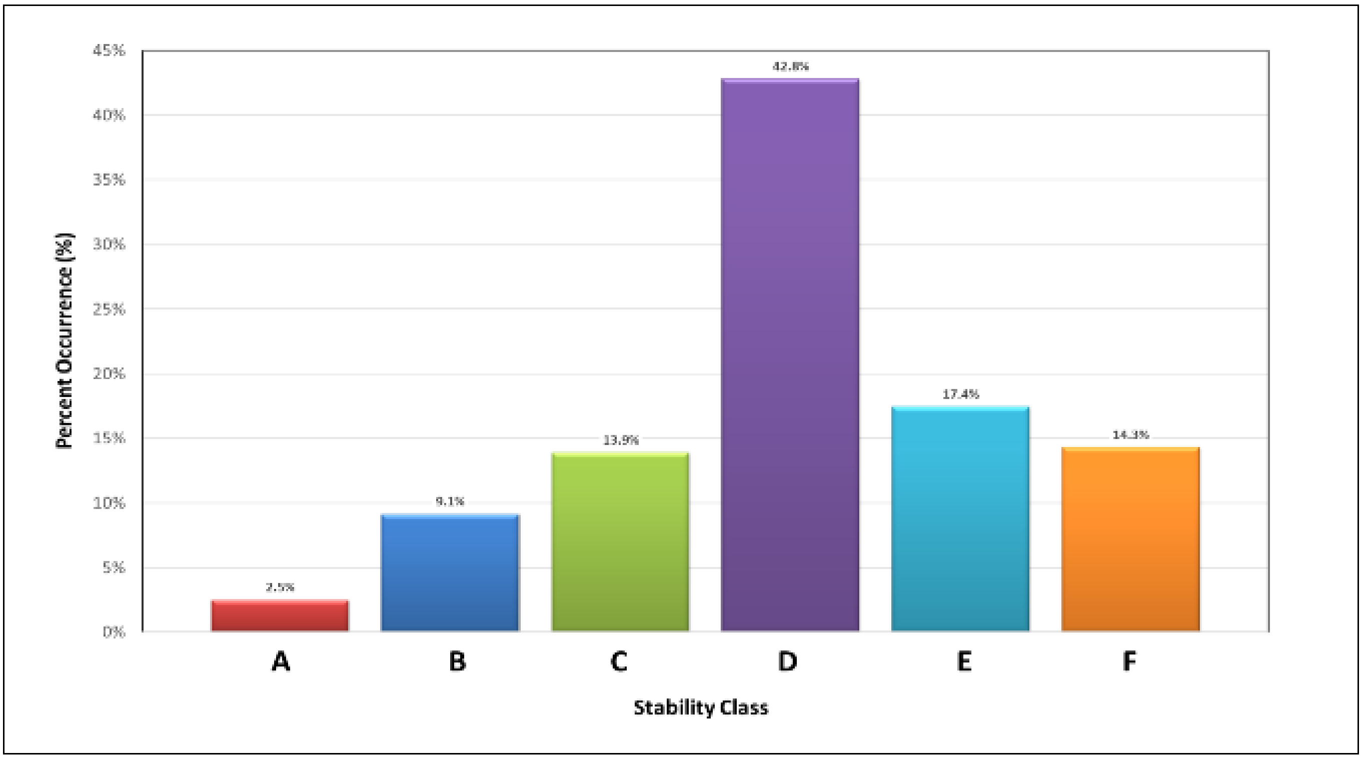
Night refers to the period from 1 hour before sunset to 1 hour after sunrise.

The neutral category D should also be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour preceding or following night as defined above.

Source: NOAA, 2018.

Figure 18 shows the frequency distribution of the atmospheric stability classes predicted for the LNG Plant site. This plot shows that neutral conditions (Stability Class D) are predicted to occur most frequently at the LNG Plant site. The high frequency of Stability Class D is due to the coastal location of the site and frequent high wind speed (wind speed > 3 m/s) conditions.

Figure 18 Stability Class Distribution for the LNG Plant Site (WRF/CALMET Predictions, 2015)



6.4 Source Parameters and Emission Data

6.4.1 Assessment Scenarios

The following operating scenarios have been modelled as part of the operational impact assessment:

- **Current normal operations**: The existing LNG plant operating normally, including cumulative impacts with emissions from LNG and condensate tankers and tugs manoeuvring and berthed at the jetty and the nearby gas fired power stations.
- **Current upset operations**: Train 1 off-line with flares operating at maximum capacity, including cumulative impacts with emissions from LNG and condensate tankers and tugs manoeuvring and berthed at the jetty and the nearby gas fired power stations.
- **Proposed normal operations**: The existing LNG and proposed Papua LNG facilities operating normally under power share mode. Includes cumulative impacts with emissions from LNG tankers and tugs manoeuvring and berthed at the jetty, and condensate tankers and tugs manoeuvring and berthed at the CALM buoy, as well as the nearby gas fired power stations.
- **Proposed upset operations**: Papua LNG facilities off-line with the CCPP shut down, the three emergency diesel generators on-line and the Project wet flare operating at maximum capacity. The existing LNG plant is assumed to be operating normally, with power being provided by the PNG LNG Plant GTGs. Includes cumulative impacts with emissions from LNG tankers and tugs manoeuvring and berthed at the jetty, and condensate tankers and tugs manoeuvring and berthed at the CALM buoy, as well as the nearby gas fired power stations.

The integrated LNG Plant is anticipated to operate in power share mode around 94% of the time, with non-power share operations therefore occurring approximately 525 hours per year. The estimated total site air pollutant emissions for power share and non-power share operations are summarised in **Table 16**. This table shows that for NO_X, CO, particulate and benzene emissions, total site emissions for the non power share mode are either very similar to, or lower than the power share mode emissions. Therefore modelling the power share operations will provide a representative or worst case assessment for both modes of operation. Due to the peaking sulfur content in the fuel gas fed to the CCPP (see **Section 3.2**), power share mode will also provide a worst case assessment of SO_2 emissions from the site. Given this, and the low frequency of non power share operations, only the power share mode has been modelled in this assessment.

Table 16 Total Site Emissions – Power Share Mode versus Non-Power Share Mode

Pollutant	Power Share Mode Emissions (kg/hr)			Non Power Share Mode Emissions (kg/hr)		
	Total Emissions Papua LNG	Total Emissions PNG LNG	Total Emissions Integrated LNG Plant	Total Emissions Papua LNG	Total Emissions PNG LNG	Total Emissions Integrated LNG Plant
NOx	240.2	127.5	367.7	185.6	151.6	337.2
CO	62.1	75.0	137.1	48.8	89.4	138.2
Particulate	8.5	18.8	27.3	7.7	21.6	29.3
Benzene	0.03	35.1	35.1	0.02	35.1	35.1

6.4.2 PNG LNG and Papua LNG Plant Emissions

Stack Emissions

Source and emission data used in the modelling for the stack sources at the PNG LNG and Papua LNG plants are listed in in the following tables as listed below:

- **Table 17**: Current (PNG LNG Plant) normal operations
- **Table 18**: Current (PNG LNG Plant) upset operating conditions
- **Table 19**: Proposed (Integrated LNG Plant) normal operating conditions
- **Table 20**: Proposed (Integrated LNG Plant) upset operating conditions.

The shaded cells in **Table 18** and **Table 20** highlight differences from the normal operating condition scenarios for these two scenarios.

The modelled exhaust gas characteristics (temperatures, velocities etc) and pollutant emission rates used for the existing stack sources have been derived based on a review of on-site stack monitoring data, where available. Further details of the stack locations, exhaust gas parameters and emission rates modelled for each source are provided in **Appendix A**. The emission inventory for the non-power share mode is also presented in **Appendix A**, but as noted in **Section 6.4.1**, this scenario was not modelled as any off-site air quality impacts can be expected to be less than or similar to those predicted for the power share operations.

Table 17 Point Source Emission Inventory for the Existing PNG LNG Plant - Normal Operating Conditions

Plant Area	Plant Item	Stack Parameters				Modelled Emission Rates				
		Height (mAGL)	Diameter (m)	Velocity (m/s)	Temp (°C)	NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16+	24.0	535	12.07	7.35		1.36	
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16+	24.0	535	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #1	44.0	3.39+	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #2	44.0	3.39+	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #3	44.0	3.39+	15.5	332	12.07	7.35		1.36	
	Amine Regeneration Acid Gas Vent	54.0	0.54	7.6	42					15.50
Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16+	24.0	535	12.07	7.35		1.36	
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16+	24.0	535	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #1	44.0	3.39+	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #2	44.0	3.39+	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #3	44.0	3.39+	15.5	332	12.07	7.35		1.36	
	Amine Regeneration Acid Gas Vent	54.0	0.54	7.6	42					15.50
Power Generation	Power Generation Turbine #1	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #2	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #3	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #4	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
Furnaces	Regeneration Furnace (Train 1)	42.0	0.96	9.8	259	2.13	0.03		1.67	0.0003
	Regeneration Furnace (Train 2)	42.0	0.96	8.8	265	2.13	0.03		1.67	0.0003
	Hot Oil Heater Furnace	42.0	0.96	12.7	309	2.24	0.03		1.81	0.0003
Flares	Wet Flare *	93.8	0.15	20.0	1,000	0.012	0.665			
	Dry Flare *	94.1	0.20	20.0	1,000	0.012	0.665			
	Tankage Gas Flare *	65.9	0.16	20.0	1,000	0.009	0.050			
Incinerators	Process Sludge Incinerator	20.6	0.23	16.7	152	0.17	0.01	0.02	0.06	1.3×10^{-10}
TOTAL SITE						**151.4**	**89.4**	**0.02**	**21.6**	**31.0**

* The stack parameters shown for the flares are the effective stack height and effective stack diameter calculated using the Ohio EPA modelling methodology. Refer to **Table 21** for details.

+ Effective diameter. Stack is rectangular and the diameter used in the modelling gives the same cross-sectional area . Refer to **Appendix A** for details.

Table 18 Point Source Emission Inventory for the Existing PNG LNG Plant – Upset Operating Conditions

Plant Area	Plant Item	Stack Parameters				Modelled Emission Rates				
		Height (mAGL)	Diameter (m)	Velocity (m/s)	Temp (°C)	NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16^{+}							
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16^{+}							
	MR Compressor Gas Turbine Driver #1	44.0	3.39^{+}							
	MR Compressor Gas Turbine Driver #2	44.0	3.39^{+}							
	MR Compressor Gas Turbine Driver #3	44.0	3.39^{+}							
	Amine Regeneration Acid Gas Vent	54.0	0.54							
Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16^{+}	24.0	535	12.07	7.35		1.36	
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16^{+}	24.0	535	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #1	44.0	3.39^{+}	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #2	44.0	3.39^{+}	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #3	44.0	3.39^{+}	15.5	332	12.07	7.35		1.36	
	Amine Regeneration Acid Gas Vent	54.0	0.54	7.6	42					15.50
Power Generation	Power Generation Turbine #1	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #2	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #3	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #4	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
Furnaces	Regeneration Furnace (Train 1)	42.0	0.96	9.8	259	2.13	0.03		1.67	0.0003
	Regeneration Furnace (Train 2)	42.0	0.96	8.8	265	2.13	0.03		1.67	0.0003
	Hot Oil Heater Furnace	42.0	0.96	12.7	309	2.24	0.03		1.81	0.0003
Flares	Wet Flare *	215.5	28.29	20.0	1,000	900	4,800			
	Dry Flare *	281.9	44.50	20.0	1,000	2,250	11,800			
	Tankage Gas Flare *	112.3	10.44	20.0	1,000	100	520			
Incinerators	Process Sludge Incinerator	20.6	0.23	16.7	152	0.17	0.01	0.02	0.06	1.3×10^{-10}
TOTAL SITE						**3,341**	**17,171**	**0.02**	**14.8**	**15.5**

* The stack parameters shown for the flares are the effective stack height and effective stack diameter calculated using the Ohio EPA modelling methodology. Refer to **Table 21** for details.

$^{+}$ Effective diameter. Stack is rectangular and the diameter used in the modelling gives the same cross-sectional area . Refer to **Appendix A** for details.

Blue shaded cells highlight changes from the normal operating conditions emission inventory

Table 19 Point Source Emission Inventory for the Proposed Integrated LNG Plant - Normal Operating Conditions

Plant Area	Plant Item	Stack Parameters				Modelled Emission Rates				
		Height (mAGL)	Diameter (m)	Velocity (m/s)	Temp (°C)	NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16[+]	24.0	535	12.07	7.35		1.36	
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16[+]	24.0	535	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #1	44.0	3.39[+]	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #2	44.0	3.39[+]	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #3	44.0	3.39[+]	15.5	332	12.07	7.35		1.36	
	Amine Regeneration Acid Gas Vent	54.0	0.54	7.6	42					15.50
Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16[+]	24.0	535	12.07	7.35		1.36	
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16[+]	24.0	535	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #1	44.0	3.39[+]	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #2	44.0	3.39[+]	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #3	44.0	3.39[+]	15.5	332	12.07	7.35		1.36	
	Amine Regeneration Acid Gas Vent	54.0	0.54	7.6	42					15.50
Power Generation	Power Generation Turbine #1	30.2	1.83							
	Power Generation Turbine #2	30.2	1.83							
	Power Generation Turbine #3	30.2	1.83							
	Power Generation Turbine #4	30.2	1.83							
Furnaces	Regeneration Furnace (Train 1)	42.0	0.96	9.8	259	2.13	0.03		1.67	0.0003
	Regeneration Furnace (Train 2)	42.0	0.96	8.8	265	2.13	0.03		1.67	0.0003
	Hot Oil Heater Furnace	42.0	0.96	12.7	309	2.24	0.03		1.81	0.0003
Flares	Wet Flare *	93.8	0.15	20.0	1,000	0.012	0.665			
	Dry Flare *	94.1	0.20	20.0	1,000	0.012	0.665			
	Tankage Gas Flare *	65.9	0.16	20.0	1,000	0.009	0.050			
Incinerators	Process Sludge Incinerator	20.6	0.23	16.7	152	0.17	0.01	0.02	0.06	1.3×10^{-10}
Papua LNG (Trains 3-6)	CCPP - Siemens SGT 800 Gas Turbine Generator #1	19.4	3.0	23.8	208	54.56	13.26	***variable***	0.81	0.0072
	CCPP - Siemens SGT 800 Gas Turbine Generator #2	19.4	3.0	23.8	208	54.56	13.26	***variable***	0.81	0.0072
	CCPP - Siemens SGT 800 Gas Turbine Generator #3	19.4	3.0	23.8	208	54.56	13.26	***variable***	0.81	0.0072

Plant Area	Plant Item	Stack Parameters				Modelled Emission Rates				
		Height (mAGL)	Diameter (m)	Velocity (m/s)	Temp (°C)	NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
	CCPP - Siemens SGT 800 Gas Turbine Generator #4	19.4	3.0	23.8	208	54.56	13.26	***variable***	0.81	0.0072
	Emergency Diesel Generator #1	20.0	3.0							
	Emergency Diesel Generator #2	20.0	3.0							
	Emergency Diesel Generator #3	20.0	3.0							
	Hot Oil Furnace	42.0	1.6	6.5	340	5.59	0.08		4.39	0.0007
	Wet Flare #2*	70.8	0.15	20.0	1,000	0.01	0.66			
	Dry Flare #2*	71.1	0.20	20.0	1,000	0.01	0.66			
	Inlet Liquid Separator Thermal Oxidiser	10.0	0.12	7.0	71	0.163	0.023	0.010	0.011	
	Sludge Incinerator	20.6	0.23	30.0	180	1.044	0.010	***variable***	0.097	$1.4x10^{-10}$
	New Waste incinerator	10.0	1.20	20.0	275	15.28	7.64	3.8	0.76	
TOTAL SITE						**368**	**137**	***variable***	**27.3**	**31.0**

* The stack parameters shown for the flares are the effective stack height and effective stack diameter calculated using the Ohio EPA modelling methodology. Refer to **Table 21** for details.
[+] Effective diameter. Stack is rectangular and the diameter used in the modelling gives the same cross-sectional area . Refer to **Appendix A** for details.

Table 20 Point Source Emission Inventory for the Proposed Integrated LNG Plant – Non Routine Operating Conditions

Plant Area	Plant Item	Stack Parameters				Modelled Emission Rates				
		Height (mAGL)	Diameter (m)	Velocity (m/s)	Temp (°C)	NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16$^+$	24.0	535	12.07	7.35		1.36	
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16$^+$	24.0	535	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #1	44.0	3.39$^+$	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #2	44.0	3.39$^+$	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #3	44.0	3.39$^+$	15.5	332	12.07	7.35		1.36	
	Amine Regeneration Acid Gas Vent	54.0	0.54	7.6	42					15.50
Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1	42.9	3.16$^+$	24.0	535	12.07	7.35		1.36	
	Propane Refrigerant Compressor Gas Turbine Driver #2	42.9	3.16$^+$	24.0	535	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #1	44.0	3.39$^+$	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #2	44.0	3.39$^+$	15.5	332	12.07	7.35		1.36	
	MR Compressor Gas Turbine Driver #3	44.0	3.39$^+$	15.5	332	12.07	7.35		1.36	
	Amine Regeneration Acid Gas Vent	54.0	0.54	7.6	42					15.50
Power Generation	Power Generation Turbine #1	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #2	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #3	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
	Power Generation Turbine #4	30.2	1.83	40.1	529	6.00	3.60		0.70	0.0095
Furnaces	Regeneration Furnace (Train 1)	42.0	0.96	9.8	259	2.13	0.03		1.67	0.0003
	Regeneration Furnace (Train 2)	42.0	0.96	8.8	265	2.13	0.03		1.67	0.0003
	Hot Oil Heater Furnace	42.0	0.96	12.7	309	2.24	0.03		1.81	0.0003
Flares	Wet Flare *	93.8	0.15	20.0	1,000	0.012	0.665			
	Dry Flare *	94.1	0.20	20.0	1,000	0.012	0.665			
	Tankage Gas Flare *	65.9	0.16	20.0	1,000	0.009	0.050			
Incinerators	Process Sludge Incinerator	20.6	0.23	16.7	152	0.17	0.01	0.02	0.06	1.3×10^{-10}
Papua LNG (Trains 3-6)	CCPP - Siemens SGT 800 Gas Turbine Generator #1	19.4	3.0							
	CCPP - Siemens SGT 800 Gas Turbine Generator #2	19.4	3.0							
	CCPP - Siemens SGT 800 Gas Turbine Generator #3	19.4	3.0							

Plant Area	Plant Item	Stack Parameters				Modelled Emission Rates				
		Height (mAGL)	Diameter (m)	Velocity (m/s)	Temp (°C)	NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
	CCPP - Siemens SGT 800 Gas Turbine Generator #4	19.4	3.0							
	Emergency Diesel Generator #1	20.0	3.0	20.0	350	12.71	2.05	0.0078	0.09	
	Emergency Diesel Generator #2	20.0	3.0	20.0	350	12.71	2.05	0.0078	0.09	
	Emergency Diesel Generator #3	20.0	3.0	20.0	350	12.71	2.05	0.0078	0.09	
	Hot Oil Furnace	42.0	1.6							
	Wet Flare #2*	70.8	0.15	20.0	1,000	2,300	12,500	1,140		
	Dry Flare #2*	71.1	0.20	20.0	1,000	0.01	0.66			
	Inlet Liquid Separator Thermal Oxidiser	10.0	0.12							0
	Sludge Incinerator	20.6	0.23							
	New Waste incinerator	10.0	1.20	20.0	275	15.28	7.64	3.8	0.76	
TOTAL SITE						**2,505**	**12,604**	**1,143.8**	**22.6**	**31.0**

* The stack parameters shown for the flares are the effective stack height and effective stack diameter calculated using the Ohio EPA modelling methodology. Refer to **Table 21** for details.

+ Effective diameter. Stack is rectangular and the diameter used in the modelling gives the same cross-sectional area . Refer to **Appendix A** for details.

Variable SO_2 Emission Rates

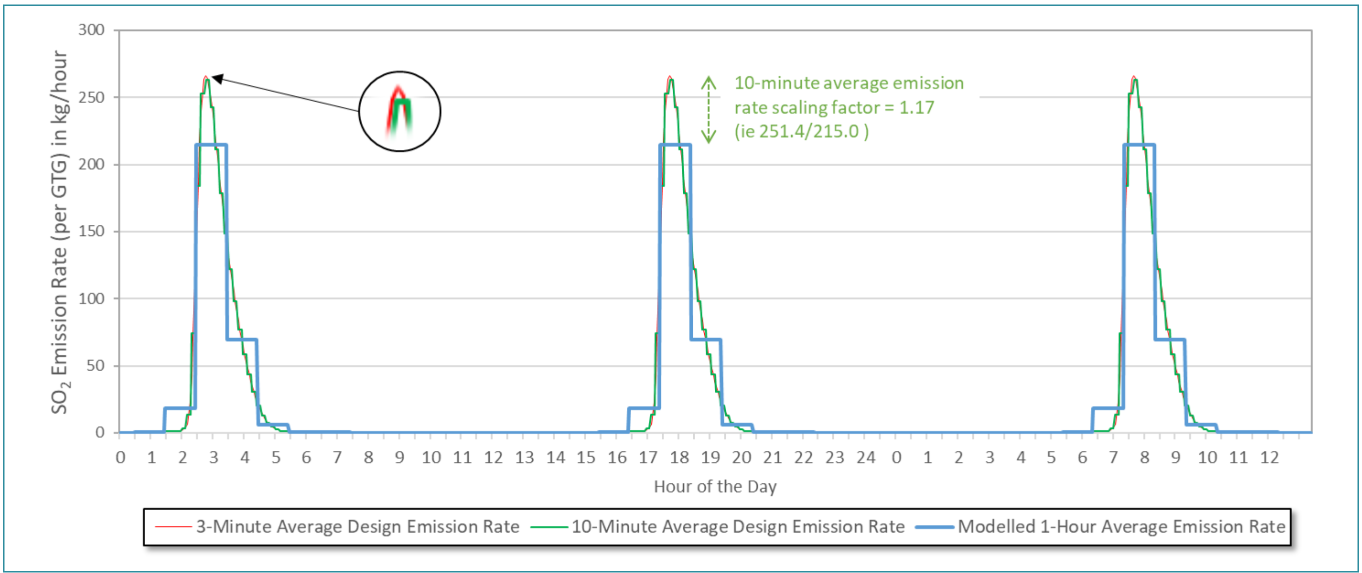
As shown in **Table 19** and discussed in **Section 3.2**, SO_2 emissions from the CCPP GTGs will be variable. This is because the regeneration gas recovered from the molecular sieves will be used as a source of high-pressure fuel gas for the CCPP, which will result in the sulfur content of the fuel gas peaking every 15 hours during the regeneration step and then reducing to trace amounts once the mole sieve bed has been regenerated. This gas will also be used in the new sludge incinerator, which will also therefore have a cyclical peak similar to the CCPP in the SO_2 emission rate, occurring at the same times.

The design and modelled SO_2 emission rates for the CCPP GTGs are shown in **Figure 19**. The shape of the peak will be controlled to ensure the maximum SO_2 discharge rate does not exceed the design value shown.

As the modelling was performed on a 1-hour time-step, the design emission profile was modelled based on the calculated 1-hour average emission rates over the emission cycle as shown by the blue line in **Figure 19**. The SO_2 emission rates from the new sludge incinerator were modelling using the same profile, but with significantly lower emission rates due to the lower gas flowrate, peaking at only 1.7 kg/hr.

As outlined in **Section 6.2.4**, in order to estimate the peak 10-minute average ground level SO_2 concentrations, a scaling factor of 1.43 was applied to the 1-hour predictions given by the model. This factor accounts for the more limited plume meander that occurs over a 10-minute period compared to a 1-hour period, and is based on conservative assumptions regarding the atmospheric stability (Turner, 1994). In addition to this, a factor of 1.17 was also applied to account for the peak 10-minute average emission rate compared to the 1-hour average emission rate used in the modelling, as shown in **Figure 19**.

Figure 19 GTG SO_2 Emission Rates



To ensure that the SO_2 modelling results cover the peak concentrations that could potentially occur over all potential meteorological concentrations in the modelling file, eight separate modelling runs were performed for the CCPP GTGs and sludge incinerator stack emissions, with the peak emission rates for all sources shifted by two hours in each run. For example, in Run 1 the increase in SO_2 emission rates started at hour 1, in Run 2 the increase started in hour 3, in Run 3 the increase started in hour 5, and so on. The predicted highest downwind SO_2 concentrations for these runs was then used in the cumulative impact assessment with the other SO_2 emission sources. This approach ensures that the worst-case meteorological conditions are captured without over-predicting the 24-hour and annual average SO_2 concentrations, or the risk of any unrealistic pooling or accumulation of SO_2 over consecutive hours being predicted within the model (as would be the case if a constant peak emission rate was used).

All other stacks were assumed to emit continuously, 24 hours per day, 7 days per week, unless noted otherwise in **Appendix A.**

Flare Parameter Calculations

As noted under **Table 17** to **Table 20**, the stack heights and diameters shown in these tables (and in **Appendix A**) for the flares are the effective stack heights and diameters used in the modelling, not the physical flare height or diameter. Flares are non-standard point sources that are modelled based on plume rise characteristics calculated for the flame tip based on the total flared gas heat release rate. For this study, the Ohio Environmental Protection Agency (Ohio EPA) guidance (Ohio EPA, 2018) for calculating model inputs for flares has been used to calculate the effective stack heights and diameters. This methodology involves the following:

- Temperature is assumed to be 1,000°C
- Initial vertical velocity is assumed to be 20 m/s
- Effective stack height is calculated using the equation:

$$h_{eff} = h_s + 1.70 \times Q_t^{0.478}$$

where:

h_{eff} = effective stack height (m)

h_s = physical flare height (m)

Q_t = total flared gas heat release rate in megawatts (MW)

- Effective stack diameter is calculated using the equation:

$$d_{eff} = \sqrt{\frac{4}{g v_s} \times \left(\frac{T_s}{T_s - T_a}\right) \times F_b}$$

where:

d_{eff} = effective stack diameter (m)

g = acceleration due to gravity (9.81 m/s^2)

v_s = stack exit velocity (assumed to be 20 m/s)

T_s = stack exit temperature (assumed to be 1,000°C)

T_a = ambient temperature (assumed to be 30°C)

F_b = buoyancy flux (m^4/s^3)

- Buoyancy flux is calculated using the equation:

$$F_b = \frac{g \times Q_s}{\pi \rho_a c_{pa} T_a}$$

  where:

  d_{eff} = effective stack diameter (m)

  g = acceleration due to gravity (9.81 m/s)

  Q_s = stack sensible heat emission (J/s)

  ρ_a = ambient air density (1.183 kg/m^3)

  c_{pa} = specific heat of ambient air (1,004 J/kg-K)

- For flares, $Q_s = Q_t - (1 - f_{hl})$, where f_{hl} is the radiative heat lost fraction. This study has used the Ohio EPA default value of 0.55 for f_{hl}.

A summary of the plume calculations is provided in **Table 21**.

Table 21 Summary of Flare Parameter Calculations

Source	H_s (m)	Quantity of Gas Flared (Sm^3/hr)	Q_T (MJ/s)	Q_S (MJ/s)	F_b (m^4/s^3)	H_{eff} (m)	D_{eff} (m)
Existing LNG Plant Normal Operating Conditions							
Wet Flare	93.0	26.05	0.211	0.095	0.82	93.8	0.15
Dry Flare	93.0	47.58	0.385	0.173	1.50	94.1	0.20
Tankage Gas Flare	65.0	32.32	0.261	0.117	1.02	65.9	0.16
Project facilities Normal Operating Conditions							
Wet Flare #2	70	26.05	0.211	0.095	0.82	70.8	0.15
Dry Flare #2	70	47.58	0.385	0.173	1.50	71.1	0.20
Source	**H_s (m)**	**Quantity of Gas Flared (tons/hr)**	**Q_T (MJ/s)**	**Q_S (MJ/s)**	**F_b (m^4/s^3)**	**H_{eff} (m)**	**D_{eff} (m)**
Existing LNG Plant Upset Operating Conditions							
Wet Flare	93.0	620.0	7,703	3,466	30,076	215.5	28.3
Dry Flare	93.0	1,520.6	19,055	8,575	74,403	281.9	44.5
Tankage Gas Flare	65.0	100.6	1,049	472	4,097	112.3	10.4
Project facilities Upset Operating Conditions							
Wet Flare #2	70	912.0	15,364	6,914	59,988	240.4	40.0
Dry Flare #2	70	1,088.0	11,277	5,075	44,031	217.0	34.2

In the Papua facilities, only Wet Flare #2 or Dry Flare #2 would be operating at its maximum flare flowrate at any point in time; they would not operate at full flow concurrently. For the proposed upset operating conditions scenario, Dry Flare #2 was therefore modelled at full flaring capacity to provide a worst case assessment.

The SO_2 emission rate modelled for the proposed operations relates to the flaring of stored RSH/H_2S containing gases from the adsorption bed, and is based on a peak design value of 1,140 kg/hr. This would be a very short duration scenario with the total amount of SO_2 that would be released over the event estimated at less than 1,500 kg/hr. The probability of this event occurring is estimated at less than 0.1%, which is equivalent to 1 in 1,000 hours of operation.

Fugitive Emissions

In addition to the stack emissions presented in **Table 17** to **Table 20**, fugitive VOC (specifically, benzene) emissions from the PNG LNG Plant and proposed Project facilities were also included in the modelling for each scenario as relevant. These emissions were modelled as volume sources as outlined in **Table 22**. Fugitive emissions of other air pollutants included in the assessment will be negligible.

The initial vertical and horizontal spreads use to characterise the fugitive benzene sources in the model were derived based on the approximate height and length of each train divided by four, as per standard modelling practice. The analyser house emissions are vented at very low flow rates from small vents at approximately 7 m above ground level and were modelled as small, elevated volume sources.

Table 22 Fugitive Emission Sources Included in the Modelling

Plant Area	Description	Release Height (m)	Initial Horizontal Spread (m)	Initial Vertical Spread (m)	Benzene Emission (kg/hr)
LNG Plant (Trains 1 and 2)	Plant Fugitives - Trains 1 and 2	2.0	52.3	4.7	0.0108
	Analyser House AH9101	7.0	2.0	1.0	0.0050
	Analyser House AH9201	7.0	2.0	1.0	0.0050
	Analyser House AH9501	7.0	2.0	1.0	0.0020
	Analyser House AH9801	7.0	2.0	1.0	0.0030
Papua LNG (Train 3-6)	Plant Fugitives - Train 3-6	2.0	52.3	4.7	0.0108
	Analyzer House-1	7.0	2.0	1.0	1.0100
	Analyzer House-2	7.0	2.0	1.0	1.0100
	Analyzer House-3	7.0	2.0	1.0	1.0100
	Analyzer House-4	7.0	2.0	1.0	1.0100

6.4.3 Shipping Emissions

The modelling for both normal and upset operations included emissions to air associated with LNG carriers, condensate tankers and tugboat operating at the jetty for current operations, and at the jetty and CALM buoy for proposed operations. The source characteristics used in the modelling for each were as follows:

- LNG carriers and condensate tankers:
    - 20 m release height
    - 0.8 m diameter
    - 25 m/s exit velocity

    - 282°C exhaust temperature
- Tugboats:
    - 10 m release height
    - 0.8 m diameter
    - 10 m/s exit velocity
    - 282°C exhaust temperature

The pollutant emission rates entered into the model are shown in **Table 23**. The source characteristics and emission rates were sourced from a detailed air dispersion modelling performed in 2010 for the shipping operations at the PNG LNG Plant (URS, 2010). The short-term peak emissions represent worst case emissions associated with the manoeuvring mode, when the main propulsion engine and auxiliary engine will be operated. Once berthed (hotelling mode), only the auxiliary engine will be operated. The 24-hour and annual average emission rate estimates are time weighted averages based on the period of time spent in each mode over these time periods. Further details on the basis of the estimates are provided in **Appendix A**.

Table 23 Emission Rates Modelled for Shipping Operations at the Jetty and CALM Buoy

Source	Maximum 1-Hour Emission Rates (kg/hr)				24 Hour Average Emission Rates (kg/hr)				Annual Average Emission Rates (kg/hr)			
	NO_X	CO	SO_2	PM	NO_X	CO	SO_2	PM	NO_X	CO	SO_2	PM
CURRENT OPERATIONS												
LNG Carrier - hotelling	0.00	0.00	0.00	0.00	13.87	1.10	4.23	0.49	2.35	0.19	0.72	0.08
LNG Carrier - manoeuvres	22.42	1.81	5.92	0.70	0.93	0.08	0.25	0.03	0.27	0.02	0.07	0.01
Condensate Tanker - hotelling	0.00	0.00	0.00	0.00	13.87	1.10	4.23	0.49	0.26	0.02	0.08	0.01
Condensate Tanker - manoeuvres	26.11	2.11	6.70	0.80	1.09	0.09	0.28	0.03	0.04	<0.01	0.01	<0.01
Tugboats (2 of) - hotelling	0.00	0.00	0.00	0.00	0.52	0.04	0.16	0.02	0.17	0.01	0.05	0.01
Tugboats (2 of) - manoeuvres	68.78	5.58	17.00	2.04	2.87	0.23	0.71	0.09	0.91	0.07	0.23	0.03
	117.31	**9.50**	**29.62**	**3.54**	**33.14**	**2.63**	**9.85**	**1.14**	**3.99**	**0.32**	**1.15**	**0.13**
PROPOSED OPERATIONS												
BERTH												
LNG Carrier - hotelling	0.00	0.00	0.00	0.00	13.87	1.10	4.23	0.49	3.79	0.30	1.16	0.13
LNG Carrier - manoeuvres	22.42	1.81	5.92	0.70	0.93	0.08	0.25	0.03	0.43	0.03	0.11	0.01
Tugboats (2 of) - hotelling	0.00	0.00	0.00	0.00	0.52	0.04	0.16	0.02	0.27	0.02	0.08	0.01
Tugboats (2 of) - manoeuvres	68.78	5.58	17.00	2.04	2.87	0.23	0.71	0.09	1.47	0.12	0.36	0.04
	91.20	**7.39**	**22.92**	**2.74**	**18.19**	**1.44**	**5.34**	**0.62**	**5.95**	**0.47**	**1.71**	**0.20**
CALM BUOY												
Condensate Tanker - hotelling	0.00	0.00	0.00	0.00	13.87	1.10	4.23	0.49	0.51	0.04	0.16	0.02
Condensate Tanker - manoeuvres	26.11	2.11	6.70	0.80	1.09	0.09	0.28	0.03	0.07	0.01	0.02	0.00
Tugboats (2 of) - hotelling	0.00	0.00	0.00	0.00	0.52	0.04	0.16	0.02	0.33	0.03	0.10	0.01
Tugboats (2 of) - manoeuvres	68.78	5.58	17.00	2.04	2.87	0.23	0.71	0.09	1.83	0.15	0.45	0.05
	94.89	**7.69**	**23.70**	**2.84**	**18.34**	**1.46**	**5.38**	**0.62**	**2.75**	**0.22**	**0.73**	**0.09**

6.4.4 Third Party Power Station Emissions

The off-site emission sources included in the modelling included:

- Niu Power Energy’s 58 MW gas-fired power station, located 2.8 km east-northeast of the LNG Plant’s existing flare stack; and
- Dirio Gas and Power’s 47 MW gas-fired power station, approximately 300 m east of the Niu Power Energy site (under construction).

A summary of the stack and emission data used to model emissions from these facilities is provided in **Table 24**. Further details are provided in **Appendix A**.

Table 24 Emission Inventories for Third Party Power Stations

Source	Stack Parameters				Modelled Emission Rates				
	Height	Diameter	Velocity	Temp	NO_x	CO	SO_2	PM_{10}	Benzene
	(mAGL)	(m)	(m/s)	(°C)	(kg/hr)	(kg/hr)	(kg/hr)	(kg/hr)	(kg/hr)
NiuPower Power Station									
Main Stack [a]	27.5	2.900	27.1	364	38.88	79.20	0.025	4.00	0.0202
Dirio Power Plant									
Solar Titan PGT	30.0	1.83	40.1	529	6.00	3.60	-	0.70	0.0095
Solar Titan PGT	30.0	1.83	40.1	529	6.00	3.60	-	0.70	0.0095
Solar Titan PGT	30.0	1.83	40.1	529	6.00	3.60	-	0.70	0.0095

[a] Six Wartsila 20V34SG gas engines venting through a multi-flue stack (without CO catalyst).

7 Air Quality Impact Assessment

7.1 Assessment of Construction Phase Air Quality Impacts

The Papua LNG Plant construction works will involve the construction of both onshore facilities and marine facilities in Caution Bay, and construction of the Project is expected to take approximately four years. The nearest sensitive receptors are scattered dwellings to the north of the LNG Plant site, with the closest houses located within 50 to 200 m of the site boundary. Some of these houses have attached gardens/plantations that could also be adversely affected if dust emissions from the construction works are not appropriately controlled.

Temporary facilities including laydown areas, offices, workshops and concrete batching plants will be constructed within the existing LNG Plant perimeter fence, except for one temporary construction laydown area that will be located outside of the perimeter fence but within the Lease Boundary. The construction camp will be established within the LNG Plant site, to the east of the existing operations camp.

Site preparation, including vegetation clearance, grading and some excavation, will commence in parallel with some elements of the detailed design process. The LNG Plant site is largely already cleared of vegetation, although some remnant patches will need to be cleared, including an approximately 60 ha laydown area located outside of the security fence to the east of the LNG Plant. Clearing of vegetation for construction of new infrastructure and facilities will be undertaken so to minimise the potential for soil erosion from exposed surfaces. Vegetation will be cut as close as possible to the ground without striking the earth. Cut vegetation will be carried to a designated stockpile area for later reuse for soil stabilisation and rehabilitation works and will not infringe upon areas required for maintenance and operations. Stockpiles will be stabilised, and erosion control measures implemented in accordance with the Project's environmental management plan.

Greenfield construction sites will be graded and excavated to the designed levels and slope to provide a base for the new and expanded accommodation camps, new LNG trains, waste management facilities, storage tanks, a retention pond and associated infrastructure. These activities will be undertaken using front-end loaders, bulldozers, graders, excavators, rollers, and dump trucks. No drilling or blasting is expected to be required. Water trucks, water sprays or dust suppressants will be used as necessary to manage dust. Areas will be trimmed to final grade and compacted.

Following site preparation, equipment foundations, subsurface drains and electrical cables will be installed. The foundation construction for the new LNG trains and storage tanks will begin shortly after early site preparation. Two concrete batching plants will supply concrete to mixing trucks, which will pour the foundations for the new trains.

Most construction materials will be imported by ship via Motukea Port and trucked to site along Lea Lea Road. Transport of construction and operations personnel from Port Moresby will also occur along this road. The logistics strategy for the Project aims to provide orderly movement of personnel into, out of and within Papua New Guinea, organise a transportation network across all modes of transport and ensure logistics infrastructure and support arrangements are in place to operate the Project. Emissions to air, including exhaust emissions and wheel-generated dust, will thereby be minimised through this logistics strategy and by ensuring that designated access routes are appropriately designed, upgraded where required, and maintained to minimise dust emissions.

Water trucks, water sprays or dust suppressants will also be used as necessary to manage dust. An additional seawater intake facility is proposed to be installed on the existing LNG Plant jetty trestle. The seawater will be pumped to a temporary desalination that will provide most of the water used during construction including for equipment washing and dust control.

While there is potential for short-term elevations in dust levels close to the construction areas, particularly during vegetation clearance and earthworks, no long-term air quality impacts would be expected to occur as a result of air emissions during the construction phase. Revegetation of cleared areas will ensure rapid stabilisation of exposed soils and any settled dust is likely to be cleaned off vegetation and other surfaces relatively quickly by rain.

With good practice air quality management, there would be a low risk of adverse dust soiling and human health impacts at the nearest sensitive receptors during the construction phase of the project. Any impacts would be highly localised and are expected to be able to be managed through targeted dust suppression, supported by and consultation with potentially affected sensitive receptors.

7.2 Assessment of Operational Phase Air Quality Impacts

7.2.1 Modelling Results Summary

The cumulative (including shipping and third party power station emissions) ground level concentrations predicted by the modelling for each of the assessment scenarios are presented in **Table 25** to **Table 28**. Isopleth plots presenting the spatial distribution of the predicted concentrations of each pollutant for each averaging period are presented in the appendices as follows:

- **Appendix B**: Current (PNG LNG Plant) operations – normal and upset operating conditions
- **Appendix C**: Proposed (PNG LNG Plant and Papua LNG) integrated operations – normal and upset operating conditions.

In relation to the results presented, it is noted that:

- All modelling predictions for averaging periods of 1-hour or less are the 99.9th percentile prediction (ie, the 9th highest prediction over the one year (8,760 hours) modelling period). This is standard practice in air quality impact assessments for peak short-term predictions, as it avoids the compliance assessment being based on extreme peak results generated by the model that may be statistical outliers. This was the same approach used in the original 2009 AQIA performed as part of the PNG LNG EIS (Holmes Air Sciences, 2009).
- The NO_2 concentrations presented have been calculated from the total NO_X concentrations predicted by the model using the OLM approach and based on the maximum ozone concentrations measured at the LNG Plant site in 2015-2016 (see **Section 5.5**).
- Given the inherent accuracy of emissions estimation and air dispersion models, the results are presented to no more than two significant figures.
- As the upset operational scenarios would occur for a relatively short period of time, long-term (annual average) modelling results are not presented for these scenarios. In addition, as the peak SO_2 flaring rates modelled for the proposed operations occurs over less than two hours, 24-hour average SO_2 predictions are also not relevant for the proposed upset operations scenario and are not presented.

The model predictions for each pollutant assessed are discussed in the following sections.

Table 25 Maximum Predicted Cumulative Ground Level Concentrations – Current (PNG LNG Plant) Normal Operations

Receptor ID	CO ($\mu g/m^3$)		NO_2 ($\mu g/m^3$)			PM_{10} ($\mu g/m^3$)		SO_2 ($\mu g/m^3$)			Benzene ($\mu g/m^3$)
	1-Hour Average	8-Hour Average	1-Hour Average	24-Hour Average	Annual Average	24-Hour Average	Annual Average	10-Min Average	1-Hour Average	24-Hour Average	Annual Average
Papa 1	12	5.2	23	3.3	0.67	0.50	<0.1	7.1	4.6	0.28	0.14
Papa 2	13	5.9	120	5.5	1.5	1.3	0.28	46	30	0.67	0.78
Papa 3	16	7.8	56	6.2	2.1	1.2	0.37	21	14	0.88	0.87
Papa 4	15	9.7	31	6.1	1.0	1.0	0.17	11	7.3	0.43	0.38
Papa 5	14	8.6	46	6.5	1.7	1.1	0.29	17	11	0.67	0.69
Boera 1	11	7	34	7.3	0.27	1.2	<0.1	13	8.5	0.46	0.22
Boera 2	11	8.1	44	8.4	0.24	1.3	<0.1	17	11	0.40	0.22
Boera 3	9.7	9.1	25	7.0	0.25	1.1	<0.1	9.6	6.3	0.83	0.17
Boera 4	11	5.8	32	5.5	0.27	1.0	<0.1	12	8.0	0.71	0.21
Porebada 1	9.7	5.9	20	4.7	0.20	0.7	<0.1	7.7	5.0	0.61	0.10
Porebada 2	6.6	4.3	17	2.8	0.17	0.6	<0.1	6.8	4.4	0.54	0.09
Edai Town	7.6	2.8	23	2.5	0.25	0.4	<0.1	8.7	5.7	0.22	0.09
Bible School	13	7.1	20	5.3	0.64	0.9	<0.1	6.3	4.1	0.25	0.15
Residence 1	16	12	42	8.8	2.4	1.8	0.44	16	11	0.57	1.1
Residence 2	16	11	43	8.0	2.1	1.6	0.39	16	10	0.62	0.97
Residence 3	16	9.8	49	8.0	2.2	1.4	0.39	19	12	0.68	0.94
Residence 4	16	11	32	7.0	1.2	1.2	0.22	12	8.0	0.44	0.49
Maximum at sensitive receptors	***16***	***12***	***120***	***8.8***	***2.4***	***1.8***	***0.44***	***46***	***30***	***0.88***	***1.1***
Maximum at PPFL-2 Boundary	***41***	***26***	***210***	***15***	***2.9***	***2.9***	***0.65***	***170***	***110***	***3.0***	***2.8***
Maximum off-site	***64***	***42***	***220***	***14***	***2.8***	***2.8***	***0.59***	***140***	***93***	***3.7***	***2.8***
Assessment Criteria	**30,000**	**10,000**	**200**	**25**	**10**	**45**	**15**	**500**	**200**	**20**	**5**

Table 26 Maximum Predicted Ground Level Cumulative Concentrations – Current (PNG LNG Plant) Upset Operations

Receptor ID	CO ($\mu g/m^3$)		NO_2 ($\mu g/m^3$)		PM_{10} ($\mu g/m^3$)	SO_2 ($\mu g/m^3$)	
	1-Hour Average	8-Hour Average	1-Hour Average	24-Hour Average	24-Hour Average	10-Minute Average	1-Hour Average
Papa 1	34	18	21	2.8	0.38	7.1	4.6
Papa 2	29	30	120	3.7	1.1	46	30
Papa 3	27	28	56	4.2	1.0	21	14
Papa 4	27	20	30	4.0	0.86	11	7.3
Papa 5	29	27	45	4.8	0.83	17	11
Boera 1	11	12	34	4.7	0.89	13	8.5
Boera 2	12	11	44	5.3	0.94	17	11
Boera 3	12	12	25	4.5	0.80	9.6	6.3
Boera 4	12	12	32	3.4	0.97	12	8.0
Porebada 1	12	6.3	20	3.4	0.54	7.7	5.0
Porebada 2	9.5	6.5	17	2.1	0.47	6.8	4.4
Edai Town	16	11	23	2.1	0.29	8.7	5.7
Bible School	30	19	19	3.6	0.69	6.3	4.1
Residence 1	27	25	42	6.5	1.5	16	11
Residence 2	27	24	42	6.0	1.3	16	10
Residence 3	28	24	49	5.8	1.2	19	12
Residence 4	25	21	32	4.5	1.1	12	8.0
Maximum at sensitive receptors	***34***	***30***	***120***	***6.5***	***1.5***	***46***	***30***
Maximum at PPFL-2 Boundary	***45***	***31***	***210***	***10***	***2.6***	***170***	***110***
Maximum off-site	***68***	***44***	***200***	***13***	***2.5***	***140***	***93***
Assessment Criteria	**30,000**	**10,000**	**200**	**25**	**45**	**500**	**200**

Table 27 Maximum Predicted Ground Level Cumulative Concentrations – Proposed Integrated LNG Plant Normal Operations

Receptor ID	CO (µg/m³)		NO_2 (µg/m³)			PM_{10} (µg/m³)		SO_2 (µg/m³)			Benzene (µg/m³)
	1-Hour Average	8-Hour Average	1-Hour Average	24-Hour Average	Annual Average	24-Hour Average	Annual Average	10-Min Average	1-Hour Average	24-Hour Average	Annual Average
Papa 1	15	7.8	43	8.7	1.6	0.71	0.12	123	56	7.0	0.22
Papa 2	16	11	120	18	4.0	1.6	0.36	196	88	13	1.1
Papa 3	18	12	65	19	5.8	1.5	0.49	259	117	15	1.3
Papa 4	18	13	58	17	3.7	1.2	0.25	268	121	17	0.64
Papa 5	18	10	56	14	4.8	1.3	0.39	259	117	9.6	1.0
Boera 1	16	11	46	21	0.63	1.5	0.06	115	52	16	0.35
Boera 2	15	11	50	18	0.54	1.6	0.06	85	38	12	0.37
Boera 3	15	12	44	16	0.61	1.4	0.06	95	43	12	0.25
Boera 4	15	10	46	17	0.65	1.2	0.06	102	46	13	0.32
Porebada 1	14	9.1	45	16	0.49	1.0	0.04	83	38	13	0.12
Porebada 2	9.4	4.5	35	6.2	0.39	0.71	0.03	52	24	5.7	0.11
Edai Town	11	5.2	37	7.2	0.57	0.49	0.05	56	25	5.5	0.12
Bible School	17	9.0	46	11	1.4	1.1	0.12	132	60	7.3	0.21
Residence 1	19	14	60	19	7.1	2.1	0.60	349	158	13	1.7
Residence 2	19	13	59	17	6.4	1.9	0.53	336	152	11	1.4
Residence 3	19	12	57	17	6.1	1.7	0.52	276	125	12	1.4
Residence 4	19	14	60	18	4.6	1.5	0.31	292	132	18	0.84
Maximum at sensitive receptors	***19***	***14***	***120***	***21***	***7.1***	***2.1***	***0.60***	**349**	**158**	***18***	***1.7***
Maximum at PPFL-2 Boundary	***41***	***27***	***210***	***36***	***8.7***	***3.6***	***0.86***	**383**	**173**	***23***	***3.7***
Maximum off-site	***65***	***43***	***200***	***36***	***8.4***	***3.4***	***0.79***	**364**	**164**	***25***	***3.8***
Assessment Criteria	**30,000**	**10,000**	**200**	**25**	**10**	**45**	**15**	**500**	**200**	**20**	**5**

Table 28 Maximum Predicted Ground Level Cumulative Concentrations – Proposed Integrated LNG Plant Upset Operations

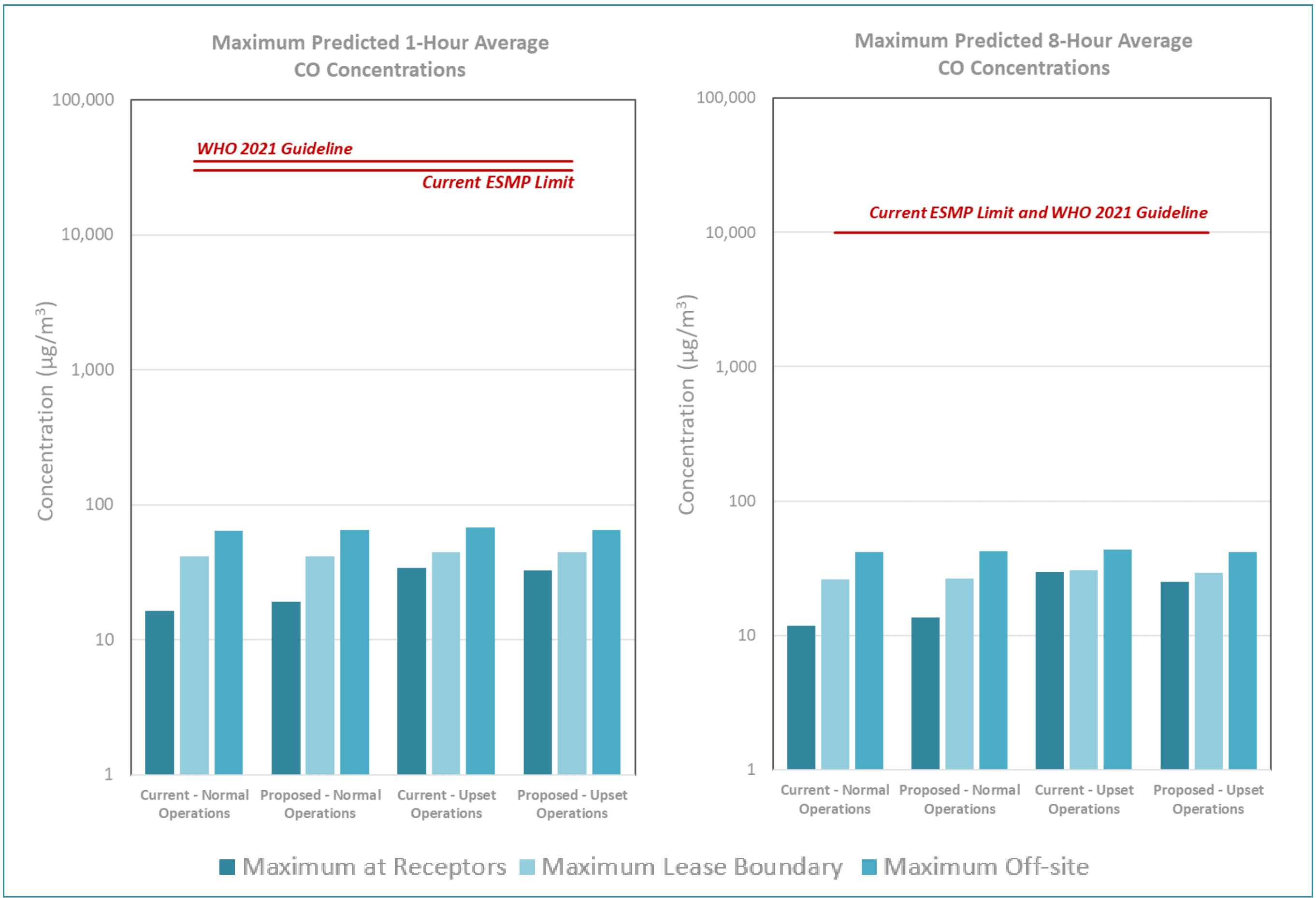
Receptor ID	CO (µg/m³)		NO_2 (µg/m³)		PM_{10} (µg/m³)	SO_2 (µg/m³)	
	1-Hour Average	8-Hour Average	1-Hour Average	24-Hour Average	24-Hour Average	10-Min Average	1-Hour Average
Papa 1	33	20	25	4.1	0.51	9.4	6.1
Papa 2	29	22	120	7.5	1.4	45	29
Papa 3	29	25	62	8.9	1.4	23	15
Papa 4	26	19	34	7.6	1.0	11	7.1
Papa 5	28	23	51	8.7	1.1	18	12
Boera 1	13	11	37	9.4	1.2	14	9.4
Boera 2	13	10	43	10	1.3	16	11
Boera 3	12	11	25	8.7	1.1	9.6	6.2
Boera 4	12	11	32	6.7	1.0	12	8.0
Porebada 1	12	9.1	24	6.8	0.75	9.0	5.9
Porebada 2	9.6	9.7	33	3.5	0.62	13	8.2
Edai Town	14	14	23	3.3	0.40	8.7	5.7
Bible School	29	19	25	6.7	0.90	7.4	4.8
Residence 1	25	22	42	11	1.8	15	10
Residence 2	26	22	42	10	1.6	15	10
Residence 3	27	24	47	10	1.5	17	11
Residence 4	26	18	33	8.8	1.2	12	7.6
Maximum at sensitive receptors	***33***	***25***	***120***	***11***	***1.4***	***45***	***29***
Maximum at PPFL-2 Boundary	***44***	***29***	***210***	***17***	***3.3***	***170***	***110***
Maximum off-site	***65***	***42***	***200***	***17***	***3.2***	***140***	***93***
Assessment Criteria	**30,000**	**10,000**	**200**	**25**	**45**	**500**	**200**

7.2.2 Impact Assessment – CO Emissions

Bar charts summarising the maximum 1-hour average and 8-hour average CO concentrations predicted at the sensitive receptor locations, along the PPFL-2 Boundary and the maximum off-site concentrations, compared to the relevant criteria, are provided in **Figure 20** (note that the concentrations are presented on a logarithmic scale). As shown by these plots, the maximum off-site concentrations predicted for both the normal and the upset operating scenarios are far below the relevant ambient air quality criteria. The Project is not predicted to result in any significant changes in the predicted maximum concentrations compared to current operations.

No adverse air quality impacts are therefore expected as a result of CO emissions from current or proposed operations at the Site.

Figure 20 Summary of Maximum Predicted Incremental CO Concentrations

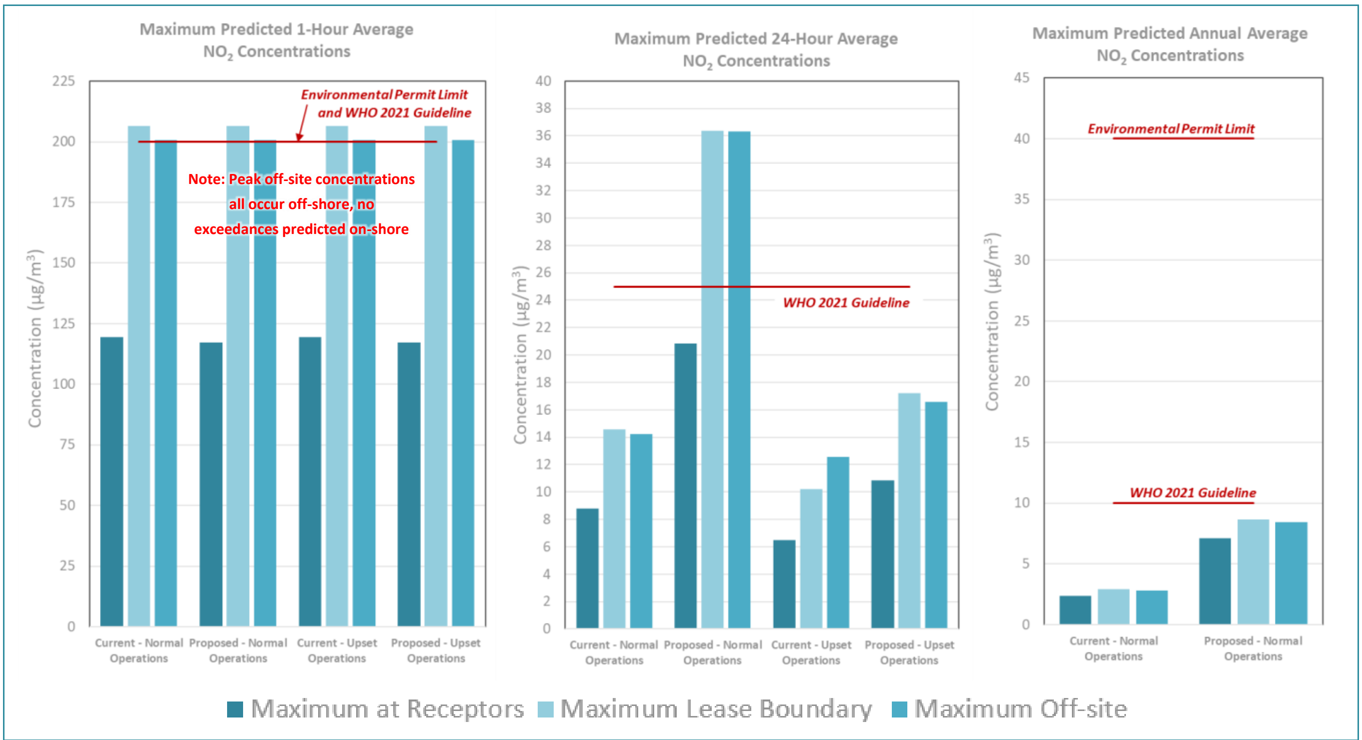


7.2.3 Impact Assessment – NO_2 Emissions

Bar charts summarising the maximum 1-hour average, 24-hour average and annual average NO_2 concentrations predicted at the representative sensitive receptor locations, along the PPFL-2 Boundary and the maximum off-site concentrations, compared to the relevant criteria for NO_2, are provided in **Figure 21**. These NO_2 concentrations have been calculated from the total NO_X concentrations predicted by the model using the OLM approach and based on the maximum ozone concentration measured at the LNG Plant site in 2015-2016 (see **Section 5.5**).

Figure 21 shows that the predicted concentrations at the sensitive receptor location comply with the relevant ambient air quality criteria for all averaging periods. However, concentrations above the adopted 1-hour average assessment criteria are predicted at other off-site locations under worst case meteorological conditions for all scenarios, and above the 24-hour average criterion for the proposed normal operations scenario.

Figure 21 Summary of Maximum Predicted NO_2 Concentrations

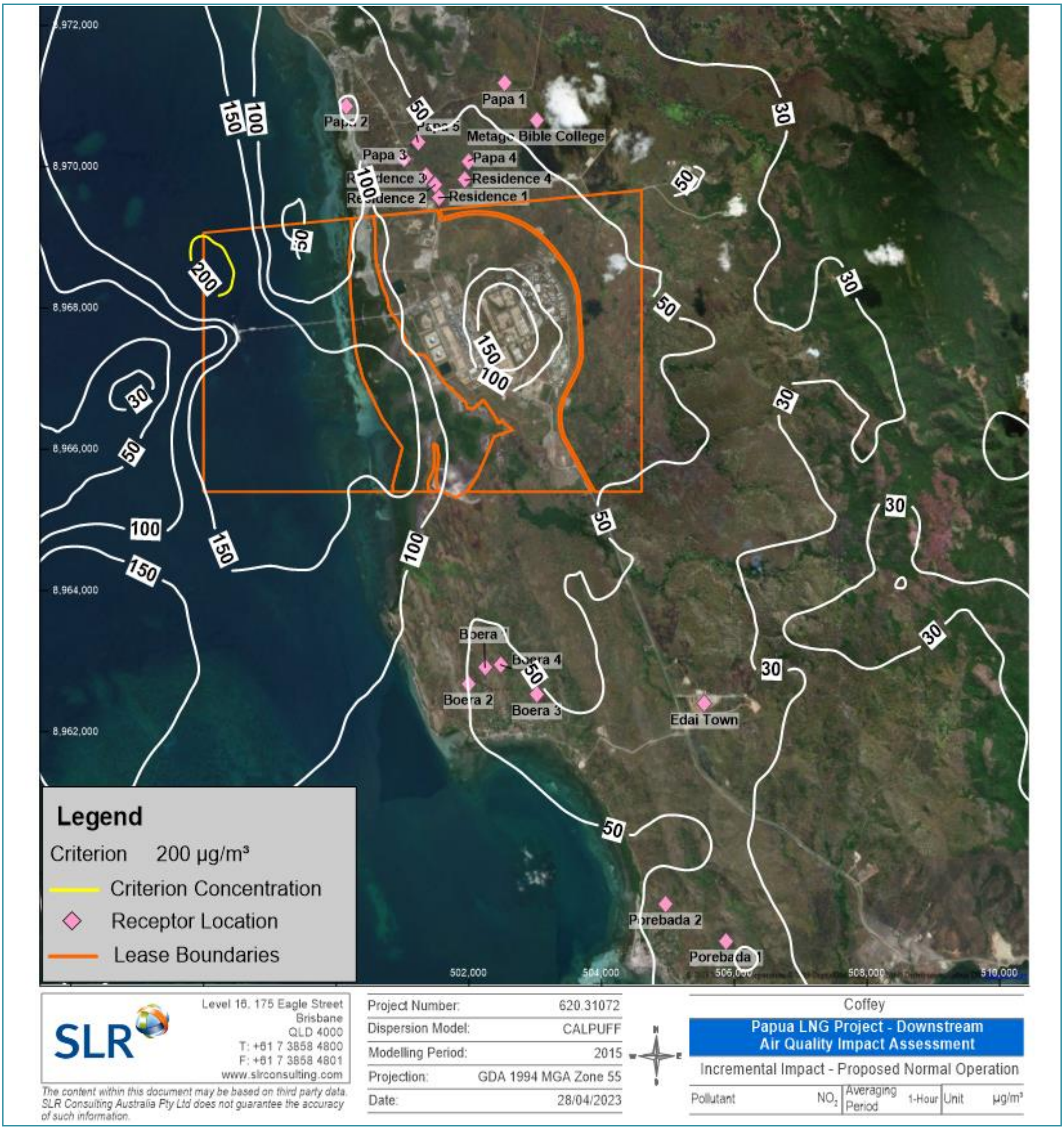


A detailed review of the modelling outputs, as well as the stack and emission data used in the current normal operations, showed that the elevated off-site 1-hour average NO_2 concentrations predicted for all operating scenarios are associated with the shipping emissions at the jetty. The highest 'ground level' 1-hour average NO_2 concentrations for all scenarios are predicted off-shore, approximately 400 m north of the jetty, with much lower impacts predicted inland at the sensitive receptors, as shown in the left-hand plot in **Figure 21** and in the isopleth plot for proposed normal operations shown in **Figure 22** (other scenario plots included in **Appendix B**).

The 1-hour average emission rates used in the modelling for shipping relate to the worst-case emission rates estimated during manoeuvres. The estimated 1-hour average NO_X emissions during hotelling are much lower. Therefore, given the restricted boat access to this area during manoeuvres operations, no potential exposures would be expected.

Compared to the onsite combustion emission sources, the plumes from the ship emissions are not as well dispersed and diluted as they travel downwind. The on-site emission sources, such as the power generation turbines and gas turbine drivers, emit at more than 40 m above ground level, and also have higher levels of thermal and mechanical buoyancy due to hotter stack temperatures and larger gas flowrates, which combines to enhance the vertical dispersion of the plumes, leading to comparatively lower ground level impacts for those sources.

Figure 22 99.9th Percentile Predicted 1-Hour Average NO_2 Concentrations – Proposed Normal Operations



The peak off-site 1-hour average NO_2 concentrations are also the same across the four assessment scenarios because the conversion of NO_X to NO_2 is limited by the background ozone concentration assumed in the calculations. In other words, there is not enough ambient ozone available to convert the remaining NO in the plume to form additional NO_2.

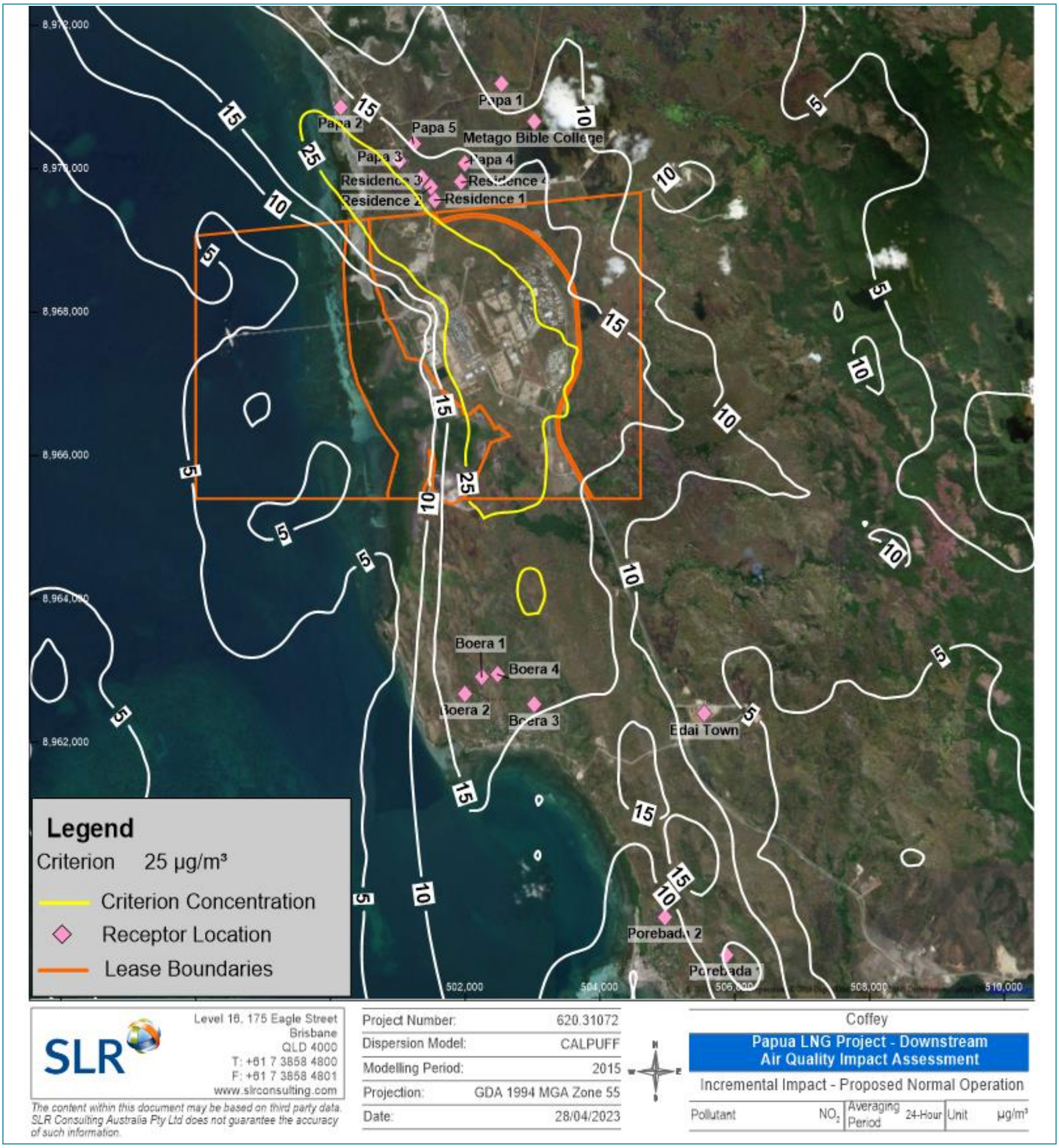
As noted above, the maximum 24-hour average NO_2 concentrations are also predicted comply with the current WHO guideline of 25 µg/m^3 at all sensitive receptor locations included in the assessment, however concentrations above this limit are predicted in a localised, undeveloped area immediately north of the LNG Plant, extending across the coastline into Caution Bay for the proposed normal operation scenario (see **Figure 23**). A small area of exceedance is also predicted at the southern boundary and on a small area of elevated terrain to the south.

These predictions are expected to be conservative overestimates of actual concentrations that may be expected to occur in reality for the following reasons:

- The NO_X emission rates from the CCPP (which is the main NO_X emission source in this assessment scenario) are based on the maximum emission specification for the units of 25 ppm. Actual stack emission concentrations are expected to be lower than this.
- The OLM approach used in this assessment to convert the NO_X predictions to NO_2 concentrations assumes that the reactions occur instantaneously, whereas they generally occur over a number of hours. Therefore NO_2 conversion rates close to the source (ie at the site boundary, as in this case) can be overestimated using this approach.
- The 24-hour average background ozone concentration of 170 µg/m^3 assumed in this study, based on the available on-site monitoring data, is very high and essentially assumes that there will be 100% conversion of NO_X to NO_2.

Given the above, and as no exceedances are predicted at the identified sensitive receptor locations, the risk of any adverse air quality impacts as a result of NO_X emissions from the Project is concluded to be low. During detailed design, the estimated emission rates will be further refined, and the modelling updated, to confirm that no exceedances are predicted beyond the Lease Boundaries.

Figure 23 Maximum Predicted 24-Hour Average NO_2 Concentrations – Proposed Normal Operations



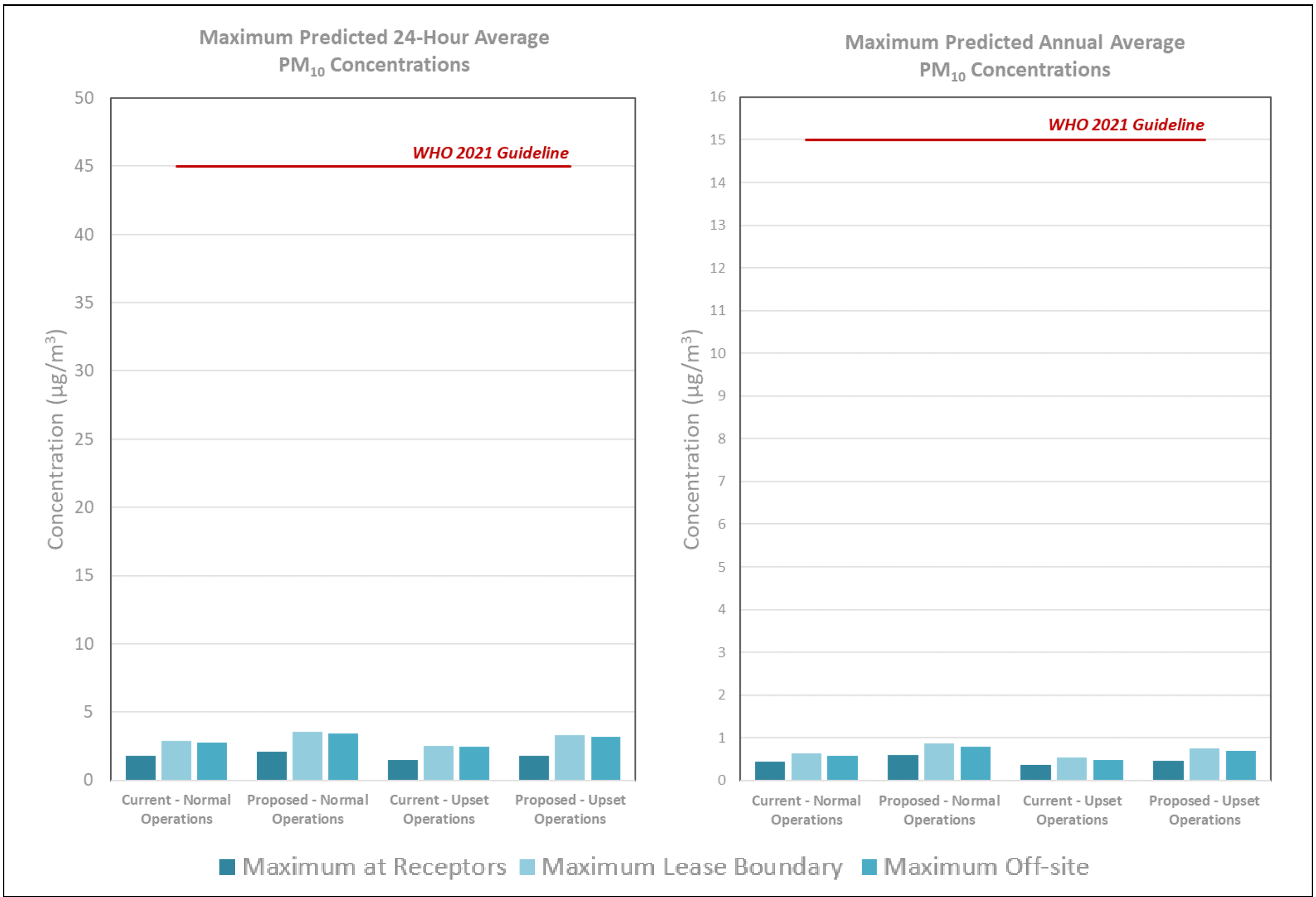
7.2.4 Impact Assessment – Particulate Emissions

Bar charts summarising the maximum incremental 24-hour average and annual average PM_{10} concentrations predicted at the representative sensitive receptor locations, along the PPFL-2 Boundary and the maximum off-site concentrations, are provided in **Figure 24** compared to the relevant criteria.

The off-site 24-hour average and annual average PM_{10} concentrations are predicted to increase slightly as a result of the Project, however the predicted concentrations are far below the adopted ambient air quality criteria. The incremental PM_{10} concentrations predicted due to existing emissions from the LNG Plant are significantly lower than the levels that were measured onsite in 2015/2016 (see **Section 5.5)**, due to the contributions of background sources of particulate matter, including wheel generated dust from Lea Lea Road.

Based on the above, no adverse air quality impacts are expected as a result of PM_{10} emissions from the sole or concurrent operation of the LNG Plant and Project facilities.

Figure 24 Summary of Maximum Predicted Incremental PM_{10} Concentrations



Emission estimation and dispersion modelling has not been performed for $PM_{2.5}$, however as the sources of PM_{10} at the LNG Plant are predominantly associated with gas combustion processes, it can be expected that the majority of PM_{10} emitted from the Project will also be in the $PM_{2.5}$ size fraction.

The maximum downwind $PM_{2.5}$ concentrations that would be predicted are therefore likely to be slightly lower, but similar to, the predicted PM_{10} concentrations presented above. These concentrations are well below the WHO (2021) $PM_{2.5}$ guidelines adopted for the Project of 15 µg/m^3 as a 24-hour average and 5 µg/m^3 as an annual average (see **Section 4.5**).

Given above, no adverse air quality impacts are expected as a result of $PM_{2.5}$ emissions from the sole or concurrent operation of the LNG Plant and Project facilities.

7.2.5 Impact Assessment - SO_2 Emissions

Bar charts summarising the maximum 10-minute average, 1-hour average and 24-hour average SO_2 concentrations predicted at the representative sensitive receptor locations, along the PPFL-2 Boundary and the maximum off-site concentrations, are provided in **Figure 25** compared to the relevant criteria.

Figure 25 shows that the maximum predicted 10-minute and 1-hour average SO_2 concentrations are below the relevant criteria for both current and proposed operations, including both normal operations and worst case upset operating conditions. A notable increase in the maximum 10-minute and 1-hour average SO_2 concentrations is predicted at the sensitive receptor locations as a result of the Project, which is due to SO_2 emissions from combustion of RSH and H_2S containing fuel gas in the CCPP.

The maximum 24-hour average concentrations predicted comply with the current environmental permit limit of 20 µg/m^3 at all sensitive receptor locations included in the assessment, however concentrations above this limit are predicted in a localised, undeveloped area immediately north of the LNG Plant, extending across the coastline into Caution Bay for the proposed normal operation scenario (see isopleth plot in **Figure 26**).

Figure 25 Summary of Maximum Predicted SO_2 Concentrations

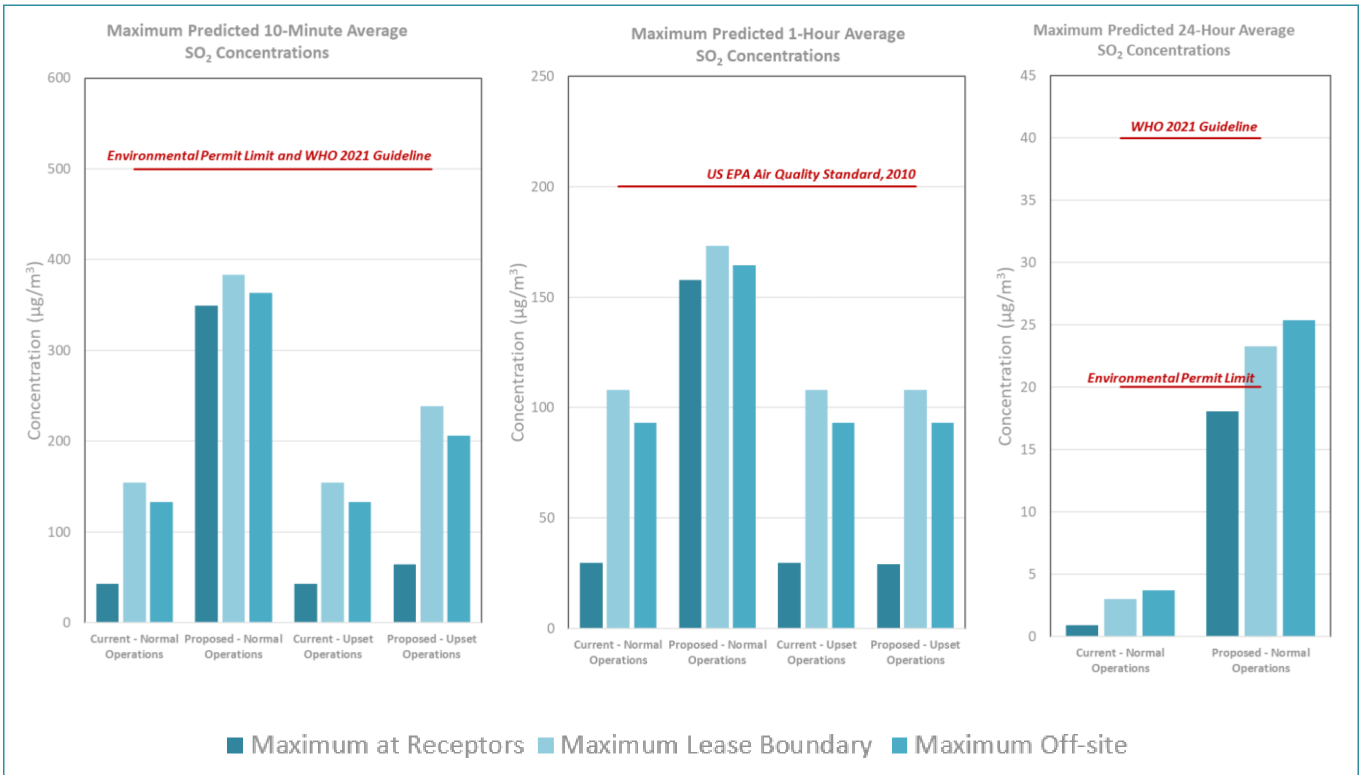
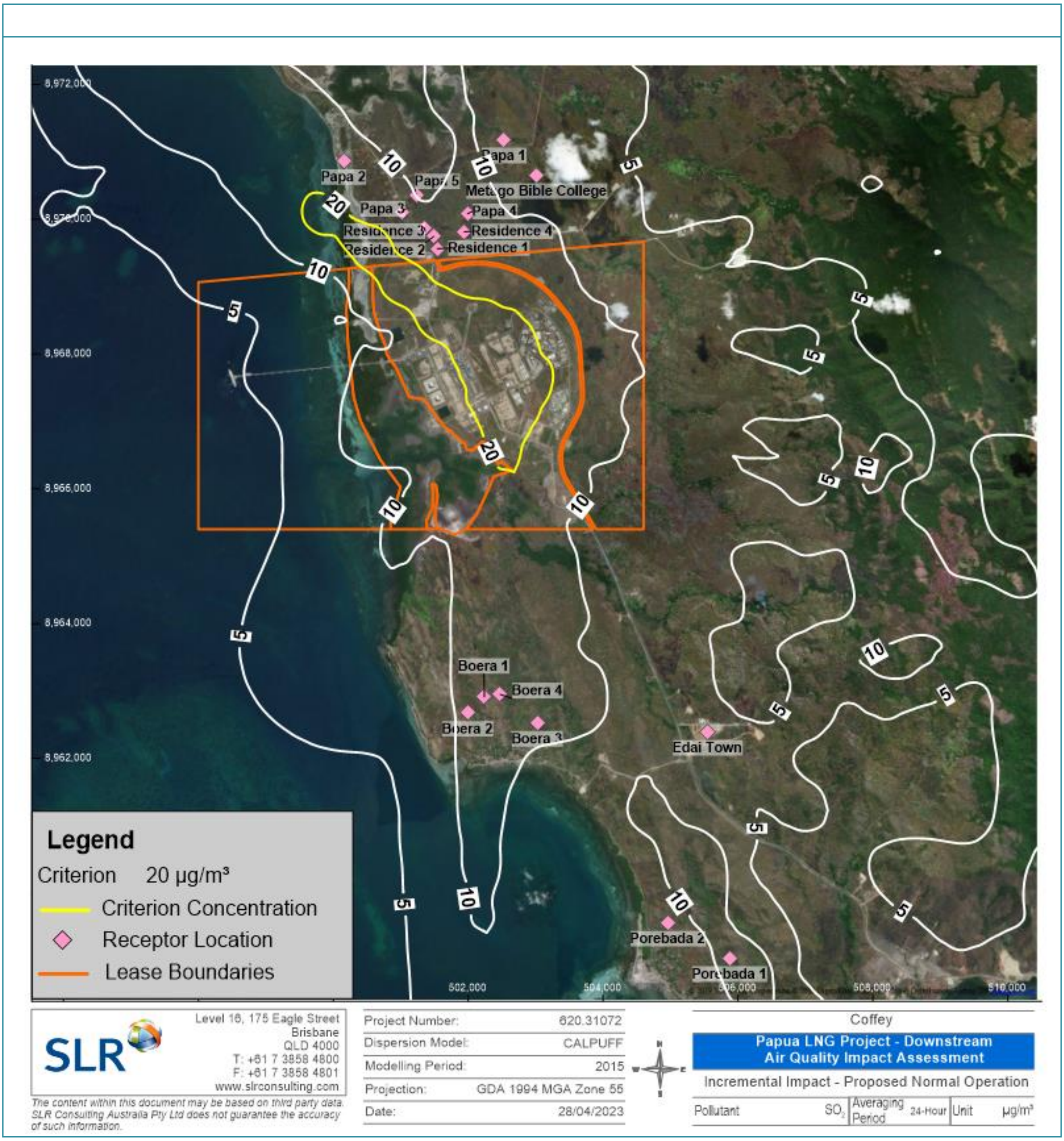


Figure 26 Maximum Predicted 24-Hour Average SO_2 Concentrations – Proposed Normal Operations



It is noted that the current PNG LNG environment permit limit is based on the WHO ambient air quality guideline of 20 µg/m^3 current at the time of preparing the PNG LNG EIS. In 2021, WHO revised this guideline to 40 µg/m^3, which the proposed operations easily complies with at all areas beyond the site boundary, as shown in **Figure 25**. A review of the current environmental permit limit for 24-hour ambient SO_2 concentrations to bring it in line with the current WHO guideline would therefore also facilitate compliance.

For the proposed upset operating condition assessed, the gas containing RSH and H_2S is to be directed to the flare, and the increased vertical dispersion given by the flare's higher release point and more thermally buoyant plume means that there is no significant change in the predicted off-site ground level 10-minute and 1-hour average SO_2 concentrations compared to the current upset operating condition scenario.

7.2.6 Impact Assessment – Benzene Emissions

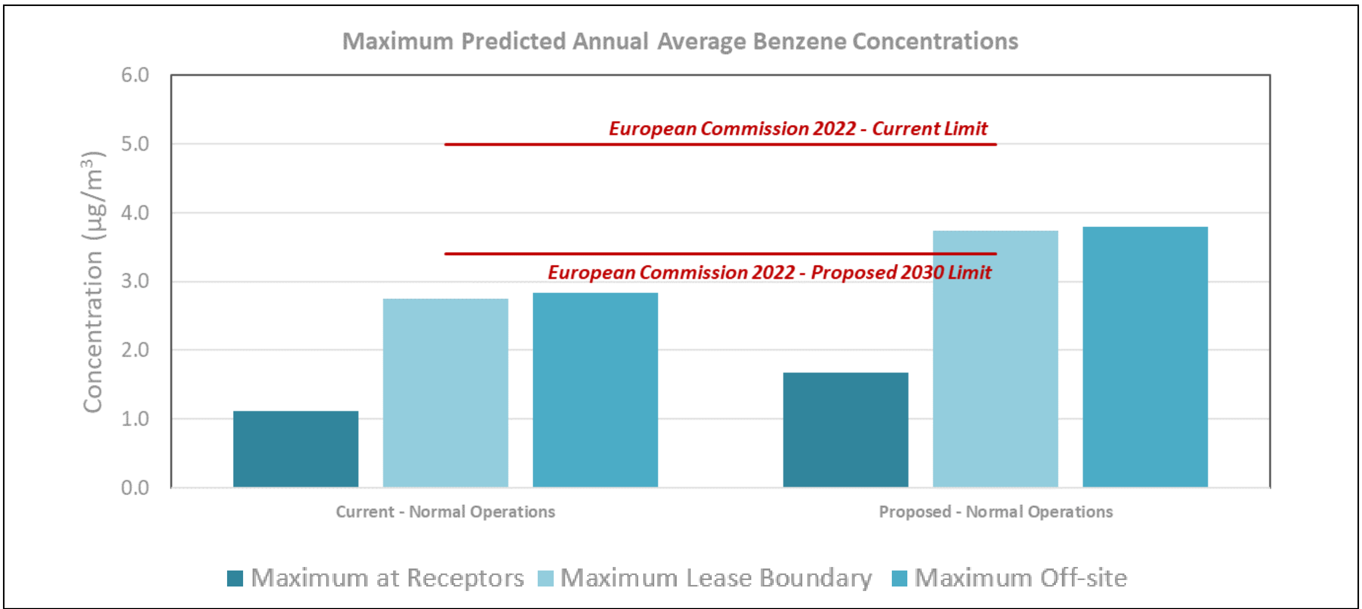
Bar charts summarising the annual average benzene concentrations predicted at the representative sensitive receptor locations, along the PPFL-2 Boundary and the maximum off-site concentrations, are provided in **Figure 27** compared to the relevant criteria.

For both current and proposed operations, the maximum predicted off-site annual average benzene concentrations are below the current limit of 5 µg/m^3 set by the EU. The predicted concentrations at sensitive receptor locations also comply with the reduced limit of 3.4 µg/m^3 proposed for attainment in the EU by 2030. For the proposed scenario however, there is a localised area to the north of the site where the 2030 limit is predicted to be exceeded (see isopleth plot in **Appendix C**). Given there are no residences located in this area, no people would be expected to be exposed to the predicted levels over a full year, and the risk of any health impacts is considered to be very low. It is also noted that this is a proposed limit that is not currently in force in the EU and the current limit is predicted to be complied with.

The predicted increase in downwind benzene concentrations for the proposed operations is related to the relatively high estimated fugitive benzene emission rates for the proposed new analyser houses in the Project facilities of 1.01 kg/hr. This estimate assumed that 0.45%(wt) of the total organic carbon emitted is benzene. The assumptions used to estimate the emissions will be confirmed during detailed design, and specifications will be developed to reduce any emissions from these units to as low as practicable.

Based on the modelling results at sensitive receptor locations, no adverse air quality impacts are expected as a result of benzene emissions from the current or proposed operations.

Figure 27 Summary of Maximum Predicted Benzene Concentrations



8 Mitigation and Monitoring

8.1 Mitigation Measures

8.1.1 Detailed Design

The Project's facilities environmental design basis includes the following requirements to ensure that potential off-site air quality impacts are appropriately addressed during the detailed design of the Project:

- Design to have zero routine flaring as per the *Company Project Environmental Standard for Greenhouse Gas*.
- Flaring is allowed for:
  - Shutdown or maintenance flaring.
  - Start-up flaring. New facilities shall be designed to minimise start-up flaring as much as practicable. An evaluation of start-up flaring shall:
    - Compare proposed flaring relative to historical data from similar assets and target improved performance.
    - Consider unplanned scenarios in the design.
    - Consider current best practices (i.e., flare gas recovery analysis and recycling, reliability of compression).
  - Emergency flaring, including unplanned shutdown.
  - Gas required for pilots or purge.
- Flares shall be designed to:
  - be smokeless under normal operating conditions
  - Include auto-ignition of pilots or continuously burning pilots, and means to verify the presence of a continuous pilot flame (e.g. thermocouple, infrared monitor, ultraviolet monitor or other).
  - Gas routed to flare shall be measured (for higher pressure streams where measurement is practicable).
- The design and selection of equipment for the project must include control technologies to achieve applicable ambient air quality standards.
- At facility level, impacts should be estimated through quantitative assessments by the use of baseline air quality assessments and/or atmospheric dispersion models to assess potential ground level concentrations.
- The ambient air impact from the Project should be no more than 25% of the applicable air quality standards to allow additional, future sustainable development in the same airshed.
- All combustion sources (operating more than 500 hours per year with an annual capacity utilisation factor of more than 30%) shall have stack sampling ports for isokinetic sampling at a location free of cyclonic flow during performance tests.
- All incinerators shall be designed with multiple combustion chambers consisting of primary and secondary chambers and meet the Project design specifications.

The air dispersion modelling performed as part of this assessment will continue to inform the detailed design of the Project and be reviewed and updated as more detailed design data becomes available. A priority of the detailed design phase will be to identify and evaluate potential additional mitigation measures to further control SO_2 emissions from the Project so that no exceedances of the 24-hour average criterion are predicted off-site, subject to any changes to the current PNG LNG environmental permit limit for 24-hour ambient SO_2 concentrations to bring it in line with the current, less stringent, WHO guideline.

IFC EHS (2007) guidance recommends that the ambient air impact from the Project be "*no more than 25% of the applicable air quality standards to allow additional, future sustainable development in the same airshed*". It is noted that due to the RSH and H_2S content of the Papua LNG feed gas, meeting this objective for off-site SO_2 concentrations may not be achievable, and the modelling currently predicted off-site NO_2 and benzene concentrations that are above 25% of the relevant criteria. Nonetheless, during detailed design, options to reduce potential off-site air pollutant concentrations will continue to be investigated in line with the design objective.

8.1.2 Construction

Air quality management measures covering fugitive dust and other air emission sources and pollutants, will be included as part of the project's Construction Environmental and Social Management Plan (CESMP). The mitigation measures adopted to manage air emissions during the PNG LNG construction project are expected to form the basis of the CEMP for the Project. These mitigation measures are reproduced in **Table 29.**

8.1.3 Operations

Air quality impacts from the operational phase of the Project will be managed in accordance with an Operations ESMP that will be developed for the Integrated LNG Plant operations, through a review and update of the existing PNG LNG EMP (PNG LNG, 2019) to address requirements for the new operating conditions.

Table 29 Construction Phase Mitigation Measures – Air Quality

Source of Impact	Potential Impact and Relevant Management Plan Objective	Mitigation and Management (Design Feature/Specific Measure)
Dust from cleared/disturbed areas causing increased particulate matter loads/ concentrations	Dust emissions creating nuisance and aesthetic and health impacts on humans.	Contractor shall develop an Air Emissions Management Plan.
		Limit erosion and dust effects of soil and spoil.
		Control speed limits via posted speed limit signs on project unsealed roads and keep vehicles to marked trafficable areas that will be maintained in a damp and compacted condition, where practicable
		Stabilise exposed areas susceptible to wind erosion using industry good practice measures such as water (non-saline), agglomerating agents, temporary grass/hydro-mulch or mulch where appropriate
		Use cleared vegetation where practicable for dust control and reinstatement.
Air emissions from fuel combustion and storage	Reduced air quality with consequent community and project nuisance.	Select construction equipment based on industry good practice.
		Locate fixed and mobile equipment (e.g., generators) with consideration of local people (generally at a minimum distance of 500 meters from residences or other sensitive receptors, except where otherwise agreed by Company).
		Service diesel-powered equipment regularly
		Maintain construction vehicles and equipment in order to limit emissions, and remove from service any equipment from which emissions are visibly excessive
Air emissions from industrial waste incineration.	Impairment of ambient air quality.	Design high temperature incinerators commensurate with proposed waste inventories.
		Prepare Operating Procedures for temporary incinerators to be utilised during construction. Operating Procedures shall detail operational and monitoring/record keeping criteria (see Table 2).
		With the exception of health care waste and oily debris (oil filters, oily rags etc), no restricted waste, shall be incinerated in the temporary incinerators
		Temporary incinerators utilised during construction shall be of dual combustion chamber design and shall provide for at least one second retention time at a minimum temperature of 850°C in the secondary chamber

Source of Impact	Potential Impact and Relevant Management Plan Objective	Mitigation and Management (Design Feature/Specific Measure)
		A temporary incinerator shall not be utilised for the incineration of health care waste or oily debris where the specification of the incinerator does not allow for a minimum temperature of 850ºC in the secondary chamber
		A temporary incinerator shall not be utilised for the incineration of health care waste or oily debris where the specification of the incinerator does not allow for a minimum retention time of one second in the secondary chamber, unless the temperature in the secondary chamber is equal to or greater than 850°C
		Incineration of restricted waste (with the exception of health care waste and oily debris as discussed above) in the temporary incinerators shall be on an exception basis and requires prior Company approval
		Incinerators burning restricted waste (other than medical waste or oily debris) shall be specified so as to meet the intent of the applicable emissions limits in US EPA 40 CFR Part 60 Subpart CCCC (*Standards of Performance for Commercial and Industrial Solid Waste Incineration Units*). Testing shall be undertaken during commissioning of the incinerator to demonstrate that stack emissions meet the required concentrations. Thereafter, monitoring of stack emissions for these parameters shall be undertaken periodically, but no less than annually.
Air emissions from landfills	Impairment of ambient air quality.	Develop and implement appropriate measures to control the accumulation and migration of landfill gases.

8.2 Monitoring

8.2.1 Construction

At this stage, an ambient air quality monitoring program to monitor particulate levels at off-site receptors is not considered to be required for the construction phase of the project**.** Monitoring of the effectiveness of the dust controls implemented during the works would instead be performed through:

- Regular visual observation of dust levels near potential dust generating activities, particularly in the end of extended periods of dry, windy conditions, to confirm that no dust clouds can be seen travelling off-site.
- Tracking water usage for dust suppression to ensure that water carts and water sprays are being used regularly, as and when required.
- Consultation with neighbouring land users to confirm that dust nuisance impacts are not being experienced as a result of the works.

Should the Project become aware that dust nuisance impacts are occurring, or have the potential to occur, procedures outlined in the ExxonMobil grievance management system would be followed. If appropriate, this could potentially involve the use of dust deposition gauges or portable dust monitors (or a combination of both), to assist in the effective targeting of increased dust suppression measures and monitoring contractor compliance with expected good practice regarding dust control.

8.2.2 Operations

Air emissions and ambient air quality monitoring programs for the operational phase of the Project will be outlined in the Integrated LNG Plant Production EMP.

Air emissions monitoring for the Integrated LNG Plant will include periodic stack sampling in accordance with standard industry methods and subject to the provisions set out in the stack emissions monitoring procedure.

The need for any continuous emissions monitoring systems (CEMS), or Predictive Emissions Monitoring Systems (PEMS) for the major emission sources will be evaluated during detailed design. PEMS employs an empirical computer model that relates the inputs of a combustion system (ie air and fuel flowrates and fuel composition) to the emissions produced by the process. Once the model is established for a particular installation, the emissions can be predicted continuously with accuracy in the range of direct measurements used in CEMS. PEMS can also be deployed as a complement to a hardware based CEMS.

For example, if deemed appropriate, continuous monitoring of sulfur in the CCPP fuel gas and the CCPP fuel feed rates may be included to provide continuous SO_2 emission rate data via a PEMS. Alternatively, provisions to enable retrofitting such a system (if deemed necessary based on the actual operation of the plant) may be considered more appropriate. Once the detailed design of the plant is completed and the air dispersion modelling study updated, the most appropriate emissions monitoring equipment and systems to meet regulatory requirements and provide the level of risk management needed can be confirmed.

Monitoring of ambient air quality will also continue to be undertaken periodically in the vicinity of the Project site to validate the predictions of the ambient air quality assessments and evaluate conformance with guideline values. An initial monitoring campaign would be undertaken once the Project achieves steady state operations. Further ambient air quality monitoring would also be conducted after major modifications to existing plant that will increase emissions affecting ambient air quality. The need for routine ambient monitoring of SO_2 concentrations would be determined once the detailed design of the plant is completed and the air dispersion modelling study updated to confirm the predicted off-site ground level concentrations.

Ambient air quality monitoring would be conducted by appropriately trained staff overseen by a qualified emission testing specialist contractor, in accordance with standard industry methods. The focus of ambient air quality monitoring would be sensitive community receptors identified as part of this air quality assessment and future dispersion modelling exercises.

9 Conclusions

Construction

The potential for off-site air quality impacts associated with fugitive dust emissions during the proposed construction activities at the Project facilities were assessed qualitatively. This assessment concluded:

- While there is potential for short-term elevations in dust levels close to the construction areas, particularly during vegetation clearance and earthworks, no long-term air quality impacts would be expected to occur as a result of air emissions during the construction phase. Revegetation of cleared areas will ensure rapid stabilisation of exposed soils and any settled dust is likely to be cleaned off vegetation and other surfaces relatively quickly by rain.
- With good practice air quality management, there would be a low risk of adverse dust soiling and human health impacts at the nearest sensitive receptors during the construction phase of the project. Any impacts would be highly localised and are expected to be able to be managed through targeted dust suppression, supported by and consultation with potentially affected sensitive receptors.
- Air quality management measures covering fugitive dust and other air emission sources and pollutants, will be included as part of the Project's CEMP.

At this stage, an ambient air quality monitoring program to monitor particulate levels at off-site receptors is not considered to be required for the construction phase of the project**.** Monitoring of the effectiveness of the dust controls implemented during the works would instead be performed through:

- Regular visual observation of dust levels near potential dust generating activities, particularly in the end of extended periods of dry, windy conditions, to confirm that no dust clouds can be seen travelling off-site.
- Tracking water usage for dust suppression to ensure that water carts and water sprays are being used regularly, as and when required.
- Consultation with neighbouring land users to confirm that dust nuisance impacts are not being experienced as a result of the works.

Should the Project become aware that dust nuisance impacts are occurring (or have the potential to occur), procedures outlined in the ExxonMobil grievance management system would be followed.

Operations

Atmospheric dispersion modelling was performed to assess the potential for off-site air quality impacts associated with air emissions from the existing LNG Plant and proposed Project facilities during the operational phase. Emissions from the site were modelled using the US EPA's CALPUFF (Version 6.42) modelling system and meteorological data compiled using WRF and CALMET. Stack and emission data used in the modelling for the existing LNG Plant and proposed Project facilities were compiled based on currently available design data, equipment and feed gas specifications, and published emission factors (as required). Multiple emission scenarios were modelled to enable the off-site pollutant concentrations predicted as a result of both normal and upset operating conditions (flaring events) for both the existing and expanded plant.

In addition to the LNG plant emissions, all modelling scenarios included:

- Shipping emissions: For the current operational scenarios this includes emissions from tankers and tugboats operating at the jetty, and for the proposed operations included emissions from tankers and tugboats operating at both the jetty and the CALM buoy.
- Third party power stations: Emissions from the Niu Power and Dirio gas-fired power plants.

Based on the results of the modelling the following conclusions were drawn:

- The maximum off-site 1-hour and 8-hour average CO concentrations predicted for both the normal and the upset operating scenarios are far below the relevant ambient air quality criteria and the Project is not predicted to result in any significant changes in the predicted maximum concentrations compared to current operations. No adverse air quality impacts are therefore expected as a result of CO emissions from current or proposed operations at the LNG Plant.
- NO_X emissions from the site are proposed to increase as a result of the proposed expansion, however the maximum 1-hour, 24-hour and annual average NO_2 concentrations at the sensitive receptors are predicted to remain well below the relevant criteria. In relation to the maximum off-site predictions, the following was noted:
  - For both current and proposed operations, maximum 1-hour average NO_2 concentrations above the guideline value are predicted in a small area off-shore (approximately 400 m north of the jetty), with much lower impacts predicted inland at the sensitive receptors. Given the restricted boat access to this area during loading operations, no potential exposures would be expected.
  - Under the proposed normal operating conditions, concentrations above the current WHO guideline of 25 µg/m^3 are predicted in an undeveloped area immediately north of the LNG Plant. The area predicted to be impacted has no houses and is a very localised area adjacent to the boundary. In addition, due to the conservative approaches used in the assessment, these predictions are expected to be overestimates of actual concentrations.

  Given the above, and as no exceedances are predicted at the identified sensitive receptor locations, the risk of any adverse air quality impacts as a result of NO_X emissions from the Integrated LNG Plant is concluded to be low.
- The off-site PM_{10} concentrations are predicted to increase slightly as a result of the Project, however the predicted concentrations are far below the adopted ambient air quality criteria. Based on the results presented, no adverse air quality impacts are expected as a result of PM_{10} emissions from the sole or concurrent operation of LNG Plant and Project facilities. The incremental PM_{10} concentrations predicted due to existing emissions from the LNG Plant are significantly lower than the levels that have been measured onsite, due to the contributions of background sources of particulate matter, including wheel generated dust from Lea Lea Road. On this basis, no adverse air quality impacts are expected as a result of PM_{10} emissions from current or proposed operations at the LNG Plant.
- Emission estimation and dispersion modelling has not been performed for $PM_{2.5}$, however as the sources of PM_{10} at the LNG Plant are predominantly associated with gas combustion processes, it can be expected that the majority of PM_{10} emitted from the Project will also be in the $PM_{2.5}$ size fraction. The maximum downwind $PM_{2.5}$ concentrations that would be predicted are therefore likely to be slightly lower, but similar to, the predicted PM_{10} concentrations presented above. These concentrations are well below the WHO (2021) $PM_{2.5}$ guidelines adopted for the Project.

- The maximum predicted 10-minute and 1-hour average SO_2 concentrations are below the relevant criteria for both current and proposed operations, including both normal operating conditions and worst case upset operating conditions. A notable increase in the maximum 10-minute and 1-hour average SO_2 concentrations is predicted at the sensitive receptor locations as a result of the Project, which is due to SO_2 emissions from combustion of RSH and H_2S containing fuel gas in the CCPP.
- The maximum predicted 24-hour average SO_2 concentrations also comply with the current environmental permit limit of 20 µg/m^3 at all sensitive receptor locations included in the assessment, however concentrations above this limit are predicted in a localised, undeveloped area immediately north of the LNG Plant, extending across the coastline into Caution Bay for the proposed normal operation scenario. It is noted that the current PNG LNG environment permit limit is based on the WHO ambient air quality guideline of 20 µg/m^3 current at the time of preparing the PNG LNG EIS. In 2021, this guideline was updated to 40 µg/m^3, which the proposed operations easily complies with at all areas beyond the site boundary. A review of the current environmental permit limit for 24-hour ambient SO_2 concentrations to bring it in line with the current WHO guideline would therefore facilitate compliance.
- For both current and proposed operations, the maximum predicted off-site annual average benzene concentrations are below the current limit of 5 µg/m^3 set by the EU. The predicted concentrations at sensitive receptor locations also comply with the reduced limit of 3.4 µg/m^3 proposed for attainment in the EU by 2030. For the proposed scenario however, there is a localised area to the north of the site where the proposed 2030 limit is predicted to be exceeded, associated with the relatively high estimated fugitive benzene emission rates for the proposed new analyser houses in the Project facilities. Based on the modelling results at sensitive receptor locations, no adverse air quality impacts are expected as a result of benzene emissions from the current or proposed operations, nonetheless during detailed design, the assumptions used to estimate the emissions will be confirmed and specifications developed to minimise any emissions from these units.
- One of the design targets for the project is that the ambient air impact from the Project is recommended to be "*no more than 25% of the applicable air quality standards to allow additional, future sustainable development in the same airshed*". It is noted that due to the RSH and H_2S content of the Papua LNG feed gas, meeting this objective for off-site SO_2 concentrations may not be achievable, and the modelling currently predicts off-site NO_2 and benzene concentrations that are above 25% of the relevant criteria. Nonetheless, during detailed design, options to reduce potential off-site air pollutant concentrations will continue to be investigated in line with the design objective.

Mitigation and Monitoring

The air dispersion modelling performed as part of this assessment will continue to inform the detailed design of the Project and be reviewed and updated as more detailed design data becomes available. A priority of the detailed design phase will be to identify and evaluate potential additional mitigation measures to reduce NO_2 and SO_2 emissions further from the Project to achieve compliance with the relevant 24-hour average criteria at all off-site locations.

Air quality management measures covering fugitive dust and other air emission sources and pollutants will be included as part of the project's Construction Environmental Management Plan (CEMP). The mitigation measures adopted to manage air emissions during the PNG LNG construction project are expected to form the basis of the CEMP for the Project.

Air quality impacts from the operational phase of the Project will also be managed in accordance with an Integrated LNG Plant Production EMP that will be developed through a review and update of the existing PNG LNG EMP (PNG LNG, 2019) to address requirements for the new operating conditions.

10 References

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Appendix A:

Air Emission Inventory Data

Current Normal Operating Conditions

PNG LNG Plus 3rd Party Power Plants

Source Group	Point Sources	Plant Item	Location (UTM,Zone 55,WGS84) Easting (mE)	Northing (mN)	Base Ht (m)	Operation Duty	Stack Dimensions Height (mAGL)	Shape	L x W (m)	Diameter (m)	Stack Gas Parameters Velocity (m/s)	Temp (°C)	Temp (K)	Emission Rates NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
Existing LNG Plant	Liquefaction - Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-1)	501,955.9	8,967,650.9	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-1)	501,962.2	8,967,637.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #1 (TR-1)	501,883.6	8,967,805.9	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #2 (TR-1)	501,889.9	8,967,792.3	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #3 (TR-1)	501,896.2	8,967,778.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		Amine Regeneration Acid Gas Vent (TR-1)	501,816.3	8,967,780.9	16	Continuous	54.0	round		0.54	7.6	42	315					15.50
	Liquefaction - Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-2)	502,091.8	8,967,714.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-2)	502,098.1	8,967,700.7	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #1 (TR-2)	502,019.4	8,967,869.5	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #2 (TR-2)	502,025.9	8,967,855.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #3 (TR-2)	502,032.2	8,967,842.1	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		Amine Regeneration Acid Gas Vent (TR-2)	501,952.3	8,967,844.3	16	Continuous	54.0	round		0.54	7.6	42	315					15.50
	Power Generation	Power Generation Turbine #1	502,100.1	8,967,591.3	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #2	502,111.9	8,967,565.9	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #3	502,123.8	8,967,540.6	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #4	502,135.6	8,967,515.2	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #5	502,147.4	8,967,489.8	15	Off-line	30.2	round		1.83								
		Power Generation Turbine #6	502,159.3	8,967,464.4	15	Off-line	30.2	round		1.83								
		Power Generation Turbine #7	502,171.1	8,967,439.1	15	Spare	30.2	round		1.83								
	Furnaces	Regeneration Furnace (TR-1)	501,943.2	8,967,939.1	16	Continuous	42.0	round		0.96	9.8	259	532	2.13	0.03		1.67	0.0003
		Common Regeneration (Standby) Furnace	501,946.4	8,967,932.3	16	Intermittent[3]												
		Regeneration Furnace (TR-2)	501,949.6	8,967,925.5	16	Continuous	42.0	round		0.96	8.8	265	538	2.13	0.03		1.67	0.0003
		Hot Oil Heater Furnace	501,940.1	8,967,945.9	16	Continuous[4]	42.0	round		0.96	12.7	309	582	2.24	0.03		1.81	0.0003
	Flares	Wet Flare (Normal)	502,096.3	8,968,674.9	16	Continuous	93.8	round		0.15	20.0	1,000	1,273	0.012	0.665			
		Dry Flare (Normal)	502,093.1	8,968,675.5	16	Continuous	94.1	round		0.20	20.0	1,000	1,273	0.012	0.665			
		Tankage Gas Flare (Normal)	501,224.0	8,967,954.1	4.5	Continuous	65.9	round		0.16	20.0	1,000	1,273	0.009	0.050			
	Incinerators	Process Sludge Incinerator	502,061.7	8,967,314.8	15	8am-5pm	20.6	round		0.23	16.7	152	425	0.17	0.01	0.02	0.06	0.0000
		General Incinerator - Out of Service	502,634.0	8,968,402.0	15	OOS	10.0	rectangular	1.0 x 1.0	1.13								
3rd Party Pwr Stns	Dirio power station	Solar Titan PGT	505,103.1	8,969,632.2	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Solar Titan PGT	505,103.4	8,969,621.7	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Solar Titan PGT	505,104.8	8,969,610.8	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
	NuiEnergy Power Plant stack	6xWartsilla 20V34SG Gas Engines - without CO catalyst	504,779.0	8,969,445.6	28	-	27.5			2.900	27.1	364	637	38.88	79.20	0.025	4.00	0.0202

	Volume Sources						Release height			Length of sid	Initial Y	Initial Z						
Existing LNG Plant	Plant Fugitives	Trains 1 and 2	501,690.9	8,967,728.6	NA	Continuous	2.0	round	0.00	225	52.33	4.7						0.0108
	Analyzers fugitive	Analyzer House (AH9101)	501,890.0	8,967,650.0	16	Intermittent	7.0			8.6	2	1						0.0050
	Analyzers fugitive	Analyzer House (AH9201)	502,026.0	8,967,713.4	16	Intermittent	7.0			8.6	2	1						0.0050
	Analyzers fugitive	Analyzer House (AH9501)	501,776.5	8,967,840.0	16	Intermittent	7.0			8.6	2	1						0.0020
	Analyzers fugitive	Analyzer House (AH9801)	501,346.8	8,967,982.3	5	Intermittent	7.0			8.6	2	1						0.0030

SLR have chosen to represent fugitive sources as volume sources, not point sources.
Volume sources based on length and height of train building

Current Plant, plus 3rd Party Power Plants

Upset Conditions

Source Group	Point Sources	Plant Item	Location (UTM,Zone 55,WGS84)		Base Ht	Operation	Stack Dimensions				Stack Gas Parameters			Emission Rates to be modelled by SLR				
			Easting	Northing		Duty	Height	Shape	L x W	Diameter	Velocity	Temp		NO_x	CO	SO_2	PM_{10}	Benzene
			(mE)	(mN)	(m)		(mAGL)		(m)	(m)	(m/s)	(°C)	(K)	(kg/hr)	(kg/hr)	(kg/hr)	(kg/hr)	(kg/hr)
Existing LNG Plant	Liquefaction - Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-1)	501,955.9	8,967,650.9	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808					
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-1)	501,962.2	8,967,637.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808					
		MR Compressor Gas Turbine Driver #1 (TR-1)	501,883.6	8,967,805.9	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605					
		MR Compressor Gas Turbine Driver #2 (TR-1)	501,889.9	8,967,792.3	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605					
		MR Compressor Gas Turbine Driver #3 (TR-1)	501,896.2	8,967,778.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605					
		Amine Regeneration Acid Gas Vent (TR-1)	501,816.3	8,967,780.9	16	Continuous	54.0	round		0.54	7.6	42	315					
	Liquefaction - Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-2)	502,091.8	8,967,714.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-2)	502,098.1	8,967,700.7	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #1 (TR-2)	502,019.4	8,967,869.5	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #2 (TR-2)	502,025.9	8,967,855.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #3 (TR-2)	502,032.2	8,967,842.1	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		Amine Regeneration Acid Gas Vent (TR-2)	501,952.3	8,967,844.3	16	Continuous	54.0	round		0.54	7.6	42	315					15.50
	Power Generation	Power Generation Turbine #1	502,100.1	8,967,591.3	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #2	502,111.9	8,967,565.9	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #3	502,123.8	8,967,540.6	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #4	502,135.6	8,967,515.2	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #5	502,147.4	8,967,489.8	15	Off-line	30.2	round		1.83								
		Power Generation Turbine #6	502,159.3	8,967,464.4	15	Off-Line	30.2	round		1.83								
		Power Generation Turbine #7	502,171.1	8,967,439.1	15	Spare[1]	30.2	round		1.83								
	Furnaces	Regeneration Furnace (TR-1)	501,943.2	8,967,939.1	16	Continuous	42.0	round		0.96	9.8	259	532	2.13	0.03		1.67	0.0003
		Common Regeneration (Standby) Furnace	501,946.4	8,967,932.3	16	Intermittent[3]												
		Regeneration Furnace (TR-2)	501,949.6	8,967,925.5	16	Continuous	42.0	round		0.96	8.8	265	538	2.13	0.03		1.67	0.0003
		Hot Oil Heater Furnace	501,940.1	8,967,945.9	16	Continuous[4]	42.0	round		0.96	12.7	309	582	2.24	0.03		1.81	0.0003
	Flares	Wet Flare (Upset)	502,096.3	8,968,674.9	16	Continuous	215.5	round		28.29	20.0	1,000	1,273	900.0	4,800.0			
		Dry Flare (Upset)	502,093.1	8,968,675.5	16	Continuous	281.9	round		44.50	20.0	1,000	1,273	2,250.0	11,800.0			
		Tankage Gas Flare (Upset)	501,224.0	8,967,954.1	4.5	Continuous	112.3	round		10.44	20.0	1,000	1,273	100.0	520.0			
	Incinerators	Process Sludge Incinerator	502,061.7	8,967,314.8	15	8am-5pm	20.6	round		0.23	16.7	152	425	0.17	0.01	0.02	0.06	0.0000000001
		General Incinerator - Out of Service	502,634.0	8,968,402.0	15	OOS	10.0	rectangular	1.0 x 1.0	1.13								
3rd Party Pwr Stns	Dirio power station	Solar Titan PGT	505,103.1	8,969,632.2	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.009
		Solar Titan PGT	505,103.4	8,969,621.7	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.009
		Solar Titan PGT	505,104.8	8,969,610.8	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.009
	Power Plant stack	6xWartsilla 20V34SG Gas Engines - without CO catalyst	504,779.0	8,969,445.6	28	-	27.5			2.900	27.1	364	637	38.88	79.20	0.025	4.00	0.020

	Volume Sources						Release height			Length of sid	Initial Y	Initial Z						
Existing LNG Plant	Plant Fugitives	Trains 1 and 2	501,690.9	8,967,728.6	NA	Continuous	2.0	round	0.00	225	52.33	4.7						0.0108
	Analyzers fugitive	Analyzer House (AH9101)	501,890.0	8,967,650.0	16	Intermittent	7.0			8.6	2	1						0.0050
	Analyzers fugitive	Analyzer House (AH9201)	502,026.0	8,967,713.4	16	Intermittent	7.0			8.6	2	1						0.0050
	Analyzers fugitive	Analyzer House (AH9501)	501,776.5	8,967,840.0	16	Intermittent	7.0			8.6	2	1						0.0020
	Analyzers fugitive	Analyzer House (AH9801)	501,346.8	8,967,982.3	5	Intermittent	7.0			8.6	2	1						0.0030

SLR have chosen to represent fugitive sources as volume sources, not point sources.

Volume sources based on length and height of train building

Proposed Expanded Plant, plus 3rd Party Power Plants

Normal Operating Conditions

Source Group	Point Sources	Plant Item	Location (UTM,Zone 55,WGS84)		Base Ht	Fuel	Operation				Stack Dimensions				Stack Gas Parameters			Emission Rates				
			Easting	Northing			Duty	Normal Operating Load			Height	Shape	L x W	Diameter	Velocity	Temp		NO_x	CO	SO_2	PM_{10}	Benzene
			(mE)	(mN)	(m)			(m3/hr)	(Sm3/hr)	(kghr)	(mAGL)		(m)	(m)	(m/s)	(°C)	(K)	(kg/hr)	(kg/hr)	(kg/hr)	(kg/hr)	(kg/hr)
Existing LNG Plant	Liquefaction - Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-1)	501,955.9	8,967,650.9	16	HP Fuel	Continuous	674,941			42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-1)	501,962.2	8,967,637.3	16	HP Fuel	Continuous	674,941			42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #1 (TR-1)	501,883.6	8,967,805.9	16	HP Fuel	Continuous	500,830			44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #2 (TR-1)	501,889.9	8,967,792.3	16	HP Fuel	Continuous	500,830			44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #3 (TR-1)	501,896.2	8,967,778.7	16	HP Fuel	Continuous	500,830			44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		Amine Regeneration Acid Gas Vent (TR-1)	501,816.3	8,967,780.9	16	NA	Continuous		8,136		54.0	round		0.54	7.6	42	315					15.500
	Liquefaction - Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-2)	502,091.8	8,967,714.3	16	HP Fuel	Continuous	674,941			42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-2)	502,098.1	8,967,700.7	16	HP Fuel	Continuous	674,941			42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #1 (TR-2)	502,019.4	8,967,869.5	16	HP Fuel	Continuous	500,830			44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #2 (TR-2)	502,025.9	8,967,855.7	16	HP Fuel	Continuous	500,830			44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #3 (TR-2)	502,032.2	8,967,842.1	16	HP Fuel	Continuous	500,830			44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		Amine Regeneration Acid Gas Vent (TR-2)	501,952.3	8,967,844.3	16	NA	Continuous		13,829		54.0	round		0.54	7.6	42	315					15.500
	Power Generation	Power Generation Turbine #1	502,100.1	8,967,591.3	15	HP Fuel	Off-line	380,156			30.2	round		1.83								
		Power Generation Turbine #2	502,111.9	8,967,565.9	15	HP Fuel	Off-line	380,156			30.2	round		1.83								
		Power Generation Turbine #3	502,123.8	8,967,540.6	15	HP Fuel	Off-line	380,156			30.2	round		1.83								
		Power Generation Turbine #4	502,135.6	8,967,515.2	15	HP Fuel	Off-line	380,156			30.2	round		1.83								
		Power Generation Turbine #5	502,147.4	8,967,489.8	15	HP Fuel	Off-line	380,156			30.2	round		1.83								
		Power Generation Turbine #6	502,159.3	8,967,464.4	15	HP Fuel	Off-line	380,156			30.2	round		1.83								
		Power Generation Turbine #7	502,171.1	8,967,439.1	15	HP Fuel	Spare[1]	380,156														
	Furnaces	Regeneration Furnace (TR-1)	501,943.2	8,967,939.1	16	LP Fuel	Continuous			8,230	42.0	round		0.96	9.8	259	532	2.130	0.030		1.670	0.0003
		Common Regeneration (Standby) Furnace	501,946.4	8,967,932.3	16	LP Fuel	Intermittent[3]			8,230												
		Regeneration Furnace (TR-2)	501,949.6	8,967,925.5	16	LP Fuel	Continuous			8,230	42.0	round		0.96	8.8	265	538	2.130	0.030		1.670	0.0003
		Hot Oil Heater Furnace	501,940.1	8,967,945.9	16	LP Fuel	Continuous[4]			8,630	42.0	round		0.96	12.7	309	582	2.240	0.030		1.810	0.0003
	Flares	Wet Flare (Normal)	502,096.3	8,968,674.9	16	LP Fuel	Continuous		26.05		93.8	round		0.15	20.0	1,000	1,273	0.012	0.665			
		Dry Flare (Normal)	502,093.1	8,968,675.5	16	LP Fuel	Continuous		47.58		94.1	round		0.20	20.0	1,000	1,273	0.012	0.665			
		Tankage Gas Flare (Normal)	501,224.0	8,967,954.1	4.5	LP Fuel	Continuous		32.32		65.9	round		0.16	20.0	1,000	1,273	0.009	0.050			
	Incinerators	Process Sludge Incinerator	502,061.7	8,967,314.8	15	Diesel Fuel	8am-5pm				20.6	round		0.23	16.7	152	425	0.167	0.014	0.0153	0.058	0.0000
		General Incinerator - Out of Service	502,634.0	8,968,402.0	15	Diesel Fuel	OOS				10.0	rectangular	1.0 x 1.0	1.13								
Trains 3-6	Gas Turbine Drivers	GTD for Main Turbo - Generator Package 96-TGT83390	502,460.8	8,967,681.2	19.5	Siemens	Continuous, Except SO2 - use 15hr SO2 curve				19.4	round		3.0	23.8	208	481	54.56	13.26	variable	0.81	0.0072
		GTD for Main Turbo - Generator Package 96-TGT83391	502,427.7	8,967,665.8	19.5	HP Fuel	Continuous, Except SO2 - use 15hr SO2 curve				19.4	round		3.0	23.8	208	481	54.56	13.26	variable	0.81	0.0072
		GTD for Main Turbo - Generator Package 96-TGT83392	502,394.7	8,967,650.3	19.5		Continuous, Except SO2 - use 15hr SO2 curve				19.4	round		3.0	23.8	208	481	54.56	13.26	variable	0.81	0.0072
		GTD for Main Turbo - Generator Package 96-TGT83393	502,361.6	8,967,634.9	19.5		Continuous, Except SO2 - use 15hr SO2 curve				19.4	round		3.0	23.8	208	481	54.56	13.26	variable	0.81	0.0072
	Emergency diesel generators	Emergency Diesel Generator 96-VTDE83740	502,327.4	8,967,731.5	19.5		Upset ops only				TBD	TBD		TBD								
		Emergency Diesel Generator 96-VTDE83750	502,317.4	8,967,726.9	19.5		Upset ops only				TBD	TBD		TBD								
		Emergency Diesel Generator 96-VTDE83760	502,307.5	8,967,722.2	19.5		Upset ops only				TBD	TBD		TBD								
	Furnaces	Hot Oil Furnace93-EAW94150	502,080.5	8,967,912.6	16.0	TBD	Continuous	21612 kg/hr	42.0	1.6	42.0	round		1.6	6.5	340	613	5.59	0.08		4.390	0.0007
	Flares	Wet Flare (Normal)	502,603.5	8,968,765.7	20.0	TBD	Continuous	250 kg/h (JGC	93.0	1.6	70.8	round		0.15	20.0	1,000	1,273	0.01	0.66			
		Dry Flare (Normal)	502,603.5	8,968,765.7	20.0	TBD	Continuous	300 kg/h (JGC	93.0	1.2	71.1	round		0.20	20.0	1,000	1,273	0.01	0.66			
	Thermal Oxidiser	Inlet Liquid Separator Thermal Oxidizer 93-VEAL62330	502,123.9	8,967,937.9	16.0	TBD	Continuous	286 kg/hr	10.0	0.1	10.0	round		0.12	7.0	71	344.0	0.163	0.023	0.010	0.011	
	Incinerators	Sludge Incinerator 973 97-VZBE97394	502,121.0	8,967,285.0	15.0	OTTO	Continuous, Except SO2 - use	60 kg/h	20.6	0.2	20.6	round		0.23	30.0	180	453.0	1.044	0.010	variable	0.097	0.000
		New Waste incinerator	501,231.0	8,968,704.0	15.0	Diesel Fuel	8am-5pm	NA			10.0	rectangular	1.0 x 1.0	1.20	20.0	275	547.5	15.28	7.64	3.8	0.76	
3rd Party Pwr Stns	Dirio power station	Solar Titan PGT	505,103.1	8,969,632.2	30	Gas	Continuous	380,156			30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Solar Titan PGT	505,103.4	8,969,621.7	30	Gas	Continuous	380,156			30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Solar Titan PGT	505,104.8	8,969,610.8	30	Gas	Continuous	380,156			30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
	Port Moresby Power Station (NuPower Ltd)	6xWartsilla 20V34SG Gas Engines - without CO catalyst	504,779.0	8,969,445.6	28	-	-	-	-	-	27.5			2.900	27.1	364	637	38.88	79.20	0.025	4.000	0.0202

	Volume Sources										Release height			Length of sid	Initial Y	Initial Z						
Existing LNG Plant	Plant Fugitives	Trains 1 and 2	501,690.9	8,967,728.6	NA	NA	Continuous	NA			2.0	round	0.0	225.0	52.3	4.7						0.0108
	Analyzers fugitive	Analyzer House (AH9101)	501,890.0	8,967,650.0	16	NA	Intermittent				7.0			8.6	2.0	1.0						0.0050
	Analyzers fugitive	Analyzer House (AH9201)	502,026.0	8,967,713.4	16	NA	Intermittent				7.0			8.6	2.0	1.0						0.0050
	Analyzers fugitive	Analyzer House (AH9501)	501,776.5	8,967,840.0	16	NA	Intermittent				7.0			8.6	2.0	1.0						0.0020
	Analyzers fugitive	Analyzer House (AH9801)	501,346.8	8,967,982.3	5	NA	Intermittent				7.0			8.6	2.0	1.0						0.0030
Trains 3-6	Plant Fugitives	Trains 3-6 - assume same as Train 1,2 emission rate	502,350.0	8,967,975.0	NA	NA	Continuous	NA			2.0	round	0.0	200.0	46.5	4.7						0.0108
	Analyzers fugitive	Analyzer House-1	502,465.9	8,967,681.7	16	NA	Intermittent	0	0	0	7			8.6	2.0	1.0						1.0100
		Analyzer House-2	502,432.8	8,967,666.3	16	NA	Intermittent	0	0	0	7			8.6	2.0	1.0						1.0100
		Analyzer House-3	502,399.7	8,967,650.8	16	NA	Intermittent	0	0	0	7			8.6	2.0	1.0						1.0100
		Analyzer House-4	502,366.6	8,967,635.4	16	NA	Intermittent	0	0	0	7			8.6	2.0	1.0						1.0100

SLR have chosen to represent fugitive sources as volume sources, not point sources.
Volume sources based on length and height of train building

Proposed Expanded Plant, plus 3rd Party Power Plants Upset Conditions

Source Group	Point Sources	Plant Item	Location (UTM,Zone 55,WGS84) Easting (mE)	Northing (mN)	Base Ht (m)	Operation Duty	Stack Dimensions Height (mAGL)	Shape	L x W (m)	Diameter (m)	Stack Gas Parameters Velocity (m/s)	Temp (°C)	Temp (K)	Emission Rates to be modelled by SLR NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
Existing LNG Plant	Liquefaction - Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-1)	501,955.9	8,967,650.9	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-1)	501,962.2	8,967,637.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #1 (TR-1)	501,883.6	8,967,805.9	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #2 (TR-1)	501,889.9	8,967,792.3	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #3 (TR-1)	501,896.2	8,967,778.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		Amine Regeneration Acid Gas Vent (TR-1)	501,816.3	8,967,780.9	16	Continuous	54.0	round		0.54	7.6	42	315					15.50
	Liquefaction - Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-2)	502,091.8	8,967,714.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-2)	502,098.1	8,967,700.7	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #1 (TR-2)	502,019.4	8,967,869.5	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #2 (TR-2)	502,025.9	8,967,855.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		MR Compressor Gas Turbine Driver #3 (TR-2)	502,032.2	8,967,842.1	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.07	7.35		1.36	
		Amine Regeneration Acid Gas Vent (TR-2)	501,952.3	8,967,844.3	16	Continuous	54.0	round		0.54	7.6	42	315					15.50
	Power Generation	Power Generation Turbine #1	502,100.1	8,967,591.3	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #2	502,111.9	8,967,565.9	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #3	502,123.8	8,967,540.6	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #4	502,135.6	8,967,515.2	15	Continuous	30.2	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Power Generation Turbine #5	502,147.4	8,967,489.8	15	Off-line	30.2	round		1.83								
		Power Generation Turbine #6	502,159.3	8,967,464.4	15	Off-line	30.2	round		1.83								
		Power Generation Turbine #7	502,171.1	8,967,439.1	15	Spare[1]												
	Furnaces	Regeneration Furnace (TR-1)	501,943.2	8,967,939.1	16	Continuous	42.0	round		0.96	9.8	259	532	2.13	0.03		1.67	0.0003
		Common Regeneration (Standby) Furnace	501,946.4	8,967,932.3	16	Intermittent[3]												
		Regeneration Furnace (TR-2)	501,949.6	8,967,925.5	16	Continuous	42.0	round		0.96	8.8	265	538	2.13	0.03		1.67	0.0003
		Hot Oil Heater Furnace	501,940.1	8,967,945.9	16	Continuous[4]	42.0	round		0.96	12.7	309	582	2.24	0.03		1.81	0.0003
	Flares	Wet Flare (Normal)	502,096.3	8,968,674.9	16	Continuous	93.8	round		0.15	20.0	1,000	1,273	0.012	0.665			
		Dry Flare (Normal)	502,093.1	8,968,675.5	16	Continuous	94.1	round		0.20	20.0	1,000	1,273	0.012	0.665			
		Tankage Gas Flare (Normal)	501,224.0	8,967,954.1	4.5	Continuous	65.9	round		0.16	20.0	1,000	1,273	0.009	0.050			
	Incinerators	Process Sludge Incinerator	502,061.7	8,967,314.8	15	8am-5pm	20.6	round		0.23	16.7	152	425	0.17	0.01	0.02	0.06	0.0000000001
		General Incinerator - Out of Service	502,634.0	8,968,402.0	15	OOS	10.0	rectangular	1.0 x 1.0	1.13								
Trains 4-6	Gas Turbine Drivers	GTD for Main Turbo - Generator Package 96-TGT83390	502,460.8	8,967,681.2	19.5	Off-line	19.4	round		3.0								
		GTD for Main Turbo - Generator Package 96-TGT83391	502,427.7	8,967,665.8	19.5	Off-line	19.4	round		3.0								
		GTD for Main Turbo - Generator Package 96-TGT83392	502,394.7	8,967,650.3	19.5	Off-line	19.4	round		3.0								
		GTD for Main Turbo - Generator Package 96-TGT83393	502,361.6	8,967,634.9	19.5	Off-line	19.4	round		3.0								
	Emergency diesel generators	Emergency Diesel Generator 96-VTDE83740	502,327.4	8,967,731.5	19.5	Upset ops only	20.0	round		3.0	20.0	350.0	623	12.71	2.05	0.0078	0.09	
		Emergency Diesel Generator 96-VTDE83750	502,317.4	8,967,726.9	19.5	Upset ops only	20.0	round		3.0	20.0	350.0	623	12.71	2.05	0.0078	0.09	
		Emergency Diesel Generator 96-VTDE83760	502,307.5	8,967,722.2	19.5	Upset ops only	20.0	round		3.0	20.0	350.0	623	12.71	2.05	0.0078	0.09	
	Furnaces	Hot Oil Furnace93-EAW94150	502,080.5	8,967,912.6	16.0	Off-line	42.0	round		1.6								
	Flares	Wet Flare (Upset)	502,603.5	8,968,765.7	20.0	Upset ops only	240.4	round		40.0	20.0	1,000	1,273	2,300.00	12,500.00	1,140.00		
		Dry Flare (Normal)	502,603.5	8,968,765.7	20.0	Continuous	71.1	round		0.2	20.0	1,000	1,273	0.01	0.66			
	Thermal Oxidiser	Inlet Liquid Separator Thermal Oxidizer 93-VEAL62330	502,123.9	8,967,937.9	16.0	Off-line	10.0	round		0.1								
	Incinerators	Sludge Incinerator 973 97-VZBE97394	502,121.0	8,967,285.0	15.0	Off-line	20.6	round		0.2								
		New Waste incinerator	501,231.0	8,968,704.0	15.0	8am-5pm	10.0	rectangular	1.0 x 1.0	1.2	20.0	275.0	547.5	15.3	7.6	3.8	0.8	0.0
3rd Party Pwr Stns	Dirio power station	Solar Titan PGT	505,103.1	8,969,632.2	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.009
		Solar Titan PGT	505,103.4	8,969,621.7	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.009
		Solar Titan PGT	505,104.8	8,969,610.8	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.009
	Port Moresby Power Station (NuPower Ltd)	6xWartsilla 20V34SG Gas Engines - without CO catalyst	504,779.0	8,969,445.6	28	-	27.5			2.900	27.1	364	637	38.88	79.20	0.025	4.00	0.020

Source Group	Volume Sources	Plant Item	Easting	Northing	Base Ht	Duty	Release height	Shape	L x W	Length of side	Initial Y	Initial Z						Benzene
Existing LNG Plant	Plant Fugitives	Trains 1 and 2	501,690.9	8,967,728.6	NA	Continuous	2.0	round	0.0	225.0	52.3	4.7						0.0108
	Analyzers fugitive	Analyzer House (AH9101)	501,890.0	8,967,650.0	16	Intermittent	7.0			8.6	2.0	1.0						0.0050
	Analyzers fugitive	Analyzer House (AH9201)	502,026.0	8,967,713.4	16	Intermittent	7.0			8.6	2.0	1.0						0.0050
	Analyzers fugitive	Analyzer House (AH9501)	501,776.5	8,967,840.0	16	Intermittent	7.0			8.6	2.0	1.0						0.0020
	Analyzers fugitive	Analyzer House (AH9801)	501,346.8	8,967,982.3	5	Intermittent	7.0			8.6	2.0	1.0						0.0030
Trains 4-6	Plant Fugitives	Trains 3-6 - same as Train 1,2 emission rate	502,350.0	8,967,975.0	NA	Continuous	2.0	round	0.0	200.0	46.5	4.7						0.0108
	Analyzers fugitive	Analyzer House-1	502,465.9	8,967,681.7	16	Intermittent	7.0			8.6	2.0	1.0						1.0100
		Analyzer House-2	502,432.8	8,967,666.3	16	Intermittent	7.0			8.6	2.0	1.0						1.0100
		Analyzer House-3	502,399.7	8,967,650.8	16	Intermittent	7.0			8.6	2.0	1.0						1.0100
		Analyzer House-4	502,366.6	8,967,635.4	16	Intermittent	7.0			8.6	2.0	1.0						1.0100

SLR have chosen to represent fugitive sources as volume sources, not point sources.
Volume sources based on length and height of train building

Proposed Expanded Plant, plus 3rd Party Power Plants - NOT MODELLED **Non Power Share Operating Conditions**

Source Group	Point Sources	Plant Item	Location (UTM,Zone 55,WGS84) Easting (mE)	Northing (mN)	Base Ht (m)	Operation Duty	Stack Dimensions Height (mAGL)	Shape	L x W (m)	Diameter (m)	Stack Gas Parameters Velocity (m/s)	Temp (°C)	Temp (K)	Emission Rates NO_x (kg/hr)	CO (kg/hr)	SO_2 (kg/hr)	PM_{10} (kg/hr)	Benzene (kg/hr)
Existing LNG Plant	Liquefaction - Train 1	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-1)	501,955.9	8,967,650.9	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-1)	501,962.2	8,967,637.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #1 (TR-1)	501,883.6	8,967,805.9	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #2 (TR-1)	501,889.9	8,967,792.3	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #3 (TR-1)	501,896.2	8,967,778.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		Amine Regeneration Acid Gas Vent (TR-1)	501,816.3	8,967,780.9	16	Continuous	54.0	round		0.54	7.6	42	315					15.500
	Liquefaction - Train 2	Propane Refrigerant Compressor Gas Turbine Driver #1 (TR-2)	502,091.8	8,967,714.3	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		Propane Refrigerant Compressor Gas Turbine Driver #2 (TR-2)	502,098.1	8,967,700.7	16	Continuous	42.9	rectangular	2.3 x 3.4	3.16	24.0	535	808	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #1 (TR-2)	502,019.4	8,967,869.5	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #2 (TR-2)	502,025.9	8,967,855.7	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		MR Compressor Gas Turbine Driver #3 (TR-2)	502,032.2	8,967,842.1	16	Continuous	44.0	rectangular	3.0 x 3.0	3.39	15.5	332	605	12.070	7.350		1.361	
		Amine Regeneration Acid Gas Vent (TR-2)	501,952.3	8,967,844.3	16	Continuous	54.0	round		0.54	7.6	42	315					15.500
	Power Generation	Power Generation Turbine #1	502,100.1	8,967,591.3	15	Continuous	30.2	round		1.83	40.1	529	802	6.000	3.600		0.700	0.0095
		Power Generation Turbine #2	502,111.9	8,967,565.9	15	Continuous	30.2	round		1.83	40.1	529	802	6.000	3.600		0.700	0.0095
		Power Generation Turbine #3	502,123.8	8,967,540.6	15	Continuous	30.2	round		1.83	40.1	529	802	6.000	3.600		0.700	0.0095
		Power Generation Turbine #4	502,135.6	8,967,515.2	15	Continuous	30.2	round		1.83	40.1	529	802	6.000	3.600		0.700	0.0095
		Power Generation Turbine #5	502,147.4	8,967,489.8	15	Off-line	30.2	round		1.83								
		Power Generation Turbine #6	502,159.3	8,967,464.4	15	Off-line	30.2	round		1.83								
		Power Generation Turbine #7	502,171.1	8,967,439.1	15	Spare[1]												
	Furnaces	Regeneration Furnace (TR-1)	501,943.2	8,967,939.1	16	Continuous	42.0	round		0.96	9.8	259	532	2.130	0.030		1.670	0.0003
		Common Regeneration (Standby) Furnace	501,946.4	8,967,932.3	16	Intermittent[3]												
		Regeneration Furnace (TR-2)	501,949.6	8,967,925.5	16	Continuous	42.0	round		0.96	8.8	265	538	2.130	0.030		1.670	0.0003
		Hot Oil Heater Furnace	501,940.1	8,967,945.9	16	Continuous[4]	42.0	round		0.96	12.7	309	582	2.240	0.030		1.810	0.0003
	Flares	Wet Flare (Normal)	502,096.3	8,968,674.9	16	Continuous	93.8	round		0.15	20.0	1,000	1,273	0.012	0.665			
		Dry Flare (Normal)	502,093.1	8,968,675.5	16	Continuous	94.1	round		0.20	20.0	1,000	1,273	0.012	0.665			
		Tankage Gas Flare (Normal)	501,224.0	8,967,954.1	4.5	Continuous	65.9	round		0.16	20.0	1,000	1,273	0.009	0.050			
	Incinerators	Process Sludge Incinerator	502,061.7	8,967,314.8	15	8am-5pm	20.6	round		0.23	16.7	152	425	0.167	0.014	0.0153	0.058	0.0000
		General Incinerator - Out of Service	502,634.0	8,968,402.0	15	OOS	10.0	rectangular	1.0 x 1.0	1.13								
Trains 3-6	Gas Turbine Drivers	GTD for Main Turbo - Generator Package 96-TGT83390	502,460.8	8,967,681.2	19.5	Continuous, Except SO2 - peak only emitted over 2 hours every 14 hours, rest of time = 0 kg/hr	19.4	round		3.0	23.8	208	481	54.56	13.26	variable	0.81	0.0072
		GTD for Main Turbo - Generator Package 96-TGT83391	502,427.7	8,967,665.8	19.5	Continuous, Except SO2 - peak only emitted over 2 hours every 14 hours, rest of time = 0 kg/hr	19.4	round		3.0	23.8	208	481	54.56	13.26	variable	0.81	0.0072
		GTD for Main Turbo - Generator Package 96-TGT83392	502,394.7	8,967,650.3	19.5	Continuous, Except SO2 - peak only emitted over 2 hours every 14 hours, rest of time = 0 kg/hr	19.4	round		3.0	23.8	208	481	54.56	13.26	variable	0.81	0.0072
		GTD for Main Turbo - Generator Package 96-TGT83393	502,361.6	8,967,634.9	19.5	Standby	19.4	round		3.0								
	Emergency diesel generators	Emergency Diesel Generator 96-VTDE83740	502,327.4	8,967,731.5	19.5	Upset ops only	TBD	TBD		TBD								
		Emergency Diesel Generator 96-VTDE83750	502,317.4	8,967,726.9	19.5	Upset ops only	TBD	TBD		TBD								
		Emergency Diesel Generator 96-VTDE83760	502,307.5	8,967,722.2	19.5	Upset ops only	TBD	TBD		TBD								
	Furnaces	Hot Oil Furnace93-EAW94150	502,080.5	8,967,912.6	16.0	Continuous	42.0	round		1.6	6.5	340	613	5.59	0.08		4.390	0.0007
	Flares	Wet Flare (Normal)	502,603.5	8,968,765.7	20.0	Continuous	70.8	round		0.15	20.0	1,000	1,273	0.01	0.66			
		Dry Flare (Normal)	502,603.5	8,968,765.7	20.0	Continuous	71.1	round		0.20	20.0	1,000	1,273	0.01	0.66			
	Thermal Oxidiser	Inlet Liquid Separator Thermal Oxidizer 93-VEAL62330	502,123.9	8,967,937.9	16.0	Continuous	10.0	round		0.12	7.0	71	344.0	0.163	0.023	0.010	0.011	
	Incinerators	Sludge Incinerator 973 97-VZBE97394	502,121.0	8,967,285.0	15.0	Continuous, Except SO2 - peak only emitted over 2 hours every 14 hours, rest of time = 0 kg/hr	20.6	round		0.23	30.0	180	453.0	0.300	0.026	variable	0.104	0.000
		New Waste incinerator	501,231.0	8,968,704.0	15.0	8am-5pm	10.0	rectangular	1.0 x 1.0	1.20	20.0	275	547.5	15.28	7.64	3.8	0.76	
3rd Party Pwr Stns	Dirio power station	Solar Titan PGT	505,103.1	8,969,632.2	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Solar Titan PGT	505,103.4	8,969,621.7	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
		Solar Titan PGT	505,104.8	8,969,610.8	30	Continuous	30.0	round		1.83	40.1	529	802	6.00	3.60		0.70	0.0095
	Port Moresby Power Station (NuPower Ltd)	6xWartsilla 20V34SG Gas Engines - without CO catalyst	504,779.0	8,969,445.6	28	-	27.5			2.900	27.1	364	637	38.88	79.20	0.025	4.000	0.0202

	Volume Sources						Release height			Length of sid	Initial Y	Initial Z						
Existing LNG Plant	Plant Fugitives	Trains 1 and 2	501,690.9	8,967,728.6	NA	Continuous	2.0	round	0.0	225.0	52.3	4.7						0.0108
	Analyzers fugitive	Analyzer House (AH9101)	501,890.0	8,967,650.0	16	Intermittent	7.0			8.6	2.0	1.0						0.0050
	Analyzers fugitive	Analyzer House (AH9201)	502,026.0	8,967,713.4	16	Intermittent	7.0			8.6	2.0	1.0						0.0050
	Analyzers fugitive	Analyzer House (AH9501)	501,776.5	8,967,840.0	16	Intermittent	7.0			8.6	2.0	1.0						0.0020
	Analyzers fugitive	Analyzer House (AH9801)	501,346.8	8,967,982.3	5	Intermittent	7.0			8.6	2.0	1.0						0.0030
Trains 3-6	Plant Fugitives	Trains 3-6 - assume same as Train 1,2 emission rate	502,350.0	8,967,975.0	NA	Continuous	2.0	round	0.0	200.0	46.5	4.7						0.0108
	Analyzers fugitive	Analyzer House-1	502,465.9	8,967,681.7	16	Intermittent	7			8.6	2.0	1.0						1.0100
		Analyzer House-2	502,432.8	8,967,666.3	16	Intermittent	7			8.6	2.0	1.0						1.0100
		Analyzer House-3	502,399.7	8,967,650.8	16	Intermittent	7			8.6	2.0	1.0						1.0100
		Analyzer House-4	502,366.6	8,967,635.4	16	Intermittent	7			8.6	2.0	1.0						1.0100

SLR have chosen to represent fugitive sources as volume sources, not point sources.
Volume sources based on length and height of train building

SHIPPING EMISSION CALCULATIONS:

Taken from:
ExxonMobil Corporation – Papua New Guinea (PNG) Liquefied Natural Gas (LNG) Project Memorandum
Subject: *Air Quality Impact Modeling for Tugboats Emissions*
Prepared by URS (February 2010)

Table E-1. Basis Information for Tugboats

Variable	Value	Source
Smaller OGV Propulsion Engines	7579 kW	U.S. EPA, 2009b
Smaller OGV Auxiliary Engine	2039 kW	U.S. EPA, 2009b
Engine type	Slow Speed Diesel	Based on similar LNG carrier
LF auxiliary engine hotel	0.22	U.S. EPA, 2009a
LF auxiliary engine maneuver	0.45	U.S. EPA, 2009a
Maneuver speed	8.00 knots	U.S. EPA, 2009a
Max speed carrier	14.5 knots	U.S. EPA, 2009a
LF Main propulsion engine	0.17	Calculation
Number of tugboats	2	ExxonMobil, April 2009
Percentage of marine vessel towed/escorted	100%	Estimation (2 tugs per tanker, 1 tug for other vessel docking)
Hrs/yr of towing maneuvering LNG carrier	104.29 hours per year	Calculation/Estimation
Hrs/yr of towing hotelling LNG carrier	104.29 hours per year	Calculation/Estimation
Hrs/yr of towing maneuvering condensate tanker	12.17 hours per year	Calculation/Estimation
Hrs/yr of towing hotelling condensate tanker	12.17 hours per year	Calculation/Estimation

Table E-2. Basis Information for LNG Carriers

Variable	Value	Source
LNG loading rate	12000 m^3/hr	ExxonMobil, April 2009
Ship size minimum	125000 m^3	ExxonMobil, April 2009
Ship size maximum	220000 m^3	ExxonMobil, April 2009
Loading frequency small ship	3.5 days	ExxonMobil, April 2009
Loading frequency large ship	6 days	ExxonMobil, April 2009
Duration of tugboat engine on during ship hotelling	1 hour	Estimation
Hrs/yr tugboat operation during small ship hotelling	104.29 hours per year	Calculation
Hrs/yr tugboat operation during large ship hotelling	60.83 hours per year	Calculation
Hrs/yr hotelled large ship	1115.28 hours per year	Calculation
Duration of tugboat and ship maneuvering	1 hour	Estimation
Hrs/yr maneuver small ship	104.29 hours per year	Calculation
Hrs/yr maneuver large ship	60.83 hours per year	Calculation

Table E-3. Basis Information for Condensate Tankers

Variable	Value	Source
Capacity	20000 Dead Weight Tonnes	ExxonMobil, April 2009
Loading frequency	30 days	ExxonMobil, April 2009
Duration load ship each time	10.0 hours	Estimation
Hrs/yr hotelling	121.67 hours	Calculation
Duration of tugboat engine on during tanker hotelling	1 hour	Estimation
Hrs/yr tugboat operation during tanker hotelling	12.17 hours per year	Calculation
Hours maneuver	1 hour	Estimation
Hrs/yr maneuver ship	12.17 hours per year	Calculation

Table E-4. Emission Factors for Main Propulsion Engines and Auxiliary Engines

Engine	Engine Type	Fuel	Sulfur	NO_x	PM10	PM2.5	HC	CO	SO_x	CO_2
			(%)	(g/kWh)						
Propulsion Engine	SSD	MDO	1	17	0.45	0.42	0.6	1.4	3.62	588.79
Auxiliary Engine	--	MDO	1	13.9	0.49	0.45	0.4	1.1	4.24	690.71

Note: g/kWh – grams per kilowatt-hour

Appendix B

Isopleth Plots – Current Operations

List of Figures

Figure B-1 Maximum Predicted 1-Hour Average CO Concentrations - Current Normal Operations

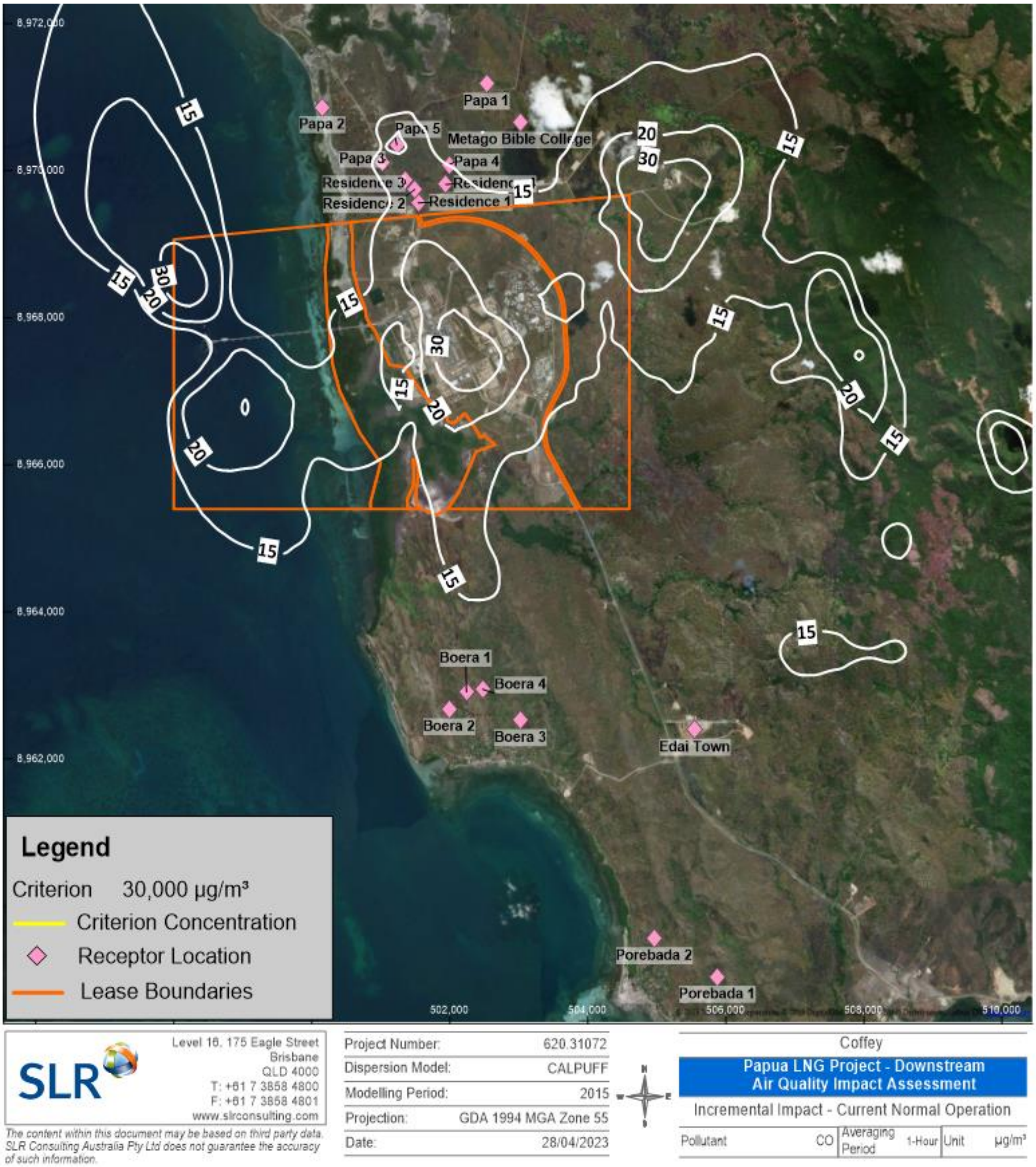


Figure B-2 Maximum Predicted 1-Hour Average CO Concentrations - Current Upset Operations

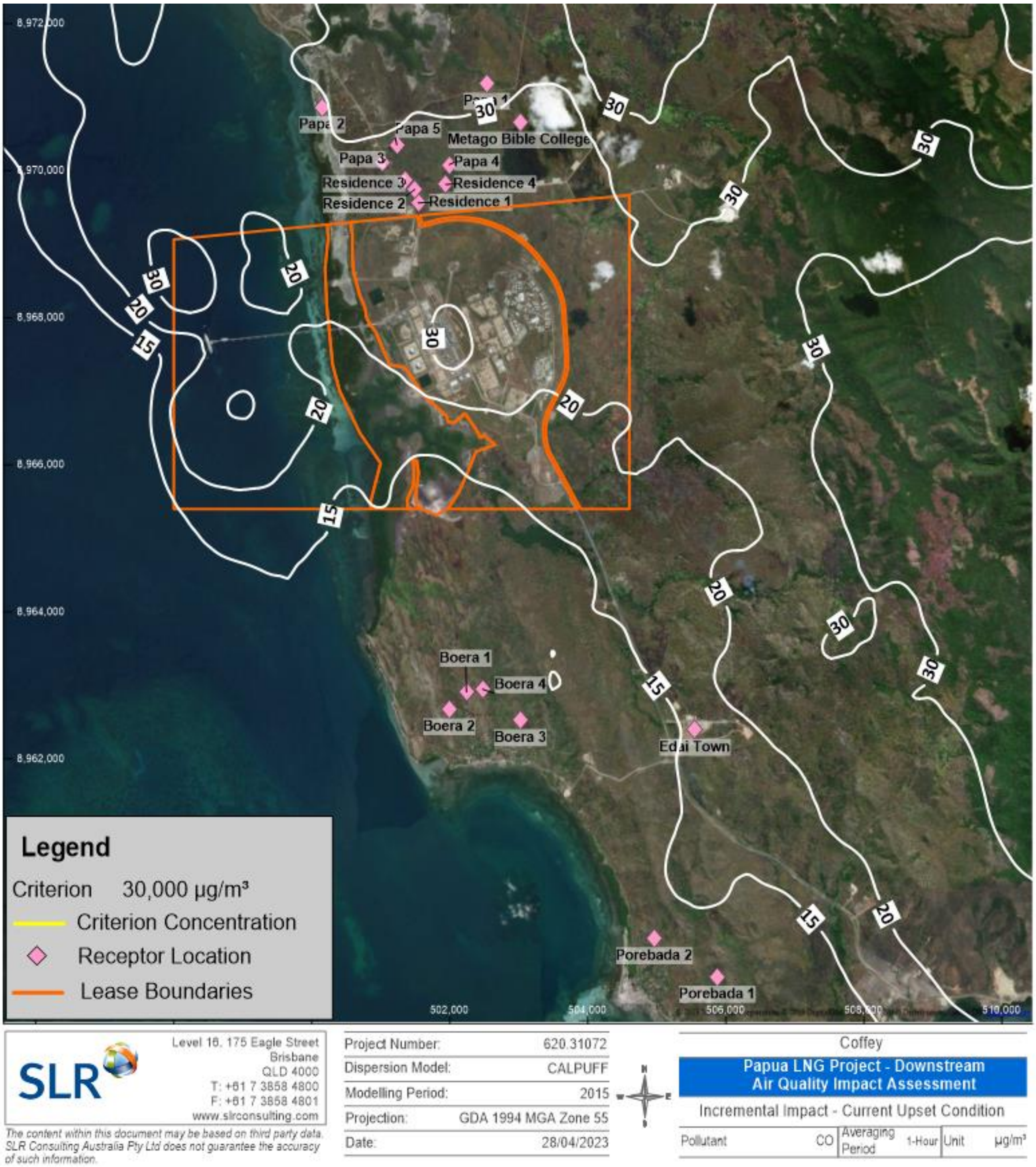
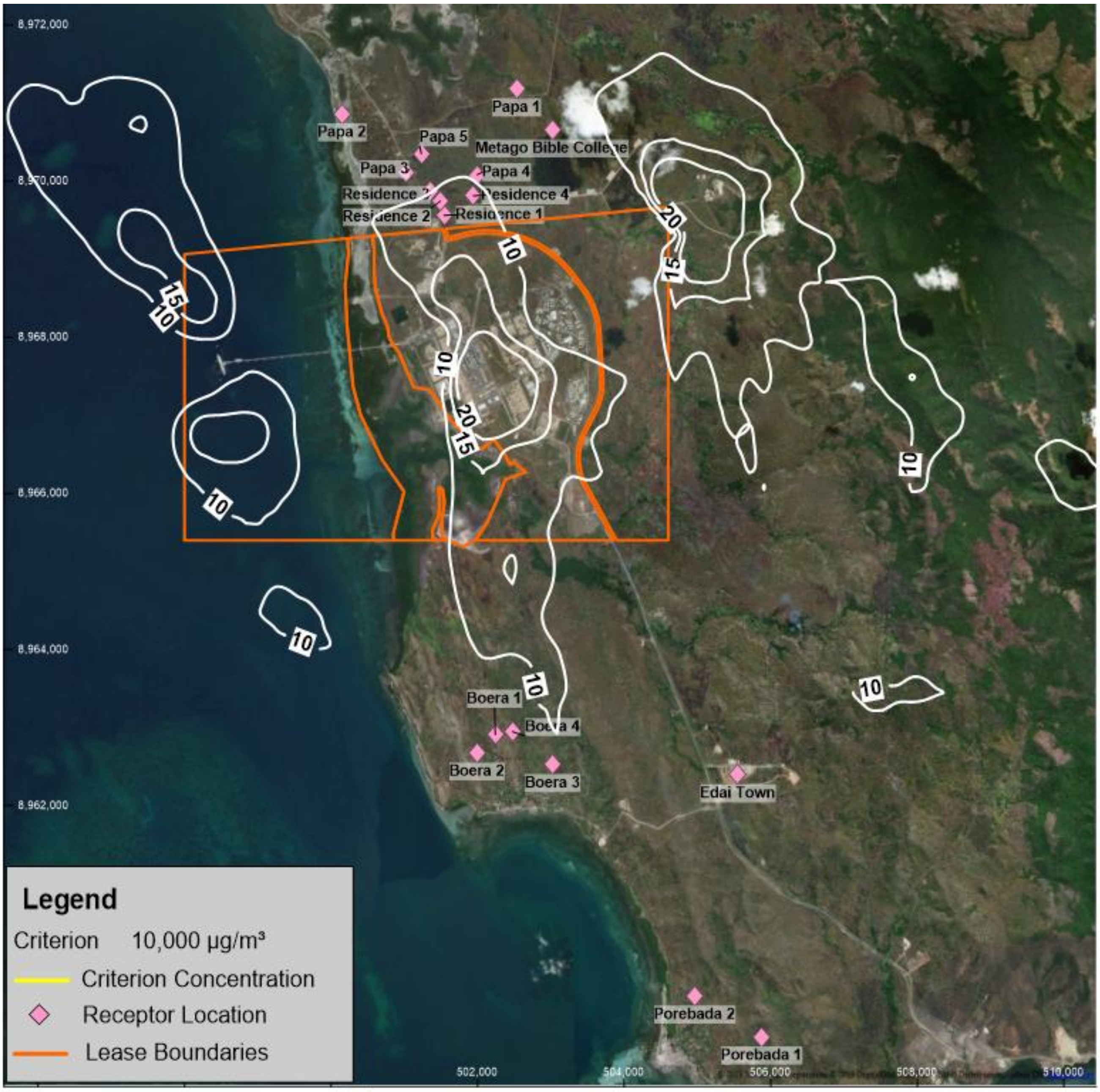


Figure B-3 Maximum Predicted 8-Hour Average CO Concentrations - Current Normal Operations



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Date:	28/04/2023

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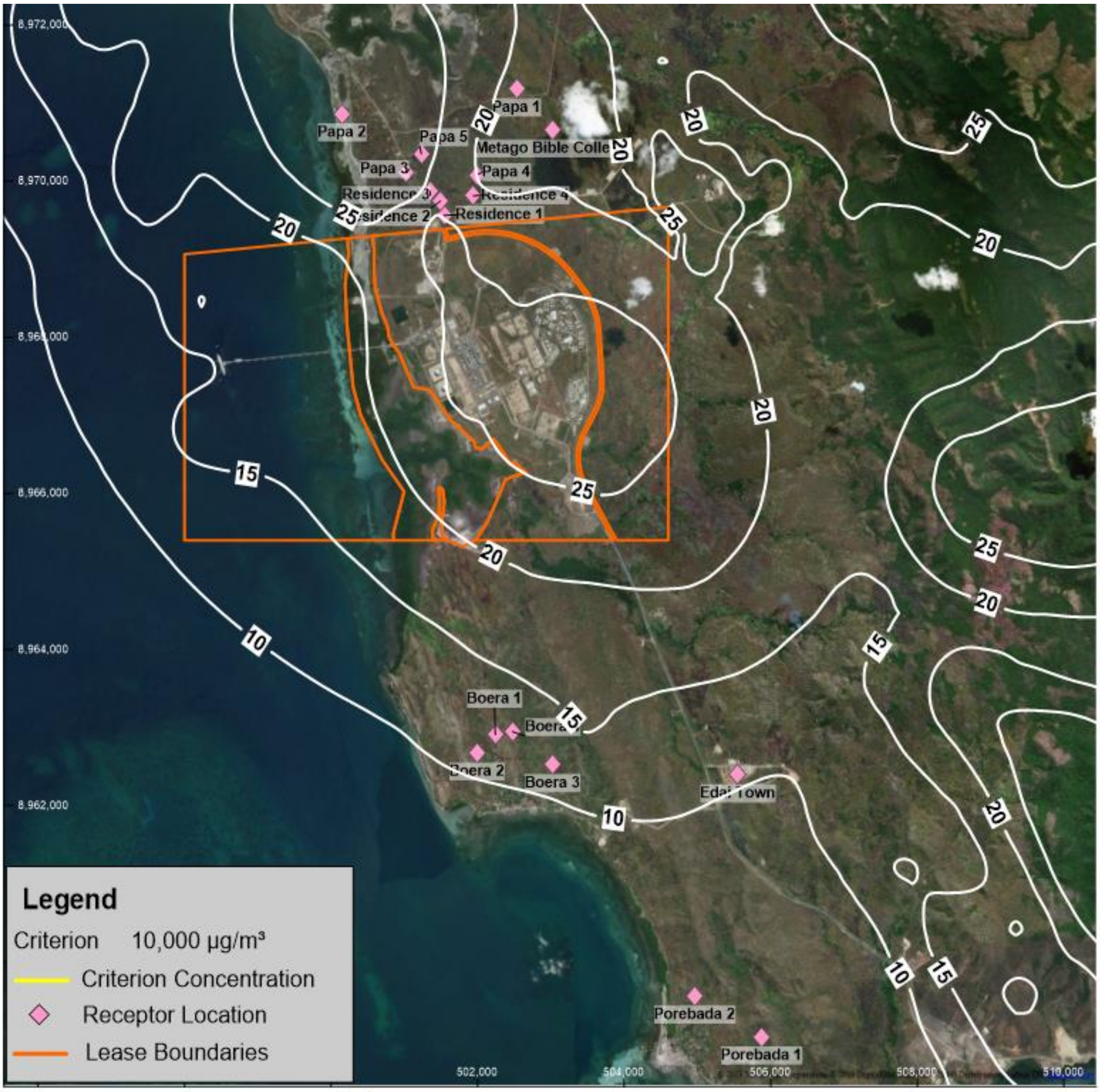
Papua LNG Project - Downstream
Air Quality Impact Assessment

Incremental Impact - Current Normal Operation

Pollutant	CO	Averaging Period	8-Hour	Unit	µg/m³

Figure B-4 Maximum Predicted 8-Hour Average CO Concentrations - Current Upset Operations



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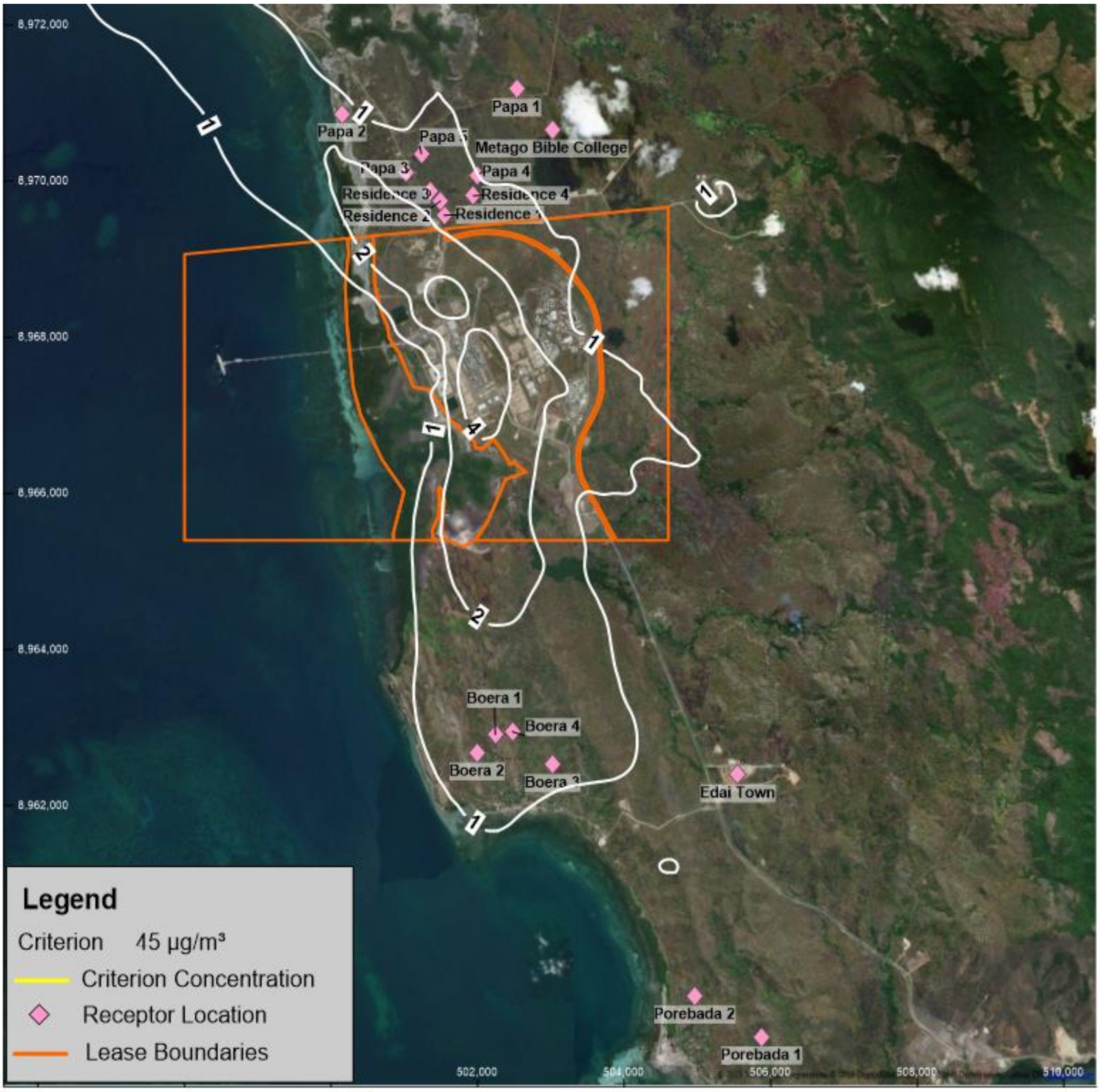
Pollutant	CO	Averaging Period	8-Hour	Unit	µg/m³

Figure B-5 Maximum Predicted 24-Hour Average PM_{10} Concentrations - Current Normal Operations



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Pollutant	PM_{10}	Averaging Period	24-Hour	Unit	µg/m³

Figure B-6 Maximum Predicted 24-Hour Average PM_{10} Concentrations - Current Upset Operations

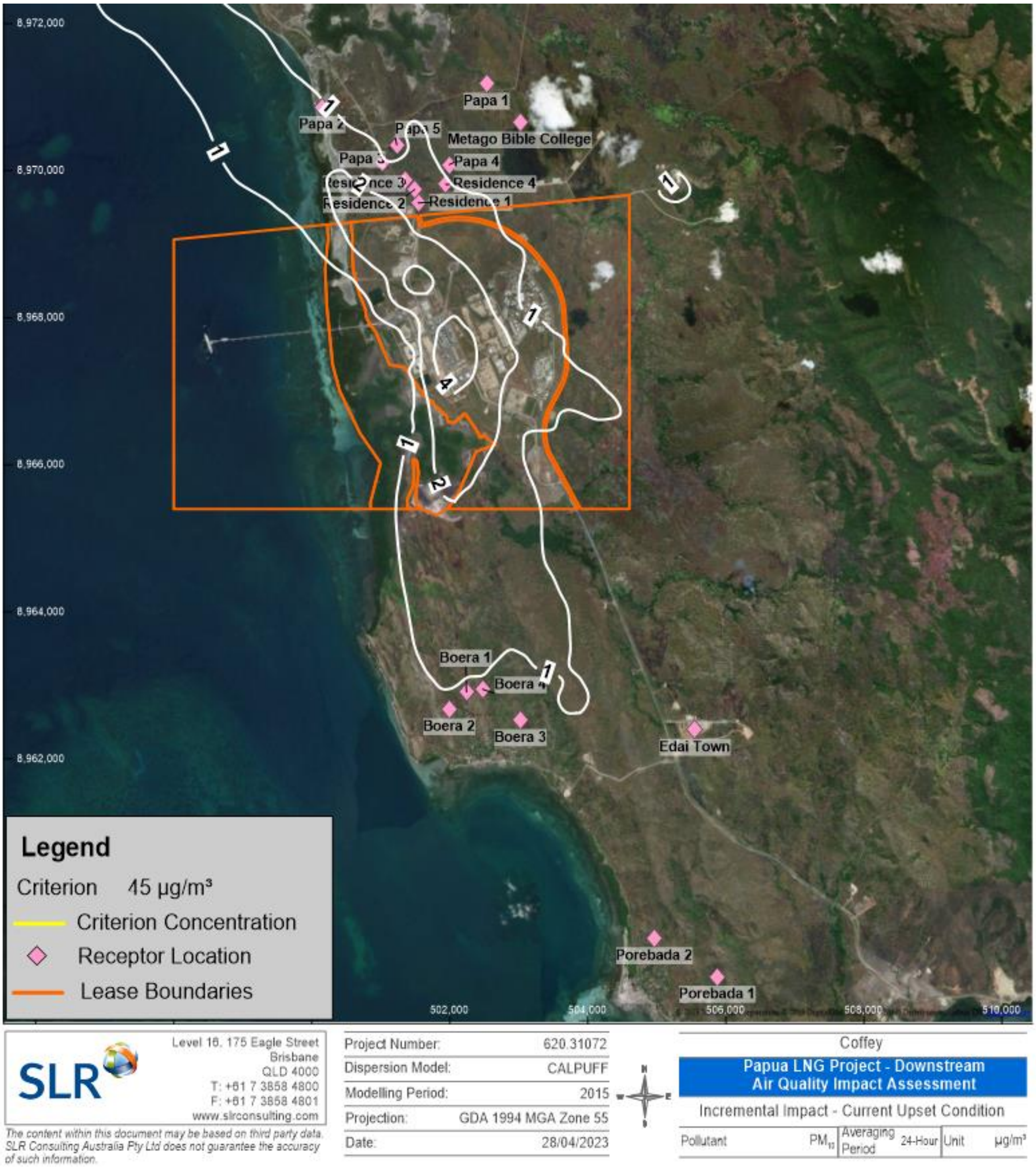


Figure B-7 Predicted Annual Average PM_{10} Concentrations - Current Normal Operations

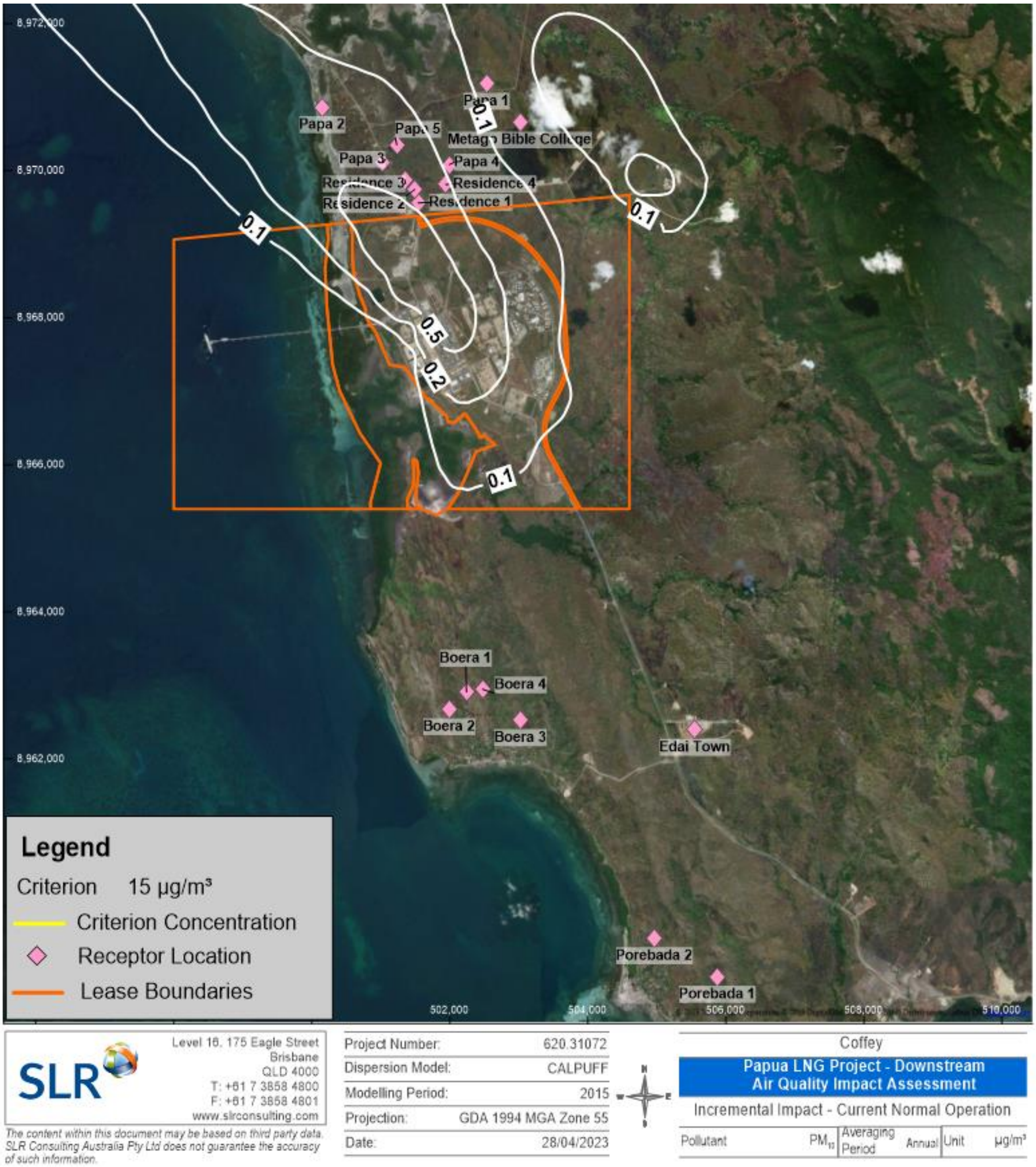


Figure B-8 Maximum Predicted 1-Hour Average NO_2 Concentrations - Current Normal Operations

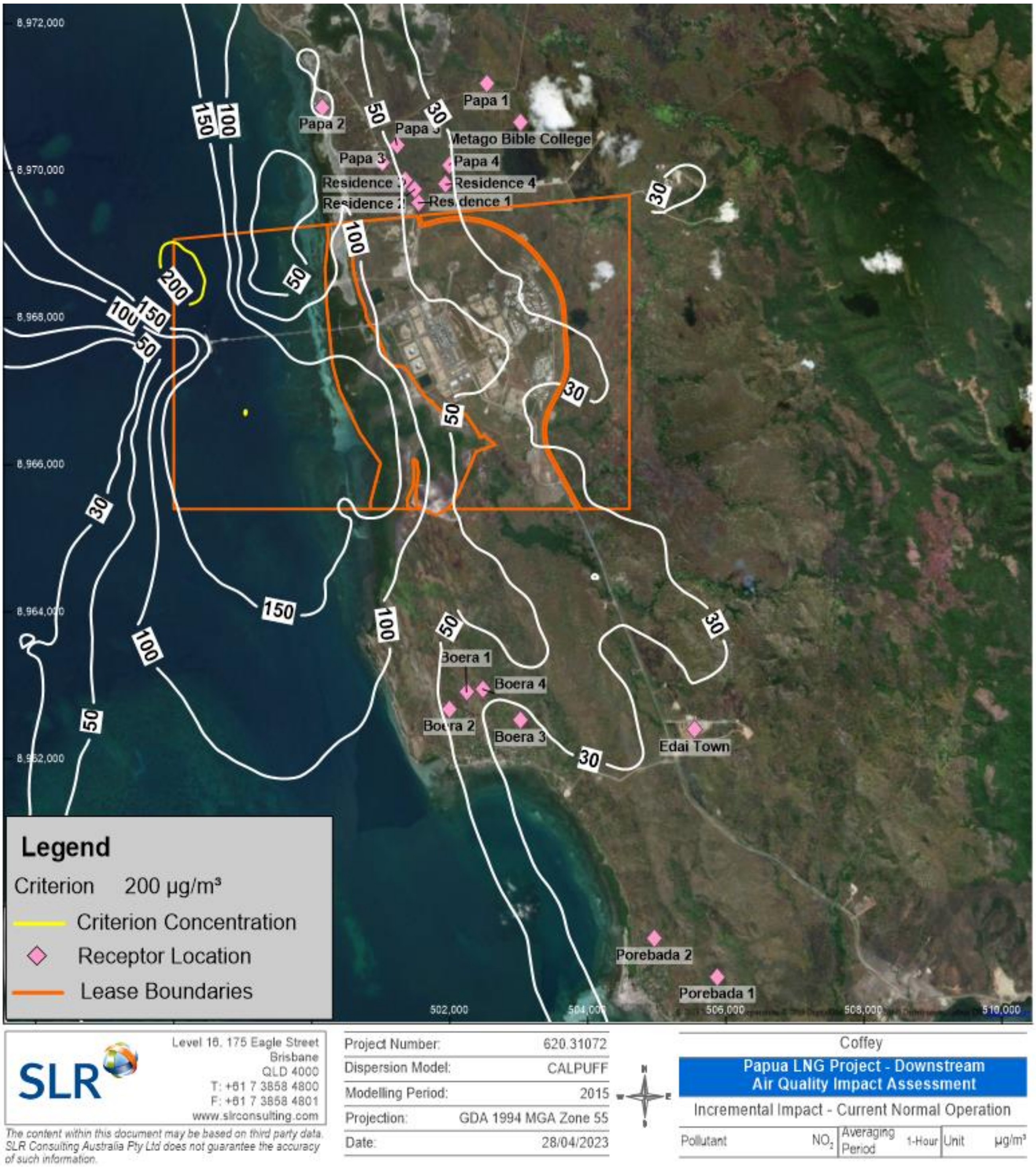


Figure B-9 Maximum Predicted 1-Hour Average NO_2 Concentrations - Current Upset Operations

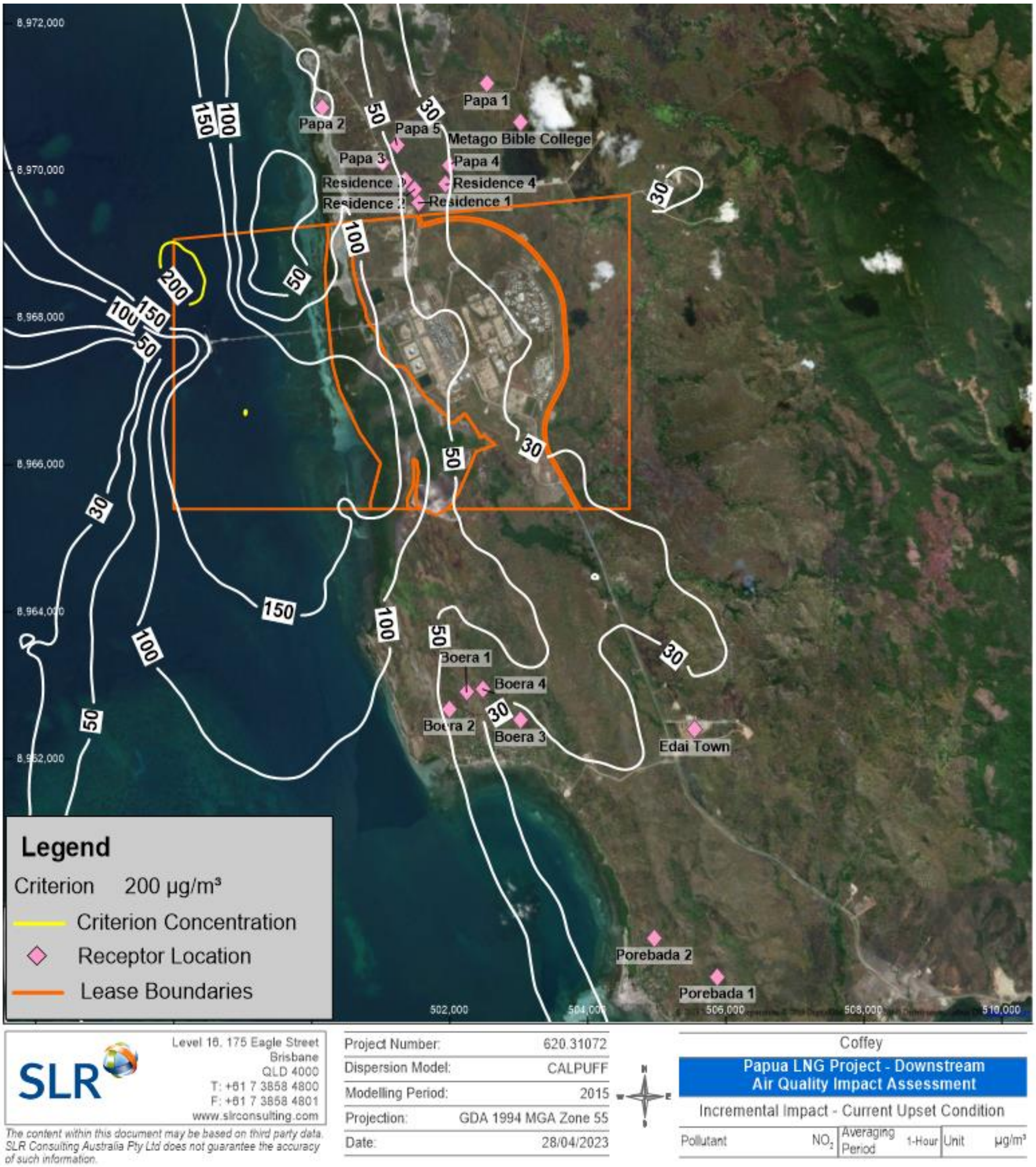


Figure B-10 Maximum Predicted 24-Hour Average NO_2 Concentrations - Current Normal Operations

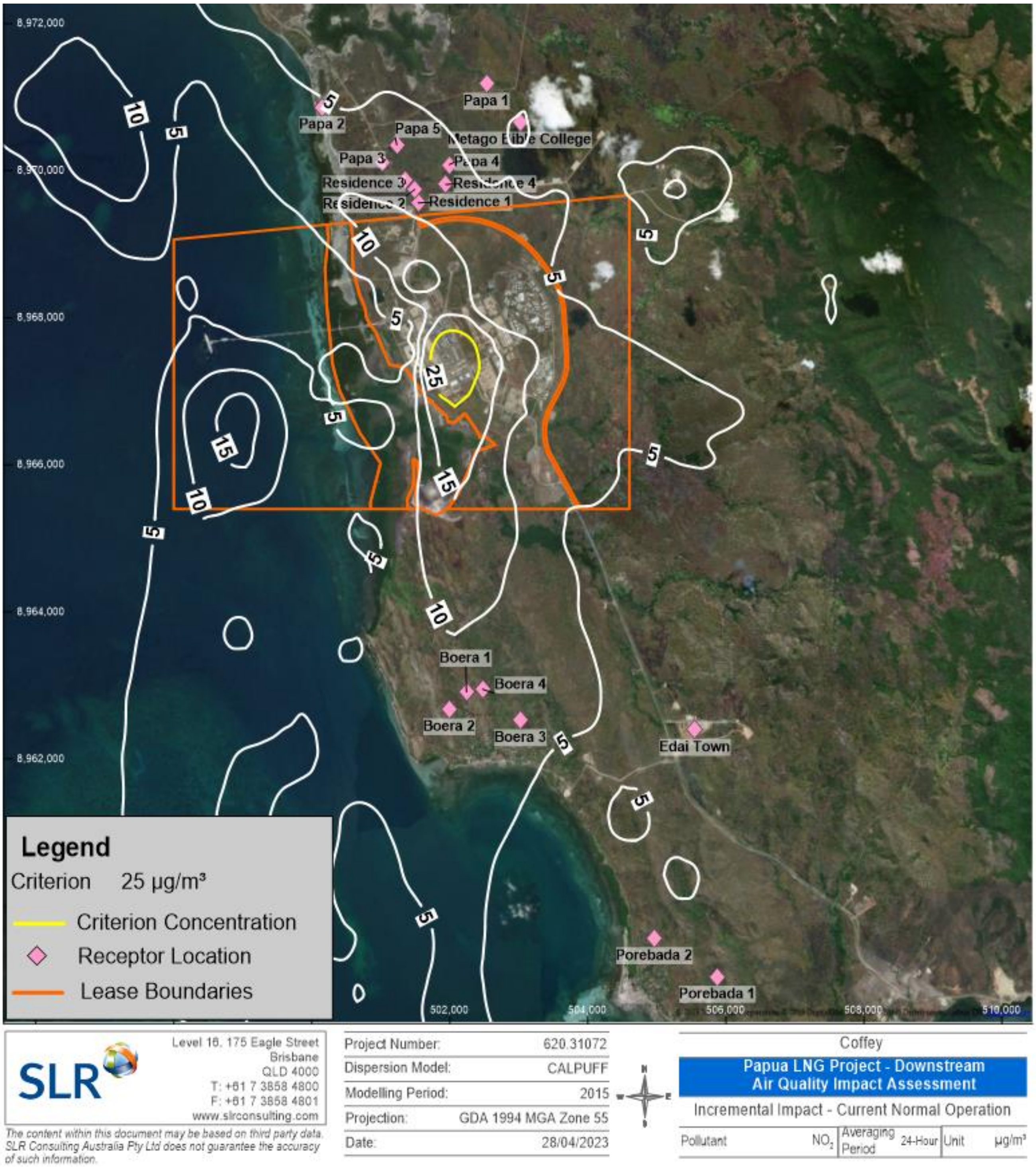
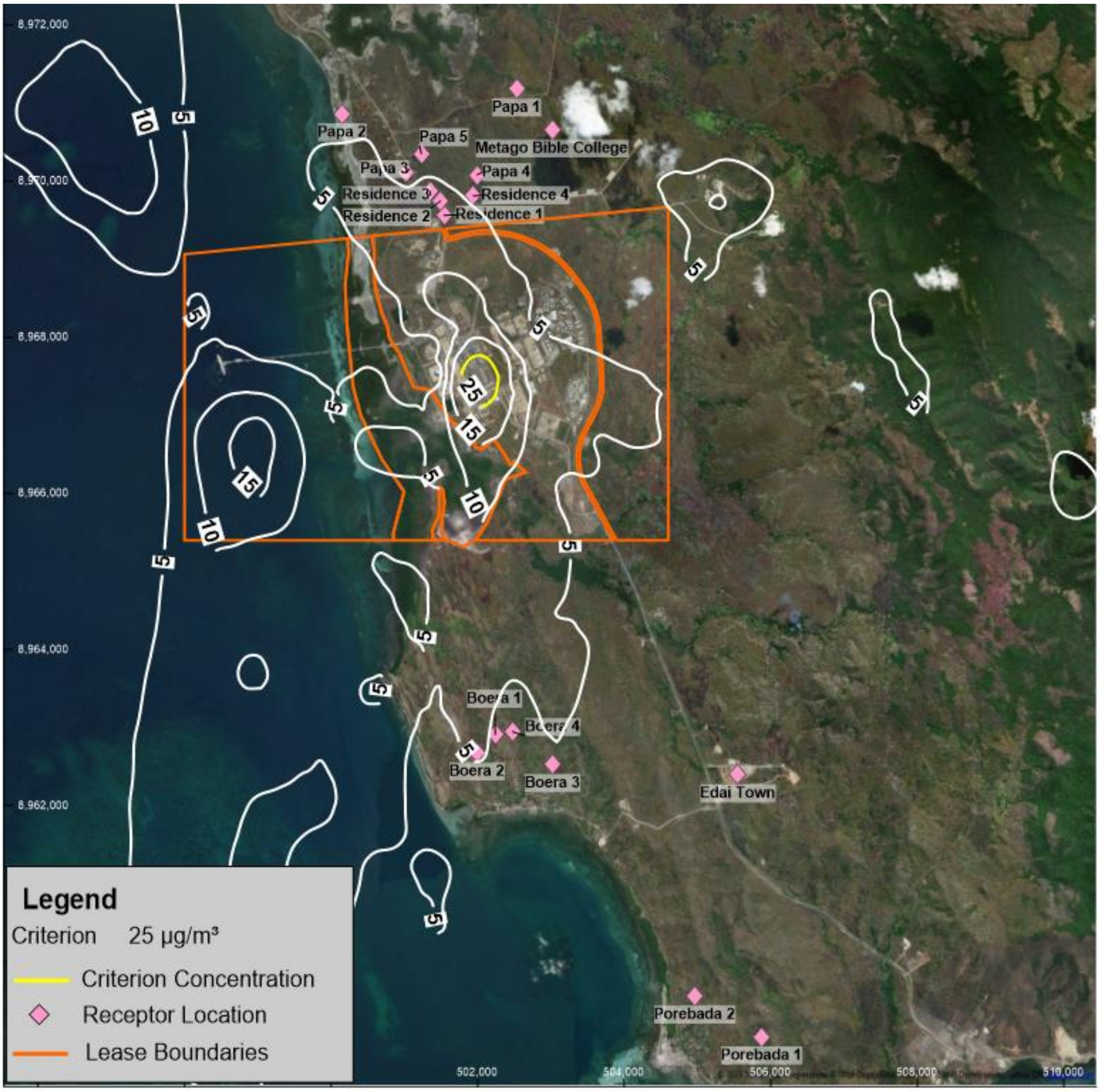


Figure B-11 Maximum Predicted 24-Hour Average NO_2 Concentrations - Current Upset Operations



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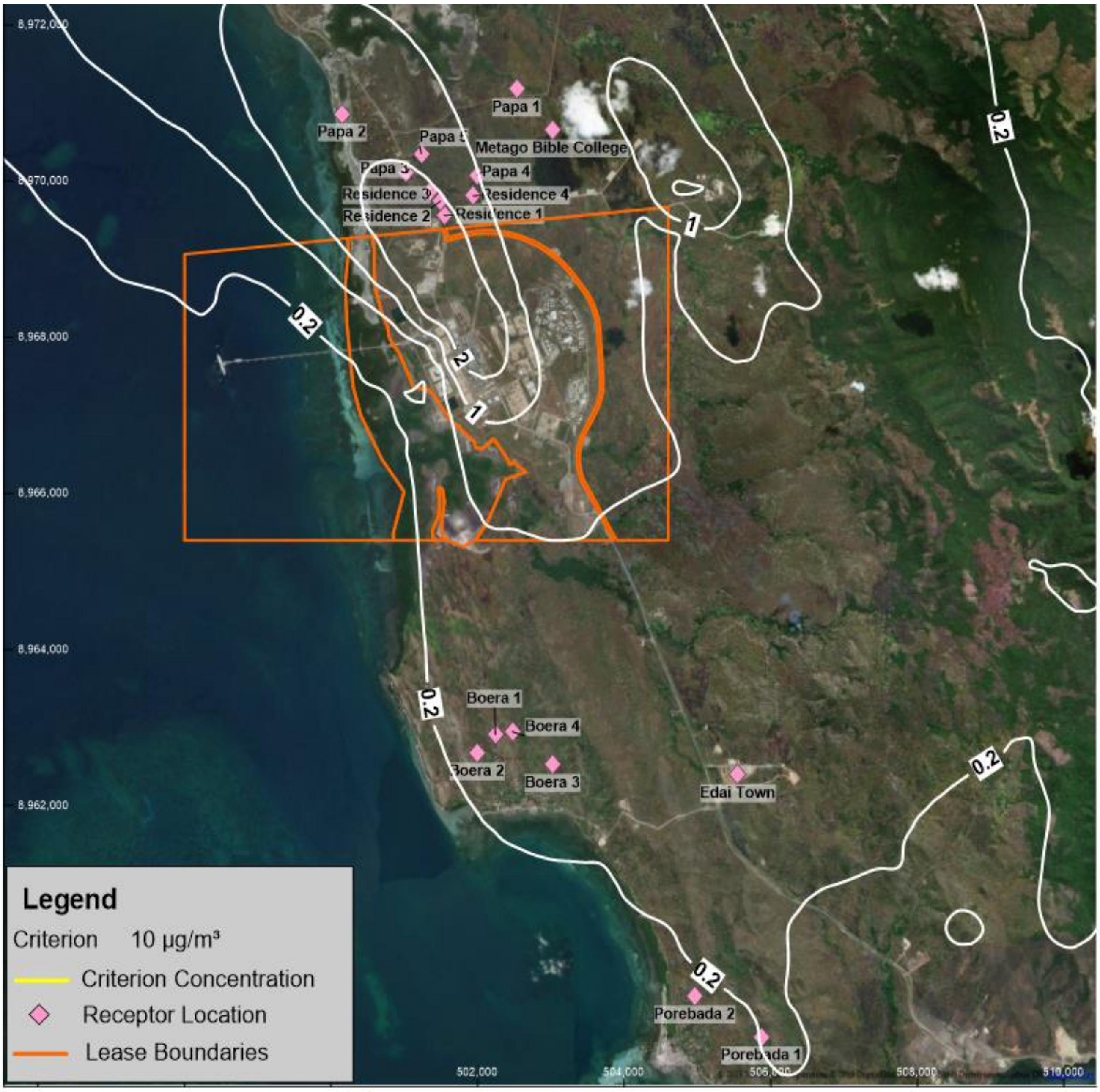
Incremental Impact - Current Upset Condition

Pollutant	NO_2	Averaging Period	24-Hour	Unit	µg/m³

Figure B-12 Predicted Annual Average NO_2 Concentrations - Current Normal Operations



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Incremental Impact - Current Normal Operation

Pollutant	NO_2	Averaging Period	Annual	Unit	µg/m³

Figure B-13 Maximum Predicted 10-Minute Average SO_2 Concentrations - Current Normal Operations

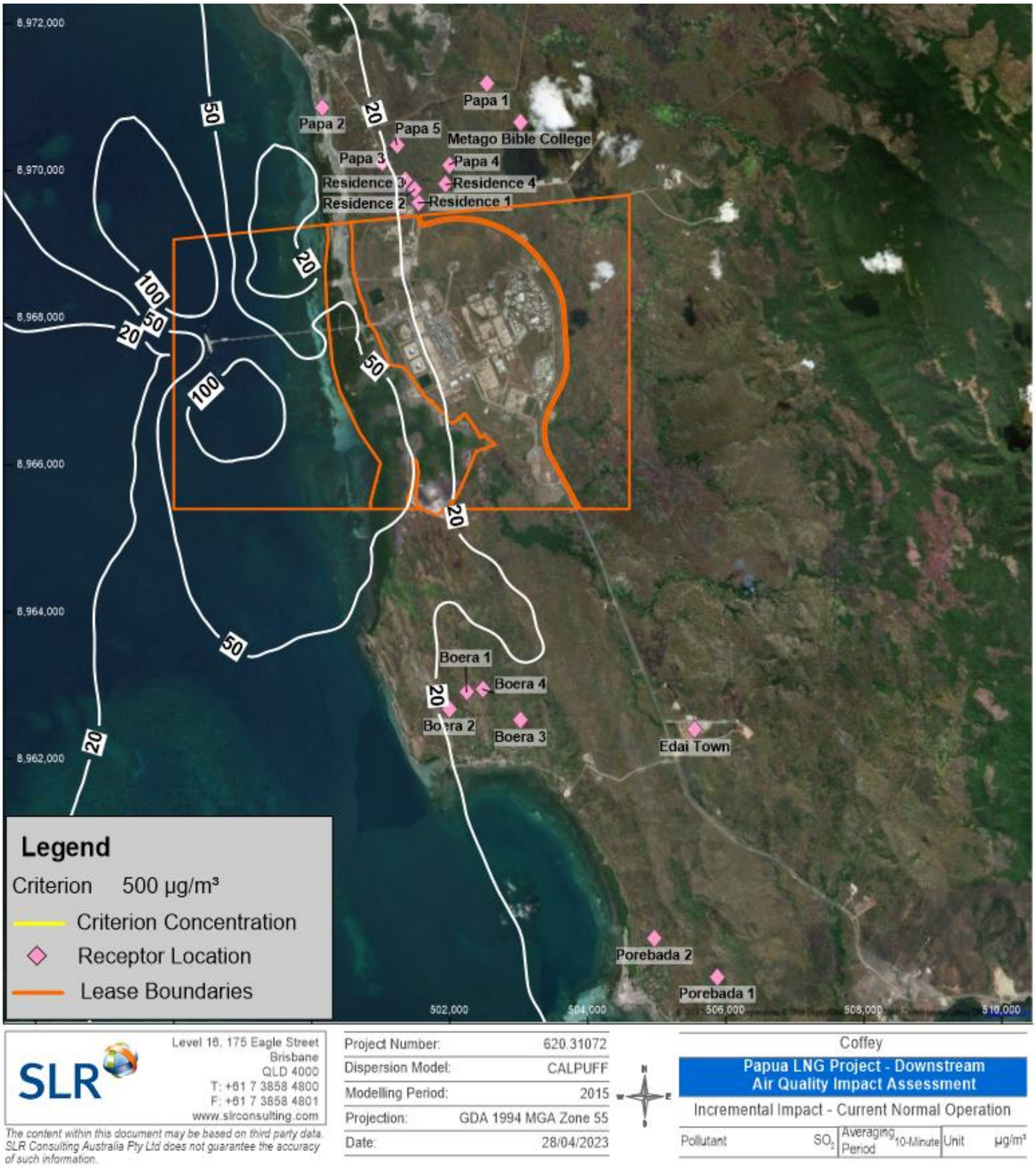


Figure B-14 Maximum Predicted 10-Minute Average SO_2 Concentrations - Current Upset Operations

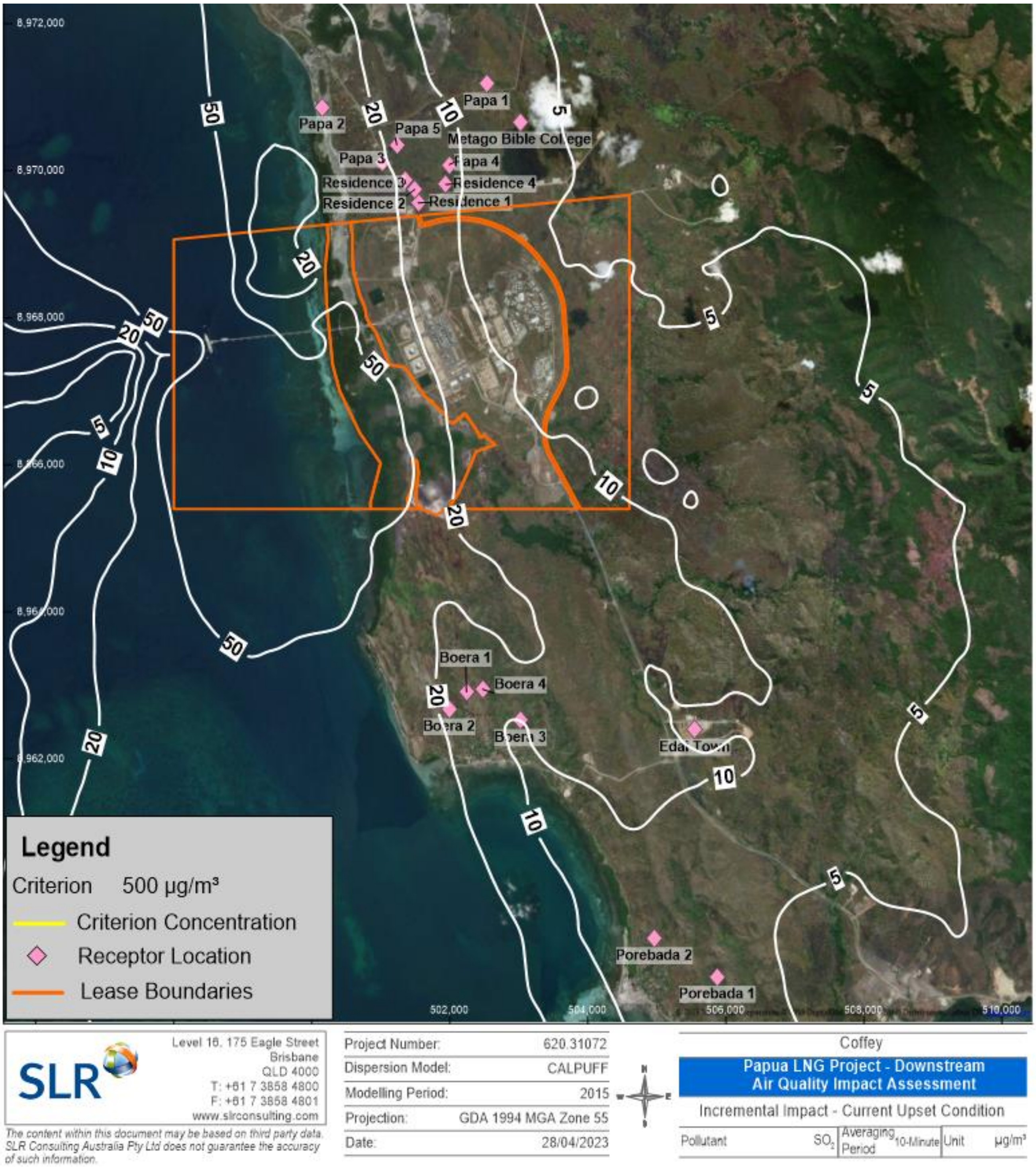


Figure B-15 Maximum Predicted 1-Hour Average SO_2 Concentrations - Current Normal Operations

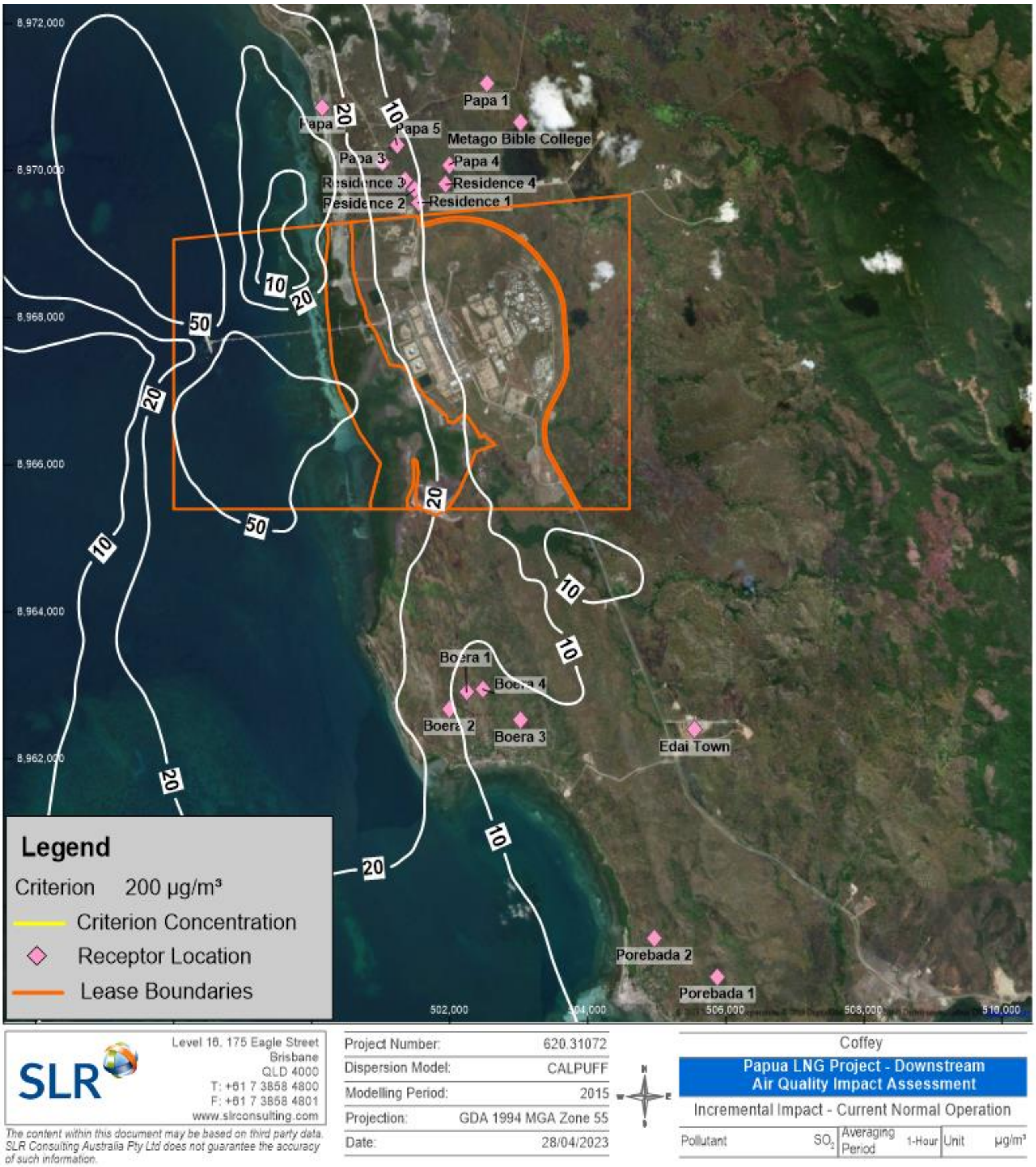
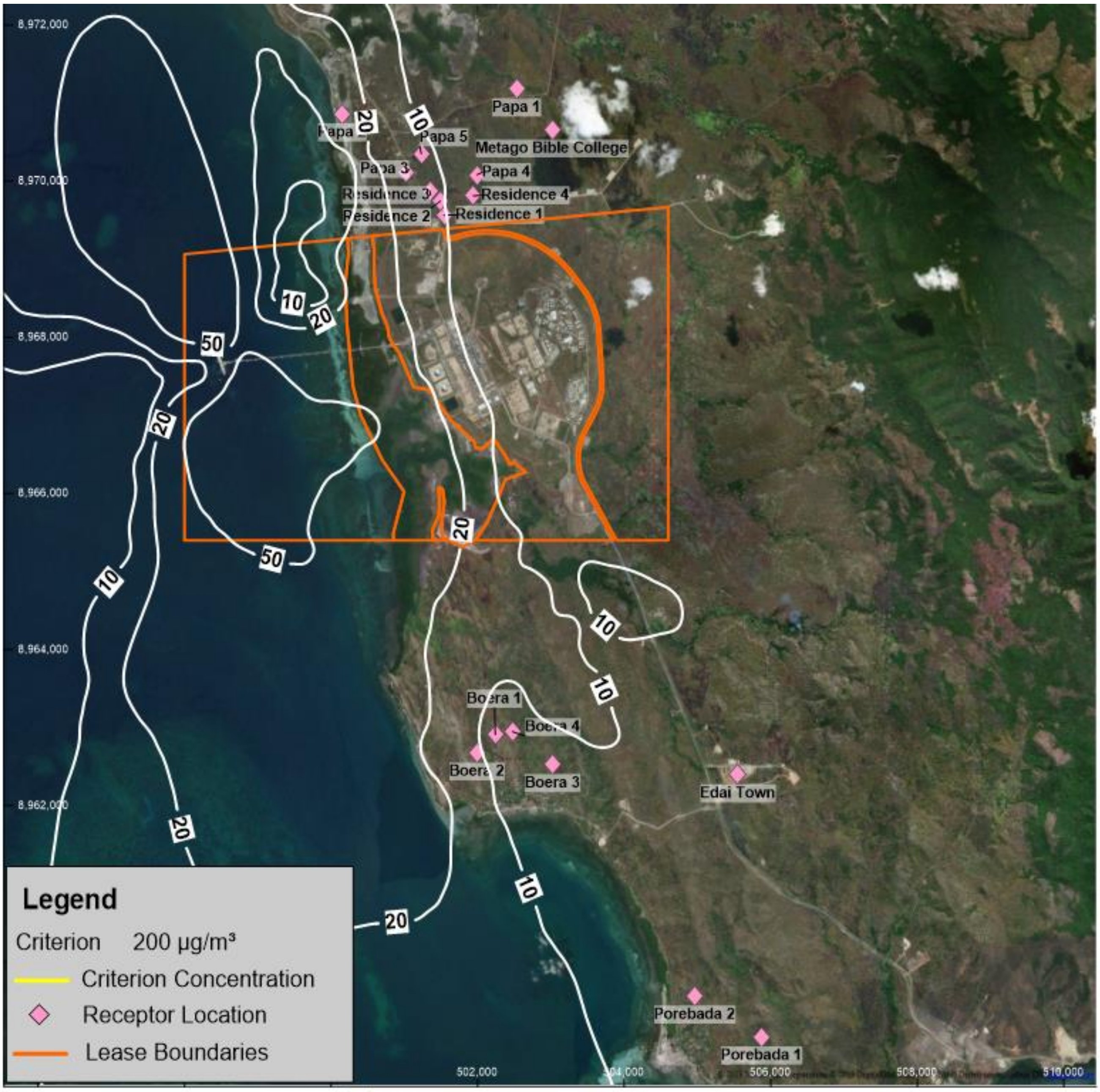


Figure B-16 Maximum Predicted 1-Hour Average SO_2 Concentrations - Current Upset Operations



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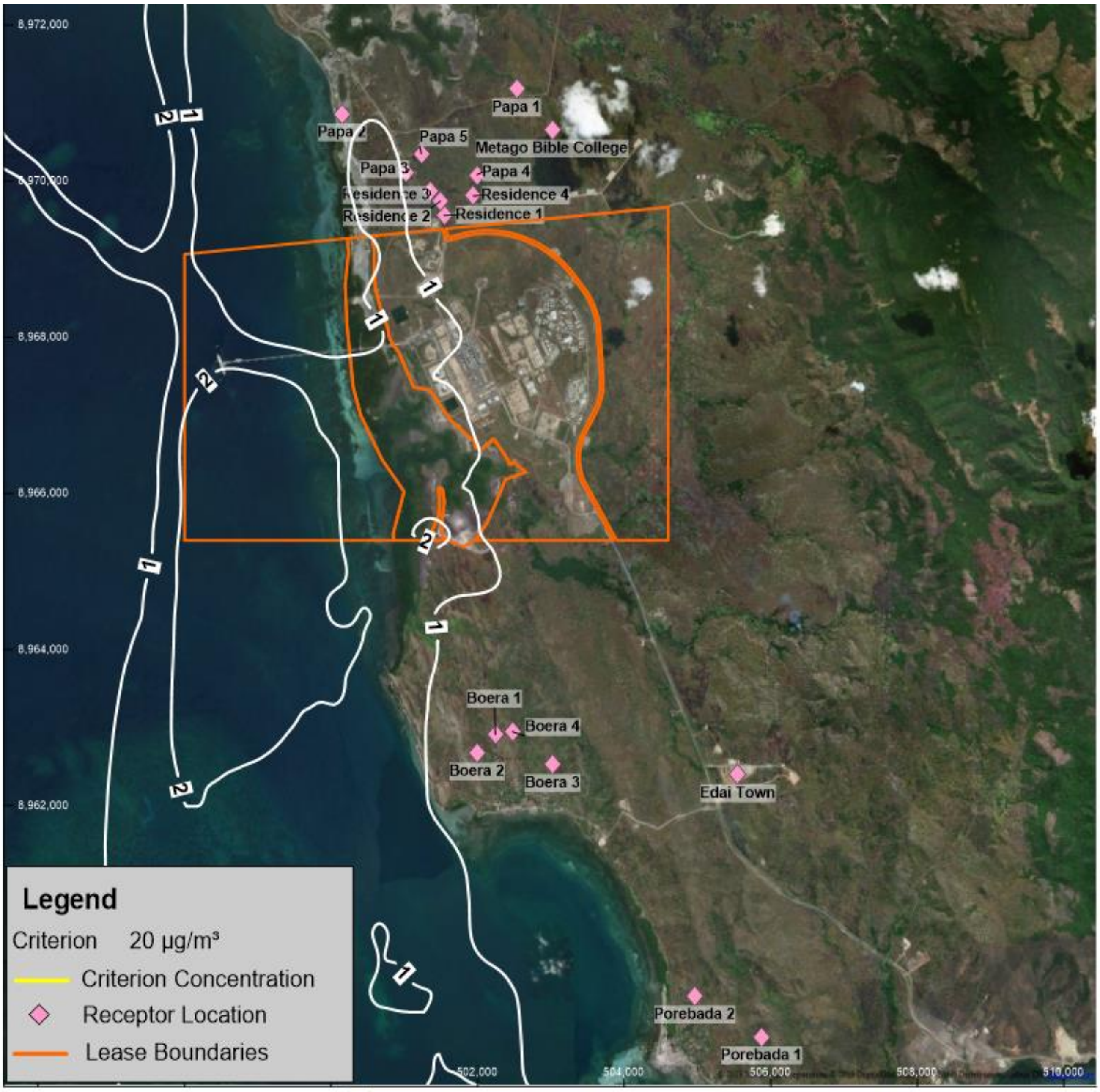
Pollutant	SO_2	Averaging Period	1-Hour	Unit	µg/m³

Figure B-17 Maximum Predicted 24-Hour Average SO_2 Concentrations - Current Normal Operations



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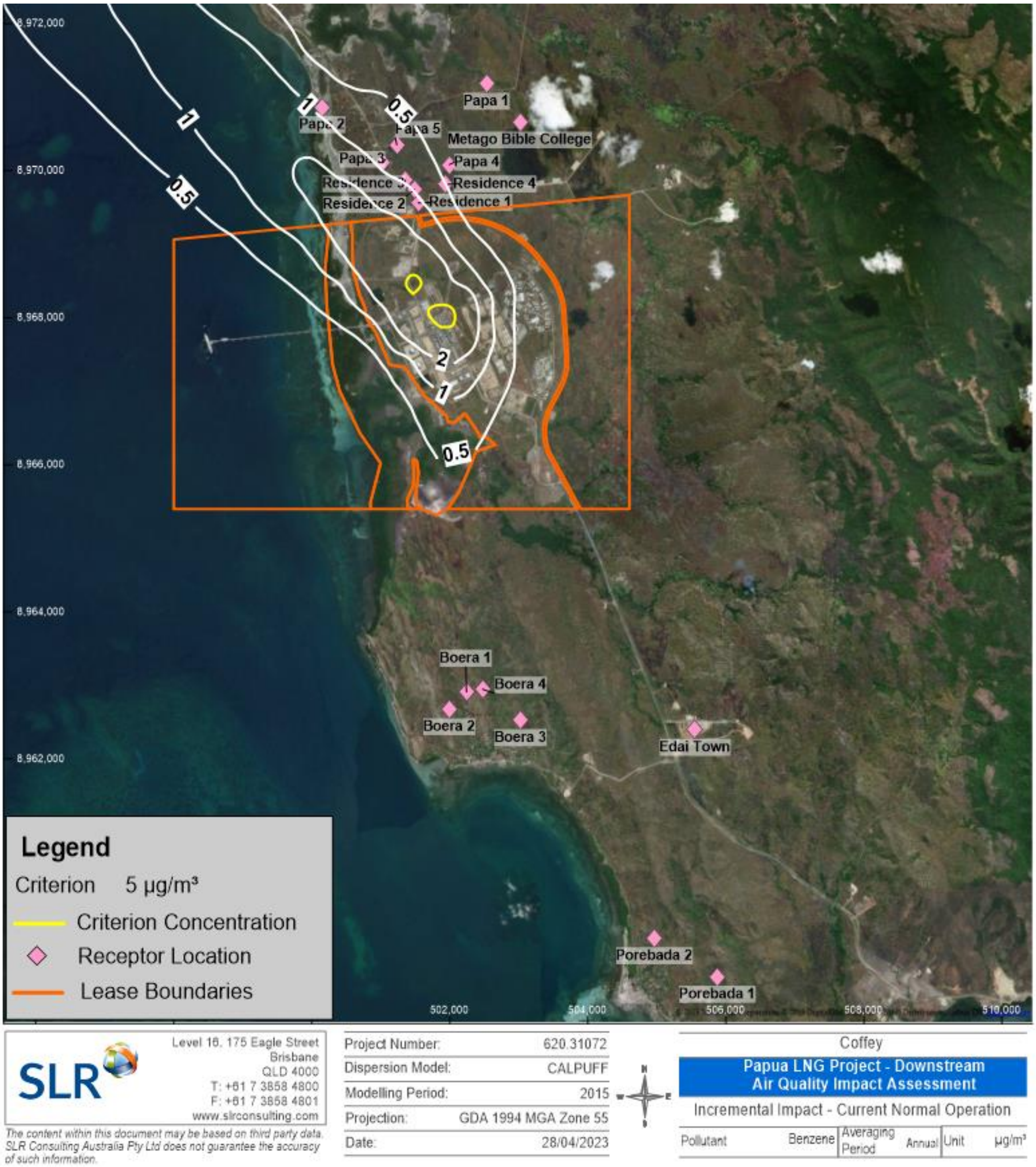
Papua LNG Project - Downstream
Air Quality Impact Assessment

Incremental Impact - Current Normal Operation

Pollutant	SO_2	Averaging Period	24-Hour	Unit	µg/m³

Figure B-18 Predicted Annual Average Benzene Concentrations - Current Normal Operations

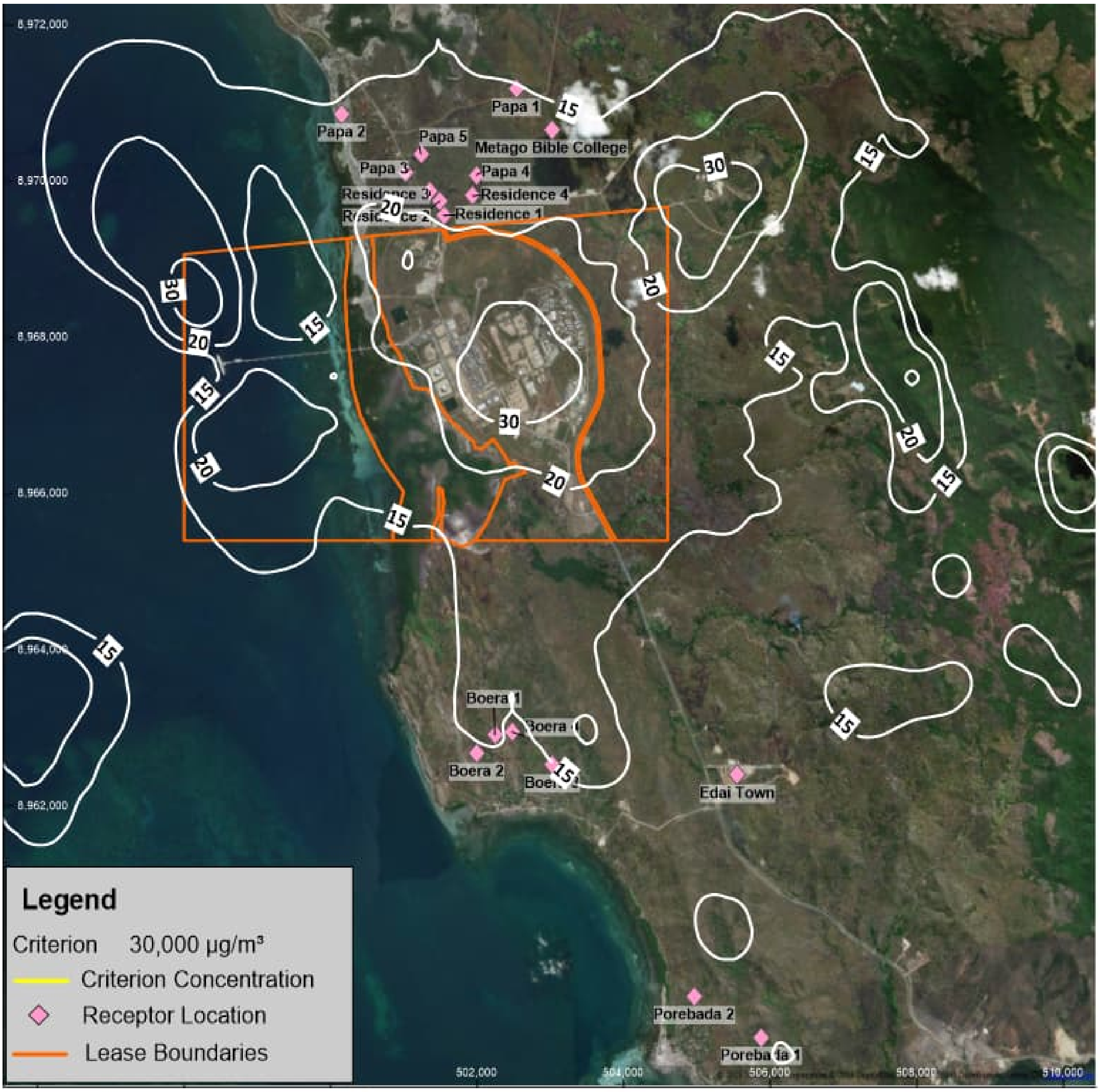


Appendix C

Isopleth Plots – Proposed Operations

List of Figures

Figure C-1 Maximum Predicted 1-Hour Average CO Concentrations - Proposed Normal Operations



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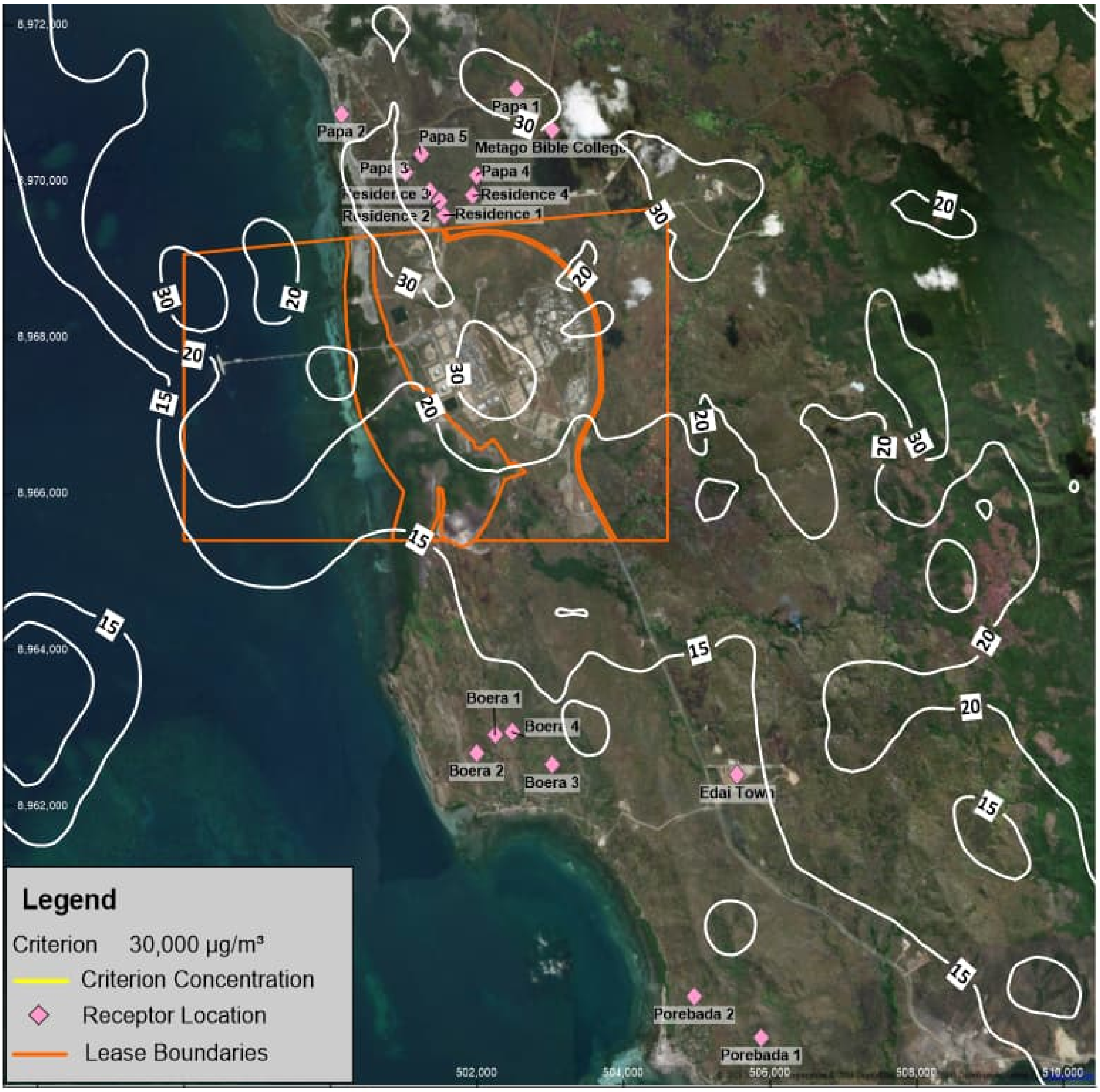
Incremental Impact - Proposed Normal Operation

Pollutant	CO	Averaging Period	1-Hour	Unit	µg/m³

Figure C-2 Maximum Predicted 1-Hour Average CO Concentrations - Proposed Upset Operations



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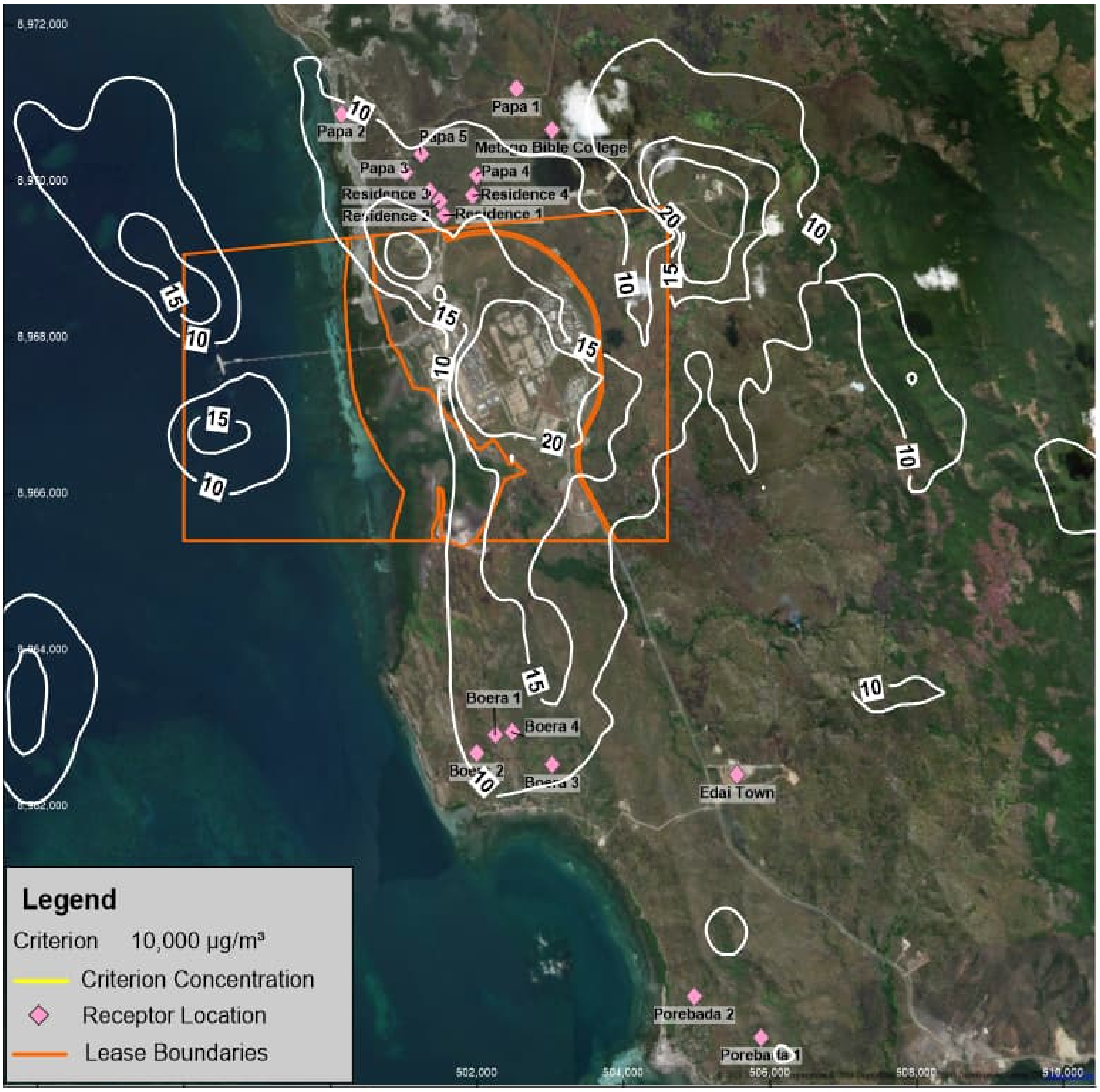
Incremental Impact - Proposed Upset Condition

Pollutant	CO	Averaging Period	1-Hour	Unit	µg/m³

Figure C-3 Maximum Predicted 8-Hour Average CO Concentrations - Proposed Normal Operations



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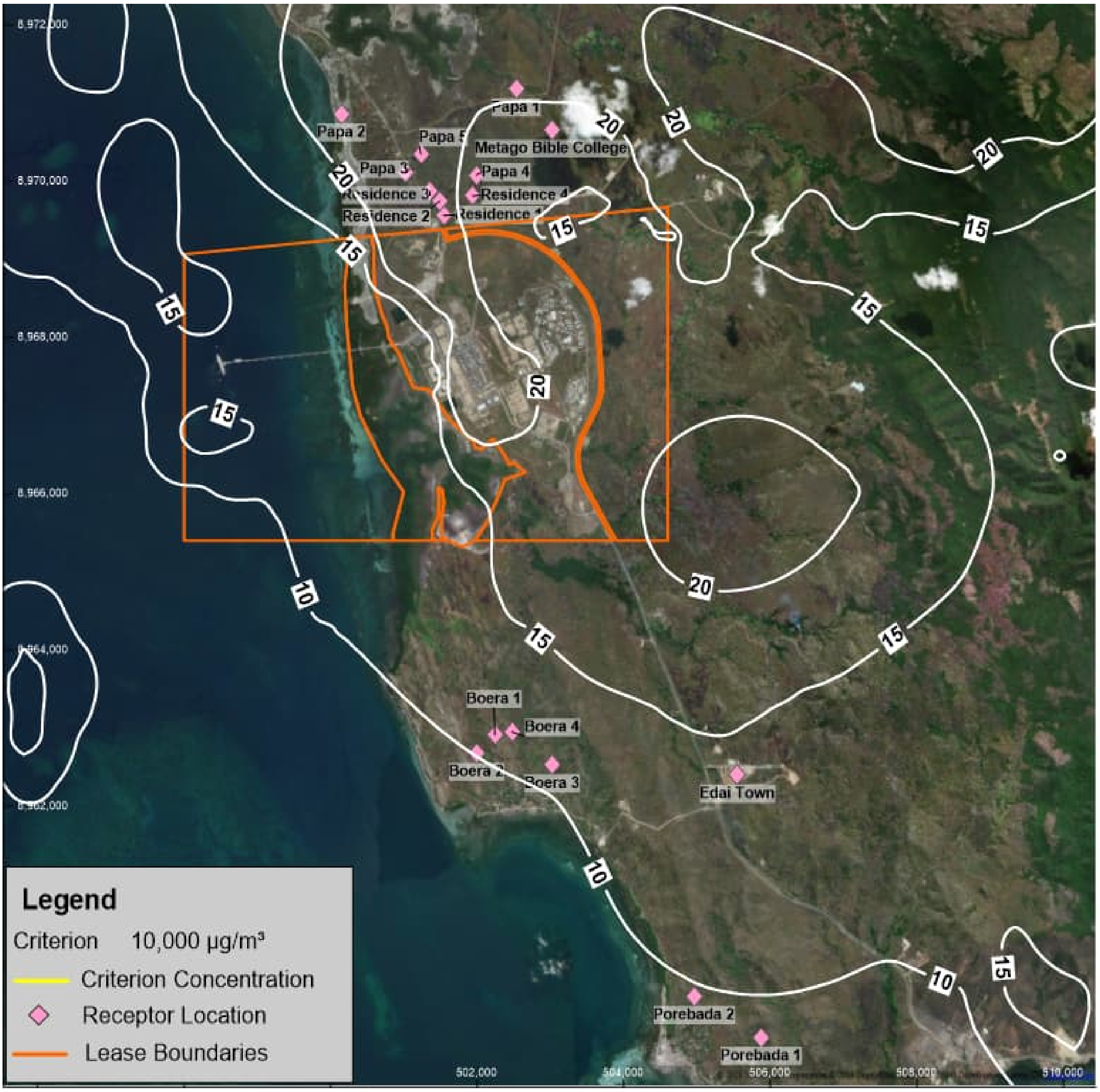
Incremental Impact - Proposed Normal Operation

Pollutant	CO	Averaging Period	8-Hour	Unit	µg/m³

Figure C-4 Maximum Predicted 8-Hour Average CO Concentrations - Proposed Upset Operations



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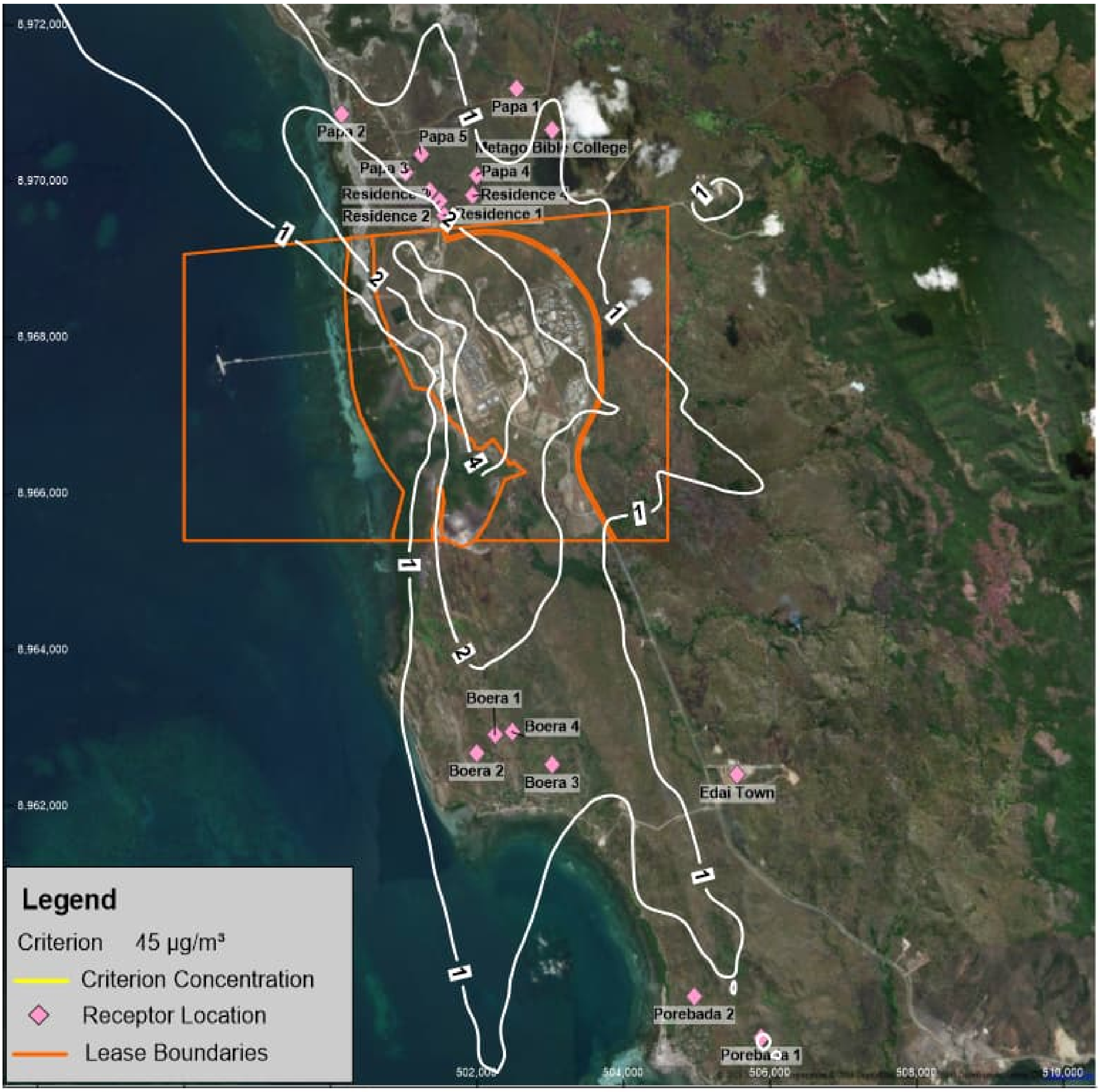
Papua LNG Project - Downstream
Air Quality Impact Assessment

Incremental Impact - Proposed Upset Condition

Pollutant	CO	Averaging Period	8-Hour	Unit	µg/m³

Figure C-5 Maximum Predicted 24-Hour Average PM_{10} Concentrations - Proposed Normal Operations



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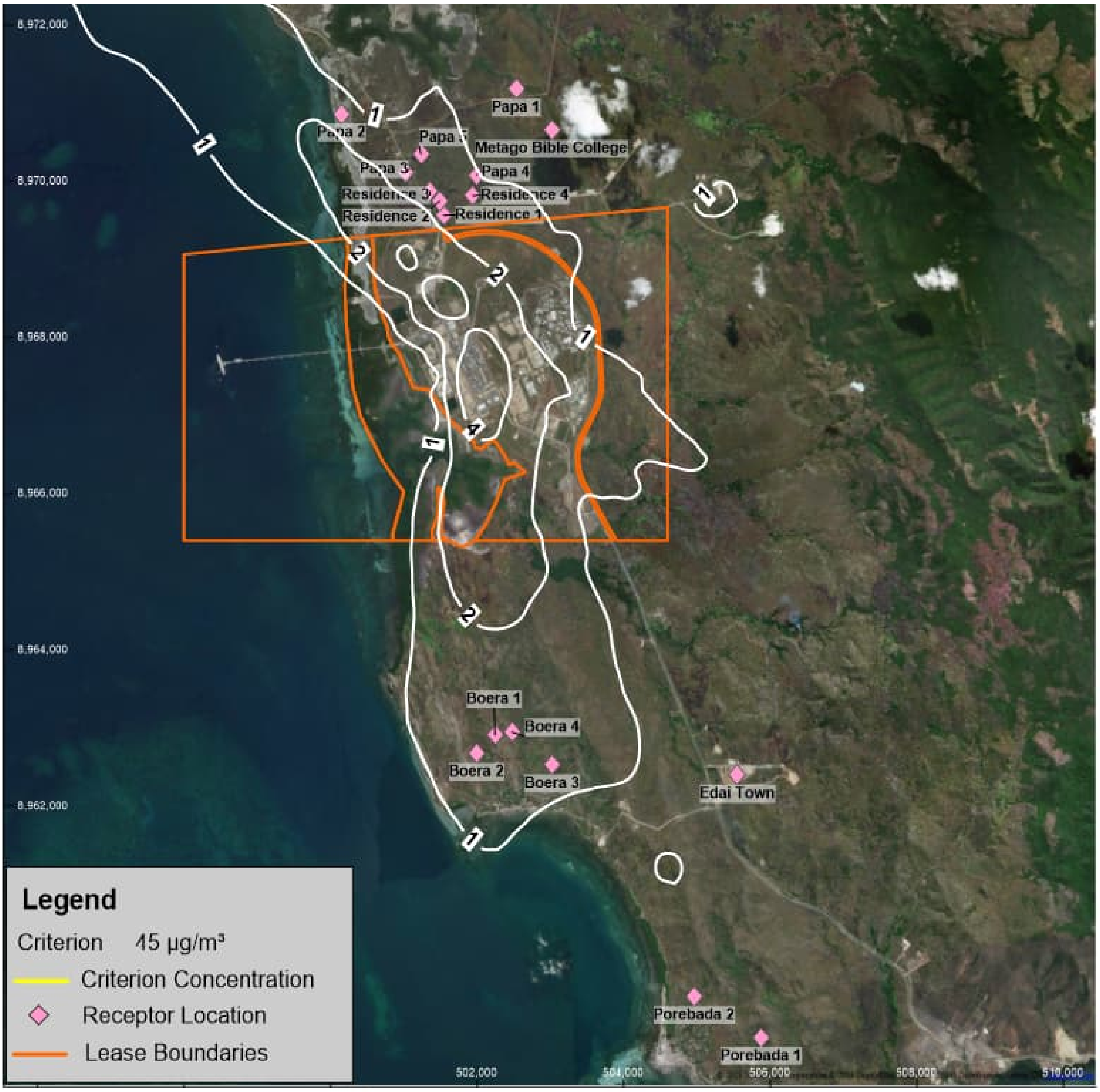
Papua LNG Project - Downstream Air Quality Impact Assessment
Incremental Impact - Proposed Normal Operation

Pollutant	PM_{10}	Averaging Period	24-Hour	Unit	µg/m³

Figure C-6 Maximum Predicted 24-Hour Average PM_{10} Concentrations - Proposed Upset Operations



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Pollutant	PM_{10}	Averaging Period	24-Hour	Unit	µg/m³

Figure C-7 Predicted Annual Average PM_{10} Concentrations - Proposed Normal Operations

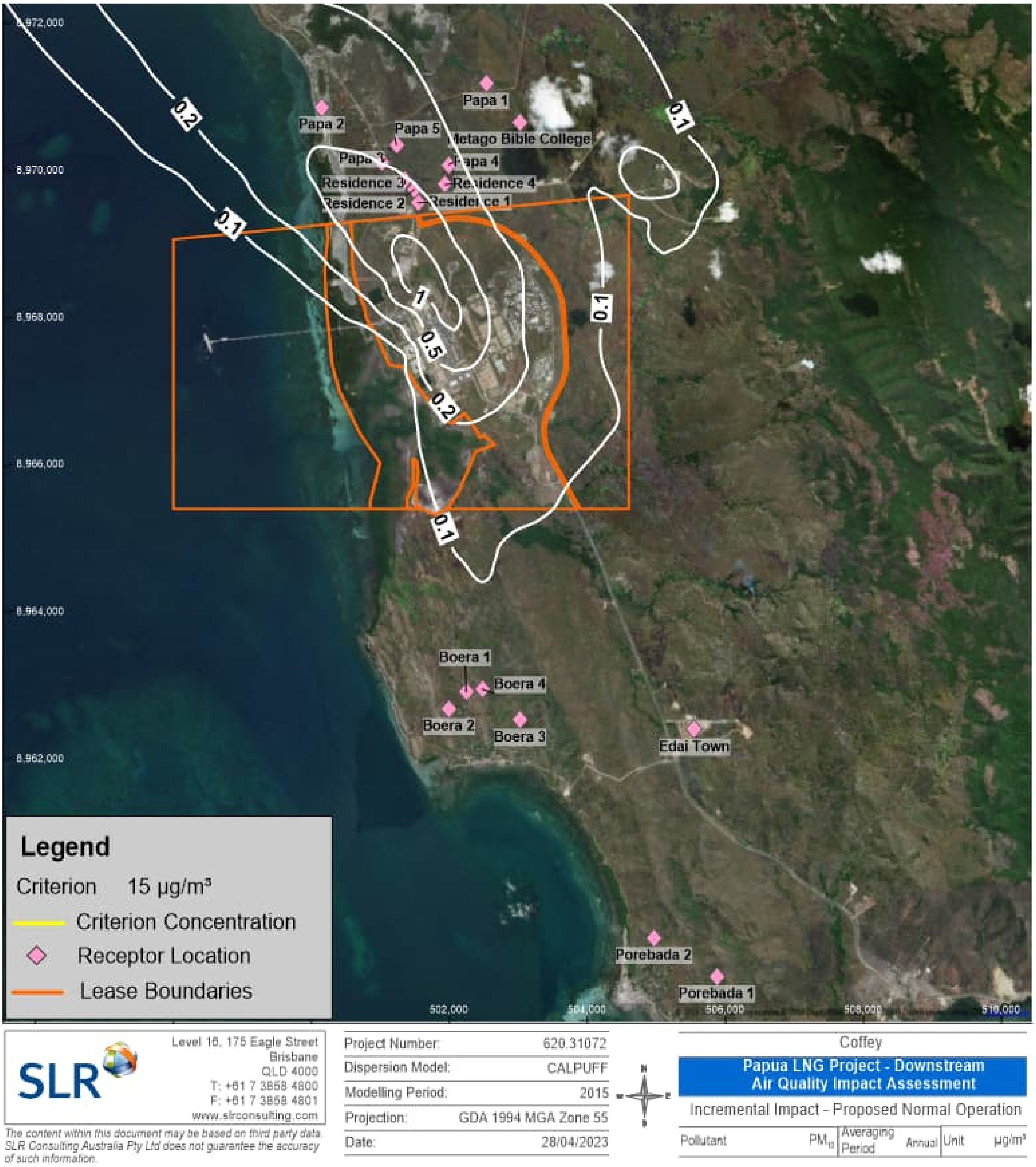
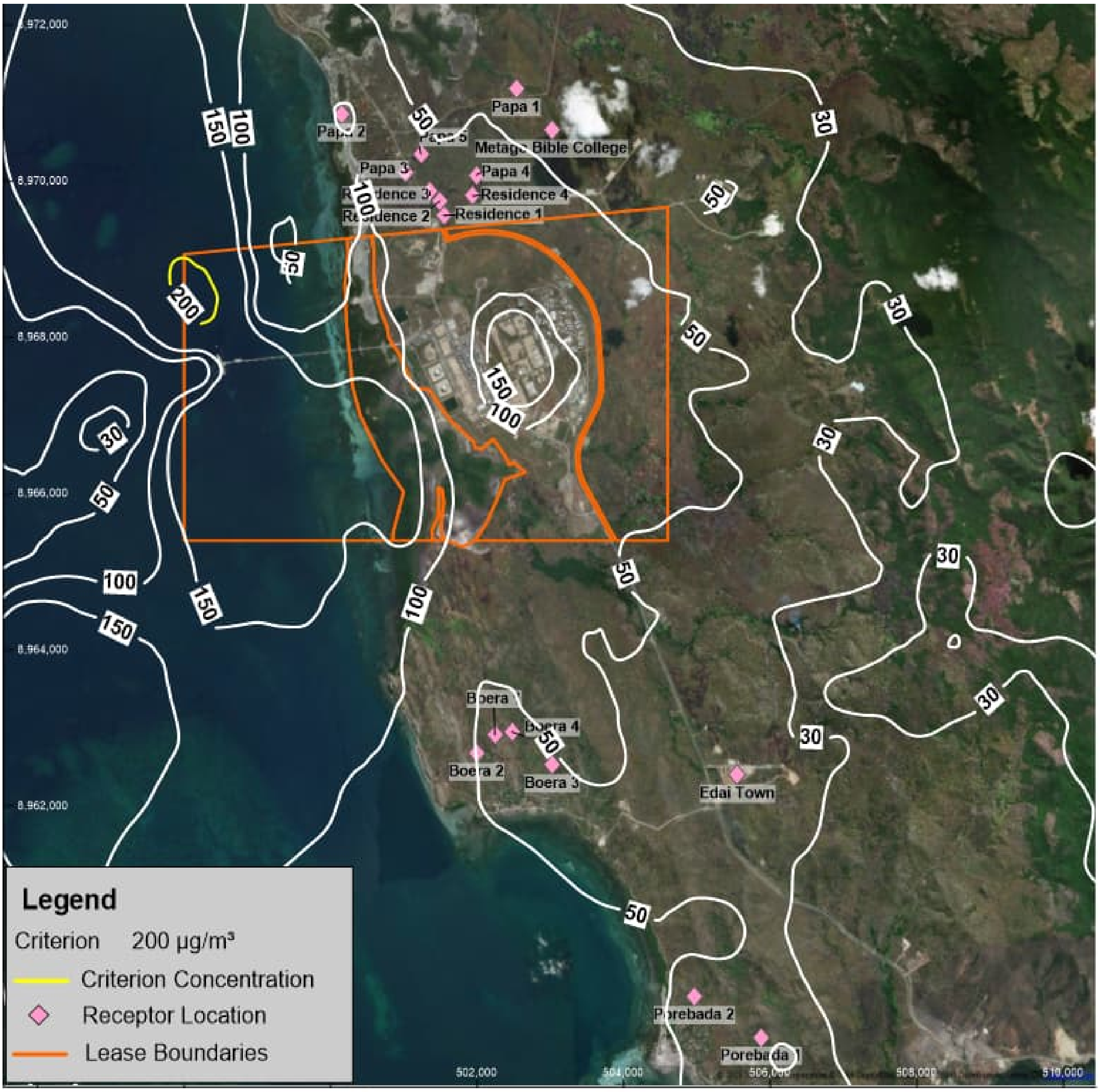


Figure C-8 Maximum Predicted 1-Hour Average NO_2 Concentrations - Proposed Normal Operations



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Air Quality Impact Assessment**
Incremental Impact - Proposed Normal Operation

Pollutant	NO_2	Averaging Period	1-Hour	Unit	µg/m³

Figure C-9 Maximum Predicted 1-Hour Average NO_2 Concentrations - Proposed Upset Operations

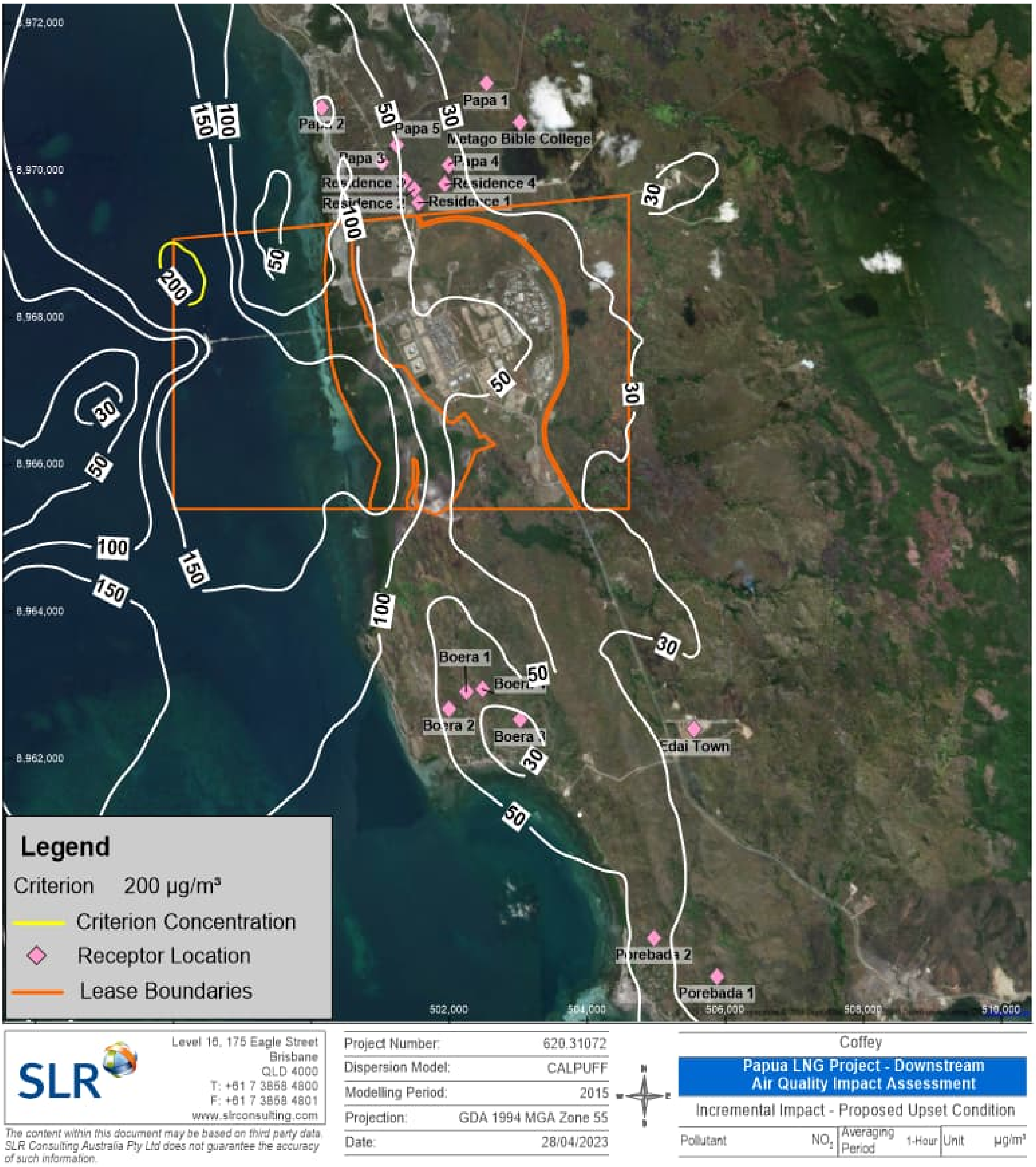
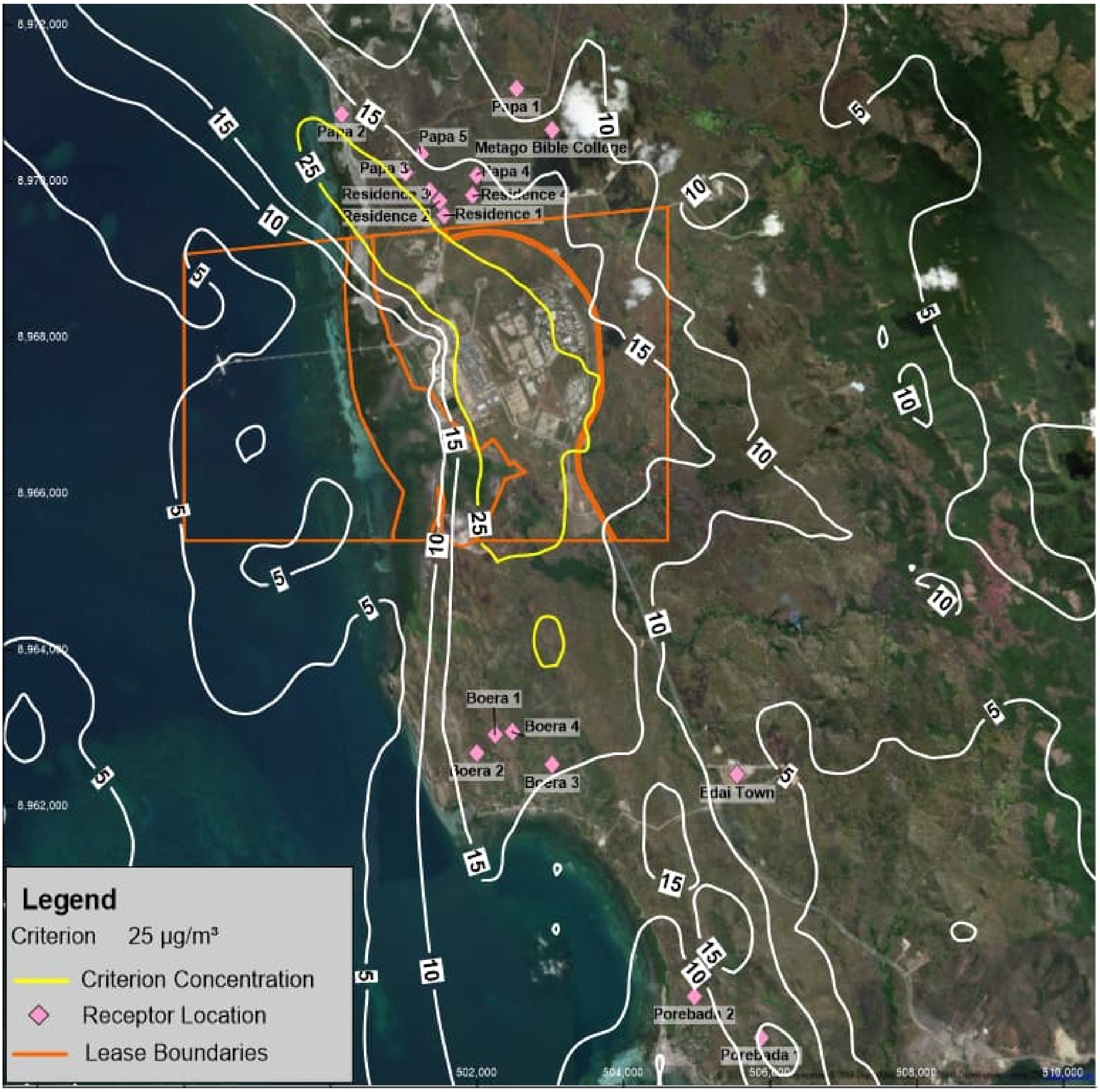


Figure C-10 Maximum Predicted 24-Hour Average NO_2 Concentrations - Proposed Normal Operations



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Pollutant	NO_2	Averaging Period	24-Hour	Unit	µg/m³

Figure C-11 Maximum Predicted 24-Hour Average NO_2 Concentrations - Proposed Upset Operations

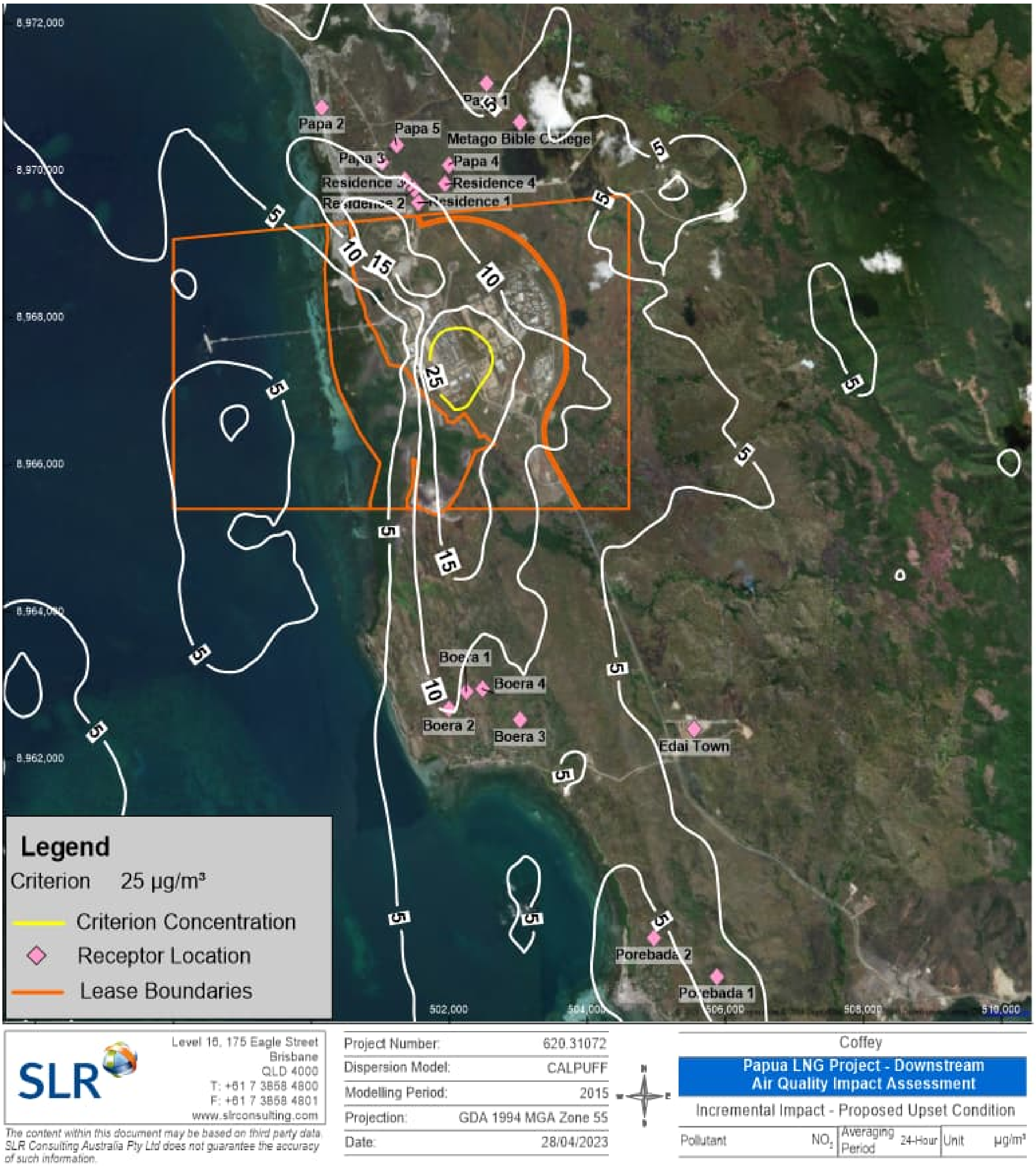
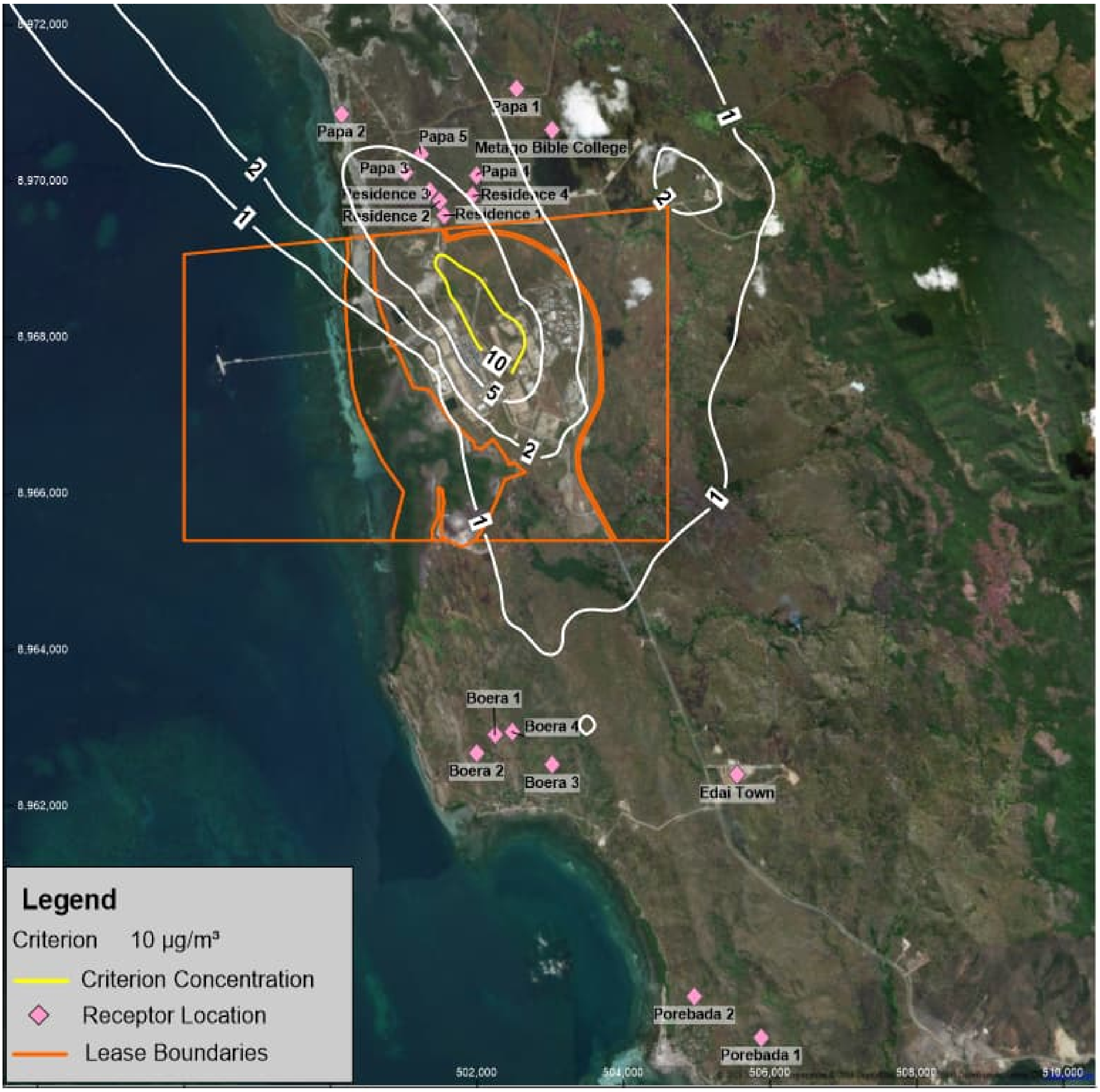


Figure C-12 Predicted Annual Average NO_2 Concentrations - Proposed Normal Operations



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Pollutant	NO_2	Averaging Period	Annual	Unit	µg/m³

Figure C-13 Maximum Predicted 10-Minute Average SO_2 Concentrations - Proposed Normal Operations

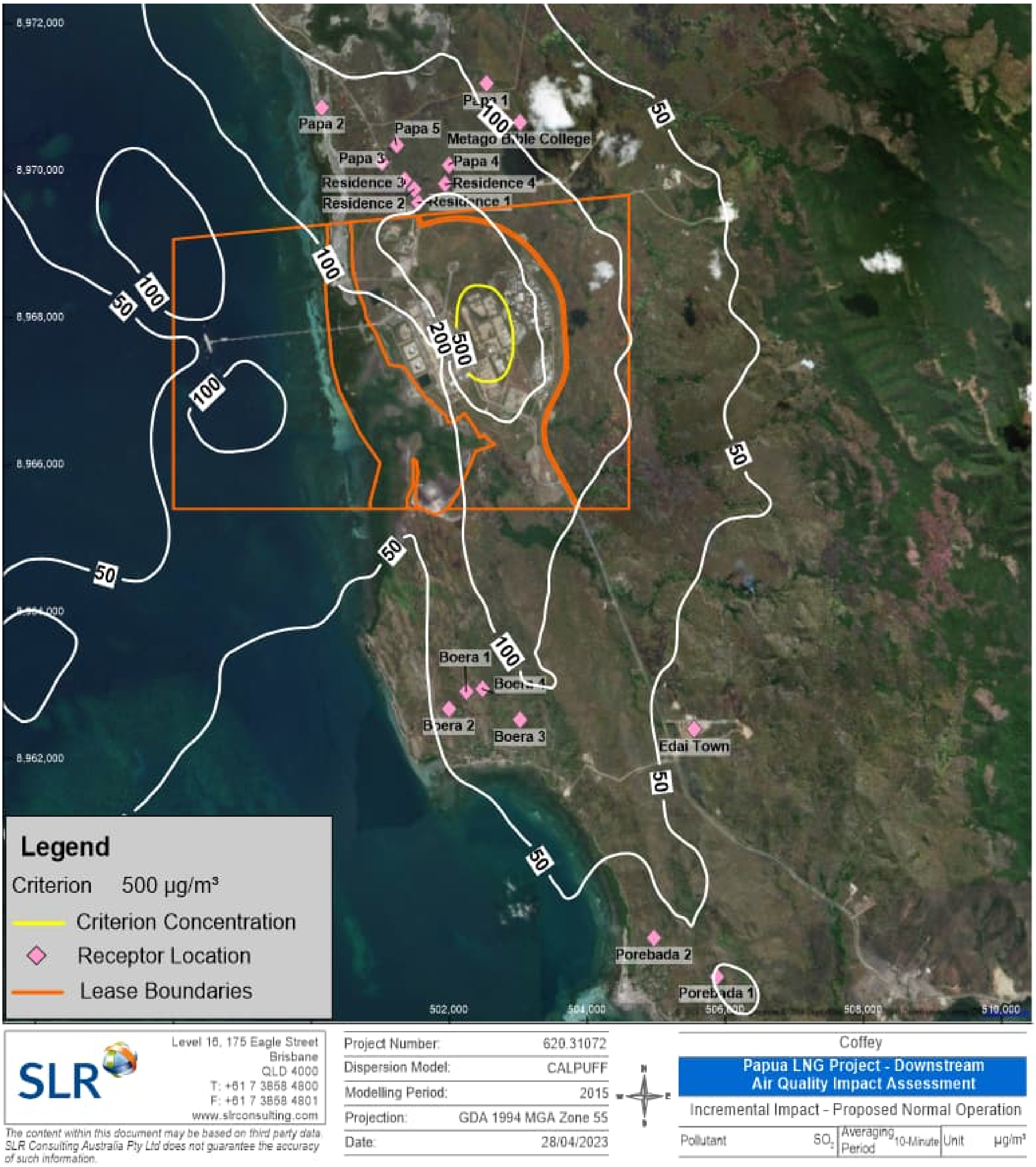


Figure C-14 Maximum Predicted 10-Minute Average SO_2 Concentrations - Proposed Upset Operations

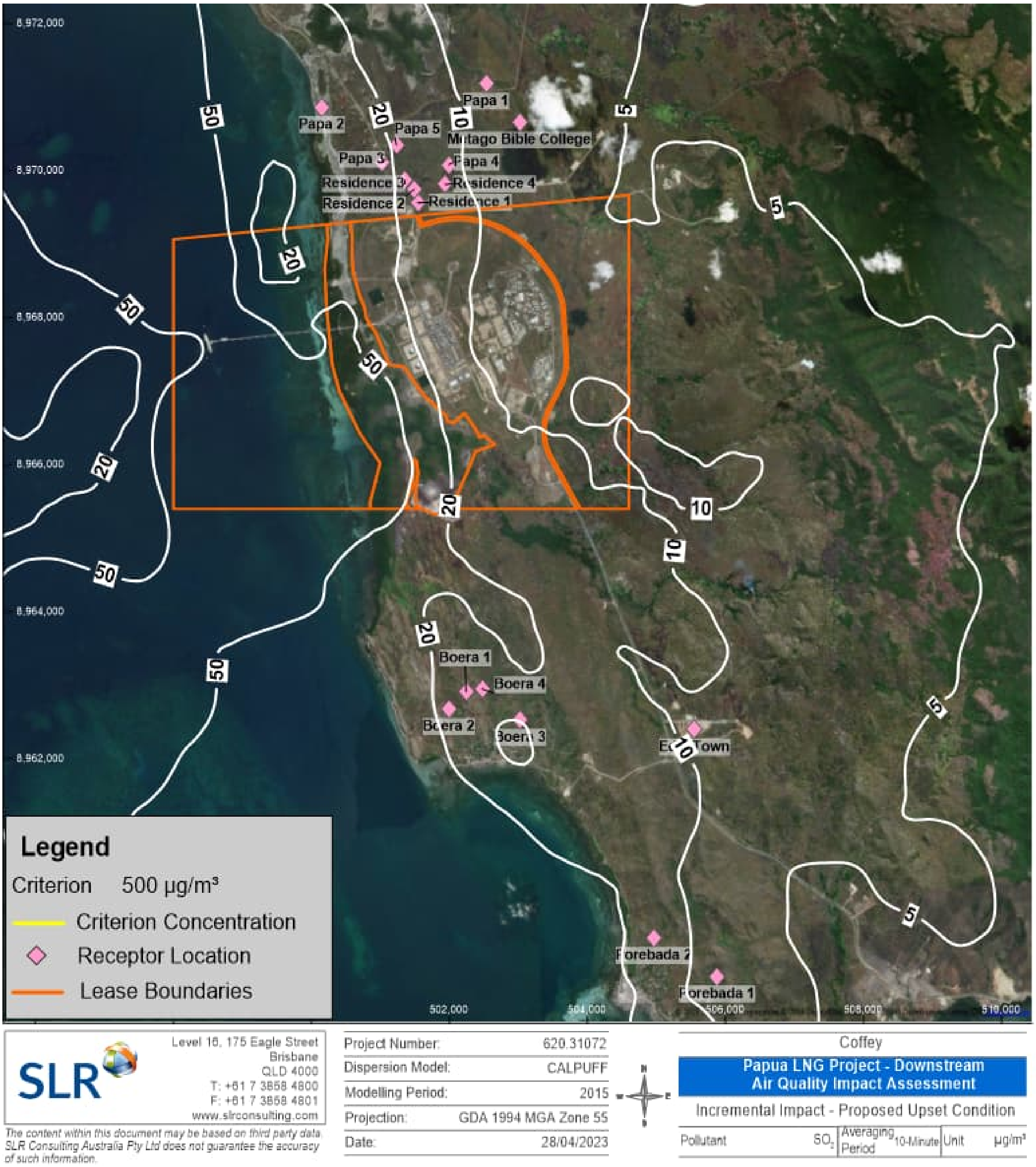
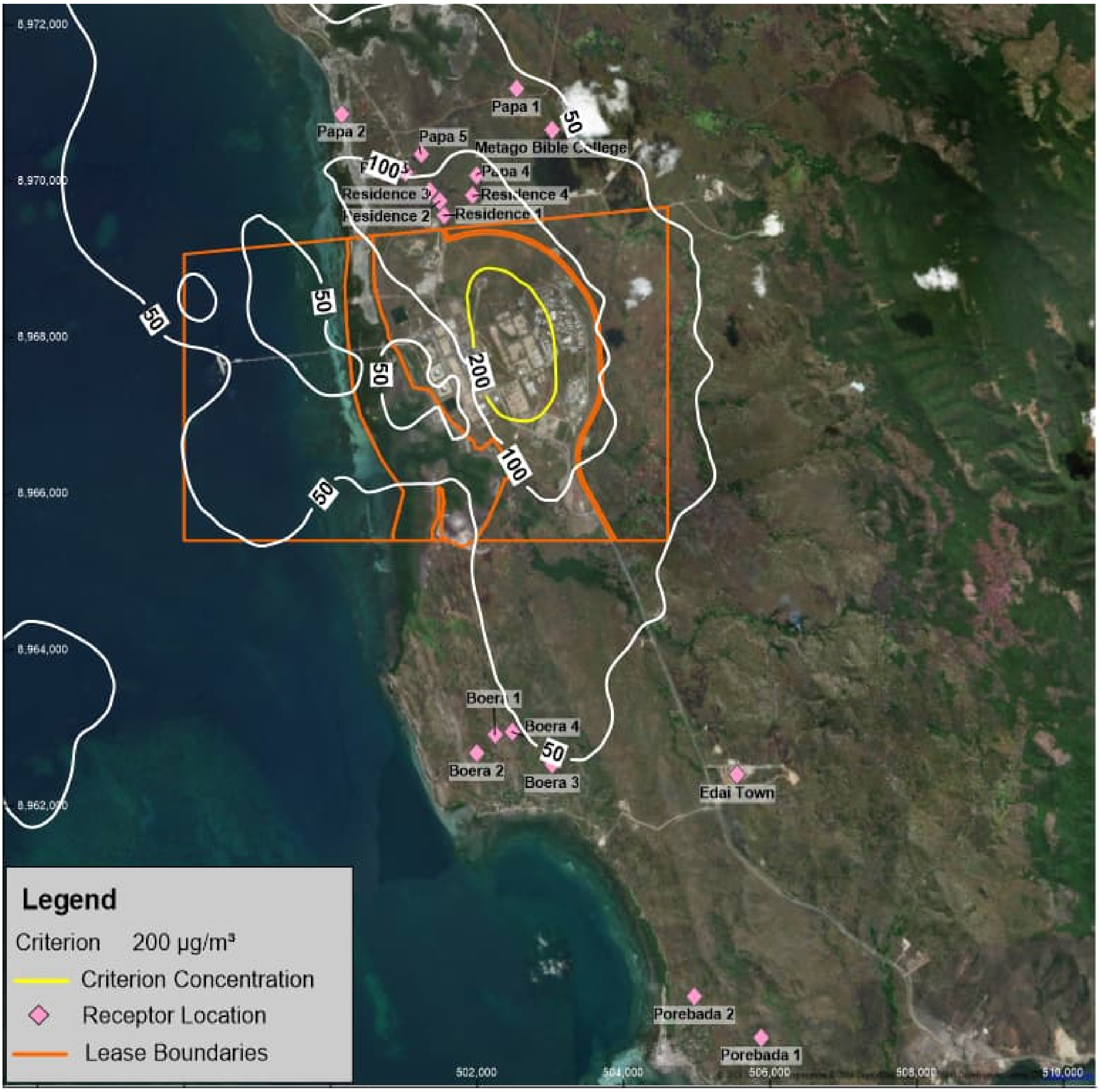


Figure C-15 Maximum Predicted 1-Hour Average SO_2 Concentrations - Proposed Normal Operations



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Incremental Impact - Proposed Normal Operation

Pollutant	SO_2	Averaging Period	1-Hour	Unit	µg/m³

Figure C-16 Maximum Predicted 1-Hour Average SO_2 Concentrations - Proposed Upset Operations

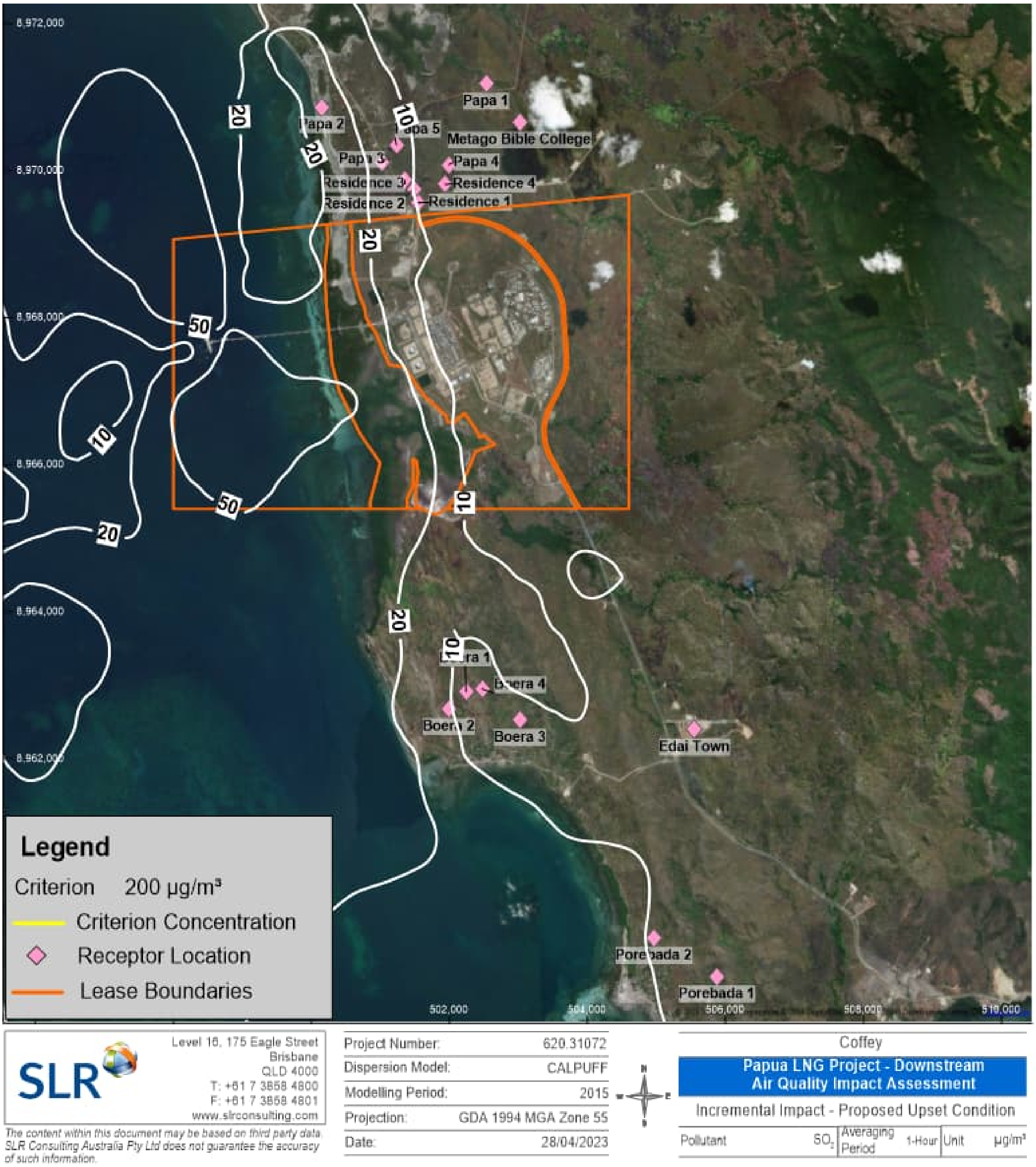


Figure C-17 Maximum Predicted 24-Hour Average SO_2 Concentrations - Proposed Normal Operations

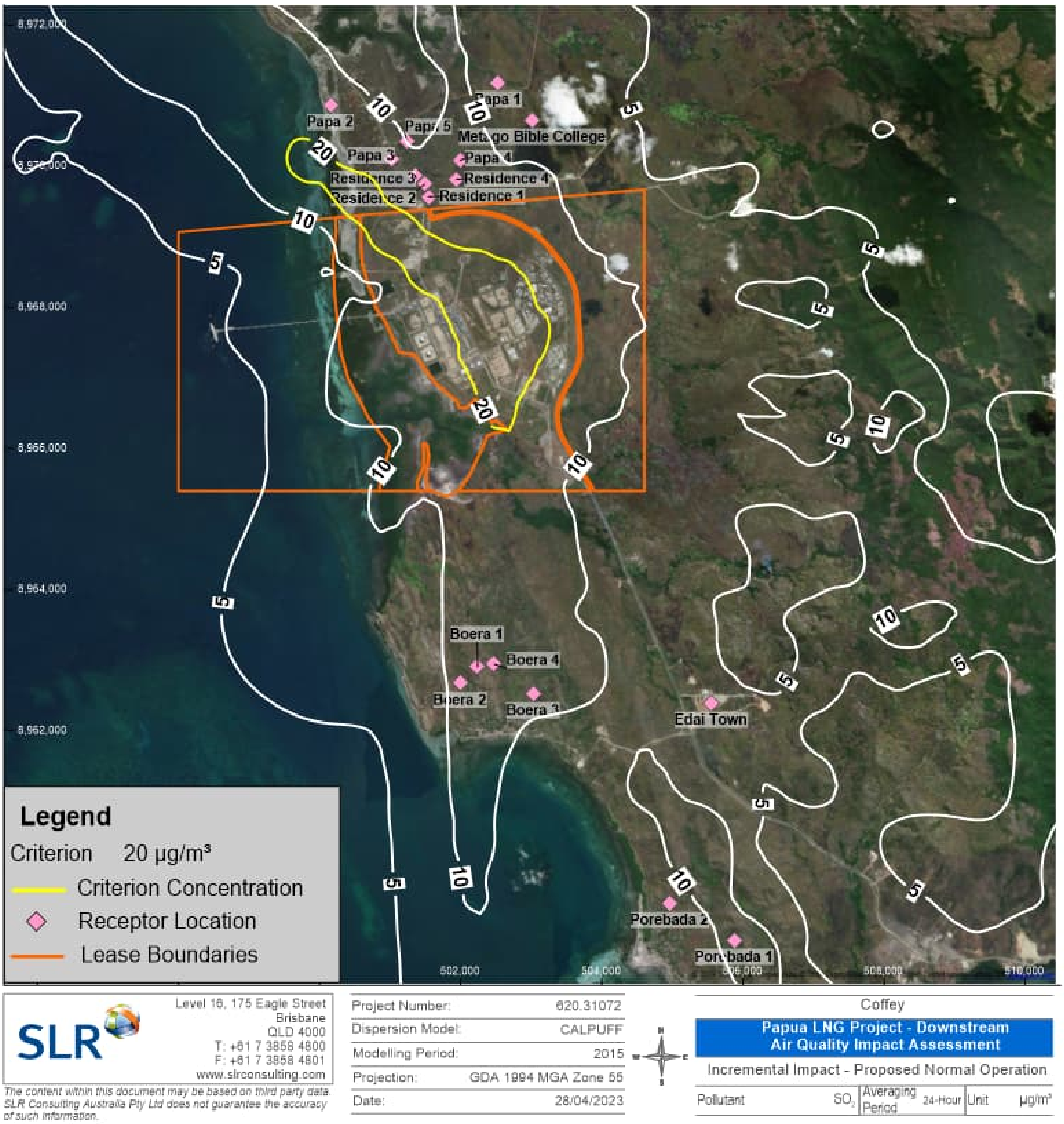
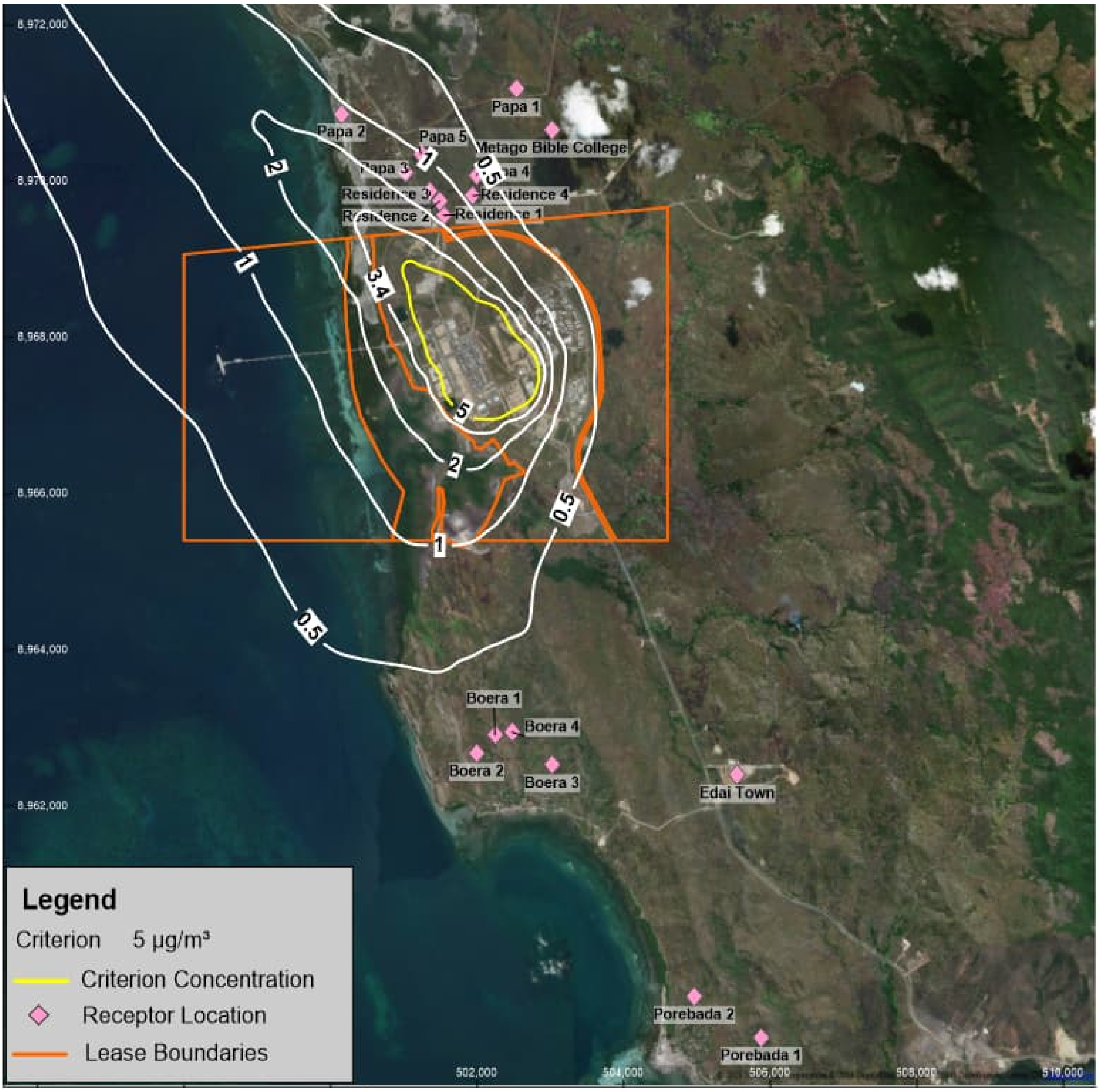


Figure C-18 Predicted Annual Average Benzene Concentrations - Proposed Normal Operations



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Pollutant	Benzene	Averaging Period	Annual	Unit	µg/m³

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