Marsden Point Refinery: A Resource Consent Application to Renew 20 Resource Consents from the Northland Regional Council

Prepared for: ChanceryGreen on behalf of The New Zealand Refining Company Limited, trading as 'Refining NZ'

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REPORT

Tonkin+Taylor

Air Quality Assessment

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1 Introduction

1.1 Overview

The New Zealand Refining Company Limited (trading as Refining NZ) owns and operates the Marsden Point Oil Refinery (the Refinery), which is located approximately 17 km southeast of Whangarei City. It holds resource consent 8319 01-16 from Northland Regional Council (NRC) authorising the discharges to air from the Refinery. This consent expires on 31 May 2022. A copy of resource consent 8319 01-16 is provided in Appendix A.

This air quality technical assessment has been prepared for Refining NZ to support a resource consent application to authorise the continued discharge of contaminants into air from the refinery. Its purpose is to assess the air quality effects associated with discharges to air from the continued operation of the refinery, including hazardous air pollutants, odour and dust emissions.

1.2 Background

The Refining NZ owns and operates New Zealand’s only oil refinery at Marsden Point on the southern headland of Whangarei Harbour. It is an independently operated “tolling” refinery, meaning that it owns neither the feed-stocks nor the finished products.

The Refinery commenced operations in February 1964, with the first fuel export in June 1964. The refinery was originally built as a “hydro-skimming” refinery consisting of a distiller, octane platformer and associated secondary processes. The Refinery Jetty was also established in the 1960s.

In the mid-1980s, the Refinery underwent a major expansion based upon a “hydrocracker” refinery with associated feedstock plant, utility and environmental facilities. As part of this expansion, the 170 km Refinery to Auckland Pipeline (RAP) from Marsden Point to the Wiri terminal was commissioned in May 1985.

The Refinery receives crude oil and other feedstocks per year delivered by ships from the Far East, Middle East, Australia and New Zealand. The bulk of the products produced by the Refinery are distributed via dedicated coastal tankers or RAP.

Crude oil is processed through the crude distillation units. The “hydrocracker” upgrades low value residues from these plants to high value finished components. Table 1.1 summarises key Refinery outputs.

Table 1.1: Overview of product outputs and uses

Output	Uses
Motor gasoline	Otherwise known as petrol, a mixture of tops, butane and reformed naphtha's blended with imported blend stock.
JET A-1/Dual Purpose Kerosene	The bulk of the refinery-produced kerosene is high quality aviation turbine fuel (Avtur) used by the jet-engines of the domestic and international airlines. Some Dual Purpose Kerosene (DPK) is produced for heating/cooking.
Diesel	Less volatile than gasoline and used mainly in compression ignition engines, in road vehicles, tractors, locomotives, boats and stationary engines.
Fuel oil	A number of grades produced from blending, lighter grades used for the larger, low speed compression engines (marine types) and heavier grades used in steam raising (land and marine boilers).
Bitumen	Used for roads and airfield runways.
Sulphur	Used as a fertiliser industry feedstock.

1.3 Purpose and scope

The purpose of this report is to detail the methods, results and findings of the assessment of actual and potential effects of discharges to air from the refinery to inform the Assessment of Environmental Effects (AEE) for the consent application. In particular, this report includes:

- A summary of the site activities as they relate to discharges of contaminants to air;
- A description of the nature of discharges to air;
- A description of the environmental setting of the discharges in terms of sensitivity of activities in the receiving environment to the discharged contaminants, background levels of the contaminants and potential influences on emissions to air from site;
- Resource consent requirements relating to the site activities;
- An assessment of the actual and potential effects of the discharges to air; and
- A summary of conclusions and findings of the assessment.

2 Description of Site and Activities

2.1 Site description

The Refinery is situated at Marsden Point, approximately 16 km southeast of Whangarei City. It covers an area of 114 ha and is bounded to the west by Port Marsden Highway and Mair Road, to the north by Ralph Trimmer Drive and the Whangarei Harbour, and to the east and south by Bream Bay.

The site and immediate surrounding area has a flat topography and is only a few metres above mean high tide sea level. The Refinery is densely developed with operational refining facilities covering the majority of the site surface.

The following sections provide a general description of the sites' oil refining processes, followed by a description of energy generation activities (furnaces used to heat crude and intermediate products – these furnaces are the principal source of discharges to air from the site). The operation of the flare, ship loading and unloading activities, abrasive blasting and fire training activities are also described.

2.2 Refinery processes

2.2.1 Introduction

The Refinery presently receives and processes over 40 million barrels of crude oil per year. That crude oil is sourced from a number of different locations and suppliers and is delivered to the site via ship. The Refinery produces a number of products, which include:

- Gasoline;
- Jet fuel A1/ Dual purpose kerosene;
- Diesel;
- Fuel oil;
- Bitumen;
- Sulphur; and
- Carbon dioxide.

Figure 2.3 is a schematic of the products that the Refinery generates and provides to New Zealand from the crude oil it receives.

There are three broad refining processes / steps listed below and which are summarised in the following sections (Figure 2.2).

- Separation;
- Conversion; and
- Purification.

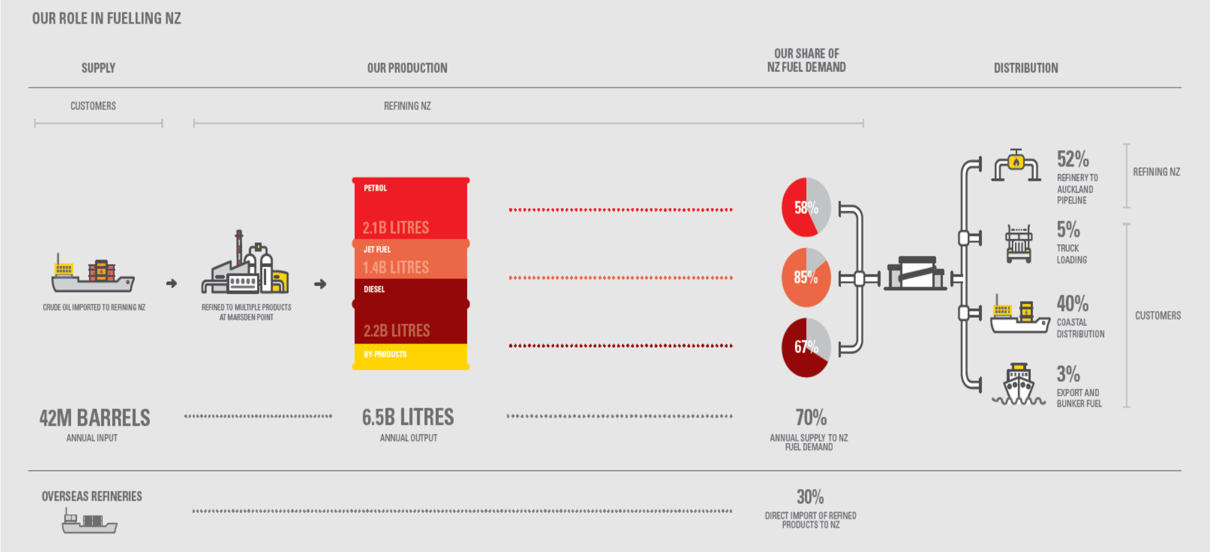


Figure 2.1: Schematic of the products generated by the Refinery (Source: Refining NZ).

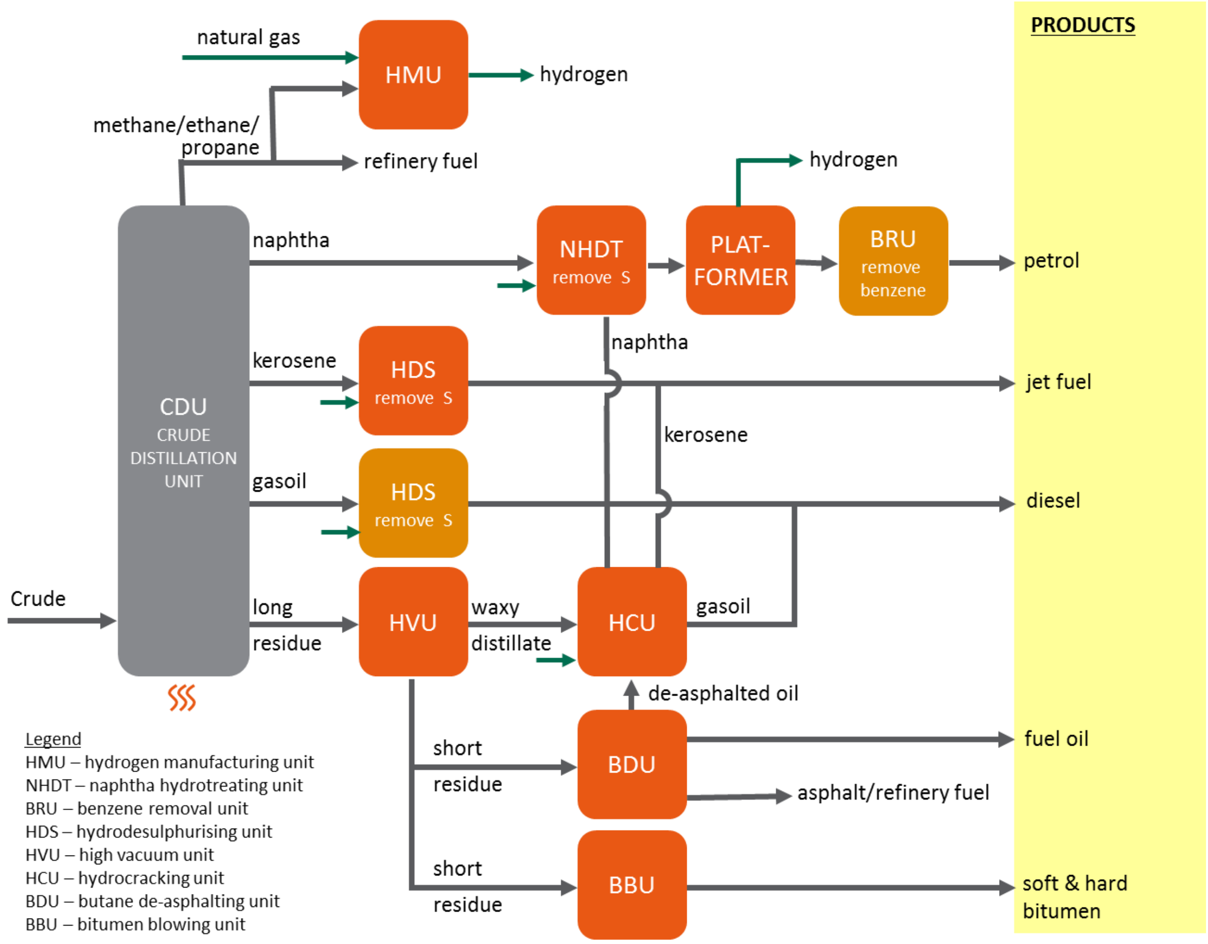


Figure 2.2: Schematic of the Refinery's processes (Source: Refining NZ).

2.2.2 Separation

Shortly after being pumped ashore and stored in above ground storage tanks, the crude oil is sent to the process units to be separated. This typically occurs via distillation. The aim of this part of the process is to separate the crude oil into individual product types, which can then be further upgraded and refined. As part of this process, the crude is 'washed' to remove any containments such as seawater, sand and other such contaminants.

2.2.3 Conversion

Conversion (or 'upgrading') is where chemical reactions occur to produce higher-grade products. There are a number of means to achieve this upgrading. They consist of processes that include:

a Desulphurisation to remove sulphur from products and intermediary products (which is sold as a commodity to customers). Nitrogen products are also removed as part of the desulphurisation process;

b Restructuring oil molecules via catalytic reforming processes;

c An air blowing technique that is used to produce 'harder' bitumen;

d Hydrocracking to convert distillate and de-asphalted oil into products such as diesel and kerosene. The hydrocracking process requires Refining NZ to manufacture its own hydrogen; and

e Conversion of hydrogen sulphide to liquid sulphur and sulphur dioxide.

2.2.4 Purification

Purification of a product may be required at any stage after the crude oil has been separated to meet a final quality specification or to avoid the contamination / poisoning of another catalyst in the refining process. Sulphur, nitrogen, chlorides, heavy metals and carbon dioxide are all compounds / elements that are removed from some of the products that are produced by the Refinery.

Figure 2.3 shows the layout of the Refinery, and labels the key facilities and areas contained therein.

2.3 Energy generation

Thermal energy required for the various refinery processes (heating crude and various products) is provided by furnaces that are predominantly fired on gas, but also include fuel oil and asphalt depending on market conditions. These furnaces are grouped by process block and discharge via a stack that relates to each block, the location of which are shown in Figure 2.4.

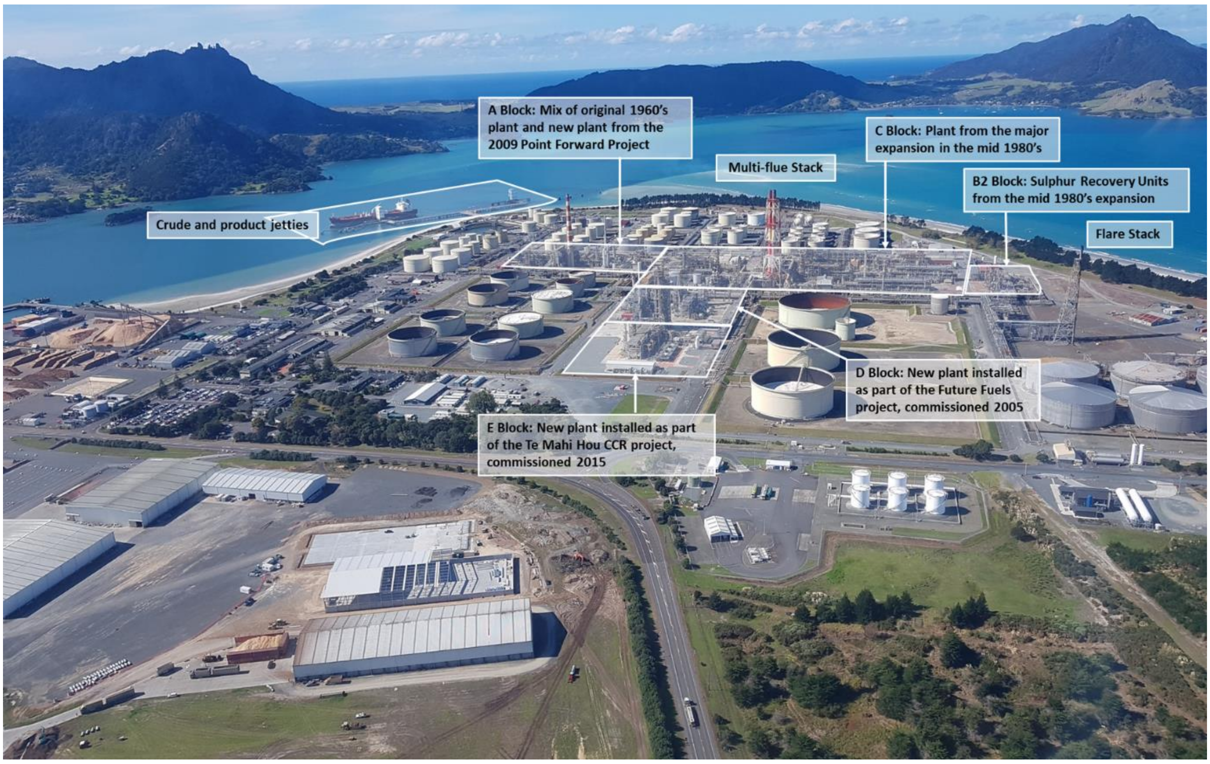


Figure 2.3: Layout of the Refinery (source: Refining NZ).

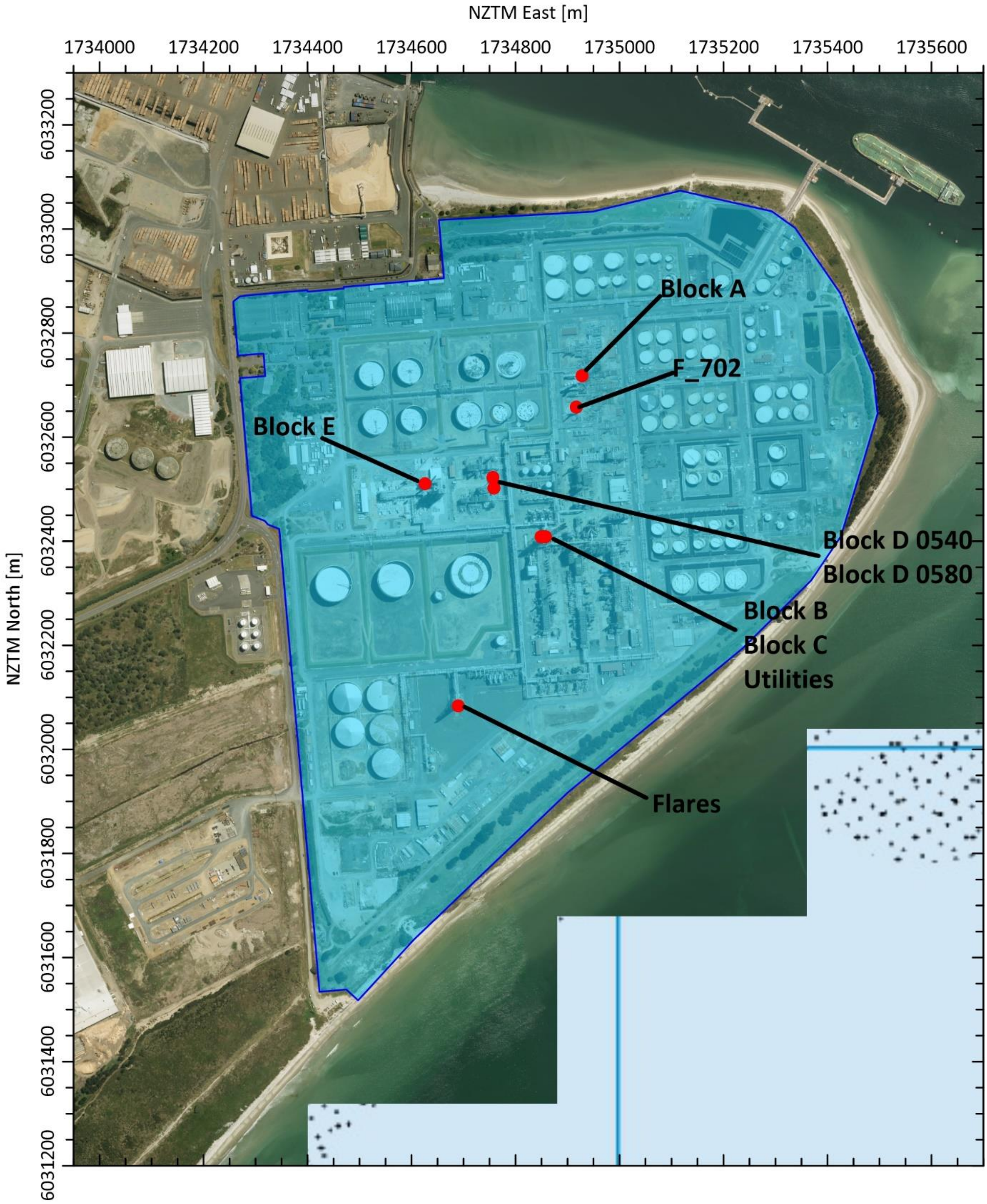


Figure 2.4: Location of discharge stacks and flares (Northland Urban Aerial photos 2014-2015 – LINZ).

2.4 Flaring

The site operates a group of flares located to the south of the site as indicated in Figure 2.4. A photograph of the flare is provided in Figure 2.5. These flares discharge at 110 m above ground level.

The Refining NZ flares are only used for emergency flaring; infrequent process flaring occurs on site. During shutdown or maintenance during operation, flaring is a crucial safety precaution that involves the releasing of pressure and safe venting of hydrocarbon gases. The flares at the Refinery are configured to only treat significant releases, meaning that unlike many refineries the flare is not being used to treat off-gas continuously.

All flares are monitored via a television link, and remedial measures are taken to minimise any smoke effects that arise.

Figure 2.5: Photo of flares with the Block B, C and Utilities stacks in the background.

2.5 Ship loading and unloading

Crude oil is delivered by ships to one of three jetty berths. The ships give rise to emissions (particularly SO_2) when berthed and consideration is given in this assessment to such emissions in terms of the cumulative effects of the site's discharges.

The refinery jetty comprises two separate arms as can be seen in Figure 2.4 and Figure 2.6:

- Jetty 1 (the eastern jetty) is the crude jetty or reception jetty, which averages six ships per month, ranging in size from 80,000 to 120,000 tonnes;
- Jetty 2 (the western or up-harbour jetty) is the product jetty which averages eight ships per month, each with a capacity of approximately 28,000 tonnes; and

- Jetty 3 was added in 2009 located on the western end of the jetty is used to load the ship bunkering vessel Awanuia, which is used to bunker (refuel) shipping in Auckland and at Northport. This jetty averages five visits per month, with an average capacity of 2,500 tonnes.

Figure 2.6: View of jetties, with two vessels docked.

The largest ships (which will also have the greatest emissions when berthed) are the crude tankers, with the Suezmax class tankers being the largest that can be accommodated. When berthed, these ships use their on-board auxiliary engines to pump the crude via the jetty to the site's holding tanks. These engines are typically fired using heavy fuel oil, with a relatively high sulphur content.

New Zealand became a signatory to International Convention for the Prevention of Pollution from Ships, now known as MARPOL, in 1998. It has ratified all of the Annexes apart from Annexes IV (pollution by sewage from ships) and VI (prevention of air pollution from ships) (International Martime Organisation, 2016). Annex VI entered into force on 19 May 2005 and a revised Annex VI, with significantly tightened emissions limits, was adopted in October 2008 and entered into force on 1 July 2010.

New Zealand law gives effect to Annexes I, II, III, and V by way of the Resource Management (Marine Pollution) Regulations 1998. Annex VI, which relates to air emissions, is given effect for ships in New Zealand that are leaving for, and coming from, the Antarctic sea area only.

Notwithstanding that New Zealand is not a signatory, the global requirements of MARPOL Annex VI largely determine the sulphur content of the fuel available to ships travelling to New Zealand. Accordingly, it is likely that there will be an improvement in shipping emissions to air (particularly of SO_2) over time.

2.6 Abrasive blasting

Abrasive blasting and ultra-high pressure water blasting is carried out routinely on site as part of the maintenance programme for site infrastructure, including storage tanks and structures. This is used to clean and/or texturize metal surfaces ahead of repainting. During dry abrasive blasting, the sand sized particles of blasting media (first pass garnet) are fed from a hopper to the blasting gun, where they are entrained in a jet of high-pressure air and directed at the surface being treated.

The scale of abrasive blasting and ultra-high water blasting activities varies significantly from ‘pencil’ blasting operations in preparation for coating welds or small areas of corrosion through to large scale blasting that may be required for a storage tank.

For most operations open air blasting is undertaken, but with restrictions for wind conditions and where there is a potential for dust to drift beyond the site.

2.7 Firefighting training

Routine firefighting training is carried out at the site to ensure that staff are experienced in responding to the fire conditions that can be associated with refineries and the burning of light hydrocarbons. This takes place in a designated part of the site near eastern-most extent of the site and south of the wastewater treatment facility.

Fire training occurs between 30 and 36 times per year, with events lasting for 1 to 1.5 hours in duration. ‘Light tops’, which is similar to petrol, is the hydrocarbon fuel used during the training event.

The existing air discharge permit restricts fire-fighting training as follows:

- Fire-fighting training shall not be conducted when it is anticipated that the wind conditions will take smoke towards the area between Darch Point and the junction of Ody and Whangarei Heads Road – i.e., winds from 165°N (south-southeast) to 240°N (southwest);
- The wind speed and direction are to be assessed prior to ignition; and
- The emission of smoke is to cease should there be any offensive or objectionable smoke beyond the site boundary.

3 Nature of Discharges

3.1 Stack discharges

3.1.1 Overview

The main discharges into air from the Refinery are associated with combustion emissions discharged from eight tall stacks (Figure 2.4). Discharges from the various stacks are combustion products associated with the burning of natural and refinery generated gas, as well as the combustion of fuel oil and asphalt.

The main contaminant of interest from the site's discharge stacks has historically been sulphur dioxide (SO_2), which mainly arises from the combustion of fuel oil and asphalt. Other contaminant discharges of interest include fine particulate matter less than ten microns (PM_{10}) and less than 2.5 microns ($PM_{2.5}$), oxides of nitrogen (NO_X), carbon monoxide (CO), various metals, and trace levels of dioxins and furans.

3.1.2 Sulphur oxides

3.1.2.1 Introduction

In terms of sulphur oxides, the stack emissions will contain principally SO_2 but can also contain lesser amounts of sulphur trioxide (SO_3), which can in turn be converted to sulphate (SO_4).

SO_2 is of interest with respect to potential human health effects because it is a potent respiratory irritant when inhaled. Asthmatics are particularly susceptible. SO_2 acts directly on the upper airways (nose, throat, trachea and major bronchi), producing rapid responses within minutes. It achieves maximum effect in 10 to 15 minutes, particularly in individuals with significant airway reactivity, such as asthmatics and those suffering similar bronchospastic conditions.

Environmental impacts from emissions of sulphur oxides relate to impacts on sensitive vegetation and acid deposition, which may cause extensive damage to materials, terrestrial ecosystems, and aquatic ecosystems.

3.1.2.2 Sulphur dioxide

SO_2 emissions from the site have historically been a key focus of air quality assessments. High emission rates are the result of burning of fuel oil and asphalt in some furnaces that discharge via certain stacks, but particularly the Block C and Utilities stacks.

Figure 3.1 summarises the last five years of stack emission testing (undertaken every nine months) for SO_2 in the form of a box and whisker plot. This type of plot is useful for depicting the statistical variation in data. It clearly shows that the Block C and Utilities stacks dominate SO_2 emissions from the site. Further data on stack emissions is available in Appendix B.

Because of the importance of assessing both the peak and longer-term impacts of SO_2, separate emission rates have been derived for modelling as follows:

- Peak emission rates are derived from the maximum measured SO_2 concentrations for each stack for the last five years; and
- Daily and longer-term emission rates are derived from the upper-quartile of measured emissions for each stack for the last five years. The upper-quartile values were used instead of the average emission rate values, as the upper-quartile values more closely aligns with the site's existing requirement of discharging not more than 12 tonnes per day of SO_2 when

averaged over a calendar year, whereas the average values fall significantly below this this aggregate emission rate.

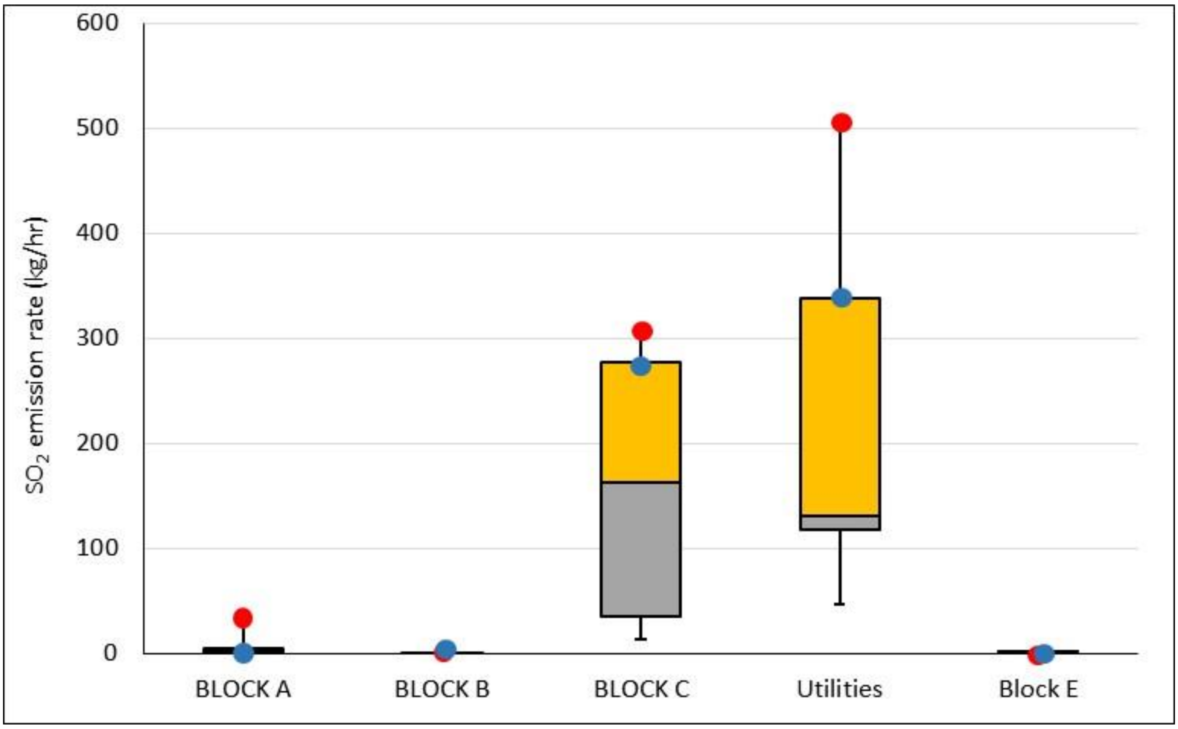


Figure 3.1: Box and whisker of SO_2 emission rates measurements for the last five years at Refining NZ. The red dots denote the peak emission rate used for modelling acute impacts, while the blue dots indicate the emission rate used for modelling longer-term impacts.

The Block D stacks and the F702 stack are associated with furnaces that only burn gas, and consequently are not part of the stack-testing programme. Emission rates of SO_2 from these sources have been derived by Refining NZ based on the hydrogen sulphide content of the gas.

Table 3.1 summarises the emission rates used for the modelling assessment of assessing peak and longer-term impacts of SO_2.

Table 3.1: Summary of SO_2 emission rates used for modelling

Stack	Peak emission rate (kg/hr)	Upper quartile emission rate (kg/hr)
Block A	34.9	5.4
Block B	2.4	0.5
Block C	306.6	277.0
Block D _5401	0.2	0.2
Block D _5801	3.0	3.0
Block E	1.1	1.0
Utilities	503.2	338.7
F702	1.0	1.0

3.1.2.3 Sulphate

Sulphate particle emissions (SO_4^{-2}) can contribute significantly to total sulphur deposition, which is of interest in terms of potential ecological impacts.

Emissions of sulphate (SO_4^{-2}) have been determined based on stack emission testing of sulphur trioxide (SO_3) and assuming that all SO_3 reacts rapidly with in-stack and atmospheric moisture to form sulphate particles. Table 3.2 summarises the SO_4 emission rates used in this assessment. Emission rates for Block D stacks and F702 stack are not measured and have been estimated based on establishing a relationship between measured SO_2 and SO_3 emissions from the other stacks.

Table 3.2: Summary of SO_4 emission rates used for modelling

Stack	Upper quartile emission rate (kg/hr)
Block A	1.46
Block B	0.13
Block C	9.14
Block D _5401	0.76
Block D _5801	0.82
Block E	0.59
Utilities	4.51
F702	0.78

3.1.3 Particulate matter

Particulate matter emissions of interest are those that are smaller than ten microns in diameter (PM_{10}) and those smaller than 2.5 microns in diameter ($PM_{2.5}$).

The health effects of particulate matter relates to its size. Particles less than 10 microns in diameter pose the greatest problems, because they can get deep into the lungs, and some may even pass into the bloodstream. Ambient air concentrations of particulate matter are typically reported as less than 10 microns in diameter (PM_{10}) or less than 2.5 microns in diameter ($PM_{2.5}$).

Epidemiological studies have provided no evidence for the existence of a threshold value below which no adverse health effects are observed. The WHO concluded that there is a need to maintain independent air quality guidelines for PM_{10} and $PM_{2.5;}$ for short-term averages (such as 24-hour averages) and annual means.

Emissions of PM_{10} have been measured as part of the stack testing requirements from Block A, B, C, E and the Utilities stacks. Testing has not been undertaken on Block D stacks and the F702 stack as these sources are only gas fired.

Measurement of $PM_{2.5}$ has not been required as part of historic stack testing for the site. However, testing was undertaken in November 2018 to determine the ratio of $PM_{2.5}$ to TSP for Block A, B, C, E and the Utilities stack, and later in August 2019 to confirm the ratio of PM_{10} to TSP and $PM_{2.5}$ to TSP for Block B, C and the Utilities stack. The results of both rounds of testing are summarised in Table 3.3 and Table 3.4 respectively.

For completeness, the results of stack testing for TSP is provided in Appendix B.

Table 3.3: Summary of testing of TSP and $PM_{2.5}$ from November-December 2018

Stack	Concentration (µg/m³)			Size fraction of TSP
	TSP	PM_{10}	$PM_{2.5}$	$PM_{2.5}$|TSP
Block A	10.7		8.3	78%
Block B	8.4		4.3	51%
Block C	8.4		4.5	54%
Utilities	13.1		4.8	37%
Block E	6.7		4.5	67%

Table 3.4: Summary of testing of TSP, PM_{10} and $PM_{2.5}$ from August 2019

Stack	Concentration (µg/m³)			Size fraction of TSP and PM_{10}		
	TSP	PM_{10}	$PM_{2.5}$	PM_{10}|TSP	$PM_{2.5}$|TSP	$PM_{2.5}$|PM_{10}
Block A	-	-	-	-	-	-
Block B	9.6	6.8	4.6	71%	48%	68%
Block C	53.3	51.2	49.1	96%	92%	96%
Utilities	53.3	51.3	47.3	96%	89%	92%
Block E	-	-	-	-	-	-

Note: Block A and Block E not tested.

3.1.3.1 PM_{10}

Measured total particulate emission have been measured as part of consent requirements and the results are summarised as a box and whisker plot in Figure 3.2. These plots show the Block A, C and Utilities stacks dominating emissions, with some significant variation in emission rates for those stacks. The dominance of these stacks and the variation in rates reflects the ability of some of the furnaces discharging via these stacks to be fired on fuel oil or asphalt. Given this variation, the maximum measured values are used in order to predict peak 24-hour average PM_{10} concentrations, while the upper quartile of measured concentrations are used in the assessment of annual average PM_{10} concentrations.

Measurements are not made on Block D stacks and F702 given these stacks are only fired on gas. Refining NZ has advised on emission rates for these stacks based on previously modelled rates.

For this assessment, it is assumed that measured total particulate emissions for Block D stacks are entirely comprised of particles in the 10 micron size range (i.e., PM_{10}). Based on the results provided in Table 3.4 for the other stacks, this is a reasonable assumption, given that the PM_{10} comprised up to 96% of the TSP concentration for Block C and Utilities stacks.

Table 3.5: Summary of PM_{10} emission rates used for modelling

Stack	Peak emission rate (kg/hr)	Upper quartile emission rate (kg/hr)
Block A	18.3	6.4
Block B	13.0	0.4
Block C	36.4	23.6
Block D _5401	0.07	0.07
Block D _5801	0.04	0.04
Block E	0.3	0.2
Utilities	29.1	14.1
F702	0.09	0.09

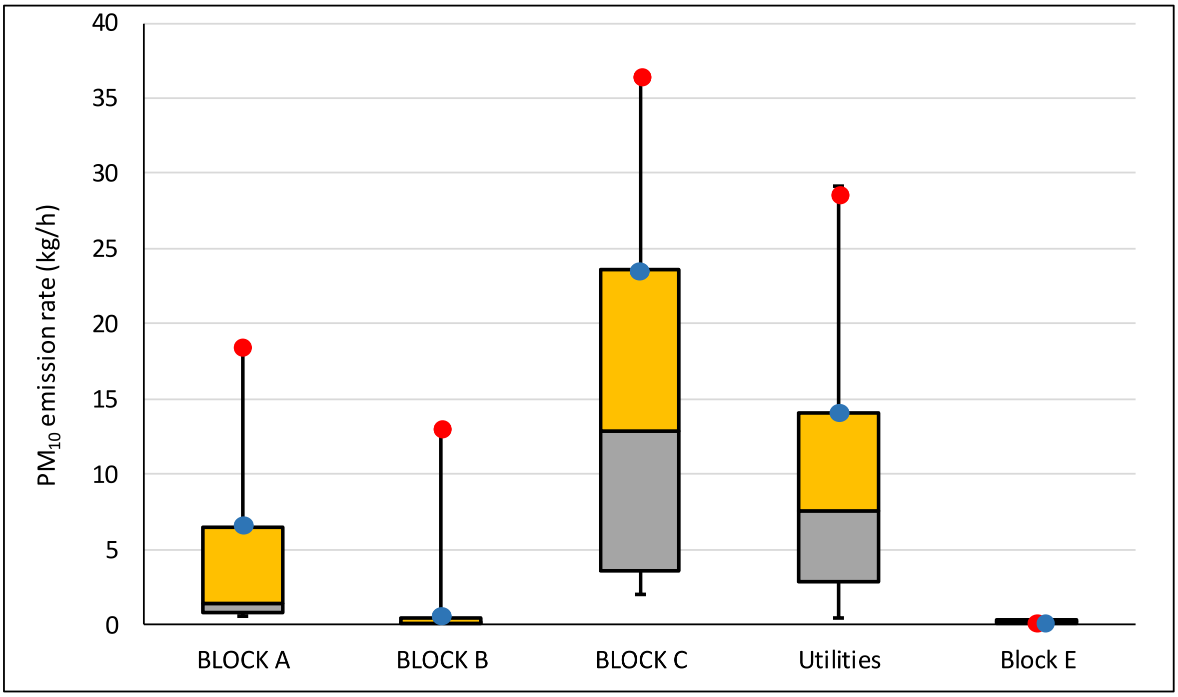


Figure 3.2: Box and whisker of PM_{10} emission rates measurements for the last five years at Refining NZ. The red dots denote the peak emission rate used for modelling acute impacts, while the blue dots indicate the emission rate used for modelling longer-term impacts.

3.1.3.2 $PM_{2.5}$

Modelling of $PM_{2.5}$ emissions was undertaken assuming all of the PM_{10} discharge was comprised of $PM_{2.5}$. The results provided in Table 3.3 and Table 3.4 indicate that this may be conservative on occasions for some stacks, with the ratio of $PM_{2.5}|PM_{10}$ being as low as 0.68 for Block B stack, but a realistic assumption for other stacks (Block C and Utilities having a ratios of 0.96 and 0.92 respectively).

3.1.4 Oxides of nitrogen

Exposure to nitrogen dioxide (NO_2) has been shown to cause reversible effects on lung function and airway responsiveness. It may also increase reactivity to natural allergens. Inhalation of NO_2 by children increases their risk of respiratory infection and may lead to poorer lung function in later life.

Recent epidemiological studies have shown an association between ambient NO_2 exposure and increases in daily mortality and hospital admissions for respiratory disease. NO_2 has also been shown to increase the effects of exposure to other known irritants, such as ozone and respirable particles.

The NOx discharge is largely composed of nitric oxide (NO) and to a lesser degree the more toxic nitrogen dioxide (NO_2). For external combustion appliances, such as the sites furnaces, NO_2 typically comprises 10 % of total NOx at the discharge point.

Emission rates for Block A, B, C, E and the Utilities stack have been derived from the maximum measured NOX emission rate from the last five years of stack testing data. Because the maximum values are used, the results are expected to be conservative when assessing against criteria with a long-term averaging period.

Stack testing of NO_X has not been undertaken for Block D stack and Furnace F702 stack. Consequently, emission rates have been calculated based on United States Environmental Protection Agency (USEPA 1995) AP-42 emission factors Table 1.4-1, which is a standard methodology for estimating such emissions in the absence of direct measurements. This gives an emission factor of 190 pounds per million standard cubic feet (lbs/1x10^{-6} scf) (3,040 kg/1x10^{-6} m^3) of natural gas consumed for an uncontrolled appliance. For each source, the maximum value of recorded daily gas consumption was used (listed below) as input to the emission calculation and a gas density of 0.51 kg of gas per cubic metre (kg/m^3) assumed:

- Block D_5408: 28 T/day;
- Block D_5801: 14 T/day; and
- F702: 54 T/day.

NO_X emission rates used in the dispersion modelling assessment are provided in Table 3.6

Table 3.6: Summary of NO_X emission rates used for modelling

Stack	Upper quartile emission rate (kg/hr)
Block A	32.4
Block B	14.4
Block C	79.2
Block D _5401	7.0
Block D _5801	2.7
Block E	7.2
Utilities	46.8
F702	13.5

3.1.5 Carbon monoxide

High exposures to carbon monoxide (CO) can cause acute poisoning, with coma and eventually collapse occurring. However, ambient exposures to CO are typically several orders of magnitude lower than those associated with acute poisoning, although some exposures in urban settings have been shown to adversely affect the heart, brain and central nervous system.

Adverse cardiovascular effects of CO inhalation include decreased blood oxygen uptake and decreased work capacity. Those with angina may suffer decreased exercise capacity and increased duration of angina. Adverse neuro-behavioural effects of CO include a decrease in vigilance, visual perception, manual dexterity, ability to learn and perform complex sensorimotor tasks in healthy individuals, and reduced birth weight in non-smoking mothers.

CO emissions are not routinely measured as part of the stack testing programme. Accordingly, emission rates for all stacks have been calculated using USEAP AP-42 emission factors. The approach used assumes each furnace is fired only on gas (rather than fuel oil or asphalt). We consider this will provide a reasonable approximation of CO emissions from the site, noting that USEPA AP-42 emission factors are typically conservative and that experience with similarly large combustion sources shows that predicted concentrations of CO seldom approach relevant health based assessment criteria. Given this, an emission factor of 84 lb/1x10-6 scf (1,344 kg/m³) from Table 1.4-1 of AP-42 for an uncontrolled appliance is used.

As with the NO_X emission calculations, CO emission rates are conservatively calculated assuming the maximum value of recorded daily gas consumption for each stack (listed below) and a gas density of 0.51 kg of gas per cubic metre (kg/m³).

- Block A: 140 T/day;
- Block B: 47 T/day;
- Block C: 339 T/day;
- Block D_5408: 28 T/day;
- Block D_5801: 14 T/day;
- Block E: 83 T/day;
- Utilities: 222 T/day; and
- F702: 54 T/day.

Table 3.7: Summary of CO emission rates used for modelling

Stack	Upper quartile emission rate (kg/hr)
Block A	15.4
Block B	5.2
Block C	37.4
Block D _5401	2.9
Block D _5801	1.2
Block E	9.1
Utilities	24.5
F702	6

3.1.6 Metals

The adverse effects of ambient concentrations of metals are varied and depends on the specific metal, and may include both acute and chronic exposure toxicity effects. A number of metals are also recognised carcinogens.

Fuel oil and asphalt contain trace levels of various metals and consequently there will be metal discharges associated with the furnaces that burn these fuels. The combustion of natural gas is not expected to contain any appreciable concentration of metals.

To determine emission rates, fuel oil and asphalt were sampled to confirm the metals content of each fuel. The subsequent test data was used to calculate metal emission rates using a mass balance approach. A summary of the initial fuel testing data is given in Table 3.8.

Table 3.8: Summary of metals testing results for asphalt and fuel oil (1 May 2019)

Metal	Concentration in fuel (mg/kg)	
	Asphalt	Fuel Oil
	Sample# 610408	Sample# 610409
Aluminium	2	2
Calcium	6	9
Iron	18	13
Sodium	18	26
Nickel	66	29
Silicon	3	3
Vanadium	75	41

Note: Arsenic, silver, barium, cadmium, chromium, copper, potassium, magnesium, manganese, molybdenum, phosphorus, lead, tin, titanium, zinc and mercury were below the limit of detection (LOD) of 1 mg/kg for both asphalt and fuel oil.

Of the metals identified for assessment, Nickel is a key focus given its very low assessment criteria (discussed in Section 5.1.3). Accordingly, additional testing of asphalt and fuel oil has been undertaken to better understand the variability of Nickel content in order to inform appropriate emissions rates for the dispersion modelling assessment. The results of the additional Nickel monitoring are summarised graphically in Figure 3.3. The maximum measured value (outlined by a red circle in Figure 3.3) has been used to derive a conservative estimate of nickel emissions from the site.

Emission rates for each metal are then calculated using the metals concentration values given in Table 3.8 and the worst case nickel concentrations given in Figure 3.3, along with the average rate of fuel consumption for oil and asphalt per stack given in Table 3.9, and summing the value for each fuel. The resulting emission rates used in the dispersion modelling assessment are given in Table 3.9.

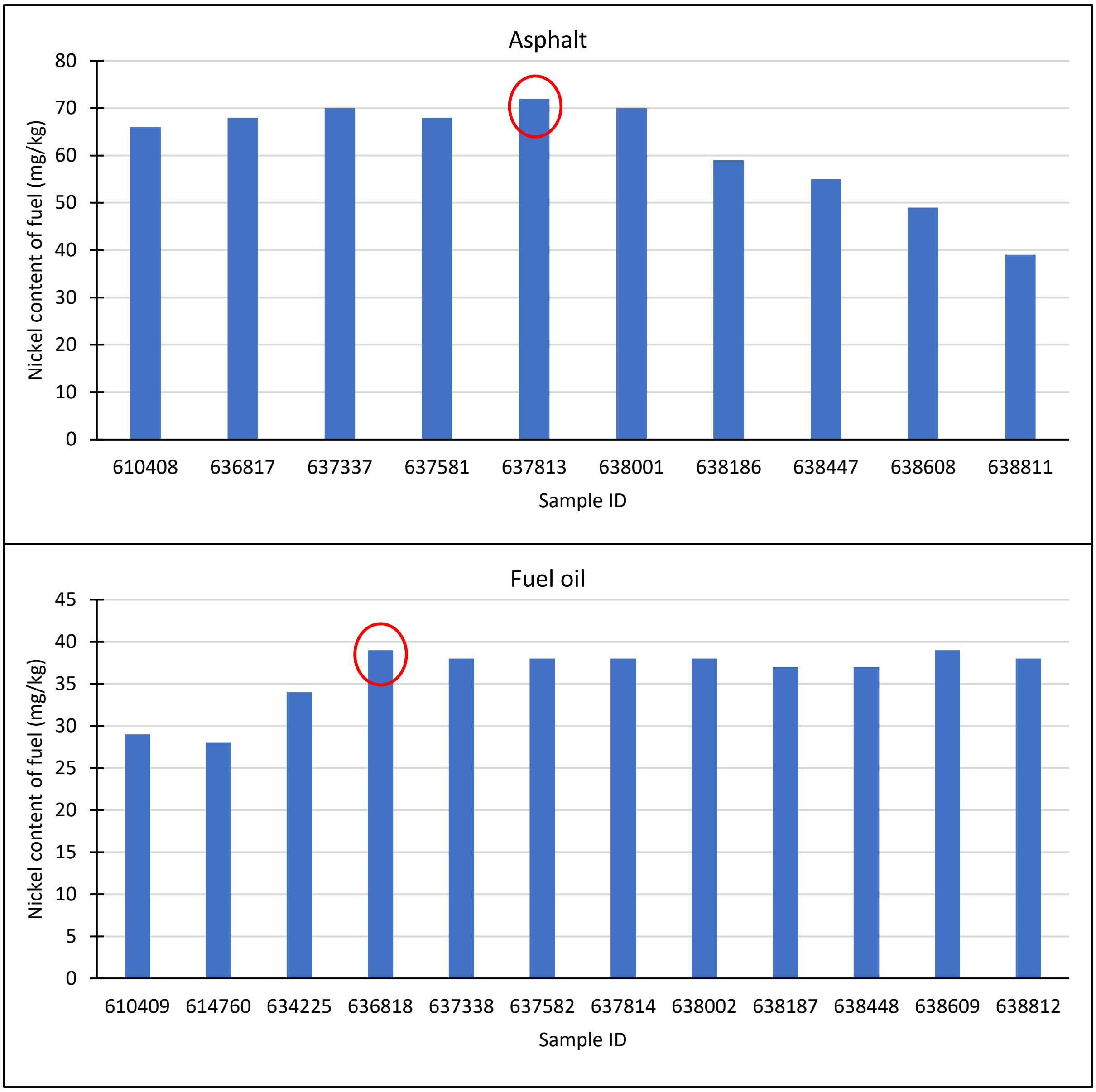


Figure 3.3: Summary of nickel testing results for asphalt and fuel oil.

Table 3.9: Summary of metals emission rates by stack

Parameter	**Block A**	**Block B**	**Block C**	**Utilities**
Annual average fuel consumption rate (T/day)				
Oil	14.9	13.8	23.8	50.6
Asphalt	0.0	0.5	42.2	59.2
Metal emission rate (kg/hr)				
Aluminium	0.0012	0.0012	0.0055	0.0091
Calcium	0.0056	0.0053	0.0195	0.0338
Iron	0.0081	0.0079	0.0446	0.0718
Sodium	0.0161	0.0153	0.0574	0.0992
Nickel	0.0242	0.0239	0.1653	0.2598

Silicon	0.0019	0.0018	0.0083	0.0137
Vanadium	0.0254	0.0252	0.1726	0.2714
Metals below LOD	0.0003	0.0003	0.0014	0.0023

Note: Block D_0540, Block D_0580, Block E and F702 only burn natural gas and therefore metal emission from these stacks are summed to be zero. Where metal concentrations were below the limit of detection of 1 mg/kg, a metals concentration of 0.5 mg/kg (half the LOD) was assumed in the emission calculation.

3.1.7 Dioxins and furans

The term 'dioxin and furans' refers to the range of dioxin, furans and dioxin-like compounds comprising polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs). The compounds often have similar toxicity profiles and common mechanisms of action, and are generally considered together as a group to set guidelines. These compounds are assigned toxicity equivalence (TEQ), which are based on their toxicity relative to the most toxic of these compounds, 2,3,7,8-tetrachlorodibenzodioxin (TCDD).

Emission testing for dioxins and furans was undertaken on the Utilities Stack in July 2019. The testing was scheduled to coincide with the furnaces discharging via the Utilities Stack being fired on asphalt, which is expected to give rise to higher emission rates when compared with burning of fuel oil or gas.

Results for the testing of other stacks fired on gas and oil is ongoing and was not available at the time of preparation of this report. Because of this, the concentration results from the Utilities stack have been used as the basis for calculating dioxin and furan emission rates for the remainder of the discharge stacks on site. This is considered a very conservative assumption given that not all furnaces burn asphalt or to the degree that is done via the Utilities stack.

Table 3.10: Summary of dioxin and furans emission rates used for modelling

Stack	Emission rate ($kg_{WHO-TEQ}$/hr)
Block A	5.4×10^{-11}
Block B	7.2×10^{-12}
Block C	7.3×10^{-11}
Block D _5401	6.5×10^{-12}
Block D _5801	2.2×10^{-12}
Block E	1.4×10^{-11}
Utilities	4.2×10^{-11}
F702	1.3×10^{-11}

3.1.8 Stack parameters

The stack discharge parameters used for the dispersion modelling assessment are summarised in Table 3.11. These parameters are derived as follows:

- Efflux temperatures are based on the average temperature from stack emission testing for the past five years, with the exception of Block A stack, which is based on values from November 2015 onwards to coincide with a change in furnace configuration. The values for Block C and Utilities are reduced by 5 °C to reflect planned changes in the refractory for those stacks. The use of lower values is conservative;

- Efflux diameter relates to the exit diameter of each stack, which in some cases varies significantly from the internal stack diameter at the point where stack emission measurements are undertaken; and
- Efflux velocities are largely based on stack measurements accounting for the efflux diameter. However, in some instances a lower value has been used based on combustion modelling advice from Refining NZ. The use of a lower value is conservative.

Table 3.11: Summary of stack discharge parameters

Stack	Stack height (m)	Efflux diameter (m)	Efflux velocity (m/s)	Efflux temperature (°C)
Block A	104.2	2.60	8.5	180
Block B	121.0	1.39	11.0	195
Block C	121.0	3.49	11.6	230
Block D _5401	49.0	0.90	12.2	153
Block D _5801	49.0	0.70	7.0	199
Block E	76.9	2.97	3.0	175
Utilities	121.0	2.66	15.0	182
F702	70.0	2.20	4.2	176

3.2 The flare

Discharges to air from the flare will be combustion gases and particulates associated with the burning of any process gases vented to the flare during emergency conditions. These emissions will be similar to those from the furnaces burning gas, but may contain higher levels of sulphur in the gas vented to the flare than present in the gas used by the furnaces. Consequently the flare could be a significant source of SO_2 emission, albeit it intermittently.

Due to the nature of the flare, essentially being a large open flame at the top of a tall stack, it is not practicable to undertake emission testing to confirm reliable emission rates. Given this challenge, the contribution of flare discharges cannot be reliably modelled and is instead assessed later in this report through the evaluation of ambient SO_2 monitoring. We consider this approach scientifically robust and appropriate to the circumstances.

Figure 3.4 presents a timeseries chart of the daily gas flow rates to the flare from 2017 to 2019 inclusive. It highlights several periods of significant emergency and process-shutdown flaring events, which include the following:

- A Block shutdown from 2 March to 13 March 2017. This resulting in flaring of gas from A D and E Bocks the hydrocracker unit (HCU) and the sulphur flare;
- Total refinery shut down from 20 April to 10 July 2018. This result in flaring of gas from the HCU, the hydrogen manufacturing units (HMU) and A D and E Blocks and the Sulphur Flare;
- Electrical sub-station trip (Sub-0) resulting in flaring on 23 May 2019;
- Natural gas control system (DCS NG) fault on 27 May 2019; and
- Power outage on 27 November 2019.

NZRC does not undertake routine analysis of the composition of the gas flow to the flare. However NZRC analysed the gas flow on three occasions, including during a recent large event associated with the shutdown of Block C where hydrogen gas comprised 97.5% of the gas, with other notable constituents being methane (1.18%), nitrogen (0.67%) and oxygen (0.13%) (composition analysis provided in Appendix D).

The other two occasions when gas composition was sampled relate to smaller flaring events, the composition of the gas is more varied and can comprise a significant portion of hydrogen sulphide, which oxidises to SO_2 when combusted. NZRC has undertaken composition analysis of the gas feed to the flare on two occasions under such conditions and a summary of those analyses is provided Table 3.12. On these occasions, the hydrogen sulphide concentrations were 3.4 and 7.9 % wt/wt.

With regard to the effects of flaring emissions, specific regard has been given to the feedback relating to the environmental and health effects of flare emissions in the draft 'cultural effects assessment report' (Patukarakeke 2020). In particular, Section 5.4 of this report providing an assessment of the air quality effects of SO_2 discharges from the flare.

Table 3.12: Summary of flare gas composition analyses during small flaring events

Year / Analysis #	**2016** **511502**	**150210**	**Average weight %**
Component	**Weight %**	**Weight %**	
Hydrogen	10.8	6.3	8.5
Methane	11.9	8.1	10
Ethane	4	6.7	5.4
Propane	10.8	12.4	11.6
Isobutane	12.6	14.1	13.3
Butane	18.7	24.4	21.5
Isopentane	6.9	7.8	7.3
Pentane	3.2	3.7	3.5
Hexane	6.4	9	7.7
Carbon Dioxide	1.1	1.9	1.5
Hydrogen Sulphide	7.9	3.4	5.7
Oxygen	1.3	0.3	0.8
Nitrogen	4.4	1.8	3.1
Water	0	0.1	0.1
Total	100	100	100

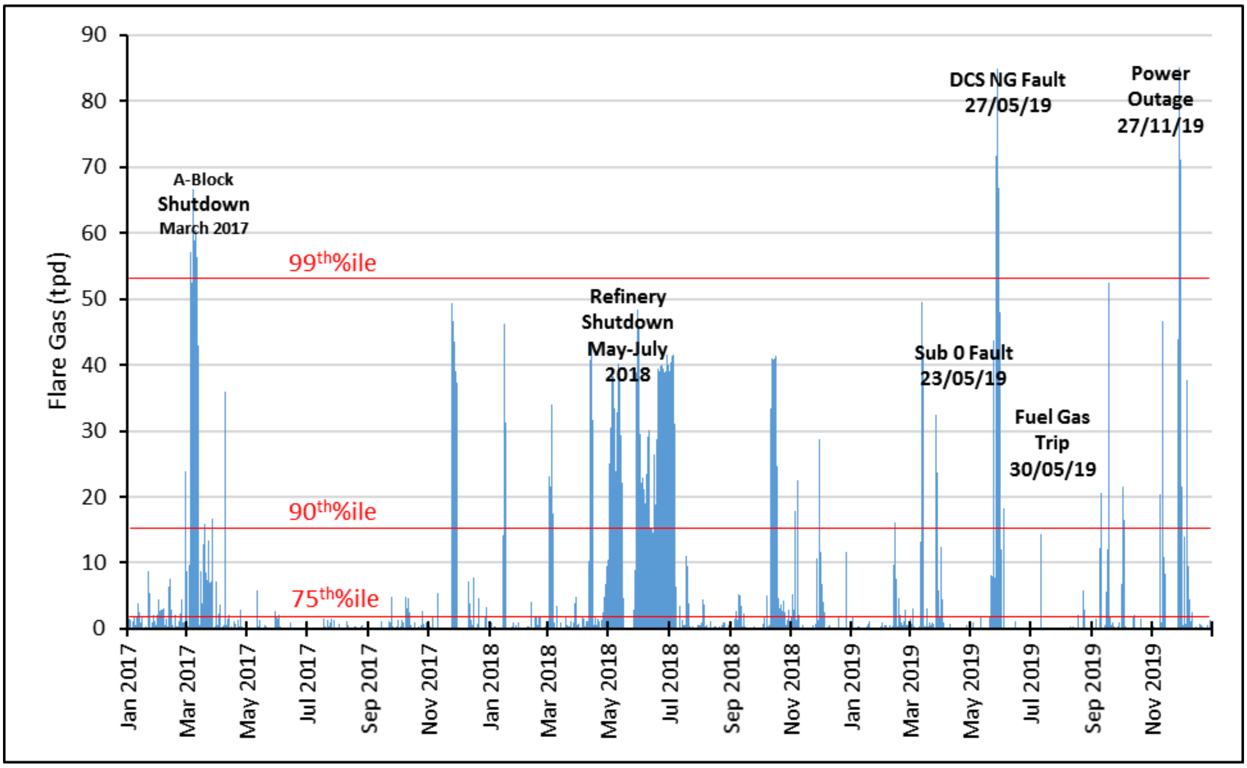


Figure 3.4: Gas flow rates to the fare, 2017 to 2019 inclusive. Redlines and text annotate the percentile gas flow rates to the flare. Black text annotation highlights various significant flaring events.

3.3 Fugitive emissions

At most refineries, the bulk of fugitive emissions are comprised of volatile organic compounds (VOC) emitted primarily from crude and product storage and transfer, as well as to some extent the process areas. The high level of control on VOC leaks from the Refinery's process area was noted in a Status Report by the then Department of Health's Regional Air Pollution Control Officer in 1991. This report commented on the Refinery's "very high degree of containment" of process emissions and indicates the site has good systems and processes in place for minimising fugitive emissions. It was noted that hydrocarbons, other odour-causing compounds and flare emissions occur only during emergency situations, from minor leaks, or during infrequent catalyst regeneration at certain processing units.

VOC fugitive emissions associated with the refinery operations and fuel storage are largely comprised of benzene, toluene, ethylbenzene and xylene (BTEX) and these compounds are typically used as indicator species for evaluating the fugitive emissions from refineries. These emissions are assessed through monitoring, which is discussed later in Section 6.

3.4 Odour

Odour emissions from the site can occur from a wide range of activities/sources. This includes the following:

- Sulphur type odours associated with combustion of high-sulphur fuels. As these sources discharge via tall stacks they are not expected to be prevalent source of odour in the receiving environment;

- Reduced sulphur compounds, such as hydrogen sulphide, which can be discharged from some onsite processes but also from the displacement of air during the filling of coastal tankers with fuel oil. H_2S is particularly odorous with an unpleasant 'rotten egg' character;
- Fugitive emissions of hydrocarbon odours (discussed in Section 3.3) associated with vapour emissions from feedstock and storage tanks. Such odours are likely to be largely localised in and around the site; and
- Oily type odours associated with the operation of the site's wastewater treatment plant. These odours are likely to be localised in and around the site.

3.5 Dust

The main source of dust associated with the operation of the refinery is from abrasive blasting associated with the maintenance of tanks and structures on the site. Abrasive blasting involves the use of an abrasive medium to remove unwanted surface materials, such as rust and paint, in preparation for resurfacing of the tank/structure. Abrasive blasting can be undertaken using wet or dry methods, with the dryer the method the greater the potential for dust to be created.

Because of the size and scale of tanks and structures, they are often too big to practicably enclose. Accordingly, there is a need for abrasive blasting to be routinely undertaken onsite as part of ongoing maintenance.

Dust associated with abrasive blasting can create a dust nuisance effect on nearby sensitive receptors, including soiling surfaces. Potential health effects can be associated with the respirable fraction of the dust, such as respiratory and lung diseases, especially where there is a high silica content of the abrasive medium. For this reason, there are limits in the regional plans limiting the silica content of abrasive medium to less than 5 % free silica (Rule C.7.2.1 of the Proposed Regional Plan for Northland – Appeals Version – 29 July 2019). Refining NZ proposes to comply with this requirement.

3.6 Firefighting training

Emissions from firefighting training activities will be combustion gases and some smoke associated with the burning of fuel (light tops). However, light tops being similar to petrol, will burn relatively cleanly compared to other types of fuel. Furthermore, emissions are expected to be negligible in the context of other combustion sources on site, given the very small scale of this combustion activity, along with it only occurring for relatively short periods and infrequently.

4 Environmental Setting

4.1 Receiving environment

The receiving environment surrounding the Refining NZ site at Marsden point has a several nearby communities that are considered to be of a 'high sensitivity' to air quality impacts. These communities as follows:

- Marsden Cove (910 m west-northwest) – Living 1;
- One Tree Point (2.7 km northwest) – Living 1;
- Bream Bay (3.8 km south-southwest – Living 1;
- The various communities on the opposite of the Whangarei Harbour (Rural Village Residential), including:
  - Whangarei Heads (2 km north-northeast);
  - Reotahi Bay (1.25 km north);
  - Little Munro Bay (1.3 km north-northwest);
  - McKenzie Bay (2.9 km east-northeast); and
  - Urquharts Bay (3.3 km east).

Whangarei City is located at the head of the Whangarei Harbour approximately 15 km northwest of the Refining NZ site. Ruakaka Township is located approximately 6.3 km south of the site.

The land immediately surrounding the site is industrial in nature, being zoned Business 4 under the Whangarei District Plan (WDC 2007). This land includes the Carter Holt Harvey plant immediately west of the site. The land to the immediate northwest of the site is occupied by Northport and is within the Marsden Point Port zone. Both the Business 4 and Port zones are considered to have a low sensitivity to air quality impacts.

Whangarei District Council has identified 'Marsden Point – Ruakaka' as an identified growth area in the district. Part of this growth is the 'Marsden Primary Centre', which *"… is intended as a new southern primary suburban centre which will complement Whangarei City itself".* The closest distance between the Marsden Primary Centre and the Refining NZ site is approximately 3.5 km to the west-southwest. Although this area is still being developed, it is considered that it will have a high sensitivity to air quality impacts.

Open space zones immediately south of the site extending towards Ruakaka, as well as areas on the opposite side of the Harbour. Within these zones are a number of ecologically sensitive locations. Further details of these locations are provided in the ecological assessment prepared by Wildland Consultants Limited.

Other sensitive locations and activities, such as schools, places of worship, marae surrounding the site are listed as follows:

- Takahiwai Marae (6 km west of site);
- One Tree Point School (2.4 km northwest of the site);
- Whangarei Heads School (2.3 km northeast of the site);
- Bream Bay College (4 km south-southwest of the site);
- Marsden Playcentre (4 km west of the site);
- Bream Bay Kindergarten (4 km south-southwest of the site);
- Life point Baptist Church (3.8 km northwest of the site);

- Holy Family Centre (4 km south-southwest of the site);
- St Pauls Anglican Church (4 km south-southwest of the site); and
- McLeod Bay Community Church (2.6 km north of the site).

4.2 Meteorology and topography

Refining NZ measures wind speed and direction at its monitoring station located near to the sites' jetty. The instruments are fixed to a 30 m high tower. Wind data for the years 2011 and 2012, which are used in the dispersion model assessment discussed later in this report, are summarised as windroses in Figure 4.1.

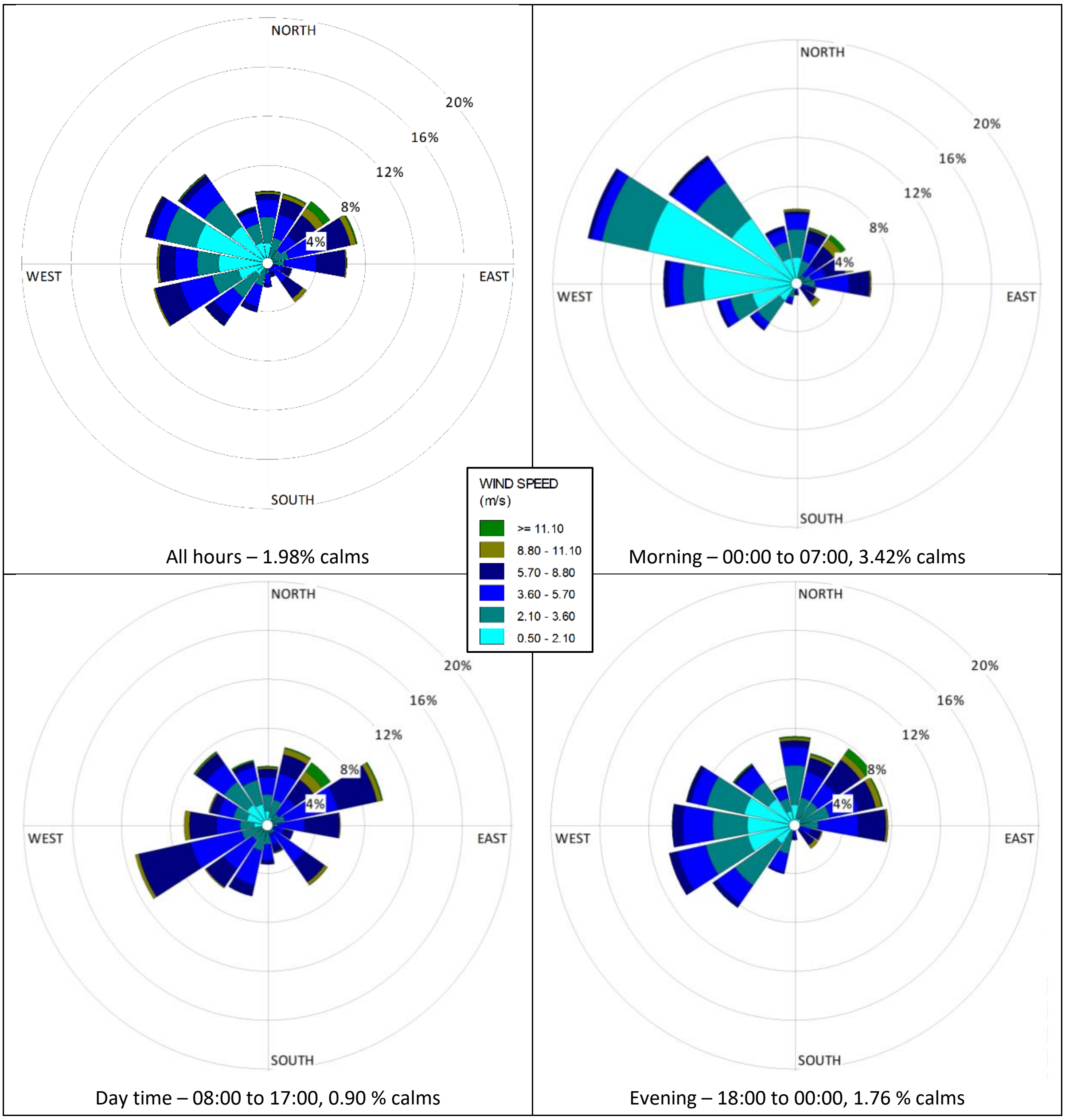
Windroses graphically summarise wind speed and direction data over a period of time. The petals of the windrose show the direction that winds come from – their length indicating the frequency of winds from that direction. The different colour bands within each petal indicates the frequency distribution of wind speeds for each direction. Figure 4.1 presents four wind roses: the first shows a summary of all wind conditions for the entire two year (2011 and 2012) period. The remaining three wind roses illustrate the wind conditions by different periods during the day:

- Early morning (00:00 hrs to 07:00 hrs);
- Daytime hours (08:00 hrs to 17:00 hrs); and
- Evening hours (18:00 hrs to 23:00 hrs).

The windrose (Figure 4.1) for all hours shows the prevailing winds are southwest through to northwest, with winds from the northeast also occurring frequently. The strongest winds occur from the northeast. The remaining three wind roses illustrate the following:

- During the early morning prior to sunrise, winds are predominantly from the northeast and generally light. This indicates a nocturnal cold-air drainage flow from elevated land down the Whangarei Harbour towards the site. This feature can be seen in the overlay of a windrose for all hours on an aerial photograph (Figure 4.2);
- Winds during daytime hours are frequently from the southwest through to the northeast. Furthermore, wind speeds are typically much higher during daytime hours that observed overnight and prior to sunrise;
- Winds in the evening reduce when winds are from the southwest to west compared with daytime hours;
- For all times of the day, the winds from the northeast are generally strong; and
- Winds from the southeast are relatively infrequent.

The topography of Marsden Point and the Whangarei Heads significantly affect local wind patterns. The topography surrounding the site is characterised by the Whangarei Harbour and surrounding terrain. The harbour has a northwest to southeast alignment. Marsden Point where the site is located is relatively flat and low-lying, with the Takahiwai Hills (200 m asl) rising approximately 5.5 km to the west of the site – this flat land acts to make the site relatively exposed to winds from the southwest. To the east of the site on the opposite side of the harbour are the Whangarei Heads where the land rises significantly. This includes Mount Aubrey (216 m asl), Mount Manaia (420 m asl) and Mount Lion (395 m asl). This elevated terrain, particularly Mount Mania, significantly acts on wind flow resulting channelling and elevated winds from the northeast. This feature can be seen in Figure 4.3 where the direction of highest strength winds aligns with area of low-lying land behind Taurikura Bay and south of Mount Manaia.



All hours – 1.98% calms

Morning – 00:00 to 07:00, 3.42% calms

Day time – 08:00 to 17:00, 0.90 % calms

Evening – 18:00 to 00:00, 1.76 % calms

Figure 4.1: Windroses generated from data from Refining NZ on-site meteorological station for 2011 and 2012, for all hours of the year, morning hours, daytime, and evening hours.

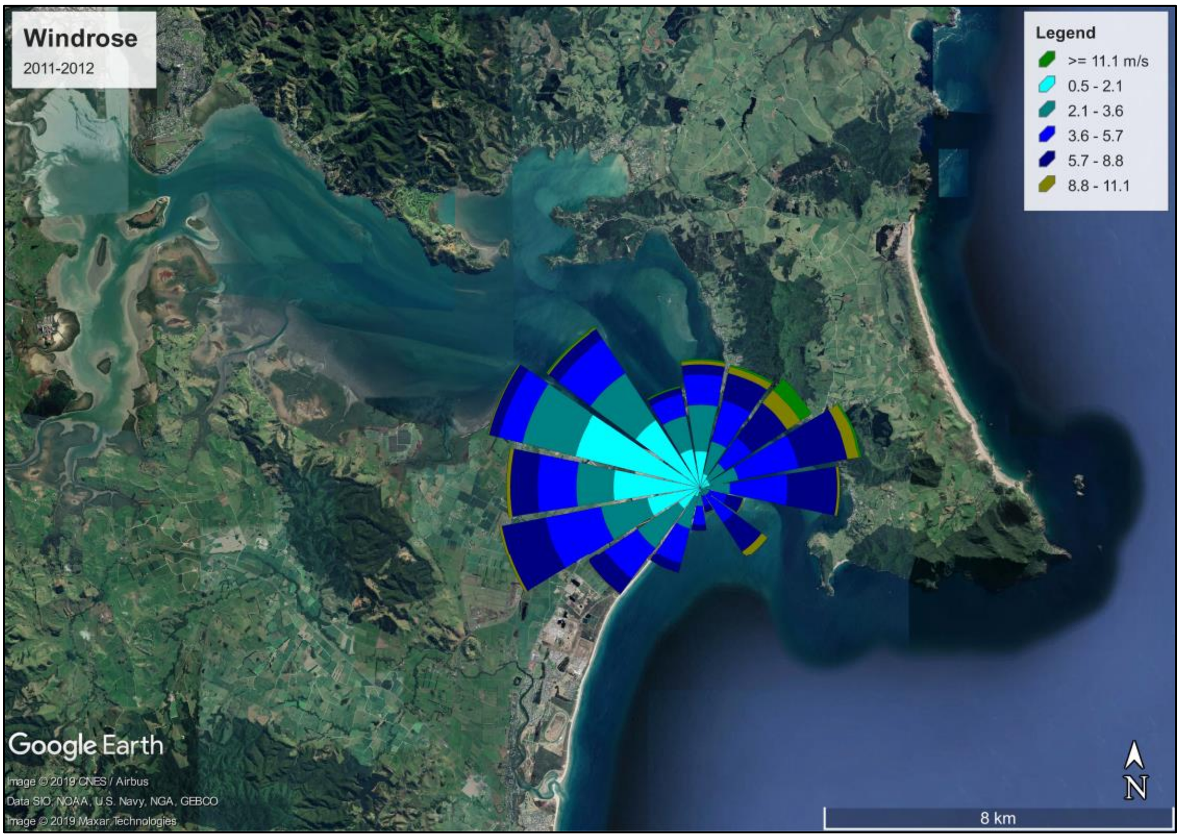


Figure 4.2: Windrose for 2011-2012 overlaid on aerial photograph of Refining NZ site location – north is aliened to the top of the figure.

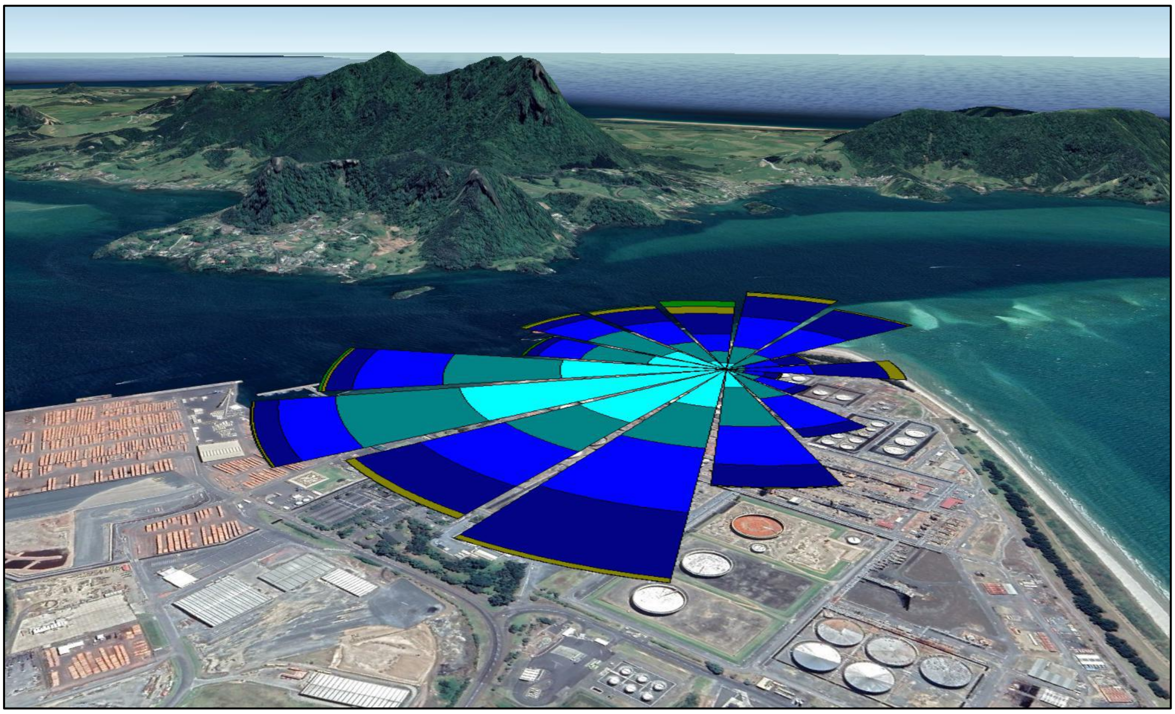


Figure 4.3: Three dimensional view of terrain looking east-northeast from the site. Mount Mania is the tall mountain rising on the left side of the image. Overlaid on the image is the wind rose for 2011 and 2012 for all hours.

4.3 Background air quality

4.3.1 Sulphur dioxide

Ambient monitoring of SO_2 is carried out at the three monitoring sites run by Refining NZ on the opposite side of the harbour from the site: Urquharts Bay, Whangarei Heads, and Little Munro Bay.

The results of the monitoring are summarised for 1-hour average and 24-hour averages for the previous five years (2013 – 2018) in Figure 4.4 and Figure 4.5, which reports the highest values for each site on a monthly basis. From these figures, the following is evident:

- Peak 1-hour concentrations are typically below 150 µg/m³ and therefore well below the National Environmental Standard for Air Quality (NES_{AQ}) of 570 µg/m³; and
- Peak 24-hour concentrations are typically below 30 µg/m³, although Little Munroe Bay recorded levels up to 52 µg/m³. These values are well below the Ambient Air Quality Guideline (AAGL) of 120 µg/m³.

As the refinery is the dominant source of SO_2 in the airshed, it is expected to be a significant contributor to measured SO_2 levels. Other sources that will contribute to SO_2 concentrations are emissions associated with shipping, which typically burn heavy fuel oil that has a significant sulphur content. However, it is difficult to separate the contribution of the refinery from other sources within the monitoring data in a robust and meaningful manner. Given this constraint, an approach of using the lowest maximum-monthly 1-hour and 24-hour average SO_2 concentration for any of the three monitoring sites has been used to derive sensible background SO_2 concentrations for this assessment. Accordingly, the following background SO_2 concentrations are derived from an inspection of Figure 4.4 and Figure 4.5:

- 1-hour average 25 µg/m³ (based on February for Urquharts Bay); and
- 24-hour average of 7 µg/m³ (based on January for Little Munro Bay).

The average of 24-hour values from Little Munro Bay for the month of January has been used to derive an annual average background SO_2 concentration. Using this approach gives a value of 1 µg/m³.

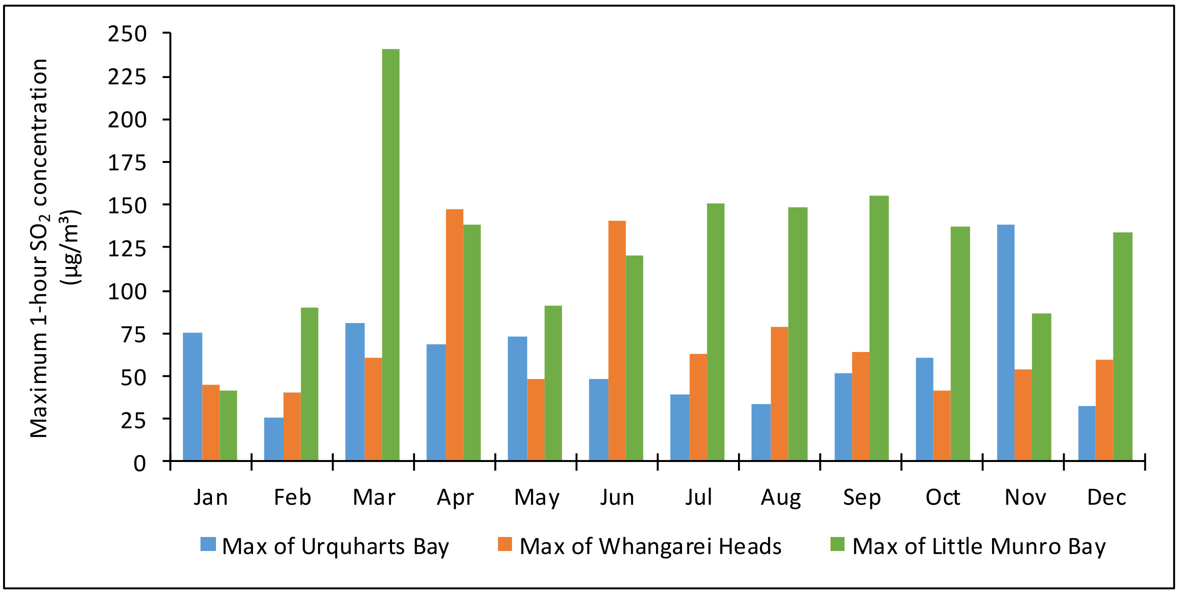


Figure 4.4: Monthly maximum 1-hour average SO_2 concentration for Urquharts Bay, Whangarei Heads and Munro Bay monitoring sites over five year period (2013-2018).

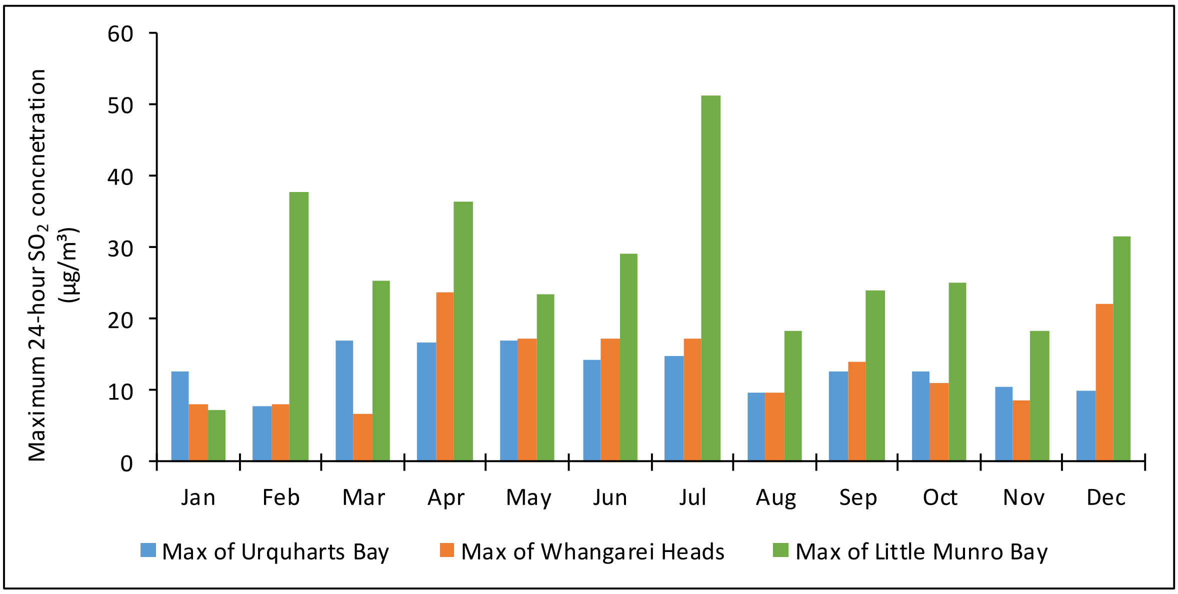


Figure 4.5: Monthly maximum measured 24-hour average SO_2 concentration for Urquharts Bay, Whangarei Heads and Munro Bay monitoring sites over five year period (2013-2018).

4.3.2 Particulate matter

4.3.2.1 PM_{10}

The State of the Environment report (NRC 2015) prepared by Northland Regional Council summarises a limited study of PM_{10} monitoring carried out at Ruakaka (Peter Snell Road) just south of the Refinery, and indicates generally low levels within 30 µg/m³ (24-hour average) as indicated in Figure 4.6.

Airshed modelling of PM_{10} emissions in the wider Marsden Point area was undertaken by Wilton *et al* (2012) for the Northland Regional Council. The study focused on domestic home heating emissions but also considered motor vehicle emissions and emissions from industry, including the Refinery. The study found that peak concentrations within the Marsden Point Airshed will generally be low, but elevated concentrations may occur on occasions because of the Whangarei urban plume and smaller contributions from Marsden Point industries. Predictions of up to 40 µg/m³ were modelled for a location between the refinery and Ruakaka over a largely rural area. This result appears to be broadly consistent with the findings of the State of the Environment Report.

On balance, given the airshed model includes the Refining NZ emissions and that measurements above 30 µg/m³ are very infrequent, we consider the ambient monitoring results will provide a more robust indicator of background concentrations for the area surrounding the site. Accordingly, a 24-hour background concentration of 30 µg/m³ is assumed for this assessment.

With regard to annual average PM_{10} concentrations, no reporting on this has been provided. However, from an inspection of the time-series trace given in Figure 4.6, we consider a conservative annual average value of 15 µg/m³ to be appropriate for this assessment.

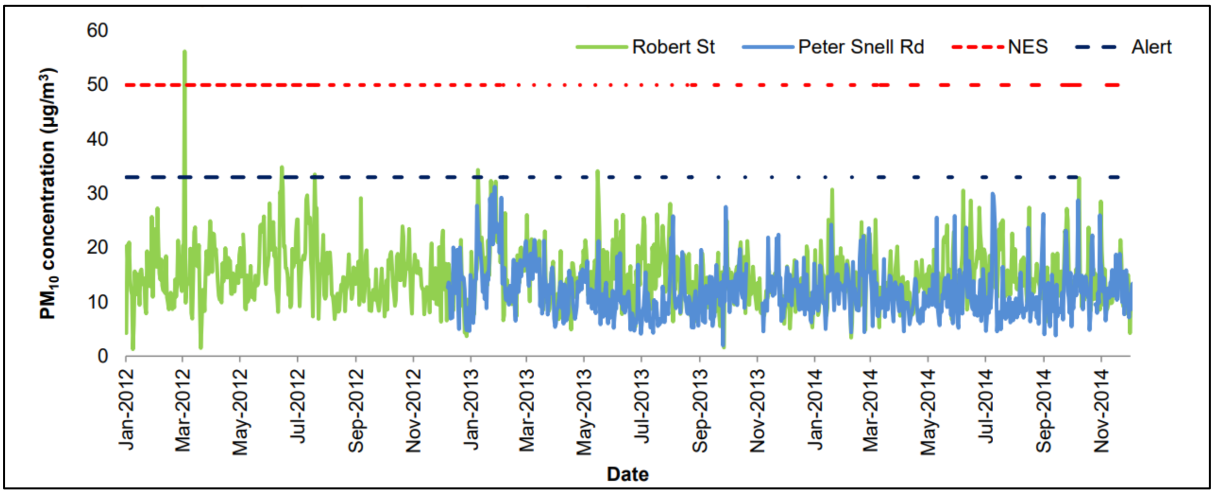


Figure 4.6: Ambient monitoring undertake in 2013 by NRC (Peter Snell Road – Ruakaka, Roberts Street – Whangarei). Source NRC 2015.

4.3.2.2 $PM_{2.5}$

There has been no monitoring of background $PM_{2.5}$ concentrations in the vicinity of the Refining NZ site, which is to be expected as there are very few $PM_{2.5}$ monitoring sites outside of large urban centres in NZ. In the absence of such data, the approach used by Auckland Council (Auckland Council, 2014) has been adopted. This describes multiplying the 24-hour and annual average PM_{10} concentration by 0.37 (for rural locations) to derive corresponding $PM_{2.5}$ values. We consider this provides an appropriate means for estimating background $PM_{2.5}$ concentrations in the absence of any monitoring. On this basis, the following values are determined for this study:

- 24-hour average of 11 µg/m³; and
- Annual average of 5.6 µg/m³.

4.3.3 Nitrogen dioxide

There is no ambient monitoring of NO_2 that takes place in the vicinity of the Refining NZ site. In the absence of such data, background air quality concentrations estimates are produced by New Zealand Transport Agency (NZTA) has been used. NZTA produces an interactive air quality map[1] for determining background concentrations of NO_2. This data, which is intended for use with air quality assessments, provides the best available indication of likely background NO_2 concentrations in the vicinity of the site. From this map, the following background NO_2 concentrations are derived:

- 1-hour average of 37 µg/m³;
- 24-hour average of 23 µg/m³; and
- Annual average of 4 µg/m³.

A number of industries near the site will give rise to NO_X emissions. The most notable is the electricity peaking plant operated by TrustPower Limited, which holds resource consent (AUT.027140.01.01) to operate a four 1.8 MWe diesel fired, with a combined output of 7.2 MWe. These generators are located approximately 650 m west of the Refining NZ site and immediately north of the Carter Hold Harvey site. These are relatively small combustion appliances in the context of the Refinery's emission sources. The generators also operate without tall stacks as indicated in

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[1] https://www.nzta.govt.nz/roads-and-rail/highways-information-portal/technical-disciplines/air-quality-climate/planning-and-assessment/background-air-quality/.

Figure 4.7, meaning that any impacts of the generators will be highly localised to the immediate vicinity of the peaking station and are very unlikely to occur under the same meteorological conditions to discharges from the refinery stacks. Given this context, short term (1-hour) background NO_2 concentrations in the vicinity of the peaking plant may be elevated at times when the peaking station is operated for electricity load management. However, those elevated concentrations are unlikely to coincide with elevated concentrations due to emissions from the Refinery. Accordingly, the background NO_2 concentrations discussed above are considered to be appropriate for the modelling assessment provided in Section 5.2.3.

Figure 4.7: TrustPower peaking station (Source – Google Earth Street View July 2012).

4.3.4 Carbon monoxide

There is no ambient monitoring of CO that takes place in the vicinity of the Refining NZ site. Ambient concentrations of CO seldom approach relevant standards and guidelines in NZ and consequently is not widely monitored outside of large metropolitan areas. Where it is monitored, it is typically in order to characterise the impacts of significant road transport routes in urban environments. In the absence of such data, values have been taken from the 'default values' listed by the Auckland Council (Auckland Council, 2014) for areas out-side the urban extent of Auckland City. This source provides the best indication of background CO concentrations typically found in NZ rural areas. This lists the following default values:

- 1-hour average of 5 mg/m³; and
- 8-hour average of 2 mg/m³.

4.3.5 Other contaminants

The remainder of contaminants considered by this assessment are expected to be present at trace levels in the receiving environment given that there are no other nearby[2] significant sources of those

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[2] The Golden Bay Cement site has been identified as a possible source of some contaminants. However, it is located approximately 14 km west-northwest of the Refinery and is not expected to appreciably contribute to background levels.

contaminants in the receiving environment. Accordingly, background concentrations are assumed to be 0 µg/m³ for this assessment.

4.3.6 Background sulphur and nitrogen deposition rates

There is no representative background monitoring data relating to sulphur and nitrogen deposition rates that T+T is aware of, nor is it routinely collected as part of air quality assessments. Therefore, in the absence of such data, an estimation of annual average deposition rates has been made based on the annual average ambient concentration of SO_2 and NO_2.

Background sulphur and nitrogen deposition rates have been calculated from estimated background SO_2 and NO_2 concentrations using UK guidance[3] and conservative dry deposition velocity values for forest conditions of 0.024 m/s for SO_2 and 0.003 m/s for NO_2. This is an appropriate approach in the absence of such data. Using this approach the following background deposition rates are determined:

- Annual sulphur deposition rate of 3.79 kg/ha/yr; and
- Annual nitrogen deposition rate of 1.15 kg/ha/yr.

4.3.7 Summary of background concentrations

Table 4.1 summarises the background contaminant concentrations assumed for the following assessment based on the above discussion.

Table 4.1: Summary of background concentrations and deposition rates

Contaminant	**Concentration**	**Averaging period**
SO_2	25 µg/m³ 7 µg/m³ 1 µg/m³	1-hour 24-hour Annual
PM_{10}	30 µg/m³ 15 µg/m³	24-hour Annual
$PM_{2.5}$	11 µg/m³ 5.6 µg/m³	24-hour Annual
NO_2	37 µg/m³ 23 µg/m³ 4 µg/m³	1-hour 24-hour Annual
CO	5 mg/m³ 2 mg/m³	1-hour 8-hour
Other contaminants	Trace (assumed zero)	Various
Contaminant	**Deposition rate**	**Accumulation period**
Sulphur	3.79 kg/ha/yr	Annual
Nitrogen	1.15 kg/ha/yr	Annual

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[3] Habitats Directive 2014. Technical Guidance on Detailed Modelling Approach for an Appropriate Assessment for Emissions to Air – AQTAG06.

5 Assessment of Effects – Combustion Emissions

5.1 Assessment method

The air quality effects of the site's combustion emissions have been assessed using both dispersion modelling and a review of ambient air quality data for SO_2.

The review of ambient air quality data also informs the assessment of the contribution of flare emissions, given theses cannot be readily measured or reliably modelled. As previously discussed, this is due to limitations measuring emissions from a large open flame, combined with difficulties reliably modelling the contribution to contaminant concentrations from an intermittent discharge source such as a flare and being able to parameterise the discharge conditions of a flare.

5.1.1 Dispersion modelling

Dispersion modelling has been used to predict contaminant ground level concentrations (GLCs) and deposition rates from stack discharge sources at the Refining NZ site and to evaluate the results against relevant health and ecological based assessment criteria for each contaminant (the assessment criteria are discussed in Section 5.1.3).

Dispersion modelling has been undertaken using the most recent version of the CALPUFF air dispersion model (latest version 7.2.1). Version 6 of the CALPUFF model is described by TRC (2011). CALPUFF is an advanced dispersion model that is widely used in New Zealand, especially in areas of complex terrain and coastal situations, with both applicable to the Refining NZ site. It is also the model described in the Marsden Point Air Quality Strategy (MPAQS, NRC 2007) for assessing industrial air discharges in the Marsden Point airshed.

CALPUFF was configured to model discharges from the stack sources described in Section 3.1 and their cumulative impacts on the receiving environment surrounding the refinery site.

A separate model run was used to assess the peak and long-term impacts of SO_2 and PM_{10}. These runs consider the peak short-term emission rates versus the upper quartile emission rates and how they relate to assessment criteria that are expressed in terms of short-term (acute) and long-term (chronic) assessment criteria for each contaminant.

In accordance with recommended good practice (MfE 2004), the maximum predicted one-hour average results are the 99.9th percentile of the yearly model predictions.

Further details on the configuration of the CALPUFF model are provided in Appendix E.

5.1.1.1 Receptor locations

The CALPUFF model was configured to predict GLCs for a number of discrete receptor locations representing locations of particular interest for the assessment, as well as a three girds of evenly spaced receptors at increasing resolution. The nested receptor grid approach provides a high level of detail close to the site where the magnitude and spatial variation in impacts is typically greatest, with decreasing resolution in grid spacing the further afield. This allows for a significant reduction in model computation time. Figure 5.1 shows the location of three receptor grids and discrete receptors relative to the Refining NZ site. The extents and resolution of the three nested receptors are as follows:

- Innermost grid – 7.5 km by 5.5 km extent at 250 m grid spacing;
- Middle grid – 14.5 km by 12.5 km extent at 500 m gird spacing; and
- Outer grid – 26 km by 21 km extent at 1,000 m grid spacing.

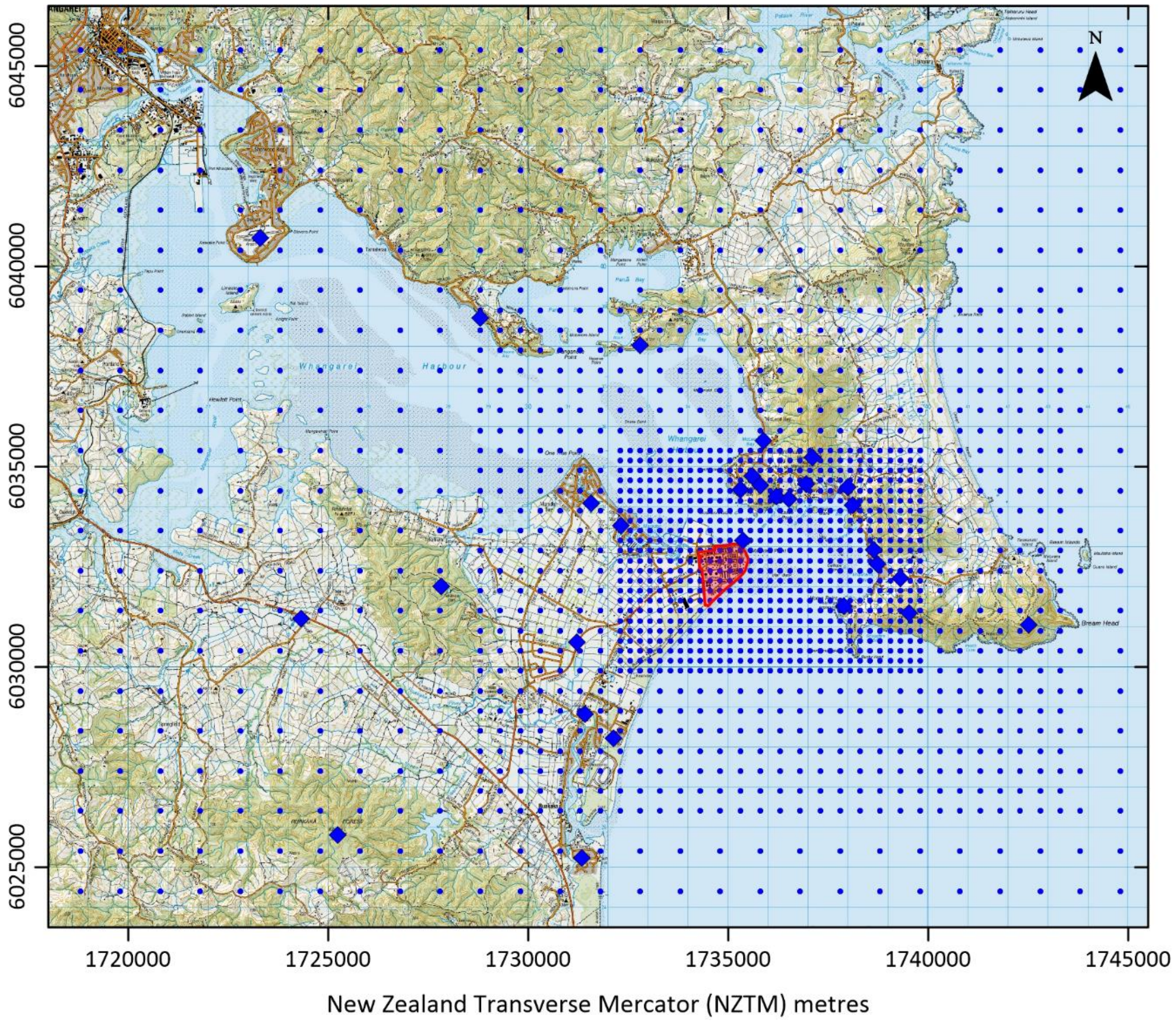

Figure 5.1: Location of discrete receptors (large blue diamonds) and nested receptor grids (small blue circles). Site boundary shown in red. Base aerial image sourced from LINZ.

5.1.1.2 Building downwash

Buildings and structures can affect the dispersion of a plume from a stack, causing it to be brought to the ground rapidly – this is known as 'building downwash'. To account for this, the PRIME building downwash algorithm with the CALPUFF model is used to simulate this effect. The PRIME building downwash algorithm is the recommended option for dispersion modelling (MfE 2004)[4].

Building downwash ordinarily needs to be considered where a building or structure located near to a stack is greater than 40% of the height of the stack. At the Refining NZ site the CCR Tower is more than 40% of the height of the Block E, Block D_580 and Block D_540 Stack. Although this tower is not a solid structure, it is considered likely to result in some degree of downwash effect and therefore has been included in the dispersion model. Figure 5.3 provides a three-dimensional view of the site, overlaid with the stacks and the CCR Tower as configured in the CALPUFF model.

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[4] MfE 2004. Good Practice Guide for Atmospheric Dispersion Modelling. Publication number ME 522. Ministry for the Environment. June 2004.

5.1.1.3 Atmospheric chemistry

The MESOPUFF II atmospheric chemistry scheme within the CALPUFF model was used to enable the prediction of sulphur and nitrogen deposition. This scheme enables the model to simulate the conversion of SO_2 to sulphate and NO_X to nitrate aerosols using a 'five species' scheme (SO_2, SO4, NO_X, HNO_3 and NO_3). Emissions of HNO_3 and NO_3 from combustion sources at the Refinery are expected to be negligible. All other emission rate inputs are described in Section 3.

The MESOPLUFF II scheme also requires monthly average background concentrations of ozone and ammonia. There is very little information on ambient ammonia concentrations and a default (conservative) value of 10 ppb[5] for each month has been used. Monthly average ozone values have been derived from measurements made at Whangaparaoa[6] between 2011 and 2015. These values are presented in Figure 5.2

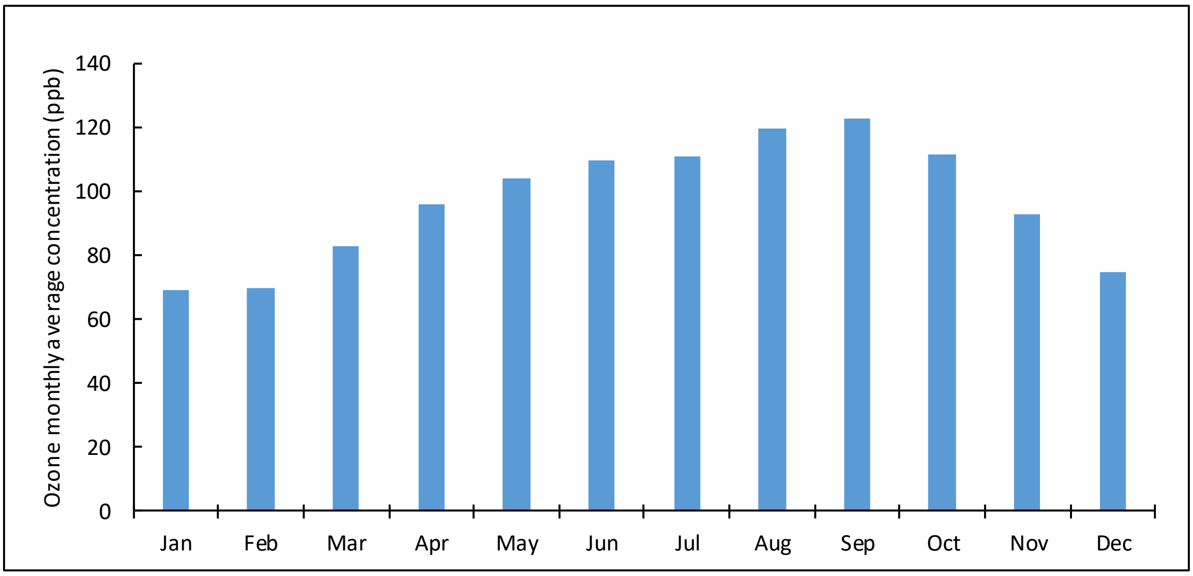

Figure 5.2: Monthly average background ozone concentrations measured at Whangaparaoa between 2011 and 2015.

5.1.1.4 Conversion of NO to NO_2

To account for the atmospheric conversion of NO to NO_2, the 'NO_2 screening method', as recommended by MfE (2016a) has been used. This assumes all NO_X emissions are in the form of NO_2. The predicted ground level concentration of NO_2 is therefore:

$$[NO_2] = [NO_X]mod + [NO_2]bkd$$

Where:

- $[NO_2]bkd$ = Background nitrogen dioxide; and
- $[NOx]mod$ = The nitrogen oxides concentration at the receptor estimated from the modelled nitrogen oxides emissions. In this very conservative screening approach, all NO_X is assumed to be NO_2 (i.e., NO_X as NO_2).

---

[5] An alternative value of 1 ppb, was also used and made no appreciable difference to the model results.

[6] https://www.stats.govt.nz/indicators/ground-level-ozone-concentrations.

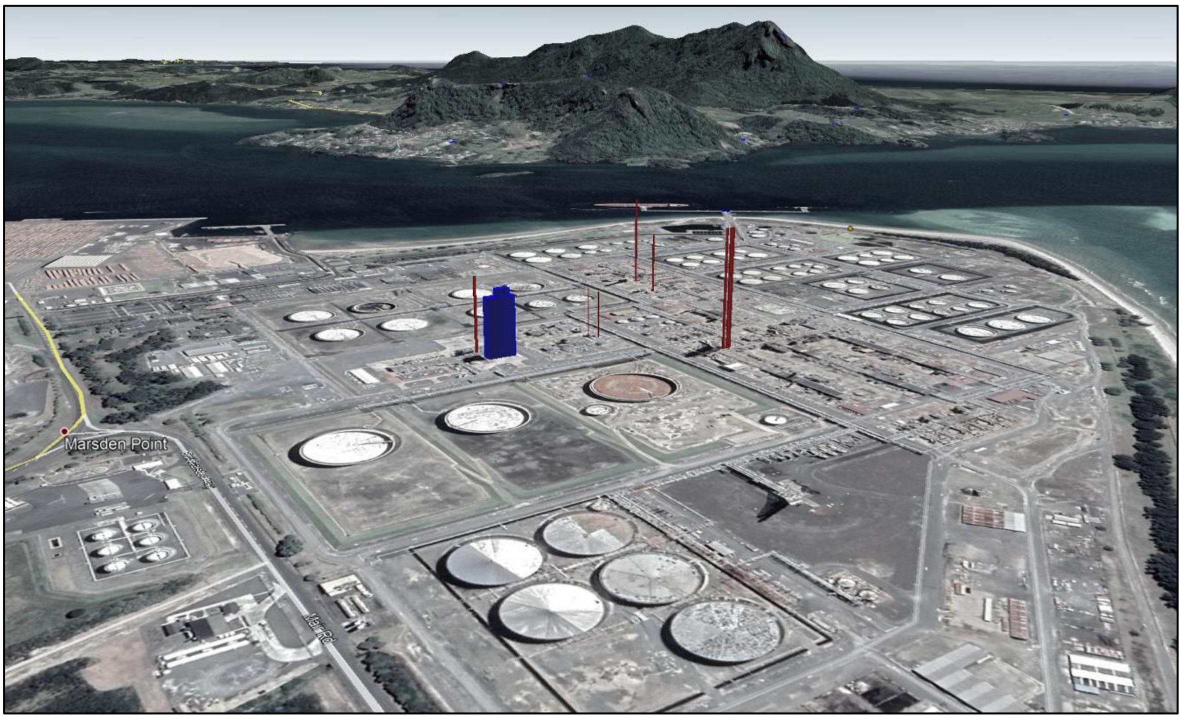

Figure 5.3: Schematic 3-dimentional view looking towards Mt Mania of stacks (red) and building-downwash structures (blue) as represented in the CALPUFF model. Source aerial Google earth.

5.1.2 Meteorological modelling

Meteorological information is one of the key inputs for dispersion modelling. Meteorological inputs to the CALPUFF model are generated using the CALMET model (latest version 6.5.0). The CALMET model generates hourly, three-dimensional fields of meteorological parameters that are used by CALPUFF.

The CALMET dataset used for this assessment was originally developed for Refining NZ by Golder Associated (NZ) Limited. It was configured to use inputs from a combination of surface-based meteorological observations and outputs from the prognostic meteorological model component of the TAPM model. TAPM provides the surface conditions for locations not directly covered by surface monitoring observations, as well as upper-air information needed to initialise the three-dimensional fields within the CALMET model. Hourly surface-based meteorological observations included the following:

- Wind data from the Refining NZ on-site meteorological site; and
- Wind, temperature, relative humidity and atmospheric pressure data from the monitoring station at Whangarei Airport.

The CALMET dataset was updated by T+T to include rainfall data, which is a necessary input in order to be able to model wet deposition of contaminants. Hourly rainfall data from measurements made at Water Street, Whangarei (nearest location with hourly observations of rainfall) were used for this purpose. It is assumed that rainfall measured at Water Street will be representative of conditions at the Refining NZ site and beyond. This is a reasonable and practical assumption given the relative close proximity of the Refining NZ site to Whangarei and that no other nearby rainfall site measures rainfall hourly intervals.

The CALMET model covers an area that is 30 km by 30 km centred just west of the Refining NZ site and extending up from the surface to the atmospheric boundary layer. It has been run at horizontal grid resolution of 250 m, which is considered sufficiently high to capture variations in the meteorology caused terrain and land use, in particular the significant terrain feature of Whangarei Heads and Mount Mania.

Details of the TAPM and CALMET configuration are provided in Appendix F.

CALMET was run for a two-year period covering 2011 and 2012 in accordance with good practice (MfE 2016a). These two years have been selected to encompass a wide array of meteorological conditions that are likely to be encountered in the locality of the site. The selection of 2011 and 2012 was made based on the following considerations:

- Availability of wind data from the Refining NZ on-site meteorological station; and
- Publicly available data within the National Climate Database.

An analysis of the meteorological data for the period 2010 to 2017 that informed the selection of the years 2011 and 2012 is provided in Appendix G.

5.1.3 Assessment criteria

The choice of ambient air quality assessment criteria used to evaluate the results of dispersion modelling is based on MfE (2016) guidance, which sets out the following criteria to be used in order of priority:

- Ambient air quality standards set in the National Environmental Standards for Air Quality (NES_{AQ});
- The National Ambient Air Quality Guidelines (AAQG – MfE 2002);
- Regional objectives (unless more stringent than above criteria – note NRC does not have any specific air quality guidelines or standards that are more stringent than the NES_{AQ} or AAQG in its operative or proposed plans);
- World Health Organisation (WHO) air quality guidelines;
- California reference exposure levels (acute and chronic) and US EPA inhalation reference concentrations and unit risk factors (chronic) (OEHHA 2016); and
- Texas effects screening levels (if these have been derived from toxicological data in a transparent manner) (TCEQ 2016).

Based on these sources, the relevant ambient air quality assessment criteria for the contaminants considered in the modelling assessment are set out in Table 5.3, along with the corresponding averaging period and the source for each criteria.

Under the RMA, the magnitude of an effect arising from the discharge has relevance, both in terms of a decision on notification, and the substantive determination.

In assessing the magnitude of effects, T+T has considered the model predictions against the relevant assessment criteria. Further, and to include consideration of potential cumulative adverse effects relative to the various assessment criteria, T+T has adapted guidance set out in the UK Institute of Air Quality Management (IAQM, 2009). This approach takes into account:

- The magnitude of the change resulting from the discharge (whether that change is ‘large’, ‘medium’, ‘slight’ or ‘imperceptible’); and
- The absolute magnitude of effect (whether the effect is ‘above’, ‘just below’, ‘below’ or ‘well below’ the assessment criteria).

Table 5.1 sets out the matrix used for this assessment based on the above and IAQM (2009) guidance.

Table 5.1: Descriptors used for evaluating magnitude of effect

		Increase with activity			
Absolute magnitude		**Imperceptible**	**Slight**	**Medium**	**Large**
		<1%	**1% - 5%**	**5% - 10%**	**> 10%**
Above	**>100%**	Less than minor	minor	More than minor	More than minor
Just below	**90% - 100%**	Negligible	Less than minor	Minor	Minor
Below	**75% - 90%**	Negligible	Negligible	Less than minor	Less than minor
Well below	**<75%**	Negligible	Negligible	Negligible	Less than minor

Specific discussion regarding the NES_{AQ} and WHO guidelines is also provided below.

The MfE (2016a) sets out guidance for where the ambient air quality standards (and by inference other guidance) should be applied in terms of the location of the impact. This is summarised in Table 5.2.

Table 5.2: Location and applicability of the ambient standards for assessment purposes (source MfE 2016a)

Averaging period	**Locations where assessment against the ambient standards should apply**	**Locations where assessment against the ambient standards should not apply**
1-hour	This includes any outdoor areas where the public might reasonably be expected to spend one hour or longer, including pavements in shopping streets, as well as accessible facades (e.g., balconies, terraces).	Any industrial premises that have resource consents (for that pollutant)[7].
8-hour	This includes all outdoor locations where members of the public are likely to be exposed for eight hours as well as the facades of residential properties, schools, hospitals, libraries, etc.	Any industrial premises that have resource consents (for that pollutant). Any location where people are not likely to be exposed for eight hours – for example roads and footpaths.
24-hours	This includes all outdoor locations where members of the public might reasonably be exposed for 24-hours.	Any industrial premises that have resource consents for that pollutant. Any location where people are not likely to be exposed for 24-hours – for example roads, footpaths and industrial areas where residential use is not allowed.
All		In any enclosed space (i.e., not in the open air), including: indoors, inside tunnels or Inside vehicles.

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[7] In this context, the NES_{AQ} do not apply to the Refining NZ site, but consideration of the NES_{AQ} is given to all industrial locations beyond the site.

5.1.3.1 National Environmental Standards

The NES_{AQ} were published in 2004 and amended in 2011. The NES_{AQ} regulations are mandatory and include standards relating to ambient concentrations of PM_{10}, SO_2, NO_2, CO and ozone (O_3). The standards include concentration limits relating to certain averaging periods, a maximum number of exceedences per year, and monitoring methods. The standards generally apply in all areas where people may be exposed.

Regulation 13, 14, 16B to D, 17 and 20 of the NES_{AQ} apply to this application.

Regulation 13 describes the numerical standards and discusses the number of exceedences per year for all contaminants covered by the NES_{AQ}. These are provided in Table 5.3.

Regulation 14 sets out the locations where the standards apply as follows:

> *(1) The ambient air quality standard for a contaminant applies at any place –*
>
> *(a) That is in an airshed; and*
>
> *(b) That is in the open air; and*
>
> *(c) Where people are likely to be exposed to the contaminant.*
>
> *(2) However, if the discharge of a contaminant is permitted by a resource consent, the ambient air quality standard for the contaminant does not apply to area that the resource consent applies to."*

Regulation 17 relates to resource consent applications for discharges of PM_{10} into a polluted airshed. It requires consent applications to be declined under certain circumstances or else those emissions offset. Marsden Point is not located within a polluted airshed in relation to PM_{10} and therefore the requirements of Regulation 17 are not applicable to this application.

Regulation 20 relates to resource consent applications that discharge CO, NO_X and volatile organic compounds, all of which are discharged from the site. It states:

> *(1) A consent authority must decline an application for a resource consent to discharge carbon monoxide into air if the discharge to be expressly allowed by the resource consent—*
>
> *(a) Is likely, at any time, to cause the concentration of that gas in the airshed to breach its ambient air quality standard; and*
>
> *(b) Is likely to be a principal source of that gas in the airshed.*
>
> *(2) A consent authority must decline an application for a resource consent to discharge oxides of nitrogen or volatile organic compounds into air if the discharge to be expressly allowed by the resource consent—*
>
> *(a) Is likely, at any time, to cause the concentration of nitrogen dioxide or ozone in the airshed to breach its ambient air quality standard; and*
>
> *(b) Is likely to be a principal source of oxides of nitrogen or volatile organic compounds in the airshed.*
>
> *(3) In this regulation, volatile organic compound—*
>
> *(a) Means a hydrocarbon based compound with a vapour pressure greater than 2 millimetres of mercury (0.27 kilopascals) at a temperature of 25°C; but*
>
> *(b) Does not include methane.*

The site is considered the most significant air discharge source of NO_X, CO and VOCs within the designated Marsden Point Airshed and is likely to be the principal source of these contaminants. Accordingly, Regulation 20 is applicable to this application.

The site is located within the Marsden Point Airshed, which was gazetted on the basis of the need to manage discharges of SO_2 given historically high ambient concentrations. Regulation 21 relates to resource consents for discharges of SO_2 and states:

> *"A consent authority must decline an application for a resource consent to discharge sulphur dioxide into air if the discharge to be expressly allowed by the resource consent is likely, at any time, to cause the concentration of sulphur dioxide in the airshed to breach its ambient air quality standard."*

Accordingly, Regulation 21 is a relevant consideration for this application.

5.1.3.2 WHO Guidelines

The World Health Organisation (WHO) published the *Air Quality Guidelines Global Update 2005* (WHO 2006). This included values for $PM_{2.5}$, which are widely recognised and adopted in air quality assessments such as this.

This update contains guidelines for 10-minute and 24-hour average SO_2 concentrations. While the 10-minute guideline has remained at 500 µg/m³, the 24-hour guideline was significantly reduced to 20 µg/m³, with an interim target of 50 µg/m³. The 24-hour WHO guideline is substantially lower than the AAQG of 120 µg/m³, which was based on the previous WHO guideline.

A review of the background information has clarified that the WHO 24-hour guideline relates principally to one Hong Kong study where the reduction in fuel oil sulphur levels resulted in a reduction of airshed wide 24-hour SO_2 levels. This subsequently results in a reduction in population mortality rates. The spatial and temporal patterns of ambient 24-hour SO_2 within Hong Kong are very different to New Zealand airsheds. Additionally, there also appears to be significant uncertainty about whether SO_2 is the contaminant of concern, or whether the mix of the contaminants is more important with SO_2 acting as a proxy for these contaminants in the Hong Kong study.

Given the above, there is significant uncertainty regarding the health benefits of complying with the WHO 24-hour guidelines when applying these to localised peak impacts near industrial sites that are relatively infrequent. The WHO review of the guidelines also discusses this uncertainty.

This matter has been extensively investigated in the regional planning process for Auckland Council and the Canterbury Regional Council in relation to the Auckland Unitary Plan and the Canterbury Air Regional Plan respectively. In both cases, the operative plans sought not to adopt the WHO 24-hour average SO_2 guideline.

The MfE (2016a) also set out guidance on the hierarchy or standards and guidelines. This followed consideration regarding the WHO 24-hour average SO_2 guideline and the status it should have over the New Zealand guideline. It culminated in the MfE providing guidance that the AAQGs take priority over the WHO guidelines.

5.1.3.3 Marsden Point Air Quality Strategy

The Marsden Point Air Quality Strategy (herein referred to as the 'Strategy', NRC 2007) is *"… designed to manage air quality in the Marsden point [area]. The Strategy applies to existing or new development requiring consent to discharge..."* subject to the location of the activity. The strategy focuses on emissions of SO_2 and to a lesser degree PM_{10}.

The Strategy recognises that *"… Marsden Point is an area where industrial Development is allowed to occur according to the Whangarei District Plan…"* and that development of the area will be encouraged subject to the following two policies:

> ***Policy 1***
>
> *That air quality in the Marsden Paint Airshed shall be maintained in a consistent way to allow for industrial development while ensuring that:*
>
> *(i) Ambient air quality is maintained in a state of compliance with the National Environmental Standards in Table 2, and*
>
> *(ii) That the air quality is maintained within the guidelines listed in Tables 2 and 3.*
>
> ***Policy 2***
>
> *That regard shall be given to reverse sensitivity effects from incompatible uses when considering future land use decisions in the Marsden Point area.*

The Strategy directs the NRC regarding a number of methods for implementing Policy 1. This includes:

- Maintaining a comprehensive modelling tool (CALMET and CALPUFF);
- Maintaining an emissions inventory;
- Supporting industry with emissions trading (SO_2, PM_{10}, and NO_2);
- Co-ordinating an ambient monitoring network; and
- Applying the best practicable option to minimise emissions of toxic pollutants.

Regarding Policy 2, the Strategy directs NRC to submit on the Whangarei District Plan and resource consent applications to ensure reverse sensitivity effects are managed, and to promote the use of an airshed management tool for assessing reverse sensitivity effects with new Developments.

With regard to SO_2 concentrations in the airshed, the Strategy reflects the anticipated situation at that time of the proposed re-powering of the Marsden B power station, which would have significantly contributed to SO_2 emissions in the airshed in addition to those from the Refinery. The Marsden B power station project never proceeded, with the station subsequently dismantled. Consequently, the acute predictions of cumulative SO_2 effects anticipated by that project (as described in the Strategy) have not been realised.

The Strategy goes on to outline the need to assess the cumulative effects of industry, describing the methods to be used (notably the use of the CALMET/CALPUFF modelling package) and general considerations for NRC when evaluating resource consent applications.

Notwithstanding the limited relevance of the Strategy in the current context, this assessment has sought to evaluate the cumulative effects of the discharges from the Refinery on the receiving environment, has used the latest version of the CALMET/CALPUFF model, and evaluates the compliance with the NES_{AQ}. Consequently, this assessment is consistent with the general guidance and intent of the MPAQS.

Table 5.3: Dispersion modelling assessment criteria

Contaminant	Averaging period for assessment criteria (µg/m³)					Reference source
	1-hour	8-hour	24-hour	3-month**	Annual average	
SO_2	570/350	-	120	-	10*	NES_{AQ}, AAQG
PM_{10}	-	-	50	-	20	NES_{AQ}
$PM_{2.5}$	-	-	25	-	10	WHO
NO_2	200	-	100	-	30*	NES_{AQ}, AAQG
CO	30,000	10,000	-	-	-	NES_{AQ}
Dioxins and Furans	-	-	-	-	0.00004 (0.04 ng/m³) (40 pg/m³)	CA OEHHA (chronic exposure)
Metals						
Arsenic	-	-	-	-	0.0055	AAQG
Silver	0.1	-	-	-	0.01	TCEQ ESL
Aluminium	50	-	-	-	5	TCEQ ESL (insoluble compounds)
	20	-	-	-	2	TCEQ ESL (soluble compounds)
Barium	5	-	-	-	0.5	TCEQ ESL
Cadmium	-	-	-	-	5 ng/m3	WHO
Chromium	-	-	-	-	0.11	AAQG (Chromium metal and chromium III)
					0.0011	AAQG (Chromium VI)
Copper	100	-	-	-	-	CA OEHHA (copper and compounds) (acute exposure)
Potassium	20	-	-	-	2	TCEQ ESL
Magnesium	40	-	-	-	4	TCEQ ESL
Manganese	-	-	-	-	0.15	WHO

Contaminant	Averaging period for assessment criteria (µg/m^3)					Reference source
	1-hour	8-hour	24-hour	3-month**	Annual average	
Molybdenum	30	-	-	-	3	TCEQ ESL
Nickel	0.2	0.06***	-	-	0.014	CA OEHHA (nickel & nickel compounds, except nickel oxide for chronic inhalation exposures) (acute, 8 and chronic exposures)
	-	-	-	-	0.025	WHO – 1 in 100,000 excess lifetime cancer risk
Phosphorus	1	-	-	-	0.1	TCEQ ESL
Lead	-	-	-	0.2**	-	AAQG
Tin	20	-	-	-	2	TCEQ ESL
Titanium	50	-	-	-	5	TCEQ ESL
Vanadium	-	-	1	-		WHO
Zinc	20	-	-	-	2	TCEQ ESL
Mercury	-	-	-	-	0.33	AAQG (0.33 µg/m^3 inorganic, 0.13 µg/m^3 organic)
Ecological critical deposition loading rates (kg/ha/year)						
Sulphur critical load	-	-	-	-	N/A	
Nitrogen critical load	-	-	-	-	5	MfE 2000[8]

NES$_{AQ}$ = National Environmental Standards for Air Quality; AAQGL = Ambient Air Quality Guidelines; WHO = World Health Organisation; CA OEHHA = Californian Office of Environmental Health Hazard Assessment; TCEQ ESL = Texas Commission on Environmental Quality – Effects Screening Levels.

* MfE 2002 - AAQG. Critical levels for protecting ecosystems.
** MfE 2002 – rolling average.

*** For repeated 8-hour exposure over a significant fraction of a lifetime.

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[8] MfE 2000. Effects of air contaminants on ecosystems and recommended critical levels and critical loads. Ministry for the Environment. Air Quality Technical Report 15.

5.2 Model results

5.2.1 Sulphur dioxide

The model-predicted maximum 1-hour average, 24-hour average and annual average GLCs due to SO_2 emissions from the site's energy plant are summarised in Table 5.4. Corresponding contour plots are provided in Figure 5.4, Figure 5.6 and Figure 5.10 respectively.

The contour plots show that the greatest impacts occur immediately west of the site boundary over the adjoining industrial land, and also on the opposite side of the Whangarei Harbour when the plumes can be seen as impacting against the elevated terrain.

In terms of the 1-hour average GLCs, the results are well below the 'never to be exceeded' value in the NES_{AQ} (570 µg/m³), with the predicted maximum being approximately 355 µg/m³ (including background) at the immediate western site boundary over Mair Road[9] in the industrial area. Analysis of the model data for this location has determined that cumulative concentrations exceeding 350 µg/m³ (1-hour average) may occur up to four times over the two-year model period, and is therefore within the requirements of the NES_{AQ}, which allows up to nine exceedances of 350 µg/m³ in a calendar year. Notwithstanding this, given the model is conservatively configured for the maximum measured SO_2 emission rate, the number of occasions concentrations will approach or exceed 350 µg/m³ is expected be much lower.

On the opposite side of the harbour, the peak predicted 1-hour average concentration is approximately 230 µg/m³ at Reotahi Bay. This is a consequence of the plumes impacting against Mount Aubrey. Other locations along the opposite side of the harbour and south of Reotahi Bay vary between 150 and 220 µg/m³.

Maximum predicted 1-hour average concentrations over the nearest part of the Marsden Bay community are approximately 130 µg/m³, with One Tree Point being less than 100 µg/m³. Concentrations to the south around Ruakaka are between 65 and 85 µg/m³. To the west over the location of the Marsden Primary Centre concentrations are less than 90 µg/m³. When applying a 1-hour average background concentration of 25 µg/m³ (see Section 4.3.6), it is clear that concentrations will not approach the NES_{AQ} of 570 µg/m³.

Table 5.4: Summary of predicted SO_2 GLC compared with assessment criteria

Location	Averaging period	Maximum off-site GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location	1-hour	330	[25] 355	570 / 350**
	24-hour	73	[7] 80	120
	Annual	3.3	[1] 4.3	10
Most impacted sensitive location	1-hour	230	[25] 255	570 / 350**
	24-hour	60	[7] 67	120
	Annual	2.5	[1] 3.5	10

Note: * Site discharges plus background (see Table 4.1). Background concentrations in square brackets.
** the NES_{AQ} for 1-hour average SO_2 includes a concentration of 570 µg/m³ that must not be exceeded, and a concentration of 350 µg/m³ that can be exceeded up to nine times in a calendar year.

The peak 24-hour average concentrations occurs at the immediate west boundary of the site (73µg/m³) and then decreases rapidly with distance. On the opposite side of the harbour, 24-

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[9] Predicted to occur over the Wiri Oil Services Limited (WOSL) site.

hour average SO_2 GLC are highest around Urquharts Bay (60 µg/m³), with various other locations along the western side of the harbour reaching between 40 and 50 µg/m³. Concentrations over Marsden bay, One Tree Point, Ruakaka and Marsden Community Centre vary between 20 and 35 µg/m³. When allowing for a background SO_2 concentration 7 µg/m³ (see Section 4.3.6), these concentrations remain well below the AAQG of 120 µg/m³.

The predicted annual average concentration is of interest in terms of impacts on sensitive ecological areas. Figure 5.10 illustrates that annual average GLC due to site discharges are very low, with the highest off-site concentrations occurring over the industrial land immediately west of the site (3.5 µg/m³). On the opposite side of the harbour, concentrations go as high as 2.8 µg/m³ in and around Mount Mania. When allowing for a background concentration of 1 µg/m³ (see Section 4.3.6), this remains well below the AAQG of 10 µg/m³.

When the above results for SO_2 are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects can be considered as less than minor for the most impacted sensitive location.

Although the above 24-hour average SO_2 GLCs are well below the AAQG, the GLCs are above the WHO guideline of 20 µg/m³ over a wide area surrounding the site. As described in Section 5.1.3, the WHO 24-hour average guideline has not been adopted as an assessment criterion for this assessment for the reasons given in Section 5.1.3.2 and consequently our conclusion of less than minor effects associated with SO_2 remains unchanged. However, for completeness the frequency of predicted concentrations above 20 µg/m³ is provided in Figure 5.8. This plot shows the predicted annual frequency (averaged for the two years modelled) that concentrations exceed 20 µg/m³ is low over sensitive populated areas, varying between 4 and 16 days per year.

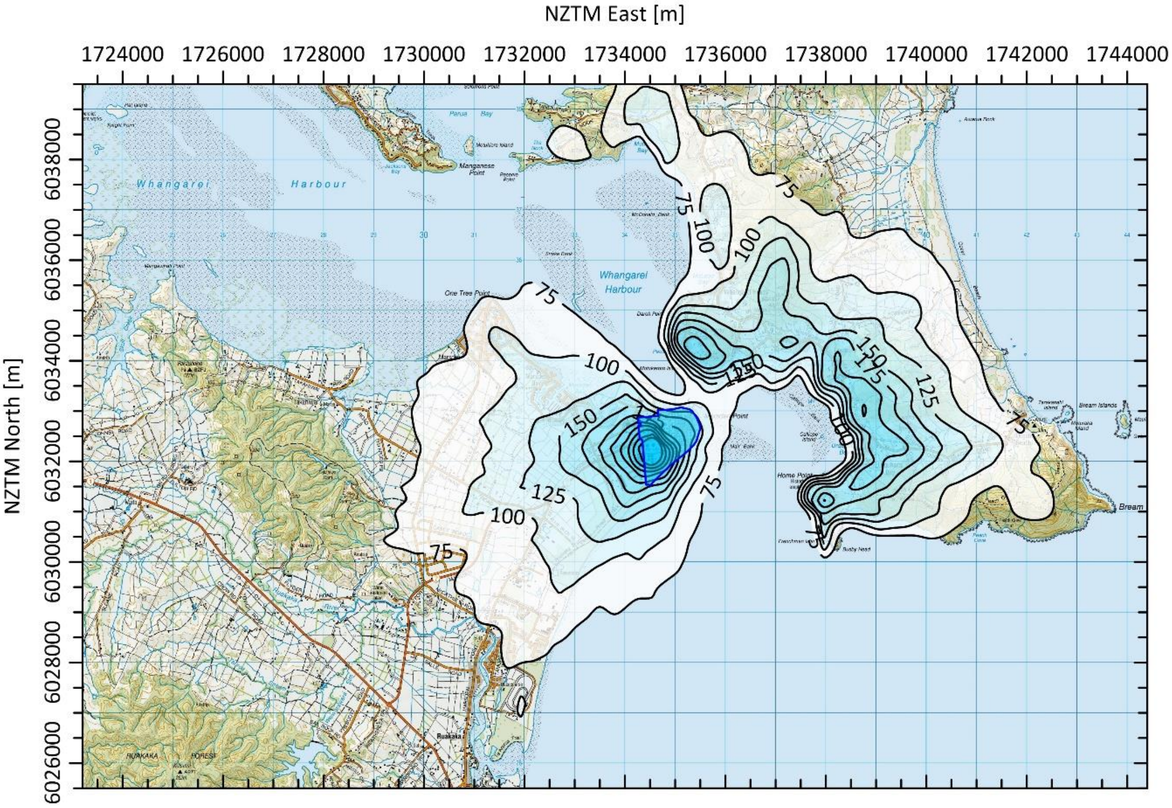

Figure 5.4: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_2 GLC (µg/m³) – based on peak SO_2 emission rates. Site emissions only.

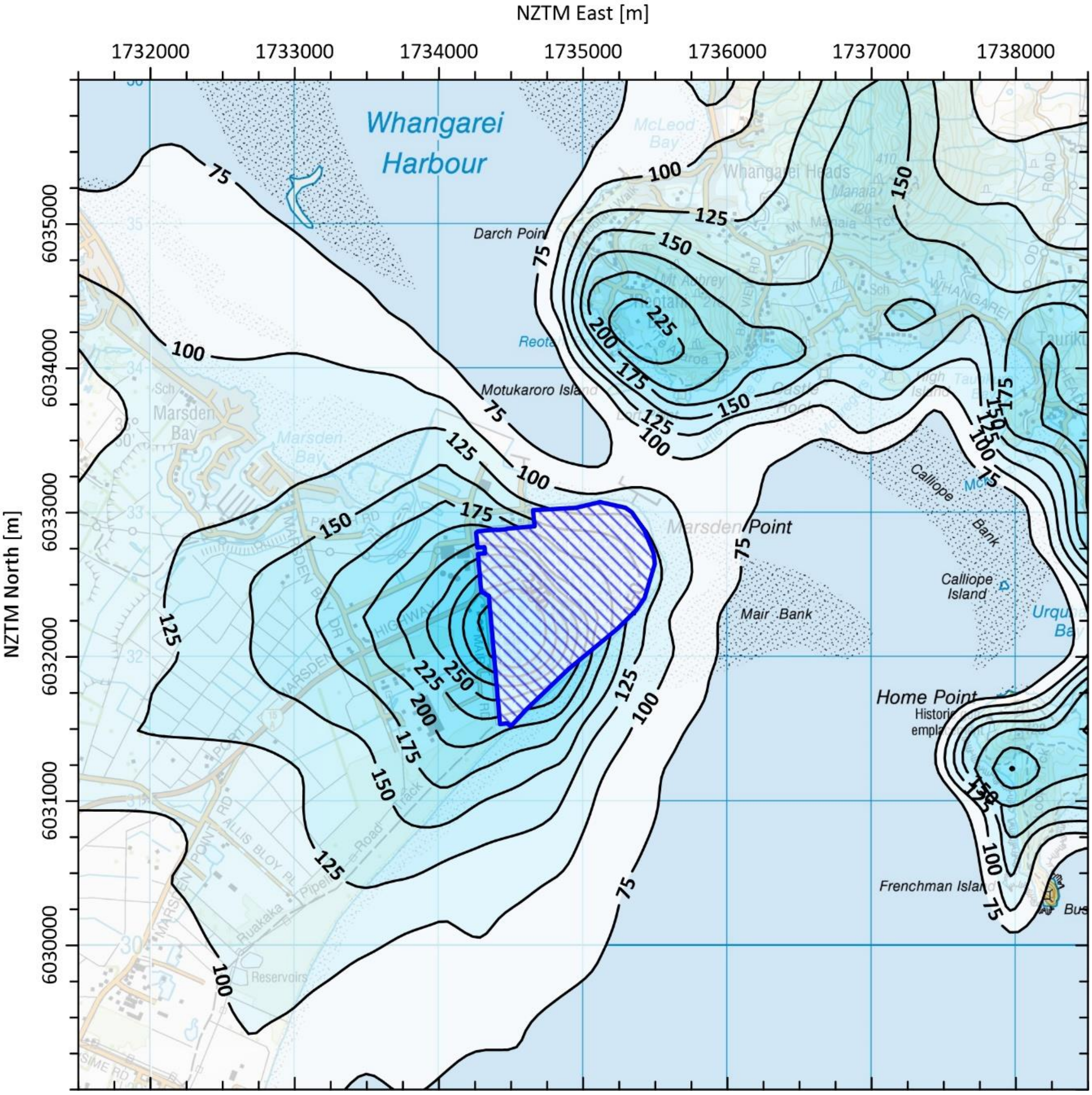

Figure 5.5: Predicted maximum (modelled 99.9th percentile) 1-hour average SO_2 GLC (µg/m³) in the immediate surroundings – based on peak SO_2 emission rates. Site emissions only.

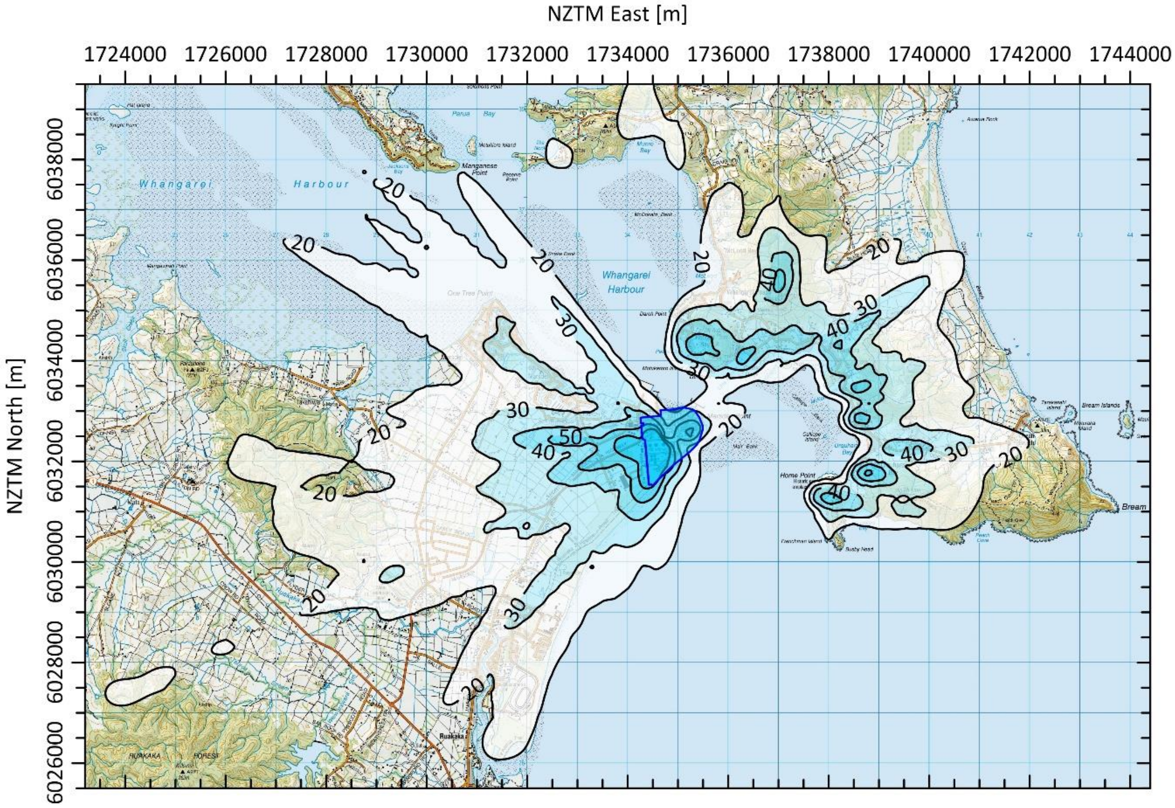

Figure 5.6: Predicted maximum 24-hour average SO_2 GLC (µg/m³). Site emissions only.

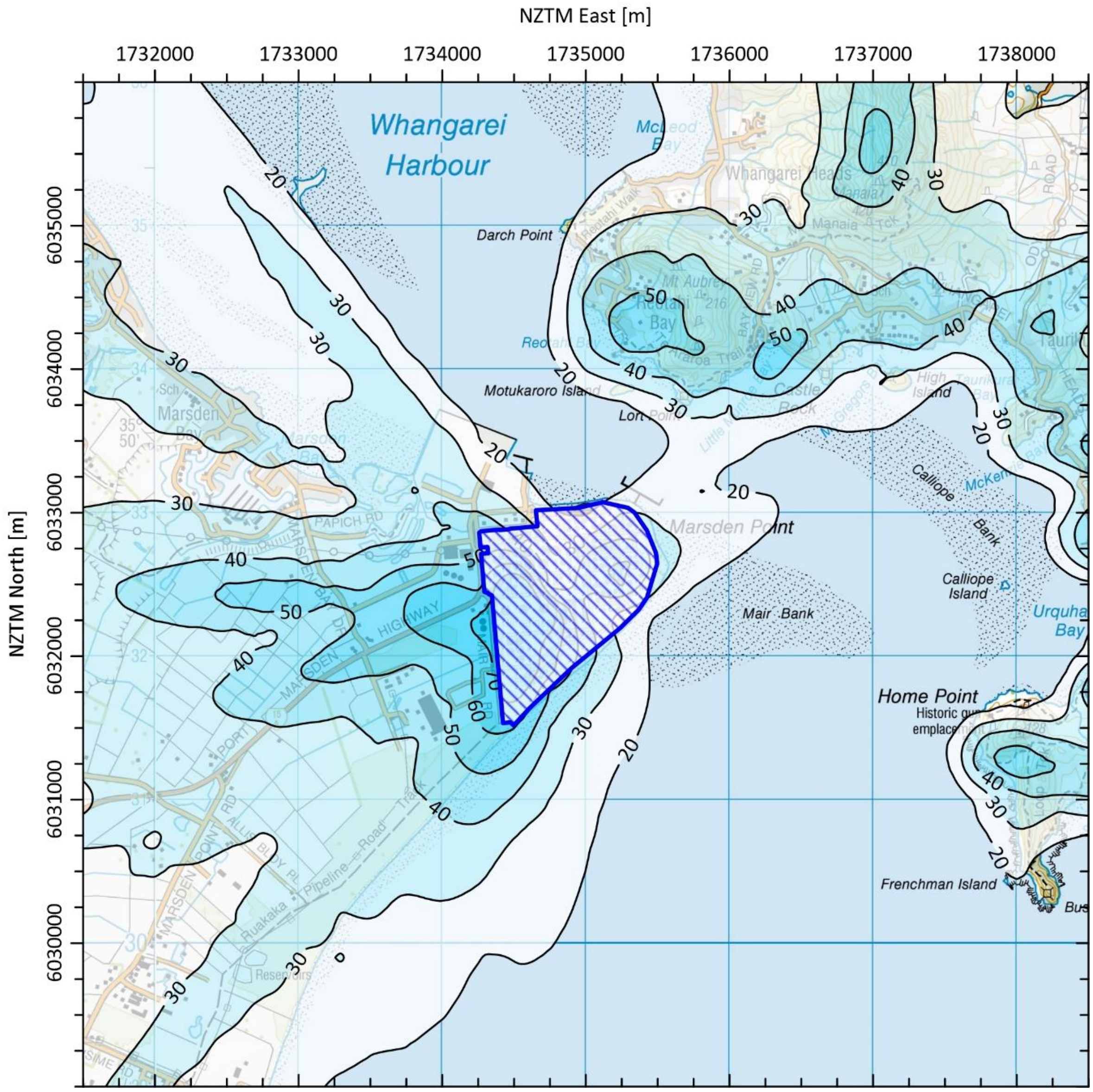

Figure 5.7: Predicted maximum 24-hour average SO_2 GLC (µg/m³) in the immediate surroundings. Site emissions only.

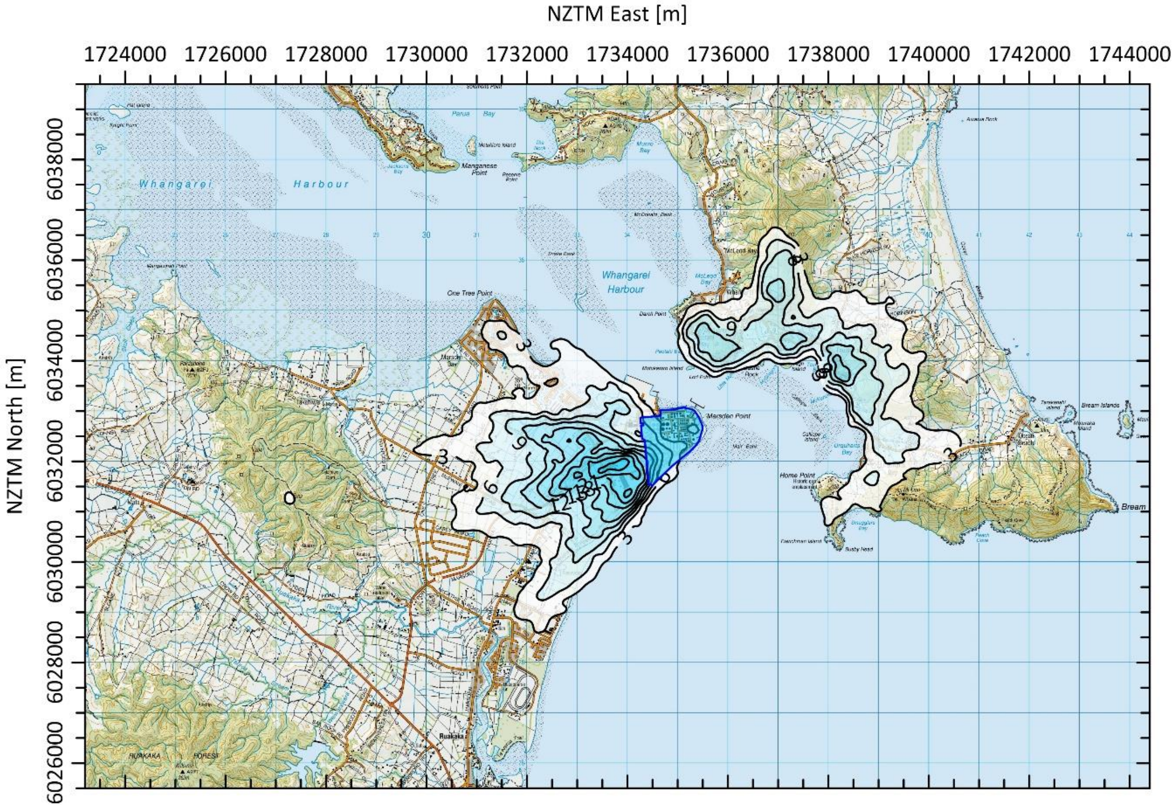

Figure 5.8: Predicted number of exceedances of a 24-hour average concentration of 20 µg/m³ per year (annualised for the 2011 and 2012 modelled period).

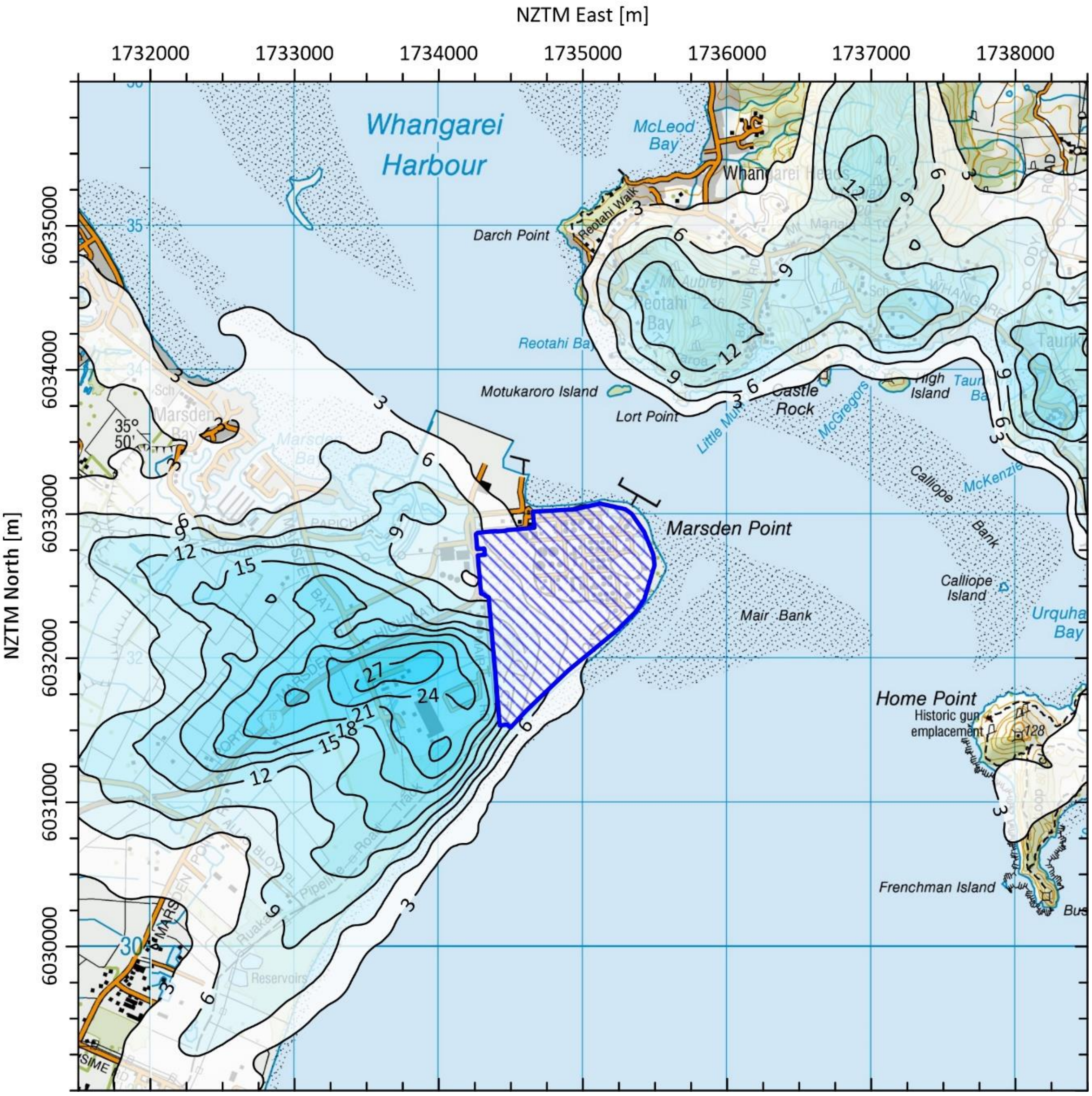

Figure 5.9: Predicted number of exceedances of a 24-hour average concentration of 20 µg/m³ per year in the immediate surroundings (annualised for the 2011 and 2012 modelled period).

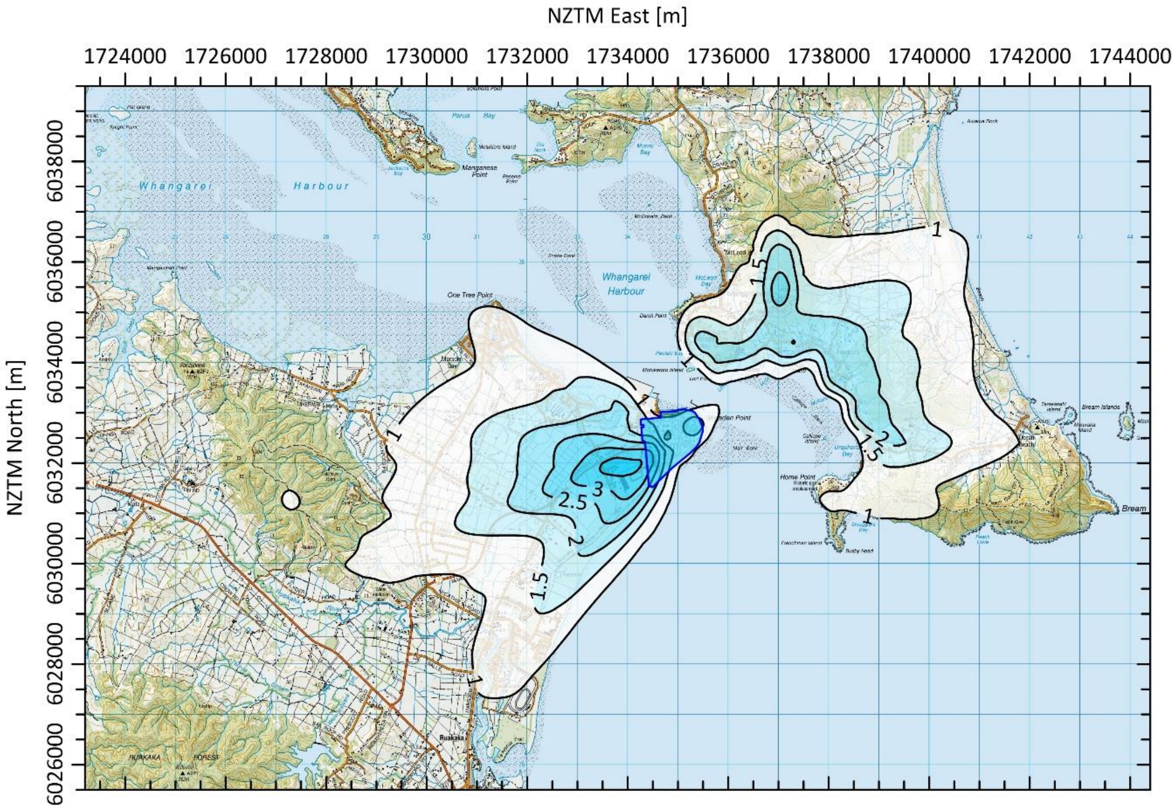

Figure 5.10: Predicted annual average SO_2 GLCs (µg/m³). Site emissions only.

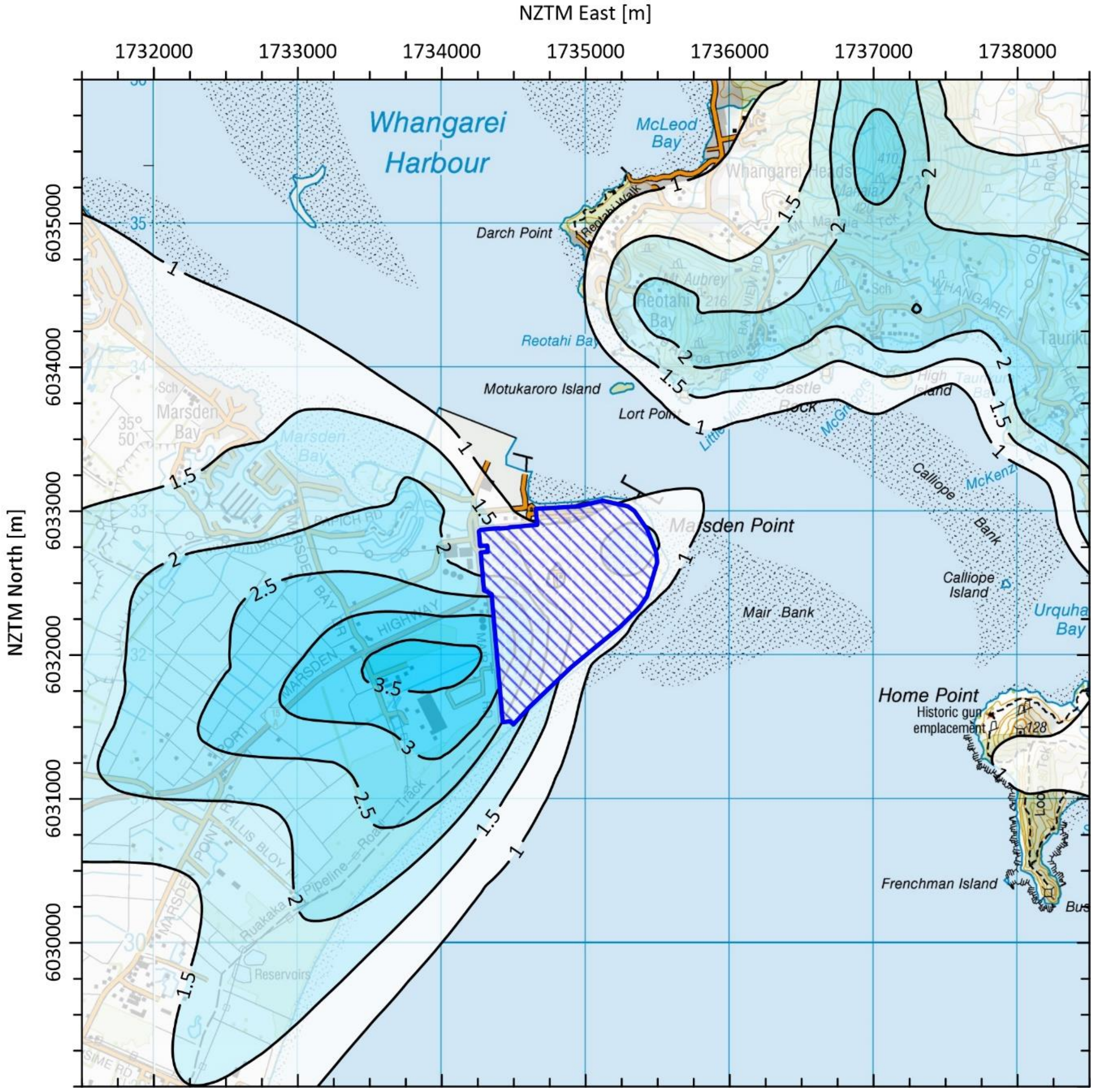

Figure 5.11: Predicted annual average SO_2 GLCs (µg/m³) in immediate surroundings. Site emissions only.

5.2.2 Particulate matter

5.2.2.1 PM_{10}

The predicted pattern of impacts for 24-hour and annual average PM_{10} is very similar to those for SO_2. That is, peak impacts occur to the immediate west of the site boundary over the adjoining industrial land, with elevated levels also occurring on the opposite side of the harbour where the plumes impact against elevated terrain, such as Mount Aubrey and Mount Mania. A summary of the model predictions is provided in Table 5.4

The predicted maximum off-site 24-hour average PM_{10} GLC is approximately 12 µg/m³ at the immediate western site boundary, and predicted concentrations reduce rapidly with increasing distance (Figure 5.12). On the opposite side of the harbour, the peak 24-hour impact is 11 µg/m³ over Reotahi Bay and varies between 5 and 8 µg/m³ over other communities along the easterly side of the harbour. Concentrations over Marsden Bay, One Tree Point, Marsden Community Centre and Ruakaka vary between 4 and 6 µg/m³. Allowing for a 24-hour average background concentration of 30 µg/m^3, cumulative concentrations are not expected to approach or exceed the NES$_{AQ}$ of 50 µg/m^3.

Predicted annual average concentrations are very low (Figure 5.14), with the most impacted location being immediately to the west of the site boundary reaching 0.3 µg/m^3. On the opposite side of the Harbour, concentrations reach approximately 0.2 µg/m^3 over Mount Manaia. Concentrations over Marsden Bay, One Tree Point, Marsden Community Centre and Ruakaka vary between 0.09 and 0.15 µg/m^3. Allowing for an annual average background concentration of 15 µg/m^3, cumulative concentrations will not approach the AAQG of 20 µg/m^3.

When the above results for PM$_{10}$ are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects can be considered as less than minor for the most impacted sensitive location.

Table 5.5: Summary of predicted PM$_{10}$ GLC compared with assessment criteria

Location	**Averaging period**	**Maximum off-site GLC (µg/m^3)**	**Cumulative off-site GLC (µg/m^3)***	**Assessment Criteria (µg/m^3)**
Most impacted off-site location	24-hour	12	[30] 42	50
	Annual	0.3	[15] 15.3	20
Most impacted sensitive location	24-hour	11	[30] 41	50
	Annual	0.2	[15] 15.2	20

Note: * Site discharges plus background. Background concentrations are in square brackets.

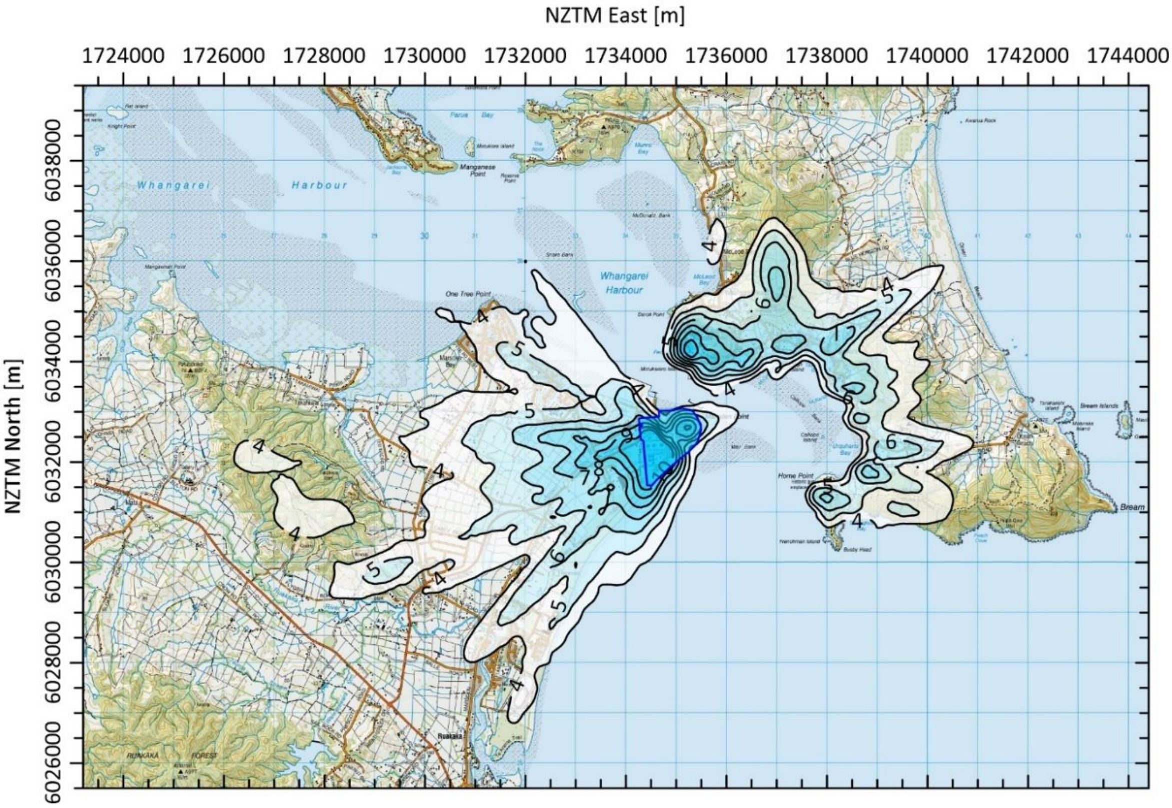

Figure 5.12: Predicted maximum 24-hour average PM$_{10}$ GLC (µg/m^3) – based on peak PM$_{10}$ emission rates. Site emissions only.

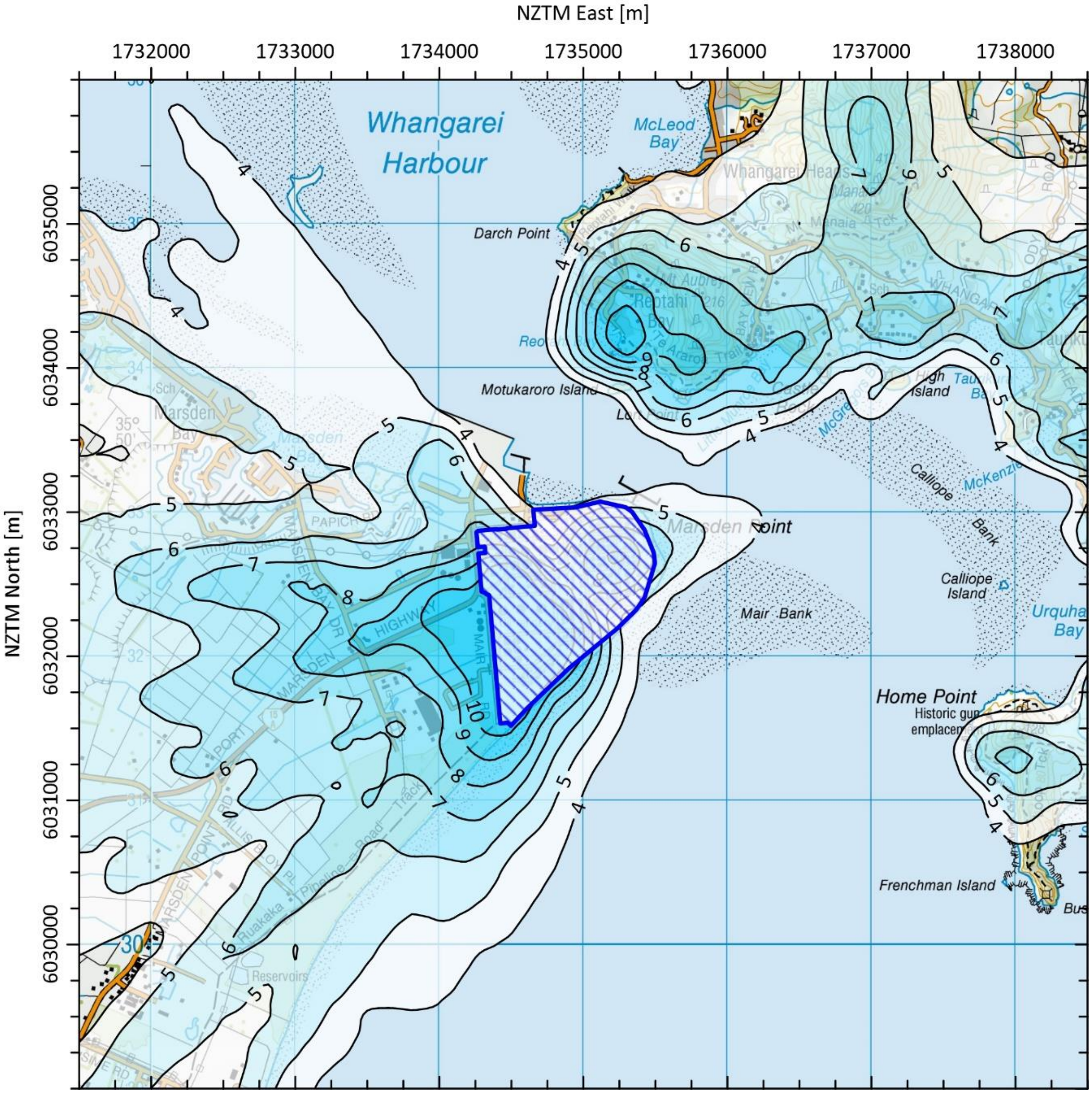

Figure 5.13: Predicted maximum 24-hour average PM_{10} GLC (µg/m³) in the immediate surroundings – based on peak PM_{10} emission rates. Site emissions only.

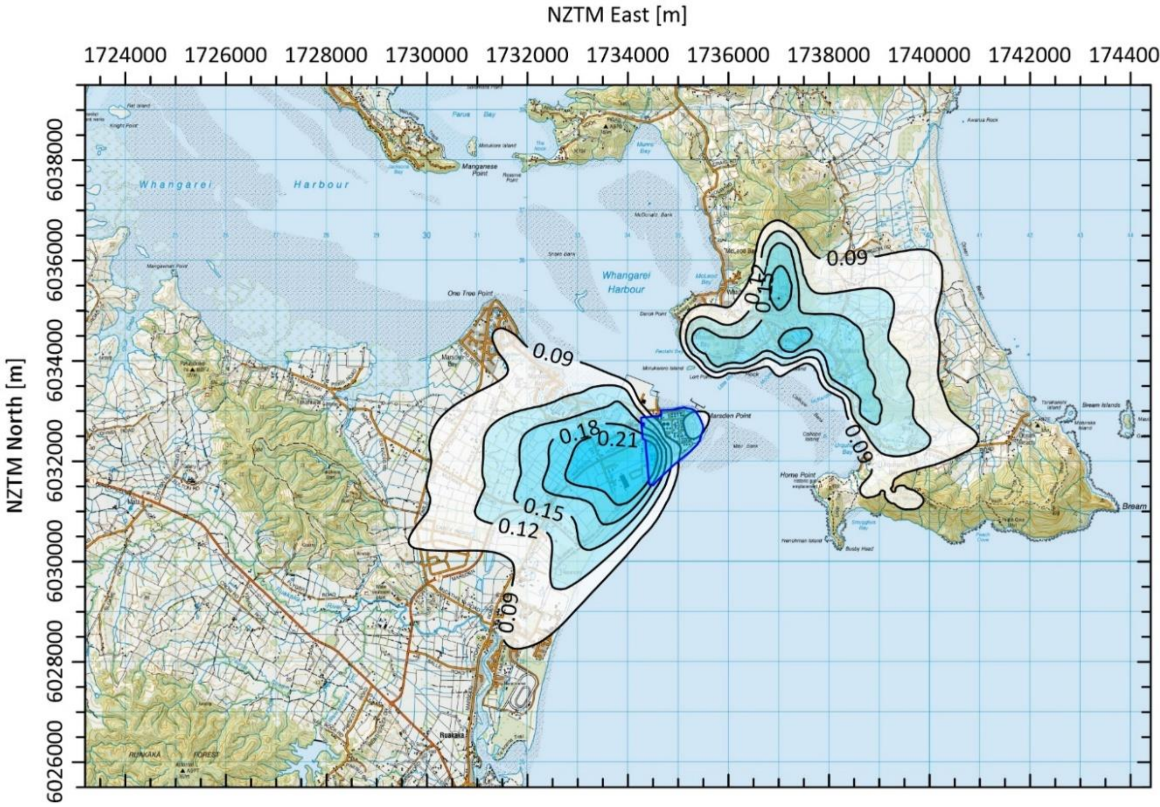

Figure 5.14: Predicted annual average PM₁₀ GLC (µg/m³) – based on average PM₁₀ emission rates. Site emissions only.

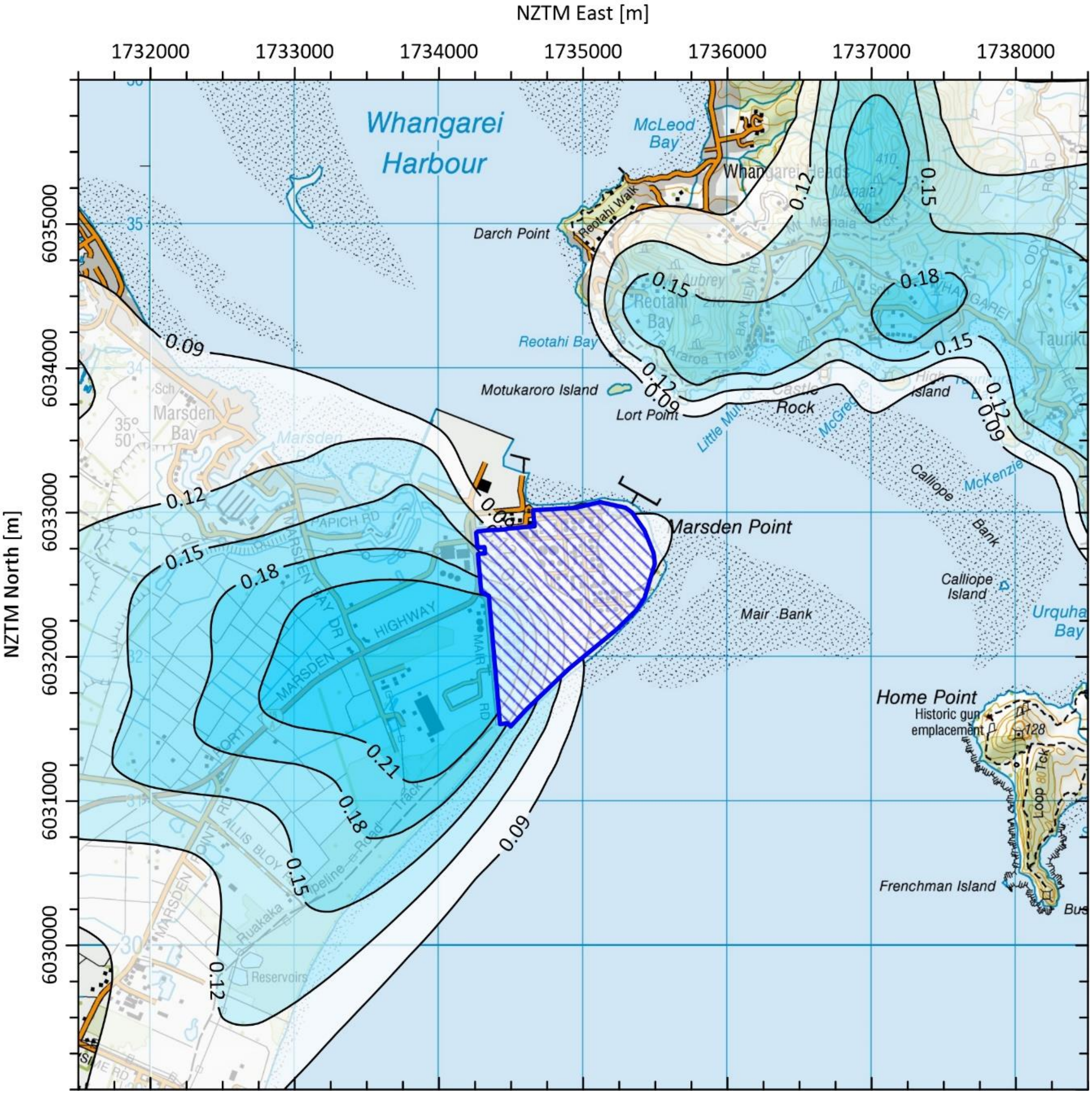

Figure 5.15: Predicted annual average PM₁₀ GLC (µg/m³) in the immediate surroundings – based on average PM₁₀ emission rates. Site emissions only.PM₂.₅

The distribution of $PM_{2.5}$ GLCs is the same as that for PM_{10}. A summary of the model predictions is provided in Table 5.6.

The predicted maximum off-site 24-hour average $PM_{2.5}$ GLC is approximately 12 µg/m³ at the immediate western site boundary, and reduces rapidly with increasing distance (Figure 5.16). On the opposite side of the harbour, the peak impact is 11 µg/m³ over Reotahi Bay and varies between 5 and 8 µg/m³ over other communities along the easterly side of the harbour. Concentrations over Marsden Bay, One Tree Point, Marsden Community Centre and Ruakaka vary between 4 and 6 µg/m³. Allowing for a 24-hour average background concentration of 11 µg/m³, cumulative concentrations are not exceed the WHO guideline of 25 µg/m³.

Predicted annual average $PM_{2.5}$ concentrations are very low (Figure 5.14), with the most impacted location being immediately to the west of the site boundary reaching 0.3 µg/m³. On the opposite side of the Harbour, concentrations reach approximately 0.2 µg/m³ over Mount Manaia. Concentrations over Marsden Bay, One Tree Point, Marsden Community Centre and Ruakaka vary between 0.09 and 0.15 µg/m³. Allowing for an annual average background concentration of 5.6 µg/m³, cumulative concentrations will not approach the WHO guideline of 10 µg/m³.

When the above results for $PM_{2.5}$ are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects can be considered as less than minor for the most impacted sensitive location.

Table 5.6: Summary of predicted $PM_{2.5}$ GLC compared with assessment criteria

Location	Averaging period	Maximum off-site GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location	24-hour	12	[11] 23	25
	Annual	0.3	[5.6] 5.9	10
Most impacted sensitive location	24-hour	11	[11] 22	25
	Annual	0.2	[5.6] 5.8	10

Note: * Site discharges plus background. Background concentrations are in square brackets.

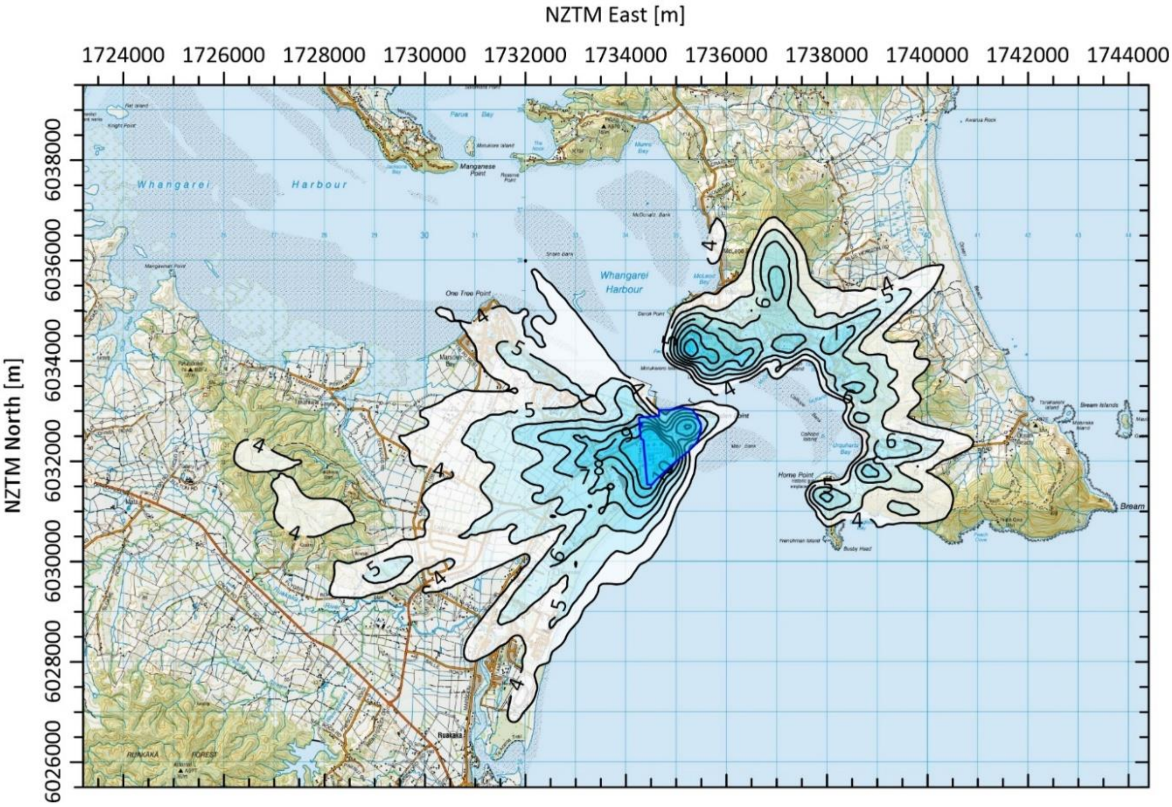

Figure 5.16: Predicted maximum 24-hour average $PM_{2.5}$ GLC (µg/m³). Site emissions only.

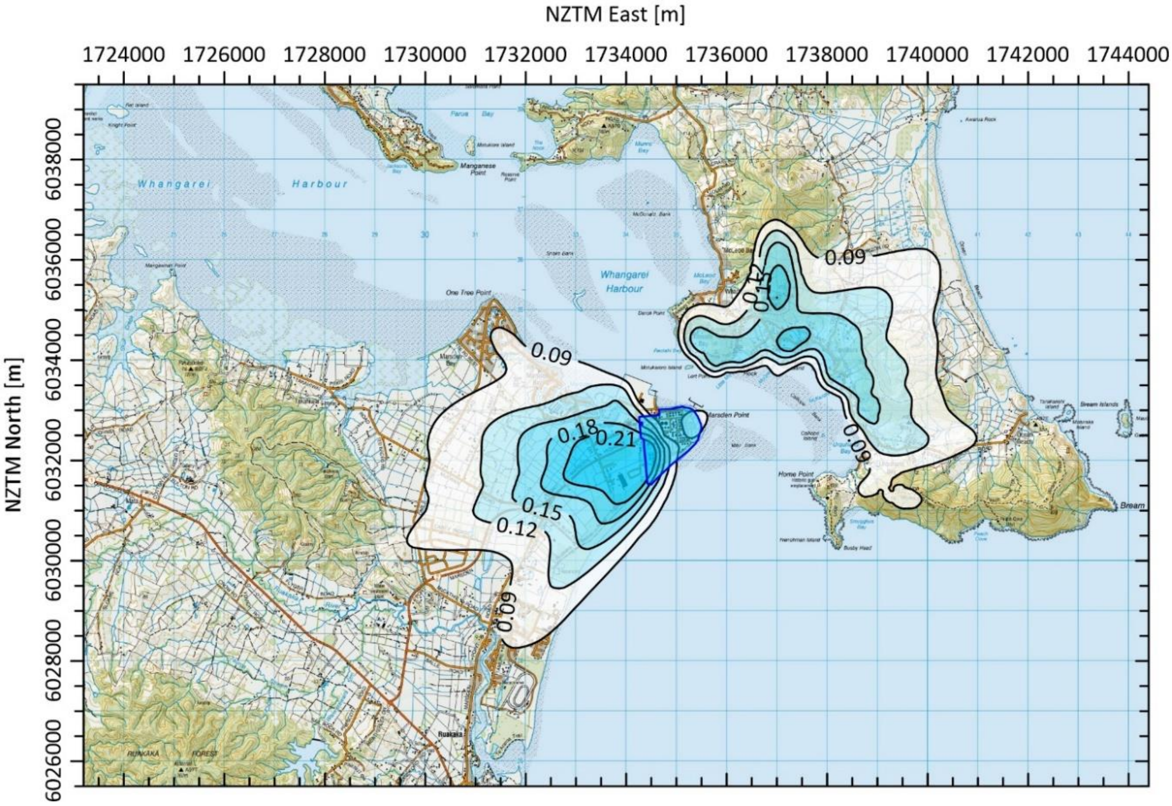

Figure 5.17: Predicted annual average $PM_{2.5}$ GLC (µg/m³). Site emissions only.

5.2.3 Nitrogen dioxide

The model-predicted maximum 1-hour average, 24-hour average and annual average GLCs due to NO_2 emissions from the site's energy plant are summarised in Table 5.7. Corresponding contour plots are provided in Figure 5.18, Figure 5.20 and Figure 5.22 respectively. The results assume all NO_X emissions are in the form of NO_2 in line with the screening approach described in 5.1.1.4. This is a highly conservative approach in treating the atmospheric conversion of NO to NO_2.

The contour plots show that the greatest impacts occur immediately west of the site boundary over the adjoining industrial land and also on the opposite side of the Whangarei Harbour where the plumes can be seen as impacting against the elevated terrain.

In terms of the 1-hour average GLCs, the maximum offsite concentration occurs to the immediate west of the site reaching 75 µg/m³ as a result of site emissions only. The most impacted sensitive location is on the other side of the harbour at Reotahi Bay where concentrations reach approximately 60 µg/m³. At other communities on the eastern side of the harbour, concentrations vary between 30 and 45 µg/m³. Concentrations at Marsden Bay, One Tree Point, Marsden Community Centre and Ruakaka vary between 14 and 25 µg/m³. Given a 1-hour average NO_2 background concentration of 37 µg/m³, cumulative concentrations are expected to be well below the NES_{AQ} of 200 µg/m³.

Model predicted 24-hour average concentrations are approximately 27 µg/m³ at the most impacted off-site location immediately to the west of the site boundary, and drop away rapidly with increasing distance from the site. The most impacted sensitive location is on the eastern side of the harbour at Reotahi Bay where the predicted concentration is approximately 22 µg/m³. Concentrations at Marsden Bay, One Tree Point, Marsden Community Centre and Ruakaka vary between 8 and 15 µg/m³. Given a 24-hour average NO_2 background concentration of 24 µg/m³, cumulative concentrations are expected to be well below the AAQG of 100 µg/m³.

Model predictions of the annual average NO_2 concentrations are very low (maximum off site concentration of 3 µg/m³ and 1ug/m³ at the most impacted sensitive location). With a background concentration of 4 µg/m³, it is clear that the cumulative concentrations will not approach the WHO guideline of 40 µg/m³.

When the above results for NO_2 are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects can be considered as less than minor for the most impacted sensitive location.

Table 5.7: Summary of predicted NO_2 GLC compared with assessment criteria

Location	Averaging period	Maximum off-site GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location	1-hour	85	[37] 122	200
	24-hour	30	[24] 54	100
	Annual	3	[4] 7	40
Most impacted sensitive location	1-hour	58	[37] 95	200
	24-hour	20	[24] 44	100
	Annual	0.98	[4] 4.98	40

Note: * Site discharges plus background. Background concentrations are in square brackets.

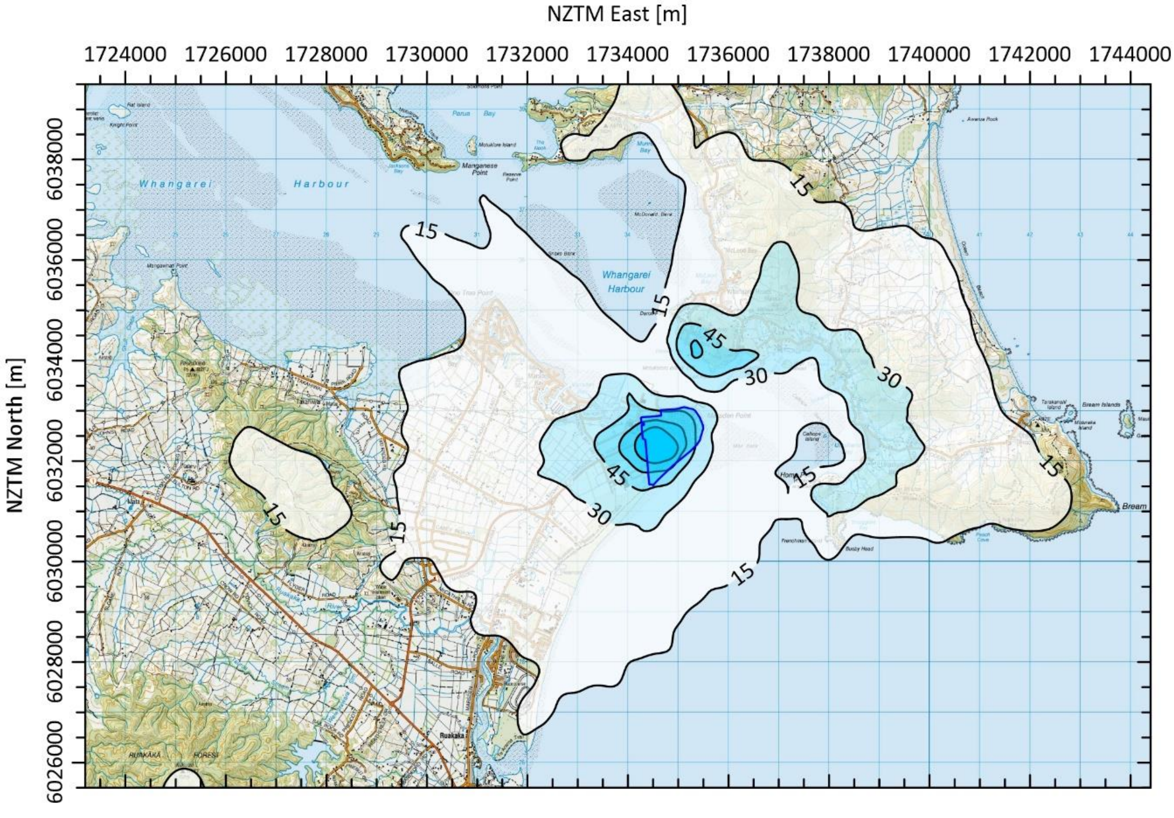

Figure 5.18: Predicted maximum 1-hour average NO_2 GLCs (µg/m³) – assuming all NO_X is NO_2. Site emissions only.

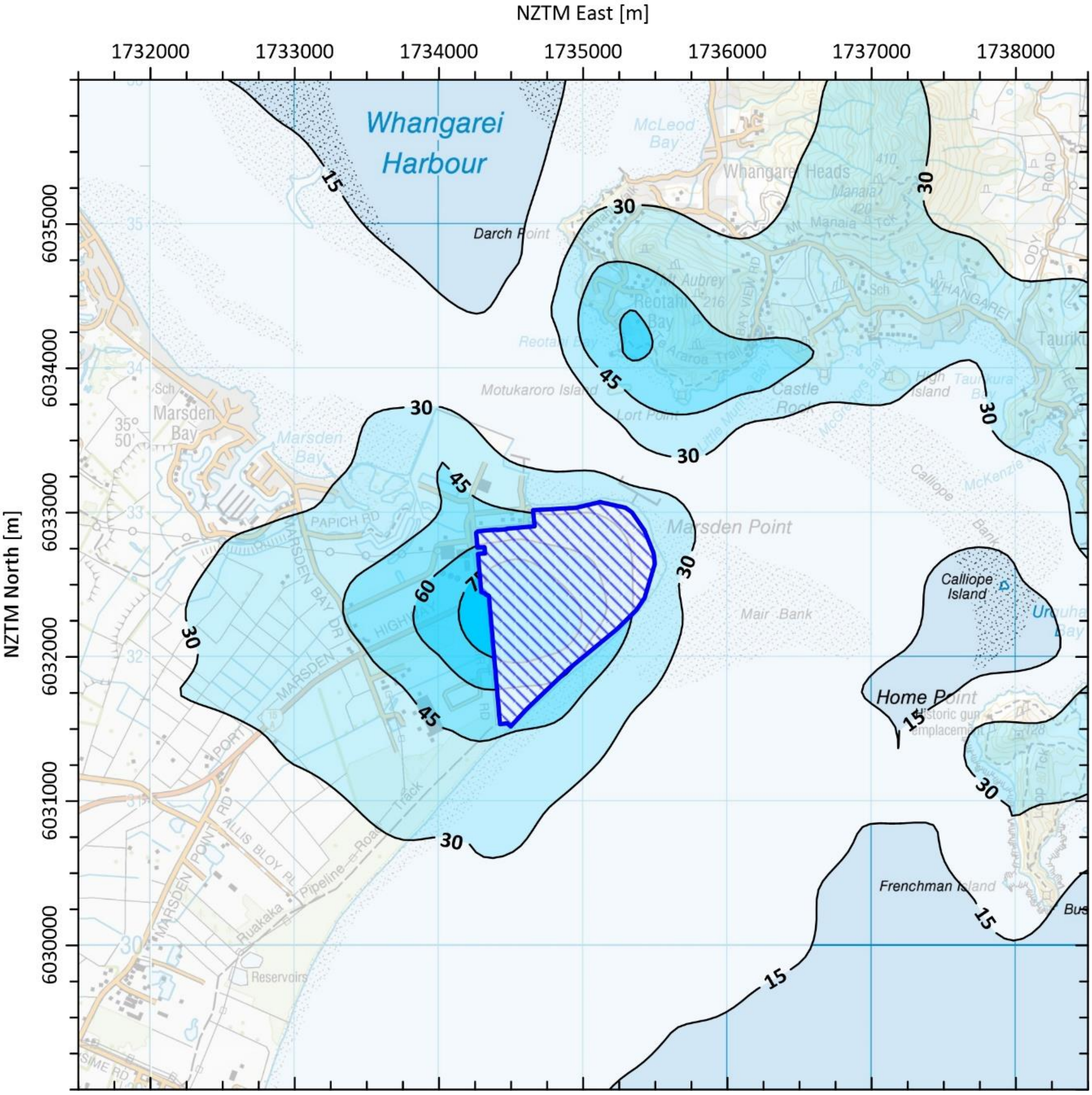

Figure 5.19: Predicted maximum 1-hour average NO_2 GLCs (µg/m³) in the immediate surroundings– assuming all NO_X is NO_2. Site emissions only.

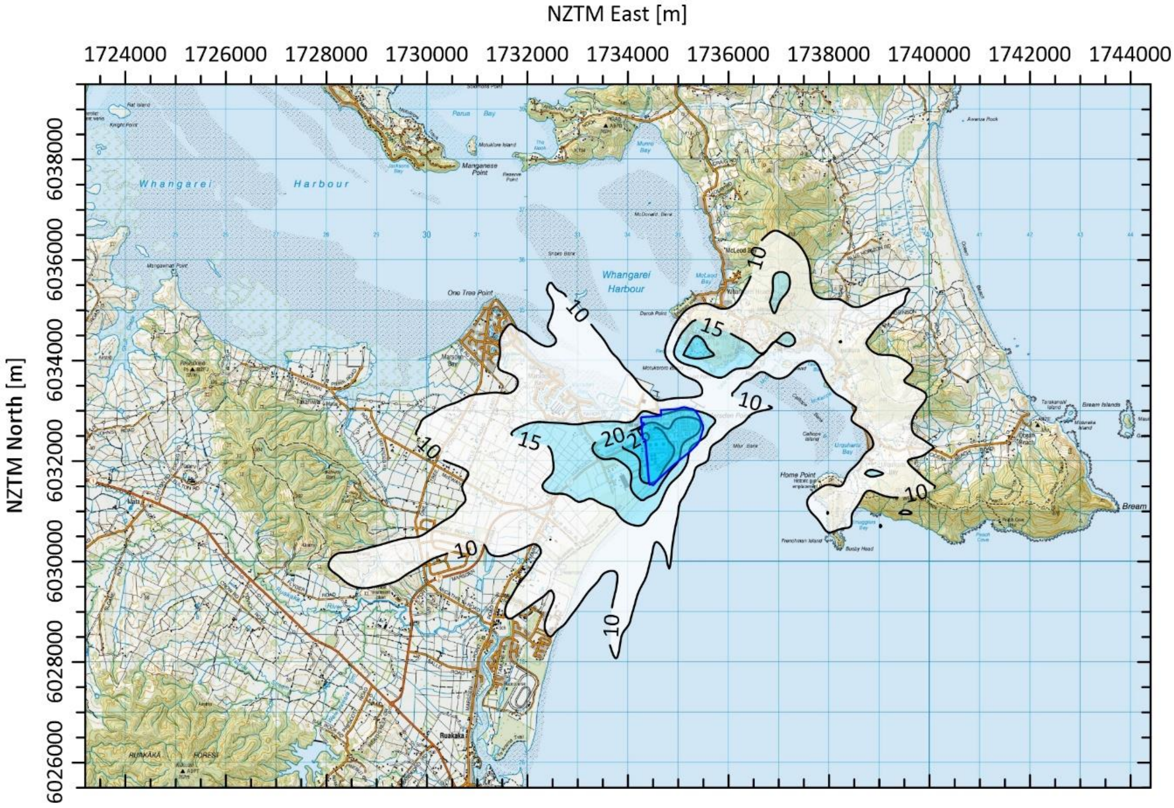

Figure 5.20: Predicted maximum 24-hour average NO_2 GLCs (µg/m³) – assuming all NO_X is NO_2. Site emissions only.

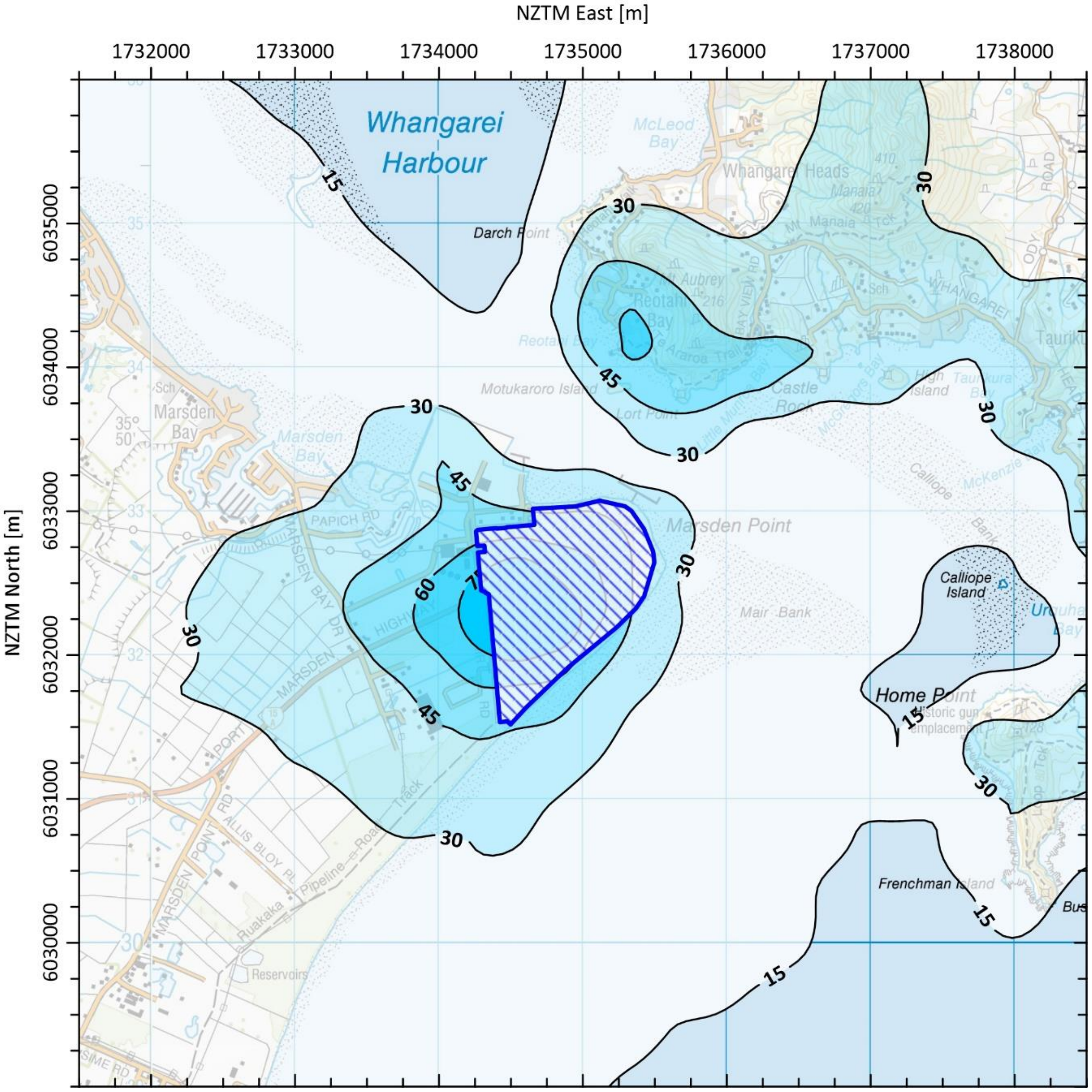

Figure 5.21: Predicted maximum 24-hour average NO_2 GLCs (µg/m³) in the immediate surroundings – assuming all NO_X is NO_2. Site emissions only.

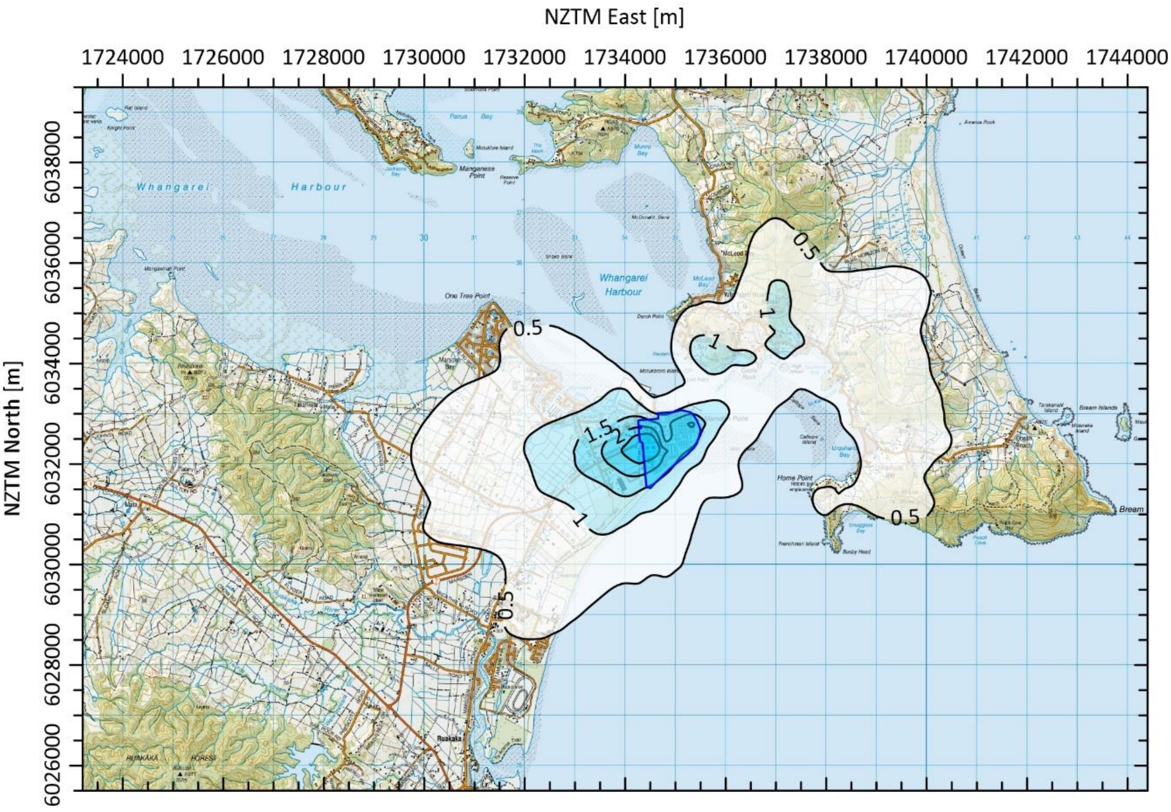

Figure 5.22: Predicted annual average NO_2 GLCs (µg/m³) – assuming all NO_X is NO_2. Site emissions only.

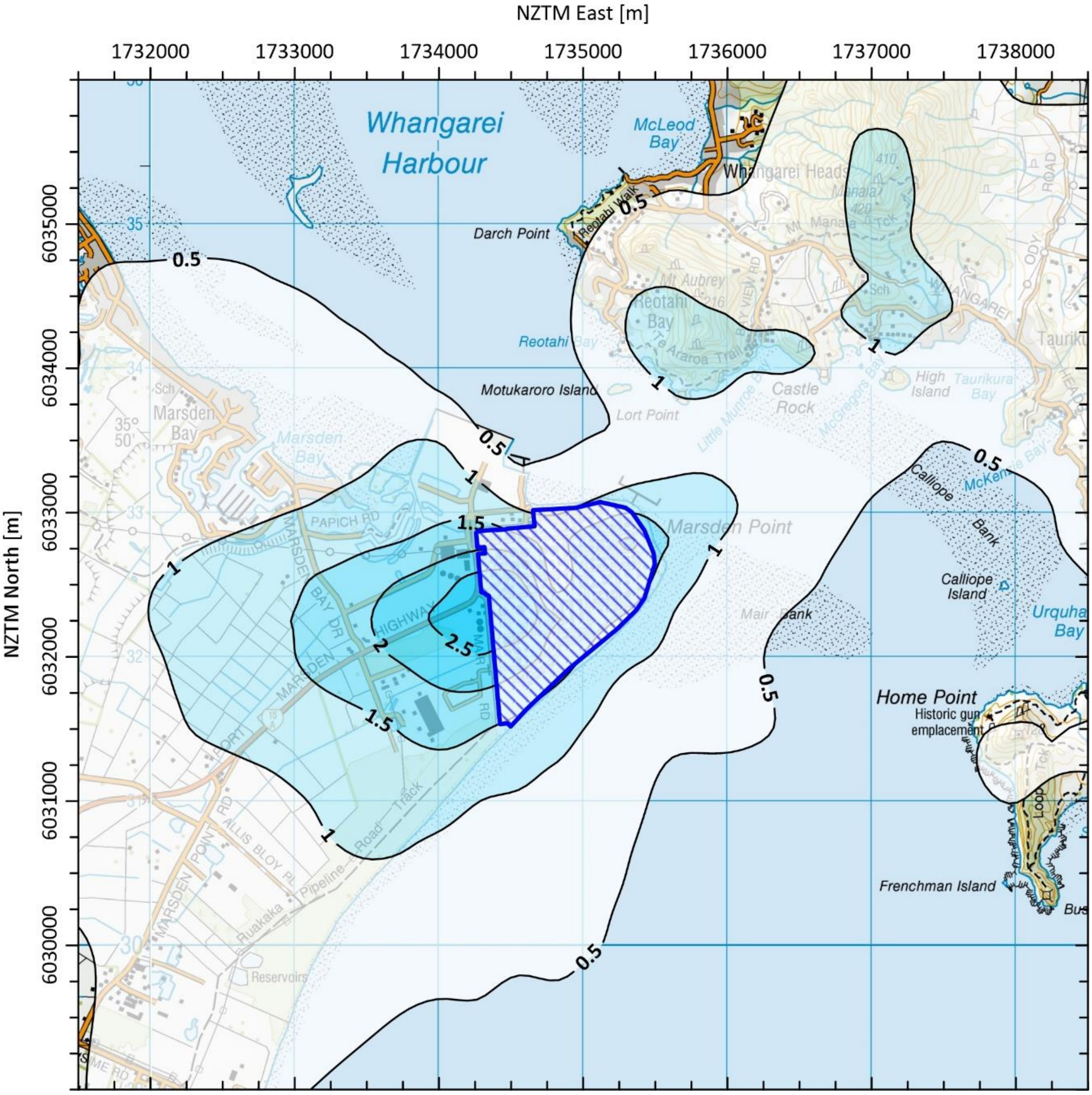

Figure 5.23: Predicted annual average NO_2 GLCs (µg/m³) in the immediate surroundings – assuming all NO_X is NO_2. Site emissions only.

5.2.4 Carbon monoxide

The model-predicted maximum 1-hour average and 8-hour average GLCs due to CO emissions are summarised in Table 5.7. From this table, it can be seen that the cumulative effects of CO are extremely low relative to the assessment criteria. Given this, no contour plots have been produced, however it is noted that the spatial distribution of impacts is similar to those presented for other the contaminants described above.

When the above results for CO are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects can be considered as negligible for the most impacted sensitive location.

Table 5.8: Summary of predicted CO GLCs compared with assessment criteria

Location	Averaging period	Maximum off-site GLC (µg/m³)	Cumulative off-site GLC (µg/m³)*	Assessment Criteria (µg/m³)
Most impacted off-site location	1-hour	51	[5] 56	30,000
	8-hour	37	[2] 39	10,000
Most impacted sensitive location	1-hour	33	[5] 38	30,000
	8-hour	30	[2] 32	10,000

Note: * Site discharges plus background. Background concentrations are in square brackets.

5.2.5 Dioxins and furans

The annual average predicted ground level concentrations for dioxins and furans are summarised in Table 5.9. The resulting concentrations are compared against the OEHHA guideline of 40 picograms per cubic metre (pg/m³ - equivalent to $4x10^{-5}$ µg/m³). The model predictions, which are considered to be very conservative due to the emission assumptions, indicate very low concentrations relative to the guideline, with the site contribution to most impacted sensitive location being 0.000003% of the guideline. Accordingly, it is considered that the potential adverse effects from dioxin and furan air discharges are negligible.

Table 5.9: Summary of predicted dioxin and furan GLCs compared with assessment criteria

Location	Averaging period	Maximum off-site GLC ($pg_{WHO-TEQ}$/m³)	Assessment criterion ($pg_{WHO-TEQ}$/m³)
Most impacted off-site location	Annual	3.3×10^{-6}	40 (OEHHA)
Most impacted sensitive location	Annual	1.2×10^{-6}	

5.2.6 Metals

The model results for the various metals and averaging periods are summarised in Table 5.10. The results are presented for each averaging period where emission rates were calculated for metals that were above the limit of detection. For all other metals, the results are presented for the corresponding metal that has the lowest assessment criteria for the averaging period.

The results for all but nickel are very low relative to the corresponding assessment criteria. However, for nickel:

- 1-hour average GLCs reach 75% of the corresponding assessment criteria;
- 8-hour average GLCs slightly exceed the corresponding assessment criteria; and
- Annual average GLCs are less than 10% of the assessment criteria.

Although the results for nickel exceed the 8-hour average OEHHA guideline of 0.06 µg/m³, this guideline is based on repeated 8-hour exposure over a significant fraction of a lifetime. The model results have been analysed to evaluate the likely frequency of exposure to 8-hour periods where the concentrations go above 0.06 µg/m³ at a sensitive location (Reotahi). At this location, the model predicts concentrations going above 0.06 µg/m³ on 10 occasions over a two-year period (0.5% over this period), or an average of five occasions per year.

When the above results for the various metals, excluding that for nickel, are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects can be considered as less than minor for the most impacted sensitive location.

With regard to nickel, the report by Environmental Medicine Limited concludes that, because the 1-hour and 8-hour OEHHA guideline values are not associated with acute effects but are based on the same health end-point as the annual average criteria, the predicted exceedances of the 8-hour average OEHHA guideline results in adverse effects that are less than minor.

Table 5.10: Summary of predicted GLC for various metals compared with assessment criteria

Contaminant	GLC (µg/m³)	Assessment Criteria (µg/m³)
1-hour average		
Aluminium	0.007 (west site boundary) 0.005 (Reotahi)	20
Nickel	0.18 (west site boundary) 0.13 (Reotahi)	0.2
Other metals (silver)*	0.0016 (west site boundary) 0.0012 (Reotahi)	0.1
8-hour average		
Nickel	0.13 (west site boundary) 0.11 (Reotahi)	0.06
24-hour average		
Vanadium	0.06 (west site boundary) 0.04 (Reotahi)	1
3-month average		
Lead	0.00008 (west site boundary) 0.00006 (McGregors Bay)	0.2**
Annual Average		
Aluminium	0.00011 (west site boundary) 0.00006 (Reotahi)	2
Nickel	0.0027 (west of site boundary) 0.0017 (McGregors Bay)	0.014
Other metals (chromium)	0.000029 (west site boundary) 0.000016 (Reotahi)	0.0011

Note: 'Other metals' relates to those metals were the fuel concentration was below detection limits.).
Of those other metals with 1-hour average assessment criteria, silver has the most stringent criteria.
Of those other metals with annual average assessment criteria, chromium has the most stringent criteria.
** MfE 2002 – rolling average.

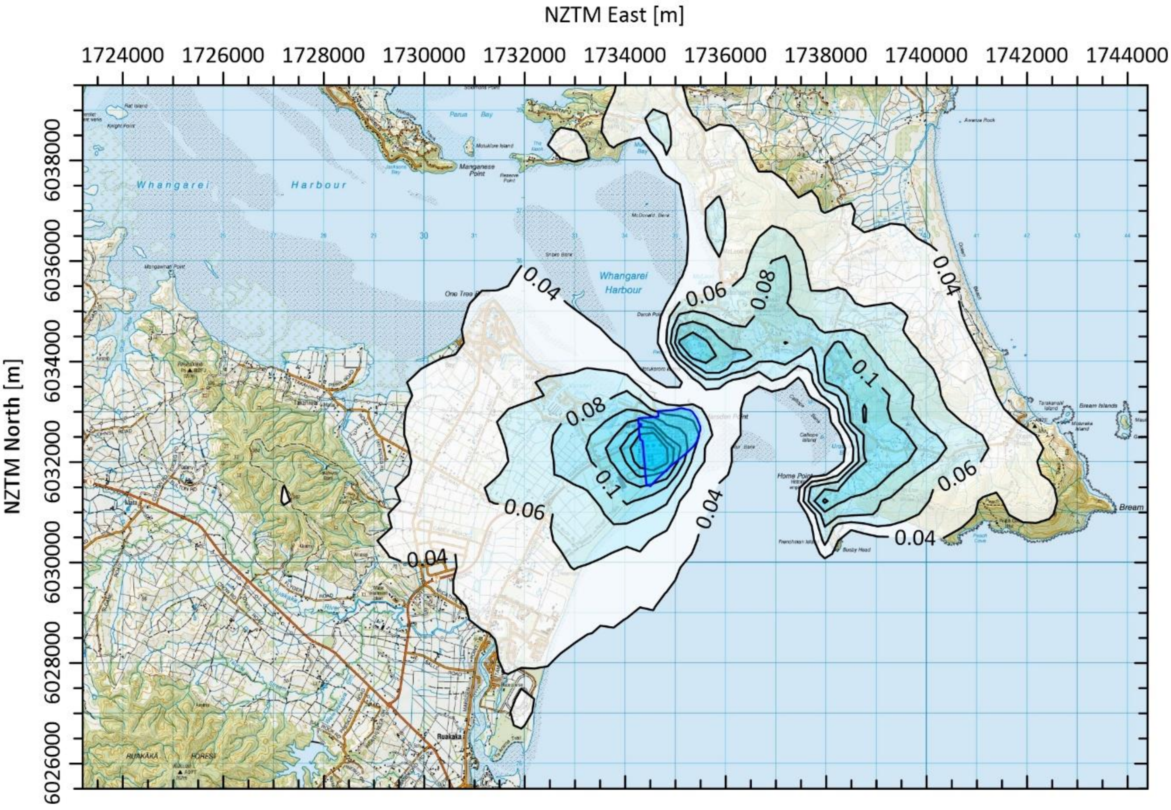

Figure 5.24: Predicted maximum 1-hour average nickel ground level concentrations (µg/m³). Site emissions only.

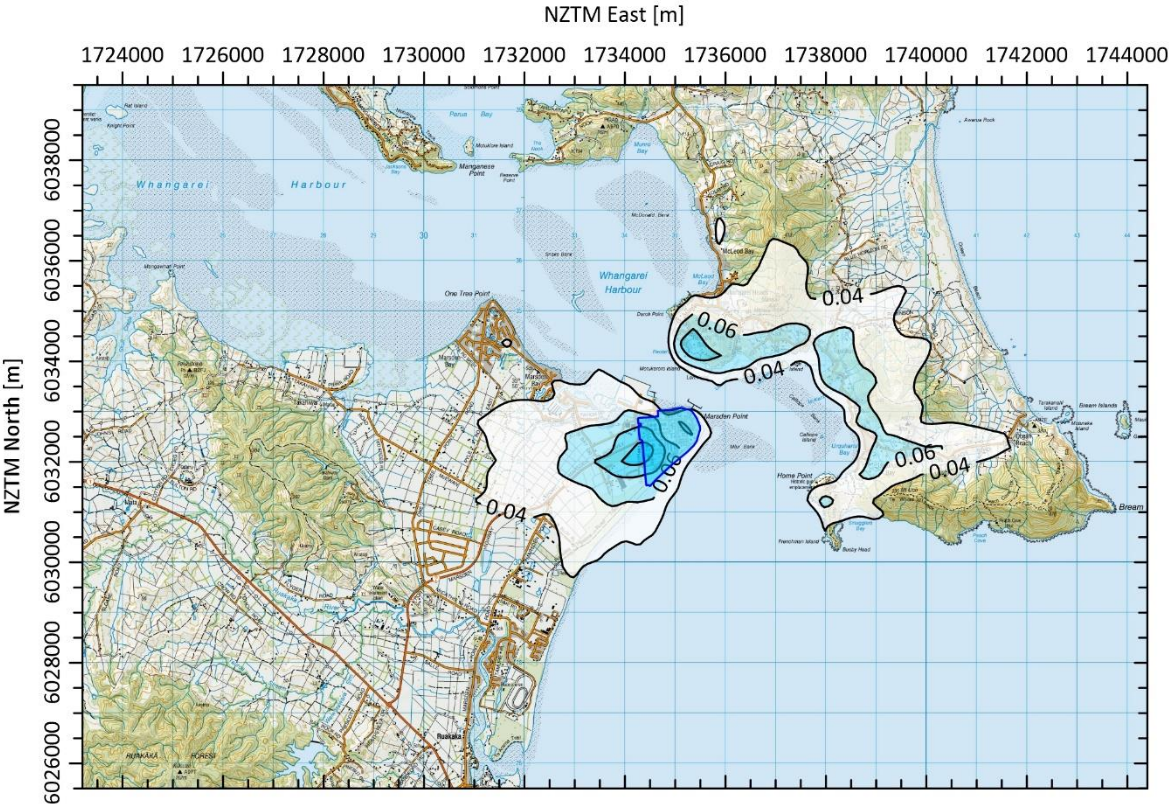

Figure 5.25: Predicted maximum (modelled 99.9th percentile, i.e. 2nd highest) 8-hour average nickel ground level concentrations. Site emissions only.

5.2.7 Nitrogen and sulphur deposition

Nitrogen and sulphur deposition have been modelled to inform the terrestrial ecological assessment. Both wet and dry deposition were modelled and the combined total deposition rates determined. Default wet and dry deposition parameters for the above contaminant species were assumed within the model.

The annual nitrogen deposition rates are presented in Figure 5.26 and are summarised in Table 5.11. When added to a background accumulation rate of 1.15 kg/ha/yr, this indicates very low deposition rates relative to the assessment criteria of 10 kg/ha/yr.

Table 5.11: Summary of predicted nitrogen deposition rate compared with assessment criteria

Location	Maximum off-site deposition rate (kg/ha/yr)	Cumulative deposition rate *	Assessment Criteria (kg/ha/yr)
Most impacted off-site location	1.0 (west site boundary)	[1.15] 2.15	10
Most impacted sensitive location	0.4 (Mt Aubrey)	[1.15] 1.55	

Note: * Site discharges plus background. Background deposition rates are in square brackets.

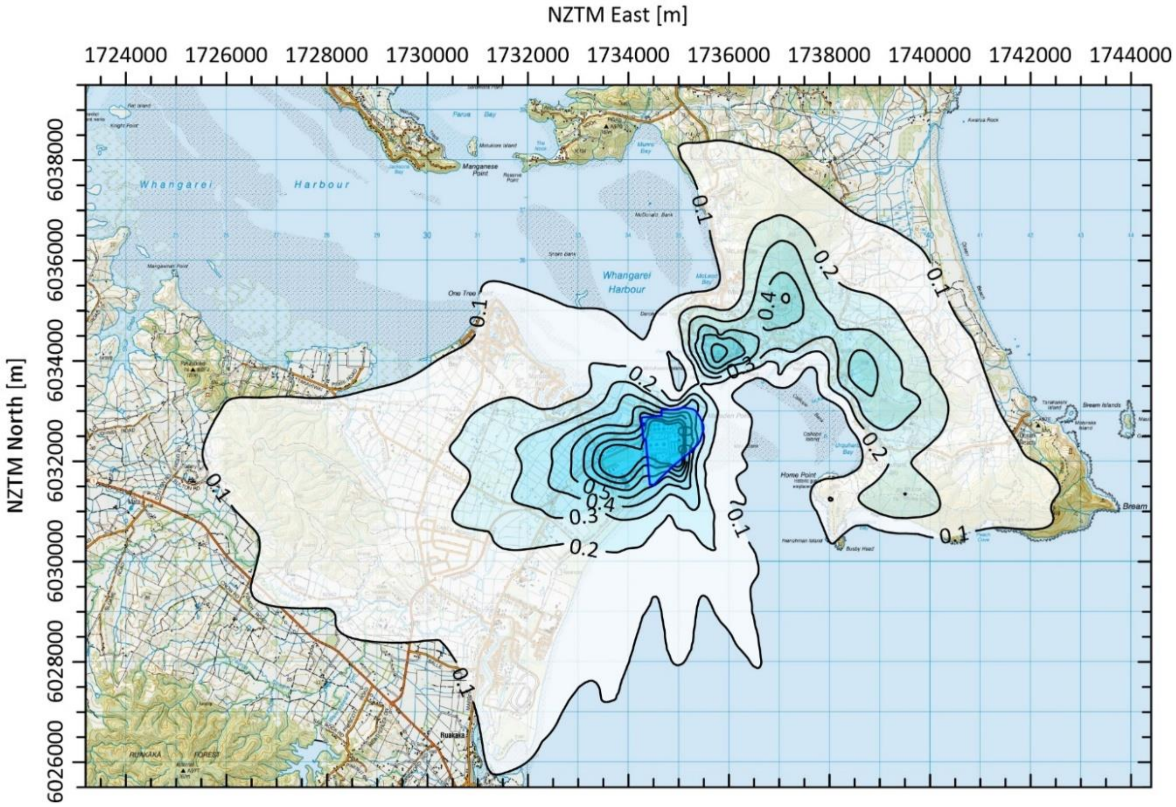

Figure 5.26: Annual nitrogen deposition (kg/ha/yr).

The annual sulphur deposition rates are summarised in Table 5.12 and a contour plot is provided in Figure 5.27. Unlike nitrogen deposition, there is no direct criteria that the cumulative sulphur deposition rates are compared against, and we do not consider them to have any adverse air quality effects which require further characterisation and/or assessment – instead these results are provided here as an input to the ecological assessment.

Of note is the different spatial distribution of nitrogen and sulphur deposition. In the case of sulphur deposition, the effect of wet deposition is much more pronounced, particularly for sulphate particles.

Table 5.12: Summary of predicted sulphur deposition rate compared with assessment criteria

Location	Maximum off-site deposition rate (kg/ha/yr)	Cumulative deposition rate (kg/ha/yr) *
Most impacted off-site location	13.5 (southeast site boundary)	[3.8] 17.3
Most impacted sensitive location	5.6 (Lort Point)	[3.8] 9.4

Note: * Site discharges plus background. Background deposition rates are in square brackets.

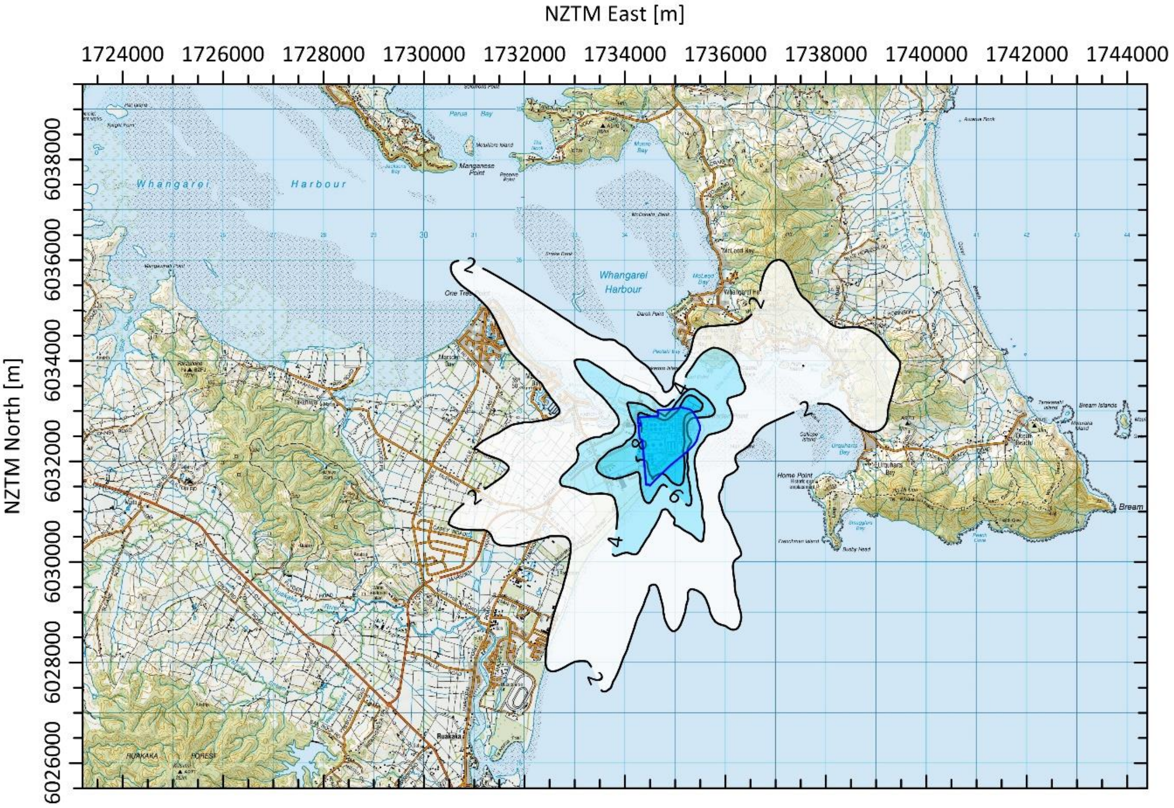

Figure 5.27: Annual sulphur deposition (kg/ha/yr).

5.3 Cumulative effects of emissions from ships at berth

Crude oil is received via ships at its jetty, with some product also being shipped from the site via its jetty. The largest ships, and therefore emissions, are associated with the receipt of crude oil. These ships when berthed use on-board auxiliary engines fired with heavy fuel oil to run pumps that are used to transfer the crude from the ship to the sites' storage tanks. The heavy fuel oil contains a relatively high proportion of sulphur and is therefore a source of SO_2 emissions, which can have cumulative effects with SO_2 emissions from the refinery site.

Although no consent is required for the berthing of ships at the jetties, it is nevertheless necessary to consider the cumulative effects of the discharge of SO_2 from berthed ships. Therefore, to assess the cumulative effects of ship discharges, dispersion modelling has been carried out to examine the potential impact of emissions from a berthed crude tanker when operating off its auxiliary engine. The following conservative assumptions have been made for this assessment:

- The largest ship (Suezmax class tanker) is berthed at the jetty;
- The ship is berthed continuously for the entire period. In practice, a crude tanker will be present about once every week for less than two days in duration;
- Downwash effects are modelled, assuming the structure of the ship is 275 m in length, 50 m in width and 15 m in height; and
- A typical auxiliary engine for a Suezmax class tanker is approximately 4 megawatts (MW) and operating at 75% output.

Based on these assumptions the discharge parameters and emission rates given in Table 5.13 have been determined for the modelling assessment.

Table 5.13: Ship auxiliary engine discharge and emission parameters

Parameter	Value
Stack height (m)	37
Stack diameter (m)	1.2
Stack efflux temperature (°C)	214
Stack efflux velocity (m/s)	42
SO2 emission rate (g/s)	3.5

The 1-hour average SO_2 model results for shipping emissions only is given in Figure 5.28. This figure shows impacts to be very low relative to the NES_{AQ} of 570 µg/m³, with elevated concentrations being mainly around the jetty. However, some localised impaction can be seen around Little Munro Bay where concentrations reach 27 µg/m³.

To evaluate the cumulative impact of shipping emissions, the model results have been added to those for refinery site. The resulting contours (in blue) have then be overlaid on top of the results for the refinery on its own, allowing a comparison of the change in impact. The results of this are presented in Figure 5.29 for the maximum predicted 1-hour average concentration and Figure 5.30 for the 24-hour average. The cumulative impacts (refinery site plus shipping) are essentially unchanged. Given this outcome, the conclusions reached in Section 5.2 regarding 1-hour average impacts of the refinery are unchanged.

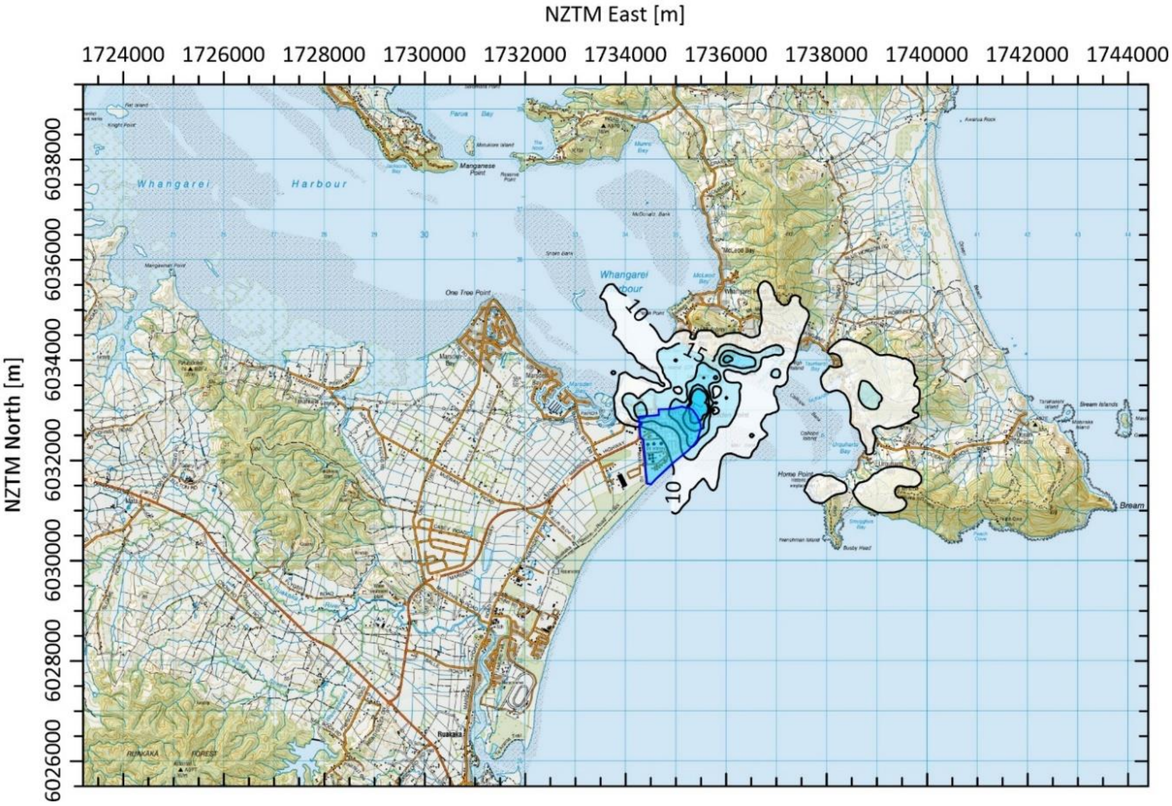

Figure 5.28: Predicted maximum (modelled 99.9th percentile) 1-hour average SO₂ GLC (µg/m³) from shipping emissions.

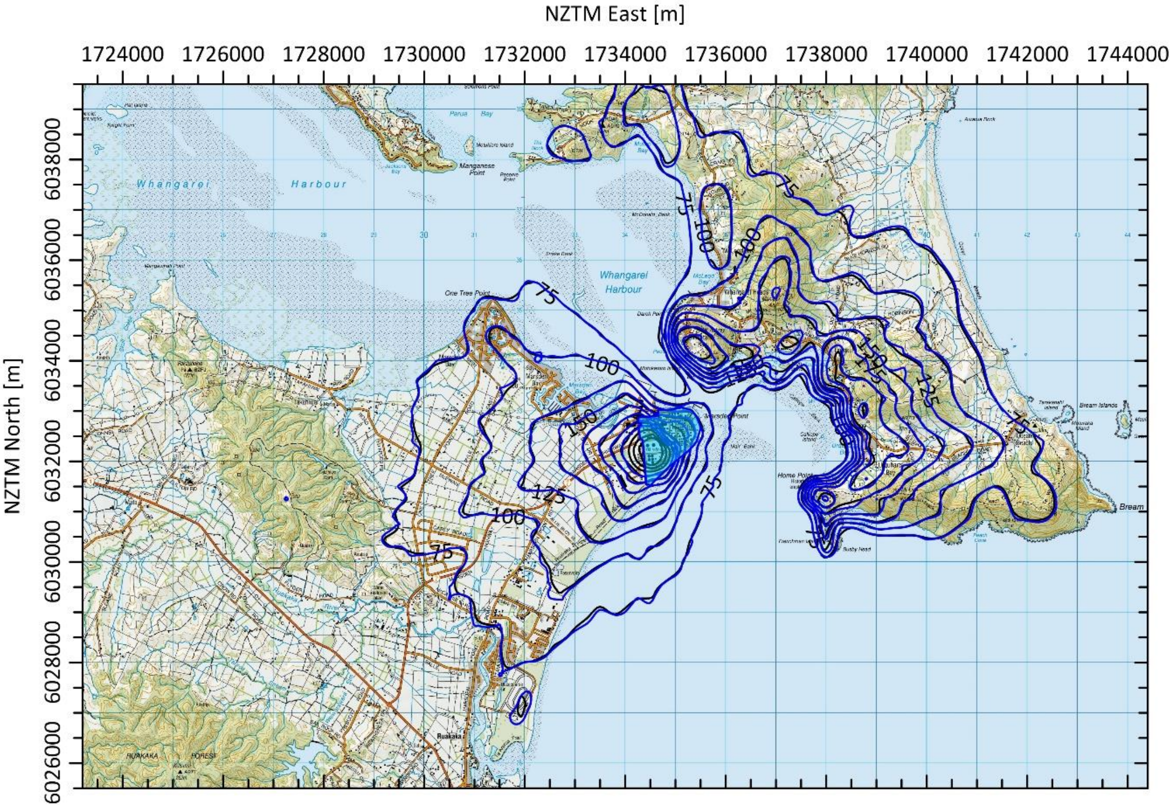

Figure 5.29: Comparison of predicted maximum 1-hour average SO₂ GLCs of the refinery emissions (black contours) with shipping emissions added in (blue contours).

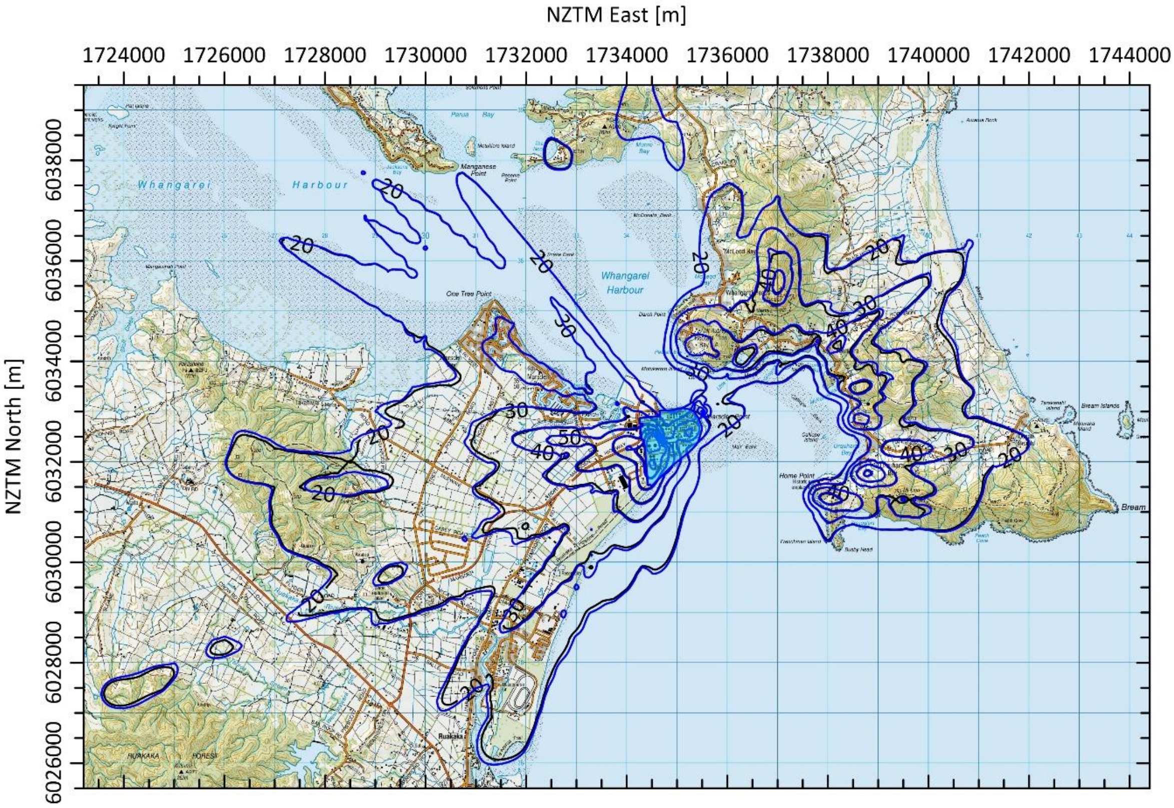

Figure 5.30: Comparison of predicted maximum 24-hour average SO_2 GLCs of the refinery emissions (black contours) with shipping emissions added in (blue contours).

5.4 The flare

Emissions of SO_2 from the operation of the flare have been separately modelled using the US EPA screening model 'SCREEN3', which includes provision for modelling flare sources where a high heat release occurs. As a screening model, the results from SCREEN3 are generally expected to be conservative.

Assessment of the impacts of emissions from the flare are treated separately from the other combustion sources. This is due to the significant variability in the operation of the flare and that different model inputs are required for characterising a flare discharge compared with a normal stack source.

Inputs to SCREEN3 have been derived from the flare gas composition data provided in Appendix D and the measured gas flow rate to the flare (summarised in Figure 3.4). The SCREEN3 model uses the following inputs parameters:

- Flare stack height (m);
- Total heat release rate (calories per second); and
- SO_2 emission rate (g/s).

The heat release rate varies depending on the gas flow rate to the flare – the more gas the more heat release that occurs. For the purposes of assessing the flare emissions, the theoretical calorific value of the flare gas was determined using the average of flare gas analysis data where hydrogen was not the predominant constituent of the gas (provided in Appendix D – samples 150210 and 511502). This gives a calorific value of 11,150 kCal/kg, which was then used to calculate the heat release rate for a number of different scenarios representing different percentile values for the gas flow rate to the flare.

The SO_2 emission rate is derived from the content of hydrogen sulphide (H_2S) in the flare gas and gas flow rate to the flare. This assumes all H_2S is oxidised to SO_2 when combusted. The average H_2S content of 5.7% was derived from the flare gas samples where hydrogen was not the predominant consistent of the gas (Appendix D – samples 150210 and 511502).

Given the above considerations, five model scenarios were derived representing different flow rates of gas to the flare. The parameters for each scenario are provided in Table 5.14. The scenarios for the maximum and 99th percentile gas flow rate are expected to be highly conservative as these events are expected to be dominated by hydrogen gas with significantly lower content of H_2S in the gas.

Table 5.14: SCREEN3 model scenario inputs

Parameter	**Scenario value**				
Percentile of flare gas rate	Maximum	99th%ile	90th%ile	75%ile	50%ile
Flare gas rate (T[gas]/day)	85	53	17	1.7	0.23
Flare gas CV rate (cal/s)	10,995,500	6,841,500	2,156,000	217,000	30,500
Flare gas SO_2 rate (g/s)	63	39	12.4	1.24	0.17

The results for SCREEN3 are outputted as a predicted 1-hour average concentration at varying distances away from the flare source. The model settings, inputs and results are provided in Appendix H and are summarised in Figure 5.31.

The results as illustrated in Figure 5.31 shows the peak 1-hour average SO_2 concentrations for all scenarios occurring at least 500 m from the flare, with concentrations within the first 500 m being no more than 10 to 15 $\mu g/m^3$. Given this, it is unlikely that emissions from the flare will contribute significantly to predicted peak off-site concentrations at the western boundary of the site due to combustion emissions from the main stacks as described in Section 5.2.1.

The scenarios representing the large gas flow rates to the flare give rise to peak impacts that are in the order of 900 m to 1 km from the flare, with concentrations between 50 and 85 $\mu g/m^3$. This is beyond the distance where peak SO_2 impacts due to the main combustion stacks is expected to occur (at the eastern site boundary). At this distance from the flare, the worst case 1-hour average concentration due to stack discharges is approximately 250 $\mu g/m^3$ (including background). Adding the predicted 1-hour average SO_2 concentration of up to 85 $\mu g/m^3$ due to flare emissions would not result in an exceedance of the NES_{AQ} for SO_2. Further afield at the nearest residential areas of Marsden Cove Marina and Little Munro Bay, predicted concentrations due to flare emissions are further reduced and the cumulative effect with stack discharges will be lower still.

Notwithstanding the above, we consider the SCREEN3 model predictions of the flare emissions to be conservative due to:

i Using a screening model, which is purposefully designed to give conservative predictions of ground level concentrations;

ii Large flaring events typically comprising a high portion of hydrogen gas and a relatively small proportion of H_2S; and

iii The likelihood that significant stack sources of SO_2 will have reduced emission rates at times when a large flaring even occurs.

Further consideration of the impacts of SO_2 emissions from the flare are provided in Section 5.5, which considers the ambient SO_2 monitoring.

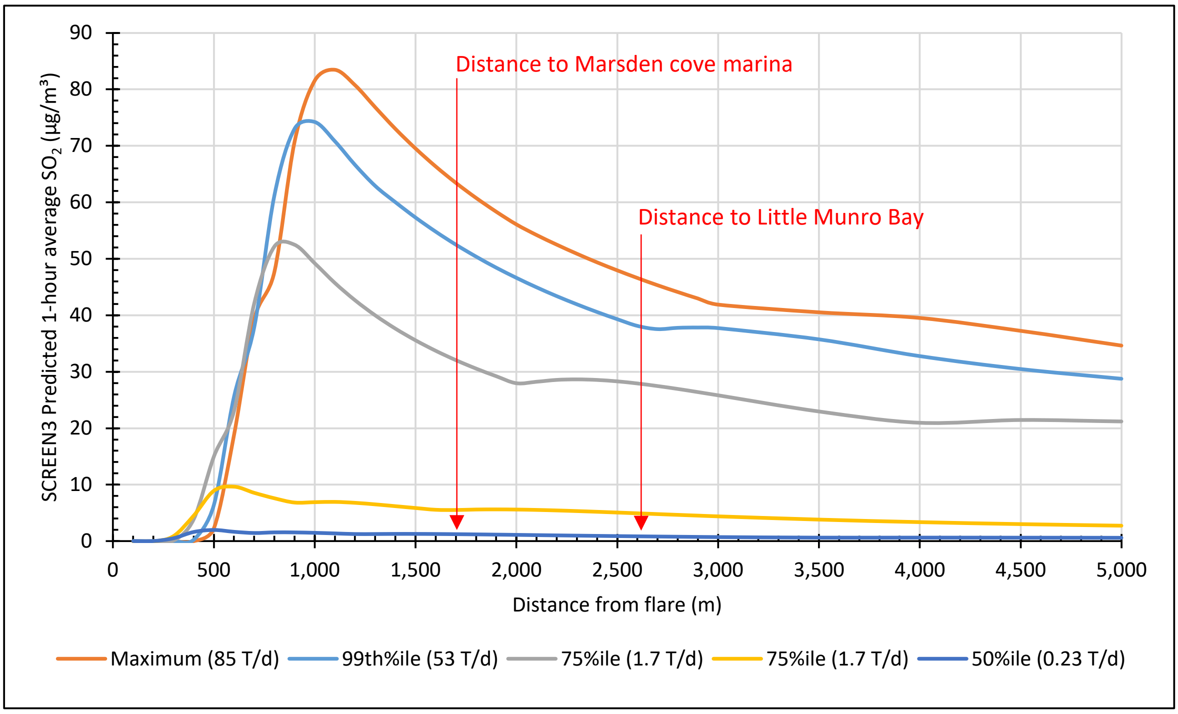

Figure 5.31: Predicted 1-hour average SO_2 ground level concentrations due to flare emissions varying by gas flow rate to flare. Model results do not include contribution from other site sources.

5.5 Detailed evaluation of ambient sulphur dioxide monitoring data

5.5.1 Introduction

Further analysis (to that in Section 4.3.1) of the ambient SO_2 monitoring data is presented here to evaluate the results of the modelling and to examine the possible cumulative impacts of the flare emissions, which are not able to be reliably modelled.

This analysis is undertaken in two parts:

- Evaluating the monitoring data in terms of the wind conditions so as to confirm peak SO_2 concentrations are from the direction of the Refinery, jetty and Northport; and
- Direct comparison of the model results against monitoring results.

5.5.2 Evaluation with winds

Polar plots are a useful too that combines ambient monitoring data and concurrent wind monitoring data together, providing a graphical representation of the direction from which peak concentrations occur from and the typical wind speed associated with those conditions. Polar plots have been generated based on the 95th percentile of 1-hour average SO_2 concentrations measured at the three monitoring sites on the opposite side of the harbour from the Refinery. Although wind speed and direction is measured at each of these three stations, a review of that wind data identified that it was not of sufficient quality[10] for the analysis and so that wind data from the Refinery site was used instead.

Figure 5.32 provides polar plots for the three monitoring sites. Overall, the three plots show measured SO_2 concentrations originating from the direction of the Refinery, and are predominantly being transported in average wind speeds between 5 and 10 m/s.

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[10] This is due to the very short mast on which wind monitoring equipment is fitted to.

Little Munro Bay recorded higher concentrations than the other two sites in lower wind speed conditions. This may be due in part to its closer proximity to Refining NZ but also potentially due to the impact of shipping emissions at this location and localised impacts of shipping emissions would likely occur at lower speeds than those associated with the Refinery.

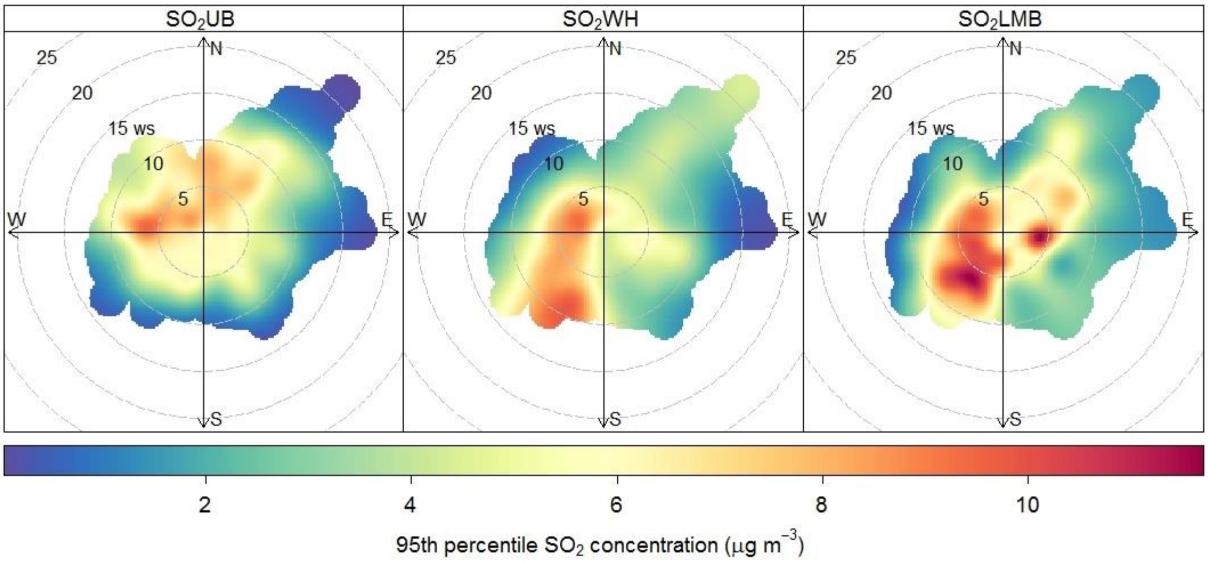

Figure 5.32: Polar plots of the 95th percentile ambient 1-hour average SO_2 measurements from January 2013 – September 2017 at Urquharts Bay, Whangarei Heads and Little Munro Bay, respectively.

5.5.3 Evaluation of model results

Quantile-quantile plots allow for the comparison of two disparate datasets, such as model predictions derived from meteorology for 2011 and 2012, with monitoring data for the period of 2013 through to 2018. Concentrations for each percentile (1st through to 100th) are calculated from each dataset and the plotted against each other. The resulting quantile-quantile plot enables a general comparison of model performance against measured concentrations.

Figure 5.33 provides quantile-quantile plots of both 1-hour average and 24-hour average SO_2 concentrations derived from the observed ambient monitoring data for Little Munro Bay from 2013 to 2018 with the model predicted concentrations for the same location (2011 to 2012). From these plots the following conclusions are made:

- For 1-hour average concentrations, the model typically over-predicts concentrations relative to the observed concentrations. This is to be expected given the model was configured for worst-case maximum emission rates occurring for all hours of the years modelled. For example, an observed 1-hour average SO_2 concentrations of 50 µg/m³ corresponds to the 99.7th percentile of measured concentrations between 2013 and 2018. By comparison, the 99.7th 1-hour average modelled concentration is 151 µg/m³;
- Notwithstanding the above comment, the maximum 1-hour average observed concentration (250 µg/m³) is significantly higher than the model predicted maximum 1-hour concentration (181 µg/m³). This appears to be an outlier, with the second-highest concentration being approximately 155 µg/m³, corresponding well with the modelled highest concentration;
- The observed highest 1-hour average concentration of 241 µg/m³ occurred on 9 March 2016 at 9 pm. The observed wind conditions for this hour were relatively light (2 m/s) from 230 °N (SW), with the monitoring site being generally downwind of the Refinery from 10 am onwards. However, of note is that this date also corresponds with a period where there

was a significant electrical fault with the hydrocracker, causing it to go into safe shutdown and off-gas to be diverted to the flares, resulting in a significant flaring event;

- The modelled 24-hour average is typically higher than the observed 24-hour concentration. This is with the exception of the highest observed concentration of 51 µg/m³ on 29 July 2013, which is approximately 7 µg/m³ higher than the modelled concentration. Winds during this day varied between 200° to 300°N and were generally from the direction of the site refinery, jetty and port. The corresponding daily SO_2 emission rate from the site on this date was 5.57 T/d and well below the annual average daily limit of 12 T/day; and
- Figure 5.34 provides a time-series plot of wind speed, direction and hourly average SO_2 concentrations measured at Little Munro Bay on 29 July 2013. This plot identifies as a shaded box the values that would coincide with winds blowing from the Refinery to the monitor (from 190 to 240 °N), which occurs from 11 am through to 10 pm under wind speeds of 2.5 to 4.5 m/s. Concentrations during this period do peak, with hourly values reaching approximately 150 µg/m³. However, similarly high SO_2 concentrations occur between 6 and 9 am when the winds are from 260 to 290 °N and below 2 m/s. These winds do not strictly align with the Refinery but rather the Northport. Given the wind direction and the lower wind speeds it is possible that the shipping emissions associated with port activities may have been responsible for these elevated concentrations.

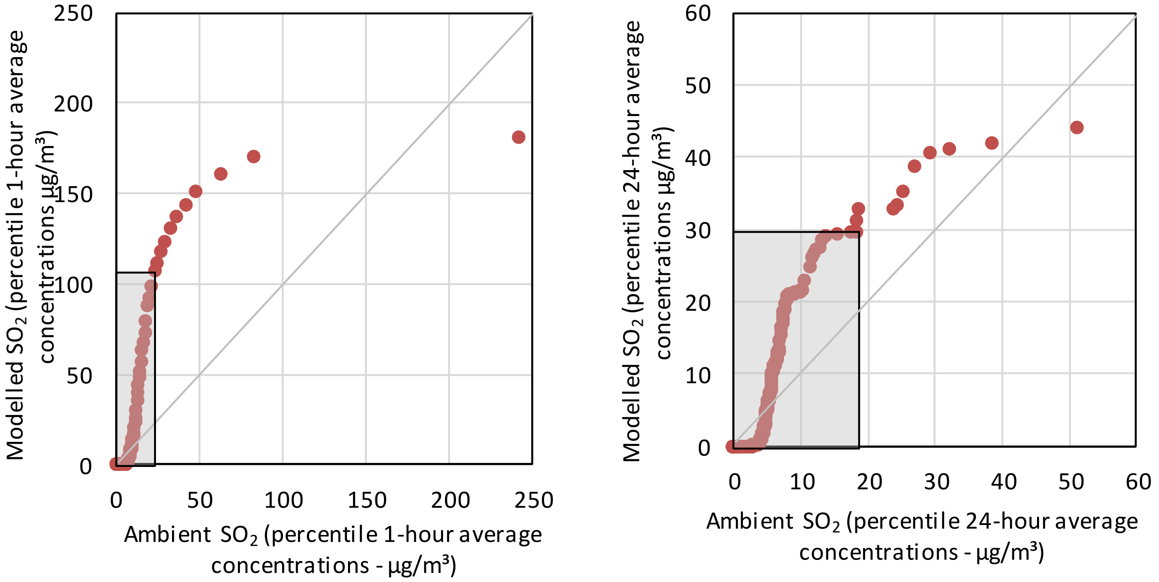

Figure 5.33: Quantile-quantile plots of ranked percentile concentrations for model predicted and observed SO_2 concentrations at Little Munro Bay – data at 0.1% intervals. Shaded area of each plot represents concentrations that are below the 99th percentile of modelled and observed data.

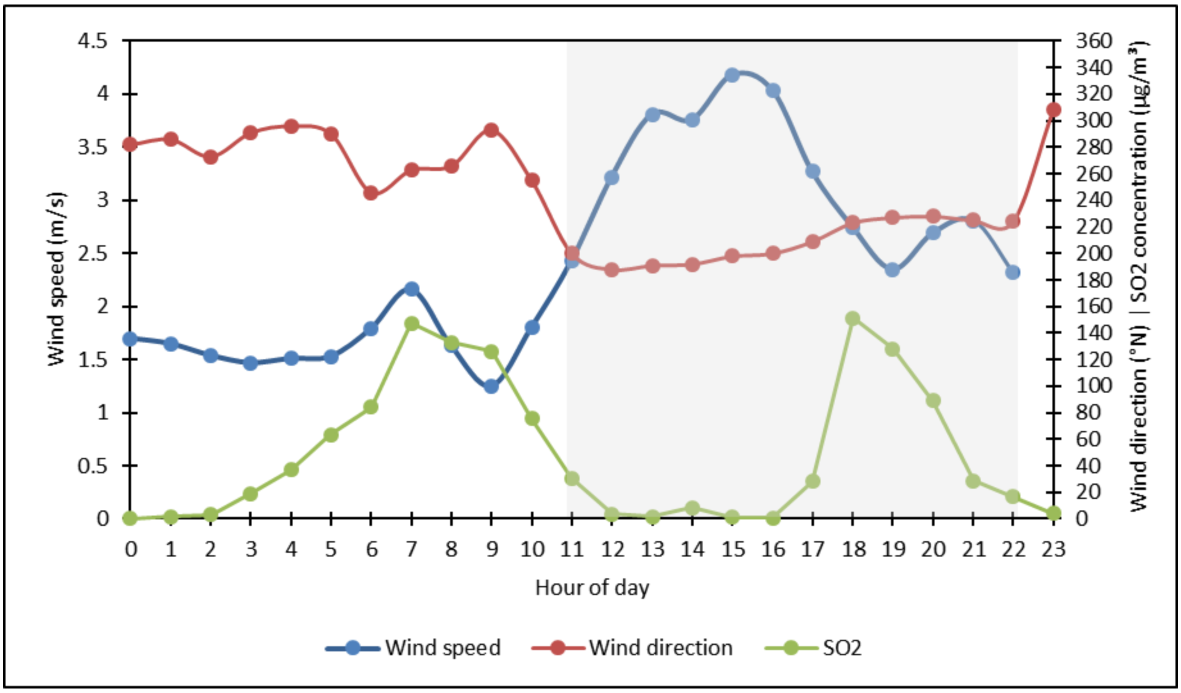

Figure 5.34: Wind condition on 23 July 2013 as measured at the Refinery site. Shaded area indicates wind directions that could carry

5.6 Conclusions

Dispersion modelling has been used to assess the potential cumulative effects of SO_2 emissions from the furnace stacks. The assessment predicts cumulative concentrations for all relevant averaging periods (1-hour, 24-hour and annual) will be below applicable assessment criteria. This includes consideration of naturally occurring background concentrations and the effect of shipping emissions associated with the largest class of ship that can be berthed at the site's Jetty.

Flaring emissions have been separately evaluated using a screening model, which predicts peak impacts from the flare will occur at least 500 m from the flare and for large events more typically 900 m to 1 km from the flare. At these distances, the peak SO_2 impacts of the flare will not coincide with the peak impacts of the main stack discharges. This is because of the different manner in which flare emissions will disperse in the atmosphere due to the significant thermal buoyancy effect of the flare. Analysis of the cumulative effects of the flare modelling results with those of the main stack discharges indicates that the NES_{AQ} for SO_2 should not be exceeded.

The results of the modelling generally compare well with (and tend to over-predict) ambient SO_2 measurements from the opposite (northern) side of the bay. A single exception to this exists in terms of 1-hour SO_2 concentrations, which appear to have coincided with a significant flaring event associated with an unplanned shutdown of the hydrocracker. This event highlights the potential contribution of the irregular and intermittent emissions from the flare. However, the comparison of modelled and measured SO_2 concentrations shows that the exclusion of flare emissions from the modelling does not result in under-prediction of the impacts on SO_2 concentrations at sensitive locations. This suggests that the impact of intermittent flare emissions is not significant in the context of the overall effects of site discharges and is consistent with the modelling of the flare emissions.

Given the above, there is no barrier in terms of Regulation 21 of the NES_{AQ} to granting resource consent for the ongoing discharge of SO_2 emissions from the Refinery.

Predicted cumulative PM_{10}, $PM_{2.5}$, NO_2, and CO concentrations at all locations beyond the site are low relative to the relevant assessment criteria. Given this, there is no barrier in terms of Regulation 20 of the NES_{AQ} to granting resource consent for the ongoing discharge of NO_X and CO emissions from the Refinery.

Predicted dioxin and furans concentrations are very low relative to the guideline, constituting only 0.000003% of the guideline.

The assessment of metal discharges shows very low ground level concentrations relative to health based guidelines for all metals assessed except nickel. For nickel, the 8-hour average concentration is predicted to exceed the OEHHA guideline, albeit infrequently. This guideline is based on the repeated 8-hour exposure over a significant fraction of a lifetime. However, additional analysis shows a low frequency of exposure to concentrations above the guideline. Further consideration of this matter is provided by the assessment prepared by Environmental Medicine Limited.

In terms of model uncertainty, the evaluation of modelled and observed concentrations clearly demonstrates the model over predicting concentrations, with the exception of a single hourly event (attributed to a flaring event) and a single 24-hour concentration (attributed in part to both the refinery and possibly shipping emissions). Put another way, this means that the predicted results are conservative and represent a worst case scenario.

When the predicted cumulative contaminant concentrations are evaluated against the relevant assessment criteria with the framework set out by the IAQM (2009), the potential adverse effects of discharges on air quality are considered to be less than minor, including for the most impacted sensitive locations. This is with the exception of the predicted concentration of nickel (8-hour average) over Reotahi, which is considered further in the report by Environmental Medicine Limited. Based on the review by Environmental Medicine Limited, we consider that the potential adverse effects of nickel are less than minor.

6 Assessment of Effects – Fugitive Emissions

6.1 Assessment method

As discussed in Section 3.2, the key indicator contaminants associated with VOC losses are the group of VOCs collectively known as BTEX (benzene, toluene, ethylbenzene and xylene). Ambient BTEX concentrations are relatively straightforward to monitor using passive sampling badges, and when measured over a sufficiently long period provide a robust indication of actual levels of exposure that may be experienced beyond site. Accordingly, the assessment of fugitive emission from the refinery site is based on an ambient monitoring programme that measures concentrations at several key locations surrounding the refinery. The results of the monitoring programme are then evaluated against relevant health based guidelines for benzene, toluene, ethylbenzene and xylene (discussed below in Section 6.2).

Given the difficulties in currently quantifying fugitive emissions (compared to the point emission sources on-site), the assessment approach based on monitoring of ambient BTEX levels is considered more robust than an approach based on using dispersion modelling of fugitive emission estimates.

The monitoring programme commenced at the start of June 2019 and will run for a period of 12 months. Monitoring is undertaken using 3M model 3500 organic vapour monitors (“badges”). These are comprised of a single charcoal sorbent water for collection of organic vapours by diffusion. The badges are deployed for a month, after which they are removed and sent for analysis, and a new badge deployed.

Five monitoring sites have been established, representing the nearest residential and industrial locations to the site. Details of the monitoring sites are provided in Table 6.1 and the locations indicated Figure 6.1. The monitoring site locations were chosen based on the following:

- Dispersion modelling of a hypothetical fugitive emission source (represented as a volume source within the model) representing the entire Refining NZ site was used to better understand the distribution of relative impacts and assist in determining the location of the monitoring sites. The modelled contours (value and unitless) are overlaid in Figure 6.1 and illustrate the greatest impacts being very close to the site and then reducing significantly with distance. That said, the general distribution extends to the east into the harbour;
- The location of the nearest sensitive residential areas, taking into account the modelled distribution of potential impacts. These will be the locations where annual average exposure is most relevant; and
- Impacts at the nearest industrial operations (Northport and CHH LVL Plant).

Table 6.1: Monitoring locations

Location / sample ID	Site category	Description	Duplicate sample
1	Residential	Adjacent the boundary of the nearest residential receptors in the Marsden Bay development on Albany Road.	Yes
2	Industrial	At the boundary between Northport and the Marsden Point refinery.	Yes
3	Industrial	At the property boundary of the Carter Holt Harvey (CHH) Laminated Veneer Lumber (LVL) Plant.	No
4	Residential	Adjacent the boundary of residential receptors in Little Munroe Bay on Bay View Road.	No
5	Residential	Adjacent the boundary of residential receptors in Urquhart's Bay on Urquhart's Bay Road.	No

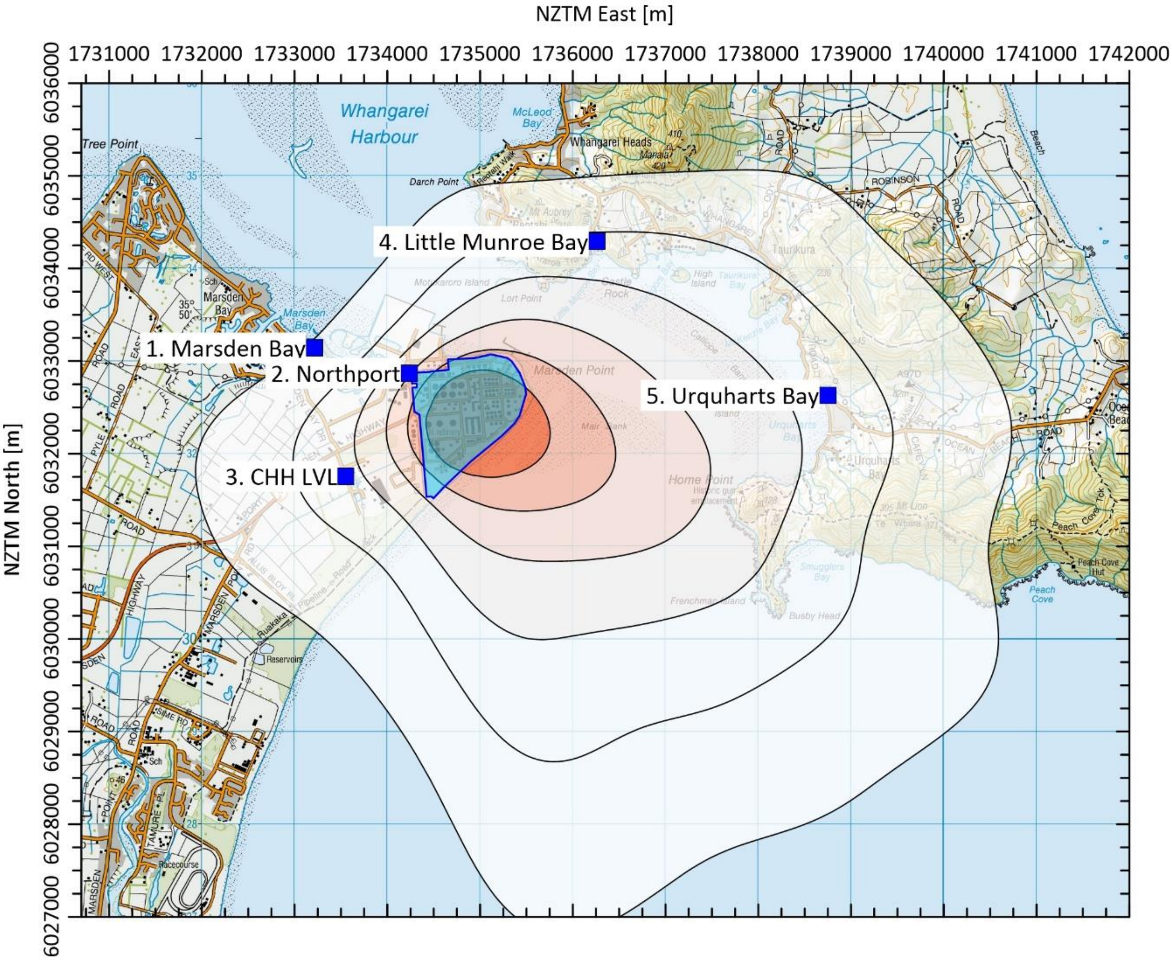

Figure 6.1: Location of BTEX monitoring sites and indicative dispersion of fugitive emissions from site (shaded contours).

6.2 Assessment criteria

The results of the monitoring are assessed against relevant assessment criteria for each BTEX contaminant. The selection of the assessment criteria follows the same approach as described in section 5.1.3. The relevant criteria are provided in Table 6.2.

Table 6.2: **BTEX monitoring assessment criteria**

Contaminant	**Averaging period for assessment criteria (µg/m³)**	**Reference source**
	Annual average	
Benzene	3.6	AAQG
Toluene	300	OEHHA
ethylbenzene	2,000	OEHHA
and xylene	700	OEHHA

6.3 Results

6.3.1 Historic monitoring

Passive BTEX sampling was undertaken for a period of 18 months between 2002 and 2003 and four sites – two immediately adjacent to the Refining NZ site boundary (referred to as the Jetty and Mair Road sites) and two at sensitive locations on the eastern side of the harbour (Little Munro and Reotahi). The results of the latter two sites, where human exposure is most relevant, are provided in Table 6.3 and can be compared against relevant air quality criteria for chronic (annual) exposure. From this comparison, it is evident that BTEX concentrations were well below the relevant air quality criteria for Little Munro and Reotahi where continuous human exposure is relevant.

The reported levels for Mair Road and the Jetty were below relevant guidelines except for benzene. However, at these two locations continuous human exposure is not relevant given the industrial location and therefore exceedance of that guideline is not material.

Table 6.3: **BTEX sampling results – Whangarei Heads – June 2002 to March 2003. All results in µg/m³. Source – ARGO 2003**

Location	**Benzene**	**Toluene**	**Ethylbenzene**	**m+p-xylene**	**o-xylene**
Assessment criteria (source)	**3.6 (AAQG)**	**300 (OEHHA)**	**2,000 (OEHHA)**	**700 (OEHHA)**	
Little Munro (residential)	0.53	0.76	0.79	0.69	0.69
Reotahi (residential)	0.53	0.62	0.69	069	0.69
Mair Road (industrial)	5.93	11.84	1.3	5.02	1.41
Jetty (industrial)	4.47	11.85	1.29	5.83	1.81

6.3.2 2019 monitoring programme

An ambient monitoring programme to measure BTEX concentrations was commenced in June 2019 and will run for a period of 12 months as described above. This monitoring will complement and update the historic monitoring undertaken in 2003 and further support the assessment of fugitive emissions from the Refinery. The BTEX monitoring is being undertaken at five sites described in Section 6.1.

At the time of preparation of this report, four rounds of monthly monitoring data were available and are summarised in Table 6.4 The results were below the limit of detection (LOD) for all contaminants with the exception of toluene, for which concentrations just above the LOD were recorded. In all cases, the measured concentrations were also below the relevant assessment criteria.

When compared with the results for the historic monitoring, the concentrations for benzene at the industrial sites (2 and 3) have noticeably reduced, with monthly concentrations within the AAQGL of 3.6 µg/m³. This is a preliminary comparison as sufficient data is not yet available to derive an annual average concentration for benzene, but is nevertheless expected to provide a strong indication of reduced ambient levels. It is considered that this change from historic levels is likely due to the changes in the fuel quality standards and subsequent measures taken at the Refinery to reduce benzene levels in the fuel that it produces.

Table 6.4: BTEX sampling results – Whangarei Heads – maximum monthly concentration for June to September 2019. All results in µg/m³. Source – ARGO 2003

Location	Benzene	Toluene	Ethylbenzene	m+p-xylene	o-xylene
Assessment criteria (source)	**3.6 (AAQG)**	**300 (OEHHA)**	**2,000 (OEHHA)**	**700 (OEHHA)**	
1 Marsden Bay*	<1	<1	<2	<4	<2
2 Northport Boundary	<1	8	<2	<4	<2
3 CHH LVL Plant	<1	<1	<2	<4	<2
4 Little Munroe Bay	<1	<4	<2	<4	<2
5. Urquharts Bay	<1	5	<2	<4	<2

Note: * only one month of data is available due to vandalism of the monitor in July.

6.4 Conclusion

The historic monitoring of ambient BTEX levels were well below the relevant assessment criteria for the sensitive locations surrounding the site where annual average exposure is relevant. At the two industrial monitoring sites benzene concentrations were below the then ambient air quality guideline (10 µg/m³ annual average) but would be above the current guideline level of 3.6 µg/m³ (annual average). However, continuous exposure over a year would not occur at these locations given the industrial nature of the site and that people would not reasonably be present for 24 hours per day and 365 days per year.

The preliminary results of the 2019 BTEX monitoring programme currently underway indicates concentrations that are well within the relevant assessment criteria. This includes the results for benzene at the nearest industrial locations. This apparent reduction in benzene is expected to be as a result of changes to the Refinery process to meet current fuel specifications for benzene.

On the basis of the results from the historic and current BTEX monitoring programmes, it is concluded that fugitive emissions from the site are having a less than minor effect at sensitive locations beyond the site boundary.

7 Assessment of Effects – Odour Emissions

7.1 Assessment method

The odour effects associated with the Refinery have been assessed qualitatively in line with MfE guidance (MfE 2016b). This includes a review of complaint records, wind information conducive to poor dispersion of odours and an objective evaluation of potential odour impacts in terms of the frequency, duration, intensity, offensiveness of impacts at sensitive locations (the FIDOL factors).

7.2 Assessment

While odour complaints (or a lack thereof) are not conclusive indicators of odour nuisance effects or an absence of those effects, the record of odour complaints and confirmed incidences of offensive or objectionable odour can provide a broad indication of odour nuisance experienced near existing operations.

The frequency of odour complaints received by Refining NZ are summarised in Table 7.1 – these records exclude complaints relating to other environmental issues such as noise. Overall, the level of recorded complaints relating to odour since 2015 has been very low for a large heavy industrial complex such as the Refinery, with only 19 complaints being recorded over the 4.5 year period. The bulk of these complaints (15) were received in 2016 and 2017. Further analysis of the complaints over this period indicates that not all of the recorded complaints are likely to have originated from the Refinery, but the majority are based on analysis of wind conditions at the time of the complaint and the description of the odours given.

Table 7.1 Summary of complaints received regarding odour from the site, 2015 to 2019

Year	# complaints	Detail
2015	2	Both complaints occurred over two days and were traced back to a process upset associated with the biotreater lasting for a few days. Winds were from the south and blowing towards the location where the complaints originated from (Little Munro Bay and McLeods Bay).
2016	7	Two of the seven complaints occurred on 2 April 2016 originating from One Tree Point and relating to hydrocarbon odours. However, the winds were from the Northwest at this time and unlikely to have originated from the site. The remainder five complaints were all associated with locations downwind of the site at the time of the complaint, include One Tree Point, Marsden Bay, Little Munro Bay and Whangarei Heads (within a radius of approximately 4 km). In most cases the source of the odour was not determined, with the exception of one complaint that was possibly linked to shipping and not the refinery. Descriptions of the odours where recorded included an 'oily smell', 'hydrocarbon smell', 'sulphur-methane smell', all of which could be associated with refinery activities. The duration of recorded odour exposure varies between less than an hour to several days.
2017	8	Of the eight complaints received, two are not likely to have been caused by the refinery as the winds were not in the direction of the complainants on those occasions. Of the remaining six complaints, these originated from Little Munro Bay, Whangarei Heads, Reotahi and Taurikura (i.e., within a radius of approximately 4 km).

Year	# complaints	Detail
		Reported durations for the six downwind complaints are mostly unknown.
2018	1	The odour complaint recorded for 2018 related to 'Shutdown 2018' and occurred on 2 May 2018. The location of the complainant was not recorded.
2019	1	A single complaint received as at June 2019 relating to odour observed at One Tree Point on 20 March.
2020	1	A complaint regarding strong odour experienced at Ody Road, Whangarei Heads throughout 4 January 2020. Strong winds from the southwest were present throughout the day. Refinery operation was normal within discharge limits. Monitoring of ambient SO_2 at Whangarei heads showed levels in the excellent range. This indicates the stack emission were unlikely to be significantly contributing to the described odour. No refinery shipping related activity was occurring and no other obvious odour sources were identified on site.

Local meteorology has an important role in the dispersion of odours. Strong winds will act to rapidly disperse and dilute odours, whereas light winds (typically below 2.5 m/s) will poorly disperse and dilute odours and are therefore 'worst-case' in terms of odour effects. Figure 7.1 provides a windrose for the site overlaid onto of an aerial of the site, showing the direction from which light winds typically blow. From this, it is evident that the vast majority of light wind is from the upper harbour (westerly) and would carry odours away from most sensitive residential locations. Light winds from the east (which could carry odours towards One Tree Point and Marsden Bay) are very infrequent. Similarly, winds from the southeast through to south that could carry odours towards Reotahi, Whangarei Heads and Little Munro Bay are also infrequent. This analysis is consistent with the relative low number of odour complaints from these locations associated with the Refinery.

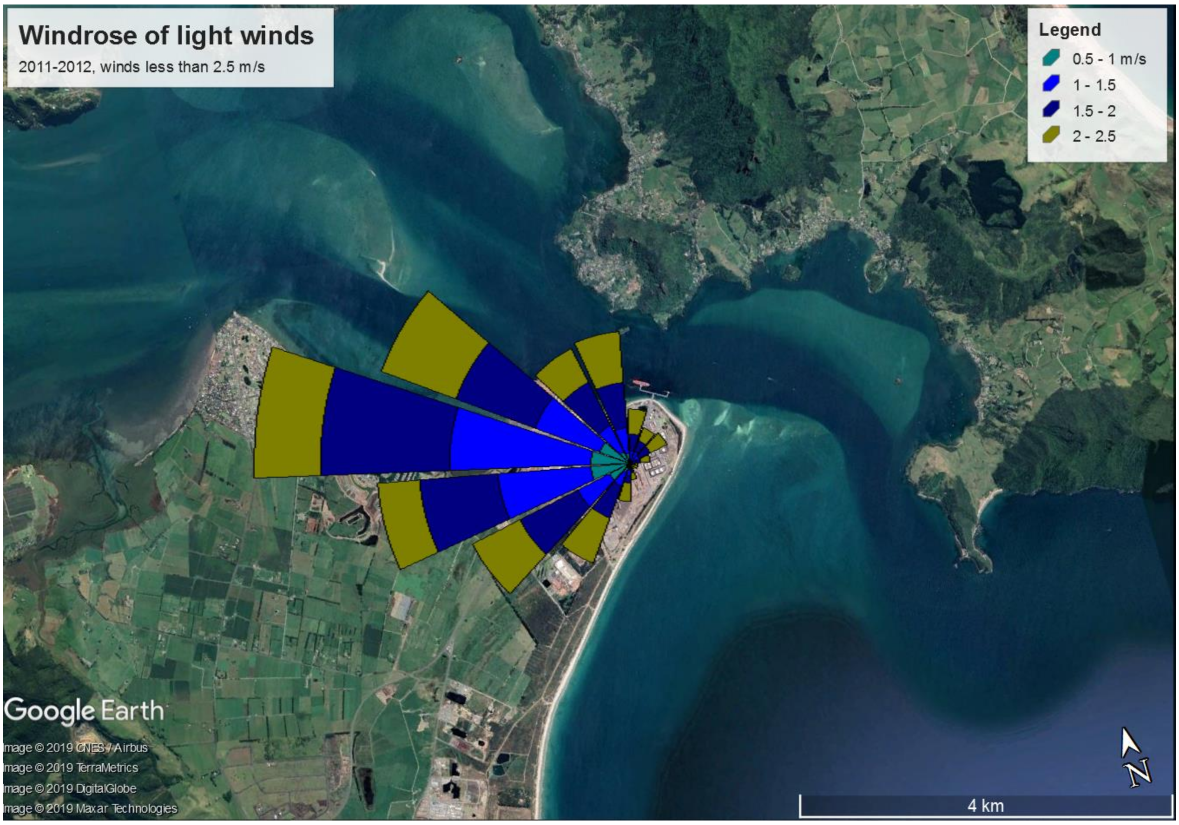

Figure 7.1: Windrose showing light winds (≤ 2.5 m/s) measured at the Refinery for 2011 – 2012.

The potential for offensive or objectionable odour effects can be objectively assessed by considering the FIDOL factors (frequency, intensity, duration, offensiveness/character and location) for locations where odour may be observed. A FIDOL assessment of odour impacts, informed by the above complaints analysis, is provided in Table 7.2.

Table 7.2: FIDOL odour assessment

Frequency	The frequency of exposure to odours is a function of both the frequency of discharges and the frequency of winds that might carry odours towards a sensitive receptor location. On-site activities that give rise to odour will be intermittent, typically associated with a particular activity or event. Winds, particularly light winds that are worst case for dispersing odours, blow infrequently from the direction of the Refinery towards sensitive locations as discussed above. The combination of both infrequent wind conditions and odour activities means the overall frequency of odour events should be low. This is also reflected in complaint records being relatively infrequent (up to six valid complaints per year since 2015, and only one for each of 2018,2019 and 2020 to date).
Intensity	The intensity of odour impacts (i.e., the strength of odours) is difficult to ascertain from complaint records, with the exception of the most recent complaint in 2020 which notes the occurrence of strong odour. However, given that sensitive locations are located a significant distance from the site, it is expected any odours would normally be significantly diluted by the time they reach those locations. Given this, it is expected that the strength of any such odours is at worst distinct, and that strong odours are unlikely.
Duration	The duration of odour exposure depends on both exposure to winds from the direction of the refinery and in relation to events. Wind data suggests very infrequent light winds (and therefore duration) blowing towards sensitive locations surrounding the site. This is reflected in records where the odour exposure duration is recorded, which is mostly less than 1-hour.
Offensiveness	The descriptions of odours recorded in complaint records include ‘oily’, ’hydrocarbon’, ‘sulphur/methane’. These types of odours are generally considered to be unpleasant in character.
Location	Sensitive locations surrounding the site are buffered by the adjoining industrial zone and port, or the Whangarei Harbour. The industrial zone and port are considered to be of a low sensitivity to any odour impacts.

On balance, given the relatively low level of recent odour complaints, the infrequent light wind conditions that could transport odours towards sensitive locations, and the overall FIDOL analysis, it is considered that odour effects as a result of discharges from the Refinery are less than minor.

8 Assessment of Effects – Dust Emissions

8.1 Assessment method

Potential adverse dust effects associated with the abrasive blasting activities undertaken at the site are assessed using a qualitative approach consistent with MfE guidance (2016c). The approach considers the FIDOL factors in terms of the potential impacts at sensitive locations. It also considers published separation distance criteria relating to dust impacts associated with the activity.

In the absence of any published separation distance guidance in New Zealand, published guidance from various state environmental protection authorities in Australia are widely adopted and accepted by regulatory agencies in New Zealand. Of the various Australian state EPAs, only the South Australia EPA (2016) lists recommended separation distances for dust associated with abrasive blasting. That guidance recommends the following:

- 500 m for dry abrasive cleaning in open; and
- 300 m for wet abrasive cleaning in the open.

8.2 Assessment

Separation distances from the site infrastructure where abrasive blasting may be undertaken in shown in Figure 8.2. From this figure, it is clear that there are no sensitive residential locations within a 500 m of the site infrastructure, although users of the beach adjacent to the refinery may be downwind on occasions. The only other activities within this distance are the port and the Carter Holt Harvey plant, but which are considered to have a low sensitivity to dust impacts and will in themselves be a source of dust in the wider environment.

Table 8.1: FIDOL dust assessment

Frequency	Frequency is determined by the both the frequency of an activity and the frequency that a sensitive location is downwind. Prevailing winds, particularly those that are strong with the potential to transport dust (≥ 5 m/s, see Figure 8.1), are from the east to northeast. Winds from this direction would transport any dust inland towards the surrounding industrial area where the CHC plant is located. Winds blowing from the west-southwest occur less frequently, but have the potential to transport dust towards the marine environment. However, this can be managed by planning blasting activities closest to the coast to take place on days when the wind is from an off-shore direction. Winds from the southeast are also prevalent and have the potential to transport material to the northwest the direction of the port. In terms of the frequency of the activity, this varies significantly depending on site requirements, but may occur on a monthly basis.
Intensity	Intensity of impacts will reduce significantly with distance from blasting activities. The majority of any dust will deposit within the first 100 m where dust intensities will be greatest. Beyond 500 m effects are expected to be negligible. The intensity is also a function of the scale of the activity being undertaken, with larger scale maintenance projects potentially resulting in more intensive abrasive blasting activities and potential impacts
Duration	In terms of the generation of dust emissions, the duration of the activity may be in the order of an hour to several days depending on the nature and scale of the activity.

	However, this is further moderated by the duration that the wind blows in a particular direction.
Offensiveness	The dust generated by the activity will contain mineral dust from the garnet abrasive sand, as well as paint and metal (particularly zinc). Given this is expected to be of a more offensive character that inert aggregate or soil derived dust, with the potential for surface contamination.
Location	The immediate receiving environment where blasting may occur (i.e., within 500 m is largely insensitive to dust impacts), being largely industrial or port land. However, the adjoining marine environment is likely to be more sensitive to dust deposition impacts with the potential for contaminating marine sediments.

In summary, given the above consideration of the FIDOL factors, it is considered that the potential for dust nuisance effects is very low, primarily as a function of there being no sensitive human receptors near to the site. There is the potential for impact on the marine environment through possible contamination of marine sediments resulting from wind-blown deposition of dust. However, this can be avoided by managing blasting activities near the coast and avoiding blasting during winds that could carry material into the marine environment.

In conclusion, it is considered that the potential adverse air quality effects associated with abrasive blasting at the site can be managed in a manner that will ensure that effects are less than minor. This is on the basis that standard industry good practice measures are used to minimise dust emissions, including the use of low silica blasting media.

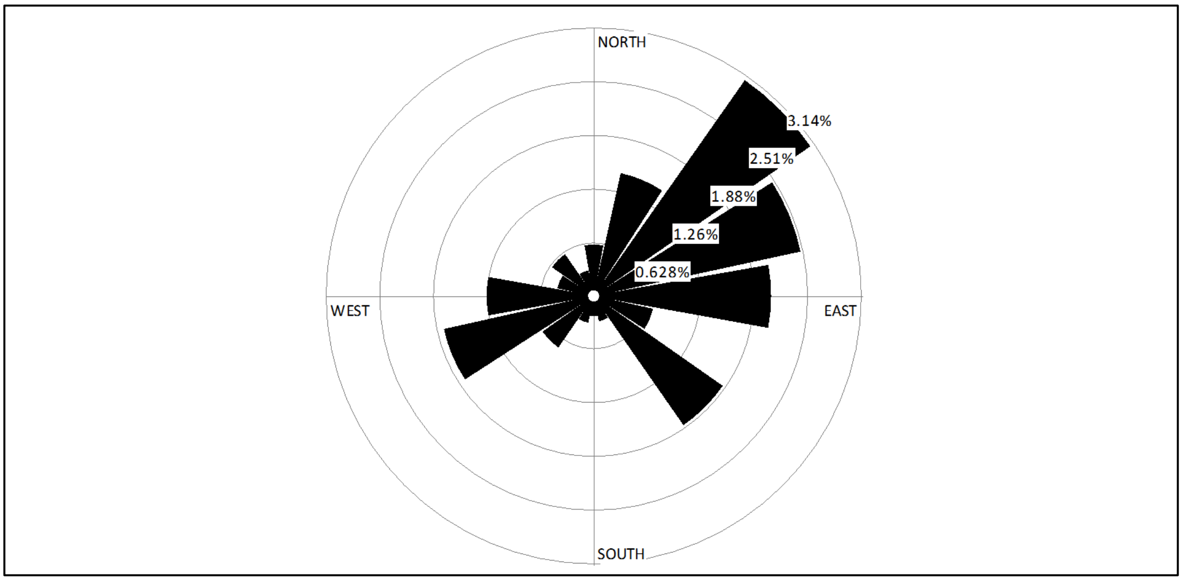

Figure 8.1: Strong winds (≥ 5 m/s) measured at the site and adjusted for an equivalent 10 m height – year 2011-2012.

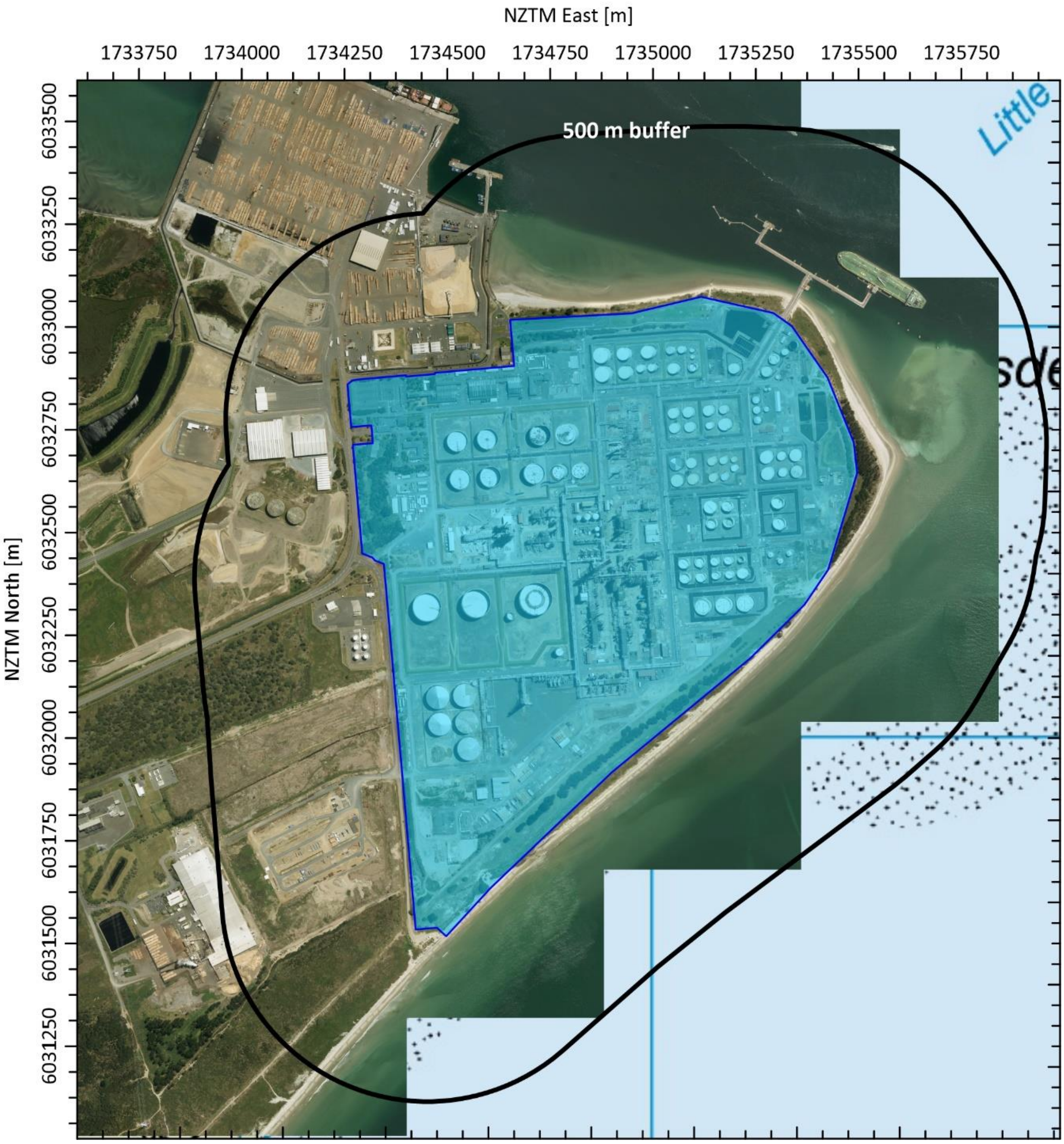

Figure 8.2: 500 m buffer distance from structures and tanks that could require abrasive blasting. Blue shaded area indicates the Refining NZ site.

9 Mitigation and Monitoring

9.1 Mitigation

Mitigation of combustion emissions from the site is principally achieved through dispersion of emissions from the site's tall discharge stacks. This is combined with the management of sulphur containing fuels to manage SO_2 emissions on a daily basis within consent limits and avoid excessive discharges. Refining NZ (2019) advises that it minimises liquid fuel firing (and therefore SO_2 emissions) by maximising the use of natural gas where possible and stockpiles fuel oil stocks when processing low sulphur crude. Routine maintenance of combustion plant is also undertaken to ensure efficient combustion conditions that minimise particulate matter discharges.

The installation of flue gas desulphurisation to reduce SO_2 emissions is a control measure that can be employed for new discharge sources and where it is necessary to manage potential adverse effects. Such measures have been investigated by Refining NZ (2019), but the significant capital costs (US$120 m +50%/-20%) are considered by Refining NZ to not be justified in the context of the assessed 'less than minor' effects of SO_2 emissions. Consequently, the significant investment in desulphurisation technology is not considered the best practicable option.

Notwithstanding the above, we consider that the existing level of mitigation associated with combustion discharges is appropriate given:

- The scale and degree of effects associated with combustion discharges;
- the assessment that those discharge give rise to effects that are less than minor; and
- The relative separation of the site from sensitive locations (e.g., residential areas).

Fugitive emissions have been assessed as being less than minor beyond the site boundary (see Section 6). This reflects the Refinery's high level of control of VOC leaks and very high level of containment and several other measures used to minimise fugitive emissions that are described in Refining NZ (2010).

Eliminating SO_2 emissions from the operation of the flare is not possible, as it a vital safety mechanism for the site, with no viable alternatives (Refining NZ 2019).

9.2 Monitoring

Refining NZ currently undertakes ambient monitoring of SO_2 at three locations on the opposite side of the Whangarei Harbour as discussed in Section 4.3.1 and it is recommended that this monitoring continue to occur.

In addition to ambient monitoring, Refining NZ undertakes routine stack emission monitoring at nine-month intervals for the purpose of quantifying SO_2, total suspended particulate matter (TSP), and nitrogen oxides. It is recommended that this stack monitoring continue to occur, albeit that the monitoring of TSP be replaced with the monitoring of PM_{10}.

The opacity (smokiness) of emission from the stacks where liquid fuel (fuel oil or asphalt) is used for firing furnaces is measured continuously in line with existing resource consent requirements.

The site also undertakes monitoring to determine overall site SO_2 emission based on a mass balance approach that accounts for fuel burned and the sulphur content of that fuel. This is linked to an annual average daily SO_2 emission rate. Refining NZ seeks to continue this monitoring requirement.

On-site monitoring of weather conditions is undertaken and assists with various on-site decisions regarding activities, including abrasive blasting and firefighting training, and will continue to occur. Similarly, recording and investigation of any air quality related complains will continue to occur.

Monitoring of fugitive emissions (BTEX) is not considered necessary based on the results of the historic and current BTEX monitoring.

10 Conclusions

This air quality assessment has been prepared on behalf of the New Zealand Refining Company to accompany a resource consent application to the Northland Regional Council for a resource consent authorising the continued discharges of contaminants into air from the Marsden Point Oil Refinery.

The proposed discharges to air require resource consent from the Northland Regional Council.

The air quality assessment concludes that the ongoing discharges to air from the Refinery will have a less than minor effect on the environment. The assessment of nickel exposure in terms of environmental/human health exposure is further considered by Environmental Medicine Limited and based on its conclusions we consider the potential effects to be less than minor.

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12 Applicability

This report has been prepared for the exclusive use of our client New Zealand Refining Company Limited, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement. It has been prepared in accordance with our engagement dated 5 April 2019.

Tonkin & Taylor Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Richard Chilton Senior Air Quality Scientist	Jenny Simpson Project Director

29-Jun-20

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Appendix A: Existing Resource Consent

FILE: 8319
01-06
Change to Conditions

Document Date: 11.11.2016

Resource Consent

Pursuant to the Resource Management Act 1991, the Northland Regional Council (hereinafter called "the Council") does hereby grant a Resource Consent to:

THE NEW ZEALAND REFINING COMPANY LIMITED, PRIVATE BAG 9024, WHANGAREI MAIL CENTRE, WHANGAREI 0148

To carry out the following activities associated with the operation of a petroleum refinery at Marsden Point:

AUT.008319.01.04 To discharge treated: process wastewater from the refining of petroleum hydrocarbons; stormwater; groundwater; dredging decant water and ballast water from the Refinery, to Whangarei Harbour, via an outfall sited close to the harbour bed at the No. 2 (western) Oil Jetty, on Pt Section 7 Blk VIII Ruakaka SD, Map Reference Q07:460-950;

AUT.008319.02.02 To discharge contaminants into the air from all site activities at the Refinery, Map Reference Q07:466-943;

AUT.008319.03.01 To discharge uncontaminated seawater from the Refinery fire-fighting water supply system to Whangarei Harbour, on Pt Section 7 Blk VIII Ruakaka SD, Map Reference Q07:461-948;

AUT.008319.04.01 To discharge contaminants to ground as a result of activities associated with the normal operation of the Refinery, on Section 10 Blk VIII Ruakaka SD, in the catchment of Whangarei Harbour and Bream Bay;

AUT.008319.05.01 To take groundwater from bores, in the catchments of Whangarei Harbour and Bream Bay, on Section 10 Blk VIII Ruakaka SD, for water table depression purposes and supply of refining processes on that property;

AUT.008319.06.01 To occupy and use the coastal marine area with the Refinery wharf and associated structures, including toilets and sewerage holding tanks, fire pump diesel tanks, slops tanks, dolphins and breastings and a wastewater diffuser outfall structure, on Pt Section 7, and Lot 1 DP 52379 Blk VIII Ruakaka SD, Whangarei Harbour, Map Reference Q07:461-949 (central);

Subject to the following conditions:

Treated Discharge to Water

1 The quantities permitted to be discharged are:

(a) A combined discharge of treated process wastewater and groundwater that does not exceed an average of 8000 cubic metres per "dry weather discharge" day, as calculated using the most recent 30 "dry weather discharge" days;

(b) A combined discharge of treated process wastewater and groundwater, and dredging decant water that does not exceed an average of 10,000 cubic metres per "dry weather discharge" day as calculated using the most recent 30 "dry weather discharge' days, when the dredge decant pond is operational;

(c) An intermittent discharge of ballast water, not exceeding 8,400 cubic metres per day; and

(d) An intermittent discharge of stormwater which, when combined with all of the above discharges, will give a total discharge flow of not more than 2,000 cubic metres per hour.

For compliance purposes, a "dry weather discharge" day is defined as when:

(i) There has been 2 millimetres or less of rainfall on that day, being 8.00 am to 8.00 am; and

(ii) That day occurs after two consecutive days with 2 millimetres or less of rainfall on each day; and

(iii) A discharge from the stormwater basin that is compliant with Condition 2 could have been undertaken in the period since the last day, being 8.00 am to 8.00 am, when more than 2 millimetres of rainfall occurred. If no discharge has occurred from the basin during this period, then the Consent Holder shall provide monitoring results for this period to confirm water quality.

2 The quality of the discharge measured at the sampling point (NRC Sample Site No 532) shall not exceed the following standards:

Column A is the maximum permitted concentration on any one day and Column B is the maximum permitted average concentration calculated using data from any 30 consecutive days:

Parameter	**Unit**	**A**	**B**
Temperature	Degrees of Celsius	37	
pH	Range	6 to 9	
BOD_5	mg/l	70	40
TSS	mg/l	50	30
COD	mg/l	540	280
Total Petroleum Hydrocarbons (TPH)	mg/l	12	6
Total Phenols	mg/l	0.5	0.15
Ammoniacal 'N'	mg/l	85	40
Sulphides	mg/l	0.5	0.15

3 Notwithstanding any other conditions of this consent, the discharge shall not result in any of the following effects in the receiving water, at the edge of the mixing zone:

(a) A reduction in the dissolved oxygen concentration to below 80 per cent of saturation;

(b) A change in the natural water temperature greater than 3 degrees Celsius;

(c) A change in the natural pH greater than 0.2 units;

(d) Any significant change in the colour and clarity;

(e) The production of any conspicuous oil or grease films, scums or conspicuous floating or suspended materials;

(f) The median value of the faecal coliform bacteria content of the waters shall not exceed 14 per 100 millilitres, nor shall the 90%ile value exceed 43 per 100 millilitres;

(g) Any emission of objectionable odour; and

(h) Any adverse effect on aquatic life, or any edible aquatic life becoming unfit and/or unsuitable for human consumption.

4 The mixing zone is defined as the volume of water vertically beneath a rectangular surface area, the axis of which is a line through the fixed mooring dolphins at the Marsden Point oil terminal and whose landward and seaward boundaries are determined by lines parallel to that axis at a distance of 100 metres from it. The New Zealand Map Grid co-ordinates of the corners of this rectangular area as follows:

Corner Point	Easting	Northing
NW Corner	2645810E	6595150N
NE Corner	2646450E	6594770N
SE Corner	2646340E	6594600N
SW Corner	2645710E	6594980N

5 The Consent Holder shall maintain flow measuring devices to measure total flow through the diffusers with an accuracy of ±5% over the range of 130 to 2000 cubic metres per hour. The Consent Holder shall also maintain instrumentation to permit the estimation of total flows to the diffusers in the event of failure of the above devices.

6 The outfall and diffusers shall be maintained so as to achieve a dilution of a minimum of 400 to 1 at slack low water spring tide with a discharge in the range 130 cubic metres per hour to 2,000 cubic metres per hour. The dilution ratio shall be achieved by the time the discharge plume reaches the edge of the mixing zone.

7 The Consent Holder shall maintain easy access to NRC Sampling Sites 532 and 5105.

8 The Consent Holder shall make an underwater examination of the diffusers and pipelines at least once every two years, and take such measures as are necessary to ensure that the diffusers operate as designed and that all the effluent passes through the diffusers.

9 A report on all such examinations and action taken to remedy defects shall be made to the Council within one month of the examination.

Discharge to Air

10 Notwithstanding the maximum discharge limits prescribed in this consent, the Consent Holder shall, at all times, operate, maintain, supervise, monitor and control all processes on site so that emissions authorised by this consent are maintained at a minimum practicable level.

11 Subject to the exclusions in Condition 14 for visible smoke, the Consent Holder's operations shall not give rise to any discharge of contaminants to the air, which is noxious, dangerous, offensive or objectionable at or beyond the property boundary.

12 The opacity of any discharge to air when measured by photoelectric means, or visually for discharges from the flare and D Block stacks, in accordance with AS3543-1989 shall not equal or exceed a value of 20% for more than two minutes continuously, or for an aggregate of four minutes in any period of 60 minutes.

13 All stacks with the exception of the flare and D Block stacks, discharging contaminants into the air shall be equipped with instrumentation to continuously measure opacity in accordance with AS3543-1989.

14 Notwithstanding the requirement of Condition 12 above, the Consent Holder may, during the following circumstances, discharge visible smoke other than in accordance with the opacity limits specified in that condition, subject to the requirements specified in Condition 15:

(a) Smoke emissions from the Block "A" stack during in-situ catalyst regeneration at the platformer by burning as part of a Block "A" "shut-down", or from the Block "C" stack during in-situ catalyst regeneration at the hydrocracker complex as part of a hydrocracker "shut-down", or from the respective Refinery stack(s) during the ten day period when a main process block of the Refinery is re-started after a scheduled "turnaround" or after an unscheduled "shut-down" resulting from unforeseen circumstances;

(b) Smoke emissions from the respective Refinery stack(s) during the two hour period immediately following the restarting of a process furnace or steam-raising boiler from cold;

(c) Smoke emissions from the respective Refinery stack(s) during the period of one hour immediately following the change of the fuel supply to a process furnace or steam-raising boiler from liquid to gas, or vice versa;

(d) Smoke emissions from the respective Refinery stack(s) during a period of two hours during which the process furnace or steam-raising boiler emergency safeguards are being tested;

(e) Smoke emissions from the respective Refinery stack(s) during soot-blowing or shot-cleaning operations at a process furnace or steam-raising boiler;

(f) Smoke emissions from the flare stacks; and

(g) Smoke emissions from the premises during fire-fighting training operations.

15 The exemptions specified in Condition 14 shall be subject to the following requirements:

(a) The Consent Holder shall ensure that during the circumstances mentioned above, the best practicable option (as detailed in the management plan required by Condition 31) is employed to minimise emissions of smoke;

(b) The Consent Holder shall report to the Council at monthly intervals, any periods during which smoke was discharged from any process(es) which would contravene the requirements of Condition 12, including those allowed by these exemptions;

(c) Fire-fighting training is restricted to the requirements of the Consent Holder's own safety programme and shall not be conducted when it is anticipated that the wind conditions will take smoke towards the area between Darch Point and the junction of Ody and Whangarei Heads Roads;

(d) For each fire-fighting training exercise there shall be a wind speed and direction indicator in the vicinity of the fire fighting-training site. The Consent Holder shall assess the wind speed and direction prior to ignition; and

(e) Should there be any offensive or objectionable smoke beyond the boundary of the Consent Holder's property from any fire-fighting training exercise; then the Consent Holder shall as soon as practicable cease the emission of smoke associated with the exercise such that it is no longer offensive or objectionable.

Sulphur Dioxide

16 The discharge of sulphur dioxide from the refinery in aggregate shall not exceed:

(a) 12 tonnes per day averaged over the Gregorian calendar year; nor

(b) 1000 kilograms per hour as a 90th percentile of all emissions over the Gregorian calendar year for any one hour period; nor

(c) 1250 kilograms per hour as a 99th percentile of all emissions over the Gregorian calendar year for any one hour period; nor

(d) 1700 kilograms per hour as a 99.9th percentile of all emissions over the Gregorian calendar year for any one hour period.

For the purpose of determining compliance or non-compliance with this condition, the use of calculated emission values based on the sulphur content of fuel, as described in the monitoring programme is acceptable.

17 The Consent Holder shall prepare to the satisfaction of the Council, a monitoring programme, for inclusion in Schedule 1, to monitor the:

(a) Ambient concentration of sulphur dioxide and nitrogen oxides;

(b) The deposition of acid species (e.g. sulphur dioxide and nitrogen oxides); and

(c) Soil acid neutralising capacity at the beginning and end of the monitoring period (at the same location).

This monitoring shall take place in the immediate vicinity of:

(d) The area of maximum predicted impact as identified in the application; and

(e) The vegetation on Mt Manaia identified in the consent application as being under stress.

The monitoring programme shall be conducted for a contiguous period of between 12 and 14 months and shall begin within six months of the date of commencement of this consent. The monitoring methods used and sampling locations shall be to the satisfaction of the Council. Results shall be forwarded to the Council on a quarterly basis.

18 The Consent Holder shall prepare a monitoring programme to the satisfaction of the Council, for inclusion in Schedule 1, to monitor the impact of the emissions authorised by this consent. This monitoring programme shall be carried out by appropriately qualified and competent people and shall include an assessment of the vegetation, lichens, and soil:

(a) On Mount Manaia in the area already identified as being under stress in the consent application;

(b) In the general vicinity of Mount Aubrey and Mount Lion; and

(c) At least at one suitable control site.

This monitoring shall be carried out immediately after the completion of the ambient sulphur dioxide monitoring required by Condition 17 and then again at intervals of not greater than two years. The content and timing of the programme may be reviewed under Condition 33 of this consent.

19 The Consent Holder shall prepare a monitoring programme to the satisfaction of the Council for inclusion in Schedule 1 to monitor the long term ambient air concentrations of benzene, toluene, and xylene near the Refinery and where people live. The monitoring programme shall be implemented within six months of the exercise of this consent.

20 The Consent Holder shall provide all required monitoring programmes to the Council for approval at least three months prior to their required implementation unless specified otherwise.

Discharge to Ground

21 The Consent Holder shall undertake such measures as are necessary to minimise the discharge of contaminants to ground within the Refinery site. These measures shall be incorporated into the Management Plan required by Condition 31 of this Consent.

Taking of Groundwater

22 The total quantity taken shall not exceed 2,000 cubic metres per day.

23 The Consent Holder shall install a meter on the rising main of each pumped well to measure the quantities taken from the aquifer with an accuracy of ±5%.

Occupation and use of the Coastal Marine Area

24 This consent is to occupy and use those parts of the Whangarei Harbour for the purposes of the consent and applies only to the area identified on New Zealand Refinery Company Limited Plan No. 62736.

25 The Consent Holder shall relinquish coastal permits, NLD 93 6294, NLD 60 5631, NLD 60 5899, and NLD 60 5685 effective of the date of commencement of this consent.

26 The Consent Holder shall keep the coastal marine area free of debris resulting from the Consent Holder's activities.

27 The Consent Holder shall maintain all facilities covered by this consent in good order and repair. The facilities shall not be altered, added to, demolished or removed, in part or in whole, without obtaining the prior consent of the Council.

28 The Consent Holder shall, upon the issue of this consent, notify in writing:

The Hydrographer
RNZ Navy
P O Box 33-341
Takapuna
Auckland

Northland Regional Council
Private Bag 9021
Whangarei

The Consent Holder shall include a scale plan of the completed works with the notification.

29 The Consent Holder shall exercise this consent in a manner, which ensures that the effects listed in Condition 4 of this Consent do not occur outside of the mixing zone.

30 Upon the expiry, cancellation or lapsing of this consent the Consent Holder shall remove all structures associated with this consent from the consent area and shall restore the consent area to the satisfaction of the Council.

General Conditions Applying to all Consents

31 The Consent Holder shall submit a Management Plan to the Council within six months of the date of commencement of these consents. The Management Plan shall cover all aspects of:

(a) The exemptions listed in the air discharge component of the consent;
(b) The operation and maintenance of the Process Wastewater Treatment System;
(c) The Continuously Oil Contaminated System;
(d) The Accidentally Oil Contaminated System;
(e) The Ballast Water System;
(f) Shutdown procedures to minimise the risk of adverse environmental effects;
(g) Measures to minimise the discharge of contaminants to ground; and
(h) Contingency measures for unforeseen or emergency situations.

The operation and maintenance of the above systems, and the Refinery operations, shall be carried out in accordance with the Management Plan.

32 The Consent Holder shall review the Management Plan in consultation with the Council at no greater than three yearly intervals.

33 The Consent Holder shall monitor and report on the consents in accordance with the **attached** Schedule 1. The Consent Holder in conjunction with the Council shall review Schedule 1 at least once every seven years to ensure that the most appropriate monitoring and reporting is being conducted to determine compliance with conditions of all consents. Monitoring and reporting undertaken by the Consent Holder, after such a review, shall be in accordance with the revised Schedule.

34 The Consent Holder shall advise the Council in writing in advance of any changes to plant or processes, which may significantly change the nature, and quantity of contaminants discharged. Such changes shall not be given effect to, without the prior written approval of the Council.

35 The Council may, in accordance with Section 128 (1)(a) of the Resource Management Act 1991, serve notice on the Consent Holder of its intention to review the conditions of this consent. Such notice may be served one year after the date of commencement of the consent, and thereafter at annual intervals. The review may be initiated for any one or more of the following purposes:

(a) To deal with any adverse effects on the environment that may arise from the exercise of the consent and which it is appropriate to deal with at a later stage, or to deal with any such adverse effects following assessment of the results of the monitoring of the consent and/or as a result of the monitoring of the state of the environment in the area;

(b) To require consistency with a current Marsden Point Air Quality Strategy prepared in accordance with a Proposed or Operative Regional Air Quality Plan for Northland;

(c) To require the adoption of the best practicable option to remove or reduce any adverse effect on the environment; and

(d) To assess the need for ongoing monitoring of soils and vegetation as required by Conditions 17 and 18.

The Consent Holder shall meet the reasonable costs of any such review.

EXPIRY DATE: 31 MAY 2022

This change to the conditions of consent is granted this Eleventh day of November 2016 under delegated authority from the Council by:

Savill

Stuart Savill
Consents Manager

SCHEDULE 1

MONITORING PROGRAMME (as at 10 November 2016)

The Consent Holder is to undertake the following monitoring:

1. DISCHARGE CONSENT

1.1 Discharge Volumes

The Consent Holder will record the total daily discharge, median daily discharge rate, maximum daily discharge rate and minimum daily discharge rate (expressed as cubic metres per hour).

For the purpose of determining compliance with Condition 1(b) (discharges containing dredging decant water), the Consent Holder shall record the day(s) when the dredge decant pond is operational.

1.2 Water Quality

Continuous Monitoring

The following determinands will be measured directly in the final discharge to the diffusers. Results for these measurements shall be recorded on each day a discharge occurs in the required manner (see Section 3 on Reporting).

Determinands
pH
Temperature
Total Organic Carbon (TOC)

The online analysers will be operated and maintained in accordance with good quality assurance procedures.

Composite Sample Analysis

On Monday, Wednesday, Friday and Saturday, or on the following day if no discharge occurs on one of these days, a flow proportioned composite sample taken over the preceding 24 hours will be analysed for the following determinands:

Determinands
Ammoniacal Nitrogen
Chemical Oxygen Demand (COD)
Five Day Biochemical Oxygen Demand (BOD_5)
Total Suspended Solids (TSS)
Total Petroleum Hydrocarbons (TPH)
Sulphide
Phenols

Notwithstanding the above sampling and analysis schedule, should the average daily TOC, as measured by analysis of the flow proportioned composite sample, exceed 13 grams per cubic metre on a day when analysis is not required, then the above analyses will be undertaken on the flow proportioned composite sample taken during the preceding 24 hours.

In the event where a discharge has occurred and there is inadequate flow proportioned composite sample and analysis is required, then the daily grab sample shall be analysed for the above determinands.

Between 1st October and 31st March inclusive, every Wednesday, or if no discharge occurs on that day then the next day a discharge does occur, one sample shall be analysed for faecal coliforms.

Each determinand will be analysed for in accordance with the specified Analytical Method (see Appendix 1).

2. AIR DISCHARGE MONITORING

The Consent Holder will carry out daily tests to determine the quantity of total sulphur in all fuel components used for onsite process combustion using standard methods to the satisfaction of the Council.

The quantity of sulphur dioxide discharged from the site will be continuously calculated. Sulphur dioxide discharges determined in this way will be continuously logged, and records retained for at least 24 months.

The Consent Holder will conduct emission tests for:

(a) Sulphur dioxide as a:
  - Continuous 10 minute average emission rate;
  - Continuous 1 hour average emission rate; and
  - A daily average emission rate.

(b) Sulphur trioxide;

(c) Particulate matter; and

These tests will be carried out by qualified and competent persons using appropriate methods to the satisfaction of the Council, on all discharges from stacks within the A, B, C and utilities blocks. All data collected during the monitoring of these emissions will be reported with the results, e.g. field notes, temperature and flow rates etc.

These tests will be conducted within six months of the date of commencement of this consent and every nine months thereafter. Testing will be conducted as far as is practicable during normal process conditions and the results will be reported to the Council within one month of the testing being completed.

Opacity measurements will be continuously logged and the results recorded. Recorded data shall be retained by the Consent Holder for a minimum of 12 months. Reporting shall be subject to the requirement of Section 3 and in addition shall be made available to the Council immediately upon request.

The Consent Holder will operate and maintain continuous ambient sulphur dioxide monitors at the following locations:

- Urquharts Bay;
- Whangarei Heads School; and
- Little Munro Bay.

This monitoring will be carried out in accordance with an appropriate standard to the satisfaction of the Council.

2.1 Groundwater Take Consent

The Consent Holder will record the following:

(a) The total quantity of water taken from all groundwater abstraction bores on a weekly basis.

(b) Monthly water levels in perimeter wells P1 to P20 as detailed in the application.

(c) Monthly hydrocarbon vapour levels in perimeter wells P1 to P20.

(d) Monthly total petroleum hydrocarbons (TPH) levels in the three perimeter wells with highest hydrocarbon vapour levels at any time.

(e) Results of samples taken six monthly from the pumped wells, and analysed for total petroleum hydrocarbons, chlorides, pH and conductivity;

Results of the measurements and sampling undertaken in points (a) to (d) above shall be provided to the Council by the end of the following month.

3. REPORTING

The Consent Holder is to report the results of the above monitoring on a monthly basis, unless otherwise stated, to the Council within two weeks of the month's end.

All results reported shall be in a format that is to the satisfaction of the Council and any non-compliance with consent limits shall be clearly identified.

Results from the on-line analysers will be reported on the following basis:

(a) Median Value;

(b) Maximum Value;

(c) Minimum Value.

The following will be reported from the discharge flow meters:

(d) The total daily discharge volume;

(e) The rolling average dry weather day discharge volume.

In addition to the above values:

(f) the daily rainfall will also be reported; and

(g) the days when the dredge decant pond is operational shall be clearly identified.

The above values are to be calculated using data collected over a twenty-four hour period ending at 8:00 a.m. each day.

The Consent Holder shall, for the purposes of adequately monitoring the consent as required under Section 35 of the Act, on becoming aware of any significant tank leakage, advise the Council of the discharge within 24 hours. The Consent Holder shall then supply a written report to the Council within two weeks detailing:

(h) The location of the discharge;

(i) The time of discharge;

(j) The duration of discharge;

(k) The quantity of contaminant discharged;

(l) The measures taken to stop the discharge; and

(m) The proposed measures to minimise the risk of similar discharges in future.

For the purpose of adequately monitoring the consent as required under Section 35 of the Act, the Consent Holder on becoming aware of any incident or situation that does not comply with this consent shall immediately advise the Council of the incident or situation. The Consent Holder will then supply a written report to the Council on the cause, effects, and the actions taken to mitigate the effects on the environment and to prevent recurrence. The written report will be submitted to the Council within one week of the incident occurring.

For the purposes of adequately monitoring the consent as required under Section 35 of the Act, the Consent Holder will maintain records of any complaints received relating to the discharge of contaminants into the environment, as detailed below:

(n) The name and address of the complainant, where provided;

(o) The date and time the complaint is received;

(p) The nature of the complaint;

(q) The duration of the event that gave rise to the complaint;

(r) The location from which the complaint arose;

(s) The weather conditions prevailing at that time;

(t) Any events in the management and operation of any processes that may have resulted in the increased discharge of contaminants; and

(u) Any actions taken by the Consent Holder, where possible, to minimise the contaminant emissions.

The Consent Holder will notify the Council as soon as is practicable of any complaint received. Records of the above are to be sent to the Council upon request.

4. REVIEW

The monitoring programme is to be reviewed at least every seven years, with the first review being undertaken in 2007. The discharge monitoring programme was reviewed in 2013.

The Consent Holder, in conjunction with the Northland Region Council, will undertake the review. The Consent Holder will consult with the Marsden Point Liaison Committee and tangata whenua as part of the review.

In addition to the above review, the analytical methods detailed as part of this monitoring will be reviewed on an as need be basis, depending on:

(a) Any operational difficulties experienced by the Consent Holder or the Council during the monitoring of the consent; and

(b) New, or other, more appropriate methods becoming available.

APPENDIX 1

METHODS FOR NEW ZEALAND REFINING COMPANY DISCHARGE CONSENT

1 **Ammonia in Water**
APHA Method 4500-NH_3E Ammonia-Selective Electrode Using Known Addition

2 **Biological Oxygen Demand (BOD)**
APHA Method 4500-O G and APHA 5210 B

3 **Chemical Oxygen Demand (COD)**
Hach Method 8000
LOD = 50 mg/L

4 **Faecal Coliforms**
APHA 9222 D Fecal Coliform Membrane Filter Procedure

5 **Hydrocarbons (Total) in Water**
Method ENV-001WR08 (In house designation)
LOD (total hydrocarbon concentration in sample) = 0.2 mg/L

6 **Phenol (Total Steam Distillable) in Water**
ASTM D1783
LOD (concentration of steam distillable phenol in sample) = 0.10 mg/L

7 **Sulphide (Total) in Water and Soil Conservation Act 1967**
APHA 4500-S^2-D
LOD (total sulphide concentration in sample) = 0.03 mg/L

8 **Total Suspended Solids**
APHA Method 2540 D Total Suspended Solids Dried at 103-105° C

9 **Salinity**
APHA Method 2520 B Electrical Conductivity Method

Appendix B: Summary of Stack Emission Testing

Source	Date	Temp (°C)	Moisture (%)	Velocity (m/s)	Flow (dry STP) m^3/s	TSP (kg/hr)				SO2 (kg/hr)				Sulfuric acid (kg/hr)			
						Run1	Run2	Run3	Ave	Run1	Run2	Run3	Ave	Run1	Run2	Run3	Ave
Block A	Nov-12	230.0	9.1	3.85	52.90	1.38	1.52	4.00	2.30	4.42	2.54	3.84	3.60	1.09	0.06	0.21	0.45
	Aug-13	244.0	10.5	5.15	68.10	7.98	7.28	6.17	7.14	0.85	4.90	6.12	3.96	0.00	1.46	1.30	3.70
	May-14	227.0	10.6	3.50	48.20	12.00	5.09	3.56	6.88	5.80	5.57	5.29	5.55	0.55	0.40	0.36	0.44
	Feb-15	246.0	9.9	4.80	63.85	0.59	0.92	3.79	1.76	1.52	1.11	1.45	1.36	1.14	0.49	0.50	0.71
	Nov-15	174.5	6.2	5.80	90.30	0.53	0.52	0.55	0.53	0.58	1.05	1.17	0.93	2.74	0.88	0.92	1.52
	Aug-16	176.0	8.2	3.00	47.50	12.95	14.46	18.27	15.23	34.82	32.98	33.01	33.60	1.32	1.53	1.60	1.48
	May-17	191.5	9.7	4.80	71.95	0.53	6.04	0.53	2.37	0.16	0.43	0.43	0.34	0.21	0.94	0.42	0.52
	Feb-18	178.2	7.1	3.60	57.05	0.87	1.42	1.38	1.22	0.12	0.13	0.24	0.16	0.23	0.09	0.09	0.14
	Nov-18	173.9	10.7	3.70	56.10	0.53	0.49	0.48	1.22	4.27	4.35	4.62	4.41	0.84	0.96	0.98	0.14
	Aug-19																
Block B	Nov-12	197.0	13.3	7.80	7.80	0.05	0.05	0.05	0.05	0.10	0.08	0.07	0.08	0.08	0.07	0.03	0.06
	Aug-13	174.5	13.3	8.10	8.55	0.01	0.52	0.13	0.26	0.33	0.46	0.46	0.41	0.11	0.11	0.10	0.11
	May-14	178.5	14.3	8.50	8.75	0.08	0.07	0.07	0.07	0.19	0.89	2.40	1.16	0.05	0.06	0.08	0.06
	Feb-15	193.0	13.8	8.75	9.00	0.00	0.30	0.12	0.21	0.08	0.09	0.10	0.09	0.05	0.05	0.07	0.06
	Nov-15	196.8	12.9	9.25	9.45	12.97	0.58	0.22	4.59	0.02	0.02	0.01	0.02	0.08	0.09	0.09	0.09
	Aug-16	190.0	15.3	9.45	9.00	0.78	1.98	4.02	2.26	0.16	0.15	0.17	0.16	0.07	0.01	0.04	0.04
	May-17	198.5	15.7	8.40	8.20	0.06	0.06	0.06	0.06	0.29	0.31	0.34	0.31	0.13	0.15	0.07	0.12
	Feb-18	202.9	15.8	10.45	35.05	0.08	0.11	0.09	0.09	0.93	0.68	0.83	0.81	0.27	0.16	0.21	0.21
	Dec-18	202.4	16.2	7.20	6.90	N/A	N/A	N/A	N/A	0.09	0.09	N/A	0.09	0.15	0.08	N/A	0.12
	Aug-19	192.3	14.3	6.70	6.70	N/A	N/A	N/A	N/A	0.09	0.09	0.10	0.09	0.14	0.05	0.05	0.08
Block C	Nov-12	235.5	10.2	14.50	86.70	24.43	26.91	26.43	25.92	116.82	0.00	0.00	116.82	0.36	0.00	0.00	0.36
	Aug-13	234.5	11.0	14.30	90.15	23.32	4.28	2.84	10.15	285.97	219.82	286.21	274.00	3.20	3.79	5.27	4.09
	May-14	239.0	12.5	15.50	90.75	12.28	13.45	15.45	13.73	146.00	163.00	146.00	152.00	2.86	3.37	3.00	3.08
	Feb-15	230.5	11.6	13.95	84.65	3.81	5.54	6.47	5.24	37.43	35.13	33.02	35.19	2.18	2.35	2.17	2.23
	Nov-15	234.8	12.1	15.65	93.05	17.60	17.80	15.70	15.70	227.73	215.65	230.82	224.73	8.42	9.14	9.94	9.17
	Aug-16	240.5	11.6	14.95	87.15	35.39	36.37	36.37	36.04	277.00	263.10	285.44	275.21	9.03	40.23	0.16	16.47
	May-17	233.0	12.9	14.55	86.40	2.01	2.46	2.66	2.37	306.51	299.63	299.55	301.90	8.34	5.42	5.44	6.40
	Feb-18	222.4	13.5	13.30	79.65	2.09	4.41	2.68	3.06	13.68	20.59	21.61	18.63	1.26	0.67	0.56	0.83
	Nov-18	220.6	12.4	13.00	79.00	N/A	N/A	N/A	N/A	166.33	174.80	N/A	170.60	3.24	5.47	N/A	1.37
	Aug-19	215.2	9.6	13.10	82.40	N/A	N/A	N/A	N/A	169.66	188.01	194.20	183.96	6.47	8.32	8.03	7.61
Block E	Aug-16	168.0	15.2	3.35	13.70	0.17	0.21	0.56	0.31	0.64	0.50	0.14	0.43	0.49	0.23	0.68	0.47
	May-17	176.0	15.6	3.55	13.90	0.08	0.09	0.11	0.09	0.98	1.02	1.19	1.06	6.03	0.41	0.24	2.23
	Feb-18	175.4	13.0	5.45	21.80	0.18	0.23	0.31	0.24	0.30	0.46	1.15	0.64	0.30	0.08	0.09	0.16
Utilities	Nov-12	182.5	12.5	6.50	43.05	0.90	0.68	0.47	0.68	121.00	132.00	108.00	120.00	2.28	1.94	1.42	1.88
	Aug-13	185.0	21.9	7.20	41.75	3.34	4.57	11.53	6.48	53.47	47.29	53.93	51.56	1.31	1.97	3.12	2.13
	May-14	197.5	10.7	7.95	51.75	7.71	29.11	7.33	14.72	393.00	403.00	376.00	391.00	0.02	1.49	1.61	1.04
	Feb-15	200.5	9.9	9.00	58.85	23.12	23.44	22.15	22.90	312.00	285.12	292.85	296.91	5.76	6.72	5.67	6.05
	Nov-15	193.8	11.2	8.65	60.30	14.52	13.96	13.90	14.13	299.69	336.73	340.64	325.69	0.07	0.07	0.07	0.07
	Aug-16	157.0	11.1	8.45	39.90	24.39	8.24	8.35	13.70	129.57	123.23	130.60	127.80	1.68	2.97	2.39	2.35
	May-17	180.0	9.3	8.35	57.35	6.01	5.74	5.81	5.85	503.18	490.97	439.89	478.00	6.01	5.74	5.81	5.54
	Feb-18	189.9	12.9	7.40	47.90	1.34	0.88	0.80	1.01	79.58	118.00	137.00	111.64	0.18	0.36	0.43	0.32
	Nov-18	182.2	13.3	7.50	49.10	N/A	N/A	N/A	N/A	38.06	48.24	37.18	41.16	0.73	0.40	0.40	0.51
	Aug-19	194.7	11.5	7.70	49.40	N/A	N/A	N/A	N/A	168.10	167.28	158.75	164.71	4.06	3.90	3.17	3.71

Appendix C: Metal Analysis of Asphalt and Oil

ASPHALT	Date	1/05/2019	22/02/2020	28/02/2020	2/03/2020	4/03/2020	6/03/2020	9/03/2020	11/03/2020	13/03/2020	16/03/2020
	Sample	610408	636817	637337	637581	637813	638001	638186	638447	638608	638811
Properties	Units										
Arsenic	mg/kg	<1	<1							<1	<1
Silver	mg/kg	<1	<1							<1	<1
Aluminium	mg/kg	2	3							3	2
Barium	mg/kg	<1	1							<1	<1
Calcium	mg/kg	6	12							8	7
Cadmium	mg/kg	<1	<1							<1	<1
Chromium	mg/kg	<1	<1							<1	<1
Copper	mg/kg	<1	<1							<1	<1
Iron	mg/kg	18	23	23	20	21	22	25	23	27	22
Potassium	mg/kg	<1	1							1	1
Magnesium	mg/kg	<1	1							<1	<1
Manganese	mg/kg	<1	<1							<1	<1
Molybdenum	mg/kg	<1	<1							<1	<1
Sodium	mg/kg	18	40	49	39	50	60	35	22	32	35
Nickel	mg/kg	66	68	70	68	72	70	59	55	49	39
Phosphorus	mg/kg	<1	<1							<1	<1
Lead	mg/kg	<1	<1							<1	<1
Silicon	mg/kg	3	5							6	5
Tin	mg/kg	<1	<1							<1	<1
Titanium	mg/kg	<1	<1							<1	<1
Vanadium	mg/kg	75	90	85	86	87	85	76	73	77	66
Zinc	mg/kg	<1	1							<1	<1

FUEL OIL	Date	1/05/2019	18/06/2019	23/01/2020	22/02/2020	28/02/2020	2/03/2020	4/03/2020	6/03/2020	9/03/2020	11/03/2020	13/03/2020	16/03/2020
	Sample	610409	614760	634225	636818	637338	637582	637814	638002	638187	638448	638609	638812
Properties	Units												
Arsenic	mg/kg	<1	<1		<1							<1	<1
Silver	mg/kg	<1	<1		<1							<1	<1
Aluminium	mg/kg	2	<1	6	3							3	3
Barium	mg/kg	<1	<1		1							<1	<1
Calcium	mg/kg	9	8	18	15							17	16
Cadmium	mg/kg	<1	<1		<1							<1	<1
Chromium	mg/kg	<1	<1		<1							<1	<1
Copper	mg/kg	<1	<1		<1							<1	<1
Iron	mg/kg	13	11	34	23	24	23	23	24	25	23	26	25
Potassium	mg/kg	<1	<1		1							2	1
Magnesium	mg/kg	<1	<1		2							2	2
Manganese	mg/kg	<1	<1		<1							<1	<1
Molybdenum	mg/kg	<1	<1		<1							<1	<1
Sodium	mg/kg	26	22	64	47	52	52	49	55	53	51	58	52
Nickel	mg/kg	29	28	34	39	38	38	38	38	37	37	39	38
Phosphorus	mg/kg	<1	<1	2	<1							<1	<1
Lead	mg/kg	<1	<1		<1							<1	<1
Silicon	mg/kg	3	2	12	5							7	6
Tin	mg/kg	<1	<1		<1							<1	<1
Titanium	mg/kg	<1	<1		<1							<1	<1
Vanadium	mg/kg	41	42	46	50	48	47	46	47	46	46	52	50
Zinc	mg/kg	<1	<1	2	2							2	1

Sample Results - Customer

VA
Validated & Approved

610408
Lab: **Fuels**

SITE **U9500 Asphalt □urning System**

SAMPLE POINT **95QPA013 - Asphalt**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **01-May-2019 8:00**

SAMPLE TYPE **U9500 Asphalt - □ ee□ly** 99

			Results	Low Limit 2	High Limit 2	✓
D70	**Density by Pycnometer**	Method No: 9				
10	Density @ 15°C	kg/L	1.0504			
D445	**□lac□ Viscosity □one tube□**	Method No: 67				
4	Viscosity @ Test Temperature	cSt	734.2			
5	V Number @ 50°C		45.579			
6	Viscosity @ 50°C	cSt	1348000			
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	3.865		5.300	
3	Sulphur	mg/kg	38650		53000	
D5185 mod A	**ICP 22 Elements in Hydrocarbon**	Method No: 169				
24	Arsenic	mg/kg	□1			
17	Silver	mg/kg	□1			
1	Aluminium	mg/kg	2			
2	□arium	mg/kg	□1			
4	Calcium	mg/kg	6			
23	Cadmium	mg/kg	□1			
5	Chromium	mg/kg	□1			
6	Copper	mg/kg	□1			
7	Iron	mg/kg	18			
14	Potassium	mg/kg	□1			
9	Magnesium	mg/kg	□1			
10	Manganese	mg/kg	□1			
11	Molybdenum	mg/kg	□1			
15	Sodium	mg/kg	18			
12	Nickel	mg/kg	66			
13	Phosphorus	mg/kg	□1			
8	Lead	mg/kg	□1			
16	Silicon	mg/kg	3			
19	Tin	mg/kg	□1			
20	Titanium	mg/kg	□1			
21	Vanadium	mg/kg	75			
22	Zinc	mg/kg	□1			

END OF RESULTS - SAMPLE# **610408**

The best at all we test

Sample Results - Customer

VA
Validated & Approved

637337
Lab: **Fuels**

SITE **U9500 Asphalt Burning System**

SAMPLE POINT **95QPA013 - Asphalt**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **28-Feb-2020 6:00**

SAMPLE TYPE **U9500 Asphalt - M,F** 99

			Results	Low Limit 2	High Limit 2	✓
D2170□D2170M□D445	**Viscosity of Asphalt by Auto**	Method No: 603				
1	Bath Temperature	°C	135.00			
6	Auto Viscosity @ 135°C	cSt	2697			
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**	Method No: 170				
1	Sodium	mg/kg	49			
2	Nickel	mg/kg	70			
3	Vanadium	mg/kg	85			
4	Iron	mg/kg	23			
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	2.908		5.300	
3	Sulphur	mg/kg	29080		53000	

END OF RESULTS - SAMPLE# **637337**

Sample Results - Customer

C
Complete - All Results Entered

637581

Lab: **Fuels**

SITE **U9500 Asphalt Burning System**

SAMPLE POINT **95QPA013 - Asphalt**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **02-Mar-2020 2:00**

SAMPLE TYPE **U9500 Asphalt - M,F** 99

			Results	Low Limit 2	High Limit 2	✓
D2170□D2170M□D445	**Viscosity of Asphalt by Auto**				Method No: 603	
1	Bath Temperature	°C	135.00			
6	Auto Viscosity @ 135°C	cSt	1851			
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**				Method No: 170	
1	Sodium	mg/kg	39			
2	Nickel	mg/kg	68			
3	Vanadium	mg/kg	86			
4	Iron	mg/kg	20			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	3.472		5.300	
3	Sulphur	mg/kg	34720		53000	

END OF RESULTS - SAMPLE# **637581**

The information in this report was last updated on: *3/03/2020 6:0□:□1p.m.*

IPL
*The **best** at all we test*

Sample Results - Customer

VA
Validated & Approved

638001
Lab: **Fuels**

SITE **U9500 Asphalt Burning System**

SAMPLE POINT **95QPA013 - Asphalt**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **06-Mar-2020 5:15**

SAMPLE TYPE **U9500 Asphalt - M,F** 99

			Results	Low Limit 2	High Limit 2	✓
D2170□D2170M□D445	**Viscosity of Asphalt by Auto**				Method No: 603	
1	Bath Temperature	°C	135.00			
6	Auto Viscosity @ 135°C	cSt	3659			
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**				Method No: 170	
1	Sodium	mg/kg	60			
2	Nickel	mg/kg	70			
3	Vanadium	mg/kg	85			
4	Iron	mg/kg	22			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	2.889		5.300	
3	Sulphur	mg/kg	28890		53000	

END OF RESULTS - SAMPLE# **638001**

Sample Results - Customer

C
Complete - All Results Entered

638186

Lab: **Fuels**

SITE **U9500 Asphalt Burning System**

SAMPLE POINT **95QPA013 - Asphalt**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **09-Mar-2020 6:00**

SAMPLE TYPE **U9500 Asphalt - M,F** 99

			Results	Low Limit 2	High Limit 2	✓
D2170□D2170M□D445	**Viscosity of Asphalt by Auto**	Method No: 603				
1	Bath Temperature	°C	135.00			
6	Auto Viscosity @ 135°C	cSt	1053			
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**	Method No: 170				
1	Sodium	mg/kg	35			
2	Nickel	mg/kg	59			
3	Vanadium	mg/kg	76			
4	Iron	mg/kg	25			
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	2.856		5.300	
3	Sulphur	mg/kg	28560		53000	

END OF RESULTS - SAMPLE# **638186**

Sample Results - Customer

VA
Validated & Approved

638447
Lab: **Fuels**

SITE	**U9500 Asphalt Burning System**
SAMPLE POINT	**95QPA013 - Asphalt**
CUSTOMER	**The New Zealand Refining Co. Limited** **Asset North**
SAMPLE DATE	**11-Mar-2020 6:00**
SAMPLE TYPE	**U9500 Asphalt - Weekly** 99

			Results	Low Limit 2	High Limit 2	✓
D2170□D2170M□D445	**Viscosity of Asphalt by Auto**	Method No: 603				
1	Bath Temperature	°C	135.00			
6	Auto Viscosity @ 135°C	cSt	862.4			
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**	Method No: 170				
1	Sodium	mg/kg	22			
2	Nickel	mg/kg	55			
3	Vanadium	mg/kg	73			
4	Iron	mg/kg	23			
D70	**Density by Pycnometer**	Method No: 9				
10	Density @ 15°C	kg/L	1.0494			
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	2.880		5.300	
3	Sulphur	mg/kg	28800		53000	
IP501 Other	**ICP Other Metals □IP501□**	Method No: 174				
1	Calcium	mg/kg	8			
2	Iron	mg/kg	37			
3	Nickel	mg/kg	49			
4	Phosphorus	mg/kg	1			
5	Zinc	mg/kg	2			
6	Used Lubricating Oil		Not present			
IP501 Na, V	**ICP Sodium and Vanadium □IP501□**	Method No: 172				
1	Sodium	mg/kg	31			
2	Vanadium	mg/kg	69			
IP501 Al, Si	**ICP Aluminium and Silicon □IP501□**	Method No: 173				
1	Aluminium	mg/kg	7			
2	Silicon	mg/kg	14			
3	Aluminium + Silicon	mg/kg	21			

END OF RESULTS - SAMPLE# **638447**

The information in this report was last updated on: *1□/03/2020 3:0□:□□p.m.*

Sample Results - Customer

VA
Validated & Approved

638608
Lab: **Fuels**

SITE **U9500 Asphalt Burning System**

SAMPLE POINT **95QPA013 - Asphalt**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **13-Mar-2020 6:00**

SAMPLE TYPE **U9500 Asphalt - M,F** 99

			Results	Low Limit 2	High Limit 2	✓
D2170□D2170M□D445	**Viscosity of Asphalt by Auto**	Method No: 603				
1	Bath Temperature	°C	135.00			
6	Auto Viscosity @ 135°C	cSt	774.2			
D5185 mod A	**ICP 22 Elements in Hydrocarbon**	Method No: 169				
1	Aluminium	mg/kg	3			
2	Barium	mg/kg	□1			
4	Calcium	mg/kg	8			
5	Chromium	mg/kg	□1			
6	Copper	mg/kg	□1			
7	Iron	mg/kg	27			
8	Lead	mg/kg	□1			
9	Magnesium	mg/kg	□1			
10	Manganese	mg/kg	□1			
11	Molybdenum	mg/kg	□1			
12	Nickel	mg/kg	49			
13	Phosphorus	mg/kg	□1			
14	Potassium	mg/kg	1			
15	Sodium	mg/kg	32			
16	Silicon	mg/kg	6			
17	Silver	mg/kg	□1			
19	Tin	mg/kg	□1			
20	Titanium	mg/kg	□1			
21	Vanadium	mg/kg	77			
22	Zinc	mg/kg	□1			
23	Cadmium	mg/kg	□1			
24	Arsenic	mg/kg	□1			
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	3.344		5.300	
3	Sulphur	mg/kg	33440		53000	

END OF RESULTS - SAMPLE# **638608**

IPL
The **best** at all we test

Sample Results - Customer

VA
Validated & Approved

638811
Lab: **Fuels**

SITE **U9500 Asphalt Burning System**

SAMPLE POINT **95QPA013 - Asphalt**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **16-Mar-2020 6:00**

SAMPLE TYPE **U9500 Asphalt - M,F** 99

			Results	Low Limit 2	High Limit 2	✓
D2170□D2170M□D445	**Viscosity of Asphalt by Auto**	Method No: 603				
1	Bath Temperature	°C	135.00			
6	Auto Viscosity @ 135°C	cSt	431.1			
D5185 mod A	**ICP 22 Elements in Hydrocarbon**	Method No: 169				
1	Aluminium	mg/kg	2			
2	Barium	mg/kg	□1			
4	Calcium	mg/kg	7			
5	Chromium	mg/kg	□1			
6	Copper	mg/kg	□1			
7	Iron	mg/kg	22			
8	Lead	mg/kg	□1			
9	Magnesium	mg/kg	□1			
10	Manganese	mg/kg	□1			
11	Molybdenum	mg/kg	□1			
12	Nickel	mg/kg	39			
13	Phosphorus	mg/kg	□1			
14	Potassium	mg/kg	1			
15	Sodium	mg/kg	35			
16	Silicon	mg/kg	5			
17	Silver	mg/kg	□1			
19	Tin	mg/kg	□1			
20	Titanium	mg/kg	□1			
21	Vanadium	mg/kg	66			
22	Zinc	mg/kg	□1			
23	Cadmium	mg/kg	□1			
24	Arsenic	mg/kg	□1			
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	3.556		5.300	
3	Sulphur	mg/kg	35560		53000	

END OF RESULTS - SAMPLE# **638811**

Sample Results - Customer

VA
Validated & Approved

637338
Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **28-Feb-2020 6:00**

SAMPLE TYPE **U9520 Fuel Oil - Extra** 100

			Results	Low Limit 2	High Limit 2	✓
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**				Method No: 170	
1	Sodium	mg/kg	52			
2	Nickel	mg/kg	38			
3	Vanadium	mg/kg	48			
4	Iron	mg/kg	24			
ISO12185	**Density of Fuel Oil by AP**				Method No: 401	
3	Density @ 15°C	kg/L	0.9718			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	1.964			
D445A	**Auto Viscosity**				Method No: 395	
5	Viscosity Auto@50°C	cSt	1199			
6	V Number @ 50°C		35.56			

END OF RESULTS - SAMPLE# **637338**

Sample Results - Customer

C
Complete - All Results Entered

637582
Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **02-Mar-2020 2:00**

SAMPLE TYPE **U9520 Fuel Oil - Extra** 100

			Results	Low Limit 2	High Limit 2	✓
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**				Method No: 170	
1	Sodium	mg/kg	52			
2	Nickel	mg/kg	38			
3	Vanadium	mg/kg	47			
4	Iron	mg/kg	23			
ISO12185	**Density of Fuel Oil by AP**				Method No: 401	
3	Density @ 15°C	kg/L	0.9718			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	1.975			
D445A	**Auto Viscosity**				Method No: 395	
5	Viscosity Auto@50°C	cSt	1168			
6	V Number @ 50°C		35.51			

END OF RESULTS - SAMPLE# **637582**

Sample Results - Customer

VA
Validated & Approved

638002
Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **06-Mar-2020 5:20**

SAMPLE TYPE **U9520 Fuel Oil - Extra** 100

			Results	Low Limit 2	High Limit 2	✓
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**				Method No: 170	
1	Sodium	mg/kg	55			
2	Nickel	mg/kg	38			
3	Vanadium	mg/kg	47			
4	Iron	mg/kg	24			
ISO12185	**Density of Fuel Oil by AP**				Method No: 401	
3	Density @ 15°C	kg/L	0.9718			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	1.965			
D445A	**Auto Viscosity**				Method No: 395	
5	Viscosity Auto@50°C	cSt	1163			
6	V Number @ 50°C		35.50			

END OF RESULTS - SAMPLE# **638002**

Sample Results - Customer

VA
Validated & Approved

638187

Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **09-Mar-2020 6:00**

SAMPLE TYPE **U9520 Fuel Oil - Extra** 100

			Results	Low Limit 2	High Limit 2	✓
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**				Method No: 170	
1	Sodium	mg/kg	53			
2	Nickel	mg/kg	37			
3	Vanadium	mg/kg	46			
4	Iron	mg/kg	25			
ISO12185	**Density of Fuel Oil by AP**				Method No: 401	
3	Density @ 15°C	kg/L	0.9717			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	1.992			
D445A	**Auto Viscosity**				Method No: 395	
5	Viscosity Auto@50°C	cSt	1156			
6	V Number @ 50°C		35.49			

END OF RESULTS - SAMPLE# **638187**

IPL
The **best** at all we test

Sample Results - Customer

VA
Validated & Approved

638448
Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **11-Mar-2020 6:00**

SAMPLE TYPE **U9520 Fuel Oil - □ee□ly** 100

			Results	Low Limit 2	High Limit 2	✓
D5185 mod A	**ICP Na, Ni, V in Hydrocarbon**				Method No: 170	
1	Sodium	mg/kg	51			
2	Nickel	mg/kg	37			
3	Vanadium	mg/kg	46			
4	Iron	mg/kg	23			
ISO12185	**Density of Fuel Oil by AP**				Method No: 401	
3	Density @ 15°C	kg/L	0.9717			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	1.959			
IP501 Other	**ICP Other Metals □IP501□**				Method No: 174	
1	Calcium	mg/kg	16			
2	Iron	mg/kg	30			
3	Nickel	mg/kg	32			
4	Phosphorus	mg/kg	1			
5	Zinc	mg/kg	2			
6	Used Lubricating Oil		Not present			
IP501 Na, V	**ICP Sodium and Vanadium □IP501□**				Method No: 172	
1	Sodium	mg/kg	58			
2	Vanadium	mg/kg	42			
D445A	**Auto Viscosity**				Method No: 395	
5	Viscosity Auto@50°C	cSt	1153			
6	V Number @ 50°C		35.48			
IP501 Al, Si	**ICP Aluminium and Silicon □IP501□**				Method No: 173	
1	Aluminium	mg/kg	5			
2	Silicon	mg/kg	10			
3	Aluminium + Silicon	mg/kg	15			

END OF RESULTS - SAMPLE# **638448**

Sample Results - Customer

VA
Validated & Approved

638609

Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **13-Mar-2020 6:00**

SAMPLE TYPE **U9520 Fuel Oil - Extra** 100

			Results	Low Limit 2	High Limit 2	✓
ISO12185	**Density of Fuel Oil by AP**				Method No: 401	
3	Density @ 15°C	kg/L	0.9717			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	1.961			
D445A	**Auto Viscosity**				Method No: 395	
5	Viscosity Auto@50°C	cSt	1151			
6	V Number @ 50°C		35.48			
D5185 mod A	**ICP 22 Elements in Hydrocarbon**				Method No: 169	
24	Arsenic	mg/kg	□1			
17	Silver	mg/kg	□1			
1	Aluminium	mg/kg	3			
2	Barium	mg/kg	□1			
4	Calcium	mg/kg	17			
23	Cadmium	mg/kg	□1			
5	Chromium	mg/kg	□1			
6	Copper	mg/kg	□1			
7	Iron	mg/kg	26			
14	Potassium	mg/kg	2			
9	Magnesium	mg/kg	2			
10	Manganese	mg/kg	□1			
11	Molybdenum	mg/kg	□1			
15	Sodium	mg/kg	58			
12	Nickel	mg/kg	39			
13	Phosphorus	mg/kg	□1			
8	Lead	mg/kg	□1			
16	Silicon	mg/kg	7			
19	Tin	mg/kg	□1			
20	Titanium	mg/kg	□1			
21	Vanadium	mg/kg	52			
22	Zinc	mg/kg	2			

END OF RESULTS - SAMPLE# **638609**

Sample Results - Customer

VA
Validated & Approved

638812
Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **16-Mar-2020 6:00**

SAMPLE TYPE **U9520 Fuel Oil - Extra** 100

			Results	Low Limit 2	High Limit 2	✓
D5185 mod A	**ICP 22 Elements in Hydrocarbon**				Method No: 169	
1	Aluminium	mg/kg	3			
24	Arsenic	mg/kg	□1			
2	Barium	mg/kg	□1			
4	Calcium	mg/kg	16			
23	Cadmium	mg/kg	□1			
5	Chromium	mg/kg	□1			
6	Copper	mg/kg	□1			
7	Iron	mg/kg	25			
8	Lead	mg/kg	□1			
9	Magnesium	mg/kg	2			
10	Manganese	mg/kg	□1			
11	Molybdenum	mg/kg	□1			
12	Nickel	mg/kg	38			
13	Phosphorus	mg/kg	□1			
14	Potassium	mg/kg	1			
15	Sodium	mg/kg	52			
16	Silicon	mg/kg	6			
17	Silver	mg/kg	□1			
19	Tin	mg/kg	□1			
20	Titanium	mg/kg	□1			
21	Vanadium	mg/kg	50			
22	Zinc	mg/kg	1			
ISO12185	**Density of Fuel Oil by AP**				Method No: 401	
3	Density @ 15°C	kg/L	0.9717			
D4294	**Sulphur by X-Ray**				Method No: 73	
2	Sulphur	%mass	1.980			
D445A	**Auto Viscosity**				Method No: 395	
5	Viscosity Auto@50°C	cSt	1151			
6	V Number @ 50°C		35.48			

END OF RESULTS - SAMPLE# **638812**

IPL
The best at all we test

Sample Results - Customer

VA
Validated & Approved

610409
Lab: **Fuels**

SITE	**U9520 Fuel Oil System**
SAMPLE POINT	**95QPA201 - Fuel Oil**
CUSTOMER	**The New Zealand Refining Co. Limited** **Asset North**
SAMPLE DATE	**01-May-2019 8:00**
SAMPLE TYPE	**U9520 Fuel Oil - Weekly** 100

			Results	Low Limit 2	High Limit 2	✓
D4052	**Density of Fuel Oil by AP**	Method No: 401				
3	Density @ 15°C	kg/L	0.9615			
D445	**Black Viscosity □Cone tube□**	Method No: 67				
1	Bath Temperature	°C	50.00			
4	Viscosity @ Test Temperature	cSt	425.7			
5	V Number @ 50°C		33.27			
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	2.253			
D5185 mod A	**ICP 22 Elements in Hydrocarbon**	Method No: 169				
24	Arsenic	mg/kg	□1			
17	Silver	mg/kg	□1			
1	Aluminium	mg/kg	2			
2	Barium	mg/kg	□1			
4	Calcium	mg/kg	9			
23	Cadmium	mg/kg	□1			
5	Chromium	mg/kg	□1			
6	Copper	mg/kg	□1			
7	Iron	mg/kg	13			
14	Potassium	mg/kg	□1			
9	Magnesium	mg/kg	□1			
10	Manganese	mg/kg	□1			
11	Molybdenum	mg/kg	□1			
15	Sodium	mg/kg	26			
12	Nickel	mg/kg	29			
13	Phosphorus	mg/kg	□1			
8	Lead	mg/kg	□1			
16	Silicon	mg/kg	3			
19	Tin	mg/kg	□1			
20	Titanium	mg/kg	□1			
21	Vanadium	mg/kg	41			
22	Zinc	mg/kg	□1			

END OF RESULTS - SAMPLE# **610409**

The information in this report was last updated on: *□/0□/201□ 1:0□:30p.m.*

Sample Results - Customer

VA
Validated & Approved

614760
Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **18-Jun-2019 8:00**

SAMPLE TYPE **U9520 Fuel Oil** 100

			Results	Low Limit 2	High Limit 2	✓
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	2.006			
D5185 mod A	**ICP 22 Elements in Hydrocarbon**	Method No: 169				
24	Arsenic	mg/kg	□1			
17	Silver	mg/kg	□1			
1	Aluminium	mg/kg	1			
2	Barium	mg/kg	□1			
4	Calcium	mg/kg	8			
23	Cadmium	mg/kg	□1			
5	Chromium	mg/kg	□1			
6	Copper	mg/kg	□1			
7	Iron	mg/kg	11			
14	Potassium	mg/kg	□1			
9	Magnesium	mg/kg	□1			
10	Manganese	mg/kg	□1			
11	Molybdenum	mg/kg	□1			
15	Sodium	mg/kg	22			
12	Nickel	mg/kg	28			
13	Phosphorus	mg/kg	□1			
8	Lead	mg/kg	□1			
16	Silicon	mg/kg	2			
19	Tin	mg/kg	□1			
20	Titanium	mg/kg	□1			
21	Vanadium	mg/kg	42			
22	Zinc	mg/kg	□1			
ANC011	**Mercury by DMA-80**	Method No: 445				
1	Mercury	□g/kg	□3			

END OF RESULTS - SAMPLE# **614760**

Sample Results - Customer

VA
Validated & Approved

634225
Lab: **Fuels**

SITE **U9520 Fuel Oil System**

SAMPLE POINT **95QPA201 - Fuel Oil**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset North

SAMPLE DATE **23-Jan-2020 6:00**

SAMPLE TYPE **U9520 Fuel Oil** 100

			Results	Low Limit 2	High Limit 2	✓
D4294	**Sulphur by X-Ray**	Method No: 73				
2	Sulphur	%mass	1.976			
IP501 Al, Si	**ICP Aluminium and Silicon (IP501)**	Method No: 173				
1	Aluminium	mg/kg	6			
2	Silicon	mg/kg	12			
3	Aluminium + Silicon	mg/kg	18			
IP501 Other	**ICP Other Metals (IP501)**	Method No: 174				
1	Calcium	mg/kg	18			
2	Iron	mg/kg	34			
3	Nickel	mg/kg	34			
4	Phosphorus	mg/kg	2			
5	Zinc	mg/kg	2			
6	Used Lubricating Oil		Not present			
IP501 Na, V	**ICP Sodium and Vanadium (IP501)**	Method No: 172				
1	Sodium	mg/kg	64			
2	Vanadium	mg/kg	46			

END OF RESULTS - SAMPLE# **634225**

Appendix D: Flare Gas Analysis Data

Sample Results - Customer

VA
Validated & Approved

511502
Lab: **Analytical**

SITE **U3400 Flare System**

SAMPLE POINT **Misc - Gas syringe from Flare**

CUSTOMER **The New Zealand Refining Co. Limited**
Asset Offplots Components

SAMPLE DATE **18-Mar-2016 12:15**

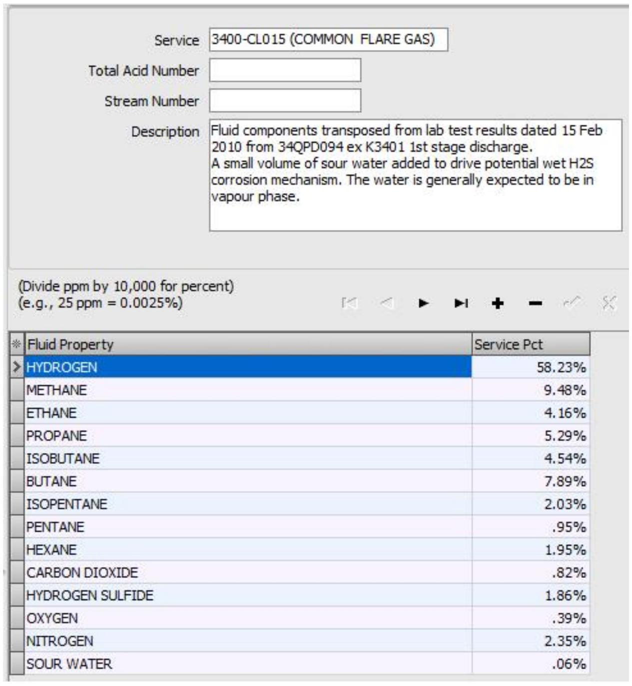
SAMPLE TYPE **U3400 Gas** 310

			Results	Low Limit 2	High Limit 2	✓
ANC004	**Full Gas Analysis**				Method No: 205	
18	Hexane+	%vol	0.94			
6	Propane	%vol	3.10			
5	Acetylene	%vol	<0.10			
8	Propylene	%vol	<0.10			
9	iso-Butane	%vol	2.74			
7	Propadiene	%vol	<0.10			
10	n-Butane	%vol	4.07			
12	Butene-1	%vol	<0.10			
15	iso-Butylene	%vol	<0.10			
14	t-Butene-2	%vol	<0.10			
13	c-Butene-2	%vol	<0.10			
11	1,3-Butadiene	%vol	<0.10			
16	iso-Pentane	%vol	1.21			
17	n-Pentane	%vol	0.57			
3	Ethane	%vol	1.69			
4	Ethylene	%vol	<0.10			
2	Methane	%vol	9.38			
1	Hydrogen	%vol	68.03			
20	Carbon Dioxide	%vol	0.33			
22	Oxygen+Argon	%vol	1.02			
23	Nitrogen	%vol	3.99			
19	Carbon Monoxide	%vol	<0.10			
21	H2S	%vol	2.93			
N/A	**H2S by GasTec**				Method No: 208	
1	H2S in Gas	ppm	20000			

END OF RESULTS - SAMPLE# **511502**

Flare Gas Composition

Component	Mol % (100 mol base)	Mol Mass g/mol	Weight g	**Weight %**		
Hydrogen	58.23	2.016	117.4	**6.3**		
Methane	9.48	16.04	152.1	**8.1**		
Ethane	4.16	30.07	125.1	**6.7**		
Propane	5.29	44.1	233.3	**12.5**		
Isobutane	4.54	58.12	263.9	**14.1**		
Butane	7.89	58.12	458.6	**24.5**		
Isopentane	2.03	72.15	146.5	**7.8**		
Pentane	0.95	72.15	68.5	**3.7**		
Hexane	1.95	86.18	168.1	**9**		
Carbon Dioxide	0.82	44.01	36.1	**1.9**		
Hydrogen Sulphide	1.86	34.1	63.4	**3.4**		
Oxygen	0.39	15.999	6.2	**0.3**		
Nitrogen	2.35	14.0067	32.9	**1.8**		
Water	0.06	18.01528	1.1	**0.1**		
Total	100		1873.1	**100**		



Service: 3400-CL015 (COMMON FLARE GAS)

Total Acid Number:

Stream Number:

Description: Fluid components transposed from lab test results dated 15 Feb 2010 from 34QPD094 ex K3401 1st stage discharge.
A small volume of sour water added to drive potential wet H2S corrosion mechanism. The water is generally expected to be in vapour phase.

(Divide ppm by 10,000 for percent)
(e.g., 25 ppm = 0.0025%)

Fluid Property	Service Pct
HYDROGEN	58.23%
METHANE	9.48%
ETHANE	4.16%
PROPANE	5.29%
ISOBUTANE	4.54%
BUTANE	7.89%
ISOPENTANE	2.03%
PENTANE	.95%
HEXANE	1.95%
CARBON DIOXIDE	.82%
HYDROGEN SULFIDE	1.86%
OXYGEN	.39%
NITROGEN	2.35%
SOUR WATER	.06%

IPL
The best at all we test

Sample Worksheet

C
Complete - All Results Entered

640339

SITE	**U3400 Flare System**
SAMPLE POINT	**Misc - Miscellaneous**
CUSTOMER	**The New Zealand Refining Co. Limited** **HSE Environmental**
SAMPLE TYPE	**Miscellaneous Gas Analysis** 160
CONTAINER	**Bladder**
REMARKS	Please email Riaan Elliot with results. Riaan.Elliot@refiningnz.com

	BY	DATE
ENTERED	**MXB**	**03-Apr-2020 9:46**
COLLECTION	NA	**03-Apr-2020 12:00** **Planned: 10:30**
RECEIVED	**SCANNE**	**03-Apr-2020 12:11**
APPROVED		
DUE DATE	NA	**03-Apr-2020 9:40**

D1945 Mod A **Gas Analysis D1945 ModA** Method No: 570

2nd Last Result	Last Result				Results	Low Limit 2	High Limit 2
		49	C6+	%vol	0.48		
		6	Propane	%vol	<0.01		
		5	Acetylene	%vol	<0.01		
		8	Propylene	%vol	<0.01		
		39	Isobutane	%vol	<0.01		
		7	Propadiene	%vol	<0.01		
		10	n-Butane	%vol	<0.01		
		42	1-Butene	%vol	<0.01		
		43	Isobutylene	%vol	<0.01		
		41	trans-2-Butene	%vol	<0.01		
		44	cis-2-Butene	%vol	<0.01		
		11	1,3-Butadiene	%vol	<0.01		
		46	Isopentane	%vol	0.01		
		17	n-Pentane	%vol	<0.01		
		3	Ethane	%vol	0.01		
		4	Ethylene	%vol	<0.01		
		2	Methane	%vol	1.18		
		1	Hydrogen	%vol	97.49		
		20	Carbon Dioxide	%vol	<0.01		
		50	Oxygen	%vol	0.13		
		23	Nitrogen	%vol	0.67		
		19	Carbon Monoxide	%vol	<0.01		
		38	Hydrogen Sulphide	%vol	<0.01		
		31	Methyl Acetylene	%vol	<0.01		
		32	2-Methyl-2-Butene	%vol	<0.01		
		33	1-Pentene	%vol	<0.01		
		36	Helium	%vol	0.04		
		45	2,2-Dimethylpropane	%vol	<0.01		
		47	trans-2-Pentene	%vol	<0.01		
		48	cis-2-Pentene	%vol	<0.01		

Appendix E: CALPUFF Configuration

CALPUFF Parameters

NZRC 1009695 - Tonkin + Taylor
Whangarei Met Set 2011-2012 with precipitation
11 Sources ; 1 Building

INPUT GROUP: 0 -- Input and Output File Names		
Parameter	**Description**	**Value**
PUFLST	CALPUFF output list file (CALPUFF.LST)	CALPUFF.LST
CONDAT	CALPUFF output concentration file (CONC.DAT)	CONC.DAT
DFDAT	CALPUFF output dry deposition flux file (DFLX.DAT)	DFLX.DAT
WFDAT	CALPUFF output wet deposition flux file (WFLX.DAT)	WFLX.DAT
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NMETDOM	Number of CALMET.DAT domains	1
NMETDAT	Number of CALMET.DAT input files	12
NPTDAT	Number of PTEMARB.DAT input files	0
NARDAT	Number of BAEMARB.DAT input files	0
NVOLDAT	Number of VOLEMARB.DAT input files	0
NFLDAT	Number of FLEMARB.DAT input files	0
NRDDAT	Number of RDEMARB.DAT input files	0
NLNDAT	Number of LNEMARB.DAT input files	0
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET01.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET02.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET03.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET04.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET05.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET06.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET07.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET08.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET09.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET10.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET11.MET
METDAT	CALMET gridded meteorological data file (CALMET.DAT)	CALMET12.MET

INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
METRUN	Run all periods in met data file? (0 = no, 1 = yes)	0
IBYR	Starting year	2011
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0

INPUT GROUP: 1 -- General Run Control Parameters		
Parameter	**Description**	**Value**
IBMIN	Starting minute	0
IBSEC	Starting second	0
IEYR	Ending year	2012
IEMO	Ending month	12
IEDY	Ending day	31
IEHR	Ending hour	22
IEMIN	Ending minute	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC+1200
NSECDT	Length of modeling time-step (seconds)	3600
NSPEC	Number of chemical species modeled	11
NSE	Number of chemical species to be emitted	9
ITEST	Stop run after SETUP phase (1 = stop, 2 = run)	2
MRESTART	Control option to read and/or write model restart data	0
NRESPD	Number of periods in restart output cycle	0
METFM	Meteorological data format (1 = CALMET, 2 = ISC, 3 = AUSPLUME, 4 = CTDM, 5 = AERMET)	1
MPRFFM	Meteorological profile data format (1 = CTDM, 2 = AERMET)	1
AVET	Averaging time (minutes)	60
PGTIME	PG Averaging time (minutes)	60
IOUTU	Output units for binary output files (1 = mass, 2 = odour, 3 = radiation)	1

INPUT GROUP: 2 -- Technical Options		
Parameter	**Description**	**Value**
MGAUSS	Near field vertical distribution (0 = uniform, 1 = Gaussian)	1
MCTADJ	Terrain adjustment method (0 = none, 1 = ISC-type, 2 = CALPUFF-type, 3 = partial plume path)	3
MCTSG	Model subgrid-scale complex terrain? (0 = no, 1 = yes)	0
MSLUG	Near-field puffs modeled as elongated slugs? (0 = no, 1 = yes)	0
MTRANS	Model transitional plume rise? (0 = no, 1 = yes)	1
MTIP	Apply stack tip downwash to point sources? (0 = no, 1 = yes)	1
MRISE	Plume rise module for point sources (1 = Briggs, 2 = numerical)	1
MTIP_FL	Apply stack tip downwash to flare sources? (0 = no, 1 = yes)	0
MRISE_FL	Plume rise module for flare sources (1 = Briggs, 2 = numerical)	2
MBDW	Building downwash method (1 = ISC, 2 = PRIME)	2
MSHEAR	Treat vertical wind shear? (0 = no, 1 = yes)	0
MSPLIT	Puff splitting allowed? (0 = no, 1 = yes)	0
MCHEM	Chemical transformation method (0 = not modeled, 1 = MESOPUFF II, 2 = User-specified, 3 = RIVAD/ARM3, 4 = MESOPUFF II for OH, 5 = half-life, 6 = RIVAD w/ISORROPIA, 7 = RIVAD w/ISORROPIA CalTech SOA)	1

INPUT GROUP: 2 -- Technical Options

Parameter	Description	Value
MAQCHEM	Model aqueous phase transformation? (0 = no, 1 = yes)	0
MLWC	Liquid water content flag	1
MWET	Model wet removal? (0 = no, 1 = yes)	1
MDRY	Model dry deposition? (0 = no, 1 = yes)	1
MTILT	Model gravitational settling (plume tilt)? (0 = no, 1 = yes)	0
MDISP	Dispersion coefficient calculation method (1= PROFILE.DAT, 2 = Internally, 3 = PG/MP, 4 = MESOPUFF II, 5 = CTDM)	2
MTURBVW	Turbulence characterization method (only if MDISP = 1 or 5)	1
MDISP2	Missing dispersion coefficients method (only if MDISP = 1 or 5)	3
MTAULY	Sigma-y Lagrangian timescale method	0
MTAUADV	Advective-decay timescale for turbulence (seconds)	0
MCTURB	Turbulence method (1 = CALPUFF, 2 = AERMOD)	1
MROUGH	PG sigma-y and sigma-z surface roughness adjustment? (0 = no, 1 = yes)	0
MPARTL	Model partial plume penetration for point sources? (0 = no, 1 = yes)	1
MPARTLBA	Model partial plume penetration for buoyant area sources? (0 = no, 1 = yes)	0
MTINV	Strength of temperature inversion provided in PROFILE.DAT? (0 = no - compute from default gradients, 1 = yes)	0
MPDF	PDF used for dispersion under convective conditions? (0 = no, 1 = yes)	1
MSGTIBL	Sub-grid TIBL module for shoreline? (0 = no, 1 = yes)	0
MBCON	Boundary conditions modeled? (0 = no, 1 = use BCON.DAT, 2 = use CONC.DAT)	0
MSOURCE	Save individual source contributions? (0 = no, 1 = yes)	0
MFOG	Enable FOG model output? (0 = no, 1 = yes - PLUME mode, 2 = yes - RECEPTOR mode)	0
MREG	Regulatory checks (0 = no checks, 1 = USE PA LRT checks)	0

INPUT GROUP: 3 -- Species List

Parameter	Description	Value
CSPEC	Species included in model run	SO2
CSPEC	Species included in model run	SO4
CSPEC	Species included in model run	NOX
CSPEC	Species included in model run	HNO3
CSPEC	Species included in model run	NO3
CSPEC	Species included in model run	Metals
CSPEC	Species included in model run	PM10
CSPEC	Species included in model run	PM2.5
CSPEC	Species included in model run	NO2
CSPEC	Species included in model run	SO3
CSPEC	Species included in model run	CO

INPUT GROUP: 4 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
PMAP	Map projection system	TTM
FEAST	False easting at projection origin (km)	1736.005
FNORTH	False northing at projection origin (km)	6033.005
UTMHEM	Hemisphere (N = northern, S = southern)	N
RLAT0	Latitude of projection origin (decimal degrees)	35.838S
RLON0	Longitude of projection origin (decimal degrees)	174.506E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	120
NY	Meteorological grid - number of Y grid cells	120
NZ	Meteorological grid - number of vertical layers	12
DGRIDKM	Meteorological grid spacing (km)	0.25
ZFACE	Meteorological grid - vertical cell face heights (m)	0.0, 20.0, 50.0, 90.0, 130.0, 200.0, 300.0, 450.0, 650.0, 950.0, 1400.0, 2000.0, 2896.0
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	1714.8750
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	6015.8750
IBCOMP	Computational grid - X index of lower left corner	12
JBCOMP	Computational grid - Y index of lower left corner	30
IECOMP	Computational grid - X index of upper right corner	120
JECOMP	Computational grid - Y index of upper right corner	120
LSAMP	Use sampling grid (gridded receptors) (T = true, F = false)	T
IBSAMP	Sampling grid - X index of lower left corner	40
JBSAMP	Sampling grid - Y index of lower left corner	46
IESAMP	Sampling grid - X index of upper right corner	101
JESAMP	Sampling grid - Y index of upper right corner	102
MESHDN	Sampling grid - nesting factor	1

INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
ICON	Output concentrations to CONC.DAT? (0 = no, 1 = yes)	1
IDRY	Output dry deposition fluxes to DFLX.DAT? (0 = no, 1 = yes)	1
IWET	Output wet deposition fluxes to WFLX.DAT? (0 = no, 1 = yes)	1
IT2D	Output 2D temperature data? (0 = no, 1 = yes)	0
IRHO	Output 2D density data? (0 = no, 1 = yes)	0
IVIS	Output relative humidity data? (0 = no, 1 = yes)	0
LCOMPRS	Use data compression in output file (T = true, F = false)	T

INPUT GROUP: 5 -- Output Options		
Parameter	**Description**	**Value**
IQAPLOT	Create QA output files suitable for plotting? (0 = no, 1 = yes)	1
IPFTRAK	Output puff tracking data? (0 = no, 1 = yes use timestep, 2 = yes use sampling step)	0
IMFLX	Output mass flux across specific boundaries? (0 = no, 1 = yes)	0
IMBAL	Output mass balance for each species? (0 = no, 1 = yes)	0
INRISE	Output plume rise data? (0 = no, 1 = yes)	0
ICPRT	Print concentrations? (0 = no, 1 = yes)	0
IDPRT	Print dry deposition fluxes? (0 = no, 1 = yes)	0
IWPRT	Print wet deposition fluxes? (0 = no, 1 = yes)	0
ICFRQ	Concentration print interval (timesteps)	1
IDFRQ	Dry deposition flux print interval (timesteps)	1
IWFRQ	Wet deposition flux print interval (timesteps)	1
IPRTU	Units for line printer output (e.g., 3 = ug/m**3 - ug/m**2/s, 5 = odor units)	3
IMESG	Message tracking run progress on screen (0 = no, 1 and 2 = yes)	2
LDEBUG	Enable debug output? (0 = no, 1 = yes)	F
IPFDEB	First puff to track in debug output	1
NPFDEB	Number of puffs to track in debug output	3997
NN1	Starting meteorological period in debug output	1
NN2	Ending meteorological period in debug output	10

INPUT GROUP: 6 -- Subgrid Scale Complex Terrain Inputs		
Parameter	**Description**	**Value**
NHILL	Number of terrain features	0
NCTREC	Number of special complex terrain receptors	0
MHILL	Terrain and CTSG receptor data format (1= CTDM, 2 = OPTHILL)	2
XHILL2M	Horizontal dimension conversion factor to meters	1.0
ZHILL2M	Vertical dimension conversion factor to meters	1.0
XCTDMKM	X origin of CTDM system relative to CALPUFF system (km)	0.0
YCTDMKM	Y origin of CTDM system relative to CALPUFF system (km)	0.0

INPUT GROUP: 9 -- Miscellaneous Dry Deposition Parameters		
Parameter	**Description**	**Value**
RCUTR	Reference cuticle resistance (s/cm)	30
RGR	Reference ground resistance (s/cm)	10
REACTR	Reference pollutant reactivity	8
NINT	Number of particle size intervals for effective particle deposition velocity	9
IVEG	Vegetation state in unirrigated areas (1 = active and unstressed, 2 = active and stressed, 3 = inactive)	1

INPUT GROUP: 11 -- Chemistry Parameters		
Parameter	**Description**	**Value**
MOZ	Ozone background input option (0 = monthly, 1 = hourly from OZONE.DAT)	0
BCKO3	Monthly ozone concentrations (ppb)	17, 18, 21, 24, 21, 22, 17, 18, 19, 17, 19, 15
MNH3	Ammonia background input option (0 = monthly, 1 = from NH3Z.DAT)	0
MAVGNH3	Ammonia vertical averaging option (0 = no average, 1 = average over vertical extent of puff)	1
BCKNH3	Monthly ammonia concentrations (ppb)	10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10
RNITE1	Nighttime SO2 loss rate (%/hr)	0.2
RNITE2	Nighttime NOx loss rate (%/hr)	2
RNITE3	Nighttime HNO3 loss rate (%/hr)	2
MH2O2	H2O2 background input option (0 = monthly, 1 = hourly from H2O2.DAT)	1
BCKH2O2	Monthly H2O2 concentrations (ppb)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
RH_ISRP	Minimum relative humidity for ISORROPIA	50.0
SO4_ISRP	Minimum SO4 for ISORROPIA	0.4
BCKPMF	SOA background fine particulate (ug/m**3)	1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00
OFRAC	SOA organic fine particulate fraction	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15
VCNX	SOA VOC/NOX ratio	50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00
NDECAY	Half-life decay blocks	0

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
SYTDEP	Horizontal puff size for time-dependent sigma equations (m)	550
MHFTSZ	Use Heffter equation for sigma-z? (0 = no, 1 = yes)	0
JSUP	PG stability class above mixed layer	5
CONK1	Vertical dispersion constant - stable conditions	0.01
CONK2	Vertical dispersion constant - neutral/unstable conditions	0.1
TBD	Downwash scheme transition point option (<0 = Huber-Snyder, 1.5 = Schulman-Scire, 0.5 = ISC)	0.5
IURB1	Beginning land use category for which urban dispersion is assumed	10
IURB2	Ending land use category for which urban dispersion is assumed	19
ILANDUIN	Land use category for modeling domain	20
Z0IN	Roughness length for modeling domain (m)	.25
XLAIIN	Leaf area index for modeling domain	3.0

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
ELEVIN	Elevation above sea level (m)	.0
XLATIN	Meteorological station latitude (deg)	-999.0
XLONIN	Meteorological station longitude (deg)	-999.0
ANEMHT	Anemometer height (m)	10.0
ISIGMAV	Lateral turbulence format (0 = read sigma-theta, 1 = read sigma-v)	1
IMIXCTDM	Mixing heights read option (0 = predicted, 1 = observed)	0
XMXLEN	Slug length (met grid units)	1
XSAMLEN	Maximum travel distance of a puff/slug (met grid units)	1
MXNEW	Maximum number of slugs/puffs release from one source during one time step	99
MXSAM	Maximum number of sampling steps for one puff/slug during one time step	99
NCOUNT	Number of iterations used when computing the transport wind for a sampling step that includes gradual rise	2
SYMIN	Minimum sigma-y for a new puff/slug (m)	1
SZMIN	Minimum sigma-z for a new puff/slug (m)	1
SZCAP_M	Maximum sigma-z allowed to avoid numerical problem in calculating virtual time or distance (m)	5000000
SVMIN	Minimum turbulence velocities sigma-v (m/s)	0.5, 0.5, 0.5, 0.5, 0.5, 0.5, 0.37, 0.37, 0.37, 0.37, 0.37, 0.37
SWMIN	Minimum turbulence velocities sigma-w (m/s)	0.2, 0.12, 0.08, 0.06, 0.03, 0.016, 0.2, 0.12, 0.08, 0.06, 0.03, 0.016
CDIV	Divergence criterion for dw/dz across puff (1/s)	0, 0
NLUTIBL	TIBL module search radius (met grid cells)	4
WSCALM	Minimum wind speed allowed for non-calm conditions (m/s)	0.5
XMAXZI	Maximum mixing height (m)	3000
XMINZI	Minimum mixing height (m)	50
TKCAT	Emissions scale-factors temperature categories (K)	265., 270., 275., 280., 285., 290., 295., 300., 305., 310., 315.
PLX0	Wind speed profile exponent for stability classes 1 to 6	0.07, 0.07, 0.1, 0.15, 0.35, 0.55
PTG0	Potential temperature gradient for stable classes E and F (deg K/m)	0.02, 0.035
PPC	Plume path coefficient for stability classes 1 to 6	0.5, 0.5, 0.5, 0.5, 0.35, 0.35
SL2PF	Slug-to-puff transition criterion factor (sigma-y/slug length)	10
FCLIP	Hard-clipping factor for slugs (0.0 = no extrapolation)	0
NSPLIT	Number of puffs created from vertical splitting	3
IRESPLIT	Hour for puff re-split	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0
ZISPLIT	Minimum mixing height for splitting (m)	100

INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters		
Parameter	**Description**	**Value**
ROLDMAX	Mixing height ratio for splitting	0.25
NSPLITH	Number of puffs created from horizontal splitting	5
SYSPLITH	Minimum sigma-y (met grid cells)	1
SHSPLITH	Minimum puff elongation rate (SYSPLITH/hr)	2
CNSPLITH	Minimum concentration (g/m**3)	0
EPSSLUG	Fractional convergence criterion for numerical SLUG sampling integration	0.0001
EPSAREA	Fractional convergence criterion for numerical AREA source integration	1E-006
DSRISE	Trajectory step-length for numerical rise integration (m)	1.0
HTMINBC	Minimum boundary condition puff height (m)	500
RSAMPBC	Receptor search radius for boundary condition puffs (km)	10
MDEPBC	Near-surface depletion adjustment to concentration (0 = no, 1 = yes)	1

INPUT GROUP: 13 -- Point Source Parameters		
Parameter	**Description**	**Value**
NPT1	Number of point sources	8
IPTU	Units used for point source emissions (e.g., 1 = g/s)	2
NSPT1	Number of source-species combinations with variable emission scaling factors	0
NPT2	Number of point sources in PTEMARB.DAT file(s)	0

INPUT GROUP: 14 -- Area Source Parameters		
Parameter	**Description**	**Value**
NAR1	Number of polygon area sources	0
IARU	Units used for area source emissions (e.g., 1 = g/m**2/s)	1
NSAR1	Number of source-species combinations with variable emission scaling factors	0
NAR2	Number of buoyant polygon area sources in BAEMARB.DAT file(s)	0

INPUT GROUP: 15 -- Line Source Parameters		
Parameter	**Description**	**Value**
NLN2	Number of buoyant line sources in LNEMARB.DAT file	0
NLINES	Number of buoyant line sources	0
ILNU	Units used for line source emissions (e.g., 1 = g/s)	1
NSLN1	Number of source-species combinations with variable emission scaling factors	0
NLRISE	Number of distances at which transitional rise is computed	6

INPUT GROUP: 16 -- Volume Source Parameters		
Parameter	**Description**	**Value**
NVL1	Number of volume sources	0

INPUT GROUP: 16 -- Volume Source Parameters		
Parameter	**Description**	**Value**
IVLU	Units used for volume source emissions (e.g., 1 = g/s)	1
NSVL1	Number of source-species combinations with variable emission scaling factors	0
NVL2	Number of volume sources in VOLEMARB.DAT file(s)	0

INPUT GROUP: 17 -- FLARE Source Control Parameters (variable emissions file)		
Parameter	**Description**	**Value**
NFL2	Number of flare sources defined in FLEMARB.DAT file(s)	0

INPUT GROUP: 18 -- Road Emissions Parameters		
Parameter	**Description**	**Value**
NRD1	Number of road-links sources	0
NRD2	Number of road-links in RDEMARB.DAT file	0
NSFRDS	Number of road-links and species combinations with variable emission-rate scale-factors	0

INPUT GROUP: 19 -- Emission Rate Scale-Factor Tables		
Parameter	**Description**	**Value**
NSFTAB	Number of emission scale-factor tables	0

INPUT GROUP: 20 -- Non-gridded (Discrete) Receptor Information		
Parameter	**Description**	**Value**
NREC	Number of discrete receptors (non-gridded receptors)	2116
NRGRP	Number of receptor group names	0

Appendix F: CALMET Configuration

CALMET Parameters

NZRC 1009695 - Tonkin + Taylor
Whangarei Met Set 2011-2012 with precipitation
30 km by 30km, at 250 m resolution

INPUT GROUP: 0 -- Input and Output File Names

Parameter	Description	Value
GEODAT	Input file of geophysical data (GEO.DAT)	Geo.dat
SRFDAT	Input file of hourly surface meteorological data (SURF.DAT)	SURF.dat
PRCDAT	Input file of hourly precipitation data (PRECIP.DAT)	PRECIP.dat
METLST	Output file name of CALMET list file (CALMET.LST)	CALMET.LST
METDAT	Output file name of generated gridded met files (CALMET.DAT)	CALMET01.MET
LCFILES	Lower case file names (T = lower case, F = upper case)	F
NUSTA	Number of upper air stations	0
NOWSTA	Number of overwater stations	0
NM3D	Number of prognostic meteorological data files (3D.DAT)	1
NIGF	Number of IGF-CALMET.DAT files used as initial guess	0

INPUT GROUP: 1 -- General Run Control Parameters

Parameter	Description	Value
IBYR	Starting year	2011
IBMO	Starting month	1
IBDY	Starting day	1
IBHR	Starting hour	0
IBSEC	Starting second	0
IEYR	Ending year	2011
IEMO	Ending month	3
IEDY	Ending day	1
IEHR	Ending hour	0
IESEC	Ending second	0
ABTZ	Base time zone	UTC+1200
NSECDT	Length of modeling time-step (seconds)	3600
IRTYPE	Output run type (0 = wind fields only, 1 = CALPUFF/CALGRID)	1
LCALGRD	Compute CALGRID data fields (T = true, F = false)	T
ITEST	Flag to stop run after setup phase (1 = stop, 2 = run)	2
MREG	Regulatory checks (0 = no checks, 1 = US EPA LRT checks)	0

INPUT GROUP: 2 -- Map Projection and Grid Control Parameters

Parameter	Description	Value
PMAP	Map projection system	TTM

INPUT GROUP: 2 -- Map Projection and Grid Control Parameters		
Parameter	**Description**	**Value**
FEAST	False easting at projection origin (km)	1736.005
FNORTH	False northing at projection origin (km)	6033.005
UTMHEM	Hemisphere of UTM projection (N = northern, S = southern)	N
RLAT0	Latitude of projection origin (decimal degrees)	35.838S
RLON0	Longitude of projection origin (decimal degrees)	174.506E
XLAT1	1st standard parallel latitude (decimal degrees)	30S
XLAT2	2nd standard parallel latitude (decimal degrees)	60S
DATUM	Datum-Region for the coordinates	WGS-84
NX	Meteorological grid - number of X grid cells	120
NY	Meteorological grid - number of Y grid cells	120
DGRIDKM	Meteorological grid spacing (km)	0.25
XORIGKM	Meteorological grid - X coordinate for SW corner (km)	1714.8750
YORIGKM	Meteorological grid - Y coordinate for SW corner (km)	6015.8750
NZ	Meteorological grid - number of vertical layers	12
ZFACE	Meteorological grid - vertical cell face heights (m)	0.00,20.00,50.00,90.00,130.00,200.00,300.00,450.00,650.00,950.00,1400.00,2000.00,2896.00

INPUT GROUP: 3 -- Output Options		
Parameter	**Description**	**Value**
LSAVE	Save met fields in unformatted output file (T = true, F = false)	T
IFORMO	Type of output file (1 = CALPUFF/CALGRID, 2 = MESOPUFF II)	1
LPRINT	Print met fields (F = false, T = true)	F
IPRINF	Print interval for output wind fields (hours)	1
STABILITY	Print gridded PGT stability classes? (0 = no, 1 = yes)	0
USTAR	Print gridded friction velocities? (0 = no, 1 = yes)	0
MONIN	Print gridded Monin-Obukhov lengths? (0 = no, 1 = yes)	0
MIXHT	Print gridded mixing heights? (0 = no, 1 = yes)	0
WSTAR	Print gridded convective velocity scales? (0 = no, 1 = yes)	0
PRECIP	Print gridded hourly precipitation rates? (0 = no, 1 = yes)	0
SENSHEAT	Print gridded sensible heat fluxes? (0 = no, 1 = yes)	0
CONVZI	Print gridded convective mixing heights? (0 = no, 1 = yes)	0
LDB	Test/debug option: print input met data and internal variables (F = false, T = true)	F
NN1	Test/debug option: first time step to print	1
NN2	Test/debug option: last time step to print	1
LDBCST	Test/debug option: print distance to land internal variables (F = false, T = true)	F

INPUT GROUP: 3 -- Output Options		
Parameter	**Description**	**Value**
IOUTD	Test/debug option: print control variables for writing winds? (0 = no, 1 = yes)	0
NZPRN2	Test/debug option: number of levels to print starting at the surface	1
IPR0	Test/debug option: print interpolated winds? (0 = no, 1 = yes)	0
IPR1	Test/debug option: print terrain adjusted surface wind? (0 = no, 1 = yes)	0
IPR2	Test/debug option: print smoothed wind and initial divergence fields? (0 = no, 1 = yes)	0
IPR3	Test/debug option: print final wind speed and direction? (0 = no, 1 = yes)	0
IPR4	Test/debug option: print final divergence fields? (0 = no, 1 = yes)	0
IPR5	Test/debug option: print winds after kinematic effects? (0 = no, 1 = yes)	0
IPR6	Test/debug option: print winds after Froude number adjustment? (0 = no, 1 = yes)	0
IPR7	Test/debug option: print winds after slope flow? (0 = no, 1 = yes)	0
IPR8	Test/debug option: print final winds? (0 = no, 1 = yes)	0

INPUT GROUP: 4 -- Meteorological Data Options		
Parameter	**Description**	**Value**
NOOBS	Observation mode (0 = stations only, 1 = surface/overwater stations with prognostic upper air, 2 = prognostic data only)	1
NSSTA	Number of surface stations	2
NPSTA	Number of precipitation stations	1
ICLDOUT	Output the CLOUD.DAT file? (0 = no, 1 = yes)	0
MCLOUD	Method to compute cloud fields (1 = from surface obs, 2 = from CLOUD.DAT, 3 = from prognostic (Teixera), 4 = from prognostic (MM5toGrads)	4
IFORMS	Surface met data file format (1 = unformatted, 2 = formatted)	2
IFORMP	Precipitation data file format (1 = unformatted, 2 = formatted)	2
IFORMC	Cloud data file format (1 = unformatted, 2 = formatted)	1

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
IWFCOD	Wind field model option (1 = objective analysis, 2 = diagnostic)	1
IFRADJ	Adjust winds using Froude number effects? (0 = no, 1 = yes)	1
IKINE	Adjust winds using kinematic effects? (0 = no, 1 = yes)	0
IOBR	Adjust winds using O'Brien velocity procedure? (0 = no, 1 = yes)	0
ISLOPE	Compute slope flow effects? (0 = no, 1 = yes)	1
IEXTRP	Extrapolation of surface winds to upper layers method (1 = none, 2 = power law, 3 = user input, 4 = similarity theory, - = same except layer 1 data at upper air stations are ignored)	4
ICALM	Extrapolate surface winds even if calm? (0 = no, 1 = yes)	0
BIAS	Weighting factors for surface and upper air stations (NZ values)	2*-1,-0.5,7*0,2*1

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
RMIN2	Minimum upper air station radius of influence for surface extrapolation exclusion (km)	-1
IPROG	Use prognostic winds as input to diagnostic wind model (0 = no, 13 = use winds from 3D.DAT as Step 1 field, 14 = use winds from 3D.DAT as initial guess field, 15 = use winds from 3D.DAT file as observations)	14
ISTEPPGS	Prognostic data time step (seconds)	3600
IGFMET	Use coarse CALMET fields as initial guess? (0 = no, 1 = yes)	0
LVARY	Use varying radius of influence (F = false, T = true)	F
RMAX1	Maximum radius of influence in the surface layer (km)	3
RMAX2	Maximum radius of influence over land aloft (km)	6
RMAX3	Maximum radius of influence over water (km)	20
RMIN	Minimum radius of influence used in wind field interpolation (km)	0.1
TERRAD	Radius of influence of terrain features (km)	3
R1	Relative weight at surface of step 1 fields and observations (km)	1
R2	Relative weight aloft of step 1 field and observations (km)	1
RPROG	Weighting factors of prognostic wind field data (km)	0
DIVLIM	Maximum acceptable divergence	5E-006
NITER	Maximum number of iterations in the divergence minimization procedure	50
NSMTH	Number of passes in the smoothing procedure (NZ values)	2,11*4
NINTR2	Maximum number of stations used in each layer for interpolation (NZ values)	12*99
CRITFN	Critical Froude number	1
ALPHA	Empirical factor triggering kinematic effects	0.1
FEXTR2	Multiplicative scaling factor for extrapolation of surface observations to upper layers (NZ values)	12*0
NBAR	Number of barriers to interpolation of the wind fields	0
KBAR	Barrier - level up to which barriers apply (1 to NZ)	10
IDIOPT1	Surface temperature (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
ISURFT	Surface station to use for surface temperature (between 1 and NSSTA)	-1
IDIOPT2	Temperature lapse rate used in the computation of terrain-induced circulations (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPT	Upper air station to use for the domain-scale lapse rate (between 1 and NUSTA)	-1
ZUPT	Depth through which the domain-scale lapse rate is computed (m)	200
IDIOPT3	Initial guess field winds (0 = compute from obs/prognostic, 1 = read from DIAG.DAT)	0
IUPWND	Upper air station to use for domain-scale winds	-1
ZUPWND	Bottom and top of layer through which the domain-scale winds are computed (m)	1.0, 1.00
IDIOPT4	Read observed surface wind components (0 = from SURF.DAT, 1 = from DIAG.DAT)	0
IDIOPT5	Read observed upper wind components (0 = from UPn.DAT, 1 = from DIAG.DAT)	0

INPUT GROUP: 5 -- Wind Field Options and Parameters		
Parameter	**Description**	**Value**
LLBREZE	Use Lake Breeze module (T = true, F = false)	F
NBOX	Lake Breeze - number of regions	0

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters		
Parameter	**Description**	**Value**
CONSTB	Mixing height constant: neutral, mechanical equation	1.41
CONSTE	Mixing height constant: convective equation	0.15
CONSTN	Mixing height constant: stable equation	2400
CONSTW	Mixing height constant: overwater equation	0.16
FCORIOL	Absolute value of Coriolis parameter (1/s)	0.0001
IAVEZI	Spatial mixing height averaging? (0 = no, 1 = yes)	1
MNMDAV	Maximum search radius in averaging process (grid cells)	1
HAFANG	Half-angle of upwind looking cone for averaging (degrees)	30
ILEVZI	Layer of winds used in upwind averaging (between 1 and NZ)	1
IMIXH	Convective mixing height method (1 = Maul-Carson, 2 = Batchvarova-Gryning, - for land cells only, + for land and water cells)	1
THRESHL	Overland threshold boundary flux (W/m**3)	0
THRESHW	Overwater threshold boundary flux (W/m**3)	0.05
ITWPROG	Overwater lapse rate and deltaT options (0 = from SEA.DAT, 1 = use prognostic lapse rates and SEA.DAT deltaT, 2 = from prognostic)	0
ILUOC3D	Land use category in 3D.DAT	16
DPTMIN	Minimum potential temperature lapse rate (K/m)	0.001
DZZI	Depth of computing capping lapse rate (m)	200
ZIMIN	Minimum overland mixing height (m)	50
ZIMAX	Maximum overland mixing height (m)	3000
ZIMINW	Minimum overwater mixing height (m)	50
ZIMAXW	Maximum overwater mixing height (m)	3000
ICOARE	Overwater surface fluxes method	10
DSHELF	Coastal/shallow water length scale (km)	0
IWARM	COARE warm layer computation (0 = off, 1 = on)	0
ICOOL	COARE cool skin layer computation (0 = off, 1 = on)	0
IRHPROG	Relative humidity read option (0 = from SURF.DAT, 1 = from 3D.DAT)	0
ITPROG	3D temperature read option (0 = stations, 1 = surface from station and upper air from prognostic, 2 = prognostic)	2
IRAD	Temperature interpolation type (1 = 1/R, 2 = 1/R**2)	1
TRADKM	Temperature interpolation radius of influence (km)	500
NUMTS	Maximum number of stations to include in temperature interpolation	5
IAVET	Conduct spatial averaging of temperatures? (0 = no, 1 = yes)	1
TGDEFB	Default overwater mixed layer lapse rate (K/m)	-0.0098
TGDEFA	Default overwater capping lapse rate (K/m)	-0.0045

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters		
Parameter	**Description**	**Value**
JWAT1	Beginning land use category for temperature interpolation over water	999
JWAT2	Ending land use category for temperature interpolation over water	999
NFLAGP	Precipitation interpolation method (1 = 1/R, 2 = 1/R**2, 3 = EXP/R**2)	2
SIGMAP	Precipitation interpolation radius of influence (km)	100
CUTP	Minimum precipitation rate cutoff (mm/hr)	0.01

Appendix G: Selection of Meteorological Years

A significant driver in the annual variation in meteorology in New Zealand is the presence of El Niño or La Niña conditions. The Southern Oscillation Index (SOI) is a measure of the variation in sea surface temperature over the tropical eastern Pacific Ocean, which in turn affects much of the climate of adjacent tropical and sub-tropical areas. The warming phase of the tropical eastern Pacific Ocean is referred to as El Niño, whereas the cooling phase is La Niña.

Under La Niña conditions, a greater prevalence of northeasterly winds is characteristic across the northern parts of New Zealand, whereas a greater prevalence of westerly winds is characteristic of El Niño conditions. Figure G.1provides a graph of monthly SOI values from January 2010 to January 2020 and indicates the presence of both El Niño (SOI >1) and La Niña (SOI <-1) conditions.

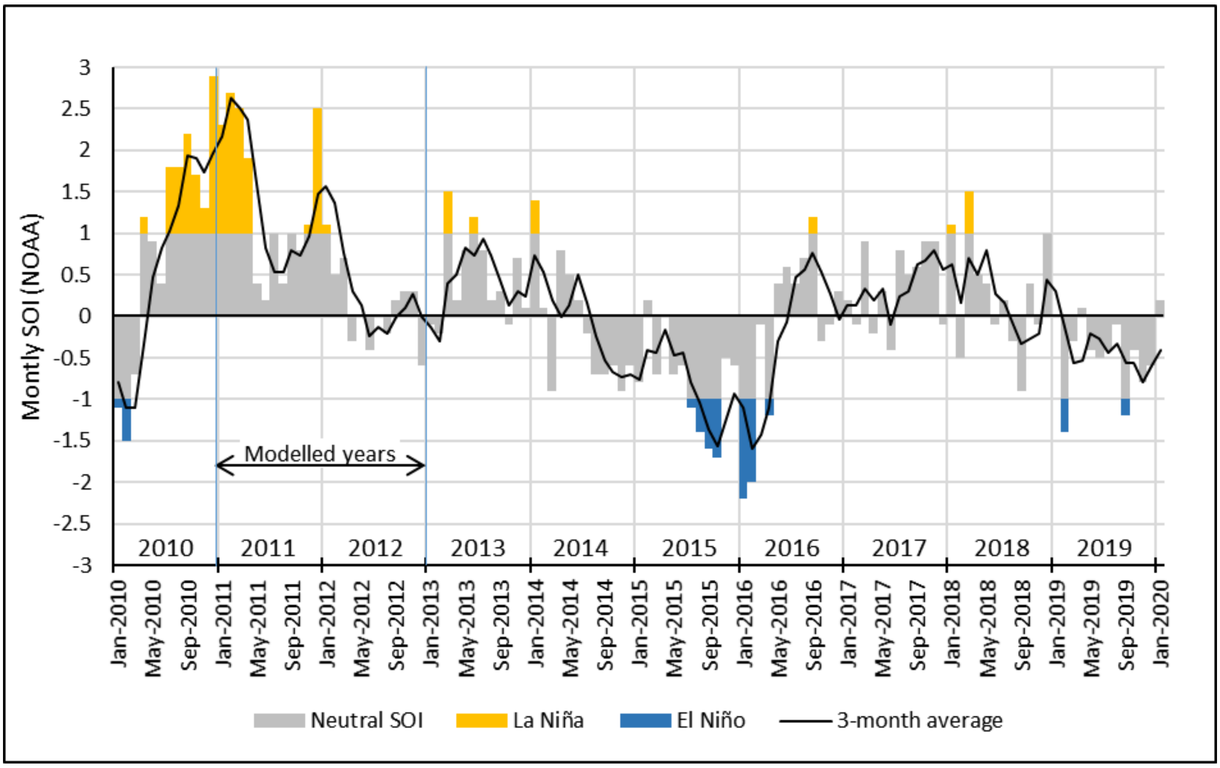


Figure G.1: Southern Oscillation Index from January 2010 to January 2020, indicating La Nina and El Nino conditions.

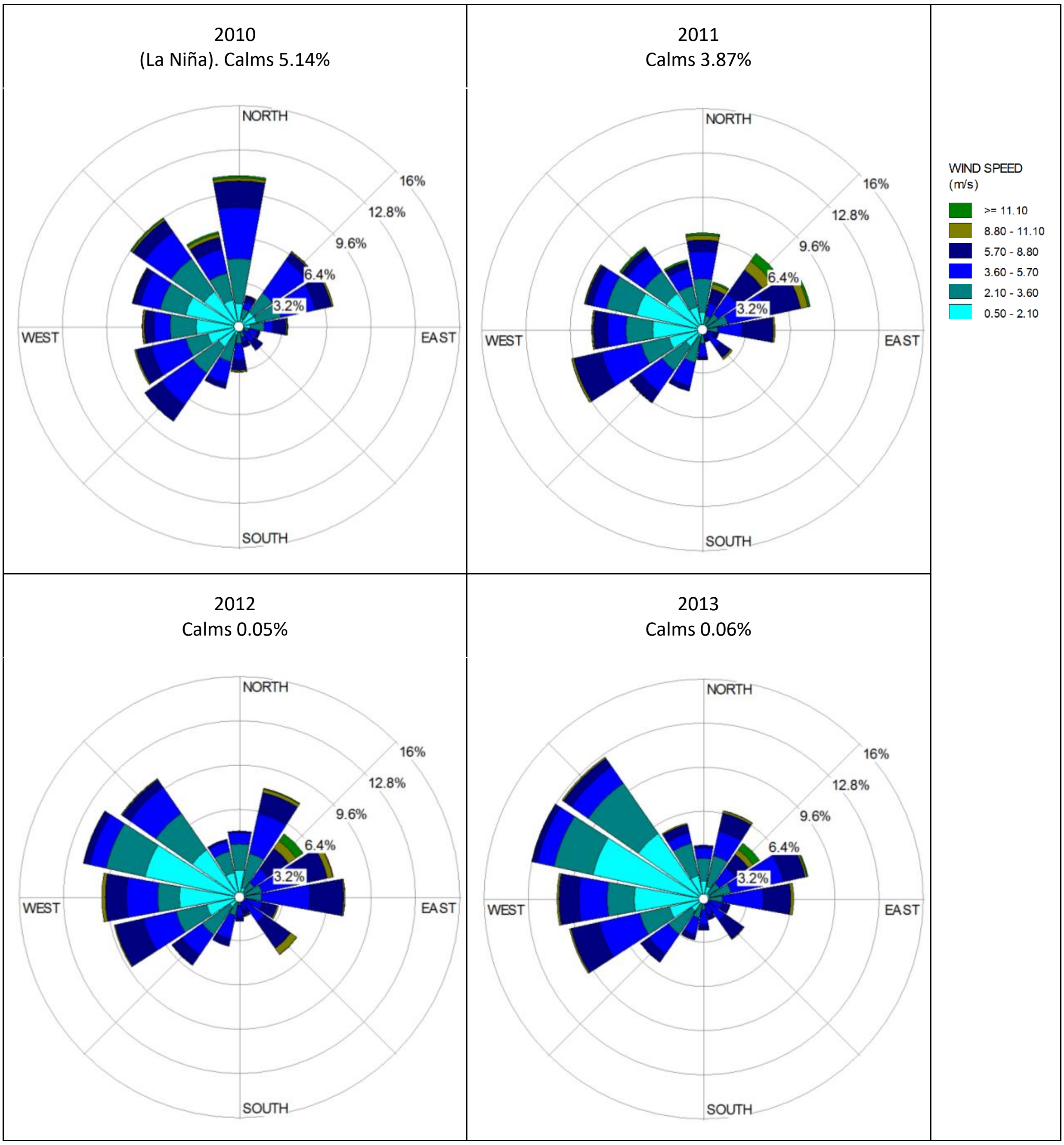
The two years that have been used in the dispersion modelling assessment (2011 and 2012) covered predominantly La Niña during 2011 with neutral conditions being prevalent in 2012 (neither tending towards being El Niño or La Niña).

Wind roses for each year from 2010 through to 2017 (including the two modelled years of 2011 and 2012) are provided in Figure G.2 and Figure G.3. The year 2010 (being a strongly La Niña year) appears distinctly different and has a greater prevalence of northerly winds, which is line with the general expectation of more northeasterly winds during La Niña conditions for the upper North Island. This northerly artefact is less prevalent in 2011 (the first of the modelled years) and is reduced further in 2012. The windrose for 2012 appears to be typical of the wind roses for other years (2013 to 2017), as would be expected given that SOI conditions were neutral for 2012.

Of the years examined, 2015 and 2016 exhibit SOI conditions that are at times typical of El Niño conditions. However, the windroses for those years are not significantly distinct from other years in the analysis, with the exception of 2010 (La Niña).

Figure G.4 provides a wind rose covering the overall 2010 to 2017 period and compares this to the modelled period (2011 and 2012). For the period 2010 to 2017 there is a slightly greater prevalence of northwesterly winds than the modelled years. However, this would tend to result in a greater prevalence of emissions from the Refinery being transported out to sea and away from sensitive land uses.

On balance and given the above discussion, T+T considers that the choice to model the years 2011 and 2012 provides a suitably robust range of meteorological conditions necessary for the dispersion modelling assessment while being representative of meteorological conditions of the site.



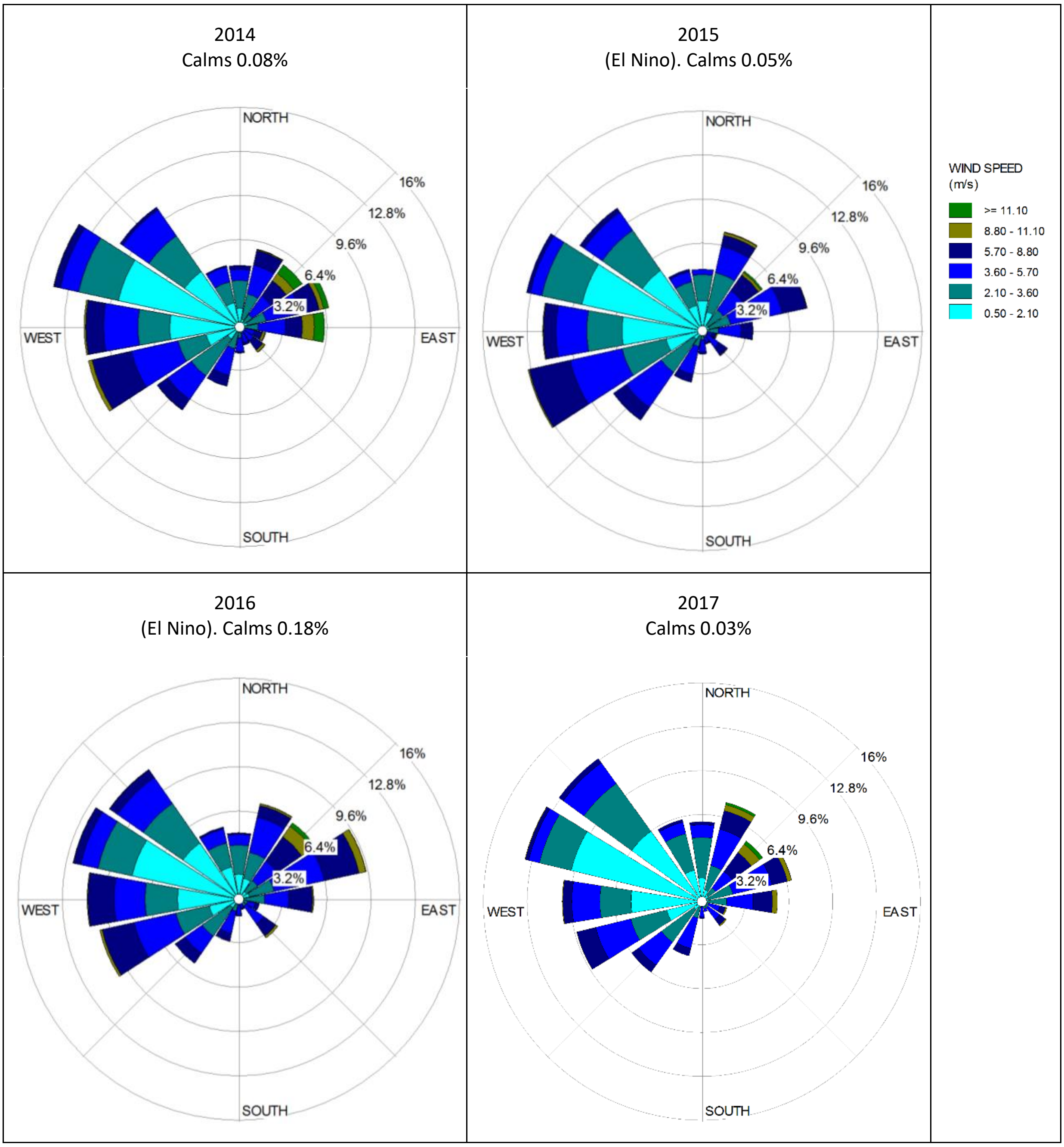
2010
(La Niña). Calms 5.14%

2011
Calms 3.87%

2012
Calms 0.05%

2013
Calms 0.06%

Figure G.2: Windroses generated from NZRC monitoring site data for the years 2010 to 2013.



2014
Calms 0.08%

2015
(El Nino). Calms 0.05%

2016
(El Nino). Calms 0.18%

2017
Calms 0.03%

Figure G.3: Windroses generated from NZRC monitoring site data for the years 2014 to 2017.

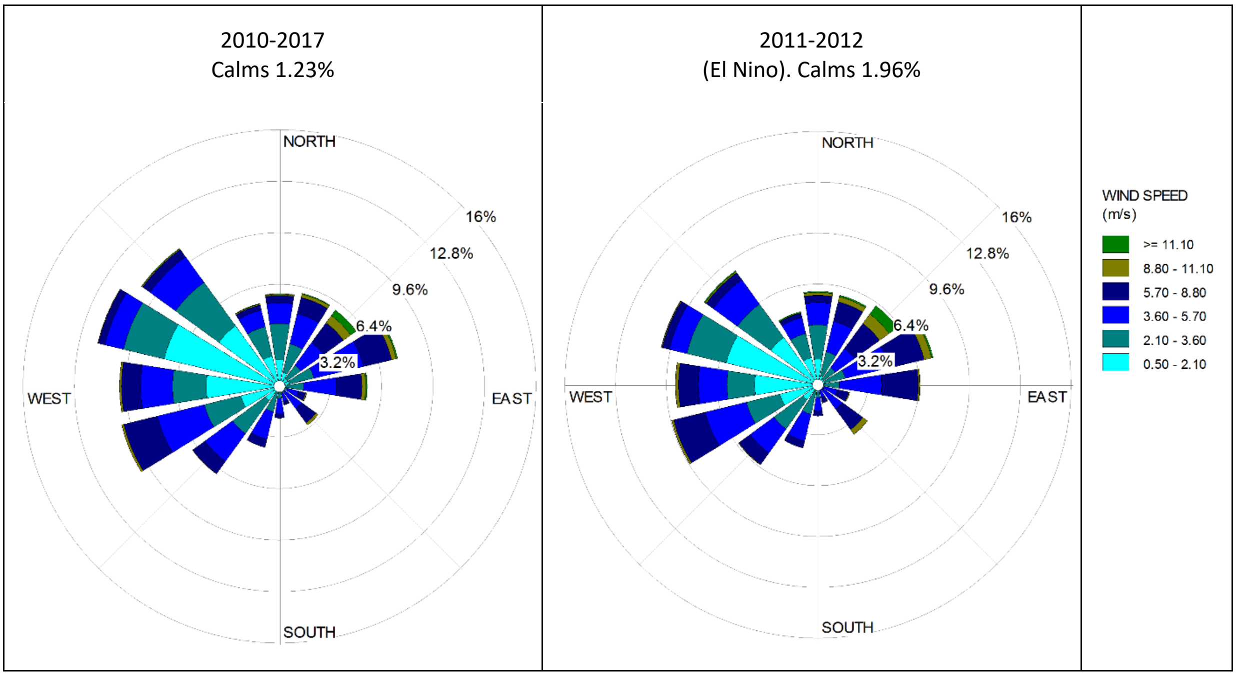


Figure G.4: Windroses generated from NZRC monitoring site data for the years 2010 to 2017 (inclusive) compared with the modelled years of 2011 and 2012 (inclusive).

Appendix H: SCREEN3 Model Inputs and Results

SCREEN3 Model inputs	Scenario value	Units
Flare height:	110	m
Emission rate	63	g/s
Dispersion coefficient	Rural	
Meteorology	Full	
Fumigation	Yes	
Shoreline fumigation	Yes	
Shoreline distance	300	m

Parameter	Scenario value					Comment
Percentile of flare gas rate	Maximum	99th%ile	90th%ile	75%ile	50%ile	
Flare gas rate (T[gas]/day)	(85 T/d)	(53 T/d)	(17 T/d)	(1.7 T/d)	(0.23 T/d)	
Flare gas CV rate (cal/s)	10,995,500	6,841,500	2,156,000	217,000	30,500	Based on average of tests
Flare gas SO_2 rate (g/s)	63.01	39.2	12.35	1.24	0.17	Based on average of tests
Distance from flare (m)	SCREEN3 1-hour averge SO2 (µg/m³)					
100	0	0	0	2.61E-13	1.31E-13	
200	7.86E-07	2.83E-08	2.79E-06	7.32E-03	6.62E-03	
300	1.81E-06	1.91E-04	1.10E-01	0.9248	0.5114	
400	2.62E-02	0.2599	3.90E+00	4.543	1.616	
500	2.314	6.429	15	8.932	1.97	
600	18.88	25.62	23.1	9.647	1.645	
700	39.32	37.9	42.1	8.557	1.433	
800	47.7	61.24	52.17	7.598	1.546	
900	70.72	73.02	52.47	6.848	1.538	
1000	81.54	74.22	49.19	6.912	1.464	
1100	83.45	70.8	45.7	6.961	1.36	
1200	80.72	66.61	42.64	6.798	1.249	
1300	76.81	62.89	39.97	6.523	1.252	
1400	72.99	60.01	37.62	6.203	1.275	
1500	69.51	57.29	35.55	5.878	1.273	
1600	66.33	54.79	33.7	5.568	1.255	
1700	63.43	52.49	32.04	5.53	1.226	
1800	60.77	50.38	30.55	5.615	1.189	
1900	58.33	48.42	29.2	5.636	1.147	
2000	56.08	46.62	27.96	5.609	1.103	
2100	54.21	44.94	28.22	5.544	1.057	
2200	52.5	43.38	28.55	5.451	1.012	
2300	50.89	41.93	28.64	5.339	0.9682	
2400	49.37	40.57	28.54	5.214	0.9254	
2500	47.95	39.3	28.29	5.082	0.8845	
2600	46.6	38.11	27.92	4.945	0.8455	
2700	45.32	37.54	27.46	4.807	0.8086	
2800	44.12	37.77	26.95	4.67	0.7738	
2900	42.97	37.82	26.39	4.537	0.7411	
3000	41.89	37.72	25.82	4.407	0.7104	
3500	40.53	35.73	22.96	3.835	0.6144	
4000	39.53	32.76	20.96	3.387	0.6189	
4500	37.25	30.47	21.45	3.037	0.6071	
5000	34.64	28.75	21.19	2.757	0.5862	

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