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PREPARED FOR

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# Regional Air Emission Inventory 2022

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# EXECUTIVE SUMMARY

In 2022 an emission inventory was carried out to assess quantities and sources of discharges to air across the Bay of Plenty Region. The sources included were domestic heating, motor vehicles, outdoor burning (including braziers, pizza ovens and solid fuel barbeques), industrial and commercial activities (including small scale activities), port and shipping emissions. The evaluation focuses on particles in the air less than 10 microns ($PM_{10}$), particles in the air less than 2.5 microns ($PM_{2.5}$), sulphur oxides, nitrogen oxides and carbon monoxide.

The purpose of the inventory was to provide a spatial disaggregation of emissions across the region as well as assess the key sources contributing to air discharges in the region.

Data from Statistics New Zealand collected through the 2018 census and adjusted for 2022 population projections was used in the assessment for dwelling-based metrics. These were available at the statistical area 1 (SA1) level for total dwelling numbers and households using different home heating fuel types. Location specific data were used for industrial discharges and shipping emissions were allocated to the Port of Tauranga SA1 area. Emission inventory data from Rotorua, Whakatane and Tauranga were spatially disaggregated to SA1 area and emissions for the remainder of the region were based on household data available at the SA1 level.

Across the region a total 1604 tonnes of $PM_{10}$ per year was estimated to be discharged with 1191 tonnes of this in the $PM_{2.5}$ size fraction. Industry was the most significant contributor to annual $PM_{10}$ with domestic heating being the largest contributor to daily winter $PM_{10}$. Domestic heating was the main source of annual and daily (winter) $PM_{2.5}$.

Motor vehicle contributed around half of the NOx emissions with shipping (24%) and industry (18%) the other significant contributors to annual NOx. Industry was the main source of SOx emissions across the region. Spatial mapping of emission densities shows the majority of the SOx emissions occur within the Mount Maunganui Airshed.

# 1 INTRODUCTION

Emission inventories are carried out to determine the sources of emissions in a particular area for air quality management purposes and to evaluate changes in emission sources with time. Emission inventories are used by Governments and Local Government internationally to provide an estimate of the quantities of contaminants from anthropogenic sources that are emitted into the air and the relative contribution of sources to total emissions. The sources that are included in emissions inventories in New Zealand are generally the domestic heating, motor vehicle, industrial and commercial and outdoor burning sector.

In New Zealand the main air contaminants of concern are $PM_{2.5}$ and $PM_{10}$ as concentrations can exceed the National Environmental Standards for Air Quality (NESAQ) for $PM_{10}$ and the proposed NESAQ for $PM_{2.5}$ (Ministry for the Environment, 2020) in many locations in New Zealand.

The Bay of Plenty Region contains two gazetted airsheds (Rotorua and Mount Maunganui) within which concentrations of $PM_{10}$ exceed the NESAQ. In Rotorua concentrations of $PM_{10}$ prior to 2010 breached the NESAQ more than 20 times each year. With the implementation of management measures targeting domestic home heating there has been a significant reduction in exceedances with no NESAQ breaches occurring in either 2020 or 2021. An airshed must record five consecutive years of no breaches before it is no longer considered to be polluted the NESAQ. The Mount Maunganui airshed was gazetted in October 2019 after measurements showed $PM_{10}$ in excess of the NESAQ.

A number of emission inventories have been carried out for areas within the Bay of Plenty Region. These include Rotorua (2005 and 2022), Whakatane (2007 and 2022), Tauranga (2018) and Mount Maunganui Airshed (2022).

Additionally in 2022 a regional emissions assessment was carried out to provide spatially disaggregated emission estimates from major sources. This report details the methodology used to estimate of emissions of particles ($PM_{10}$ and $PM_{2.5}$), carbon monoxide, nitrogen oxides and sulphur oxides from domestic heating, transportation, industrial and commercial activities and outdoor burning for the Bay of Plenty Region.

# 2 INVENTORY DESIGN

The key components of inventory design are selection of the study area, selection of sources and the focus/extent of investment in data collection for each, contaminants to be included, the spatial resolution (within the study area what breakdowns might be required), temporal resolution (hourly, daily or annual emissions).

## 2.1 Key issues

The main air quality issue for most urban areas of New Zealand have typically been particles in the air which are commonly associated with solid fuel burning for domestic home heating. Recent health studies also implicate nitrogen dioxide from roadways as a contaminant of concern. In some areas of the Region $SO_2$ concentrations have also been high historically and require ongoing assessment.

## 2.2 Selection of contaminants

The scope of the inventory with respect to contaminants is:

- particles ($PM_{10}$)
- fine particles ($PM_{2.5}$)
- carbon monoxide (CO)
- sulphur oxides (SOx)
- nitrogen oxides (NOx)

Emissions of $PM_{10}$, CO, SOx and NOx are included as these contaminants are NESAQ contaminants because of their potential for adverse health impacts. $PM_{2.5}$ has been included in the inventory because this size fraction has significance in terms health and is included in the proposed revisions to the NESAQ for $PM_{2.5}$.

## 2.3 Selection of sources

The inventory will include emission estimates from the following sources:

- Industrial and commercial activities.
- Domestic heating
- Motor vehicles
- Outdoor burning including garden waste and braziers, pizza ovens and wood fired bbq
- Shipping
- Cargo handling

Marine aerosol emissions and other natural dusts are not well characterized using inventory techniques and are not included in the emissions assessment. Other methods such as receptor modelling and source apportionment will provide a more robust approach for these sources.

## 2.4 Selection of areas

The Regional emissions assessment uses data from Statistics New Zealand to provide emission estimates by Statistical Area (SA1 and SA2) throughout the Bay of Plenty Region. Some sources such as motor vehicle emissions are not able to be easily disaggregated to this spatial resolution.

## 2.5 Temporal distribution

The temporal resolution for the Regional Emissions Inventory is daily (winter) and annual average for the year 2022.

# 3 REGION METHODOLOGY

## 3.1 Domestic heating

Domestic heating methods were determined using Statistics New Zealand data for households using wood, coal, pellet fuel and appliance type from the 2018 census which includes this data at the SA1 and SA2 level. The age distribution were taken from the household phone survey carried out by Symphony Research during June 2022 for Whakatane and the 2018 survey results for Tauranga. A survey was also carried out for Rotorua in June 2022 but was not included because of specific rules pertaining to domestic heating that would result in different age distributions in that area. The fuel use per burner was the average from all three home heating surveys (Rotorua, Whakatane and Tauranga).

Solid fuel burning dwellings were classified as; open fires, wood burners, pellet fires, multi fuel burners based on data from the census.

Emission factors were applied to these data to provide an estimate of emissions for each study area. The emission factors used to estimate emissions from domestic heating are shown in Table 3.2. The basis for these is detailed in Appendix A.

Table 3.1: Emission factors for domestic heating methods.

| | $PM_{10}$ g/kg | $PM_{2.5}$ g/kg | CO g/kg | NOx g/kg | $SO_2$ g/kg |
|---|---|---|---|---|---|
| Open fire - wood | 7.5 | 7.5 | 55 | 1.2 | 0.2 |
| Open fire - coal | 21 | 18 | 70 | 4 | 8 |
| Pre 2006 burners | 10 | 10 | 140 | 0.5 | 0.2 |
| Post 2006 burners | 4.5 | 4.5 | 45 | 0.5 | 0.2 |
| Pellet burners | 2 | 2 | 20 | 0.5 | 0.2 |
| Multi-fuel[1] - wood | 10 | 10 | 140 | 0.5 | 0.2 |
| Multi-fuel[1] – coal | 19 | 17 | 110 | 1.6 | 8 |
| Oil | 0.3 | 0.22 | 0.6 | 2.2 | 3.8 |
| Gas | 0.03 | 0.03 | 0.18 | 1.3 | 7.56E-09 |

[1] - includes potbelly, incinerator, coal range and any enclosed burner that is used to burn coal

Emissions for each contaminant were calculated based on the following equation:

Equation 3.1 CE (g/day) = EF (g/kg) * FB (kg/day)

Where:

CE = contaminant emission

EF = emission factor

FB = fuel burnt

## 3.2 Motor vehicles

Motor vehicle emissions to air include tailpipe emissions of a range of contaminants and particulate emissions occurring as a result of the wear of brakes and tyres. Assessing emissions from motor vehicles involves collecting data on vehicle kilometres travelled (VKT) and the application of emission factors to these data.

Emission factors for motor vehicles are determined using the Vehicle Emission Prediction Model (VEPM 6.0) developed by Auckland Council. Emission factors for $PM_{10}$, $PM_{2.5}$, CO and NOx for this study have been based on VEPM 6.0. Default settings were used for all variables. The default input data including the national fleet profile was used for the regional vehicle emissions assessment for areas outside of Tauranga, Rotorua and Whakatane. The latter areas used emission factors derived for 2022 based on vehicle registration data and input parameters for each district. Resulting emission factors are shown in Table 3.4.

Emission factors for SOx were estimated for diesel vehicles based on the sulphur content of the fuel (10ppm) and the assumption of 100% conversion to SOx. The g/km emission factor was estimated using VEPM 6.0 using the fuel consumption per VKT output.

The number of vehicle kilometres travelled (VKT) for the Region were based on the New Zealand Transport Authority VKT data for state highways and urban and rural roads for the year ending December 2021.

In addition to estimates of tailpipe emissions and brake and tyre emissions using VEPM an estimate of the non-tailpipe emissions (including brake and tyre wear and re-suspended road dusts) was made using the EMEP/EEA air pollutant emission inventory guidebook (2016). The emission factors from this method are shown in Table 3.4. It is noted that emission factors for fugitive sources such as resuspended dusts can have a high level of uncertainty.

Table 3.2: Emission factors for national fleet profile (2022).

| 2022 | CO g/VKT | $PM_{10}$ g/VKT | PM brake & tyre g/VKT | NOx g/VKT | $NO_2$ g/VKT | $PM_{2.5}$ g/VKT | $PM_{2.5}$ brake & tyre g/VKT |
|---|---|---|---|---|---|---|---|
| National fleet profile 2022 | 1.4 | 0.02 | 0.02 | 0.65 | 0.13 | 0.02 | 0.01 |
| Rotorua District | 1.6 | 0.02 | 0.02 | 0.70 | 0.14 | 0.02 | 0.01 |
| Tauranga City | 1.5 | 0.01 | 0.02 | 0.47 | 0.08 | 0.02 | 0.01 |
| Whakatane District | 1.3 | 0.03 | 0.02 | 0.99 | 0.22 | 0.03 | 0.01 |

Table 3.3: VKT daily and annual (NZTA, 2021).

| | Annual VKT (SH & urban/rural) |
|---|---|
| Bay of Plenty Region | 2839000000 |
| | Urban/rural total VKT |
| Kawerau District | 15274000 |
| Opotiki District | 26119651 |
| Rotorua District | 223446000 |
| Tauranga City | 651470958 |
| Western Bay of Plenty District | 292208000 |
| Whakatane District | 243704000 |

The VKT were disaggregated spatially as described in Section 4.2 with emission factors for each area used to estimate the resulting emissions.

Emission estimates emissions were calculated by multiplying the appropriate average emission factor by the VKT:

Emissions (g) = Emission Rate (g/VKT) * VKT

For the urban and rural road estimates the VKT were converted to a VKT per household ratio for each district, with VKTs spatially allocated within the area based on the number of households.

Table 3.4: Road dust TSP emissions (from EMEP/EEA guidebook, EEA, 2016).

| | TSP g/KVT |
|---|---|
| Two wheeled vehicles | 0.01 |
| Passenger car | 0.02 |
| Light duty trucks | 0.02 |
| Heavy duty trucks | 0.08 |
| Weighted vehicle fleet factor | 0.018 |
| | |
| $PM_{10}$ size fraction | 0.5 |
| $PM_{2.5}$ size fraction | 0.27 |

## 3.3 Industrial and commercial activities

Industrial and commercial activities to be included in the inventory were identified using the Bay of Plenty Region Councils resource consent database. These included a range of surface coating activities, landfills, combustion activities, composting and other odour generating activities, poultry farms, pulp production, quarrying and metal and chemical industries.

Surface coating activities (e.g., spray painters) were a common consented industrial activity. The main discharge from surface coatings is volatile organic compounds (VOC) which is a contaminant not included in the inventory. Particle emissions may occur if coatings are applied using spray guns in an uncontrolled environment. However, they are not typically included in emission inventory assessments as they are comparatively small in relation to those from other sources (Environment Australia, 1999). Similarly landfills and odour discharges from sewage, farming and other activities were not included. Fugitive dusts from yards or farming type activities were not included in the industrial emissions inventory assessment because emission estimation methods are less robust.

The approach used was to identify activities discharging to air and collect site specific information relevant to the discharge type (activity data) as well as information on seasonal variability and hours of operation where relevant.

For industries for which relatively recent site-specific emissions data were available from compliance testing or the resource consent application, emissions were estimated based on equation 3.1.

Equation 3.1 Emissions (kg/day) = Emission rate (kg/hr) x hrs per day (hrs)

Where site specific emissions data were not available, emissions were estimated using activity data and emission factor information, as indicated in Equation 3.2. Activity data from industry includes information such as the quantities of fuel used, or in the case of non-combustion activities, materials used or produced. Activity data was collected by direct contact with industry, using data from the resource consents or compliance monitoring or a combination of these methods. Maximum consent limits were used in some instances. Reliance on maximum consent limits may result in an overestimate of emissions.

Equation 3.2 Emissions (kg) = Emission factor (kg/tonne) x Fuel/Material use (tonnes)

The emission factors used to estimate the quantity of emissions discharged are shown in Table 3.7. Site specific information was available for a number of sources. The emissions factors used are from the USEPA AP42 database[1] with the exception of the animal cremation factors which are from (EEA, 2016) and combustion emissions which are largely from (Wilton & Baynes, 2010). In addition, AP 42 database was used to assess the proportion of $PM_{10}$ emissions that were likely to be $PM_{2.5}$ for a range of sources. Milk powder dryers are one $PM_{10}$ source in the Region for which no $PM_{2.5}$ emission estimates are available. Fugitive dust emissions from

[1] http://www.epa.gov/ttn/chief/ap42/index.html

industrial and commercial activities were generally not included in the inventory assessment because of difficulties in quantifying the emissions. Emissions from quarrying were included in the assessment for the $PM_{10}$ size fraction. It is noted that SWAPs, one of the main quarry operators in the region refused to provide data to assist with the assessment. For two of these quarries maximum annual extraction rates were available or able to be estimated based on data from the resource consent application. The resource consent information for the Katikati Quarry, however, was inadequate for assessing the annual extraction amounts and quantities were assumed based on the maximum extraction rate from other quarries in the region. This may still result in an underestimate of emissions.

### Table 3.5: Emission factors for industrial discharges.

| AP 42 Chapter | AP 42 Source Category Code | Discharge Type | $PM_{10}$ g/kg | CO g/kg | NOx g/kg | SOx g/kg | $PM_{2.5}$ g/kg |
|---|---|---|---|---|---|---|---|
| 1.1 | 1-03-013-02 | Waste oil combustion | 1.40 | 0.7 | 2.7 | 7.8 | 1.31 |
| 9.9.1 | 3-02-005-55 | Grain unloading – shipping | 0.019 | | | | 0.0025 |
| 9.9.1 | 3-02-005-30 | Grain handling - general | 0.017 | | | | 0.0028 |
| 9.9.1 | 3-02-008-16 | Grain processing – pellet cooler | 0.0375 | | | | 0.0062 |
| 9.9.1 | 3-02-005-51 | Grain unloading - truck | 0.0295 | | | | 0.005 |
| 9.9.1 | 3-02-005-52 | Grain unloading – hopper truck | 0.0039 | | | | 0.00065 |
| 11.19.2-1 | Range | Quarrying | 0.050 | | | | |
| 11.12 | 3-05-011-04,-21,23 | Aggregate loading/ unloading uncontrolled | 0.0017 | | | | 0.0005 |
| 11.1.11, | 3-05-002-45 | Asphalt - drum mix venturi scrubber | 0.0097 | 0.065 | 0.28 | | 0.007 |
| 11.2 | 3-05-011-07 | Cement handling controlled | 0.00017 | | | | |
| 1.3-1 | 1-02-004-02/03 | Diesel boiler | 0.3 | 0.67 | 3.2 | 0.02 | 0.2 |
| 13.2.6 | 3-09-002-04 | Abrasive blasting – garnet fabric filter | 0.69 | | | | 0.069 |
| | | | $kg/m^3$ | $kg/m^3$ | $kg/m^3$ | $kg/m^3$ | $kg/m^3$ |
| 1.4 | 1-01-006-02 | Natural gas boilers | 0.0001 | 0.0006 | 0.0016 | 0.0000 | 0.0001 |
| Source | | | | | | | |
| 5.c.1.b | (EEA, 2016) | Crematorium – animal (kg per tonne of material cremated) | 0.6 | | | | 0.5 |
| (Wilton & Baynes, 2010) | | Coal boiler – underfeed stoker | 2 | 5.5 | 4.8 | 19* | 1.2 |
| (Wilton & Baynes, 2010) | | Wood boiler | 1.6 | 6.8 | 0.8 | 0.04 | 1.4 |
| (Wilton & Baynes, 2010) | | Coal boiler – chaingrate with multicyclone | 1.46 | 3 | 3.8 | 19.0 | 1.0 |
| 5.c.1.v Table 3.1 | EEA 2016 | Crematoria kg/body | 0.0347 | 0.14 | 0.824 | 0.113 | 0.0347 |

For 1% Sulphur content but adjusted for S content percentage where available

## 3.4 Outdoor burning

Outdoor burning of green wastes or household material can contribute to $PM_{10}$ concentrations and also discharge other contaminants to air. In some urban areas of New Zealand outdoor burning is prohibited because of the adverse health and nuisance effects associated with these emissions. Outdoor burning of garden waste includes any burning in a drum, incinerator or open air on residential properties in the study area. An additional source of burning in the outdoors that can contribute to air pollution is the use of braziers, pizza ovens and wood fired barbeques. This source is also included in the emissions assessment.

Plan Change 13 (Air Quality) to the Regional Natural Resources Plan bans outdoor burning within 100 metres of a neighbouring dwelling house unless for recreational/ cultural purposes (Rule AIR-R2) or if the activity meets requirements of rules AIR-OBURN-R22 and AIR-OBURN-R23 which provide for firefighting, and emergency disposal of diseased carcasses and vegetation. In the rural areas this activity can more readily be carried out within the permitted activity conditions than in the urban areas and consequently is likely to be more prevalent.

Outdoor burning emissions for Rotorua and Whakatane were estimated for all seasons based on data collected during the 2022 domestic home heating survey. This included an assessment of the use of braziers, pizza ovens and wood fired barbeques. The regional emissions assessment used the emission estimates for outdoor burning and braziers, pizza ovens and wood fired barbeques from the 2022 inventories for Rotorua and Whakatane and distributed them to the SA1 areas based on the proportion of households in each SA1. Similarly, the household outdoor burning emissions from the Tauranga emission inventory were used to estimate per household emissions from outdoor burning and disaggregated these to the SA1 areas in Tauranga City based on the number of households in each SA1. As the Tauranga emission inventory did not include emission estimates for braziers, pizza ovens and wood fired barbeques estimates of these for Tauranga SA1 area were made based on the average per household emission across Rotorua and Whakatane. The latter approach was used to estimate emissions from these sources for all other SA1s in the Region also.

Outdoor burning (garden waste) emission estimates outside of Rotorua, Whakatane and Tauranga were estimated using an average of the per household emissions for Whakatane and two small urban areas in the neighbouring Waikato for which these data were available (Tokoroa and Morrinsville, Wilton, 2019). The reason for using small towns outside of Region was because of the Plan rules in the Bay of Plenty which make burning in urban areas difficult. In the Waikato outdoor burning is permitted in urban areas so the rates from this area are more likely to reflect practices in more rural Bay of Plenty.

The AP42 emission factor database includes estimates for a wide range of materials including different tree species, weeds, leaves, vines and other agricultural material. The factors selected are based on a combination of refuse (AP42 table 2.5.1), weeds and prunings (AP42 table 2.5.5). Emission factors for SOx are based on residential wood burning in the absence of emission factors for these contaminants within the AP42 database for outdoor burning. AP42 emission factors were selected in preference to European Environment Agency air pollution emission inventory guidebook (EEA, 2016) tier one assessment emission factors as the latter are based on tree slash for two species and tree pruning for two species only.

Table 3.6: Outdoor burning emission factors (AP42, 2002).

| Source<br>AP 42 | $PM_{10}$<br>g/kg | $PM_{2.5}$<br>g/kg | CO<br>g/kg | NOx<br>g/kg | SOx<br>g/kg |
|---|---|---|---|---|---|
| Tables 2.5- 1 and 2.5-5 | 8 | 8 | 42 | 3 | 0.5 |

# 4 SPATIAL DISAGGREGATION

## 4.1 Domestic heating

The methodology for domestic heating includes base level activity data available at the SA1 level. This is because the census collects data on both fuel type for households and the type of appliance used at a basic level. For this assessment this screening level data has been supplemented by household survey data which refines the appliance type data and includes fuel usage as described in section 3.1.

For the areas where more refined domestic heating emissions assessments have been made (Whakatane, Rotorua and Tauranga) the emission estimates from those studies have been disaggregated to the SA1 level based on in the SA1 bottom up emission estimate as a proportion of the total for the survey area. This proportion is then applied to the emission inventory estimate from the refined domestic heating emission assessment.

As the base spreadsheet is based on 2018 census data, all household numbers are adjusted for population projections. For the regional emissions assessment and the Tauranga emissions assessment, the population projection is as per Statistics New Zealand (2022) projection estimates (7.2% from 2018 to 2022)..

## 4.2 Motor vehicles

The VKT data underpinning the vehicle emissions assessment is based on NZTA VKT data which is not available with a refined spatial disaggregation. The method of spatially disaggregating the emission estimates to SA1 was based on the separation of VKT into state highways and other roads. The state highway VKT were disaggregated into the SA1 that the highway travelled through based on the length of state highway (going through each SA1) with a traffic count weighting at a District level to adjust estimates for differences in the road volumes (for example SH2 going through Tauranga City had daily traffic counts of over 20,000 compared with less than 1000 on parts of SH35 going through Opotiki District). The remainder (urban and rural road VKT) allocated to the SA1s based on household numbers in the SA1. This assessment was just used to provide an indicative distribution of motor vehicle emissions regionally and is not robust enough for use in any high detail spatial allocation assessment or traffic corridor emissions assessment. It is noted that the SH road length per SA1 was estimated manually using an online geographical measurement tool and will be subject to additional uncertainties.

## 4.3 Industrial and commercial emissions

Information on the location of industrial and commercial activities with air discharges in the Region was provided by the regional council. Each activity was retained as an individual discharge with the specific location included in a separate worksheet to enable modelling each discharge as a point source. These were allocated to SA1 areas using address data provided by Bay of Plenty Regional Council. Future applications of this tool such as dispersion modelling would need to integrate point source locations for improved spatial accuracy.

## 4.4 Shipping and port emissions

Shipping and port emission estimates were made as part of the Mount Maunganui Airshed emission inventory which was carried out concurrently with this assessment. Emissions from both sources were allocated to the SA1 area comprising the majority of the Port of Tauranga.

## 4.5 Outdoor burning

Outdoor burning emissions were estimated by converting the garden waste and braziers, pizza ovens and wood fired barbeque emission estimates (from the Whakatane et al surveys) to per household emission estimates. The household data for each SA1 was then used to estimate emissions at a high spatial resolution.

# 5 TOTALS EMISSIONS

Annually, the main source of $PM_{10}$ across the region is industry (46%) with domestic heating also a significant contributor at 35% (Figure 5.1). During the winter months domestic heating is the main contributor at 62% of daily winter $PM_{10}$. Figure 5.2 shows domestic heating to be the main source of both annual and daily (winter) $PM_{2.5}$ across the Region.

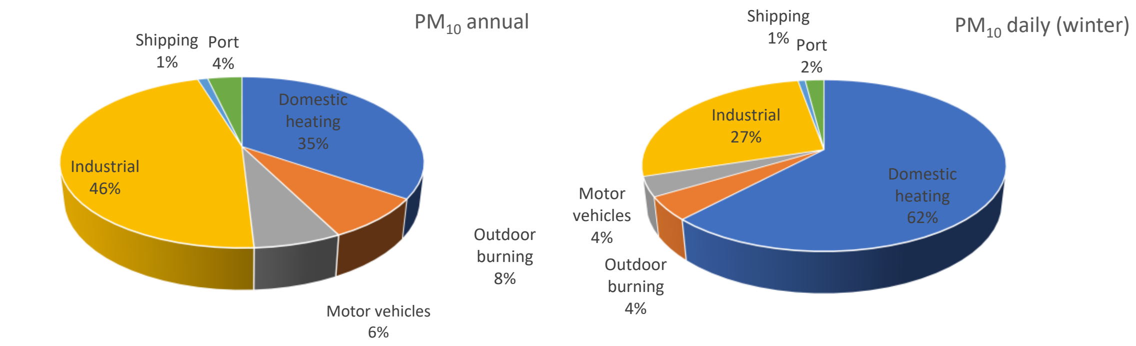


**Figure 5.1: Relative contribution of sources to regional annual and daily winter $PM_{10}$ emissions.**

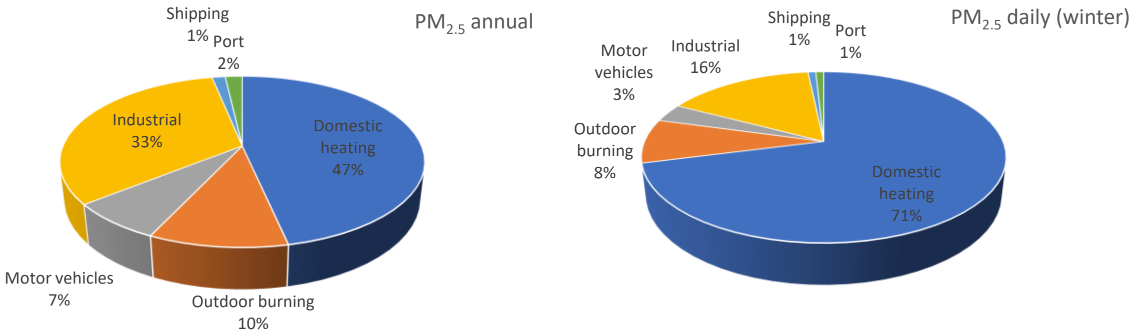


**Figure 5.2: Relative contribution of sources to regional annual and daily winter $PM_{2.5}$ emissions.**

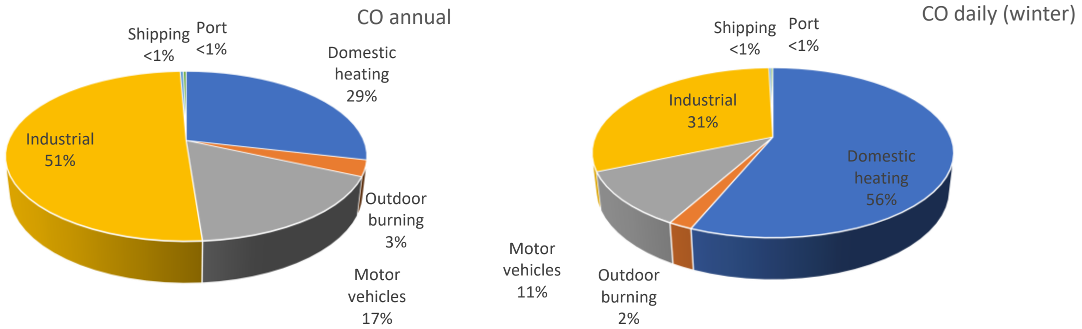


**Figure 5.3: Relative contribution of sources to regional annual and daily winter CO emissions.**

Figure 5.4: Relative contribution of sources to regional annual and daily winter SOx emissions.

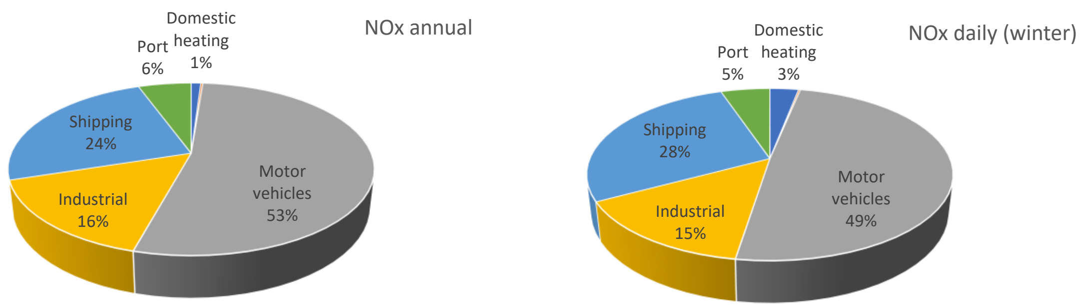


Figure 5.5: Relative contribution of sources to regional annual and daily winter NOx emissions.

Figures 5.3 to 5.5 show the relative contribution of sources to annual and daily (winter) CO, SOx and NOx. The sources vary with contaminant with industry and domestic heating being the main contributors to CO, industry being the main source of SOx and motor vehicles the main contributor to NOx. Shipping is a significant contributor to both SOx and NOx emissions in the region. Tables 5.1 and 5.2 detail the quantities of contaminants by source in tonnes per year and kilograms per day (winter) respectively.

Table 5.1: Regional emissions by source (tonnes/year).

| | $PM_{10}$ kg/day | $PM_{2.5}$ kg/day | CO kg/day | $NO_2$ kg/day | SOx kg/day |
|---|---|---|---|---|---|
| Domestic heating | 555 | 555 | 5200 | 31 | 43 |
| Outdoor burning | 127 | 123 | 553 | 7 | 39 |
| Motor vehicles | 105 | 86 | 3104 | 1630 | 2 |
| Industrial | 741 | 388 | 9176 | 485 | 267 |
| Shipping | 17 | 17 | 59 | 749 | 113 |
| Port | 58 | 21 | 57 | 171 | <1 |
| Total | 1604 | 1191 | 18149 | 3074 | 465 |

Table 5.2: Regional emissions by source (kg/day (winter).

| | $PM_{10}$ kg/day | $PM_{2.5}$ kg/day | CO kg/day | $NO_2$ kg/day | SOx kg/day |
|---|---|---|---|---|---|
| Domestic heating | 4831 | 4828 | 45543 | 274 | 371 |
| Outdoor burning | 341 | 567 | 1475 | 18 | 105 |
| Motor vehicles | 287 | 235 | 8505 | 4465 | 4 |
| Industrial | 2121 | 1061 | 25115 | 1323 | 768 |
| Shipping | 59 | 56 | 198 | 2510 | 382 |
| Port | 155 | 58 | 155 | 469 | <1 |
| Total | 7796 | 6804 | 80991 | 9058 | 1631 |

## 5.1 Uncertainty

The uncertainties associated with the input variables for different sources are discussed in the inventory reports for Rotorua, Whakatane, Tauranga and the Mount Maunganui Airshed. The uncertainties which have been quantified for each area vary slightly between inventories but are typically around 20% for total emissions.

Whilst this is indicative of the uncertainty for the regional emission estimate, the spatial disaggregation introduces an additional level of uncertainty, particularly for motor vehicles but also for domestic heating. The SA 1 data provided is likely to have a medium to high level of uncertainty.

# 6 MAPPING EMISSIONS

The spatial distribution of contaminant emissions in (tonnes/km$^2$/year) across the Bay of Plenty Region is shown in Figures 6.1 to 6.4. This distributes the emissions occurring within a geographical area, defined by Statistics New Zealand as SA1 (2018), evenly throughout the area. This provides an indication of emission density for each SA1 area throughout the region. In Figure 6.1, a significant $PM_{10}$ source is located in a relatively large SA1 area to the south of Rotorua and consequently comes across as a larger area of impact.

Factors influencing emission density include variables such as the density of wood burning households, the prevalence of major roads or industrial discharges. In the case of wood burning houses the emission sources are typically located across the SA1 area whereas an industrial discharge will typically be a point source. Even with the point source discharges the emission estimates are spread across the whole SA1 area in the map below because this illustrates the total emission across the area rather than providing a more detailed spatial disaggregation. If the emissions data were integrated into a dispersion model to estimate the resulting concentrations, the point source discharge location would be used in preference to the distribution illustrated below. Significant point source (industrial) discharges are indicated on the figures. Note area of impact from the emission is not illustrated, just the SA1 where the emission occurs.

The emission quantities for the colour classifications shown in SA1 areas are illustrated in the figure legend. These have been selected using the natural breaks – Jenks protocol within the spatial system software. This selects legend categories based on natural groupings inherent in the data. Class breaks are created in a way that best groups similar values together and maximizes the differences between classes. Natural breaks are data-specific classifications and not useful for comparing multiple maps built from different underlying information.

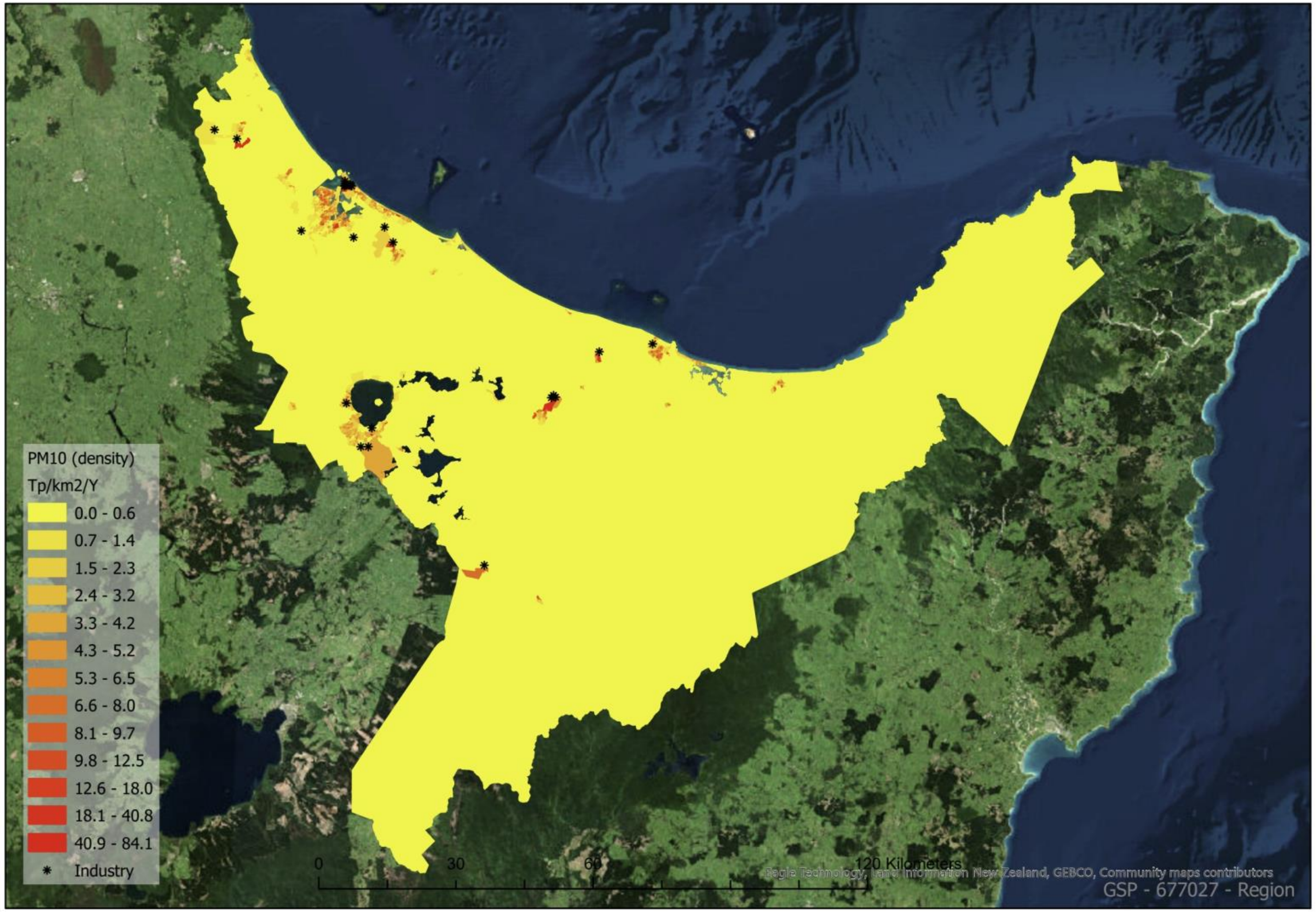


Figure 6.1: Spatial distribution in $PM_{10}$ emissions across Bay of Plenty Region.

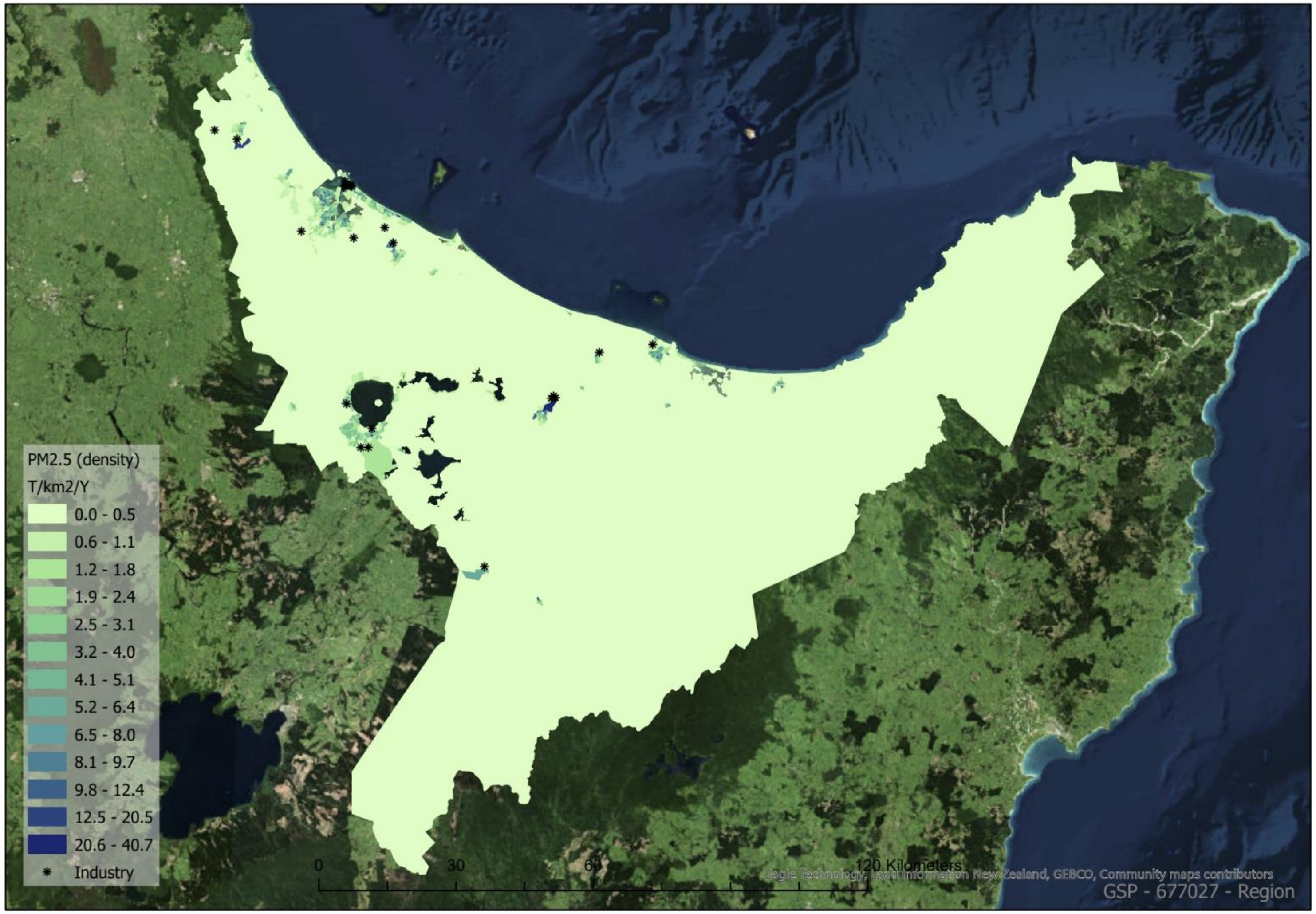


Figure 6.2: Spatial distribution in $PM_{2.5}$ emissions across Bay of Plenty Region.

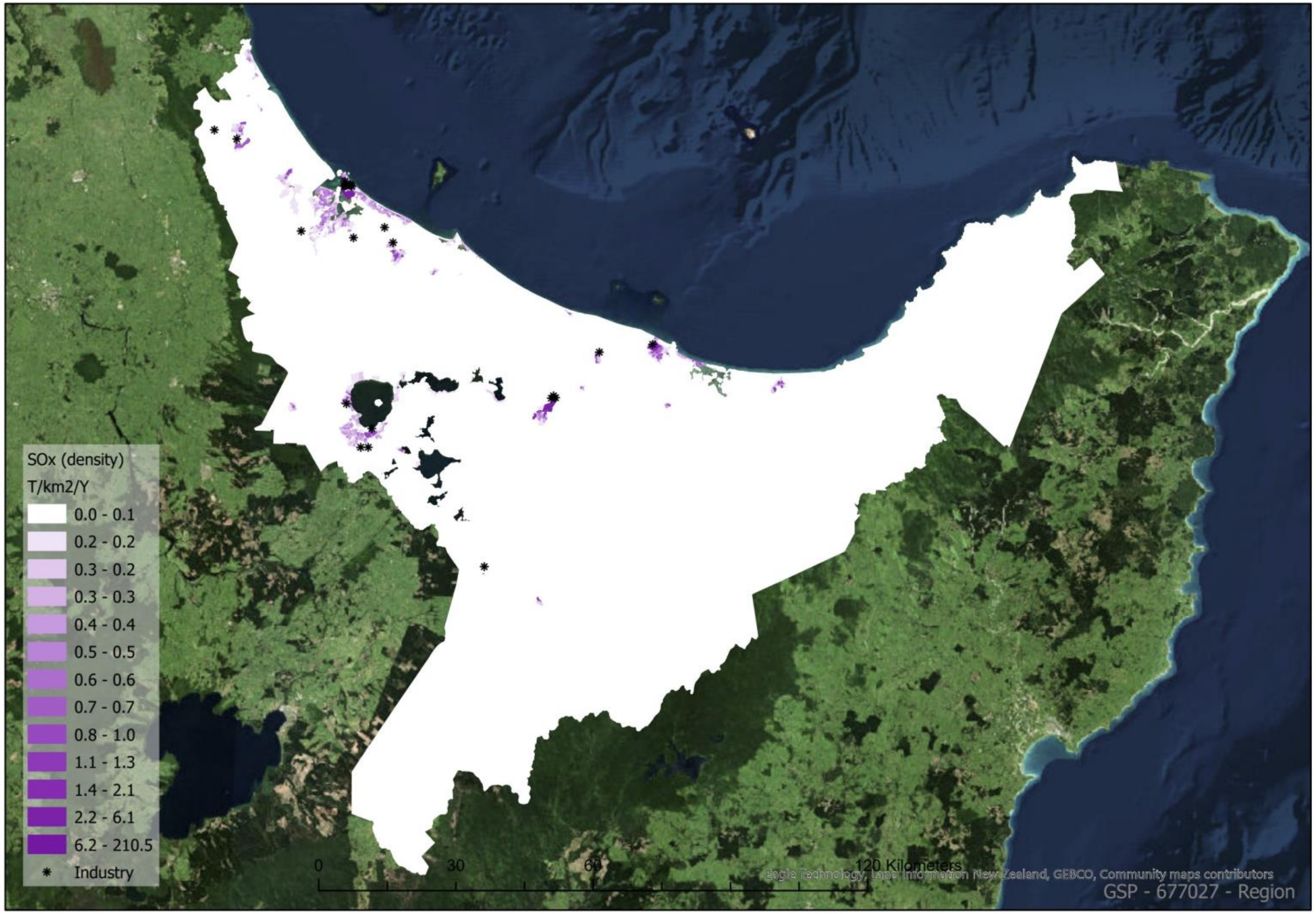


Figure 6.3: Spatial distribution in SOx emissions across Bay of Plenty Region.

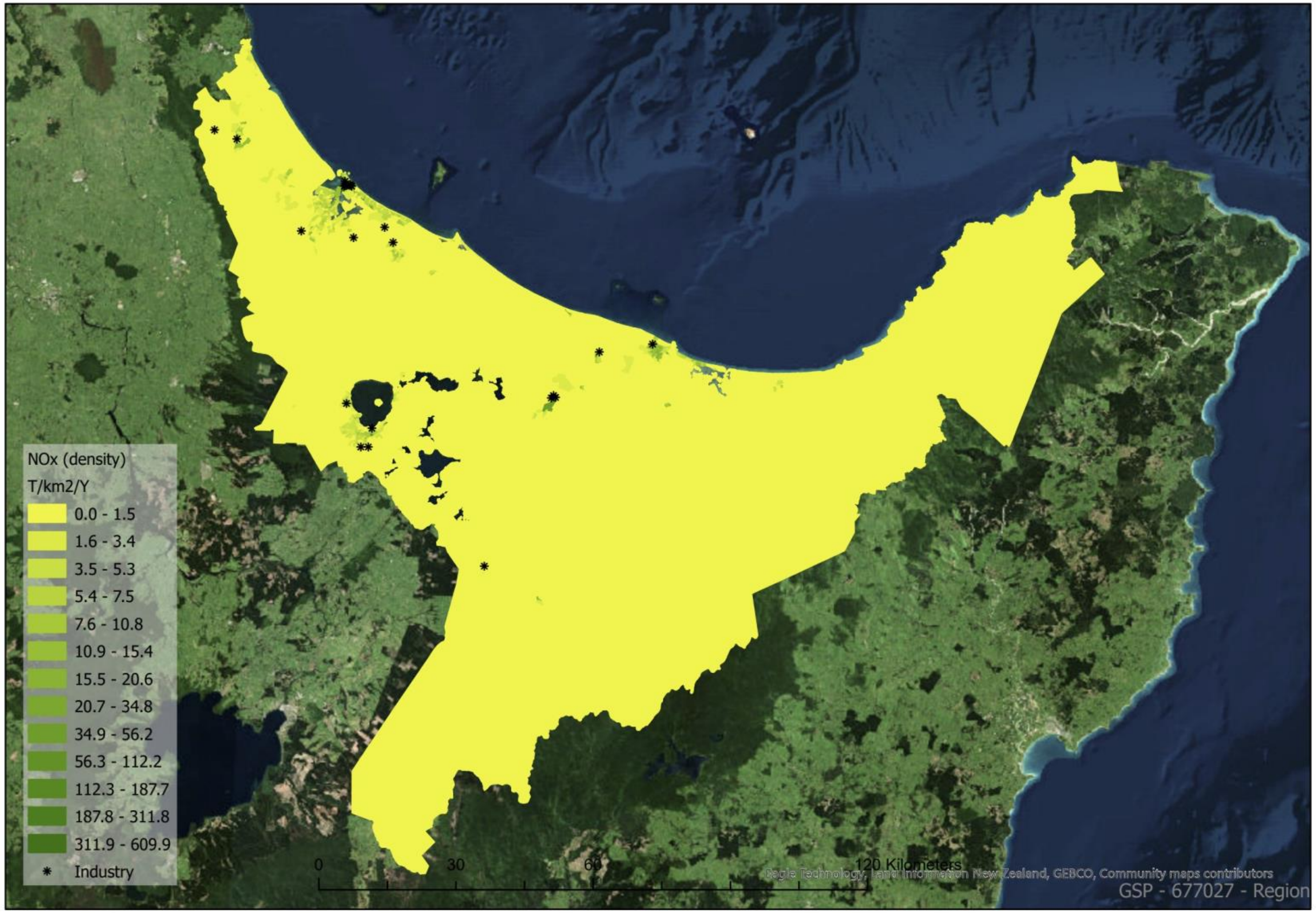


Figure 6.4: Spatial distribution in NOx emissions across Bay of Plenty Region.

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# APPENDIX A: EMISSION FACTORS FOR DOMESTIC HEATING.

Emission factors were based on the review of New Zealand emission rates carried out by Wilton et al., (2015) for the Ministry for the Environments air quality indicators programme. This review evaluated emission factors used by different agencies in New Zealand and where relevant compared these to overseas emission factors and information. Preference was given to New Zealand based data where available including real life testing of pre 1994 and NESAQ compliant wood burners (Wilton & Smith, 2006; Smith, et. al., 2008) and burners meeting the NESAQ design criteria for wood burners (Bluett et al., 2009; Smith et al., 2009).

The $PM_{10}$ open fire emission factor was reduced in the review relative to previous factors. Some very limited New Zealand testing was done on open fires during the late 1990s. Two tests gave emissions of around 7.2 and 7.6 g/kg which at the time was a lot lower than the proposed AP42 emission factors (http://www.rumford.com/ap42firepl.pdf) for open fires and the factors used in New Zealand at the time (15 g/kg). An evaluation of emission factors for the 1999 Christchurch emission inventory revised the open fire emission factor down from 15 g/kg to 10 g/kg based on the testing of Stern, Jaasma, Shelton, & Satterfield, (1992) in conjunction with the results observed for New Zealand (as reported in Wilton, 2014). The proposed AP42 emission factors (11.1 g/kg dry) now suggest that the open fire emission factor may be lower still and closer to the result of the limited testing carried out in New Zealand. Consequently a factor of 7.5 g/kg for $PM_{10}$ (wet weight) is proposed to be used for open fires in New Zealand based on the likelihood of the Stern et al., (1992) data being dry weight (indicating a lower emission factor), the data supporting a proposed revised AP 42 factor and the results of the New Zealand testing being around this value. It is proposed that other contaminant emissions for open fires be based on the proposed AP42 emission factors adjusted for wet weight.

The emission factor for wood use on a multi fuel burner was also reduced from 13 g/kg (used in down to the same value as the pre 2004 wood burner emission factor (10 g/kg). The basis for this was that there was no evidence to suggest that multi fuel burners burning wood will produce more emissions than an older wood burner burning wood.

Emission factors for coal use on a multi fuel burner are based on limited data, mostly local testing. Smithson, (2011) combines these data with some further local testing to give a lower emission factor for coal use on multi fuel burners. While these additional data have not been viewed, and it uncertain whether bituminous and subbituminous coals are considered, the value used by Smithson has been selected. The Smithson, (2011) values for coal burning on a multi fuel burner have also been used for $PM_{10}$, CO and NOx as it is our view that many of the more polluting older coal burner (such as the Juno) will have been replaced over time with more modern coal burners.

No revision to the coal open fire particulate emission factor was proposed as two evaluations (Smithson, (2011) and Wilton 2002) resulted in the same emission factor using different studies. Emissions of sulphur oxides will vary depending on the sulphur content of the fuel, which will vary by location. A value of 8 g/kg is proposed for SOx based on an assumed average sulphur content of 0.5 g/kg and relationships described in AP42 for handfed coal fired boilers (15.5 x sulphur content).

Emission factors for $PM_{2.5}$ are based on 100% of the particulate from wood burning being in the $PM_{2.5}$ size fraction and 88% of the $PM_{10}$ from domestic coal burning. The $PM_{2.5}$ component of $PM_{10}$ is typically expressed as a proportion. The AP42 wood stove and open fire proportion is based on 1998 data and given as 93% of the $PM_{10}$ being $PM_{2.5}$ (http://www.epa.gov/ttnchie1/efdocs/rwc_pm25.pdf). Smithson, (2011) uses a proportion of 97% which is more consistent with current scientific understanding that virtually all the particulate from wood burning in New Zealand is less than 2.5 microns in diameter (Perry Davy, pers comm, 2014). Literature review of the proportion of $PM_{10}$ that was $PM_{2.5}$ returns minimal information for domestic scale wood use. The technical advisory group to the Ministry for the Environment (2014) air quality indicators project on emissions advised their preference for a value of 100% and we have opted for this value for subsequent work because information is indicative of a value nearing 100%. Further investigations into this may be warranted in the future given the focus towards $PM_{2.5}$. A value of 88% from Ehrlich & Kalkoff, (2007) was used for the proportion of $PM_{10}$ in the $PM_{2.5}$ size fraction for small scale coal burning.

An emission factor of 0.5 g/kg was proposed for NOx from wood burners based on the AP42 data because the non-catalytic burner measurements were below the detection limit but the catalytic converter estimates (and conventional burner estimates) weren't. This value is half of the catalytic burner NOx estimate.

A ratio of 14 x $PM_{10}$ values was used for CO emission estimates as per the AP42 emissions table for wood stoves. This is selected without reference to any New Zealand data owing to the latter not being in any publically available form.