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Whangārei and Kaitāia Airshed Investigation: Phase 2 – Target Locations for Air Quality Monitoring Sites

Northland Regional Council

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Whangārei and Kaitāia Airshed Investigation: Phase 2 - Target Locations for Air Quality Monitoring Sites

Prepared for

Northland Regional Council

February 2022

PATTLE DELAMORE PARTNERS LTD
Level 2, 134 Oxford Terrace
Christchurch Central, Christchurch 8011
PO Box 389, Christchurch 8140, New Zealand

Office +64 3 **345 7100**
Website **http://www.pdp.co.nz**
Auckland Tauranga Hamilton Wellington
Christchurch Invercargill

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DOCUMENT CONTRIBUTORS

Prepared by

SIGNATURE

Jeff Bluett and Chris Bender

Reviewed by

SIGNATURE

Andrew Curtis

Approved by

Steve Pearce

Limitations:

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Executive Summary

The objective of this report is to identifying potential hotspots suitable for NESAQ PM_{10} and $PM_{2.5}$ monitoring within the Whangārei and Kaitāia airsheds.

A qualitative assessment method was used to identify an area within the Kaitāia airshed with the highest potential to exceed the NESAQ PM_{10} and proposed NESQA $PM_{2.5}$. The candidate monitoring location has been identified by considering the influence of the following factors:

- Location of dwellings;
- Density of solid fuel home heating devices;
- Topography of the surrounding area;
- Wintertime meteorology;
- Location of large-scale industrial sources;
- Locations and data from previous ambient air quality monitoring;
- Roading network and vehicle volumes;
- Backyard burning behaviour; and,
- Practical issues such as availability of potential host sites.

Considering the influence of the factors listed above, the recommended area to establish a NESAQ compliant air quality monitoring site for the Kaitāia airshed is approximately 350 m northeast of Tangonge Domain.

An airshed model for Whangārei airshed was built and run to identify suitable NESAQ PM_{10} and $PM_{2.5}$ monitoring locations. The model considered Whangārei's meteorology, topography, land use and the location, timing and quantity of particulate emissions from domestic, transport, industry and backyard burning sources. The model predicted relatively high concentrations of both PM_{10} and $PM_{2.5}$ at:

- Tikipunga South;
- Morningside;
- Granfield Reserve;
- Mairtown; and,
- Sherwood Rise.

The difference in predicted concentrations of PM_{10} and $PM_{2.5}$ for each of these locations is not considered significant. For this reason PDP recommends that the NRC select the monitoring location which is located most centrally within the Whangārei airshed. The reason for this is during winter, low windspeeds occur with similar frequency from all directions, suggesting that a centrally located monitoring site would be more frequently impacted by high particulate concentrations than a site located more toward one of the airshed boundaries.

Consequently PDP recommends that NRC select a location within Mairtown to establish its long-term NESAQ monitoring site.

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1.0 Introduction

Northland Regional Council's (NRC) responsibilities under the Resource Management Act include ensuring that air quality in its region is maintained within the requirements of National Environmental Standards for Air Quality (NESAQ).

The NRC's Regional Plan for Northland (RPN) (NRC 2016) has identified the following significant air quality issues in Northland:

- The desire to maintain Northland's high standard of air quality whilst also allowing the use and development of the region's resources.
- The numerous sources of particulate matter in Northland include unsealed roads, quarries, sandblasting, port operations, coal fired boilers, open fires, rural burn offs, cement and fertilizer works and dairy factories. Particulate matter can cause adverse health effects and amenity and visibility effects.
- The cumulative effects of smoke from domestic fires for home heating, in combination with motor vehicle emissions over Northland's urban areas, particularly during calm winter nights, can have adverse health and amenity effects.

As part of its air quality management process NRC has established airsheds around specific towns in the region (Figure 1). The National Institute of Water and Atmospheric Research (NIWA) identified that Whangārei and Kaitāia were the highest priority Northland airsheds for the development of a particulate matter ($PM_{2.5}$) monitoring programme (NIWA, 2020). NRC is now looking to develop a better understanding of the sources of pollutants and its effects within these two key airsheds.

The overarching intent of the Northland Airshed Investigation Project (the investigation) presented in this report is to provide information to assist NRC to meet its regulatory functions, and to continue to manage air quality so that people in the region enjoy the benefits of clean air. The specific objectives of this project are detailed in Section 2.0.

Given the current NESAQ focus on Particulate Matter less than 10 microns in size (PM_{10}) and the Ministry for the Environment's (MfE) proposed amendment to the NESAQ to include Particulate Matter less than 2.5 microns in size ($PM_{2.5}$) both pollutants are included in the scope of the investigation.

Figure 1: Location and extent of Northland Region Airsheds

2.0 Project Objectives

The Northland Airshed investigation project was undertaken in two phases each with a distinct objective.

The key objective of Phase 1 was to provide robust information enabling NRC to pinpoint and quantify the key PM_{10} and $PM_{2.5}$ sources within the Whangārei and Kaitāia airsheds. To meet the key project objective Pattle Delamore Partners Limited (PDP) developed particulate matter emissions inventories and reported on emissions for the Whangārei and Kaitāia airsheds (Pattle Delamore Partners, 2021).

The airshed emission inventories are used in Phase 2 of the project to meet the objective of identifying potential hotspots suitable for NESAQ PM_{10} and $PM_{2.5}$ monitoring within the Whangārei and Kaitāia airsheds. This report presents the outcomes of Phase 2 of the investigation.

3.0 Structure and Content of the Report

To achieve the project objective the structure of report is as follows:

- **Kaitāia Airshed** (Section 4.0)
  - Airshed characteristics (Section 4.1);
  - Assessment methodology (Section 4.2);
  - Emissions (Section 4.3);
  - Meteorology (Section 4.4);
  - Other factors: Impact of Industrial Sources on Ambient Air Quality (Section 4.5); and
  - Recommended air quality monitoring site (Section 4.6).
- **Whangārei Airshed** (Section 5.0)
  - Airshed characteristics (Section 5.1);
  - Assessment methodology (Section 5.2);
  - Emissions (Section 5.3);
  - Meteorology (Section 5.4);
  - Other factors: (Section 5.5); and
  - Recommended air quality monitoring site (Section 5.7).
- **Potential improvements on methods used to identify the recommended monitoring locations** (Section 6.0).

4.0 Kaitāia Airshed

4.1 Airshed Characteristics

An airshed is a legally designated air quality management area where air quality does or has the potential to breach the NESAQ. The Kaitāia airshed was designated by NRC and covers an area of approximately 30 km^2. The spatial extent of the Kaitāia airshed is shown in Figure 2 by the yellow shadow.

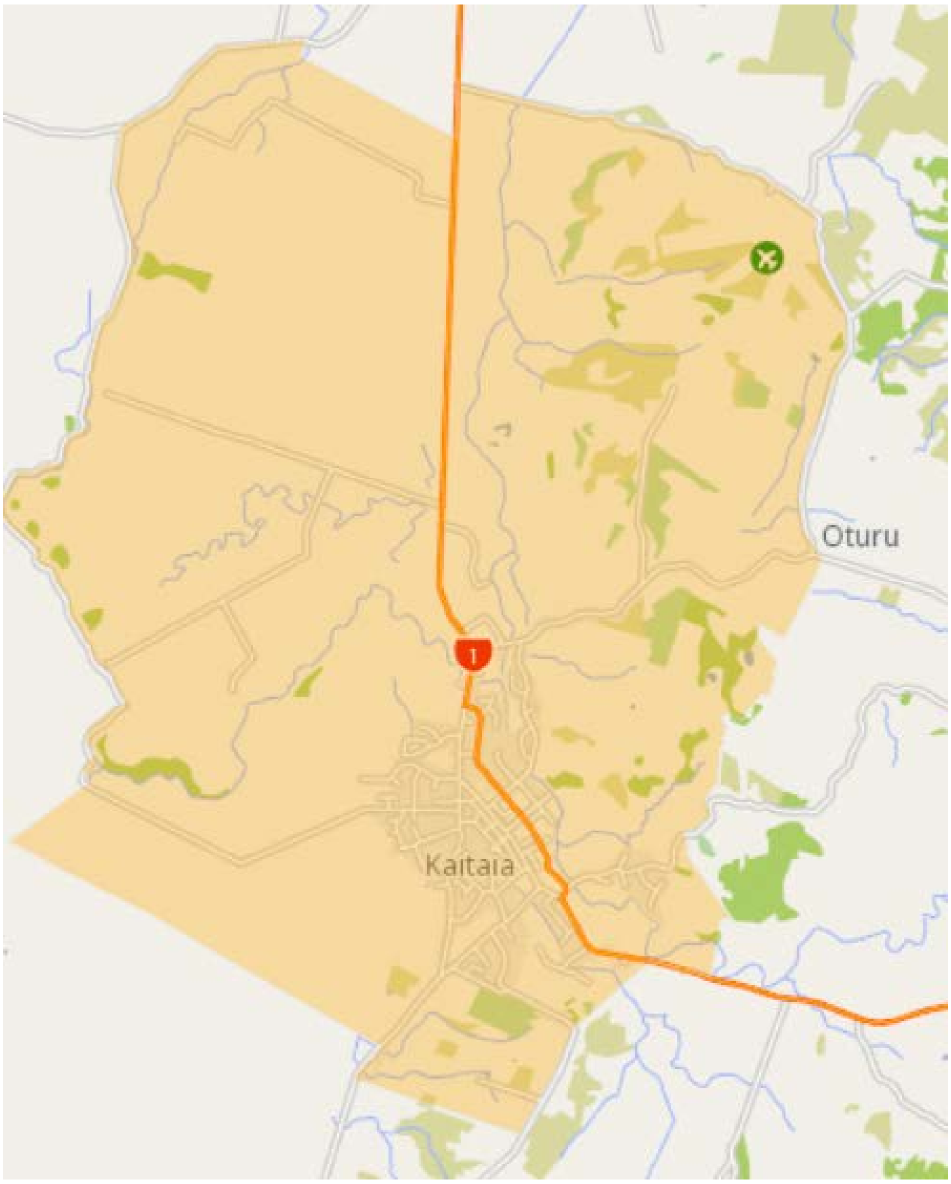


Figure 2: Spatial extent of the Kaitāia airshed

The airshed includes the township of Kaitāia, population 5,871 (2018 census). The area of Kaitāia township is approximately 8.5 km^2 and is divided by Statistics New Zealand into two Statistical Area 2 (SA2) units as shown by the red lines in Figure 3.

The Kaitāia township covers approximately one quarter of the airshed area but is the source of approximately 85% of the airshed total particulate emissions. Additional details of these air pollutant emission sources are given in Section 4.3.

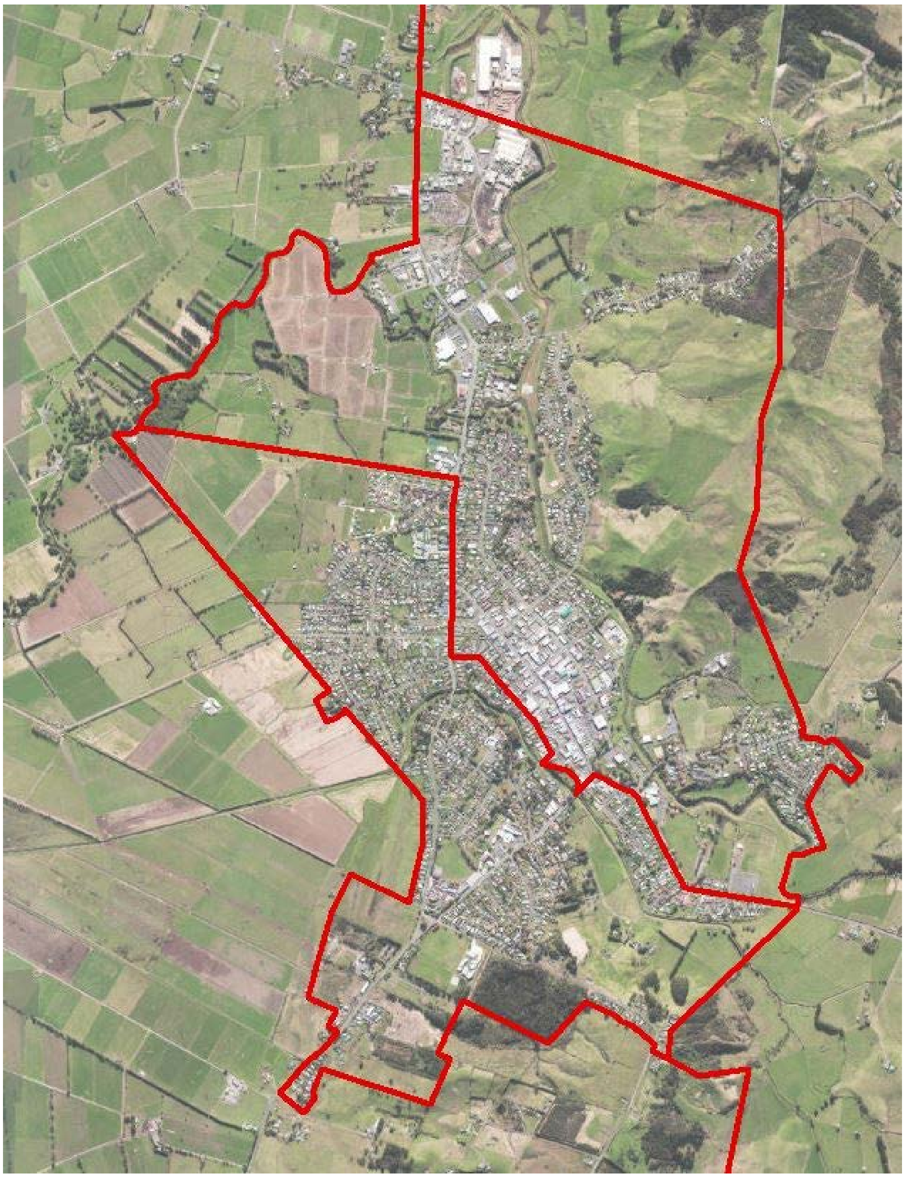


Figure 3: Kaitāia township and SA2 units

4.2 Assessment Method

A qualitative assessment method was used to identify an area within the Kaitāia airshed with the highest potential to exceed the NESAQ PM_{10} and proposed NESQA $PM_{2.5}$. PDP considered a range of factors, which based on experience have the greatest potential to influence air quality within an airshed. The candidate monitoring location has been identified by considering the influence of the following factors:

- Location of dwellings;
- Density of solid fuel home heating devices;
- Topography of the surrounding area;
- Wintertime meteorology;
- Location of large-scale industrial sources;
- Locations and data from previous ambient air quality monitoring;
- Roading network and vehicle volumes;
- Backyard burning behaviour; and,
- Practical issues such as availability of potential host sites.

The Kaitāia airshed is made up of five SA2 units as shown by the black lines in Figure 4. The division of the airshed into SA2s is an important step in the method as the spatial data collected during the 2018 census facilitates the identification of the location of domestic emissions and also provides an understanding of how the relative density of emissions varies across the airshed.

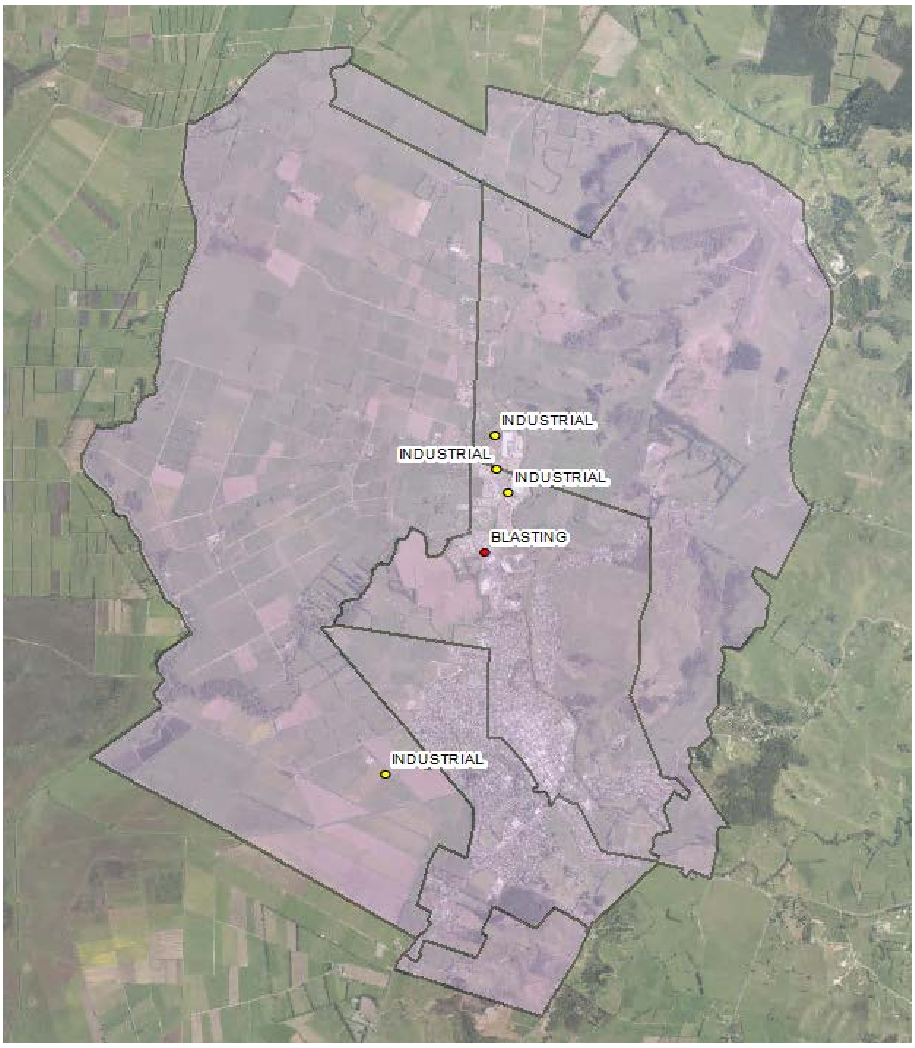


Figure 4: Kaitāia airshed and SA2

The qualitative assessment method provides a pragmatic and useful assessment which will indicate the best general location for an air quality monitoring site. However, this qualitative assessment method cannot determine the exact location where the greatest concentrations of PM_{10} and $PM_{2.5}$ may occur. Therefore, there is the potential that similar or even higher concentrations may be experienced within the airshed. Regardless, air quality data collected at the nominated location will, at the very least, give a robust benchmark of the highest concentrations of PM_{10} and $PM_{2.5}$ likely to be occurring in the airshed.

4.3 Location, Quantity and Timing of Particulate Emissions

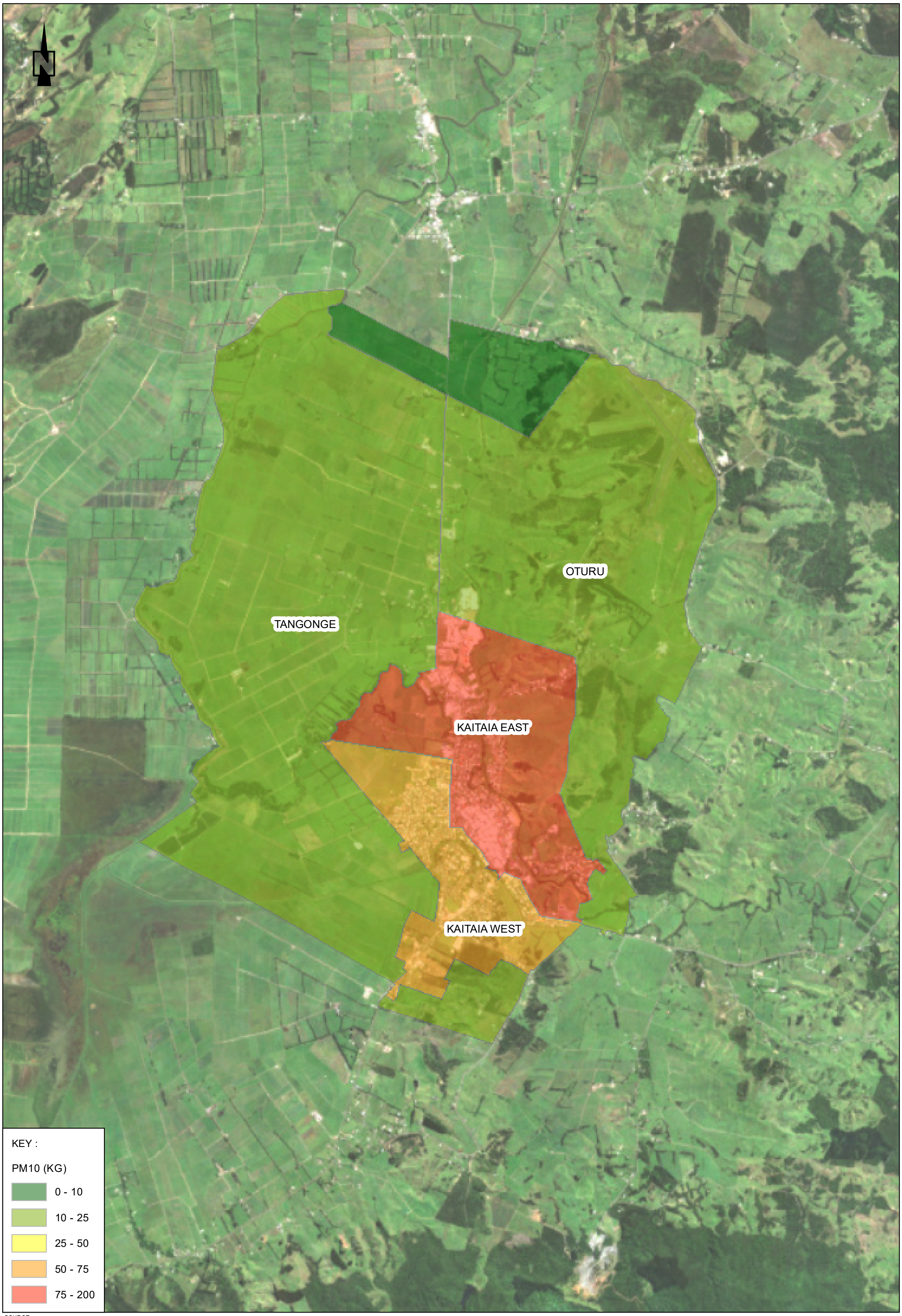
The key air pollutant emission sources within Kaitāia township are domestic solid fuel burners (domestic or domestic emissions) (during cooler months of the year), road vehicles and backyard rubbish burning.

There are three relatively large industrial sites which discharge contaminants into the air within the northern part of Kaitāia township and two additional sites located just outside the township boundary. The two largest industrial sites are within Kaitāia and process forest products.

Based on Phase 1 of this project the industrial sources of particulate emissions contribute approximately 75% of the total airshed emissions, domestic emissions approximately 15%, vehicles 6% and backyard burning 3%. The industrial, vehicle and backyard burning emissions do not vary significantly with season. Domestic emissions are seasonal with the vast majority occurring over the months May to September. Because of the additional emissions occurring in winter and the relatively large ground level impact of domestic emissions which are discharged a height of approximately 4m, the PM_{10} and $PM_{2.5}$ peak concentrations experienced in the Kaitāia airshed are likely to occur during winter.

Figure 5 shows the PM_{10} emissions in the Kaitāia airshed for a winter day and demonstrates that the PM_{10} emission density is greatest in the Kaitāia East and Kaitāia West SA2s. This reflects the location and density of domestic sources, the relatively high number of vehicle movements within the Kaitāia township and the location of three relatively large industrial discharge points in Kaitāia East. Figure 6 shows the Kaitāia airshed winter day $PM_{2.5}$ domestic emissions. Figure 6 contrasts to Figure 5, in that the highest density of emissions occurs in Kaitāia West.

Figure 7 shows the land parcels and buildings for Kaitāia township. This information was used to provide an indication of a finer spatial resolution of domestic emissions. The two SA2s which cover Kaitāia township were subdivided into four smaller areas shown in Figure 7: residential E1 (red shade), residential W1 (purple shade) residential W2 (orange shade) and commercial (no shading).



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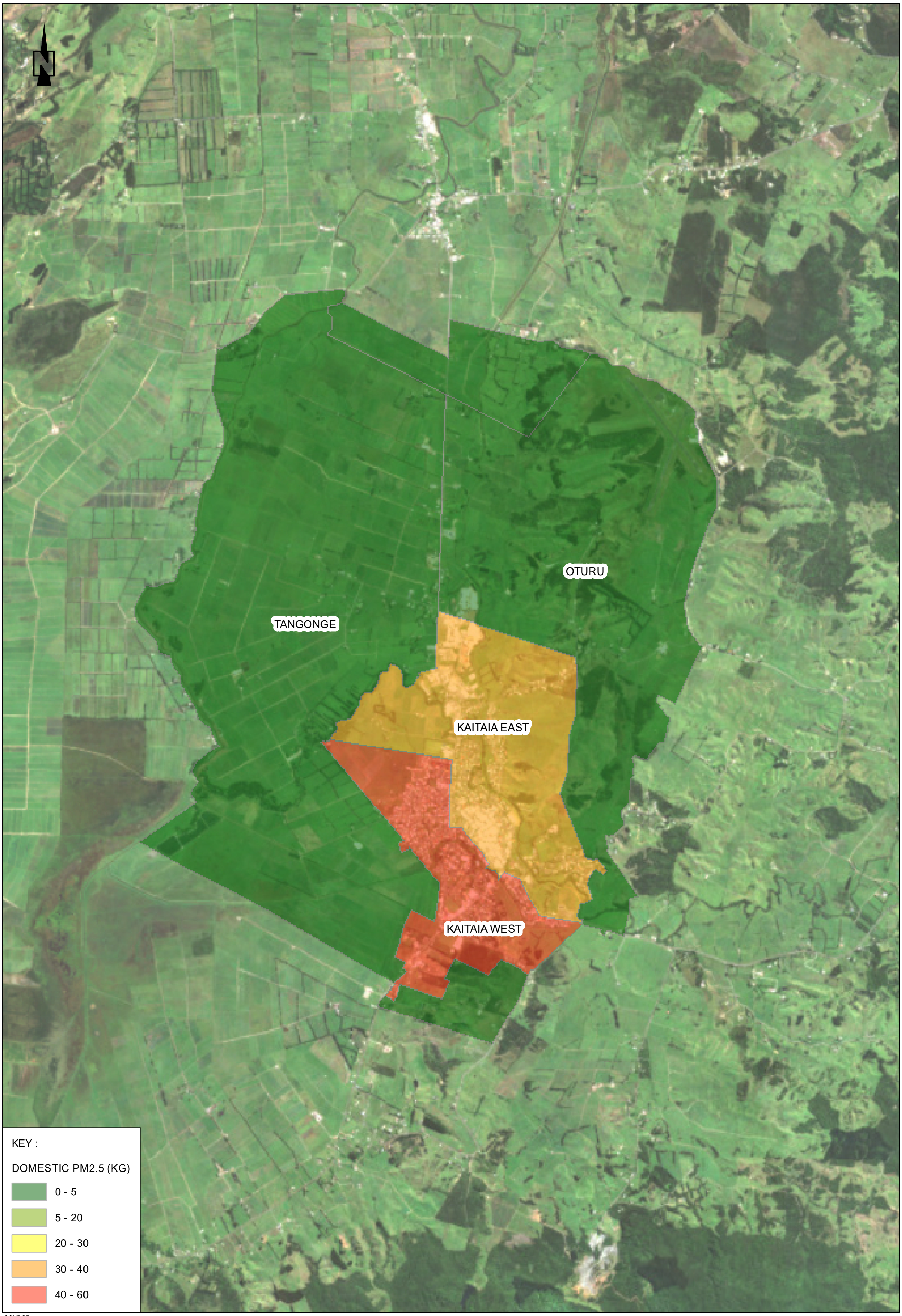
2. SA2 PROVIDED BY STATS NZ AND USED WITH PERMISSION.

FIGURE 5 : KAITAIA AIRSHED PM10 WINTER DAY

SCALE : 1:60,000 (A4)

0 0.5 1 2 3

Kilometres



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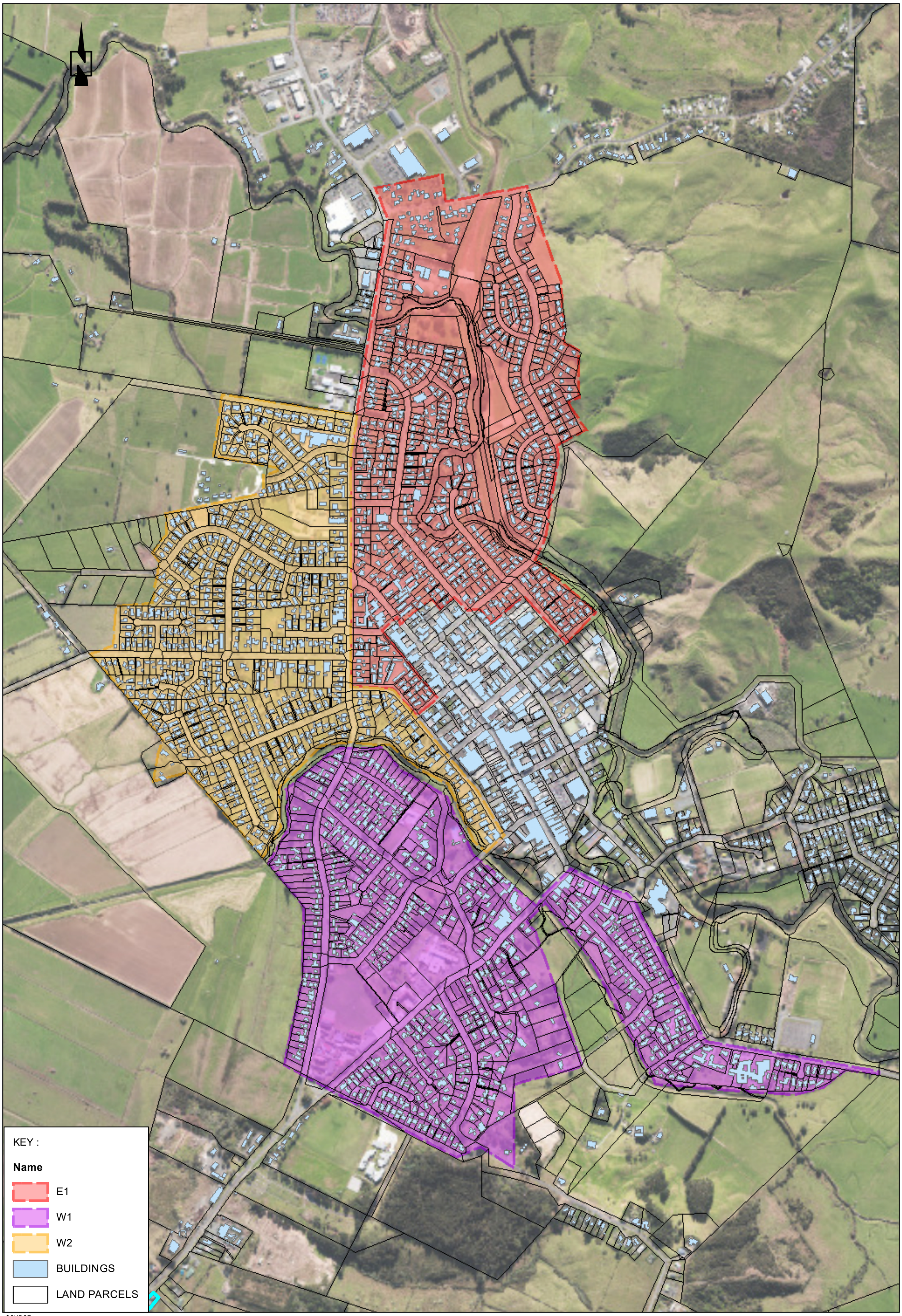
2. SA2 PROVIDED BY STATS NZ AND USED WITH PERMISSION.

FIGURE 6 : KAITAIA AIRSHED
PM2.5 WINTER DAY DOMESTIC EMISSIONS

SCALE : 1:60,000 (A4)

0 0.5 1 2 3
Kilometres



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2. SA2 PROVIDED BY STATS NZ AND USED WITH PERMISSION.

FIGURE 7 : KAITAIA BUILDING DENSITY

SCALE : 1:15,000 (A4)

The number of buildings within the residential areas E1, W1 and W2 and the density (buildings/ha) is shown in Table 1. The building density within W2 is slightly higher than in E1, which is in turn slightly higher than in W1.
The calculated building density for each sub parcel has been taken to be representative of the domestic burner density. This information suggests that the PM concentrations occurring in W2 as a result of residential solid fuel burning are likely to be slightly higher than E1 and W1.

Table 1: Residential building number and density for Kaitāia township

Sub-Parcel	Buildings (No.)	Area (m^2)	Building Density (buildings/ha)
E1	809	745800	10.85
W1	726	860113	9.73
W2	831	663067	11.14

4.4 Topography and Meteorology

The topography and meteorology of an area have significant impacts on if, when and where the pollutants in the air are dispersed. The topography of an area can channel wind in certain directions and/or create areas where cool (and polluted) air can pool, which leads to the build-up of air contaminant concentrations. The land surrounding and within the Kaitāia airshed area is relatively flat with no significant topographic features that are likely to strongly influence the dispersion or pooling of air pollutants.

A wind rose for Kaitāia (2016-2020) is shown in Figure 8. The data displayed in Figure 8 was collected at Kaitāia Electronic Weather Station (location number 17067), which is located close to the Kaitāia Observatory on Okahu Road approximately 1.5 km south from the centre of Kaitāia township.

Figure 8 shows that the predominant wind direction is east to east-south-east. Winds from the west-north-west through to the southwest also occur with relatively high frequency. There are relatively low frequencies of winds from the northerly and southerly quarters.

High air pollution episodes tend to occur during calm periods or when windspeeds are low (<3 m/s). Figure 9 shows the wind rose for Kaitāia for 2016-2020 for the winter months (June, July and August). The strongly predominant wind direction for low windspeeds in Kaitāia is east to east-south-east. This wind rose indicates that the highest frequency of high-level impacts are likely to occur to the west or the west-north-west of key pollutant sources during winter.

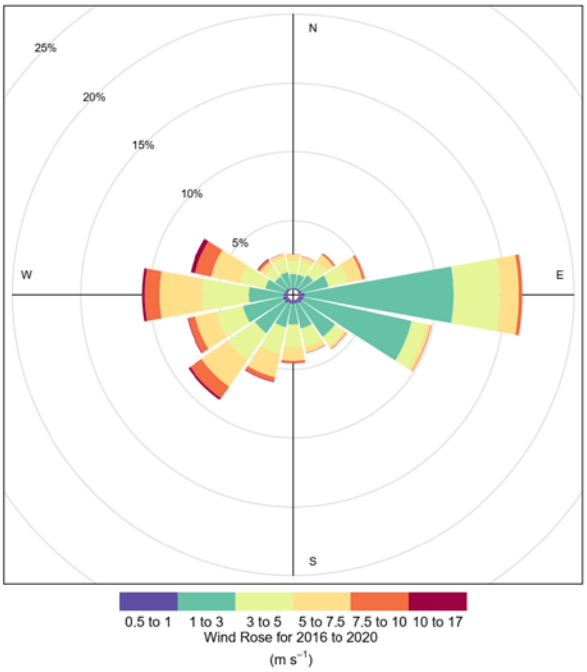

Figure 8: Windrose Kaitāia (2016 to 2020)

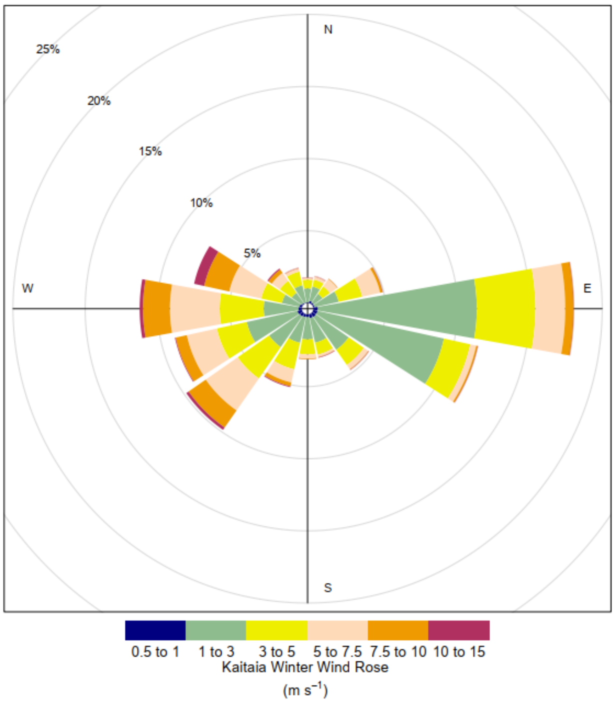

Figure 9: Windrose Kaitāia winter months 2016 to 2020

4.5 Other Factors

4.5.1 Impact of Industrial Sources on Ambient Air Quality

The Kaitāia airshed is one of a small number of airsheds in New Zealand that has a significant contribution to total particulate emissions from industrial sources. The plumes from large industrial point sources behave quite differently than those from domestic, roadway or backyard burning sources. Because the discharge points are elevated (up to 50 m above ground level) and the plumes are buoyant, discharges from large industrial point sources tend to travel a relatively large distance and are relatively well diluted before they impact at ground level. This contrasts to the low level and relatively small and diffuse domestic, roadway and backyard burning plumes which create maximum impacts very close to the source.

Two ambient air quality programmes have been undertaken in the northern part of Kaitāia East aiming to assess the impacts of the industrial plants in that part of Kaitāia township. One monitoring programme was undertaken on Donald Road (decommissioned 2014) 1 km to the south-east of the Juken Nissho plant and the other (commissioned 2015) on State Highway 1 0.5 km to the south-west of the plant. The location of the Juken Nissho plant is shown in Figure 4 by the northern most industrial site. Given the wind patterns for the area, these two monitoring sites were quite well placed to capture the impact of the two large wood mills operating in the northern part of Kaitāia. The data from these two monitoring programmes have shown industrial plumes do increase PM_{10} concentrations at the two monitoring sites but that monitored concentrations are well below the NESAQ for PM_{10}.

Based on the predominant wind directions (easterly and westerly), the plumes from these two large industrial sites will not be transported to or impact the populated parts of the Kaitāia township. Winds from the northerly quarter are required to transport the sites emissions to the populated parts of the Kaitāia and northerly winds are very infrequent in the Kaitāia airshed.

4.5.2 Vehicle Emissions

The particulate emissions from vehicles are a relatively small proportion (6%) of the total airshed emissions. The spatial impacts of large motorways are limited to about 200 m from the roadside. The key roadway source of vehicles within Kaitāia will be State Highway 1 and the relative magnitude of impacts from this roadway source are quite low compared to domestic and industrial sources. The housing density is considered a useful proxy for the amount of local traffic within Kaitāia. To measure the impact of State Highway 1 would require a roadside site which would not be in an optimal position to capture the impact of the key domestic airshed emissions. For this reason, vehicle emissions from State

Highway 1 are not used as a factor when recommending ambient air monitoring site in Kaitāia.

4.5.3 Backyard Burning Emissions

Backyard burning emissions are also a minor source (3%) of particulate emissions within the Kaitāia airshed. Backyard burning is assumed to occur mainly in residential areas. The impact of particulate discharged from this activity is therefore by default included in the assessment by considering the relative density of residential dwellings (Section 4.3).

4.6 Recommended Monitoring Location

The candidate monitoring location has been identified by considering the influence of the following factors:

- Location of dwellings;
- Density of solid fuel home heating devices;
- Topography of the surrounding area;
- Wintertime meteorology;
- Location of large-scale industrial sources;
- Locations and data from previous ambient air quality monitoring;
- Roading network and vehicle volumes;
- Backyard burning behaviour; and,
- Practical issues such as potential host sites.

The key findings from the assessment show that:

- Kaitāia township has the highest particulate emissions and peak exposure to the impact of those emissions;
- The highest density of domestic emissions and impacts likely to occur in Kaitāia West;
- Topography of the Kaitāia airshed does not have a large impact on the dispersion of pollutants;
- The predominant wind direction occurring during high-risk air pollution periods is from the east;
- Peak industrial impacts likely to occur in the northern parts of Kaitāia east or the adjacent areas in the Oturu or Tangonge SA2s.
- Industrial impacts in the more highly populated parts of Kaitāia are likely to be infrequent and relatively low;

- The impact of roadway emissions is relatively low and limited to a small spatial scales;
- The relative impact of backyard burning emissions is likely to occur in the same (or similar) locations as solid fuel burner emissions.

Considering the influence of the factors listed above, the recommended area within which to establish a NESAQ compliant air quality monitoring site for the Kaitāia airshed has been identified and is indicated by the purple patch in Figure 10.

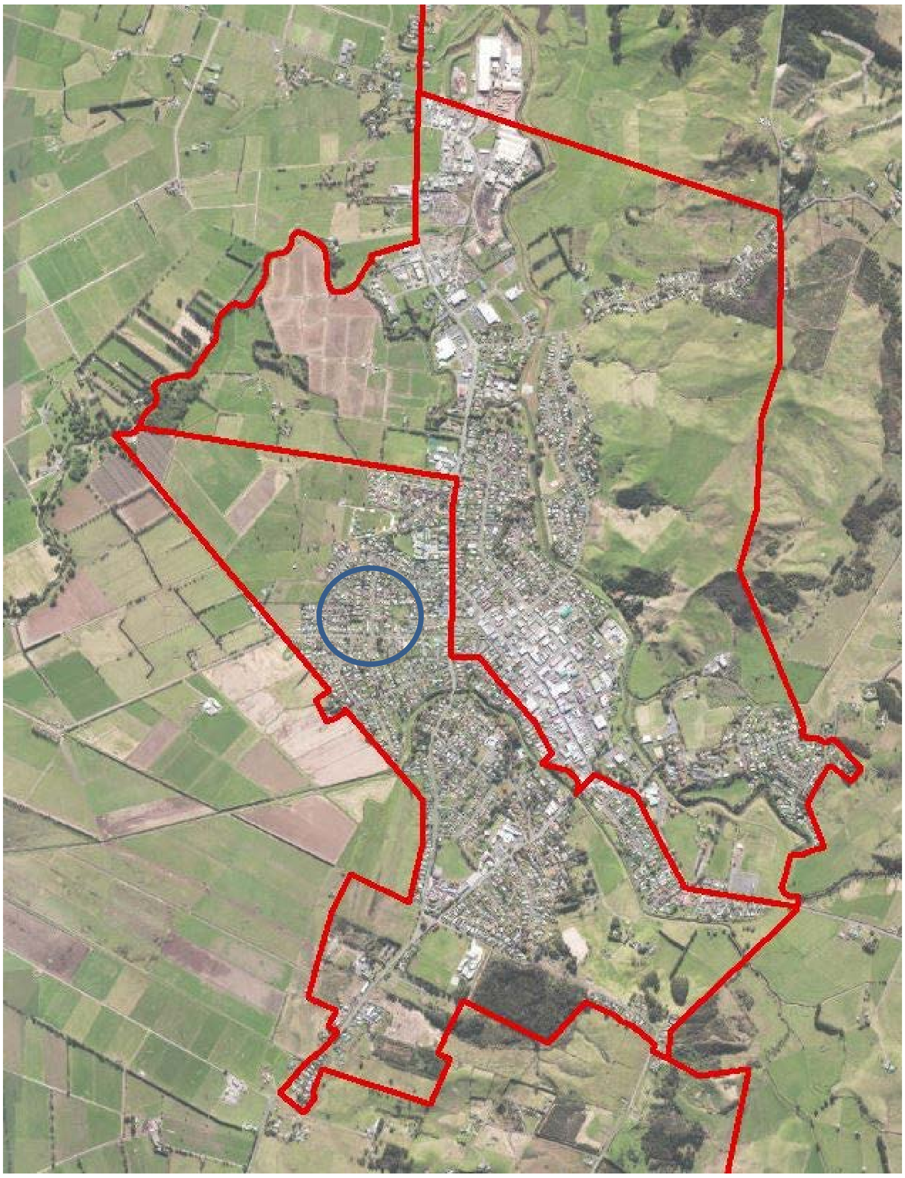

Figure 10: Recommended area for the Kaitāia NESAQ monitoring site

It is recommended that to identify a specific location within the recommended area that as far as practical the key requirements of AS/NZS 3580.1.1:2007 Part 1.1 Guide to Siting Air Monitoring Equipment be complied with. In parallel with this, practical site issues will need to be considered such as:

- Available space
- Longevity of the site
- Security
- Access
- Power supply
- Wind flow obstacles including trees

5.0 Whangārei Airshed

5.1 Airshed Characteristics

The Whangārei airshed covers an area of approximately 62 km^2 and contains 24 SA2 units. The spatial extent of the Whangārei airshed and the associated SA2 units is shown in Figure 11.

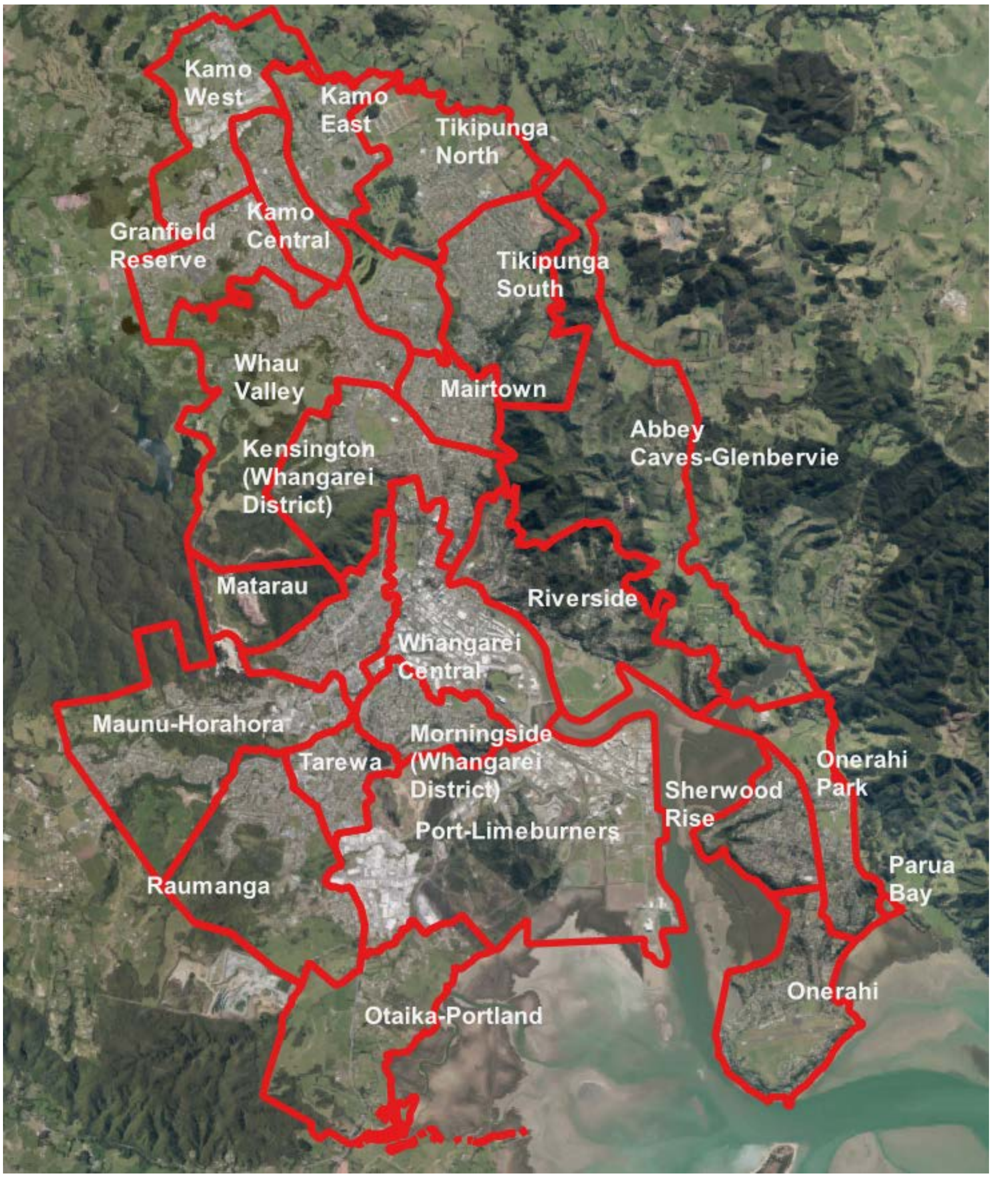

Figure 11: SA2 Units within Whangārei Airshed

The airshed includes the city of Whangārei, with a population of around 54,300 as of 2018. The key sources of particulate matter within the airshed are domestic solid fuel burners during cooler months, road transport, outdoor burning, and industrial activities. The dominant source of particulate matter emissions within the airshed is domestic heating, particularly in the winter.

5.2 Ambient Air Monitoring in Whangārei

NRC operates a long-term ambient monitoring station in central Whangārei within a commercial area at 88 Robert Street. The site currently measures both PM_{10}, $PM_{2.5}$, and meteorology, and has been in operation since the late 1990s. A second temporary ambient monitoring site was established in Mairtown at 31 Princes Street in August 2020 in order to provide monitoring data to assess the effects of domestic wood-fired heating in the winter and also to compare results obtained between two sites.

A wind rose for Whangārei as measured at the Robert St monitoring station (2016-2020) is shown in Figure 12. A wind rose for Whangārei as measured at the Robert St monitoring station for the winter months June, July and August (2016-2020) is shown in Figure 13. Figure 12 shows that over the whole year the predominant wind direction is from the north and north northwest, winds from the southwest are also relatively frequent. Figure 13 shows that during winter months windspeeds less than 3 m/s occur with similar frequency from all directions.

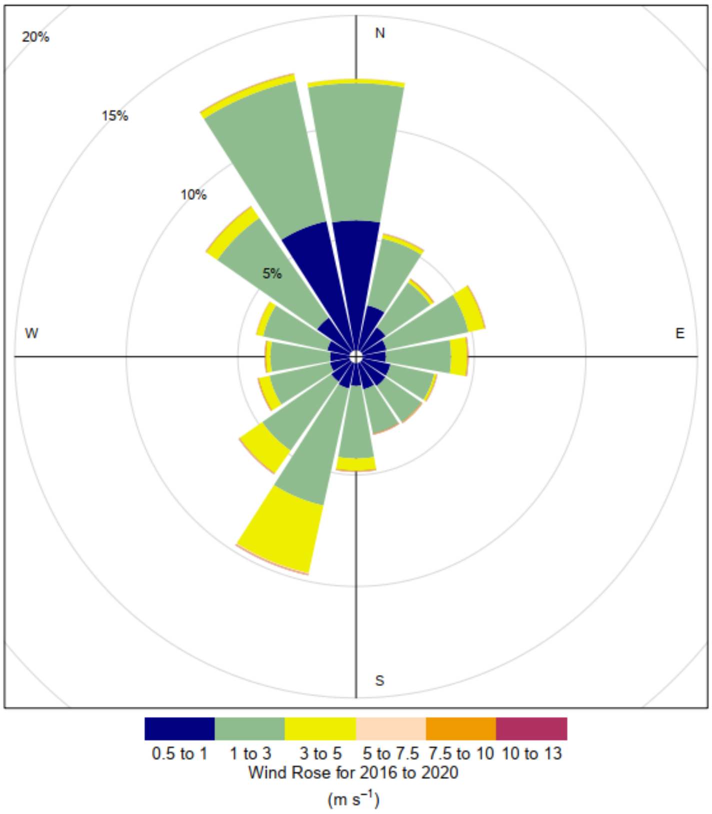

Figure 12: Windrose Whangārei (2016 to 2020)

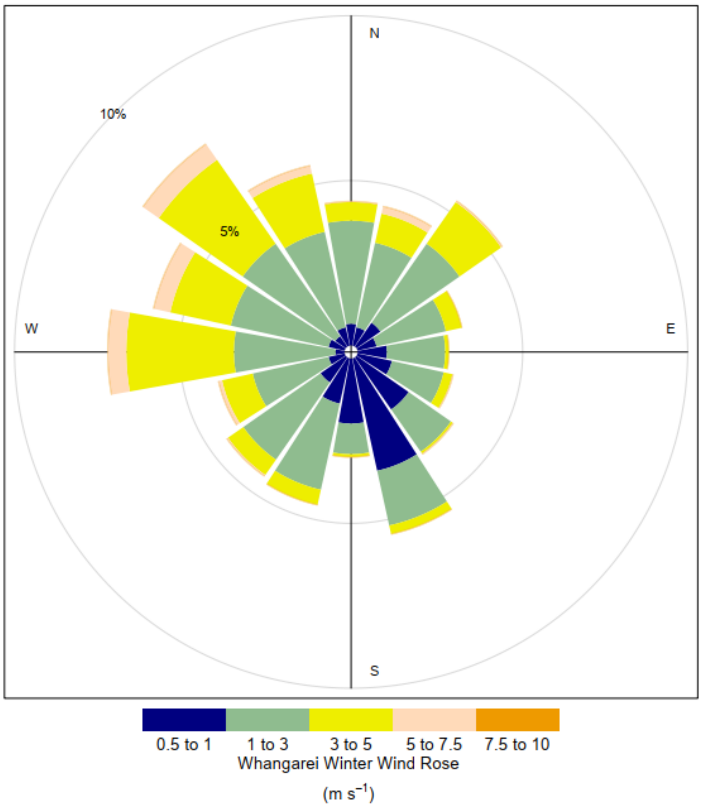

Figure 13: Windrose Whangārei winter months (2016 to 2020)

A summary of the particulate matter monitoring data for the two Whangārei monitoring sites is provided in Table 2. Comparison of the PM_{10} monitoring data at the Mairtown site and the Robert Street site indicates that the peak PM_{10} concentrations are somewhat higher at the residential Mairtown site, but overall the two sites observe similar concentrations of particulate matter. A time series plot of PM_{10} for both monitoring sites is provided as Figure 14, and also shows that the concentrations are similar.

Table 2: Whangārei Monitoring Results (µg/m³)

Statistic	Averaging Period	Mairtown – PM_{10}	Robert St – PM_{10}	Robert St – $PM_{2.5}$
Maximum	1-hour	210	173	52
	24-hour	37.0	23.6	19.0
95th percentile	1-hour	26.4	24.5	16
	24-hour	18.7	20.0	10.8
75th percentile	1-hour	16.5	16.3	8.5
	24-hour	13.9	14.3	7.3
Median	1-hour	10.8	11.3	5.2
	24-hour	11.2	11.6	5.3
Average	1-hour	11.9	12.2	6.1
	24-hour	11.8	12.2	5.9
25th percentile	1-hour	6.1	7.2	2.3
	24-hour	11.8	12.1	3.9
5th percentile	1-hour	0.4	2.1	0
	24-hour	6.9	6.9	2.6

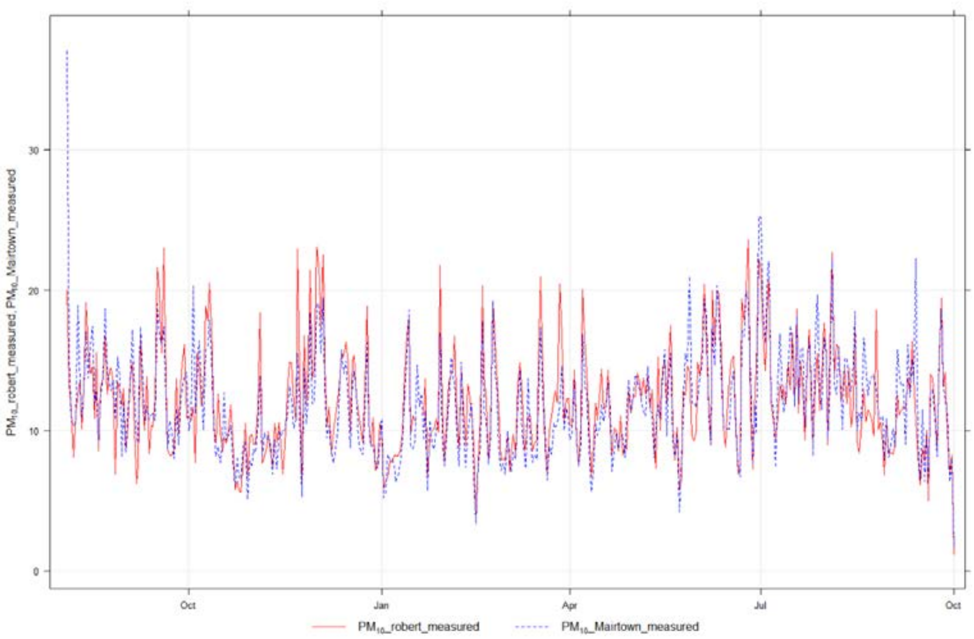

Figure 14: 24-hour average PM_{10} measured at the Robert St and Mairtown monitoring sites, August 2020 to October 2021

5.3 Assessment Method

The CALPUFF atmospheric dispersion model was used to model PM_{10} and $PM_{2.5}$ emissions within the Whangārei airshed. The CALPUFF dispersion model was used for this project because it is capable of considering the effects of local terrain features and proximity to the coast, and the capacity of the model to consider light and variable winds.

The model was setup in general accordance with the model-specific recommendations set out in the *Generic Guidance and Optimum Model Settings for the CALPUFF Modelling System for Inclusion into the 'Approved Methods for the Modelling and Assessments of Air Pollutants in NSW, Australia'* (TRC, 2011).

These model-specific guidelines are consistent with more generalised guidance for any model, such as MfE, Good Practice Guide for Atmospheric Dispersion Modelling (MfE, 2004).

Home heating, motor vehicle, outdoor burning, and industrial emissions were modelled using the emissions inventory for Kaitāia and Whangārei prepared by PDP (PDP 2021). The emissions inventory estimated the mass emissions of PM_{10} and $PM_{2.5}$ from each source category on an annual basis for each SA2 for 2018. These emissions were modelled over a two-year period 2019 to 2020 to predict the ground level concentrations (GLCs) of PM_{10} and $PM_{2.5}$ across the airshed.

Assumptions of temporal variations in the emissions were made where considered appropriate as described below.

5.4 Meteorology for Dispersion Modelling

The meteorological dataset for use with the CALPUFF dispersion model was generated using a two-stage modelling approach. First, a three-dimensional meteorological dataset was developed by the University of Canterbury using the Weather Research and Forecasting model (WRF[1]). The WRF dataset covered the Far North Region at 1 km resolution for the years 2019-2020. The WRF dataset was then used to provide inputs to the CALMET meteorological model which covered a 40 km x 40 km domain over Whangārei with a 200 m grid spacing. Surface observations from the Whangārei Airport meteorological monitoring station were also incorporated into the CALMET model.

Terrain data for the CALMET model were obtained from the LINZ data portal, in the form of an 8 m-resolution digital elevation model (DEM)[2]. Terrain data for the Whangārei area were downloaded through the portal and averaged onto the 200-m CALMET grid. Figure 15 shows the terrain heights over the modelling domain.

[1] https://www.mmm.ucar.edu/weather-research-and-forecasting-model
[2] https://data.linz.govt.nz/layer/51768-nz-8m-digital-elevation-model-2012/

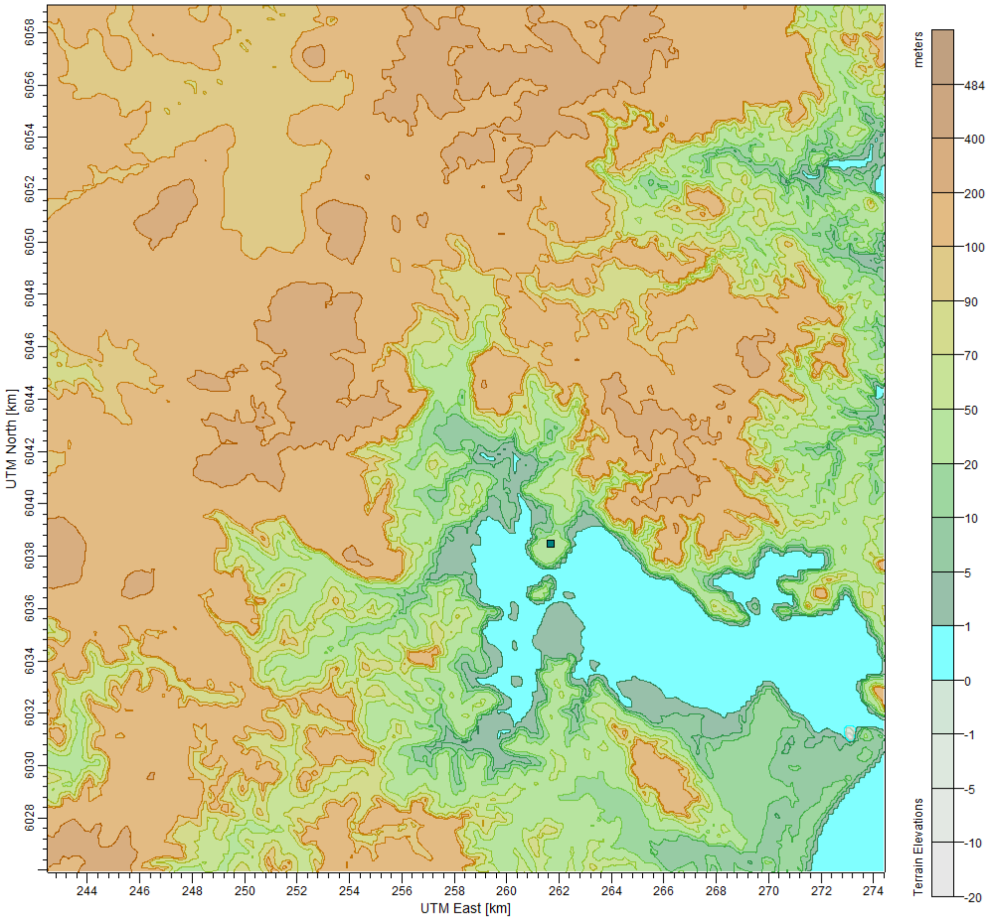

Figure 15: Terrain heights over the CALMET modelling domain for Whangārei

Landcover data from the New Zealand Land Cover Database (LCDB, version 5.0) were obtained as a shapefile from the LRIS portal[3]. The landcover classes were converted to the default CALMET land use types. The shapefile was then projected onto the CALMET 200 m grid, with the final land use type being the largest by area in the grid cell.

Figure 16 shows the land use categories used in CALMET. CALMET land use classes are urban (10), agriculture (20), rangeland (30), forest (40), water (51-55), wetlands (61-62) and barren land (70-80).

[3] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

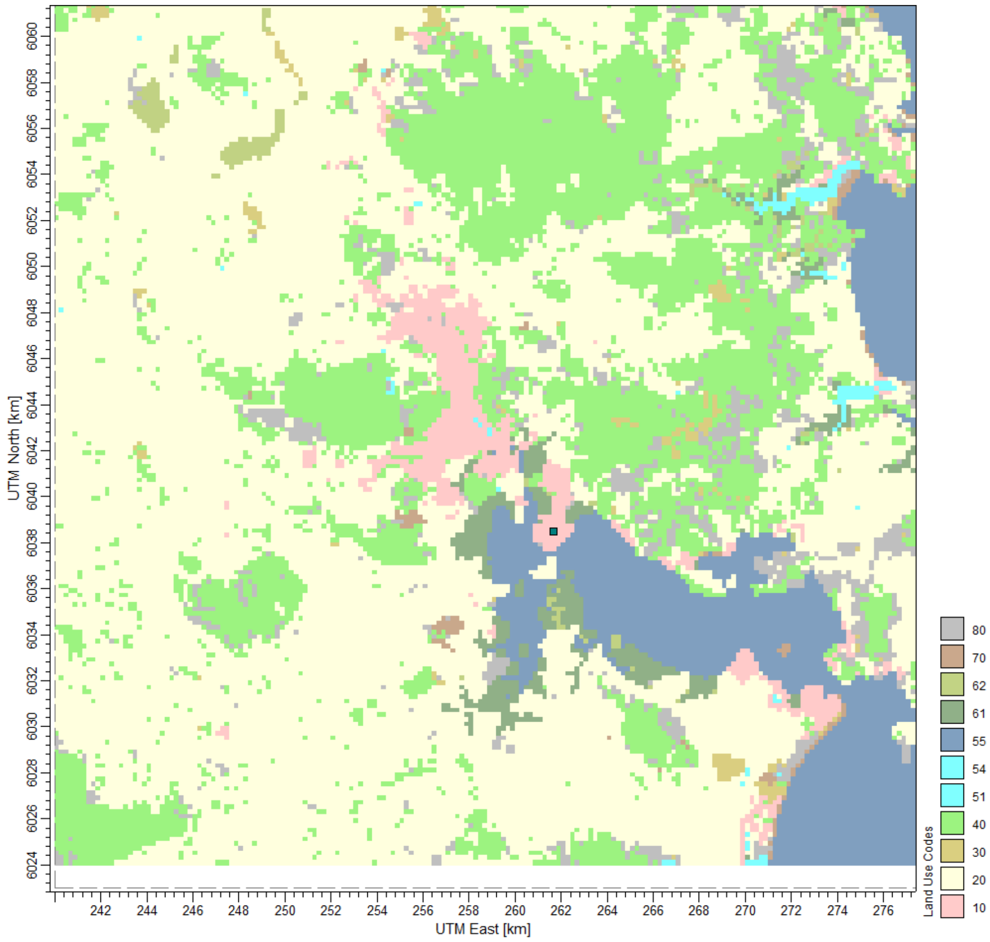

Figure 16: Land use and land cover categories over the CALMET modelling domain for Whangārei

5.5 Location, Quantity and Timing of Particulate Emissions

Emissions of PM_{10} and $PM_{2.5}$ from transport, domestic heating, and open burning were modelled as area sources based on the assumption that emissions were evenly distributed across each SA2 as shown in Figure 11.

Table 3 provides the emission rates of particulate matter for each SA2 and for each source type. The emission rates were derived from the annual emission rates for each SA2 as provided in the emissions inventory report (PDP 2021) and divided by the area of each SA2 to give emission rates in terms of grams per square meter per year(g/m^2/y).

Table 3: Area Source Emission Rates of PM_{10} and $PM_{2.5}$ in Whangārei by SA2

	Transport ($g/m^2/y$)		Domestic Heating ($g/m^2/y$)		Backyard Burning ($g/m^2/y$)	
SA2	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Kamo West	1.2	1.0	1.6	1.6	0.2	0.2
Kamo East	0.9	0.7	2.0	2.0	0.5	0.5
Granfield Reserve	1.0	0.7	2.5	2.5	0.5	0.5
Kamo Central	1.3	1.0	3.1	3.1	0.4	0.4
Whau Valley	0.5	0.4	1.0	1.0	0.2	0.2
Tikipunga North	0.6	0.4	1.3	1.3	0.3	0.3
Ōtāngarei	1.4	1.1	2.2	2.1	0.4	0.4
Tikipunga South	0.7	0.5	2.6	2.6	0.4	0.4
Kensington	1.9	1.5	1.5	1.5	0.3	0.3
Abbey Caves-Glenbervie	0.0	0.0	0.1	0.1	0.1	0.1
Mairtown	1.5	1.1	3.8	3.8	0.8	0.8
Maunu-Horahora	0.9	0.7	1.2	1.1	0.2	0.2
Woodhill-Vinetown	2.7	2.0	2.8	2.8	0.5	0.5
Whangārei Central	3.5	2.7	0.2	0.2	0.1	0.1
Riverside	0.8	0.7	1.4	1.4	0.2	0.2
Raumanga	0.3	0.2	1.0	1.0	0.2	0.2
Tarewa	2.0	1.5	2.4	2.4	0.4	0.4
Morningside	1.0	0.7	2.8	2.8	0.5	0.5
Otaika-Portland	0.1	0.1	0.1	0.1	0.1	0.1
Port-Limeburners	0.5	0.4	0.0	0.0	0.0	0.0
Onerahi Park	1.4	1.0	1.8	1.8	0.3	0.3
Sherwood Rise	0.8	0.6	3.8	3.7	0.5	0.5
Onerahi	0.5	0.4	1.8	1.8	0.3	0.3

5.5.1 Domestic Heating

Emissions from domestic wood burning occur more frequently during cooler weather. To simulate the variability in particulate matter emissions from wood burning, emissions of PM_{10} and $PM_{2.5}$ were apportioned on a monthly basis according to the monthly emissions estimates in the 2006 emissions inventory for Whangārei (Environet Limited - Air Quality Specialists , 2007). The monthly emissions of particulate matter as percentage of total annual emissions as provided in Table 3 are shown in Figure 17.

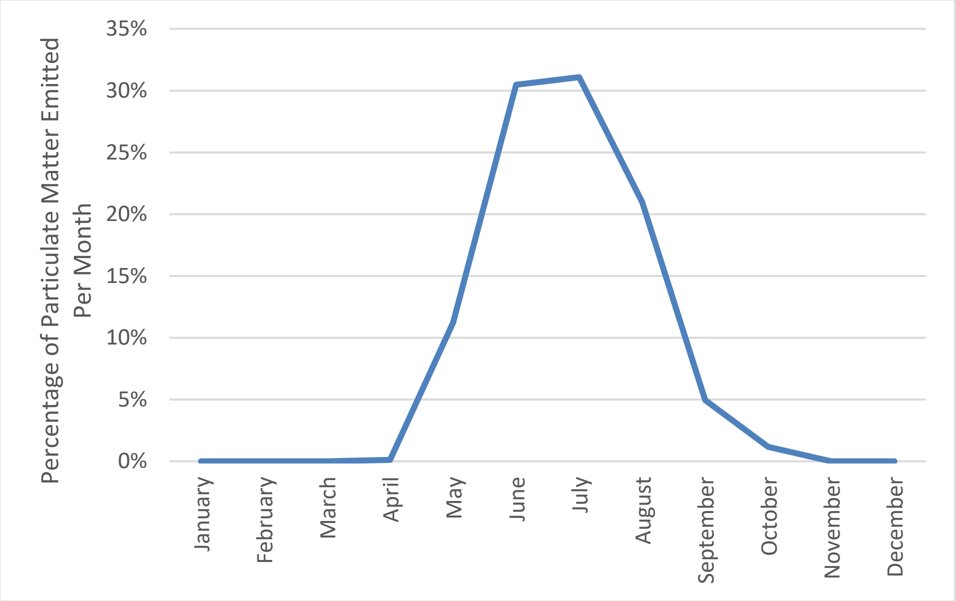

Figure 17: Proportion of Particulate Matter Emitted from Domestic Heating Per Month

Figure 18 shows the assumed diurnal pattern for the emissions from domestic burners in Whangārei. In the absence of hour-by-hour domestic fuel use survey data, the diurnal emission pattern was estimated using wintertime diurnal pattern of PM_{10} concentrations measured at the Mairtown monitoring site.

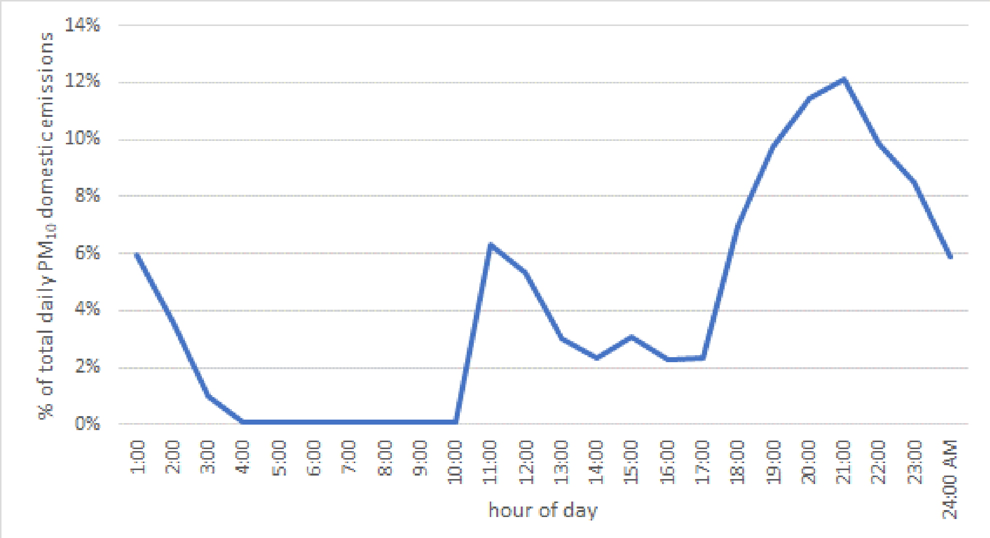

Figure 18: Diurnal Pattern of PM_{10} Emissions from Domestic Heating Per Hour of Day

5.5.2 Road Transport

Emissions from motor vehicles were derived from the estimated annual average daily traffic (AADT) for the roads in each SA2 as described in the emissions inventory report. The total emissions of PM_{10} and $PM_{2.5}$ for each SA2 were modelled on an hourly basis by apportioning the daily emissions of particulate matter by the hourly percentage of AADT as measured at the NZTA Maungatapere telemetry site[4], located around 9 km to the west of Whangārei. Figure 19 illustrates the average hourly flow profile recorded at the telemetry site which was used to factor the hourly emissions profiles for particulate matter from road transport.

[4] https://www.nzta.govt.nz/assets/resources/state-highway-traffic-volumes/docs/2011-2020-national-telemetry-site-profiles.pdf

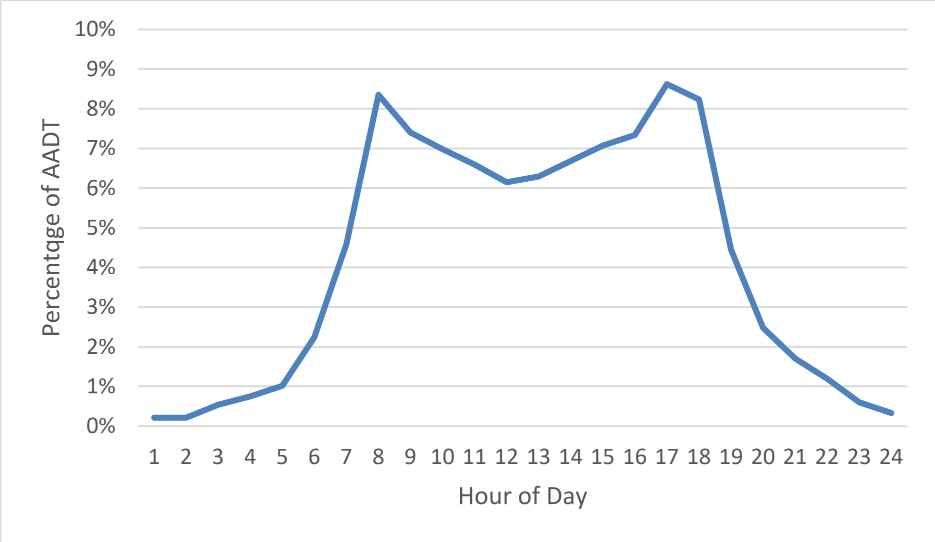

Figure 19: Average hourly traffic flow profile as percentage of AADT

5.5.3 Outdoor Burning

Outdoor burning was assumed to occur during daylight hours and were modelled at constant emission rates between the hours of 6 am and 6pm for every day of the two-year modelling period.

5.5.4 Industrial Discharges of Particulate Matter

Emission rates from industrial sources were modelled as point or volume sources depending on the nature of the activity. Industrial emissions which are discharged from stacks were modelled as point sources and included two concrete batching plants, an asphalt plant, and a crematorium. Stack parameters such as height, efflux velocity, and temperature, were obtained from resource consent where available. The majority of industrial emissions within the Whangārei airshed consist of abrasive blasting operations, which were modelled as volume sources. Table 4 summarises the industrial sources which were included in the Whangārei airshed model.

Table 4: Industrial sources of PM_{10} and $PM_{2.5}$

Emission Source	Number of Sources	Type of source	Emission Rate (g/s)		Daily Hours of Operation
			PM_{10}	$PM_{2.5}$	
Abrasive Blasting	12	Volume	0.194	0.028	10:00 to 16:00
Asphalt Manufacturing	1	Point	0.186	0.149	24 hrs
Concrete Batching	2	Point	0.043	0.022	8:00 to 16:00
Cremation	1	Point	0.005	0.048	7:00 to 17:00

5.6 Whangārei Airshed Model Results

5.6.1 Peak Modelled PM_{10} and $PM_{2.5}$ Within Airshed

The modelled peak concentrations within the Whangārei Airshed are provided as contour plots in Figure 20 (1-hour averages), Figure 21 (24-hour averages), and Figure 22 (annual averages). The locations of the two ambient monitoring stations at Mairtown and Roberts St are also indicated by red crosses.

The 1-hour average model predictions show the highest concentrations of PM_{10} occur at the eastern portion of the Port-Limeburners SA2, which is attributable to a large number of abrasive blasting operations in this area. Emissions from abrasive blasting are dominated by the coarse fraction of particulate matter, and these sources are not observed in the $PM_{2.5}$ plot. Outside of the industrial activity area, the areas with the highest 1-hour average concentrations of PM_{10} and $PM_{2.5}$ occur in those SA2s which have a high density of residences, in particular: Mairtown, Woodhill-Vinetown, Tikipunga South, Morningside, and Sherwood Rise.

The plots of particulate matter as 24-hour averages show similar spatial distributions for both PM_{10} and $PM_{2.5}$, with the SA2s having the highest concentrations of particulate matter being Mairtown, Woodhill-Vinetown, Tikipunga South, Morningside, Sherwood Rise, and to a lesser degree Onerahi.

The plots of particulate matter as annual averages again show high predictions of PM_{10} in the Port-Limeburner SA2 which is absent from the $PM_{2.5}$ plots. Outside of the industrial area, the highest predictions again occur in the residential SA2s of Mairtown, Woodhill-Vinetown, Tikipunga South, Morningside, Sherwood Rise, and to a lesser degree Onerahi.

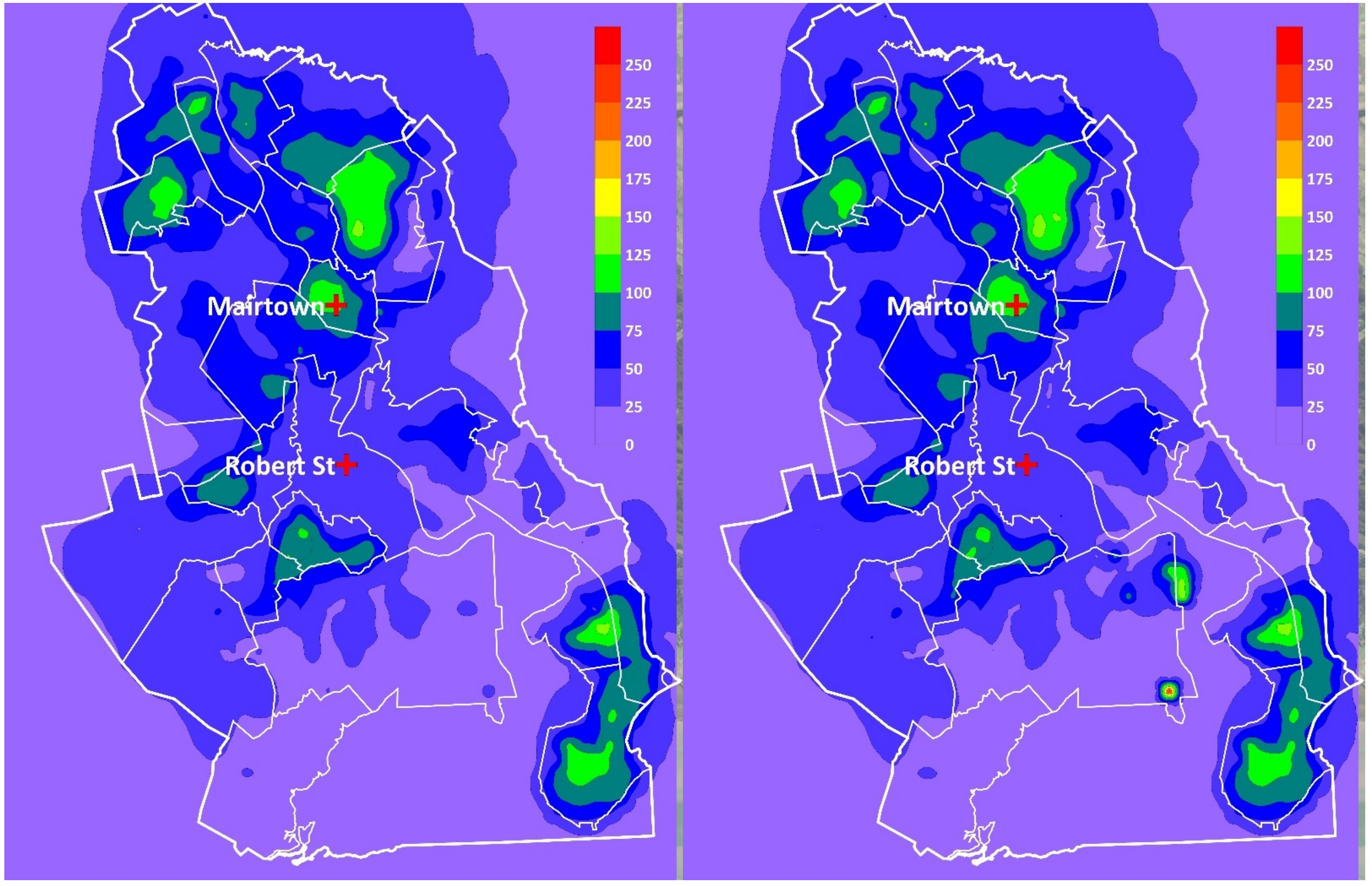

Figure 20: Highest Predicted 1-hour average GLCs (µg/m³) for $PM_{2.5}$ (left) and PM_{10} (right)

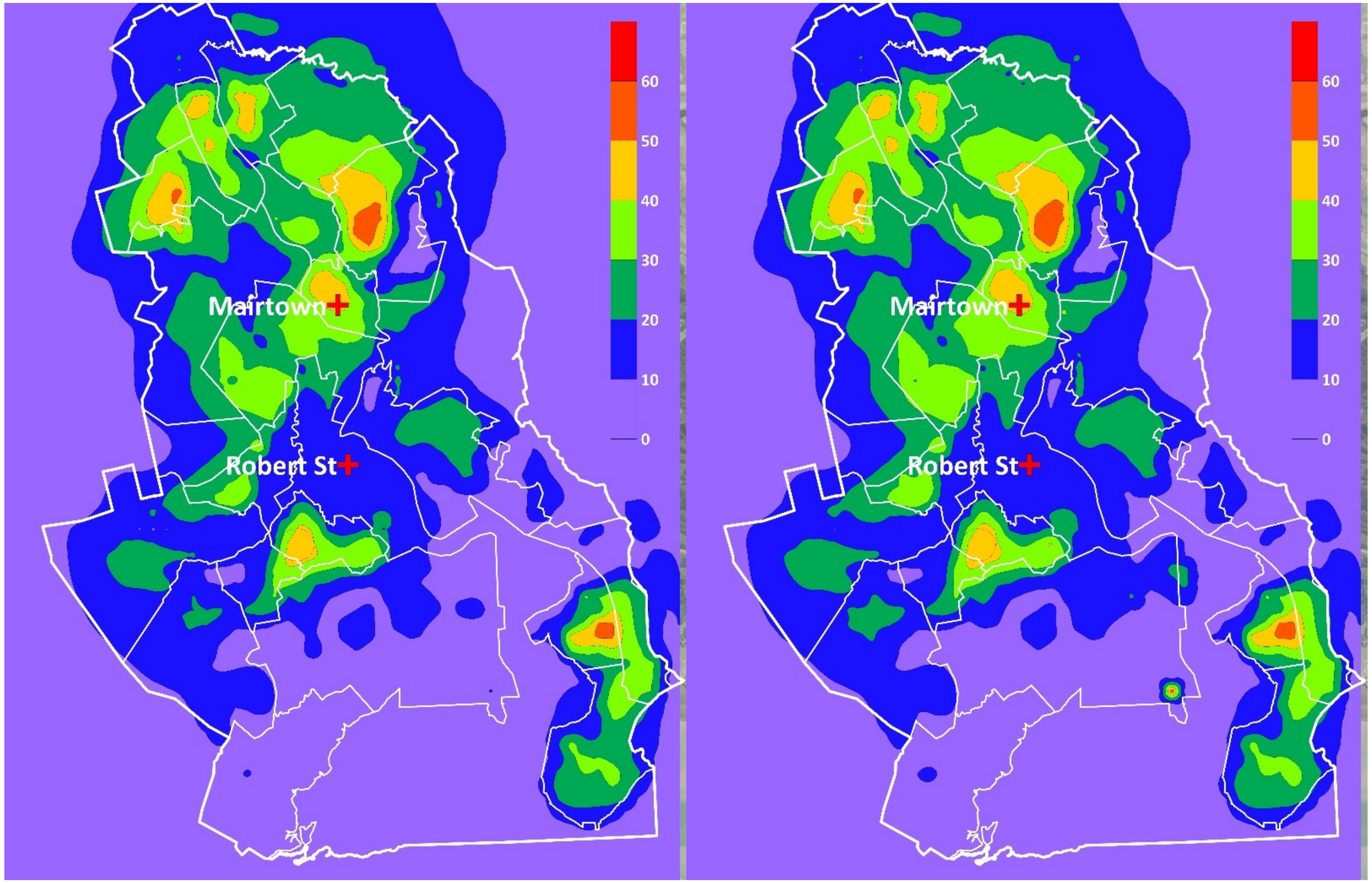

Figure 21: Highest Predicted 24-hour average GLCs (μg/m³) for $PM_{2.5}$ (left) and PM_{10} (right)

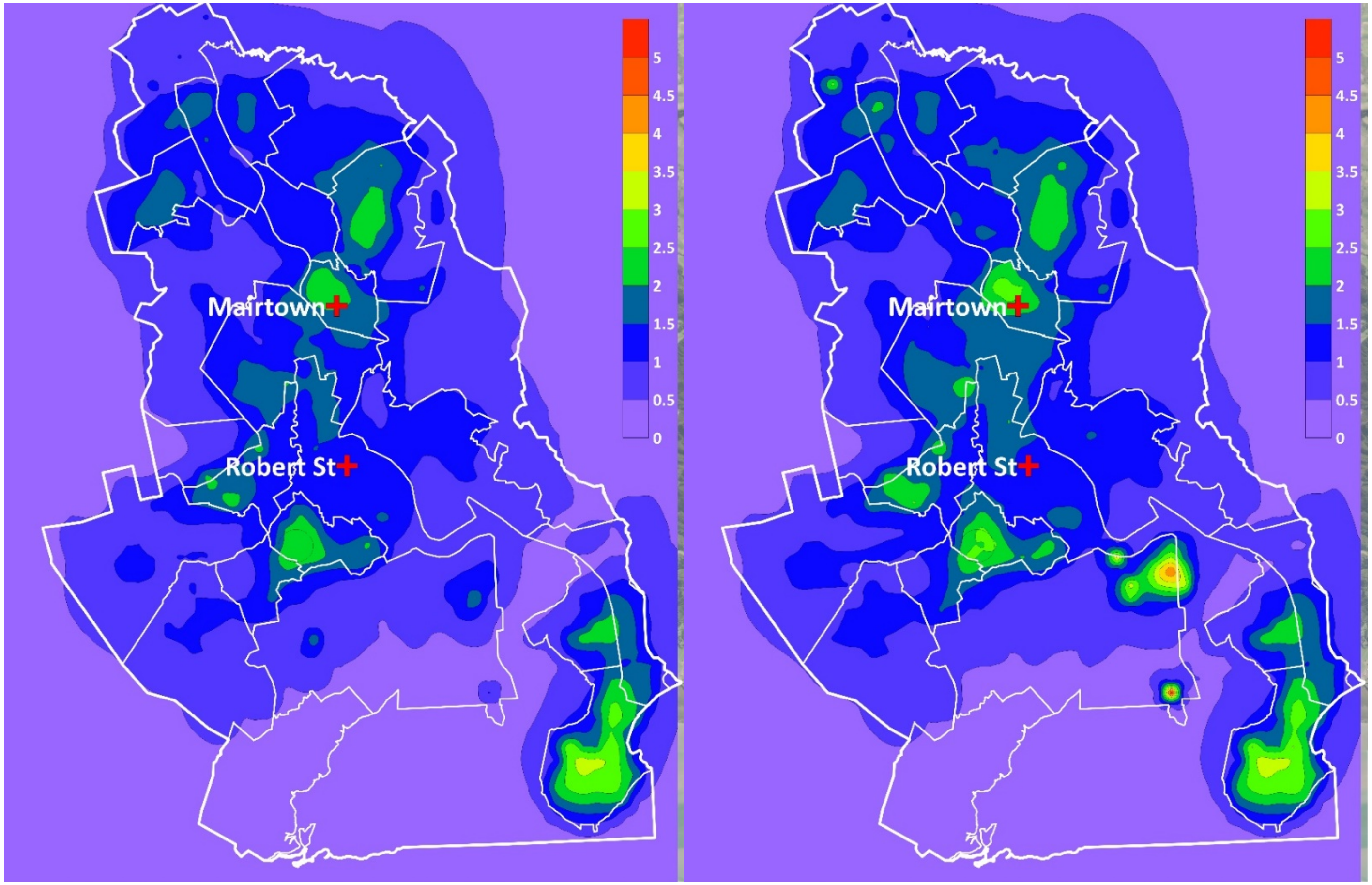

Figure 22: Highest Predicted annual average GLCs (μg/m³) for $PM_{2.5}$ (left) and PM_{10} (right)

5.6.2 Comparison of Model Predictions at Air Quality Monitoring Sites

The model predictions are overall lower than the measured concentrations at the two monitoring sites in Whangārei. This is in part due to sources of particulate matter not included in the inventory, including natural sources such as wind-blown dust, sea-spray aerosol, biogenic emissions, dust discharged from sealed and unsealed roadways and unconsolidated areas such as construction sites

A recent report (NIWA, 2019) has estimated the contribution of sea spray aerosol to total PM_{10} to be 3 to 7 $\mu g/m^3$ as an annual average, and of wind-blown dust to be 1-3 $\mu g/m^3$. An assumed concentration of 10 $\mu g/m^3$ has been added to the model predictions to account for natural sources of particulate matter which were not accounted for in the modelling.

The predictions of PM_{10} and $PM_{2.5}$ predicted in the Whangārei airshed modelling assessment have been compared to the PM_{10} values as measured at the Robert St and Mairtown monitoring sites maintained by NRC. Table 5 provides summary statistics of the highest predicted PM_{10} concentrations over the two-year 2019-2020 modelling period with monitoring data collected during a period from August 2020 to October 2021.

As discussed previously, the model predictions are qualitatively lower at the Robert Street site than at the Mairtown site, which is attributable to the fact that domestic heating emissions are more prevalent in the residential Mairtown area than in the central commercial zone. This trend is observed in the monitoring data at the higher concentrations, but to a much lesser degree at the lower percentiles. It is PDP's understanding that the Robert Street site is located within a high-traffic commercial area, and so is impacted in large part by vehicle emissions. Given that the modelling has distributed traffic emissions evenly across the SA2, the impacts of vehicle emissions at a roadside location are likely to be underestimated.

Table 5: Monitoring vs Modelling Results – PM_{10} ($\mu g/m^3$)

Statistic	Averaging Period	Mairtown		Robert St	
		Measured	Predicted	Measured	Predicted
Maximum	1-hour	210	176.2	173	66.4
	24-hour	37	56.5	23.6	24.9
95th percentile	1-hour	26.4	17.8	24.5	14.7
	24-hour	18.7	17.5	20	13.6
75th percentile	1-hour	16.5	11.4	16.3	11.3
	24-hour	13.9	12.8	14.3	11.6
Median	1-hour	10.8	10.6	11.3	10.6
	24-hour	11.2	11.1	11.6	11.0
Average	1-hour	11.9	12.0	12.2	11.3
	24-hour	11.8	12.4	12.2	11.4
25th percentile	1-hour	6.1	10.3	7.2	10.3
	24-hour	11.8	10.6	12.1	10.6
5th percentile	1-hour	0.4	10.1	2.1	10.1
	24-hour	6.9	10.3	6.9	10.2

5.7 Recommended Monitoring Location

The dispersion modelling has provided an empirical indication of locations within the Whangārei airshed where concentrations of PM_{10} and $PM_{2.5}$ are likely to be higher. The contour plots in Figure 20 to Figure 22 indicate that the highest concentrations for all averaging periods are predicted to occur in the highly residential SA2 units, which is to be expected given that the emissions inventory has shown that domestic heating is the main source of emissions of particulate matter to air.

Because of NESAQ requirements PDP considers that the predictions of 24-hour average concentrations of particulate matter are most appropriate to use as a basis for selecting the locations for monitoring. The contour plots of 24-hour average concentrations shown in Figure 21 indicate that the SA2 units with highest predicted concentrations of both PM_{10} and $PM_{2.5}$ in order of highest concentrations are:

- Tikipunga South (particularly the central portion of the SA2 unit)

- Morningside (particularly the western portion of the SA2 unit)
- Granfield Reserve (particularly the central-south portion of the SA2 unit)
- Mairtown (the location of one of the current monitoring sites); and,
- Sherwood Rise.

Table 6 shows the maximum modelled 24-hour average PM_{10} and $PM_{2.5}$ concentrations by SA2.

Table 6: Maximum modelled 24-hour average PM_{10} and $PM_{2.5}$ concentrations

SA2	$PM_{2.5}$ (µg/m³)	PM_{10} (µg/m³)
Tikipunga South	55	56
Granfield Reserve	52	53
Sherwood Rise	53	54
Mairtown	47	48
Morningside	44	45

These five SA2s represent the locations which would most likely best meet the NESAQ requirements for monitoring PM_{10} and $PM_{2.5}$. PDP understands that NRC has the resources to operate one monitoring site within the Whangārei airshed.

In context of the uncertainties contained in the modelling input data and dispersion estimation, the concentrations for each of these SA2s are most appropriately considered similar. PDP conclude that the 20% difference between the highest and lowest SA2 is likely within the uncertainties of the model predictions.

Given these factors, PDP recommend that the NRC select the monitoring location for the SA2 which is located most centrally within the Whangārei airshed. The reason for this is during winter low windspeeds occur with similar frequency from all directions, suggesting that a centrally located monitoring site would be more frequently impacted by high particulate concentrations than a site located more toward one of the airshed boundaries. For this reason, PDP recommends that NRC select a location within Mairtown to establish their long-term NESAQ monitoring site.

6.0 Potential Improvements on Methods Used to Identify the Recommended Monitoring Site Locations

The airshed modelling approach could be potentially used to refine or confirm the recommended monitoring site location for Kaitāia, but this would be a significant resource investment. The spatial scale on which the transport emissions was allocated was very coarse. Potentially this could be refined and improved by plotting the road network and VKT into the Kaitāia SA2s.

With the exception of industrial emissions, the emissions of PM_{10} and $PM_{2.5}$ in Whangārei have been modelled on a relatively coarse spatial basis, with each SA2 comprising a single area source within the CALPUFF dispersion model. This simplified approach was used to keep the model run time to a reasonable level. The spatial resolution of the model could be improved by breaking the SA2 units into a greater number of smaller area sources and apportioning the emissions of traffic, domestic heating, and open burning amongst the smaller areas. Another refinement would be to model traffic emissions as individual roads with corresponding traffic volumes rather than diffuse area sources.

However, these approaches would result in significant increases in model computation time as well as in model setup. The purpose of the modelling assessment is to indicate the general areas where particulate matter would be expected to be present in higher concentrations. Given the limited purpose of the assessment, it is unlikely that the improvements in spatial resolution provided by refining the model inputs would warrant the required increased time and expense of the refinement.

Diurnal variations in domestic wood burning emissions were not considered, and emissions were assumed to be constant over any given 24-hour period. Apportioning the emissions over a day to reflect the timing of the activity would potentially improve the model's robustness.

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