Recommendations for what areas to prioritise $PM_{2.5}$ monitoring in Northland airsheds

Prepared for Northland Regional Council

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Executive summary

Northland Regional Council (NRC) have requested NIWA review all historical monitoring and modelling data for Northland and formulate a monitoring plan for $PM_{2.5}$ across their five regional designated airsheds (Whangārei, Marsden Point, Kerikeri, Dargaville and Kaitāia). This plan will allow each area to be screened for potentially elevated $PM_{2.5}$ concentrations in anticipation of a National Environmental Standard for $PM_{2.5}$ being introduced in the near future.

Data of different types have been reviewed for each airshed:

1. Census data,
2. Emissions data from traffic, domestic heating and industrial sources,
3. Concentration data derived from the Traffic Impact Model and NRC PM_{10} and $PM_{2.5}$ monitoring, and
4. Terrain, land use and climatological data.

By combining these different types of information along with their relative impacts on potential $PM_{2.5}$ concentrations the following prioritisation for monitoring is recommended:

1. Whangārei, with a recommendation to move the monitoring site further north into the Whau Valley,
2. Kaitāia, due to its marginally elevated PM_{10} concentrations, to determine if these are caused mainly by sources of coarse fraction PM_{10} and not $PM_{2.5}$,
3. Dargaville, as it has marginally higher wood-burner density,
4. Kerikeri because of its lower wood-burner density and finally,
5. Marsden Point, to gain greater understanding of the range of $PM_{2.5}$ concentrations possible in the largely industrial area.

This review has been funded through an MBIE Envirolink Medium Advice Grant (ELF20103, MBIE Contract C01X1917).

1 Introduction

Air quality is an important environmental health problem in New Zealand and is regulated under the Resource Management Act (1991, RMA) and associated National Environmental Standards (NES). Currently, there is no standard for $PM_{2.5}$, that is concentrations of airborne particles no larger than 2.5 micrometres in diameter. However, a review of the NES is ongoing and is expected to result in a new standard for $PM_{2.5}$ in the near future.

Although, Northland Regional Council (NRC) does not have a statutory requirement under existing legislation to monitor $PM_{2.5}$, NRC wants to be prepared to commence regulatory monitoring, in a reasoned and practical sequence of areas, beginning with areas that are most likely to have elevated concentrations.

To that end, they have requested NIWA review historical monitoring and modelling data for Northland and formulate a monitoring plan for $PM_{2.5}$ across the five regional designated airsheds (Whangārei, Marsden Point, Kerikeri, Dargaville and Kaitāia - see Figure 1-1), that will allow each area to be screened for potentially elevated $PM_{2.5}$ concentrations.

This review will provide the council with the relevant information to monitor and implement air quality management plans for $PM_{2.5}$.

This report outlines the review and provides details on:

1. the datasets used,
2. the methods used to estimate relative $PM_{2.5}$ concentrations across the region's airsheds,
3. a ranking of the five airsheds from potentially highest to lowest $PM_{2.5}$ concentrations, and
4. a list of potential hotspots suitable for NES compliant monitoring, and more representative locations suitable for population health monitoring.

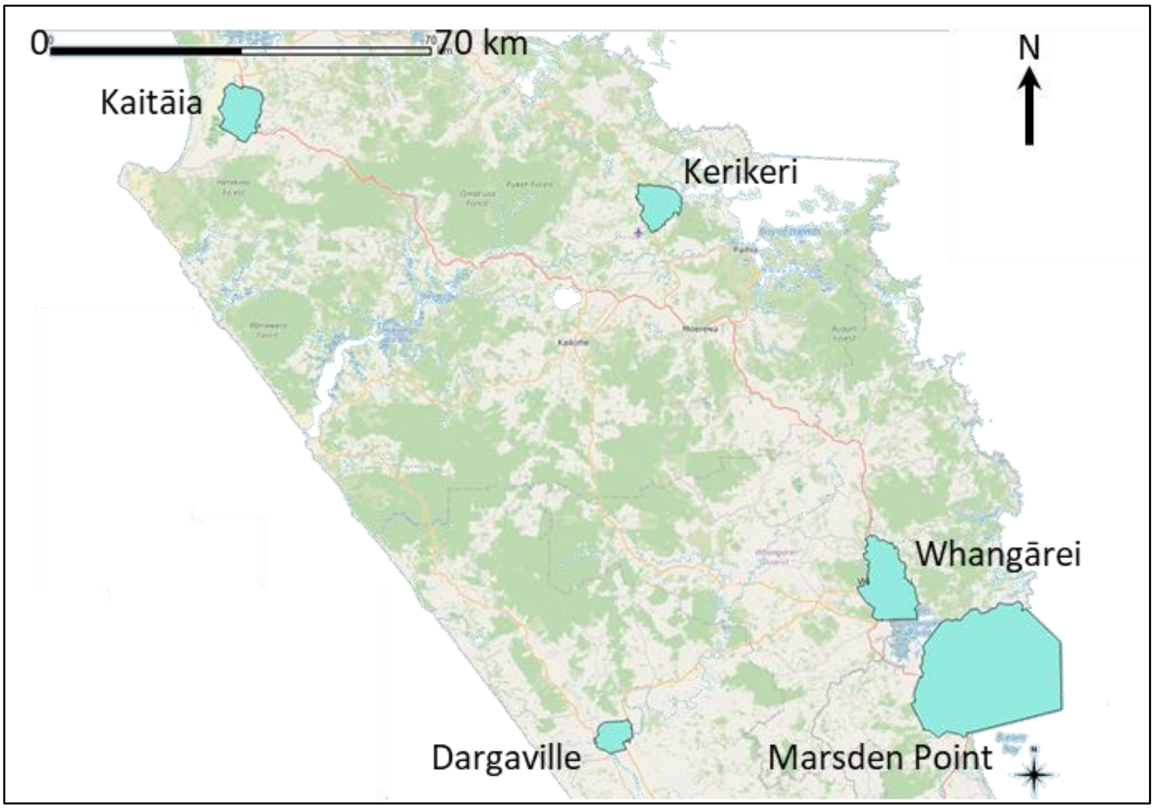

Figure 1-1: The five designated airsheds in Northland.

1.1 Method of Review

Section 2 provides details about datasets used to rank the five airsheds in Northland and comprises four sections:

1. Demographic, which gives some insight into the potential pressures on air quality,
2. Emission sources, which provides information about the variation in their expected strength and location, regardless of the extent of measurements that have been undertaken,
3. Concentration data, either measured or modelled which gives insight into the relative ambient air quality that can be expected in the airsheds, and
4. Climatological data, which includes long-term measures of meteorological variables.

Section 3 then looks at each airshed individually to determine where would be most suitable location for NES compliant monitoring, and to anticipate the relative strength of $PM_{2.5}$ concentrations that can be expected in the airshed.

2 Data reviewed

This section provides details about datasets used to rank the five airsheds in Northland and comprises four sections:

2.1 Demographic data

The New Zealand census takes place every five years (natural disasters permitting) and the most recent was conducted in 2018. Currently only preliminary results are available, at the district level. Figure 2-1 shows the population growth in Northland's districts. Although growth was flat between 2006 and 2013, since then there have been steady increases in all three districts. Whangārei, which includes the airsheds of Whangārei City and Marsden Point is growing by 3.4% per annum. The Far North, which includes the airsheds of Kaitāia and Kerikeri is growing by 3.2% per annum. The Kaipara district (including Dargaville) is growing the fastest, at 3.8% per annum but as it has a much lower population, the absolute increase in pressure is lower than for Whangārei or the Far North. As a comparison the annual growth in national population over the same period is 2.1%.

The demographic data suggests a steadily growing pressure on the environment, particularly in population-based emissions from vehicles and domestic biomass burning. Whangārei, as well as having the largest population, is also the smallest district and so the population density is greater, producing a greater emission density that is continuously increasing.

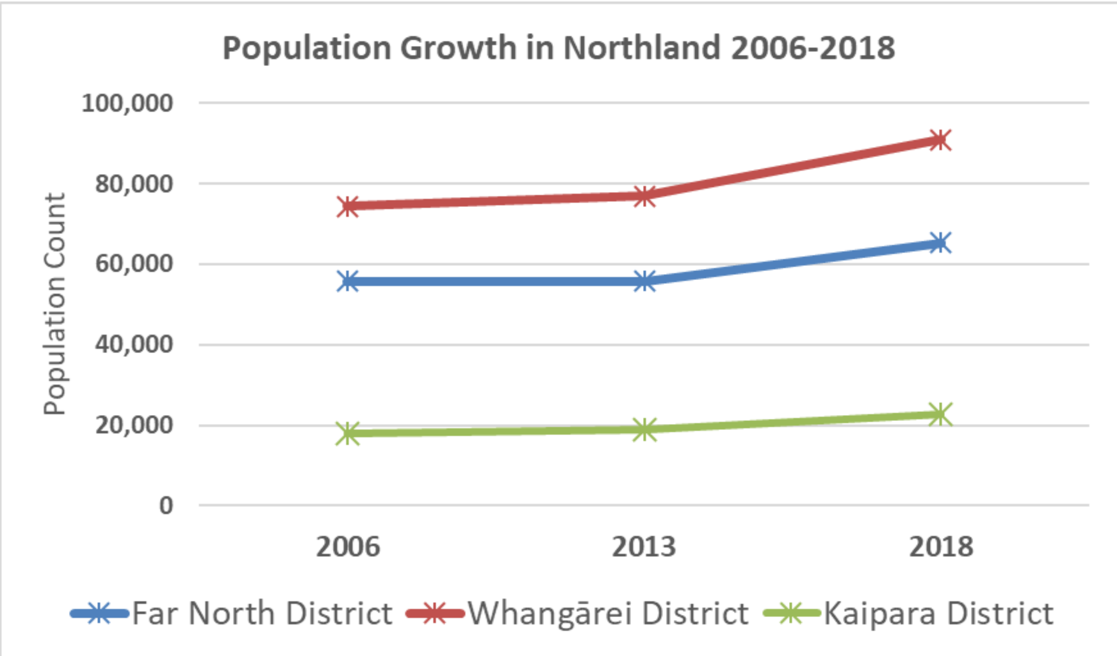

Figure 2-1: Population growth of districts in Northland 2006-2018. Census data from '2018 Census population and dwelling counts – amended.xlsx', downloaded from https://www.stats.govt.nz/information-releases/2018-census-population-and-dwelling-counts

2.2 Emission source data

The greatest source of $PM_{2.5}$ is combustion of either fossil fuels or biomass. Although many different activities include combustion and thus produce $PM_{2.5}$ emissions, this review focusses on the population dependent combustion emissions from traffic and domestic heating. Mention is made of other sources but detailed analyses of these are excluded from this review. They include:

1. Stand-alone processing or industrial plants (such as cement and fertiliser plants, meatworks, dairy factories, timber processing, and fibre board manufacture plants), which are managed by the consenting process
2. Oil refining and energy production activities, also strictly controlled by the consenting process
3. the agricultural and horticultural sectors, including the use of seasonal or rural burning, and
4. bush or wildfires.

2.2.1 Traffic

The New Zealand Transport Agency (NZTA) maintains a network of automatic traffic counters throughout New Zealand and publishes the counts at https://www.nzta.govt.nz/resources/state-highway-traffic-volumes/

Figure 2-2, Figure 2-3 and Figure 2-4 show the Annual Average Daily Traffic (AADT) for the counters in each of the five airsheds. The details of each counter, including location can be found in Appendix A. The location of the counters are also included in the maps of traffic related air pollution found in Section 2.3.1.

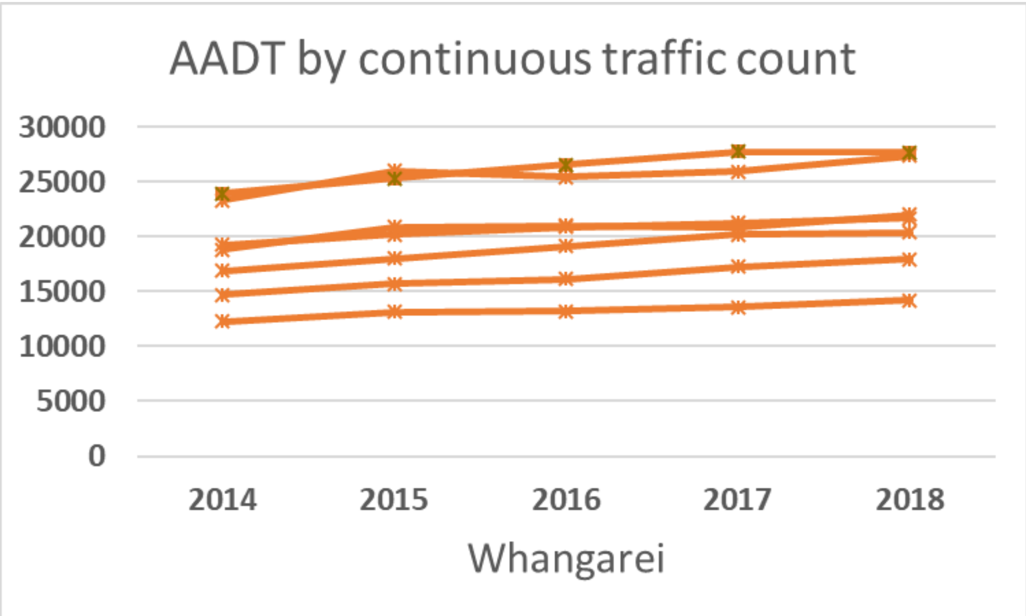

Figure 2-2: Annual Average Daily Traffic numbers recorded in Whangārei. Each line represents one NZTA counter location. Details can be found in Appendix A.

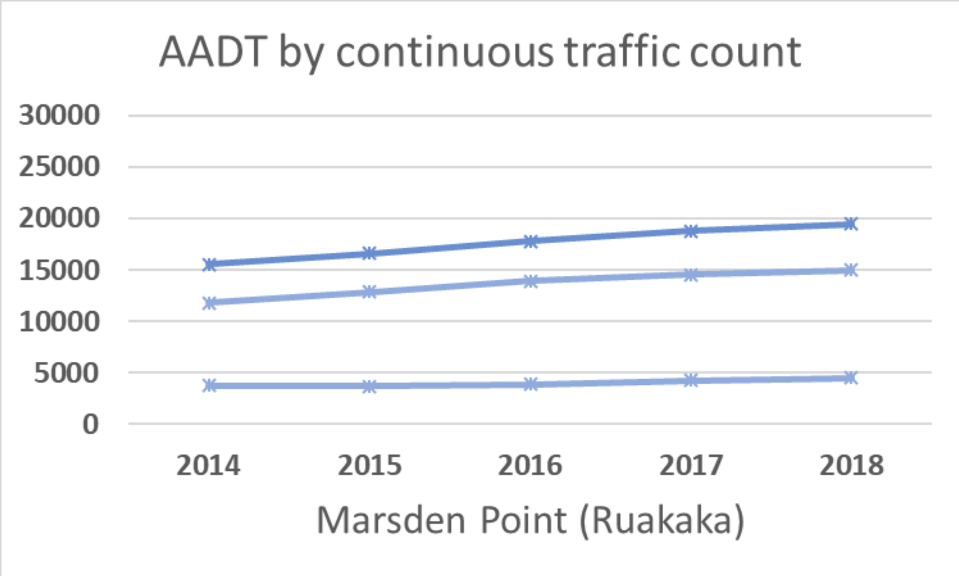

Figure 2-3: Annual Average Daily Traffic numbers recorded in Marsden Point. Each line represents one NZTA counter location. Details can be found in Appendix A.

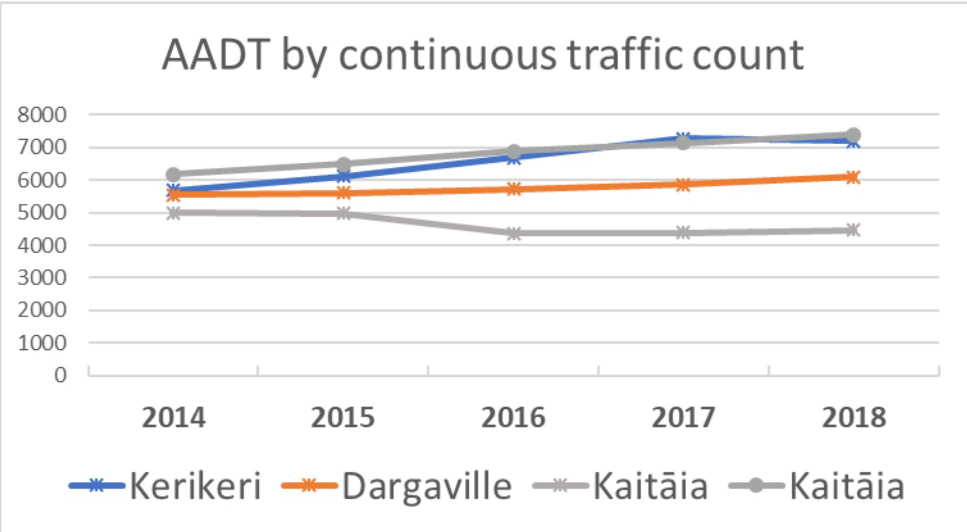

Figure 2-4: Annual Average Daily Traffic numbers recorded in Kerikeri, Dargaville and Kaitāia. Each line represents one NZTA counter location. Details can be found in Appendix A.

From the counters arrayed around and along SH1 through Whangārei, traffic has grown between 2.6% and 4.4% per annum. In the Marsden Point airshed traffic has grown between 4.0% and 5.3%. Traffic along SH1 by Kerikeri has grown 5.3% per annum, in Dargaville by 2.0% and in Kaitāia by 3.9%. These increases are in line with population growth in the region.

While Whangārei and Marsden point have comparable traffic numbers, mostly between 12,000 to 20,000 vehicles per day, Whangārei has some counts that are growing towards 30,000 (counter IDs

01N00264 and 01N00267). These could be potential hotspots for traffic related air pollution, including $PM_{2.5}$.

However, total vehicle numbers are not the only factor in producing elevated concentrations. Congestion and stop-start traffic significantly raise the impact of vehicle numbers, as each is more likely to produce higher emissions per kilometre travelled.

Another factor is the type of vehicles. Heavy Duty Vehicles (HDVs) have large diesel engines that produce more emissions than a standard passenger vehicle. The percentage of HDVs at the Whangārei City counters ranges from 4.5 to 7.9%. The counters in the Marsden Point airshed see up to 19.2% HDVs. This will have a significant impact on the traffic emissions at those sites. Counts at the Marsden Point sites are also increasing at some of the greatest rates in the region - around 5% per annum – indicating growing industrial activity in the area.

The AADTs for the counters in the three other airsheds are all substantially lower, ranging from around 6,000 to 7,500 AADT.

2.2.2 Domestic Heating

There is no direct count of domestic wood-burners available for New Zealand cities or regions. The closest proxy comes from the NZ census which includes a question about what methods people use for heating their houses:

> *"which types of heating are used most often in this dwelling"*

(Stats NZ (2018). 2018 Census: Design of forms. Retrieved from www.stats.govt.nz)

Participants can choose as many options as are appropriate to them including wood and coal burning. This data is not currently available for the 2018 census. Presented here are the results for the 2013 census, at the Census Area Unit (CAU) level. We have taken the total number of households that used wood-burning per CAU normalised by the area of that CAU. The spatial distribution of those answers can be seen in Figure 2-5, Figure 2-6 and Figure 2-7.

Both the Marsden Point (Ruakaka site) and Kerikeri airsheds have the lowest density of wood burner use among Northland's airsheds. Kaitāia and Dargaville show slightly greater wood burner density in their central townships. However, Whangārei clearly has the highest density and the highest variation of density of wood burner use among the airsheds. There are several suburbs which may have poorer air quality due to wood-burning, particularly Mairtown, Whau Valley, Kamo West, south-east of Tikipunga and east of Woodhill. This area also has the highest traffic counts from the NZTA counters.

The variation seen across Whangārei strongly suggests that while a single monitoring site might adequately capture the air quality of the smaller townships, a number of potential sites might represent Whangārei air quality equally well.

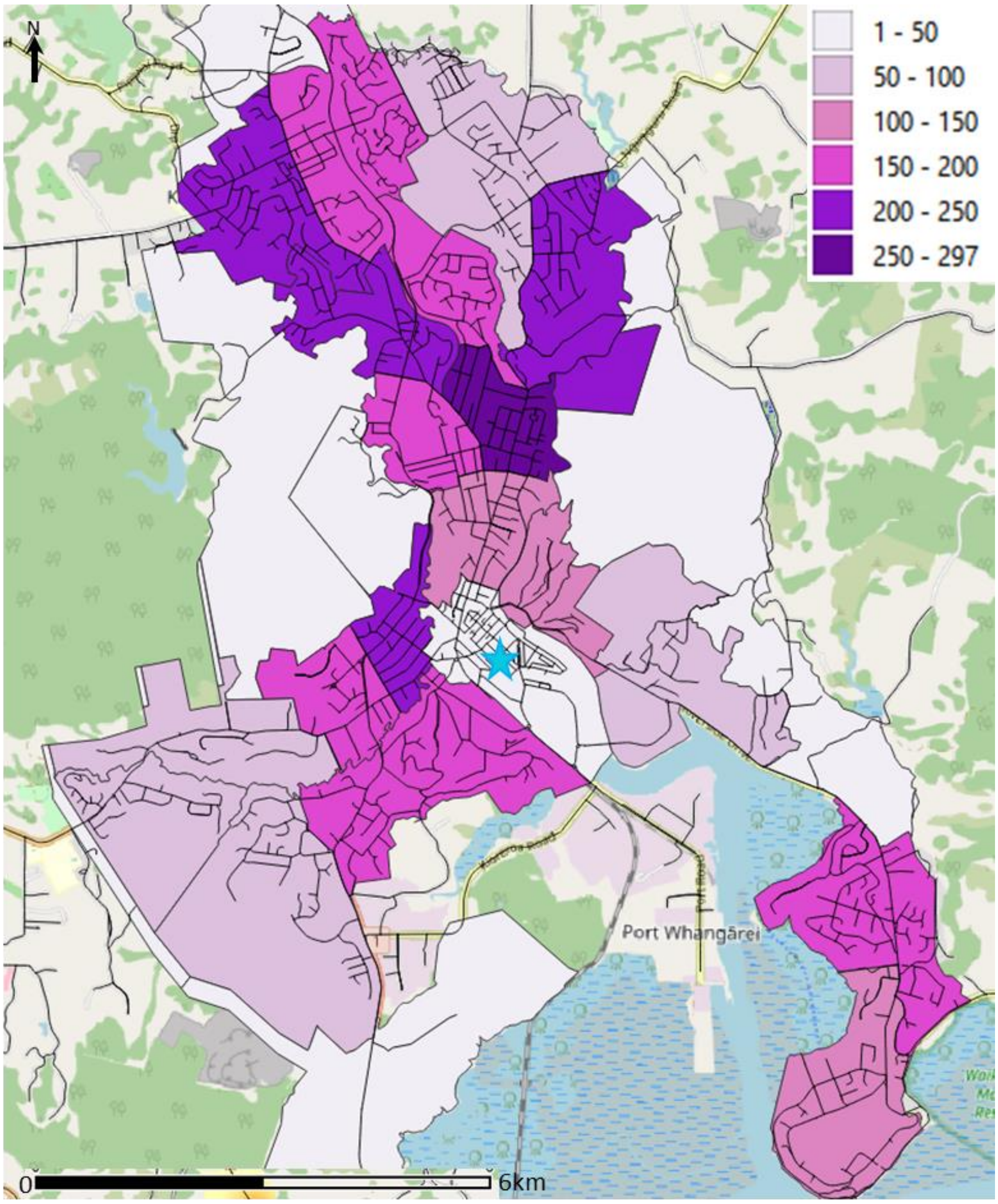

Figure 2-5: Households using wood-burning for home-heating in Whangārei. (households per square kilometre) (Blue star is the current monitoring site)

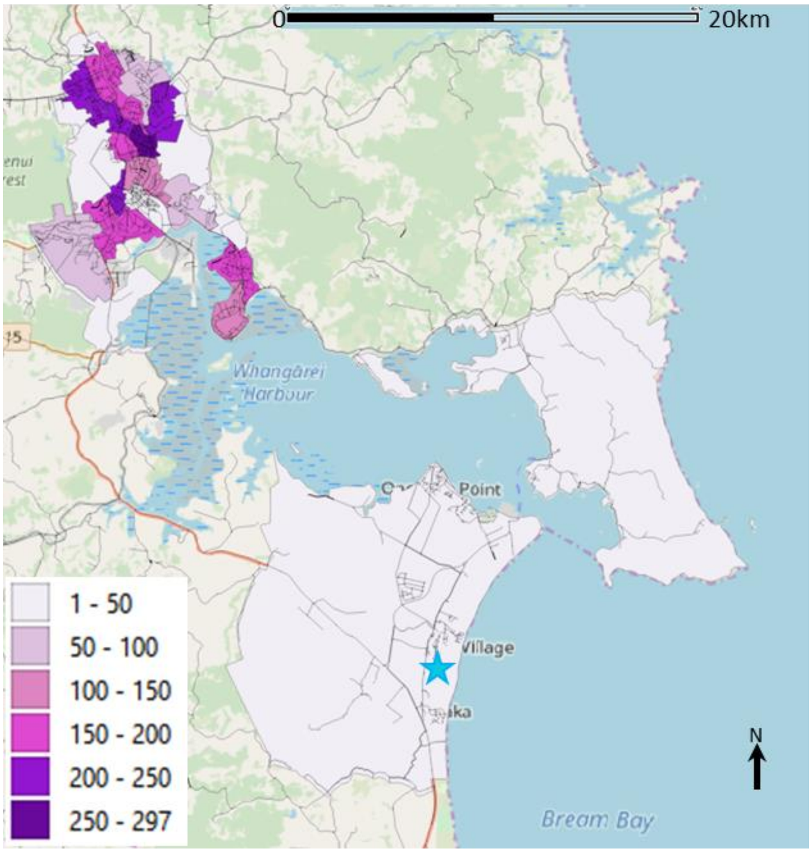

Figure 2-6: Households using wood-burning for home-heating in Whangārei and Marsden Point airsheds. (households per square kilometre) (Blue star is the current monitoring site)

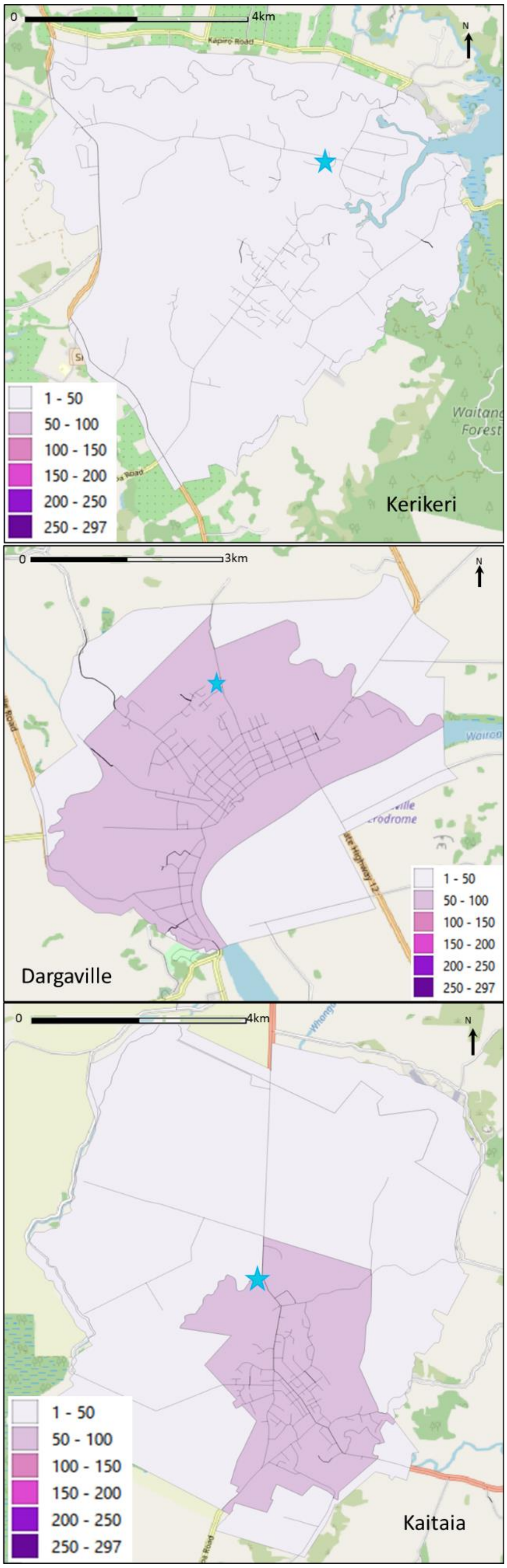

Figure 2-7: Households using wood-burning for home-heating in Kerikeri, Dargaville and Kaitāia. (households per square kilometre) (Blue star was the temporary monitoring site)

2.2.3 Additional sources

Marsden Point and shipping

Long-term data for shipping activity in and around Whangārei and Marsden Point is lacking, however it is important to mention this extra source of pollution, as it could impact ambient air quality and is expected to grow. Figure 2-8 gives an example of ships arriving into Marsden Point Port. Of particular importance are the number of tankers and cargo ships which are burning fuel oil, and the number of tug movements associated with those larger vessels. Tugs use diesel for fuel and so while they have significantly less impact than the larger vessels, because their activity is continuous, they collectively may also contribute to poorer air quality.

For comparison, the maximum number of ships arriving on any day in Marsden Point in Figure 2-8 is 20. The maximum for the same period at Tauranga Port was 26 and for Auckland was 193 (88 of which were passenger ferries).

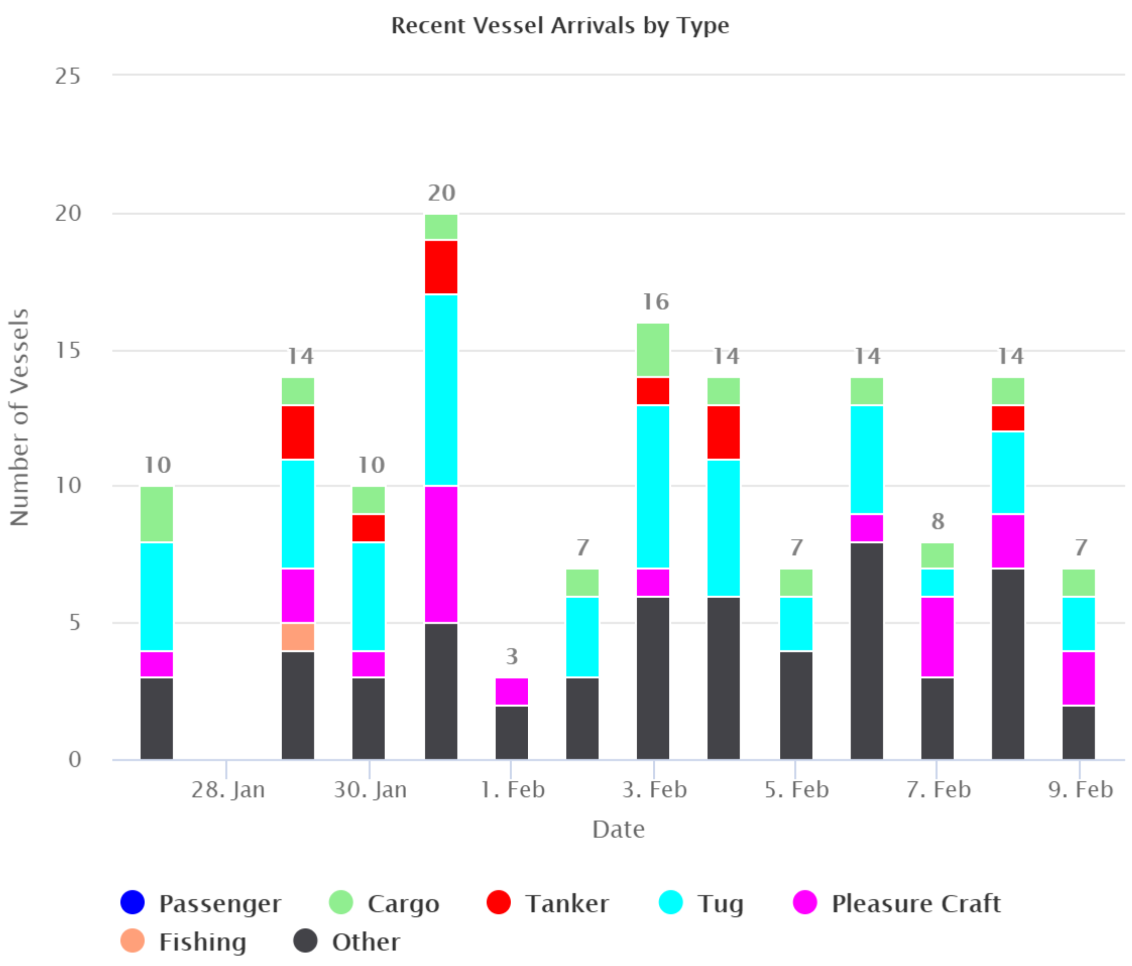

Figure 2-8: Example of ship movements into Marsden Point Port. from https://www.marinetraffic.com/en/ais/details/ports/2741/_:058752d7206e132258a558864b4f7c49

Major consented industries

Table 2-1 shows other major industries which may contribute to ambient $PM_{2.5}$ concentrations, along with any consent conditions limiting their emissions, and their locations. These sources are shown in the maps in Section 3.

Table 2-1: Major industrial sources in or around NRC airsheds.

Airshed	Industry	Easting (NZTM)	Northing (NZTM)	Description of Emission Activity	Description of Permitted Emission
Whangārei	Carter Holt Harvey Building Products	1720976	6043790	Three 9.5 MW wood boilers	Consent limit cumulative emission of PM10 from three boiler is 5.4 kg per hour
	Downer NZ limited	1721323	6043704	diesel fired hot-mix asphalt plant	Consent limit – TSP 250 mg/m^3
	Golden Bay Cement	1717558	6038961	outside airshed but discharge could contribute to airshed.	
	Other sources are several sand blasting and boat repair sheds				
Marsden Point	Carter Holt Harvey LVL	1733884	6031659		TSP consent limit from wood fired boiler stack 150 mg/m^3 and from baghouse 50 mg/m^3
	New Zealand Refining Company	1734839	6032508		
	Northport	1734351	6033188	Various shipping related activities	
	Other sources are sand blasting, cement batching plants				
Dargaville	Silver Fern Farms Limited	1680411	6023434	wood pallet boiler	TSP consent limit 250 mg/m^3
	Other sources are sand blaster, cement batching plant etc				
Kerikeri	Waipapa Pine Limited	1683195	6102670	wood fired 6 MW boiler	consent limit for TSP 330 mg/m^3
Kaitāia	Juken NZ Ltd, Northland Mill	1623794	6117165	wood fired boiler stacks	total TSP 2.8kg per hour. Individual stack limit 50 mg/m^3.
	Juken NZ Ltd, Triboard Mill	1623758	6116702		TSP from all stacks 7.8 kg per hour.

2.3 Concentration data

Two types of concentration data are presented here: modelled traffic-related air pollution and measured PM_{10} and $PM_{2.5}$ from NRC's regulatory monitoring sites.

2.3.1 Traffic Impact Model

Concentrations arising from traffic emissions have been estimated using NIWA's Traffic Impact Model (TIM), which is derived from concentration data from the NZTA's passive nitrogen dioxide (NO2) network (https://niwa.co.nz/atmosphere/research-projects/traffic-emissions-mapping-black-carbon-and-nitrogen-dioxide). The concentration data has been combined with CoreLogic's traffic model (https://www.nzta.govt.nz/about-us/open-data/national-road-centreline-data-request). to allow the relationships between traffic and air pollution to be extrapolated to all urban areas around the country.

The Traffic Impact Model is currently calibrated or scaled to NO_2 rather than $PM_{2.5}$, however, the spatial patterns will remain the same, regardless of what pollutant is expressed. So, the current model is useful in identifying potential hotspots of traffic related air pollution. Figure 2-9, Figure 2-10 and Figure 2-11 show the patterns of traffic related air pollution in the five Northland airsheds. The maximum concentrations are all moderate and below the WHO guideline value of 40 $\mu g.m^{-3}$ for annual NO_2 concentration. Therefore, the contribution of traffic to $PM_{2.5}$ concentrations is unlikely to be significant.

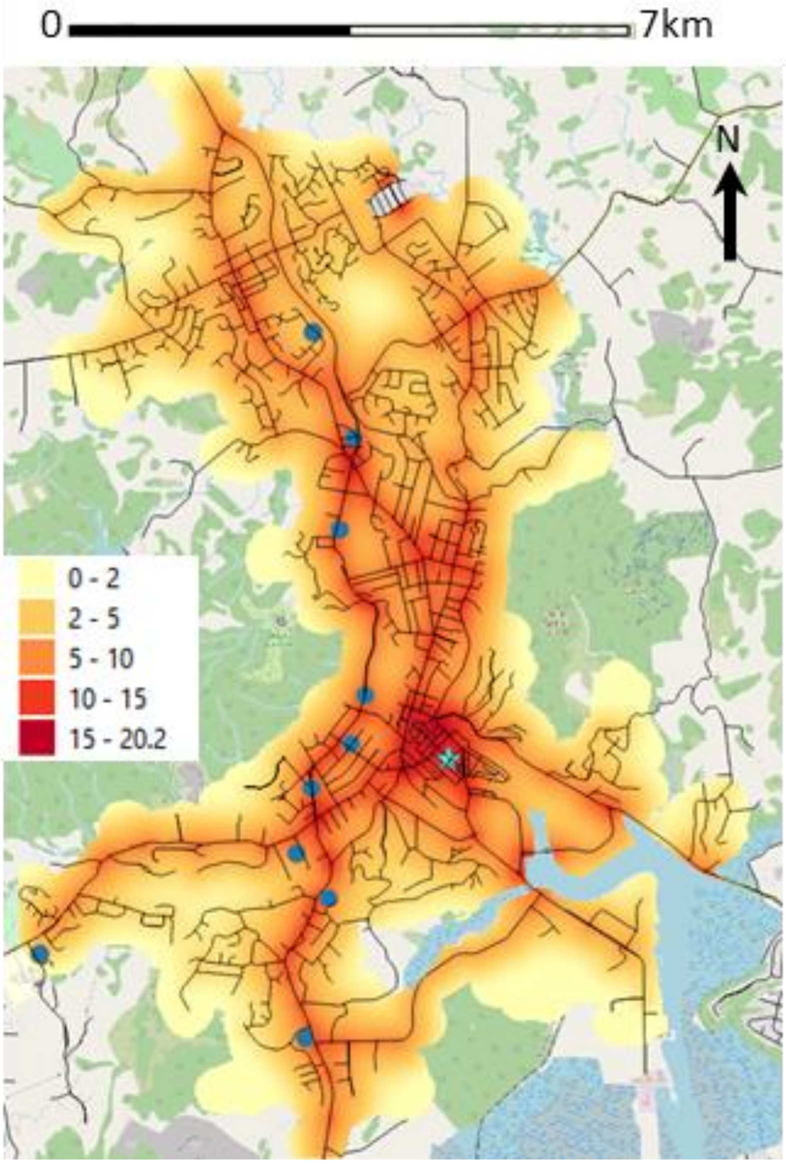

Figure 2-9: Distribution of traffic related air pollution in Whangārei. expressed as concentrations of NO_2 ($\mu g.m^{-3}$). NZTA traffic counters shown as blue dots. Robert St monitoring site as blue star.

Figure 2-9 shows that there are pollution hotspots away from the state highway, in the Whangārei city centre just northwest of the current monitoring site.

Figure 2-10 shows the predicted concentrations for the Ruakaka township, which does not include the larger area of the airshed, where the state highway runs. This is because the Traffic Impact Model has only been developed for urban areas; the assumptions providing the basis of the model (in terms of fleet makeup, emissions and dispersion characteristics) are only valid in urban areas, not industrial areas. It is a fair assumption, based on the NZTA traffic counts, that the highest concentrations of traffic related air pollution in the Marsden Point airshed will be at the intersection of SH1 and SH15, rather than in the Ruakaka township.

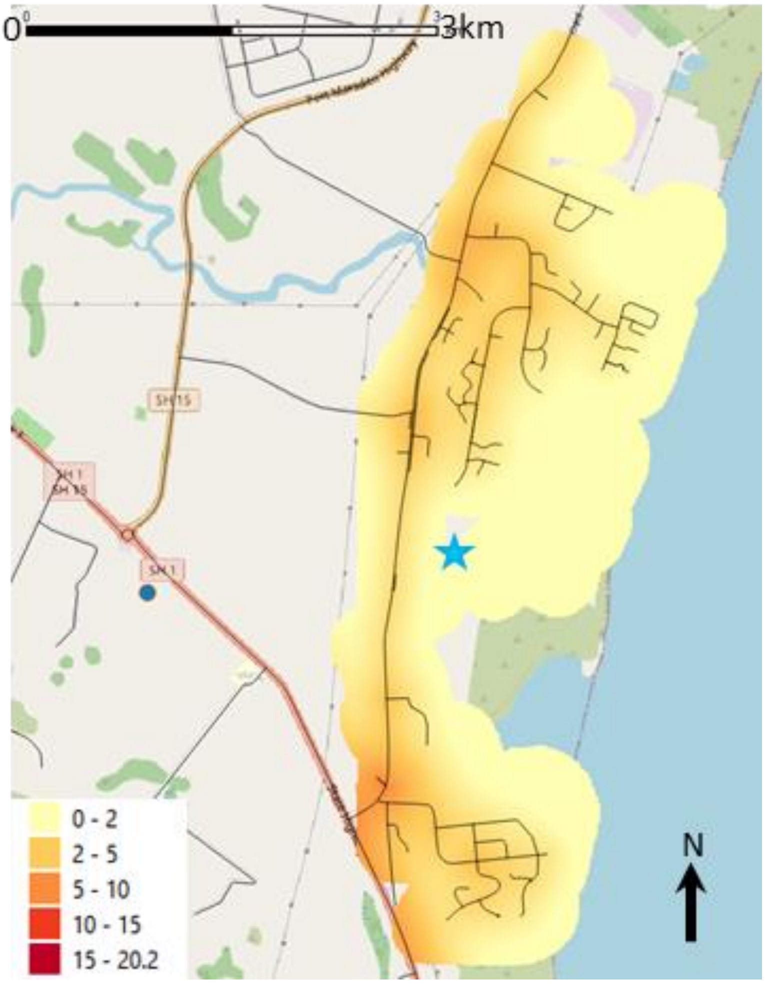

Figure 2-10: Distribution of traffic related air pollution in Marsden Point. expressed as concentrations of NO_2 ($\mu g.m^{-3}$). NZTA traffic counter shown as blue dot.

Figure 2-11 shows the spatial distribution over the three smaller airsheds. The model indicates that the main intersection in Kerikeri has potentially high concentrations of traffic related air pollution. Dargaville has an unusual hotspot in the south of the township which may be an artefact carried through from the traffic model into the TIM. This irregularity should be ignored (pers. Comm., Ian Longley, NIWA). Both Dargaville and Kaitāia have elevated concentrations along the main road, but no substantial hotspots.

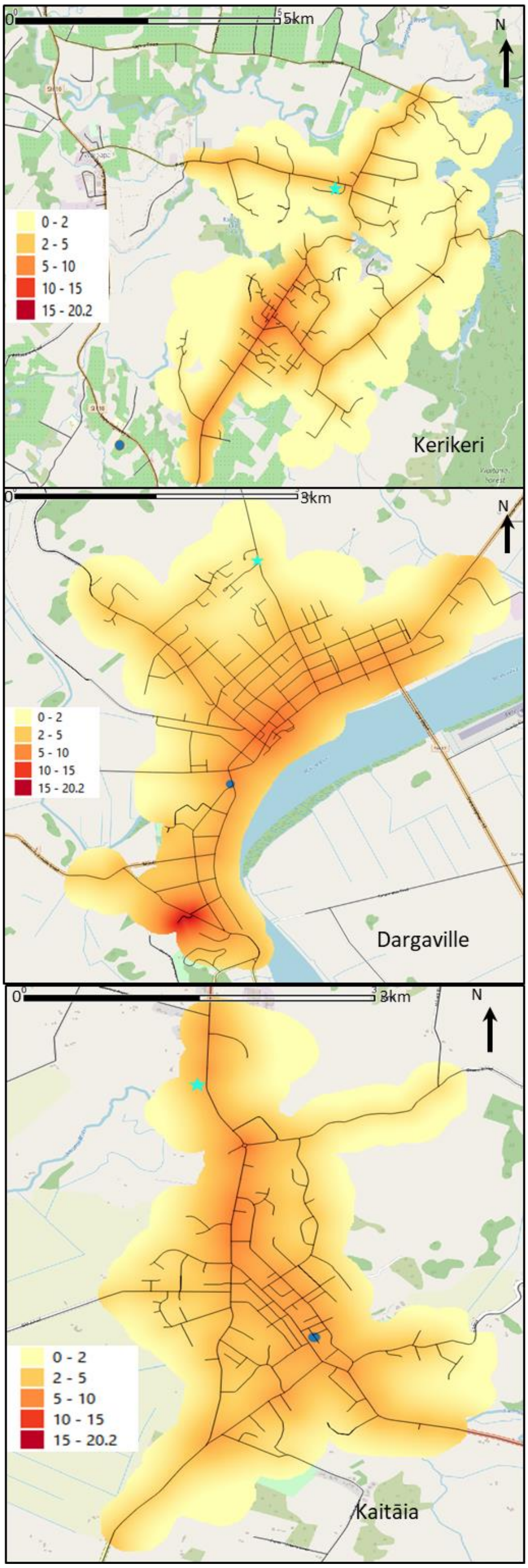

Figure 2-11: **Distribution of traffic related air pollution in Kerikeri, Dargaville and Kaitāia.** expressed as concentrations of NO_2 ($\mu g.m^{-3}$). NZTA traffic counters shown as blue dots. NRC monitoring sites as blue stars.

2.3.2 Measurement data from NRC - PM_{10}

Northland Regional Council have two long-term measurement sites: one in the city centre of Whangārei and one in Ruakaka in the Marsden Point airshed. In addition, temporary measurement sites have been set up in Kaitāia, Kaikohe, Dargaville and Kerikeri for one year at a time.

Figure 2-12 shows the daily average concentrations of PM_{10} at Robert St in Whangārei city centre and Ruakaka. Figure 2-13 shows the daily average concentrations of PM_{10} at the four temporary sites. The NES concentration limit of 50 µg.m^{-3} is highlighted as a red line. The period of monitoring is also noted. At no location has the NES been breached during monitoring except one day at Kerikeri (5th October 2016) which reached 95.5 µg.m^{-3}. This is off the scale of Figure 2-13. The 10-minute data for that day shows a large pollution event in the evening, probably a fire near the monitoring site, although no record of such an event could be found.

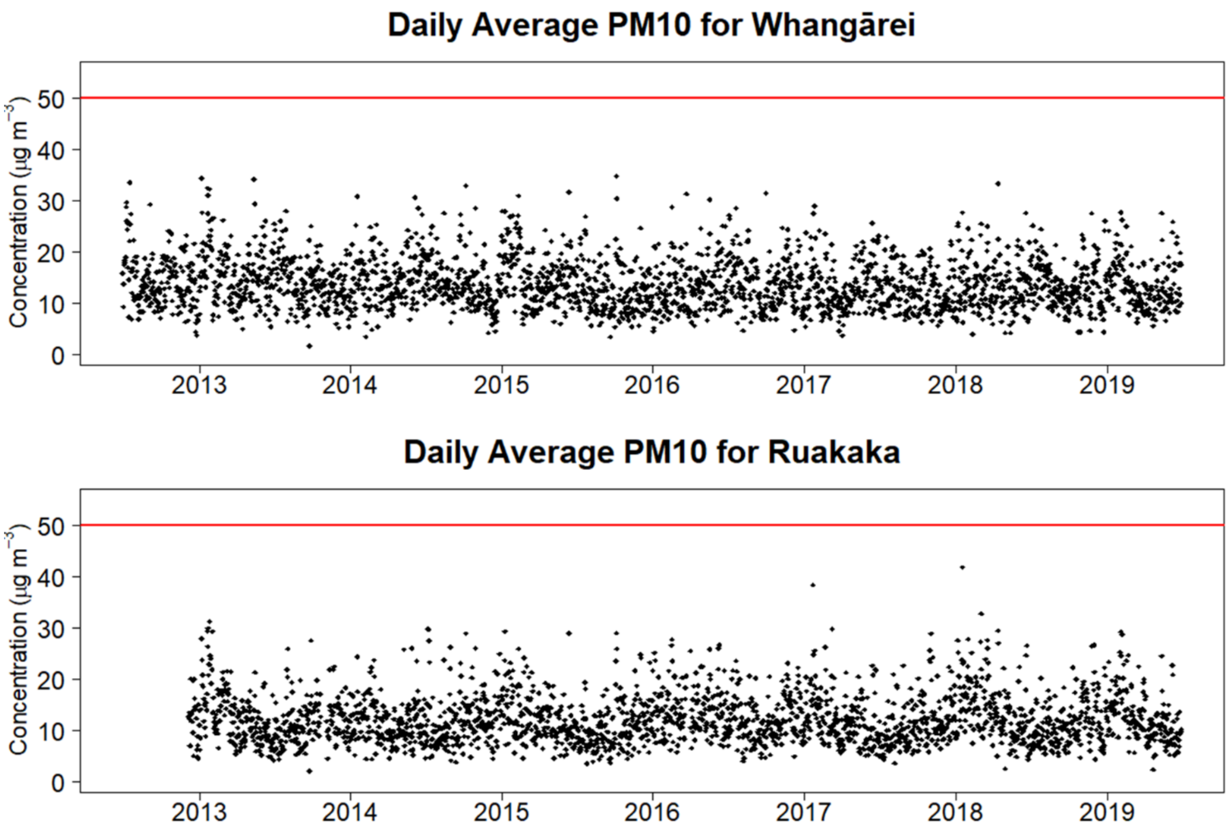

Figure 2-12: Long term record of Daily Average PM_{10} (µg.m^{-3}) at Whangārei - Robert St and Ruakaka. NES daily average concentration limit of 50 µg m^{-3}shown by red line.

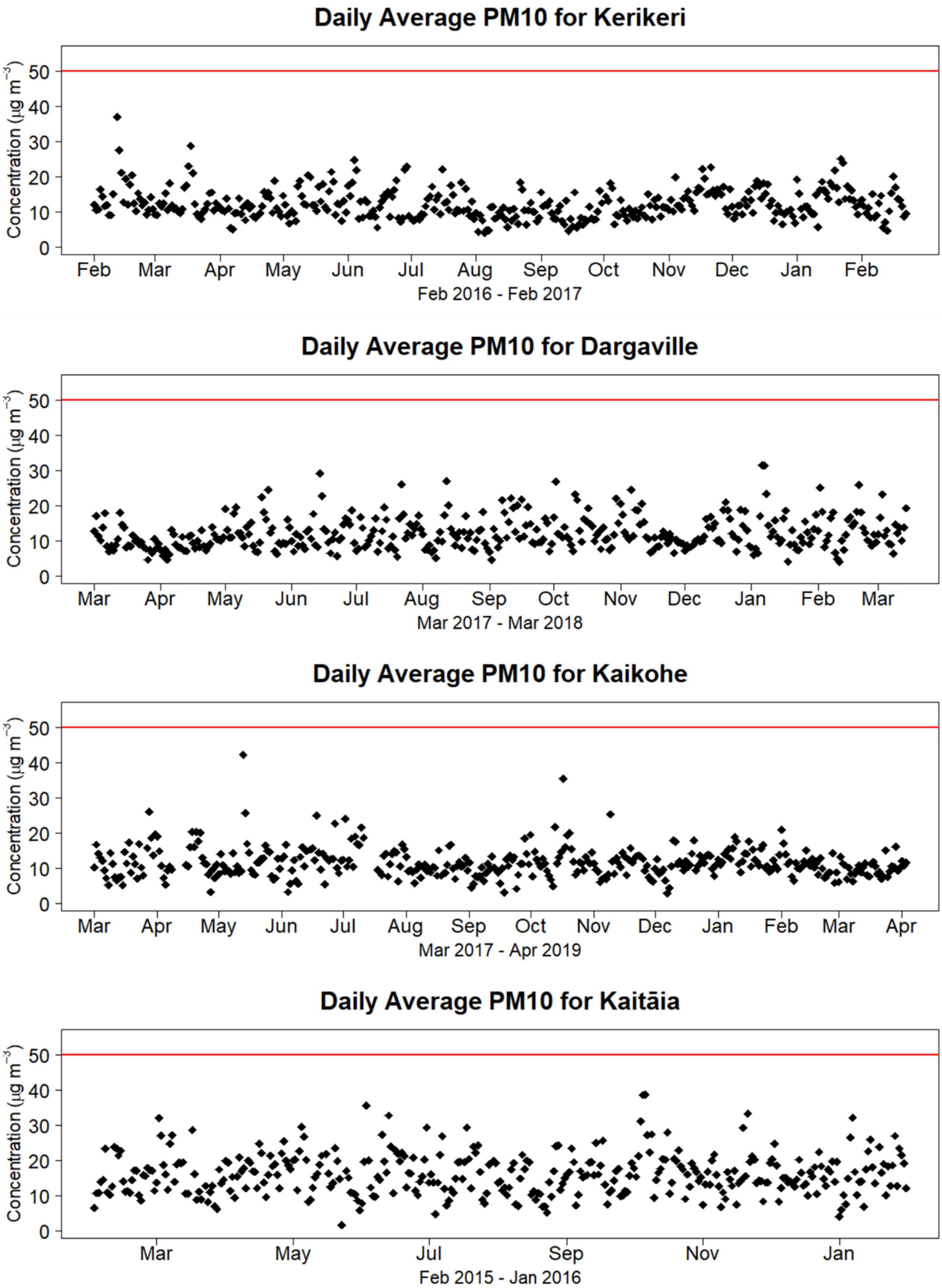

Figure 2-13: Daily average PM_{10} ($\mu g.m^{-3}$) at temporary monitoring sites. NES daily average concentration limit of 50 µg m^{-3}shown by red line.

Although not directly comparable as the measurements were taken at different times, Figure 2-14 shows the daily average concentrations across the five airsheds and Kaikohe, in order to give a general impression of the range of concentrations measured. Kaitāia stands out as having had elevated concentrations compared to the other time series. There is no obvious reason for this, and it does not necessarily mean that $PM_{2.5}$ concentrations would also be above the regional norm. The reason may be a source of coarser particles recorded only in the PM_{10} band of particle size.

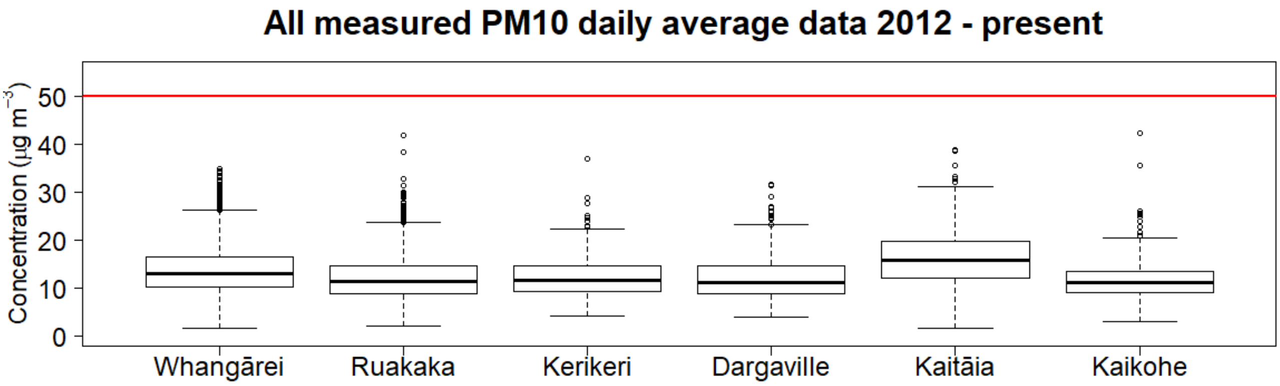

Figure 2-14: Boxplot of measured PM_{10} across Northland since 2012.

Of the two ubiquitous $PM_{2.5}$ emission sources, domestic heating follows a seasonal cycle that can be difficult to pick out of a daily time-series. For this reason, Figure 2-15 shows the monthly average concentrations for the two long-term time series. There is no discernible wintertime elevation. Often there are summertime elevations, which could be due to more sea salt or natural dust in the atmosphere. Similarly, for the temporary sites, no seasonal differences are noticeable.

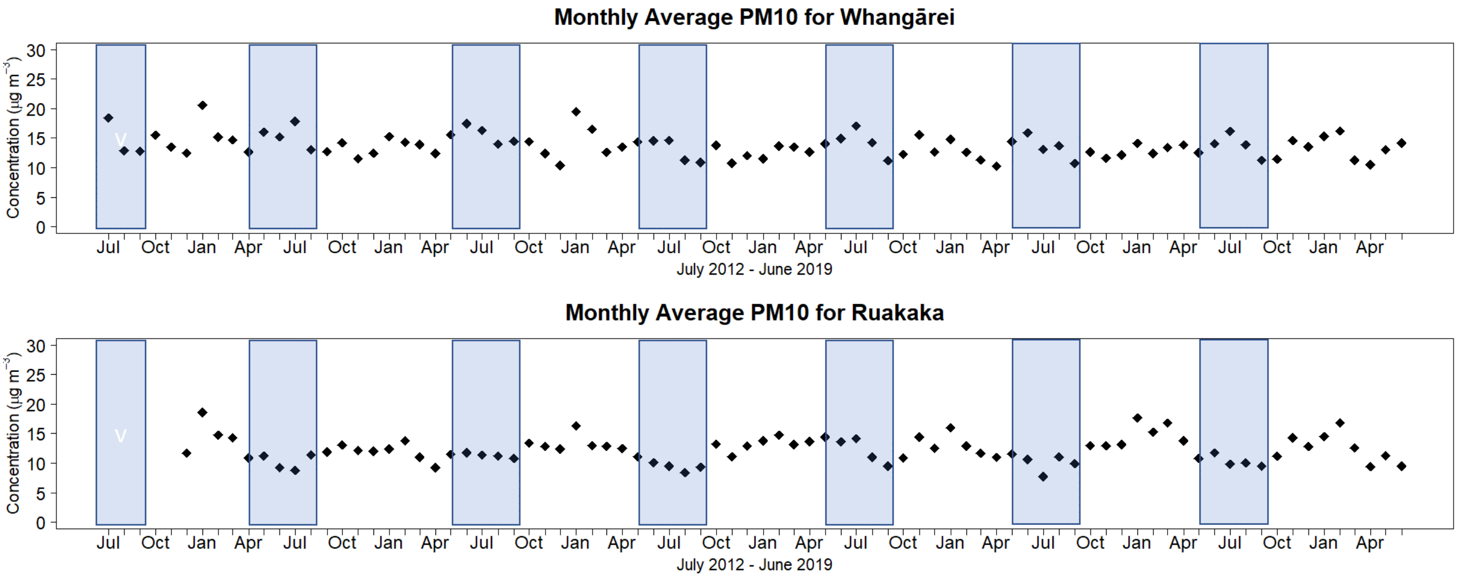

Figure 2-15: Monthly average PM_{10} ($\mu g.m^{-3}$) at Whangārei and Ruakaka. Winter months shaded in blue.

2.3.3 Measurement data from NRC - $PM_{2.5}$

Northland Regional Council began measuring $PM_{2.5}$ at their Whangārei site in July 2016. Figure 2-16 shows the daily average concentrations for $PM_{2.5}$ up until mid-2019. Although no NES concentration limit exists yet for $PM_{2.5}$, the World Health Organisation (WHO) has a guideline limit of 25 $\mu g.m^{-3}$ as a daily average. This is shown in the figure as a red line. There is a clear seasonal pattern, with elevated concentrations during the winter months, at times approaching the guideline limit. This is evidence for some domestic wood-burning activity occurring in the vicinity of the measurement site.

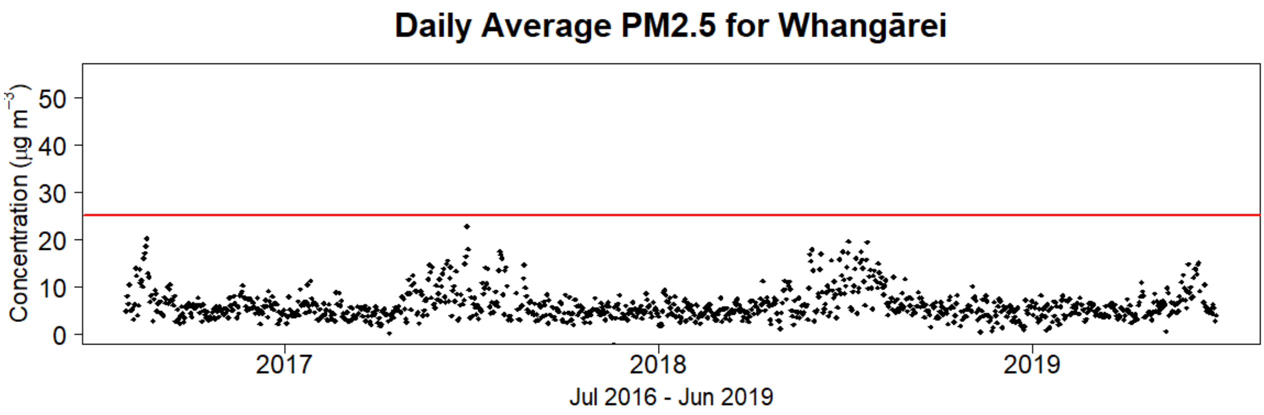

Figure 2-16: Daily average $PM_{2.5}$ ($\mu g.m^{-3}$) for Whangārei. Red line is the WHO guideline value.

2.4 Climatology

The impact of air pollution can be modified by the meteorological conditions into which pollutants are emitted. In this section, we present the seasonal cycles of three long-term variables which can impact air pollutant concentrations. For each variable, at least 10 years of data are used. In order to maximise the availability of such long-term measures, and to provide some indication of variation within an area, we present data from all available sites rather than choosing one site per airshed.

The locations of all the meteorological sites used can be found in Appendix B. The absolute value of these variables is less important than how the airsheds compare with one another, particularly during the winter months when $PM_{2.5}$ emissions are highest due to wood-burning.

2.4.1 Rainfall

Rain washes pollutant out of the atmosphere, so rainfall suppresses concentrations. Figure 2-17 shows the average amount of rain that can be expected in any given month. The airsheds experience within 50 mm of same rainfall as one another, with Dargaville the driest area for most of the year and Kerikeri the wettest.

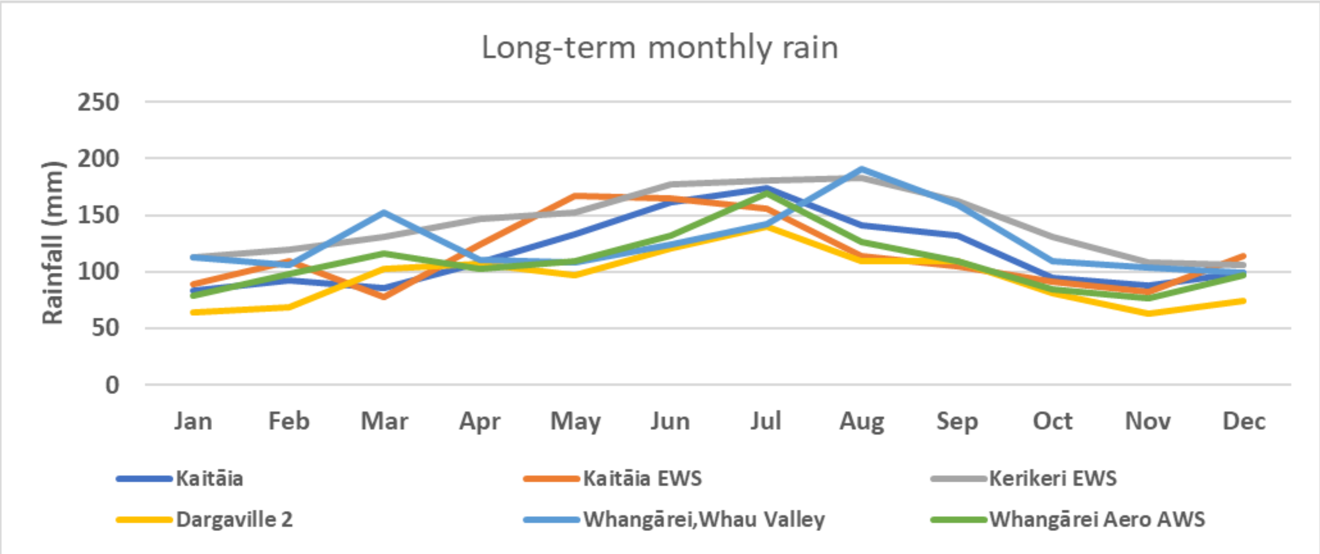

Figure 2-17: Long-term monthly rainfall measured at relevant meteorological sites.

2.4.2 Mean Windspeed

Windspeed determines how quickly air pollution disperses. Pollutants will accumulate when the windspeed drops off, which is most common overnight. Figure 2-18 shows that there are measurable differences between the airsheds. Kaitāia and Dargaville are windier than Whangārei and Kerikeri. Kerikeri is relatively sheltered compared to the other airsheds.

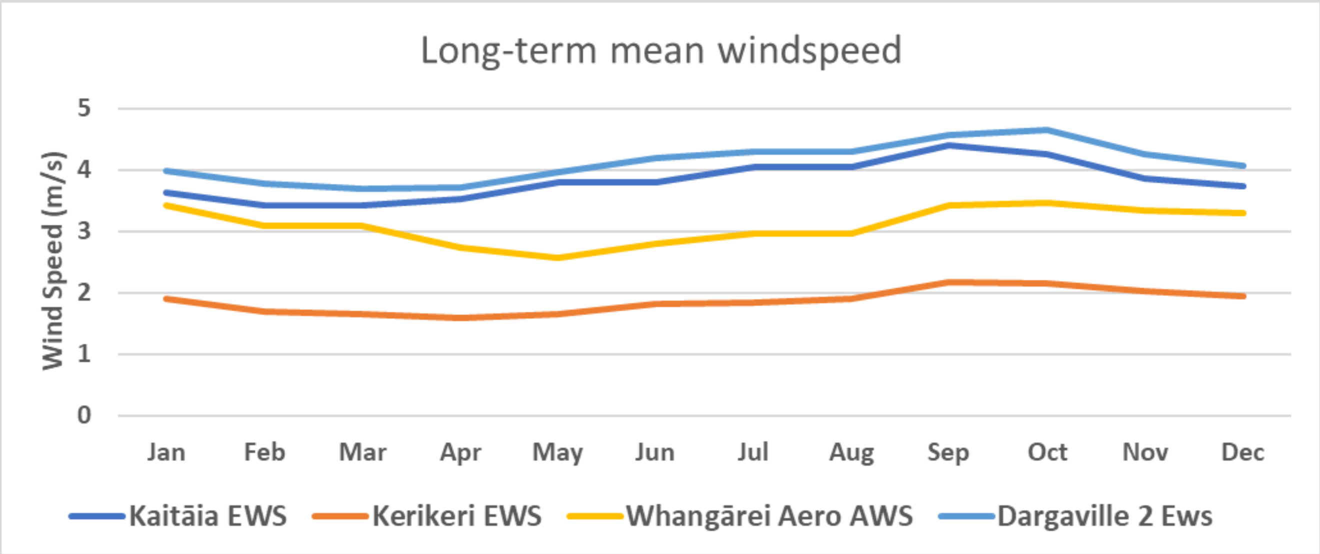

Figure 2-18: Long-term monthly mean windspeed measured at relevant meteorological sites.

2.4.3 Minimum Temperature

Low temperatures can prompt wood-burning emissions to increase as there is a greater need for domestic heating. Figure 2-19 shows there is very little difference in average monthly temperatures between the airsheds, as should be expected for areas that are relatively close to one another.

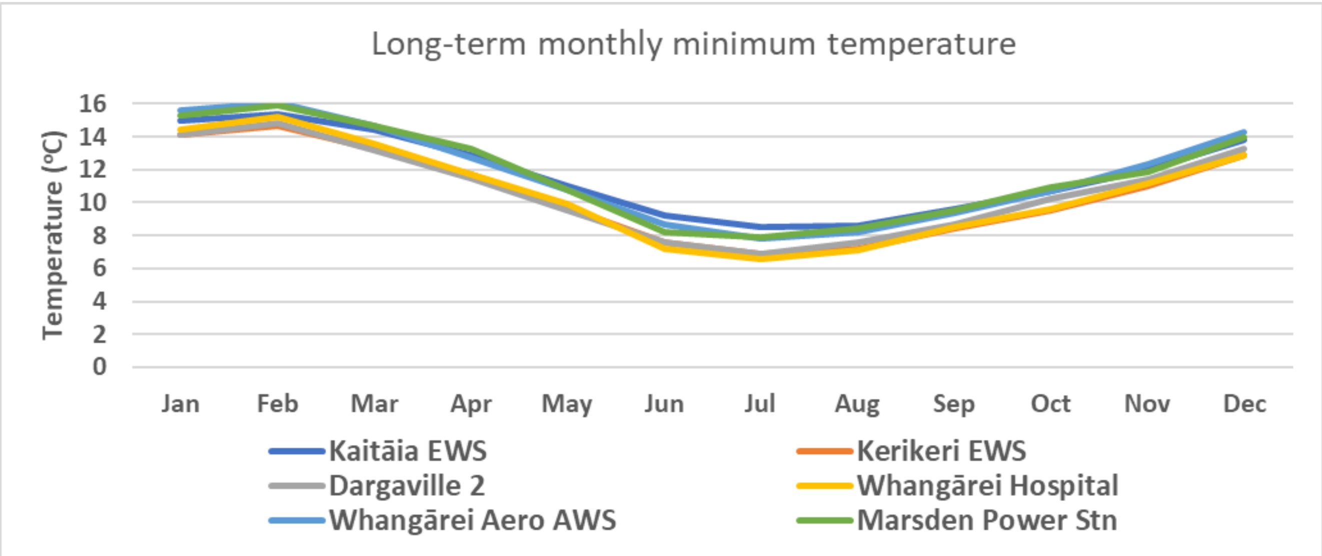

Figure 2-19: Long-term monthly minimum temperature measured at relevant meteorological sites.

3 Airsheds

In this section, the figures show the various types of information from Section 2 together, in order to more easily compare the spatial patterns of the data. From this we determine what level of $PM_{2.5}$ concentrations might be expected across each airshed and where might be expected to experience the greatest concentrations.

3.1 Whangārei

Whangārei is the airshed with the highest population. As such, air pollution here has greater health impacts than in other airsheds. In this sense, situating the monitoring site in a location that captures the exposure of the population is more important than in areas where the monitoring site represents a smaller population. Figure 3-1 brings together the maps of sources and predicted concentrations for Whangārei from previous sections.

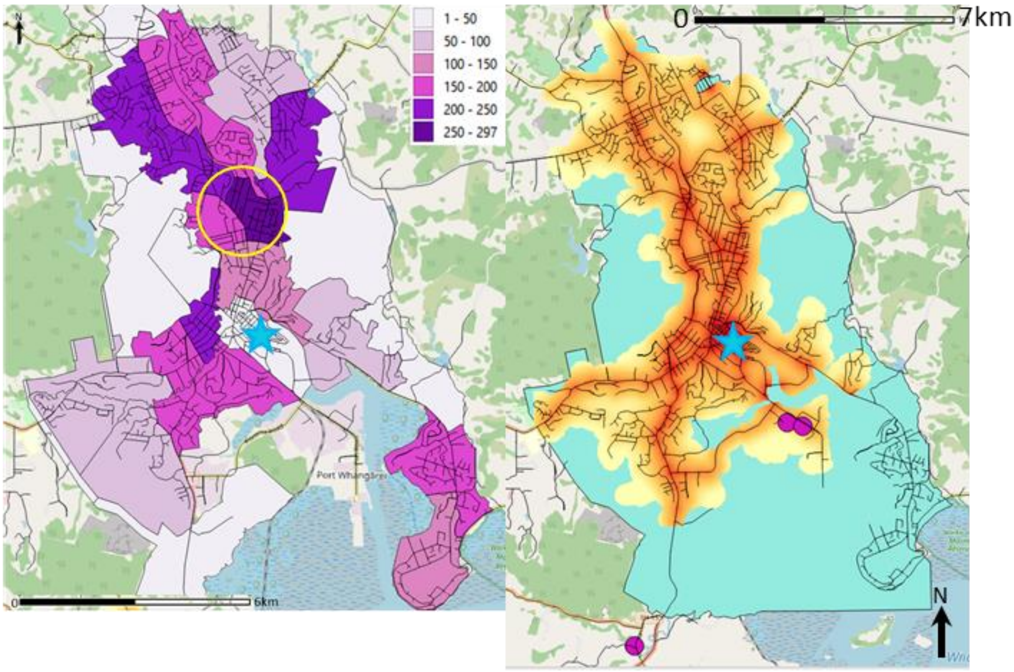

Figure 3-1: All relevant emissions and concentration information for the Whangārei airshed. (Wood-burner density on the left with the recommended monitoring area circled in yellow, and predicted traffic related air pollution on the right, with pink dots locating consented emissions)

Average windspeeds (Figure 2-18) suggest there may be Issues with air pollution accumulating rather than dispersing efficiently on still nights. This will be exacerbated by the terrain, as the main part of the city runs along a valley. During calm periods the airflow will follow the terrain, sinking towards the valley floor. In the $PM_{2.5}$ record (Figure 2-16), elevated concentrations can be seen during the winter period. The current monitoring site is located in an area expected to have some of the highest concentrations of traffic related air pollution (Figure 2-9). However, the primary source of $PM_{2.5}$ in urban areas is woodsmoke and the monitor currently sits in an area with relatively low wood-burner density (Figure 2-5 and Figure 3-1 below – first panel). Many areas have higher wood-burner density, suggesting multiple areas that could provide an alternative monitoring site. As the NES specifies that monitoring sites should be positioned where the worst air quality can be expected, the first option would be to move further north into the Whau Valley-Mairtown area, where wood-burner density is highest. The site would ideally still be close to the major roads to pick up the impact of traffic running along SH1 as well as the larger woodsmoke source. The suggested area is circled in Figure3-1, left panel.

3.2 Marsden Point

Marsden Point is a largely industrial area with a small residential population in the coastal town of Ruakaka. Figure 3-2 brings together the maps of sources and predicted concentrations for Marsden Point - Ruakaka from previous sections. Wood-burner density is minimal in Ruakaka, as is the impact of traffic related air pollution, as predicted by the Traffic Impact Model. The area is flat and coastal and so has very favourable dispersion.

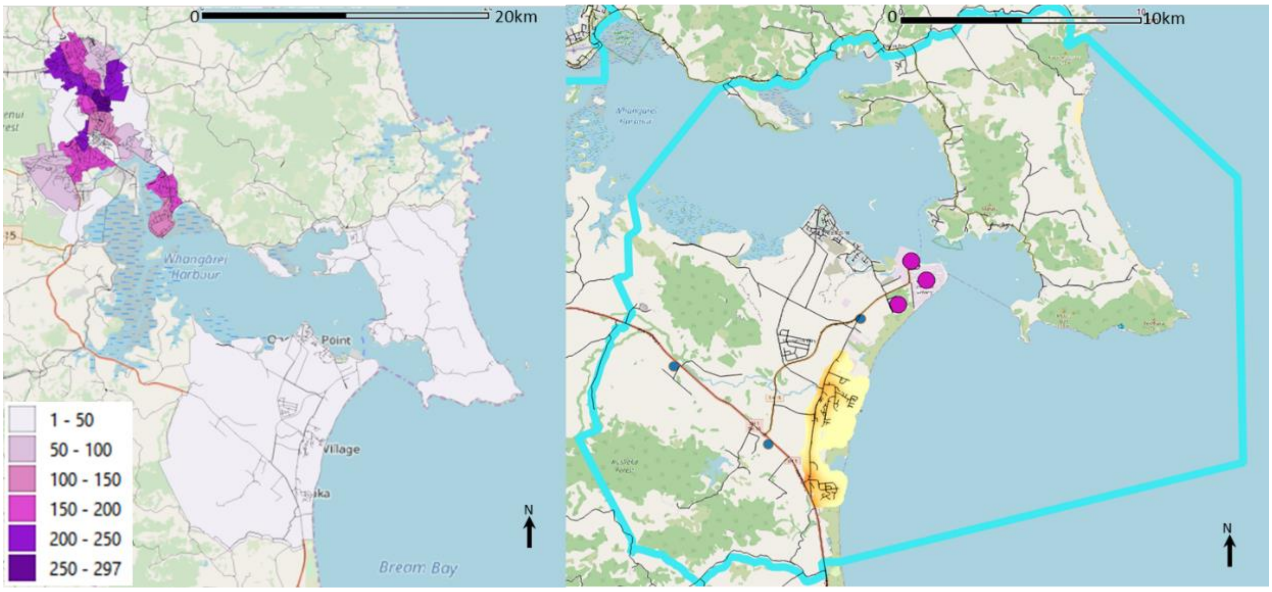

Figure 3-2: All relevant emissions and concentration information for the Marsden Point airshed. (Wood-burner density on the left, and predicted traffic related air pollution on the right, with pink dots locating consented emissions)

There are three consented industrial sources (see Figure 3-2, second panel – purple dots) but these are emitting at elevation rather than ground level, and so should not be impacting ground level concentrations significantly. Figure 2-12 and Figure 2-15 show that PM_{10} concentrations measured at Ruakaka are not cause for concern and peak over the summer, most likely due to higher amounts of sea spray. Th amount of sea spray being measured in the coarse fraction of PM_{10} may be masking a wintertime elevation of $PM_{2.5}$.

Because much of the Marsden Point airshed is industrial rather than residential, this is the airshed with the highest uncertainties about overall air quality. There is a high percentage of Heavy Duty Vehicles moving in and out of the area along SH15, and it is unclear what ground level emissions are being generated by the area's everyday industrial activities. It may be worth conducting a screening assessment in the areas outside of the Ruakaka township to understand this better, either with low cost particle sensors, or using passive diffusion tubes for gas pollutants. However, in terms of the concentrations experienced by the residential population of the airshed, $PM_{2.5}$ should have little impact.

3.3 Kerikeri

Figure 3-3 brings together the maps of sources and predicted concentrations for Kerikeri from previous sections. The town of Kerikeri is relatively flat, with low wood-burner density. There is some impact of traffic along the main road, which is slightly higher in expected concentrations than where the temporary monitoring site was situated (blue star in figures). Kerikeri had the lowest average windspeeds of all the airsheds (see Figure 2-18), indicating that dispersion here will be the least efficient. However, there is no indication that concentrations of $PM_{2.5}$ will be problematic.

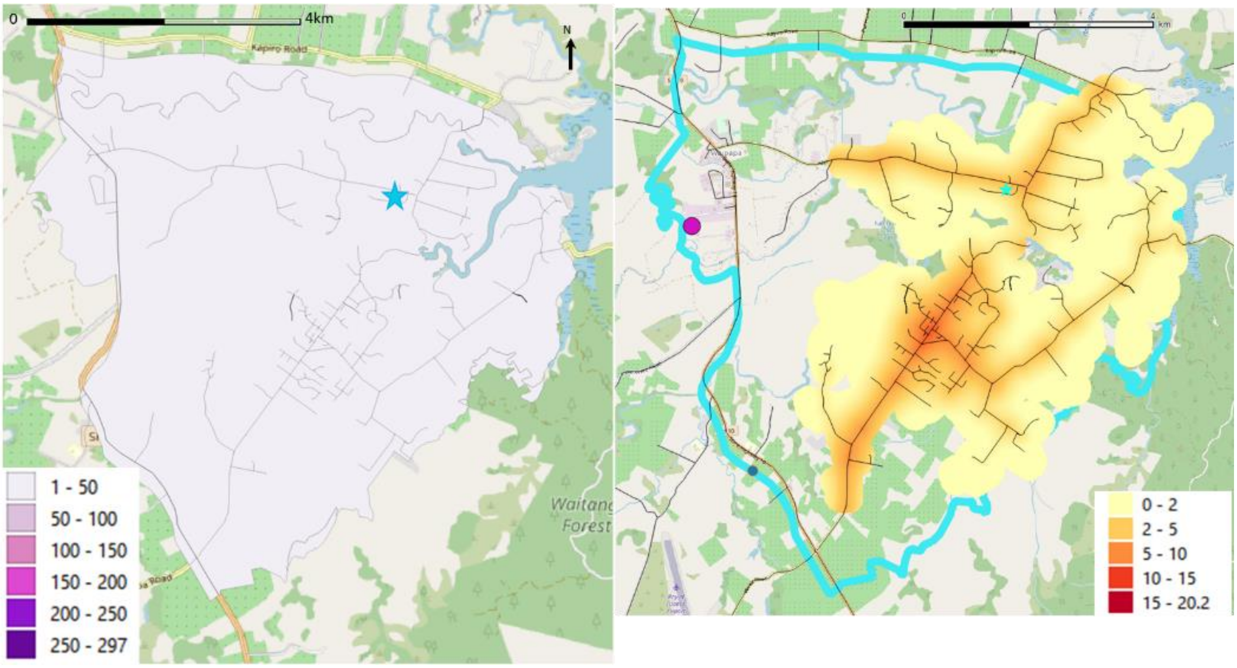

Figure 3-3: All relevant emissions and concentration information for the Kerikeri airshed. (Wood-burner density on the left, and predicted traffic related air pollution on the right, with pink dots locating consented emissions)

3.4 Dargaville

Figure 3-4 brings together the maps of sources and predicted concentrations for Dargaville from previous sections. Dargaville sits by a river in flat terrain and has slightly denser wood-burner emissions than Kerikeri or Ruakaka. There is some impact of traffic along the main road (not counting the hotspot in the southern part of the town – we are confident it is an artefact generated by the modelled traffic data). Dargaville has the highest average windspeeds of the airsheds, so dispersion should reduce any significant accumulation of pollution over winter. The previous location of the monitoring site was along a minor road set back from the river. Situating the monitor along the main road, near the river which should experience drainage flows during calm nights in winter, should provide the best chance of capturing peak $PM_{2.5}$ concentrations in Dargaville.

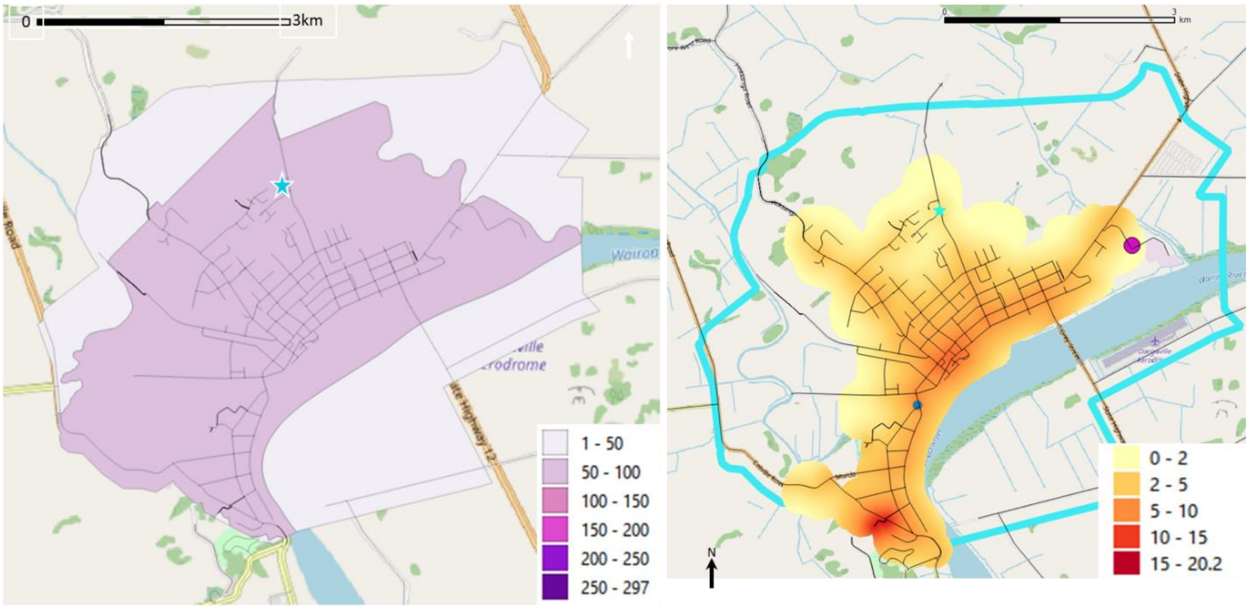

Figure 3-4: All relevant emissions and concentration information for the Dargaville airshed. (Wood-burner density on the left, and predicted traffic related air pollution on the right, with pink dots locating consented emissions)

3.5 Kaitāia

Figure 3-5 brings together the maps of sources and predicted concentrations for Kaitāia from previous sections. Kaitāia has slightly higher wood-burner density than Ruakaka or Kerikeri in the town and is also relatively flat. There are two consented activities to the north of the town, in the centre of the airshed and the previous monitoring site was near these along the main road. However, this is just on the edge of the highest wood burner density in Kaitāia and it may be advisable to move the site further south into the town proper, so it is surrounded by woodsmoke in the winter. Figure 2-14 showed that Kaitāia's PM_{10} concentrations were elevated compared to the other smaller airsheds. This may have been the impact of meteorology that year, or it may indicate a local source of PM_{10}.

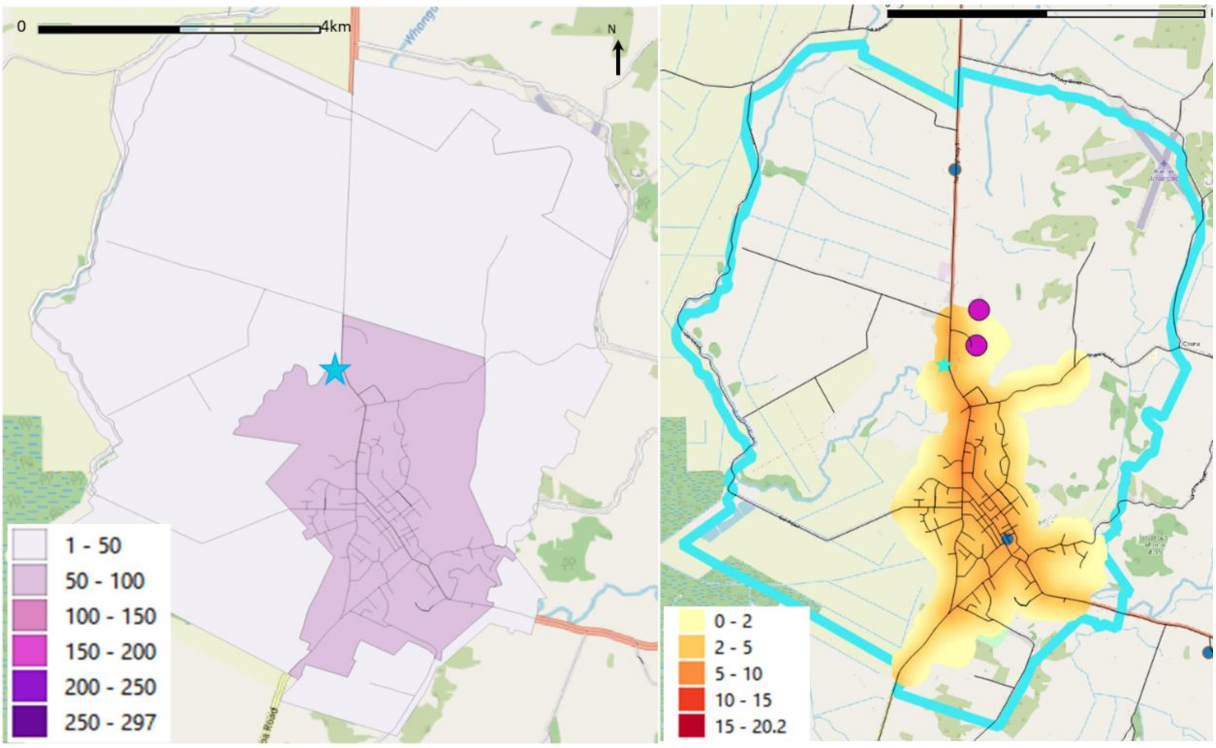

Figure 3-5: All relevant emissions and concentration information for the Kaitāia airshed. (Wood-burner density on the left, and predicted traffic related air pollution on the right, with pink dots locating consented emissions)

4 Conclusion and Recommendations

For the most part the concentration data and the estimates of relative emissions suggest that concentrations of $PM_{2.5}$ will be relatively low in the Northland airsheds and that little potential exists for breaching a new NES concentration limit for $PM_{2.5}$. The exception to this is Whangārei City, where there is evidence of consistently elevated concentrations of $PM_{2.5}$ during wintertime. The current measurement site is in an area of potentially the lowest density emission source for woodsmoke, although it is close to some of the highest impacts of traffic related air pollution. Testing a different site further north in the suburb of Mairtown or Whau Valley, where the highest potential impact of both traffic and woodsmoke coincide, is advisable.

This is the highest priority for new monitoring, in order to understand how poor air quality can be over winter in Whangārei, particularly as it has the highest population density in Northland and so the most people are exposed to these elevated concentrations.

For the remaining airsheds, we suggest considering Kaitāia, Dargaville and Kerikeri in the following order:

Firstly, Kaitāia, as it had elevated an PM_{10} concentration distribution compared to the other airsheds. It would be good to confirm that 2015-16 was either an anomalous year, or to identify a local source of coarser particles. Secondly, Dargaville also has slightly higher wood-burner density with no obvious anomalies or outstanding questions. We recommend considering moving the monitoring closer to the river to capture the most polluted conditions.

Then Kerikeri. Although Kerikeri has slightly greater pollution from traffic it has the lowest wood burner density, which is likely to be the most significant factor in determining $PM_{2.5}$ concentrations.

Finally, an exploratory monitoring campaign around the Marsden Point airshed is advisable. Although the woodsmoke emission source is minimal and the Ruakaka township itself may have the best $PM_{2.5}$ concentrations of all the airsheds due to this and its coastal situation, there are high numbers of HDV vehicles in the area, unknown industrial sources and shipping sources, which will have a much greater impact on the $PM_{2.5}$ record than on the PM_{10} concentration record. This may be currently swamped with sea salt and other coarser natural particles in the PM_{10} record. In addition, the Marsden Point airshed is geographically larger and so there may be more potential hotspots.

In terms of representative monitoring for population health assessments, almost any practical site away from the main road will be suitable for the smaller four airsheds, as their emissions vary very little spatially. The challenge arises in Whangārei where there is potentially a great deal of spatial variation. It is possible that the current site will prove just as adequate for health monitoring, as a site in a medium density wood burner area away from the state highway, such as Raumanga or Kamo East. Only a screening campaign involving mobile monitoring or a network of low-cost sensors would be able to determine which was closer to the average concentration across the airshed.

5 Acknowledgements

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Thanks to Obi Khanal for all his advice and support.

Appendix A NZTA traffic counters in the Northland airsheds

Table A-1: NZTA traffic counters located in NRC airsheds.

Airshed	Counter Number	NZMG East	NZMG North	AADT 2014	AADT 2015	AADT 2016	AADT 2017	AADT 2018	% HDV
Kerikeri	01000015	2628962	6606655	5694	6119	6691	7275	7201	4.5
Dargaville	01200151	2629607	6610833	5542	5615	5725	5869	6094	6.8
Kaitaia	01N00112	2629126	6607312	5006	4985	4372	4377	4467	5.0
Whangarei	01400000	2629683	6608229	19229	20180	20862	21242	21689	5.7
Whangarei	01N00261	2629283	6606203	14698	15680	16151	17283	17944	4.9
Whangarei	01N00262	2629017	6604791	18818	20876	20994	20908	21987	6.1
Whangarei (close to Robert St)	01N10265	2636981	6591601	12261	13131	13176	13583	14231	11.7
Whangarei (close to Robert St)	01N00264	2640001	6588917	23282	26019	25449	25911	27378	13.4
Whangarei	01N00267	2643317	6593144	23925	25322	26547	27732	27652	19.2
Whangarei	01N00268	2594816	6661592	16905	18013	19103	20206	20375	5.9
Marsden Point	01N00287	2588781	6583883	11818	12898	13936	14547	14968	6.5
Marsden Point	01N80291	2534362	6681265	15564	16603	17791	18796	19468	5.9
Marsden Point	15A00006	2535015	6676513	3746	3705	3855	4249	4500	4.6

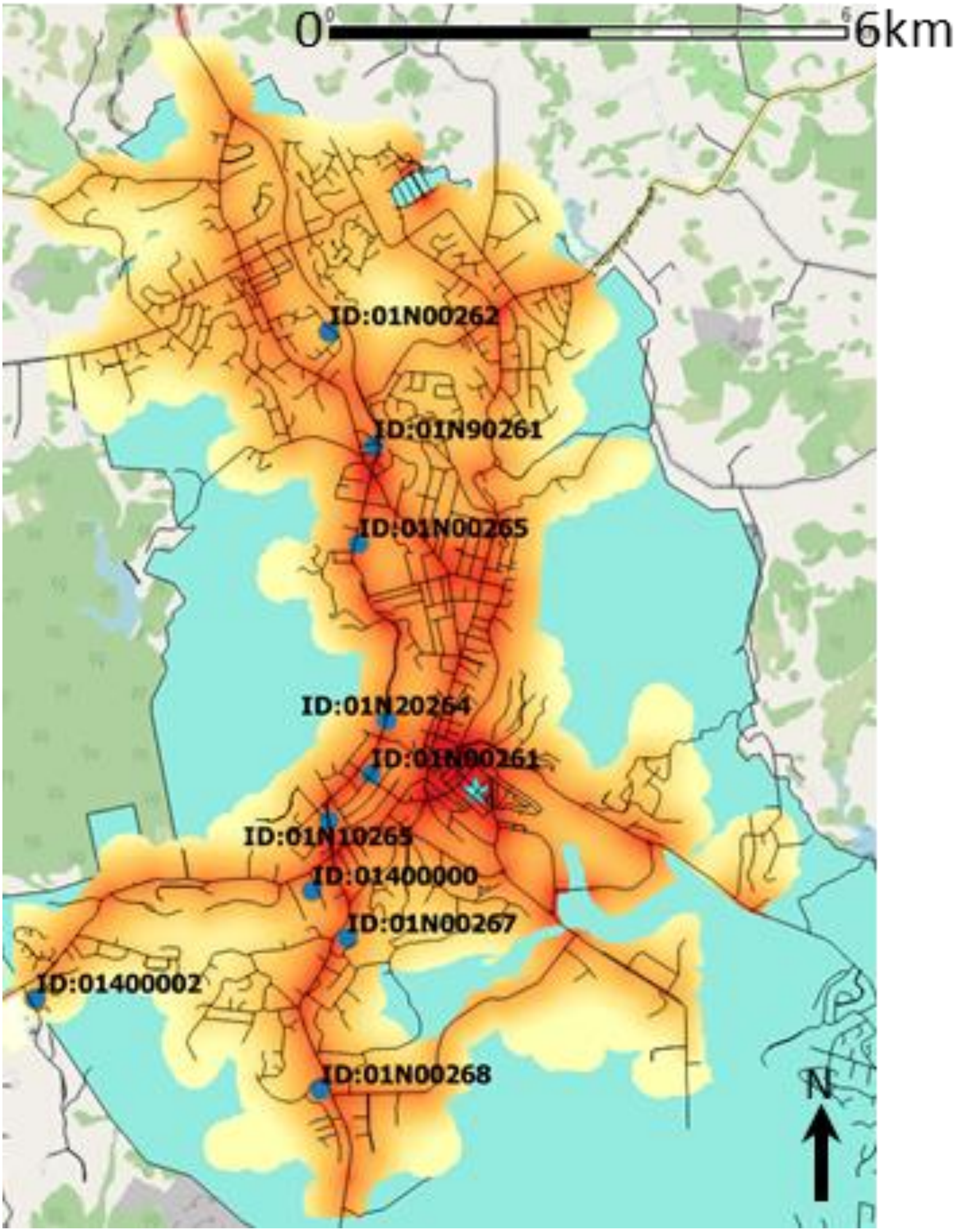

Figure A-1: Position of NZTA traffic counters within Whangārei, labelled with IDs.

Appendix B Meteorological sites for long-term climatology

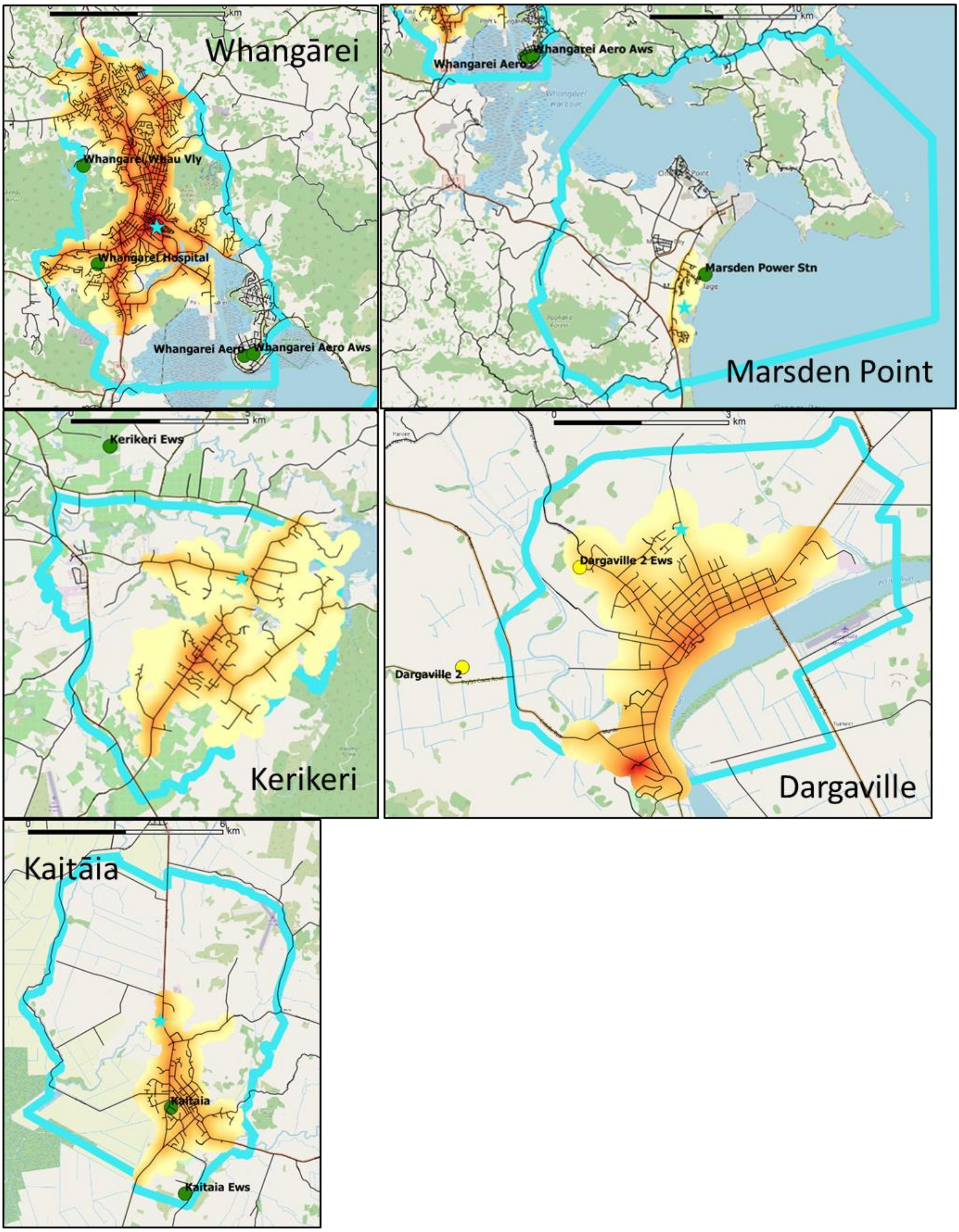

Figure B-1: Meteorological sites used for long-term climatology. Green and yellow dots.