Background air quality concentrations

Summary of methodology

Prepared for Waka Kotahi NZ Transport Agency by Tonkin + Taylor

July 2023

Version 1

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More information

Waka Kotahi NZ Transport Agency
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1. Introduction

Tonkin + Taylor Ltd (T+T) has been engaged by Waka Kotahi NZ Transport Agency (Waka Kotahi) to prepare an updated dataset of background particulate matter (PM_{10} and $PM_{2.5}$) and nitrogen dioxide (NO_2) concentrations by census area unit (CAU) for use in assessing the impact of transport projects. The key deliverable for this work were spreadsheets containing representative annual and 24-hour average concentrations of $PM_{2.5}$ and PM_{10} and annual concentrations of NO_2 by CAU.

The report is split into the methodology for the datasets of particulate matter (PM_{10} and $PM_{2.5}$) and the methodology for the dataset of NO_2.

The data is intended to represent background concentrations in the absence of the influence of transport emissions, to avoid double-counting when assessing the impact of transport projects. This report documents the methodology used to develop the background air quality dataset.

2. Particulate matter

2.1. Approach

The purpose of developing a background air quality dataset is to provide background air concentrations that can be added to the contribution of emissions from assessed local pollutant sources to evaluate the overall impacts of transport projects in relation to ambient air quality criteria. 'Background' air quality does not include the contribution of local sources, such as local roads or industry. Given that the purpose of the background maps is for use in assessing the impacts of transport projects, ideally the background concentrations would not include localised road source contributions. However, this has proven difficult due to the absence of urban background air quality monitoring sites and the focus in New Zealand on monitoring ambient air quality in 'worst case' locations. This focus is driven by the National Environmental Standards for Air Quality (NESAQ), which require regional councils to undertake ambient air quality monitoring:

- in airsheds where it is likely that the ambient standards will be exceeded, and
- in the location in the airshed where the standard is breached by the greatest margin or the standard is breached the most frequently, whichever is the most likely.

In most parts of New Zealand, the main source of particulate emissions is domestic heating, with motor vehicle emissions being a relatively small contribution. Consequently, the available air quality monitoring data is often reasonably representative of background concentrations in the absence of road impacts. The main exceptions to this are the peak traffic monitoring site at Willis Street, Wellington,[1] and the urban monitoring sites in the Auckland region (Queen Street, Penrose and Takapuna). The urban $PM_{2.5}$ monitoring sites in Auckland are all influenced by localised roading emissions.

NIWA prepared a model of annual average PM_{10} and $PM_{2.5}$ concentrations for the 2018 base year (NIWA model).[2] T+T was provided with the output of the NIWA model (an excel spreadsheet[3]). The NIWA model was used as the starting point for developing the dataset for the Waka Kotahi background air quality maps. However, it was adapted to better fit the purpose of developing representative background data, rather than data specifically representative of exposure in 2018. This has mainly involved using the average of three years monitoring data (2017 to 2019), rather than just 2018, where available.

The NIWA model does not include estimates of 24-hour average PM_{10} or $PM_{2.5}$ concentrations. A correlation was developed to estimate a representative 24-hour average PM_{10} concentrations, from the annual average concentration, in locations where there is no monitoring data. The representative 24-hour average $PM_{2.5}$ concentration is then estimated as a fraction of the 24-hour average PM_{10}.

It is important to note that, in general, no attempt has been made to remove the contribution of traffic emissions from the estimated particulate matter concentrations in each CAU because no consistent and practical way could be identified to do this with the available data. This means that where the background values are used in transport project assessments, the user needs to be aware of the potential for 'double-counting' existing traffic impacts. This will particularly be an issue in CAUs such as Willis Street (Wellington), where the background concentration is based on monitoring and is likely to include a significant transport contribution. For two CAUs in the Auckland region, where air quality is monitored relatively close to State Highway 1, representative background concentrations have been based on the modelled concentrations in adjacent CAUs rather than using the monitoring data to remove the contribution of traffic emissions (see 0).

[1] Located at the intersection of State Highway 1 and Willis Street, 8 metres from the roadway.

[2] Longley I and Coulson G. (2019). *PM2.5 in New Zealand – modelling the current levels of fine particulate air pollution*. Prepared for the Ministry for the Environment, National Institute of Water & Atmospheric Research Client report No: AKL2016-015.

[3] NIWA National PM exposure-model_2016 v6.7_20191119.xlsx

Recommendations have been made at the end of this report for the type of data that would need to be collected to enable more reliable representative background concentrations to be developed for the purpose of assessing transport projects.

2.2. Annual average $PM_{2.5}$ and PM_{10} background concentrations

Introduction

The NIWA model uses 2018 as its baseline year and therefore, where monitoring data is available, only 2018 data has been used in the NIWA model. The NIWA model was developed to inform the Health and Air Pollution in New Zealand 2016 study (HAPINZ 3.0[4]) and therefore is intended to represent exposure in a particular year. The purpose of the Waka Kotahi background maps is different, as they are intended to be more broadly representative of $PM_{2.5}$ background concentrations. For this reason, we reviewed the NIWA model in some detail and made some modifications to the model to develop the dataset for the Waka Kotahi background air quality mapping tool.

Overview of NIWA model methodology

The objective of the NIWA model was to develop a dataset of annual average $PM_{2.5}$ concentrations by CAU for the year 2018. The approach used in the model also provides estimates of PM_{10} and $PM_{2.5–10}$ (referred to as PM_{coarse}) concentrations, which are further broken down into the anthropogenic and non-anthropogenic (natural) components.

The NIWA model is complex and uses a hierarchy of data sources as shown diagrammatically in Figure 2.2 for $PM_{2.5}$ and Figure 2.3 for PM_{10}. The methodology is briefly summarised below.

Where a measured annual average $PM_{2.5}$ concentration is available, this value has been used in each CAU within the gazetted airshed to estimate anthropogenic contributions. The only airsheds where a different approach has been used are:

- Auckland, where NIWA considered the monitoring density was sufficiently to develop an empirical correlation between observed concentrations and an “emissions density” factor; and
- Otago, where a single $PM_{2.5}$ value has been adopted in CAUs across a number of towns.[5]

Where CAUs cross airshed boundaries, there has been a smoothing applied to avoid large step changes in concentration.

The NIWA model estimates the natural (non-anthropogenic) contributions to $PM_{2.5}$, PM_{coarse} and PM_{10} as follows:

- the natural $PM_{2.5}$ concentration is the sum of a modelled marine aerosol component, based on the distance from the east or west coast, and a fixed ‘soil and sulphate’ contribution of 1.4µg/m^3
- the natural PM_{coarse} concentration is the sum of a modelled marine aerosol component and a dust component of 3µg/m^3 for Otago and Canterbury, and 1µg/m^3 for every other region, and
- the natural PM_{10} concentration is the sum of natural PM_{coarse} and natural $PM_{2.5}$.

The anthropogenic component of PM_{10} is calculated by subtracting the modelled natural PM_{10} component from observed annual concentrations or, where PM_{10} observations are not available, from default PM_{10} concentration values based on the HAPINZ 2.0 rural and urban classification codes.[6]

The anthropogenic component of $PM_{2.5}$ is calculated using the following methods (in order of priority):

- subtracting the modelled natural $PM_{2.5}$ component from $PM_{2.5}$ observations where available (2018 or the most recent available data), or

[4] Documentation for the HAPINZ 3.0 study can be found at https://www.ehinz.ac.nz/projects/hapinz3/

[5] This decision was made in agreement with the Ministry for the Environment, according to the NIWA report.

[6] Fisher, G. et al. (2007). Health and air pollution in New Zealand (HAPiNZ). Main Report.

- where PM_{10} observations (but not $PM_{2.5}$) are available:
  - estimating total PM_{coarse} by adding the modelled natural PM_{coarse} component and a modelled urban PM_{coarse} component based on a relationship with traffic (vehicle kilometres travelled), and
  - subtracting the modelled PM_{coarse} and natural $PM_{2.5}$ from the PM_{10} observations (2018 or the most recent available data), or
  - using the same method, but substituting default PM_{10} concentration values based on the HAPINZ rural and urban classification codes for PM_{10} observations.

The NIWA model output is presented as a spreadsheet that includes static predictions of natural particulate matter contributions (only the outputs of the underlying marine aerosol model are presented and fixed values are assumed for other natural sources). This means that ‘updating’ the model, for example to use more recent PM_{10} observations, will have a limited impact because the PM_{coarse} estimates are fixed and therefore only the anthropogenic $PM_{2.5}$ concentrations will change. In practice, this means that if the 2018 baseline PM_{10} measurement is changed to a higher value (for example substituting data from 2019), the difference is assumed to all comprise anthropogenic $PM_{2.5}$. In reality, the higher PM_{10} concentrations measured in a different year will comprise a mixture of $PM_{2.5}$ and PM_{coarse}.

The basis for the ‘emissions density’ factor used in the empirical $PM_{2.5}$ model developed for the Auckland region is not presented in the NIWA report. However, this appears to be based on a spatial relationship developed from 2018 monitoring data, which may not hold for other years. For this reason, the representative background concentrations in the Auckland region cannot be modified using more recent, or longer term, observational data other than in the CAU where the monitor is located.

A large-scale map of the predicted $PM_{2.5}$ concentrations by CAU is shown in Figure 2.1.

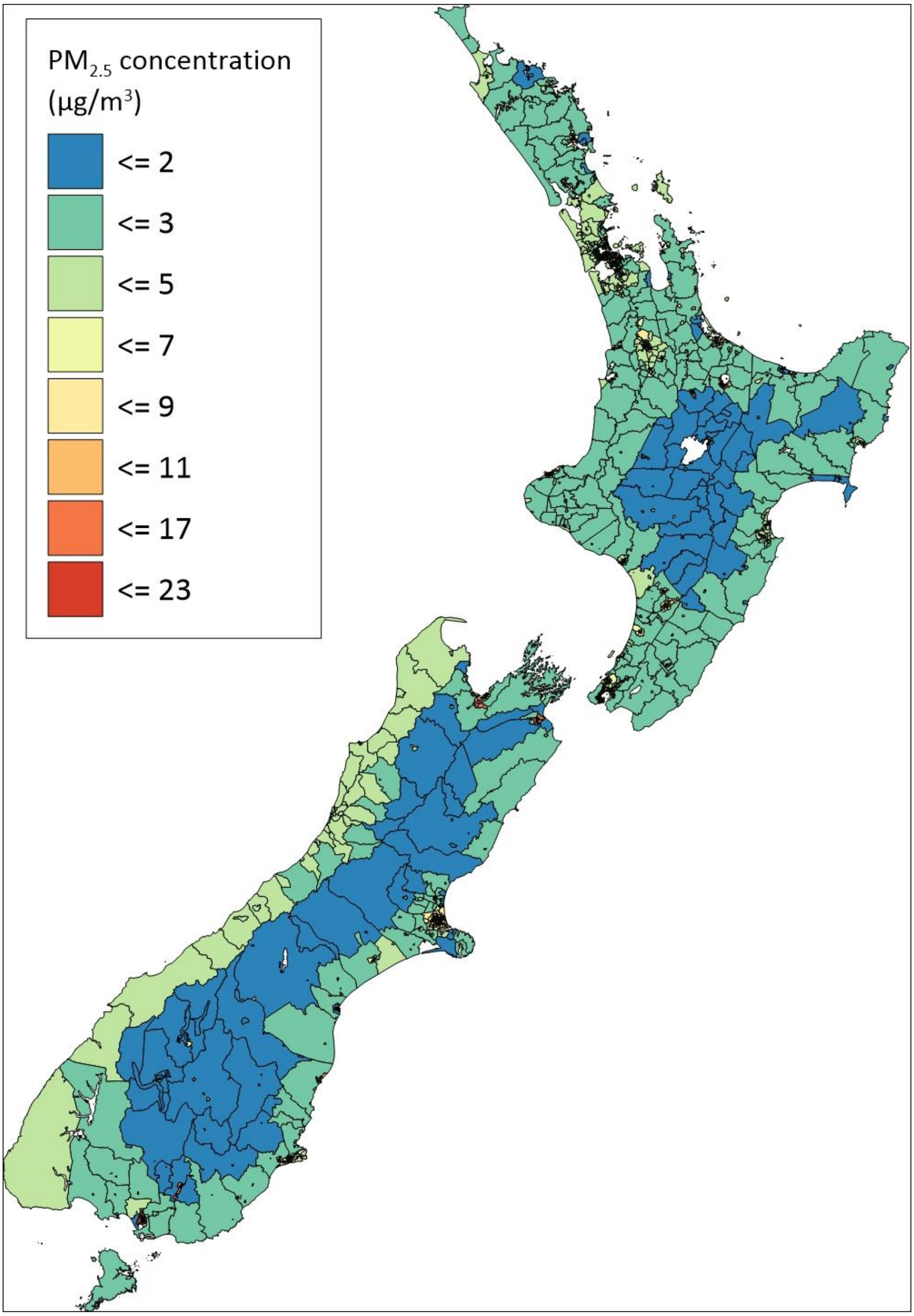

Figure 2.1: $PM_{2.5}$ concentrations per census area unit calculated using the NIWA model

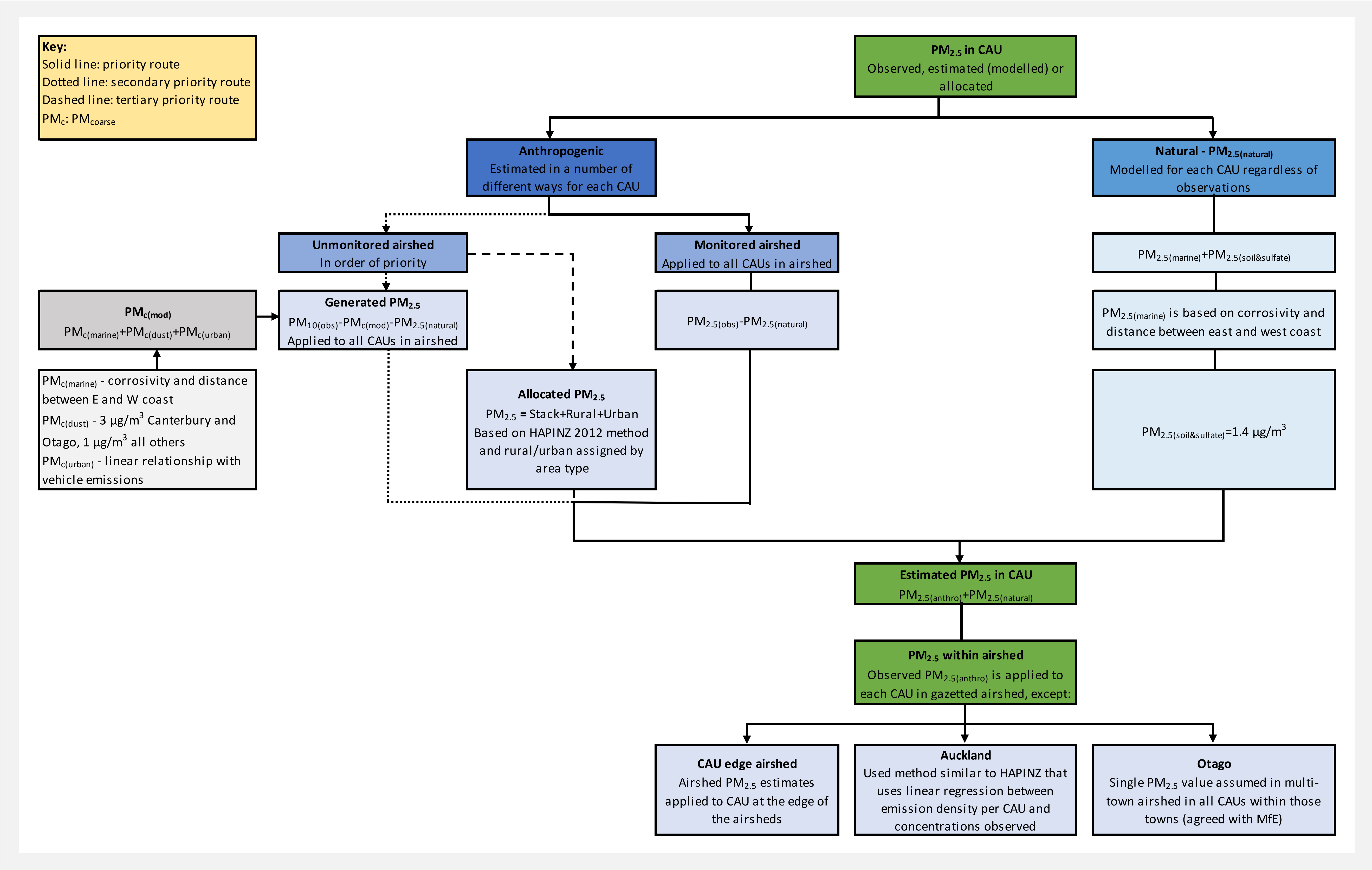

Figure 2.2: Conceptual diagram for NIWA's $PM_{2.5}$ exposure model.

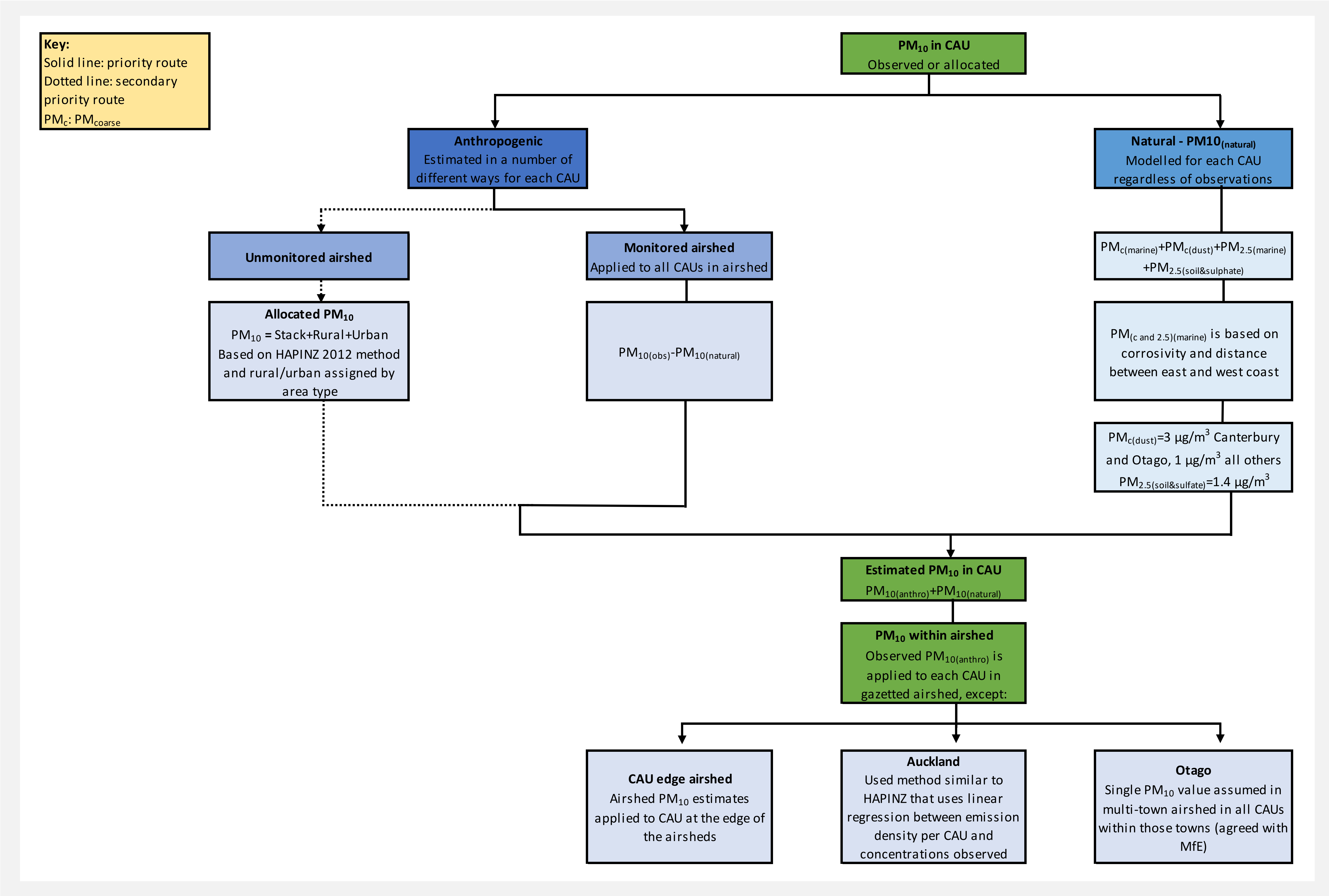

Figure 2.3: Conceptual diagram for NIWA's PM_{10} exposure model.

Discussion of the NIWA model

The model developed by NIWA is the best tool currently available to predict background annual average $PM_{2.5}$ and PM_{10} concentrations in New Zealand, in locations where monitoring data is not available. A critical analysis of the performance of the NIWA model is set out in 0. The key findings of our review of the NIWA model are as follows:

- In airsheds where $PM_{2.5}$ and PM_{10} monitoring data was available, the NIWA model tended to overestimate PM_{coarse} concentrations (that is, the difference between PM_{10} and $PM_{2.5}$). This suggests that the NIWA model will tend to underestimate the annual average $PM_{2.5}$ concentrations in airsheds where there is monitoring data for PM_{10} but not for $PM_{2.5}$. As the PM_{coarse} contributions are fixed values, the use of higher PM_{10} concentrations based on longer-term air quality measurements may disproportionately increase the predicted $PM_{2.5}$ concentrations. However, these two impacts are expected to largely cancel each other out.
- The NIWA model over-predicted PM_{10} concentrations at Thames. This appears to be largely due to over-prediction (conservatism) of the marine aerosol contribution to PM_{coarse} and $PM_{2.5}$, in this relatively sheltered location on the western side of the Coromandel Peninsula.
- The NIWA model under-predicted both $PM_{2.5}$ and PM_{10} concentrations at Gladstone Park, Parnell by approximately 10%.
- 2018 appears to have been a relatively low pollution year with respect to $PM_{2.5}$. Consequently, the NIWA model tends to under-predict longer term average $PM_{2.5}$ concentrations in airsheds where monitoring data is available.

Overall, we found that the NIWA model is likely to under-predict representative longer term $PM_{2.5}$ background concentrations due to a combination of aspects of the model (a tendency to overestimate PM_{coarse} concentrations) and the use of the 2018 base year.

Adaptation of NIWA model to develop representative annual average background concentrations for transport assessments

The NIWA model has been used as the basis for developing the representative annual average PM_{10} and $PM_{2.5}$ concentrations in the Waka Kotahi background air quality dataset. However, several modifications have been made to adapt the model to better fit the purpose of developing representative background data, rather than data specifically representative of exposure in 2018.

The 2018 base year in the NIWA model was a relatively low $PM_{2.5}$ pollution year in most airsheds. Therefore, the 2018 $PM_{2.5}$ and PM_{10} observations have been substituted with the average of monitoring data available for the years 2017 to 2019 (that is, three-year average data, where available) to develop a representative background dataset.

The $PM_{2.5}$ predictions for the Auckland region, other than in CAUs where there is an air quality monitor, were not able to be adapted to use longer-term observational data because we cannot be certain the empirical relationship developed by NIWA between $PM_{2.5}$ concentrations and emissions density will hold for years other than 2018.

In Auckland, the data from the monitoring sites at Takapuna and Penrose includes a significant influence of traffic emissions. Therefore, to develop background concentrations for assessing transport projects (that is, excluding the effects of traffic emissions), the annual average $PM_{2.5}$ and PM_{10} concentrations in the CAUs containing the Takapuna and Penrose monitoring sites were manually adjusted based on concentrations in adjacent CAUs. The method used for these manual adjustments is set out in 0.

There were some locations where PM_{10} or $PM_{2.5}$ monitoring data was identified that had not been used in the NIWA model, such as Morrinsville. Where possible, these have been incorporated. It was decided not to use the monitoring data for Thames because of an identified issue with generating negative values (see 0).

A bespoke approach was used in the Nelson C airshed. The NIWA model does not use the observed data in this airshed and there was no explanation for the substituted value used. We considered that the monitoring data from The Brook, which is located in a confined valley, would not be representative of all of the CAUs in the Nelson C airshed, particularly those located east of the Maitai River. Therefore, the monitoring data from The Brook was generally only used for CAUs in the Nelson C airshed west of the Maitai River and the areas north of the river used the NIWA model default urban classification model (see map in 0, Figure A.1).

Summaries of the observational data used in the NIWA model compared to the adapted model for the Waka Kotahi background air quality dataset are shown in 0.

2.3. Daily average $PM_{2.5}$ and PM_{10} background concentration

Introduction

The NIWA model does not include estimates of 24-hour average PM_{10} and $PM_{2.5}$ concentrations. Therefore, in airsheds where there is no monitoring data, it has been necessary to estimate the representative daily average background concentration from another parameter.

There are two key issues to consider in developing representative 24-hour average background concentrations:

- the most appropriate percentile value to adopt as representative of the background, and
- in locations where there is no monitoring data, identifying an appropriate relationship (for example linear versus exponential) to estimate a representative 24-hour average concentration from the annual average concentration.

Each of these issues is discussed in turn in the following sub-sections.

Selection of appropriate percentile value

The most conservative approach for assigning a 24-hour background concentration is to use the highest measured 24-hour value in a year. This approach is extremely conservative as the highest measured value can often be an ‘outlier’, caused by unusual emissions and/or meteorological conditions. Where air quality monitoring data is available, the previous Waka Kotahi background maps adopted the second highest measured 24-hour average PM_{10} concentration in the baseline year, which is still conservative but avoids using an extreme outlier.

In considering the most appropriate percentile to adopt as representative of the background 24-hour average $PM_{2.5}$ concentration, it is relevant to consider the likelihood of temporal coincidence. In other words, the likelihood of the worst case 24-hour peak caused by the transport emissions occurring at the same time as the peak 24-hour background concentration. Where these conditions are unlikely to coincide, there would be a justification for adopting a lower percentile monitoring value. This approach is sometimes recommended in assessing point source industrial emissions.[7]

In most airsheds in New Zealand, domestic heating emissions are the most significant contributor to anthropogenic $PM_{2.5}$. For these type of low elevation releases (from domestic chimneys), the worst-case dispersive conditions will be stable atmospheric conditions with calm or low wind speeds. These are the same meteorological conditions that are likely to be the worst case for dispersion of transport emissions. Consequently, there is no justification to adopt a lower percentile value. However, it is desirable to avoid selecting an overly high outlier value as representative of the background concentration. On balance, it was decided that the 99th percentile (approximately equal to the 4th highest daily average concentration) was an appropriate compromise.

[7] Environment Agency (UK). (2006). *Review of background air-quality data and methods to combined these with process contributions*. Science Report SC030174/1 SR1

In CAUs where monitoring data was available, the representative background 24-hour average PM_{10} and $PM_{2.5}$ concentrations were based on the average of the measured 99th percentile 24-hour average concentrations over the 2017 to 2019 period.

Estimating 24-hour average concentrations from annual average concentrations

Figure 2.4 and Figure 2.5 show the relationship between the 99th percentile of the measured 24hour average and annual average concentrations of PM_{10} and $PM_{2.5}$, respectively, using all available monitoring data from across New Zealand. Although the 99th percentile will be approximately the same as the fourth highest daily concentration, using the fourth highest measured value would be more prone to being affected by data outliers than a statistical approach looking at the whole dataset. Therefore, the relationship was developed from the 99th percentile values in each year of measured data.

There is a strong linear relationship in both correlations (R^2 values over 0.9), however the (marginally) stronger relationship was in the PM_{10} correlation relationship. A power law relationship (when a relative change to one quantity leads to a proportional relative change in the other quantity) was also investigated but was not found to be any stronger than a linear correlation.

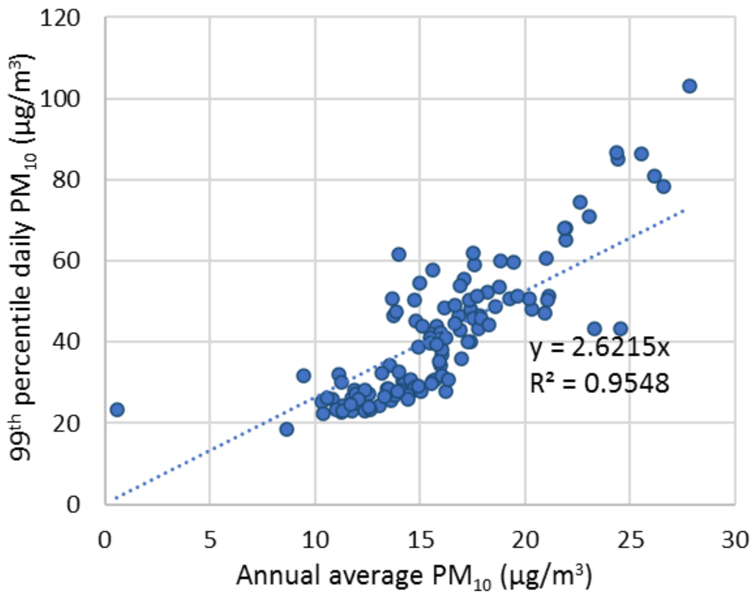

Figure 2.4: Relationship between annual average and 99th percentile daily average PM_{10} concentrations (µg/m^3) from available monitoring sites across New Zealand 2010–20.

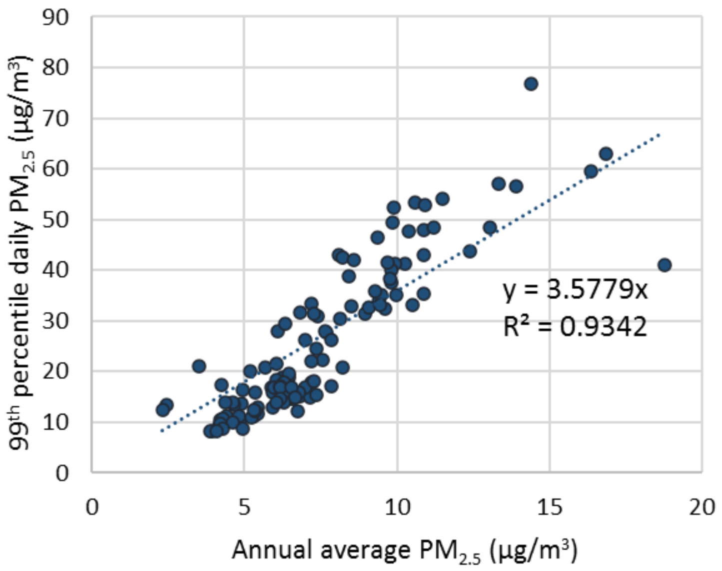

Figure 2.5: Relationship between annual average and 99th percentile daily average $PM_{2.5}$ concentrations (µg/m³) from available monitoring sites across New Zealand 2010–20.

Although it would be possible to calculate the 24-hour average PM_{10} and $PM_{2.5}$ concentrations independently from the respective annual average concentration using these relationships, this would not maintain the integrity of the relationship between the $PM_{2.5}$ and PM_{10} background concentrations (it could result in background $PM_{2.5}$ concentrations greater than the corresponding PM_{10} concentration). Therefore, it was decided that these values should not be calculated independently.

Given the strongest relationship was in the PM_{10} correlation, it was decided that the best approach was to estimate the 24-hour PM_{10} concentration first, using the linear relationship shown in Figure 2.4 (multiplying the annual average concentration by 2.6125) and then to estimate the 24-hour $PM_{2.5}$ concentration from that value.

An adjustment factor to estimate the default $PM_{2.5}$ background concentration from the default PM_{10} background concentration was developed by:

1. Calculating the average ratio between 24-hour average $PM_{2.5}$ and PM_{10} concentrations at each available site for each available year (from 2010–20).
2. Taking an overall average of the dataset.

The resulting adjustment factor is 0.48 (see 0).

Differing relationships can be discerned in the $PM_{2.5}$ to PM_{10} ratio depending on source profiles (for example industrial locations compared to locations strongly influenced by domestic heating). However, there is no easy way to categorise CAUs within the current spreadsheet. A source-type categorisation approach could be used more readily in a GIS (graphic information system) tool and is an improvement that could be considered in the future.

2.4. Validation of background

As all available PM_{10} and $PM_{2.5}$ monitoring data for the 2017 to 2019 period is used as input data for the background concentrations, it is difficult to validate the performance of the model.

In the first instance, the updated predictions have been compared against the original NIWA model outputs to identify CAUs where there was a more than $\pm$10% difference in PM_{10} or $PM_{2.5}$ concentrations. The relevant CAUs are identified in 0 along with an explanation of the reason for the difference.

A search was carried out to identify any new monitoring locations for PM_{10} or $PM_{2.5}$ that were not used as inputs to the model. There are several additional PM_{10} monitoring sites in the Mt Maunganui industrial area (Omanu CAU) that were not used in the background model. Air quality at these locations is known to be influenced by local dust sources, including handling of bulk cargo and logs, that are not included in the NIWA model. Therefore, these monitoring data are not suitable for PM_{10} model validation purposes.

$PM_{2.5}$ monitoring data is also available for the Totara Street monitoring site in the Mt Maunganui industrial area. The contributing dust sources at Totara Street are expected to be dominated by PM_{coarse} and therefore this monitoring data may be suitable for validation of the modelled background $PM_{2.5}$ concentrations. The only other new monitoring site that has been identified is $PM_{2.5}$ monitoring at the Rotorua Edmund Street site (Mangakakahi CAU). Monitoring data for these sites, obtained from the Bay of Plenty Regional Council Environmental Data Portal, is shown in Table 2.1.[8]

The measured concentration in the Mangakakahi CAU is significantly lower than the background map estimate. The difference may be explained by trends in the annual average PM_{10} concentrations, which have reduced steadily over time. The background maps (based on 2017 to 2019 data) adopt a three-year average concentration of 13.8µg/m^3 in the Mangakakahi CAU. However, in 2021 the annual average PM_{10} concentration was 11.0µg/m^3. The measured $PM_{2.5}$ concentration, compared to the background map concentration, shows a similar proportional reduction.

Table 2.1: Comparison of new $PM_{2.5}$ monitoring data with background map estimates

Location	Background map concentration (µg/m^3)	Measured concentration (µg/m^3)
Omanu[a]	6.0	6.3[a]
Mangakakahi[b]	9.3	7.5[b]

Table notes:

a. Totara Street monitoring site 2021

b. Edmund Street monitoring site 2021

2.5. Recommendations for further work

In terms of refining the existing methodology outlined in this report, the following additional work could be carried out to improve the background air quality dataset.

The NIWA model, which has been used as the basis for the development of the background air quality dataset, is a spreadsheet-based model. It requires effort to familiarise with the spreadsheet and caution is required in modifying the spreadsheet as there are a number of ‘exceptions’ to the general modelling approach. A key limitation to the spreadsheet-based approach is that the background estimates cannot be readily updated, for example as new air quality monitoring data becomes available. The longer-term recommendation (see below) to move to a code-based geospatial model using updatable source data tables could provide a more transparent and flexible architecture to overcome some of these limitations.

The focus of regional council air quality monitoring on locations where the air quality standards are most likely to be breached (as required by the NESAQ) means that there is little data collected that is representative of background urban quality. This data gap could be filled by establishing background urban air quality monitoring sites, particularly in Auckland where all the urban $PM_{2.5}$ monitoring sites are influenced by localised impacts of roads.

[8] Data sources from Bay of Plenty Regional Council Environmental Data Portal: https://envdata.boprc.govt.nz/

As outlined in Section 2.1, the background air concentrations developed in this work include the impact of traffic and other localised emissions. This means that where the background values are used as part of a transport project assessment, there is the potential for ‘double-counting’ existing traffic impacts. The approach used in the UK to develop background air quality maps uses a modelling approach to estimate the various source contributions to air quality in each 1km × 1km grid square.[9] This allows the user to remove the contributions from sources that are being explicitly considered in an assessment to avoid double-counting. This would require a shift from a spreadsheet-based model (as in the current NIWA model) to a geospatial modelling approach.

We consider a geospatial modelling approach would offer a number of advantages. For example, the current NIWA background concentration estimates are applied across entire CAUs. The CAUs (now replaced by Statistics New Zealand with ‘SA2’ geographies) are variable in size and are not necessarily representative of areas with homogeneous air quality. The CAU-averaged approach also creates anomalies at the CAU boundaries, for example different background concentrations on one side of the boundary compared to the other, which are not realistic. While the approach of defining a representative air concentration in each CAU is useful for population exposure estimates, we consider a geospatial modelling approach would provide more realistic estimates of air concentrations at a particular location. These estimates could then be aggregated/averaged across any desired physical area to determine population-averaged exposure.

[9] https://laqm.defra.gov.uk/review-and-assessment/tools/background-maps.html

3. Nitrogen dioxide

3.1. Overview

The annual average NO_2 concentrations have been assigned in each CAU using the following priority:

1. Representative background monitoring data has been used where available, including historic data, except where concentrations are above 20µg/m^3 as this is considered too high to be a true background.
2. Background values calculated from the NIWA Traffic Impact Model (TIM) have been used, where available, except where concentrations:
    a. are above 20µg/m^3 as this is unlikely to represent background – in this case representative concentrations from adjacent CAUs have been identified and adopted, and
    b. are less than the assumed default rural or urban township background – in this case an assumed default concentration is used based on urban or rural classifications (see point 3).
3. For the remaining CAUs without data, two methods have been used based on urban and rural classifications:
    a. a rural township (urban) background concentration has been assigned based on average data from monitored and NIWA TIM data in similar CAUs, and
    b. monitored rural background concentrations have been used in rural areas.

The following sections detail the rationale for each method of predicting background NO_2 concentrations.

3.2. Monitoring data

There are two sources of background monitoring data that have been considered in this study:

- national network of NO_2 diffusion tubes; and
- continuous monitoring networks managed by regional councils.

Waka Kotahi has provided all the data from their national NO_2 network, which totals 180 sites. Regional councils that have data readily available online include Auckland Council, Wellington Regional Council, and Environment Canterbury. This provides an additional 21 sites (201 monitoring locations in total).

The majority of these monitoring sites are intended to measure peak traffic impacts (in areas of high traffic density). However, some background sites have been included since the inception of the network to represent urban population exposure. The definition of a background site is where it is located:

- more than 100m from a state highway, and
- more than 50m from a busy local road.

A recent review by NIWA has reclassified sites as either ‘roadside’ or ‘urban background’, depending on the influence of a few nearby roads, or a well-mixed contribution of distant roads. Within this definition, each site is classed as being locally or regionally representative. Locally representative sites are more likely to be influenced by local road sources so may not be representative of the wider CAU.

When considering this classification, the monitoring from three locations (AUC049, DUN004, and HAM002[10]) has been removed. These sites have measured concentrations greater than 20µg/m^3,

[10] Not given a regional or local classification under the NIWA guidance, but has a concentration considered too high to be background. It is also located nearby to two busy roads.

which is considered as being too high to represent background concentrations – that is, it will likely double count traffic influences. For this reason, these sites have been excluded.

There are a remaining 35 Waka Kotahi monitoring sites that are classed as background. Where multiple monitoring locations are present in a CAU, the average value is taken. This provides data for 23 CAUs.

Regional council monitoring sites also aim to provide information for areas of peak concentrations, so there are a limited number representing background concentrations. There are 10 regional council sites that can be defined as background, summarised in Table 3.1, although some double up data with the Waka Kotahi network.

Additional data includes Ports of Auckland Ltd (POAL) monitoring data from Gladstone Park, Parnell, during 2018. This monitoring was undertaken by Watercare on behalf of POAL and is located in a representative background location.

With the addition of the regional council and POAL data, monitored background data is available for 30 CAUs.

Table 3.1: Additional monitoring locations defined as background sites

Region	Location	Distance to state highway	Distance to local busy road	Concentration (µg/m3)	Notes
Auckland	Ceramco Park, Glen Eden	6.7km	290m	4.2	Same as Waka Kotahi monitor AC001 – already included but provides 2019 data
	Musick Point	9.5km	1.2km	6.3	Historic data – pre-2013
	Milton Park, Papatoetoe	1.45km	290m	12.0	Newly installed monitor that only includes 2019 data
	Patumāhoe	10.5km	920m	3.4	Same as Waka Kotahi monitor AC004 – already included but provides 2019 data
	Waiheke	Off mainland	315m	4.2	Historic data from 2009 and 2010
	Gladstone Park, Parnell	220m	210m	14.7	One year of monitored data by the Ports of Auckland Ltd (POAL)
	Waiuku	25.4km	530m	8.2	Historic data from 2009
	Helensville	139m	139m	2.6*	Historic data from 2010

Region	Location	Distance to state highway	Distance to local busy road	Concentration (µg/m3)	Notes
Wellington	Wairarapa College, Masterton	550m	240m	5.2	Current data
	Savage Park, Upper Hutt	620m	150m	5.9	Current data
Christchurch	St Albans, Christchurch	2.5km	390m	9.7	Same as Waka Kotahi monitor CRC003 – already included but provides 2019 data

*This value is below the default rural background. It is still included as monitored data is considered more representative in this CAU than default values.

3.3. NIWA Traffic Impact Model (TIM)

Introduction

The NIWA TIM aims to predict long-term concentrations of traffic-related air pollutants at any outdoor location in urban New Zealand.

The TIM is a two-part semi-empirical model that relates distance-weighted traffic density at each location with concentrations of NO_2. Empirical values within both parts of the model describe average dispersion and emission characteristics across the whole model zone (typically a town or city). Where available, the parameters are calibrated with observed data, otherwise default derived national values are used. It predicts NO_2 concentrations in urban areas at a 10m resolution.

The model also predicts long term background concentrations across the country and aggregated to CAU level. A roadside buffer was created around every road and the roadside impacts (within the buffer) were subtracted from the concentration raster. The concentrations in each CAU are aggregated, and the mean value gives the estimated background concentration in the CAU.

This approach is used to predict background concentrations for 1,239 CAUs. These CAUs are primarily in urban areas but do include some CAUs classified as rural. Below we discuss how the model outputs compare with monitored data, and how the TIM outputs have been used.

Evaluation of the TIM model

Limitations

The TIM model is based on average traffic conditions, therefore there are a number of limitations to the predicted background concentrations:

- As the model predicts concentrations from road traffic only, it will under-predict concentrations where other sources are present (such as near ports, airports, and some industrial areas).
- By assuming average emissions and average dispersion conditions, the model cannot account for:
  - densely built-up areas with the unmodelled street-canyon effect
  - busy intersections where average emissions do not describe excess acceleration
  - steep road gradients leading to extra emissions, and
  - higher than average concentration from heavy-duty vehicles.
- Concentrations are only predicted in CAUs in urban areas, with rural areas not covered in the model. This can include rural townships that are not connected to large urban centres.

These limitations need to be taken into account when evaluating the model outputs. However, these limitations largely do not affect the use of the model outputs to determine background concentrations. Further, as background concentrations are small compared to the ambient air quality guideline, a small level of inaccuracy is unlikely to significantly alter the conclusions of assessments using the data.

Comparison to monitored concentrations

We have evaluated the NIWA TIM against measured data at the urban background monitoring sites (Figure 3.1). The TIM has moderately good predictability with expected concentrations (r^2=0.94). As previously discussed, the NIWA TIM is a traffic-only model and will therefore under-predict concentrations where there are other sources of NO_2 or local terrain or meteorological effects.

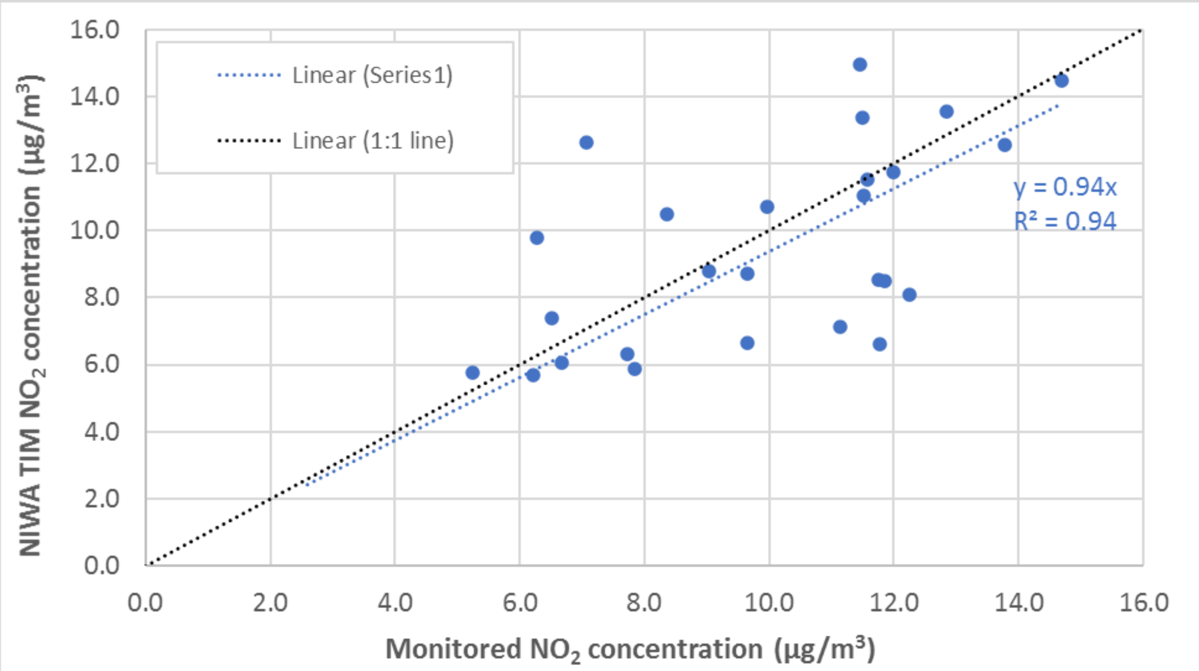

Figure 3.1: Comparison of monitored versus modelled annual average NO_2 concentrations at urban background monitoring sites, and showing a 1:1 line (black) and linear correlations with 1:1 comparison (blue)

Applying the model

The TIM output values have been applied in all CAUs where concentrations are predicted, except where monitoring data is available or in the following situations:

- Where concentrations are above 20µg/m^3, as it is considered too high to represent background. This is only present in two city centres and the concentrations used in these areas are an average of adjacent CAUs (see Auckland and Nelson central business districts below and 0).
- Where concentrations are below default rural or urban township concentrations the default concentrations are used instead (see Section 3.4).

Auckland and Nelson central business districts (CBDs)

The NIWA TIM predicts concentrations higher than 20µg/m^3 in some central Auckland CAUs and one CAU in Nelson. In Auckland, these CAUs are the CBD and areas with influences from SH1 and SH16. In Nelson, the relevant CAU is the city centre.

In these CAUs, adjacent CAUs were considered to provide more representative background concentrations. A discussion of the method used to develop these assumed background concentrations is included in 0, and the outputs summarised in Table 3.2.

On reviewing Auckland CBD concentrations, the concentration in Auckland Harbourside CAU is much lower than others in the area, 6.7µg/m^3. This CAU consists of the open port area and will likely have low AADT and traffic influences due to absence of roads. However, there will be an influence of port emissions (particularly shipping) not captured in the NIWA TIM. Monitoring undertaken at Gladstone Park, Parnell represents a background monitoring location that is influenced by localised shipping emissions from the port. This concentration of 14.7µg/m^3 will be used to represent conditions at Auckland Harbourside.

Table 3.2: Predicted NIWA TIM and assumed annual average NO_2 concentrations in central Auckland and Nelson CAUs

CAU description	CAU number	Predicted NIWA TIM concentration (µg/m^3)	Assumed background concentration (µg/m^3)
Auckland			
Auckland Central West	514102	23.3	19.0
Auckland Central East	514103	21.1	19.0
Newton	514200	28.6	19.0
Grafton West	514301	24.4	18.8
Arch Hill	515500	23.1	17.9
Eden Terrace	515600	22.7	18.8
Auckland Harbourside	514302	6.7	14.7
Nelson			
Trafalgar	582500	21.9	15.2

3.4. Urban and rural assignments

Small urban centres

The NIWA TIM does not predict concentrations in most small urban centres (townships) with a population less than about 20,0000. It is likely that background NO_2 concentrations in these townships will be higher than the rural default value (discussed in the following sub-section) due to a higher density of domestic heating emissions and small-scale commercial activities compared to rural areas.

In order to estimate a representative background concentration for small townships where there is no monitoring or TIM data, we have reviewed the TIM outputs for townships with a population between approximately 20 and 30,000 (see Table 3.2). Based on this analysis, a default concentration of 4.5µg/m^3 has been adopted for urban classifications where there is no monitoring data or NIWA TIM values.

Table 3.2: NO_2 concentrations in urban centres (population approximately 20,000–30,000)

Township	Measured concentration (µg/m³)	Predicted NIWA TIM concentration (average over all CAUs) (µg/m³)
Paraparaumu		4.0
Timaru		5.3
Blenheim		4.1
Pukekohe	3.0	-
Taupō		3.8
Rolleston	-	-
Masterton	5.2	4.6
Cambridge		5.3
Average		4.5

Rural background

A default rural background concentration of 3.0µg/m³ has been adopted based on the annual average concentration from three years of monitoring (2017–19)[11] at a rural site in Patumāhoe (southwest of Auckland).

[11] The concentrations ranged from 2.6–4.4µg/m³.

Appendix A: PM_{10} and $PM_{2.5}$ observations used in the background air quality maps

Table A.1: Changes to PM_{10} monitoring data used in NIWA model

Monitoring location	NIWA model (2018 base year)	Waka Kotahi background air quality map 3-year average (2017–19)
Queen Street	15.4	16.3
Penrose II	14.2	15.1*
Takapuna	13.5	13.7*
Henderson	12	12.6
Glen Eden	12.2	12.7
Pakuranga	12.9	14.0
Patumāhoe	10.8	12.4
Morrinsville	-	11.7
Hamilton	11.6	12.7
Tokoroa	14.7	15.0
Putaruru	11.2	12.0
Te Kūiti	13.4	14.1
Taupō	11.2	12.3
Rotorua Edmond Road	13.7	13.8
Napier	13	12.9
Hastings	13.6	13.1
Awatoto	19.7	18.5
Taihape	17.8	15.3
Taumarunui	10.5	11.2
Upper Hutt	10.4	10.6
Masterton East	14.2	14.9
Masterton West	14	14.1
Wainuiomata	10.9	11.4

Monitoring location	NIWA model (2018 base year)	Waka Kotahi background air quality map 3-year average (2017–19)
Wellington Central	12.4	12.5
Lower Hutt	11.3	11.4
Nelson Airshed A	16.9	17.2
Nelson Airshed B	17.9	18.5
Nelson Airshed C	7.7	12.5
Blenheim Redwoodtown	17.8	17.7
Reefton	12.4	12.5
Rangiora	15.5	16.2
Kaiapoi	16.6	17.3
Christchurch St Albans	17.4	17.6
Christchurch Woolston	17.2	17.7
Ashburton	16	16.8
Timaru	19.5	20.8
Washdyke	15.1	15.6
Geraldine	16	16.6
Waimate	14	15.0
Alexandra	14.2	13.9
Arrowtown	18.5	19.0
Dunedin	15	13.8
Mosgiel	19.2	18.2
Gore	18.5	18.1
Invercargill Pomona	21	20.0

* Note: these monitoring values were ultimately not used in the background maps as they were replaced with data derived from adjacent CAUs to remove the impact of traffic emissions (see 0)

Table A.2: Changes to $PM_{2.5}$ monitoring data used in NIWA Model

Monitoring location	NIWA model (2018 base year)	Waka Kotahi background air quality (3-year average)
Queen Street	6.8	7.0
Penrose II	6.0	6.9*
Takapuna	6.3	6.9*
Patumāhoe	4.1	5.3
Tokoroa	10.2	12.5
Hastings	6.1	6.3
Awatoto	6.0	6.3
Masterton East	10.0	10.7
Masterton West	9.9	10.1
Wainuiomata	5.7	6.0
Wellington Central	5.5	5.5
Nelson Airshed A	11.3	11.3
Nelson Airshed B	7.6	7.6
Blenheim Redwoodtown	13.2	13.2
Rangiora	7.4	8.3
Kaiapoi	9.9	10.8
Christchurch St Albans	8.1	8.6
Christchurch Woolston	6.8	7.1
Ashburton	8.9	9.2
Timaru	10.8	11.4
Washdyke	4.9	5.2
Geraldine	9.6	9.9
Waimate	7.8	8.7

* Note: these monitoring values were ultimately not used in the background maps as they were replaced with data derived from adjacent CAUs to remove the impact of traffic emissions (see 0)

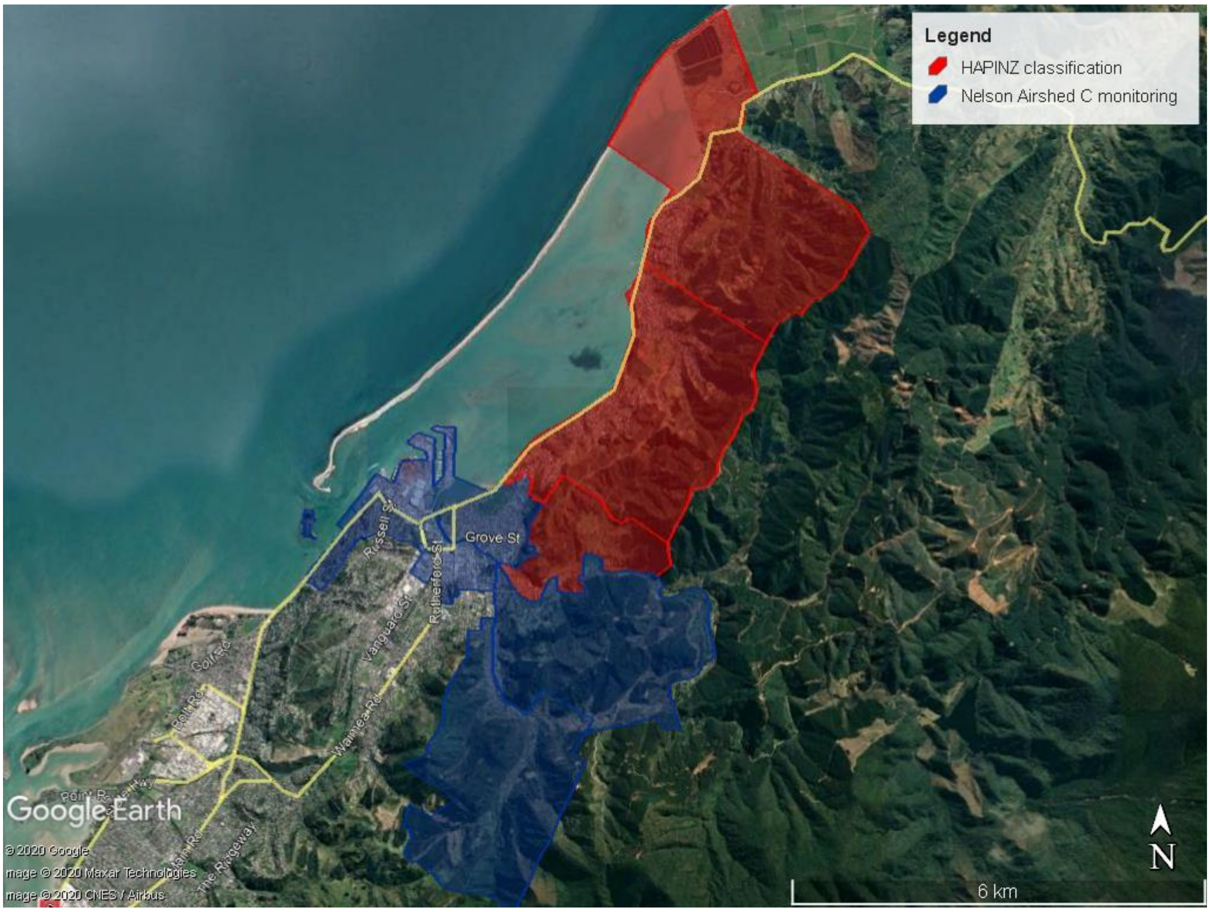

Figure A.1: Nelson Airshed C – CAUs shown in blue have used Nelson Airshed C monitoring data and CAUs shown in red have used the default urban classification in the NIWA model

Appendix B: Evaluation of the NIWA model

Introduction

There is limited $PM_{2.5}$ monitoring data in New Zealand airsheds and the vast majority of available data for the base year 2018 has been incorporated into the NIWA model. Consequently, there is limited independent data to verify the model predictions. Three techniques have been used to investigate the performance of the NIWA model:

- comparison of the modelled PM_{coarse} predictions against measured PM_{coarse} at monitoring sites where both PM_{10} and $PM_{2.5}$ data is available
- comparison of the model predictions with observations at two sites where observational data was not used (Thames and Parnell, Auckland), and
- comparison of the modelled $PM_{2.5}$ concentrations and $PM_{2.5}/PM_{10}$ ratios with longer-term measurements to evaluate the impact of year-to-year variability.

Comparison of modelled and measured PM_{coarse}

The NIWA report states that the model predicted annual average PM_{coarse} concentrations at sites without an industrial influence are within 1.2µg/m³ of observed concentrations. The modelled and measured PM_{coarse} values for 2018 are plotted against each other in Figure B.1.

The NIWA model tends to overestimate PM_{coarse} concentrations. This correlation suggests the model will tend to underestimate the annual average $PM_{2.5}$ concentrations in airsheds where there is PM_{10} monitoring data but not $PM_{2.5}$.

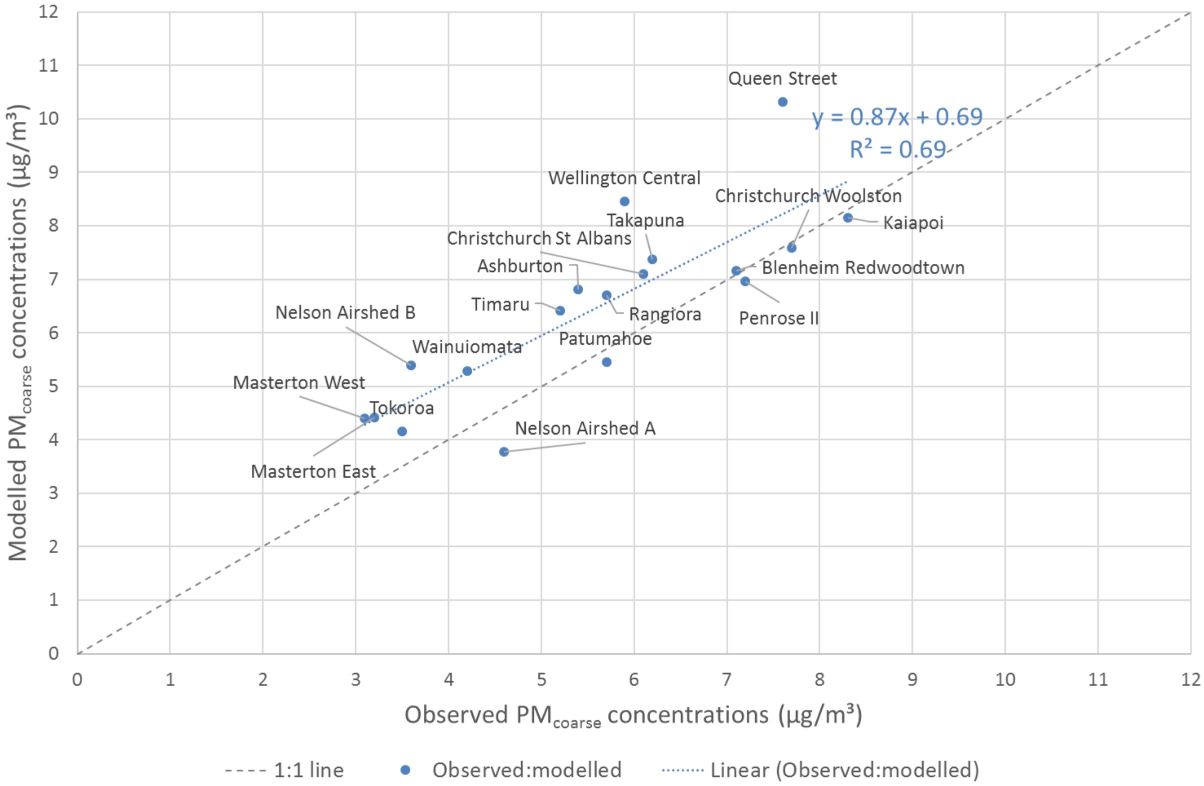

Figure B.1: Comparison of modelled and observed PM_{coarse} concentrations

Comparison with monitoring data from sites not used as inputs to the NIWA model

Two sets of particulate monitoring data were located that were not used as inputs to the NIWA model and can therefore be used for model validation:

- Thames, Coromandel – PM_{10}, and
- Gladstone Park, Newmarket - PM_{10} and $PM_{2.5}$.

Thames is a small coastal town at the base of the Coromandel Peninsula with relatively low levels of particulate air pollution. The measured PM_{10} concentration in 2018 was 5.4µg/m^3 (annual average) and the 2017 to 2019 three-year average was 8.3µg/m^3. In comparison, the NIWA model predicts a PM_{10} concentration of 12.0µg/m^3 (annual average).

Table B.1 shows the predicted natural PM_{coarse} and natural $PM_{2.5}$ components from the NIWA model for the Thames (Moanataiari) CAU. The anthropogenic PM_{10} component calculated using the NIWA method[12] gives a negative value (-3.6µg/m^3). A negative value (-0.6µg/m^3) is also obtained if the calculation is repeated using the three-year average observed PM_{10} concentration. This suggests that the NIWA model is overpredicting natural sources of PM_{coarse}, which are dominated by marine aerosols (5.3µg/m^3). It is also likely that the model is over-predicting the marine aerosol contribution to $PM_{2.5}$ (1.3µg/m^3) in this location. This may be due to conservatism in the marine aerosol model, given the relatively sheltered location of Thames on the western side of the Coromandel Peninsula.

Table B.1: Anthropogenic PM_{10} contribution at Thames calculated according to NIWA's methodology

Parameter	Concentration (µg/m^3)
NIWA model outputs for Thames CAU	
Modelled natural PM_{coarse}	6.3
Modelled natural $PM_{2.5}$	2.7
Calculations using observed PM_{10} data	
Observed PM_{10}	5.4
Calculated anthropogenic PM_{10} Observed PM_{10} – PM_{coarse}(natural) – $PM_{2.5}$(natural)	-3.6

Ports of Auckland Ltd (POAL) has provided data from air quality monitoring of PM_{10} and $PM_{2.5}$ at Gladstone Park, Parnell (Parnell West CAU). Table B.2 compares the observed and modelled concentrations of PM_{10} and $PM_{2.5}$. For both parameters, the NIWA model underpredicts the observed values.

The NIWA model uses a different approach in Auckland compared to other parts of New Zealand. The annual average $PM_{2.5}$ concentration is directly estimated based on a relationship with annual PM_{10} concentrations (the standard PM_{coarse} estimate is not used). However, the PM_{coarse} calculation is still presented in the spreadsheet and can be compared with the measured data as a check of the standard PM_{coarse} predictions used elsewhere. At this location, the observed PM_{coarse} (which is a

[12] Observed PM_{10} – PM_{coarse}(natural) – $PM_{2.5}$(natural)

combination of natural and anthropogenic contributions) was 8.2µg/m³ compared to a modelled PM_{coarse}[13] of 6.8µg/m³.

Table B.2: Comparison of modelled and observed data at Gladstone Park, Parnell

Parameter	Pollutant concentration (µg/m³)		
	Observed*	Modelled (Parnell West CAU)	% difference from observed
PM_{10}	13.4	12	-10%
$PM_{2.5}$	5.2	4.5	-13%

**Annual concentration calculated from 27 January 2018–27 January 2019.*

Consideration of year-to-year variability in PM concentrations

Ambient concentrations of PM_{10} and $PM_{2.5}$ will vary from year-to-year due to changes in local source emission profiles and meteorological conditions, which influence dispersive conditions. Another way to investigate the validity of the NIWA model with respect to CAUs where monitoring data is available, is to consider the model results against observations in other years not used as inputs to the model.

The $PM_{2.5}$ monitoring data used in the NIWA model have been evaluated against longer term observations in the Auckland, Hawke's Bay, Greater Wellington and Canterbury regions (see Table B.3). This illustrates that 2018 was a relatively low pollution year with respect to $PM_{2.5}$ in all of these regions. For this reason, the NIWA model $PM_{2.5}$ predictions may not be representative of 'typical' annual average concentrations.

Table B.3: Comparison of $PM_{2.5}$ predictions and observed data

Region	Location	Years of measured data	$PM_{2.5}$ concentration (µg/m³, annual average)		
			Modelled (2018)	Measured (all data)	Difference
Auckland	Takapuna	11	6.3	6.5**	-3.2%
Canterbury	Rangiora	4	7.4	8.3	-12.2%
Canterbury	St Albans	9	8.1	10.0***	-23.5%
Canterbury	Ashburton	4	8.9	9.4	-5.6%
Canterbury	Waimate	4	7.8	8.9	-14.1%
Canterbury	Geraldine	4	9.6	10.1	-5.2%
Canterbury	Kaiapoi	3	9.9	10.8	-9.1%
Wellington	Masterton East*	3	10.0	11.1	-11.0%

* 2014 – 2016 data
** Reduces to 5.7 µg/m³ (+9.5% difference) if only the last 5 years data considered

[13] Because the NIWA model uses a different approach in Auckland, the 'modelled PM_{coarse}' referred to here is not used in the model and is not the same as the modelled PM_{10} minus the modelled $PM_{2.5}$.

*** Reduces to 9.4 µg/m^3 (-16% difference) if only the last 5 years data considered

Industrial sources

The NIWA model includes a number of industrial source contributions. It is beyond the scope of this project to review the validity of all of these sources in the NIWA model. However, based on our knowledge of the Auckland area we can see that some of the industrial facilities have closed (such as Southdown Cogeneration Plant), and at least one of the major sources is in the wrong location (New Zealand Steel, which has been located in Penrose (CAU 519500)). The implications of this appear to be relatively small. For example, the New Zealand Steel emissions are assumed to contribute 0.24 µg/m^3 (annual average). However, this is noted as a possible source of error in the NIWA model, and consequently in the Waka Kotahi background air quality data.

Appendix C: CAUs with significantly different values in Waka Kotahi background air quality dataset compared to NIWA model outputs

Table C.1 identifies the CAUs with a + 10% difference in the annual average $PM_{2.5}$ and/or PM_{10} concentration compared to the NIWA model output and provides a brief explanation of the reason for the difference.

Table C.1: CAUs with significantly different values in Waka Kotahi background air quality dataset compared to NIWA model outputs

Census area data			Annual average concentration (µg/m³)				Percentage difference		Reason for difference
			Waka Kotahi background map		NIWA model				
CAU code	Region	Census area unit description	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	
505602	Auckland Region	Huapai	15.9	6.5	15.9	2.9	0%	55%	Based on historic $PM_{2.5}$ monitoring data that was not read into the NIWA model.
507900	Auckland Region	Westlake	11.9	4.6	13.5	6.3	13%	37%	Based on adjacent CAU data to exclude traffic impacts in monitoring data
520202	Auckland Region	Ellerslie South	10.7	4.5	14.2	6.0	33%	33%	Based on adjacent CAU data to exclude traffic impacts in monitoring data
521112	Auckland Region	Eden Road-Hill Top	12.4	5.3	10.8	4.1	13%	23%	Based on actual $PM_{2.5}$ monitoring data
534901	Waikato Region	Morrinsville West	11.6	6.5	10.1	5.1	13%	22%	Based on PM_{10} monitoring data at Morrinsville and modelled PM_{coarse}.
534902	Waikato Region	Morrinsville East	11.7	6.5	10.2	5.1	13%	22%	
535211	Waikato Region	Mangakaretu	15.0	12.5	14.7	10.2	2%	18%	Based on $PM_{2.5}$ monitoring data at Tokoroa (selected by NIWA as
535212	Waikato Region	Kinleith	17.5	15.2	17.3	12.9	2%	15%	
535310	Waikato Region	Paraonui	15.0	12.5	14.7	10.2	2%	18%	

Census area data			Annual average concentration (µg/m³)				Percentage difference		Reason for difference
			Waka Kotahi background map		NIWA model				
CAU code	Region	Census area unit description	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	
535320	Waikato Region	Parkdale	15.0	12.5	14.7	10.2	2%	18%	representative of this urban classification in the Waikato region).
535330	Waikato Region	Matarawa	15.0	12.5	14.7	10.2	2%	18%	
535340	Waikato Region	Stanley Park	15.0	12.5	14.7	10.2	2%	18%	
535350	Waikato Region	Tokoroa Central	15.0	12.5	14.7	10.2	2%	18%	
535360	Waikato Region	Aotea	14.9	12.5	14.7	10.2	2%	18%	
535370	Waikato Region	Strathmore	14.9	12.5	14.7	10.2	2%	18%	
535380	Waikato Region	Amisfield	14.9	12.5	14.7	10.2	2%	18%	
545632	Hawke's Bay Region	Awatoto	18.5	6.3	19.7	11.5	-7%	-82%	Based on actual $PM_{2.5}$ monitoring data
549100	Hawke's Bay Region	Waipawa	16.9	12.1	19.4	14.6	-15%	-21%	Based on updated PM_{10} values at Taihape (selected by NIWA as representative of this urban classification in the Hawke's Bay region)
549500	Hawke's Bay Region	Waipukurau	16.7	12.1	19.3	14.6	-15%	-21%	
545500	Hawke's Bay Region	Wairoa	14.9	11.5	17.5	14.0	-17%	-22%	
559400	Manawatū-Wanganui Region	Taihape	15.3	11.8	17.8	14.4	-17%	-21%	Based on PM_{10} monitoring data from Taihape and modelled PM_{coarse}
578600	Wellington Region	Masterton Central	14.1	10.1	6.4	9.9	55%	2%	Corrected formula for Masterton West PM_{10} concentrations. NIWA model did not calculate natural and anthropogenic contributions to be read through the spreadsheet.
578700	Wellington Region	Masterton West	14.1	10.1	6.4	9.9	55%	2%	
578901	Wellington Region	Solway North	14.1	10.1	6.4	9.9	55%	2%	
579000	Wellington Region	Ngāumutawa	14.1	10.1	6.3	9.9	55%	2%	
579100	Wellington Region	Masterton Railway	14.1	10.1	6.3	9.9	55%	2%	
582200	Nelson Region	Port Nelson	16.8	9.8	12.0	5.0	29%	49%	Based on actual monitoring data in Nelson Airshed C.
582300	Nelson Region	The Wood	16.3	9.7	11.5	4.9	30%	50%	
582401	Nelson Region	Britannia	16.8	9.8	12.0	5.0	29%	49%	

Census area data			Annual average concentration (µg/m^3)				Percentage difference		Reason for difference
			Waka Kotahi background map		NIWA model				
CAU code	Region	Census area unit description	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	
582500	Nelson Region	Trafalgar	14.8	9.3	10.0	4.5	32%	52%	
582900	Nelson Region	Atmore	11.2	8.5	6.4	3.7	43%	57%	
583400	Nelson Region	The Brook	12.5	8.6	7.7	3.8	38%	56%	

Appendix D: $PM_{2.5}/PM_{10}$ ratios

Table D.1: Annual mean monitored $PM_{2.5}/PM_{10}$

Monitoring site name	Region	Year	Annual average $PM_{2.5}/PM_{10}$ ratio
Woolston Road	Canterbury	2011	0.44
		2012	0.45
		2013	0.45
		2014	0.39
		2015	0.39
		2016	0.41
		2017	0.41
		2018	0.38
		2019	0.37
Washdyke Flat Road	Canterbury	2015	0.37
		2016	0.36
		2017	0.35
		2018	0.34
Waimate	Canterbury	2016	0.56
		2017	0.55
		2018	0.53
		2019	0.52
Ashburton	Canterbury	2016	0.54
		2017	0.51
		2018	0.54
		2019	0.53
Rangiora	Canterbury	2016	0.41
		2017	0.45
		2018	0.44
		2019	0.50
Timaru	Canterbury	2012	0.50
		2013	0.47
		2014	0.60
		2015	0.62
		2016	0.58
		2017	0.62
		2018	0.55
		2019	0.44
Geraldine	Canterbury	2016	0.59
		2017	0.57
		2018	0.58
		2019	0.56
Kaipoi	Canterbury	2017	0.59
		2018	0.56
		2019	0.55
Patumāhoe	Auckland	2010	0.36
		2011	0.39
		2012	0.41
		2013	0.40
		2014	0.38
		2015	0.36
		2016	0.38

Monitoring site name	Region	Year	Annual average $PM_{2.5}/PM_{10}$ ratio
		2017	0.57
		2018	0.42
		2019	0.41
Penrose	Auckland	2010	0.40
		2011	0.45
		2012	0.55
		2013	0.43
		2014	0.42
		2015	0.46
		2016	0.43
		2017	0.48
		2018	0.47
		2019	0.46
Takapuna	Auckland	2010	0.49
		2011	0.44
		2012	0.46
		2013	0.51
		2014	0.42
		2015	0.45
		2016	0.51
		2017	0.50
		2018	0.53
		2019	0.53
Totara Street	Bay of Plenty	2019	0.33
Rotorua	Bay of Plenty	2019	0.62
Dunedin Central	Otago	2019	0.44
Willis Street	Wellington	2017	0.49
		2018	0.46
		2019	0.44
Wainuiomata	Wellington	2017	0.52
		2018	0.49
		2019	0.48
Masterton West	Wellington	2017	0.65
		2018	0.66
		2019	0.68
Masterton East	Wellington	2017	0.68
		2018	0.65
		2019	0.65
Claudelands	Waikato	2018	0.46
		2019	0.49
Whangārei	Northland	2016	0.50
		2017	0.48
		2018	0.46
		2019	0.45
Richmond	Tasman	2016	0.52
		2017	0.71
		2018	0.41
		2019	0.57
Awatoto	Hawke's Bay	2017	0.40
		2018	0.35
		2019	0.38
Average ratio			**0.48**

Appendix E: Update to background annual average $PM_{2.5}$ and PM_{10} concentrations in two Auckland CAUs

Background

The concentrations generated from the NIWA model do not represent true 'background' air quality concentrations for use in transport assessments because, where monitored data is available, it is adopted as the representative concentration within the CAU.

By default, air quality monitoring sites in New Zealand tend to be located to monitor peak urban concentrations than measure background air quality. Therefore, monitoring locations are generally targeted at 'worst-case' locations often impacted by local sources, such as roads and domestic heating. In urban Auckland, the current $PM_{2.5}$ and PM_{10} monitoring sites are influenced by road emissions – most significantly at Takapuna and Penrose. This means that the 'background' $PM_{2.5}$ and PM_{10} concentrations in these CAUs include a significant road contribution, which will be double counted if these background concentrations are used in transport project assessments. Most of the regional council air quality monitoring sites outside Auckland are less significantly impacted by road sources and therefore the impact of double-counting is not as great.

During work verifying model predictions of annual roadside contributions, T+T estimated background annual $PM_{2.5}$ concentrations (excluding road contributions) for Takapuna and Penrose based on modelled concentrations in adjacent (less traffic-impacted) CAUs.[14] This method can used in the Auckland region because (unlike in other regions) the NIWA model only uses the monitored concentrations in the CAUs where they're located, and not others within the airshed. This method can also be used to estimate background annual PM_{10} concentrations.

Recommended background concentrations

The NIWA model estimates particulate matter concentrations by summing derived natural and anthropogenic components in each CAU. In the majority of airsheds, anthropogenic concentrations are derived from its one monitored CAU. However, in Auckland the NIWA model uses an empirical correlation between an 'emissions density factor' and observed particulate matter concentrations. We understand that the emissions density factor represents domestic heating and motor vehicle emissions within each CAU, although the NIWA model does not explicitly state this.[15]

This means that for CAUs in Auckland, the monitored concentrations are only used in the CAU in which they are located and are not directly used to predict anthropogenic contributions in the adjacent CAUs. Predicted concentrations in nearby CAUs can be evaluated and used to estimate the background concentration in the monitored CAU, in the absence of road contributions.

The NIWA model predictions for annual average PM_{10} and $PM_{2.5}$ in each of the adjacent CAUs was tabulated and the data was evaluated to determine which data points are likely to be representative of the background concentration in the monitored CAU by considering:

- the emissions density in the CAU compared to the monitored CAU (ideally representative CAUs would have a similar or slightly lower emissions density to account for lower traffic impacts), and
- tThe influence of marine aerosols, which was relevant to the Takapuna area (but not Penrose), to ensure that this source contribution was not overstated.

[14] Tonkin + Taylor Ltd (2020). Validation of DMRB Model Output for $PM_{2.5}$.

[15] It is stated to be the same emissions density factor used in the 2012 Health and Air Pollution in New Zealand (HAPINZ) update.

The background concentration was derived by averaging the particulate concentrations in the representative adjacent CAUs. The recommended background concentrations in the Westlake and Ellerslie South CAUs are shown in bold in Table E.1.

As previously outlined, this method is not able to be used in other airsheds in New Zealand because the monitoring data is used to predict the anthropogenic emissions in adjacent CAUs (as well as in the monitored CAU).

Table E.1: Summary of background concentrations derived from the NIWA model and recommended adopted background concentration calculated from adjacent CAUs

Roadside monitoring site	CAU name	CAU number	Annual average concentration (µg/m³)			
			$PM_{2.5}$		PM_{10}	
			NIWA model*	Derived background	NIWA model*	Derived background
Takapuna	Westlake	507900	6.9	**4.6**	13.7	**11.9**
Penrose	Ellerslie South	520202	6.9	**4.5**	15.1	**10.7**

*Actual monitored concentration in the CAU (includes traffic impacts)

Table E.2: Indicative background PM_{10} concentrations in Ellerslie South CAU (Penrose monitoring site)

Census area unit	CAU number	Emissions density (excluding industry) ($kg/m^2/year$)	Commentary	PM_{10} concentration ($\mu g/m^3$, annual average)		
				Natural	Anthropogenic	Total
Ellerslie South	520202	5912	Monitoring location	6.2	8.9	15.1
Ellerslie North	520201	7212	Very high emissions density. Not considered representative	5.5	4.9	10.5
Ferndale	520401	2354	Industrial area with low emissions density. Not considered representative	6.4	3.1	9.4
Penrose	519500	1695	Industrial area with low emissions density. Not considered representative	6.7	3.3	10.0
One Tree Hill East	519400	4463	Representative	6.8	3.8	**10.7**
Indicative background concentration (average of values in red)						**10.7**

Table E.3: Indicative background PM_{10} concentrations in Westlake CAU (Takapuna monitoring site)

Census Area Unit	CAU number	Emissions density (excluding industry) (kg/m²/year)	Commentary	PM_{10} concentration (µg/m³, annual average) Natural Marine	Other	Anthropogenic	Total	Total adjusted for marine aerosol*
Westlake	507900	4260	Monitoring location	6.0	2.4	5.3	13.7	-
Lake Pupuke	507800	3081	Representative	8.3	2.4	3.3	14.0	11.7
Crown Hill	507720	3937	Representative	6.8	2.4	3.6	12.8	12.0
Sunnybrae	508620	3232	Representative	3.8	2.4	3.4	9.5	11.7
Forrest Hill	508510	6228	Very high emissions density. Not considered representative	3.4	2.4	4.6	10.3	12.9
Takapuna Central	508010	1799	Commercial area with low emissions density. Not considered representative	8.5	2.4	2.8	13.7	11.2
Glenfield North	508320	4399	Representative	3.4	2.4	2.6	9.6	12.2
Tuff Crater	509702	5867	Very high emissions density. Not considered representative	9.2	2.4	4.4	16.0	12.8
Indicative background concentration (average of values in red)								11.9

* These values have been adjusted to the same marine aerosol contribution (6.0 µg/m³) as the Westlake CAU

Table E.4: Indicative background $PM_{2.5}$ concentrations in Ellerslie South CAU (Penrose monitoring site)

Census Area Unit	CAU number	Emissions density (excluding industry) (kg/m^2/year)	Commentary	$PM_{2.5}$ concentration (µg/m^3, annual average)		
				Natural	Anthropogenic	Total
Ellerslie South	520202	5912	Monitoring location	1.9	5.0	6.9
Ellerslie North	520201	7212	Very high emissions density. Not considered representative	1.8	3.2	4.9
Ferndale	520401	2354	Industrial area with low emissions density. Not considered representative	2.1	1.8	3.8
Penrose	519500	1695	Industrial area with low emissions density. Not considered representative	2.1	2.0	4.2
One Tree Hill East	519400	4463	Representative	2.1	2.4	**4.5**
Indicative background concentration (average of values in red)						**4.5**

Table E.5: Indicative background $PM_{2.5}$ concentrations in Westlake CAU (Takapuna monitoring site)

Census Area Unit	CAU number	Emissions density (excluding industry) (kg/m²/year)	Commentary	$PM_{2.5}$ concentration (µg/m³, annual average) Natural		Anthropogenic	Total	Total adjusted for marine aerosol*
				Marine	**Other**			
Westlake	507900	4260	Monitoring location	1.1	1.4	4.4	6.9	-
Lake Pupuke	507800	3081	Representative	1.8	1.4	1.9	5.1	4.4
Crown Hill	507720	3937	Representative	1.4	1.4	2.2	5.0	4.7
Sunnybrae	508620	3232	Representative	0.5	1.4	2.0	3.9	4.5
Forrest Hill	508510	6228	Very high emissions density. Not considered representative	0.5	1.4	2.9	4.7	5.3
Takapuna Central	508010	1799	Commercial area with low emissions density. Not considered representative	1.8	1.4	1.5	4.8	4.1
Glenfield North	508320	4399	Representative	0.4	1.4	2.3	4.2	4.9
Tuff Crater	509702	5867	Very high emissions density. Not considered representative	2.0	1.4	2.8	6.1	5.2
Indicative background concentration (average of values in red)								**4.6**

* These values have been adjusted to the same marine aerosol contribution (1.1 µg/m³) as the Westlake CAU

Figure E.1: Location of CAUs in vicinity of Penrose monitoring site (image sourced from Stats NZ https://datafinder.stats.govt.nz/)

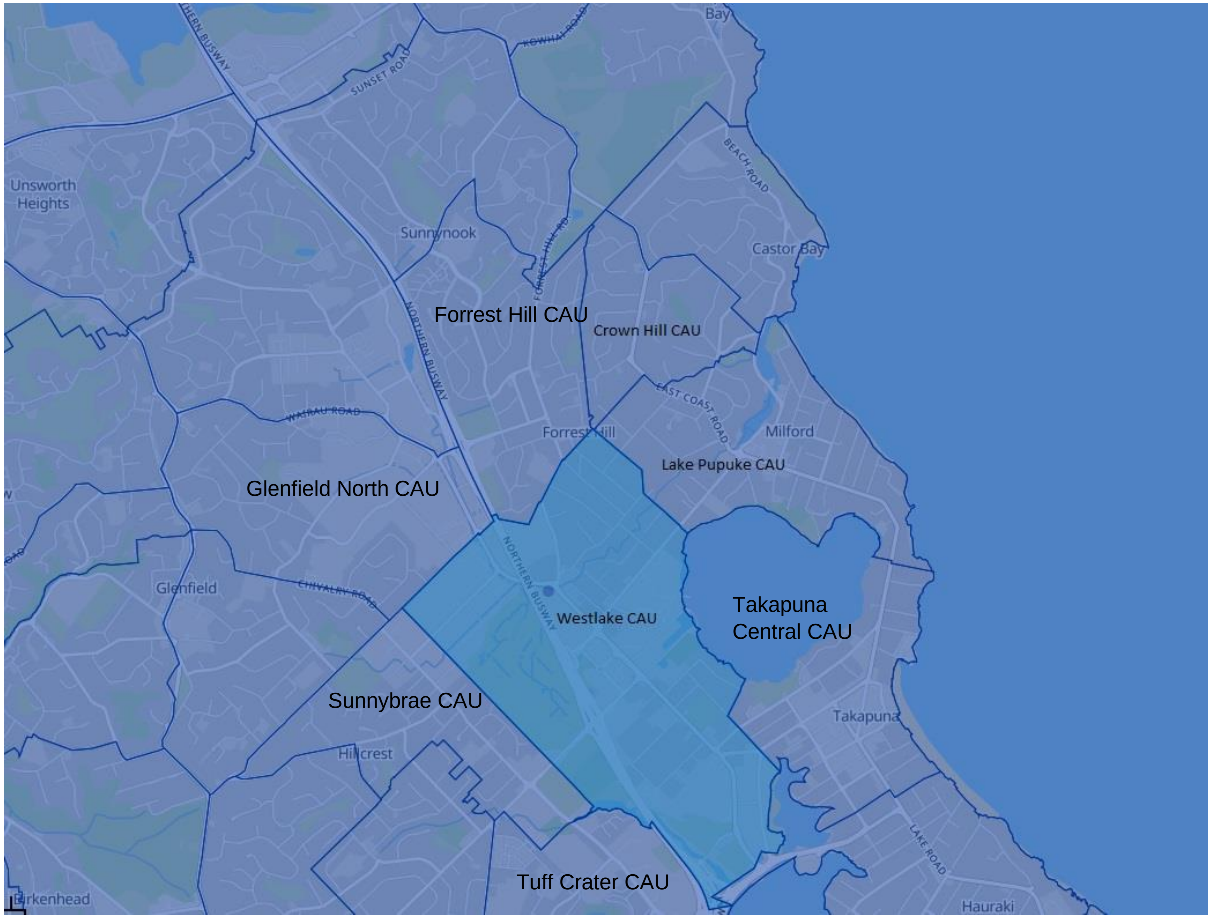

Figure E.2: Location of CAUs in vicinity of Takapuna monitoring site (image sourced from Stats NZ https://datafinder.stats.govt.nz/

Appendix F: NO_2 Auckland and Nelson CBDs

Auckland

Table F.1: Summary of NIWA TIM concentrations in central Auckland CAUs and adjacent CAUs used for determining background concentrations

CAU description	CAU number	NIWA TIM concentration (µg/m3)	Adopted concentration (µg/m3)	Description
Auckland Central West	514102	23.3	19.0	Expected high concentrations due to central Auckland location and possible street canyoning effects. However, concentrations are likely to be higher than what is considered background. Freemans Bay will have an emissions profile similar to Auckland Central CAUs.
Auckland Central East	514103	21.1	19.0	
Newton	514200	28.6	19.0	Heavily influenced by SH1 and SH16 intersections in the NIWA TIM so high concentration will be double counting traffic impacts.
Grafton West	514301	24.4	18.8	Strongly influenced by SH1 and SH16 intersection. Concentration is too high to be background and likely double counting traffic. Grafton East will likely represent conditions at this location
Arch Hill	515500	23.1	17.9	Influenced by SH1 and SH16 intersection. Concentration is too high to be background and likely double counting traffic. Grey Lynn East will likely represent conditions at this location.
Eden Terrace	515600	22.7	18.8	Strongly influenced by SH1 and SH16 intersections in the NIWA TIM so high concentration will be double counting traffic impacts.
Auckland Harbourside	514101	6.7	14.7	Open Port area with low traffic influence. The NIWA TIM will not capture the influence of shipping emissions. Monitored value from Parnell West will include shipping influence.
Adjacent CAUs				
Freemans Bay	514000	19.0	Same as NIWA TIM	Likely to be representative of central Auckland with high density occupation and transport
Grey Lynn East	515420	17.9	Same as NIWA TIM	Further removed from SH1 and SH16 influence but will have similar conditions to Arch Hill.
St Marys	515202	13.7	Same as NIWA TIM	Less likely to represent Central Auckland conditions as it will be more influenced by the coast

CAU description	CAU number	NIWA TIM concentration (µg/m3)	Adopted concentration (µg/m3)	Description
Parnell West	515902	14.5	14.7 (monitored)	Much larger CAU with the Domain park. Lower density occupation than central Auckland
Grafton East	514302	18.8	Same as NIWA TIM	Less influence from SH1 and SH16 junctions so likely to represent other Grafton and Eden Terrace CAUs.
Kingsland	517500	16.1	Same as NIWA TIM	Further out of central Auckland so unlikely to represent central Auckland locations.
Mt Eden North	518101	17.5	Same as NIWA TIM	More residential area North of the Auckland central CAUs.
St Lukes	517600	14.8	Same as NIWA TIM	Further out of central Auckland so unlikely to represent central Auckland locations.
Surrey Crescent	515431	14.0	Same as NIWA TIM	Includes Western Springs, so not as densely occupied as Auckland CBD and so unlikely to represent conditions in those CAUs.

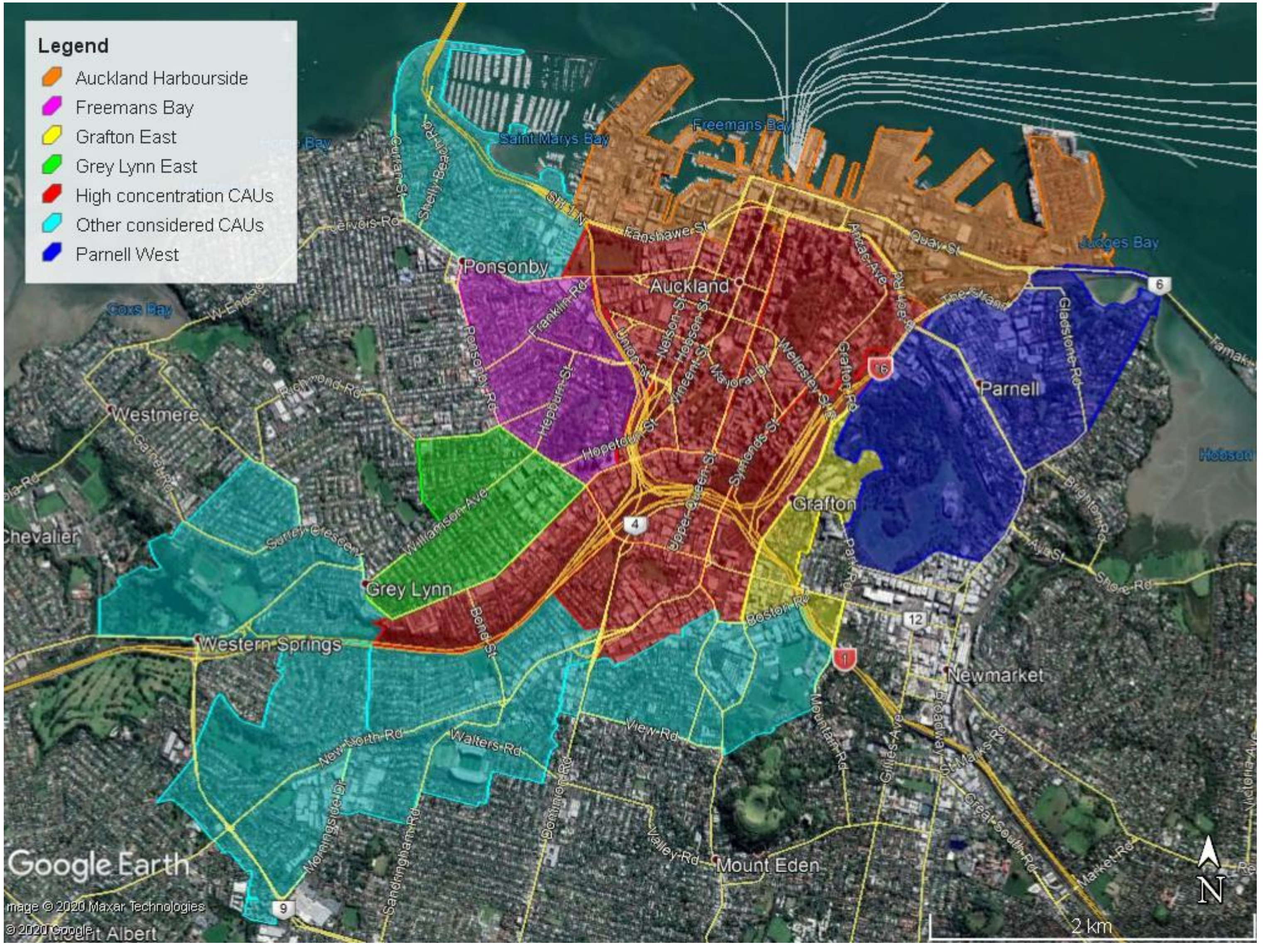

Figure F.1: Central Auckland CAUs with altered concentrations, and adjacent CAUs considered as representative locations

Nelson

Table F.2: Summary of NIWA TIM concentrations in Trafalgar (Nelson CBD) and adjacent CAUs

CAU description	CAU number	NIWA TIM concentration (µg/m^3)	Adopted concentration (µg/m^3)	Description
Trafalgar	582500	21.9	15.2	Concentration too high to represent background
Adjacent CAUs				
The Wood	582300	10.8	Same as NIWA TIM	Located northern side Maitai River
Bronte	582800	15.1	Same as NIWA TIM	Higher density occupation similar to Trafalgar
Kirks	582700	15.2	Same as NIWA TIM	Similar population and land use as Trafalgar
Washington	582402	10.3	Same as NIWA TIM	Elevated residential area above city not similar to Trafalgar
Britannia	582401	11.1	Same as NIWA TIM	Coastal CAU influenced by elevated terrain and coastal winds
Port Nelson	582200	9.9	Same as NIWA TIM	Only the port area, so not reflective of Trafalgar CAU
Representative concentrations				
Average all adjacent CAUs			12.1	Low compared to other adjacent CAUs of Bronte and Kirks
Average Bronte and Kirks CAUs			15.2	More likely to represent conditions in Trafalgar compared to other CAUs. NO_2 is expected to be higher due to being a city centre.

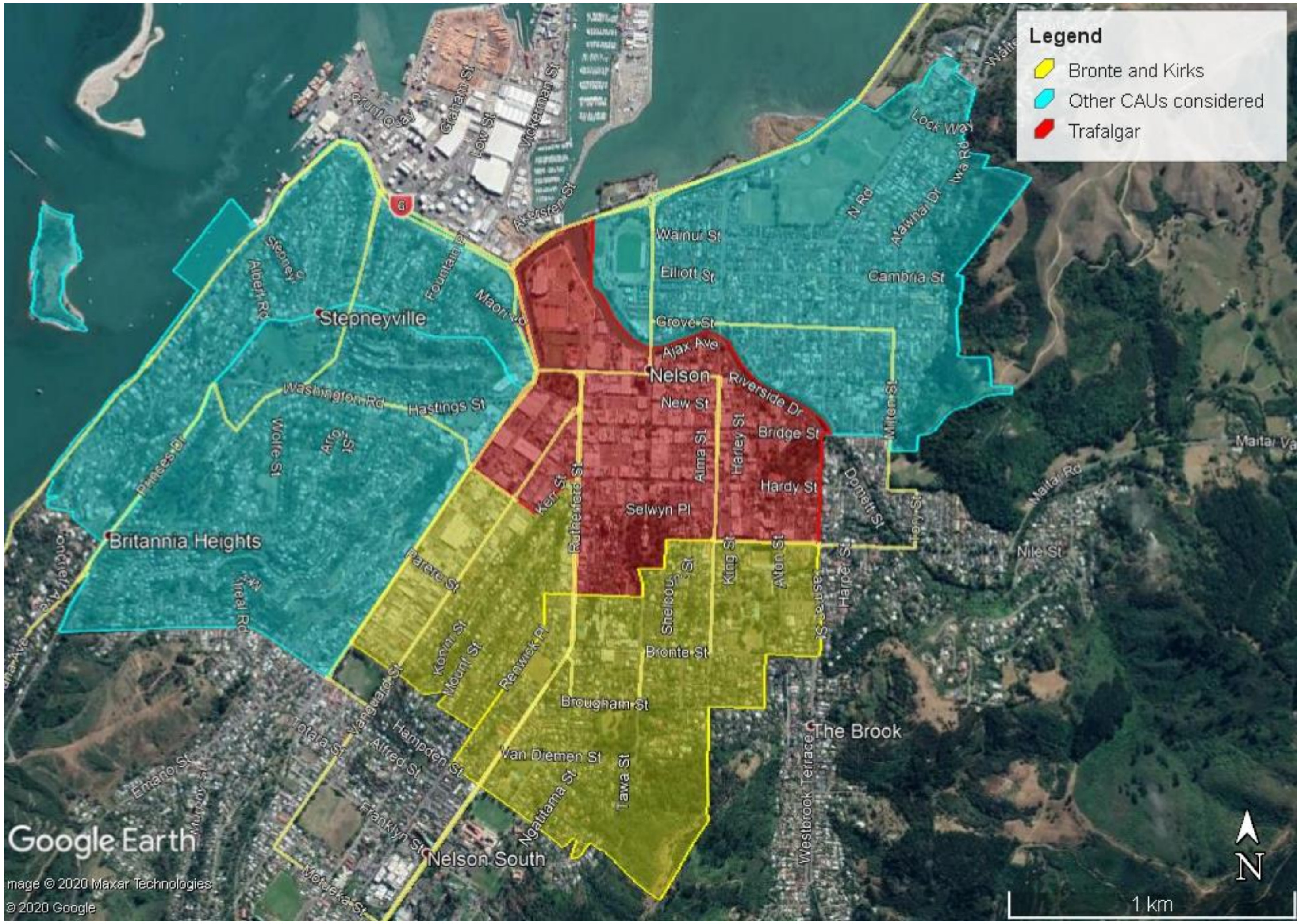

Figure F.2: Central Auckland CAUs with altered concentrations, and adjacent CAUs considered as representative locations