Use of Background Air Quality Data in Resource Consent Applications

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Use of Background Air Quality Data in Resource Consent Applications

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Contents

Executive Summary

There are significant differences in the way background air quality is handled in air quality assessments accompanying applications for resource consents. In this context background air quality means *ambient levels of air contaminants not associated with the sources that are explicitly included in the resource consent application*. The purpose of this document is to provide guidance on how background air quality should be assessed in Auckland.

The focus of this document is industrial assessments, reflecting an understanding that background air quality for transport assessments is the subject of guidance under preparation by the New Zealand Transport Authority. This guidance has been informed by current approaches taken to assessing background air quality in Auckland as well as a review of international approaches.

Procedures are described for consideration of background air quality in screening assessments and detailed assessments. For screening assessments, this guide provides default background air quality concentrations for Auckland airsheds. The guide also recommends using the New Zealand Transport Agency air quality screening model to establish the transport contribution for nitrogen dioxide and particulate matter for industries located near motorways and busy roads.

For detailed assessment, this guide includes appropriate procedures and recommendations for use of ambient air quality monitoring and meteorological data which is available from Auckland Council. By necessity, different approaches are recommended for different pollutants and different time averages. This guide is intended to be used in conjunction with the *Meteorological Datasets for the Auckland Region – User Guide* (Gimson et al, 2010).

For most situations it is expected that a detailed assessment of background air quality can be obtained by considering the results of existing ambient air quality monitoring. There may be occasions where no relevant information is available, and pre-project monitoring is required. This document discusses aspects of pre-project monitoring.

It is expected that the procedures outlined in this guide will be adopted for assessments of discharges to air from industrial sources in the Auckland region. Alternative approaches to the consideration of background air quality, such as the adoption of percentiles from ambient monitoring datasets, will not be considered appropriate.

1 Introduction

This user guide provides advice on the use of ambient air quality datasets to represent "background" air quality in assessments of environmental effects in the Auckland region.

1.1 What is background air quality?

Because the term 'background air quality' can mean various things, for the purpose of this document the following definition applies:

Background air quality means ambient levels of air contaminants not associated with the sources that are explicitly included in the resource consent application. This includes the contribution from any other anthropogenic sources such as industry, domestic heating and transport.

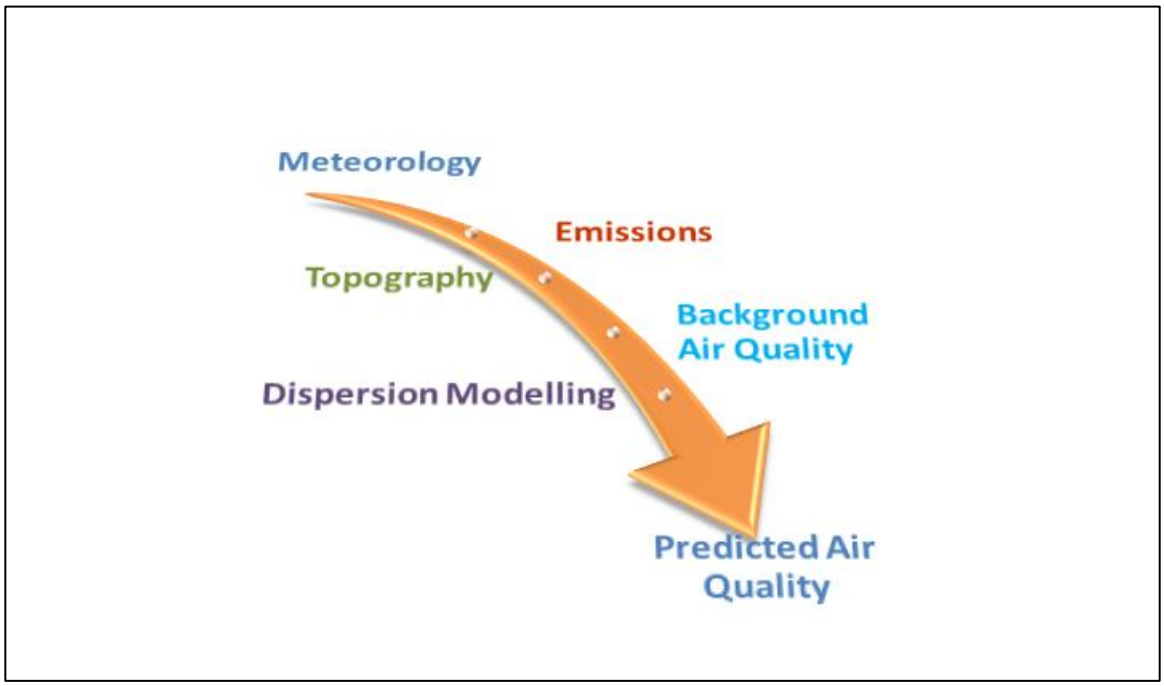
In other circumstances 'background air quality' can be defined as ambient levels of air contaminants due to non-anthropogenic sources or due to all sources other than industrial point sources. These definitions are not applicable in this document.

1.2 Why is background air quality important?

Air dispersion models are frequently used for assessing potential environmental effects of discharges to air. The models are used to predict air pollutant concentrations downwind of an emission source. A schematic of the dispersion modelling process is shown in Figure 1.1.

In order to *assess the cumulative impacts* of a discharge to air, the *predicted industry contribution* to ground level pollution concentrations must be added to *background concentrations* of air pollution.

Figure 1.1
Schematic of the dispersion modelling process



In the Auckland region, background concentrations of particulate and nitrogen dioxide are already close to, and in some locations exceeding, air quality assessment criteria. This means that the conclusions of an assessment are highly dependent on the choice of background data, and how this is combined with predicted ground level concentrations to assess cumulative impacts.

1.3 Purpose of this guide

This guide is intended to complement existing Auckland Regional Council (ARC) guidance for use of meteorological datasets in dispersion modelling studies in the Auckland region (Gimson et al, 2010). As well as providing information on the use of Auckland meteorological datasets, the meteorological datasets user guide provides advice on appropriate choice of dispersion models in the Auckland region.

This document builds on other existing guidance, in particular the *Good Practice Guide for Assessing Discharges to Air from Industry* (Ministry for the Environment, 2008) (hereafter referred to as the Industry Good Practice Guide) and the *Good Practice Guide for Atmospheric Dispersion Modelling* (MfE 2004). Both those Good Practice Guides include recommendations for the incorporation of background air quality data into atmospheric dispersion modelling. However, the recommendations are seen as ambiguous and they provide guidance for the national (rather than the Auckland regional) context.

Auckland Council understands that the New Zealand Transport Agency (NZTA) has undertaken to provide national guidance on background air quality for air quality

assessments for transport projects. The purpose of this document is to provide specific guidance on how background air quality should be considered in air quality assessments for resource consent applications in the Auckland region. The recommendations of this report are generally consistent with existing guidance and are intended to reflect current best practice. Where there is inconsistency, or where this document provides more specific guidance, the recommendations of this document supersede any previous guidance.

Awareness and implementation of this document is expected to provide for a consistent and good practice approach for the incorporation of background data into atmospheric dispersion modelling in the Auckland region. Guidance on the use of background air quality data should provide applicants and consultants with a clear understanding of the expectations of Auckland Council. This will provide for a more efficient and streamlined application process.

It is expected that the procedures outlined in this guide will be adopted for assessments of discharges to air from industrial sources in the Auckland region. Alternative approaches to the consideration of background air quality, such as the adoption of percentiles from ambient monitoring datasets, will not be considered appropriate.

This guide is a living document and will be updated periodically to reflect changing circumstances and, where applicable, lessons learned.

1.4 Target audience

The target audience of the document are applicants and their air quality consultants who prepare assessments of environmental effects to accompany applications for resource consents (discharge to air permits) in the Auckland region. Regulatory staff of the Auckland Council who process resource consent applications are also a target audience.

2 Overall approach and structure of this guide

When considering background levels of air quality, different pollutants and time averages require different approaches. This section outlines the overall recommended approach and which pollutants to consider. It also outlines relevant air quality assessment criteria.

2.1 Tiered assessment levels

This document builds on the guidance for consideration of background air quality provided by the Good Practice Guide for Assessing Discharges to Air from Industry (MfE, 2008). The Industry Good Practice Guide recommends a three tiered approach to air quality assessments to ensure that the level of assessment undertaken reflects the likely level of effect from a proposal. For example:

- A tier 1 preliminary assessment would be adequate for activities that are defined as controlled under the provisions of the Auckland Council Regional Plan: Air, Land and Water.[1]
- A tier 2 screening assessment is a relatively quick and easy assessment that is intended to provide a conservative assessment of likely air quality impacts. If the screening assessment predicts compliance with air quality criteria, then no further assessment is required.
- A tier 3 detailed assessment is required for sources or pollutants where a tier 2 screening assessment is not adequate to demonstrate compliance with air quality assessment criteria. The majority of discretionary activities (as defined by the Auckland Council Regional Plan: Air, Land and Water) will require a detailed tier 3 assessment, at least for some pollutants.

For most circumstances, the appropriate level of assessment of background air quality for each tier is described as follows:

- An application requiring only a tier 1 preliminary assessment will require no assessment of background air quality.
- An application requiring a tier 2 screening assessment uses conservative background air quality estimates based on monitoring from a similar area. Specific guidance for undertaking this type of assessment in Auckland, including default background values, is provided in Chapter 3 of this document.
- An application requiring a tier 3 assessment will often require a more detailed (less conservative) assessment of background air quality. Specific guidance for undertaking detailed assessment of background air quality in Auckland is provided by Chapter 4 of this document.

[1] Permitted activities do not require assessment so would not need to consider background air quality.

The recommendations of this report have been informed by a review of assessments in Auckland, as well as international approaches to background air quality assessment. These matters are discussed in Appendix 1. The results of ambient air quality monitoring have also been reviewed and are summarised in Appendix 2.

2.2 Pollutants considered

This report focuses on the key pollutants listed in Table 2.1 below. These are the pollutants which are most important in the context of this report, because they are common to most resource consent applications, and existing ambient concentrations tend to be elevated due to emissions from motor vehicles and domestic fires. Some guidance for estimating background concentrations of other pollutants is provided in Section 4.1.2 of this report.

Appendix 2 includes a review of ambient air quality monitoring results in Auckland. This demonstrates that the contaminants of most concern in Auckland are PM_{10}, $PM_{2.5}$ and NO_2. Concentrations of these contaminants are approaching, or exceeding, air quality criteria in the Auckland region.

2.3 Assessment criteria

Air quality criteria for Auckland are given in Table 2.1. They combine the most recent of the national environmental standards (NES) for air quality,[2] the Auckland Ambient Air Quality Standards in the Proposed Auckland Unitary Plan (AC, 2013) and the World Health Organisation global guidelines (WHO, 2006). The allowable number of exceedances per year of the standards is noted where relevant.

Auckland Council recognises that the WHO daily guideline for sulphur dioxide has not yet been formally adopted. Its inclusion in this guide, therefore, is based on a precautionary approach pending the outcome of the Auckland Unitary Plan process.

As noted above, this guide is a living document and will be updated periodically to reflect changing circumstances.

[2] Resource Management (National Environmental Standards for Air Quality) Regulations 2004.

Table 2.1
Auckland air quality criteria

Contaminant	Standard	Averaging Time	Number of permissible exceedances per year
Particles less than 10 microns (PM_{10})	50 µg/m^3	24 hour	1
	20 µg/m^3	Annual	0
Particles less than 2.5 microns ($PM_{2.5}$)	25 µg/m^3	24 hour	0
	10 µg/m^3	Annual	0
Nitrogen dioxide (NO_2)	200 µg/m^3	1 hour	9
	100 µg/m^3	24 hour	0
	40 µ/m^3	Annual	0
Carbon monoxide (CO)	10 mg/m^3	8 hours*	one 8-hour period
	30 mg/m^3	1 hour	0
Sulphur dioxide (SO_2)	350 µg/m^3	1 hour	9
	570 µg/m^3	1 hour	0
	20 µg/m^3	24 hour	0
Ozone (O_3)	150 µg/m^3	1 hour	0
	100 µg/m^3	8 hour	0
Lead	0.2 µg/m^3	3 months**	0
Benzene	3.6 µg/m^3	Annual	0
Benzo[a]pyrene	0.0003 µg/m^3	Annual	0
1,3-Butadiene	2.4 µg/m^3	Annual	0
Formaldehyde	100 µg/m^3	30 minutes	0
Acetaldehyde	30 µg/m^3	Annual	0
Mercury (inorganic)	0.33 µg/m^3	Annual	0
Mercury (organic)	0.13 µg/m^3	Annual	0
Chromium VI	0.0011 µg/m^3	Annual	0
Chromium metal and Chromium III	0.11 µg/m^3	Annual	0
Arsenic (inorganic)	0.0055 µg/m^3	Annual	0
Arsine	0.055 µg/m^3	Annual	0

* running mean
** moving average calculated monthly

3 Determining background concentration for a screening assessment

This section outlines a recommended procedure for estimating background air quality for tier 2 screening assessments in the Auckland region.

A tier 2 screening assessment is described in the Industry Good Practice Guide (MfE 2008) as a relatively quick and easy assessment that is intended to provide a conservative assessment of likely air quality impacts. If the screening assessment predicts compliance with air quality criteria, then no further assessment is required.

3.1 Using default background values in a screening assessment

The methodology for estimating the industrial contribution to ground level concentrations is described in Section 7.3.1 of the Industry Good Practice Guide (MfE 2008), and is discussed further in Section 4.2 of the ARC meteorological datasets user guide (Gimson et al, 2010).

To estimate the *cumulative* ground level concentration of contaminants for a screening assessment, the industrial contribution to the ground level concentration should be added to the relevant default background concentration specified in Table 3.1 or Appendix 3 for the area in which the receptors are located.

If the site is in a roadside location as defined in Section 3.3, either the default values specified in Table 3.3 should be used (carbon monoxide, sulphur dioxide and/or benzene) or else the transport component should be estimated separately (nitrogen dioxide and/or particulate matter). Further details are provided in Section 3.3.

If the predicted cumulative concentration (i.e., industry + transport + default background) exceeds the relevant air quality assessment criteria, as shown in Table 2.1, then a detailed assessment should be carried out.

3.2 Default values

Figure 3.1 shows all Auckland airsheds and Figure 3.2 presents all Auckland air quality monitoring stations. Table 3.1 presents default background concentrations values for carbon monoxide, nitrogen dioxide, sulphur dioxide and benzene. Default background concentration values for PM_{10} and $PM_{2.5}$ are provided in Appendix 3. (These are listed by census area unit and are too numerous to reproduce in the main body of this report).

Additional default values for roadside locations are provided in Table 3.2 and discussed in more detail in Section 3.3.

The airshed designation “Auckland Region” has been given to areas outside gazetted airsheds, but within the Auckland Region. This is considered a rural location.

The methodology for determining these default values is described in detail in Appendix 3. The overall approach was to use monitoring data, where available, and to select values that are reasonably conservative for assessment purposes.

The monitoring sites and data considered are described in Appendix 2.

Table 3.1
Background air quality default values

Contaminant	Airshed	Averaging Time	Default Value
Carbon monoxide	Auckland Urban	1-hour 8-hour	5.0 mg/m^3 3.0 mg/m^3
	Auckland Region, Beachlands, Helensville, Kumeu, Maraetai, Pukekohe, Riverhead, Snells Beach, Waiheke, Waiuku, Warkworth, Wellsford.	1-hour 8-hour	5.0 mg/m^3 2.0 mg/m^3
Nitrogen dioxide	Auckland Urban	1-hour 24-hour Annual	75 $\mu g/m^3$ 39 $\mu g/m^3$ 13 $\mu g/m^3$
	Beachlands, Helensville, Kumeu, Maraetai, Pukekohe, Riverhead, Snells Beach, Waiheke, Waiuku, Warkworth, Wellsford.	1-hour 24-hour Annual	75 $\mu g/m^3$ 37 $\mu g/m^3$ 13 $\mu g/m^3$
	Auckland Region	1-hour 24-hour Annual	41 $\mu g/m^3$ 16 $\mu g/m^3$ 4 $\mu g/m^3$
Sulphur dioxide	Auckland Urban	1-hour 24-hour	20 $\mu g/m^3$ 8.0 $\mu g/m^3$
Benzene	Auckland Urban	Annual	1.0 $\mu g/m^3$

It should be noted that some judgement is required in the use of these background default values. For example, the default values for sulphur dioxide would not be sufficiently conservative for industry located at or near the Ports of Auckland. Similarly, the default values for nitrogen dioxide would not be sufficiently conservative for industry located in the central business district.

Figure 3.1
Location of Auckland Airsheds

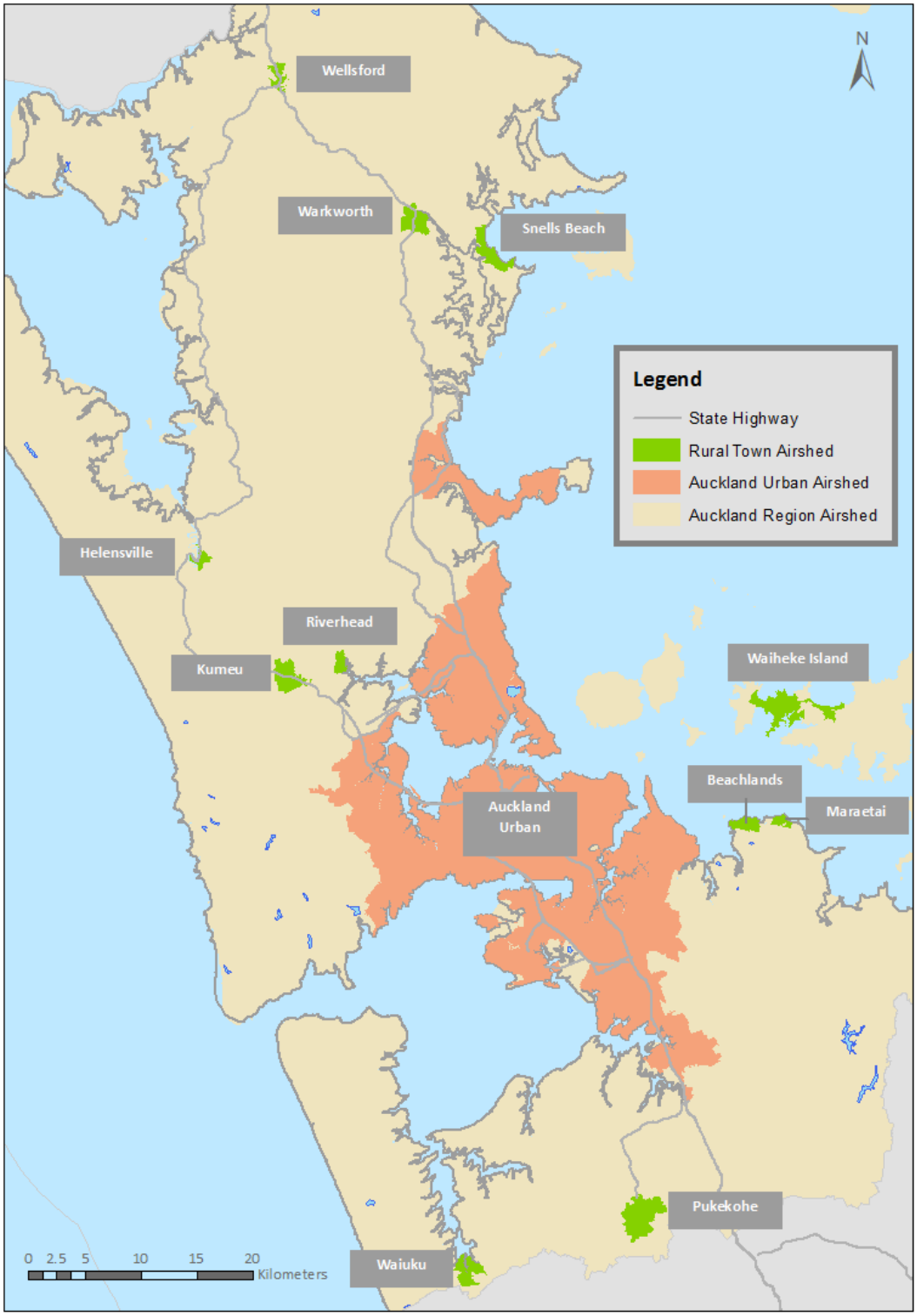
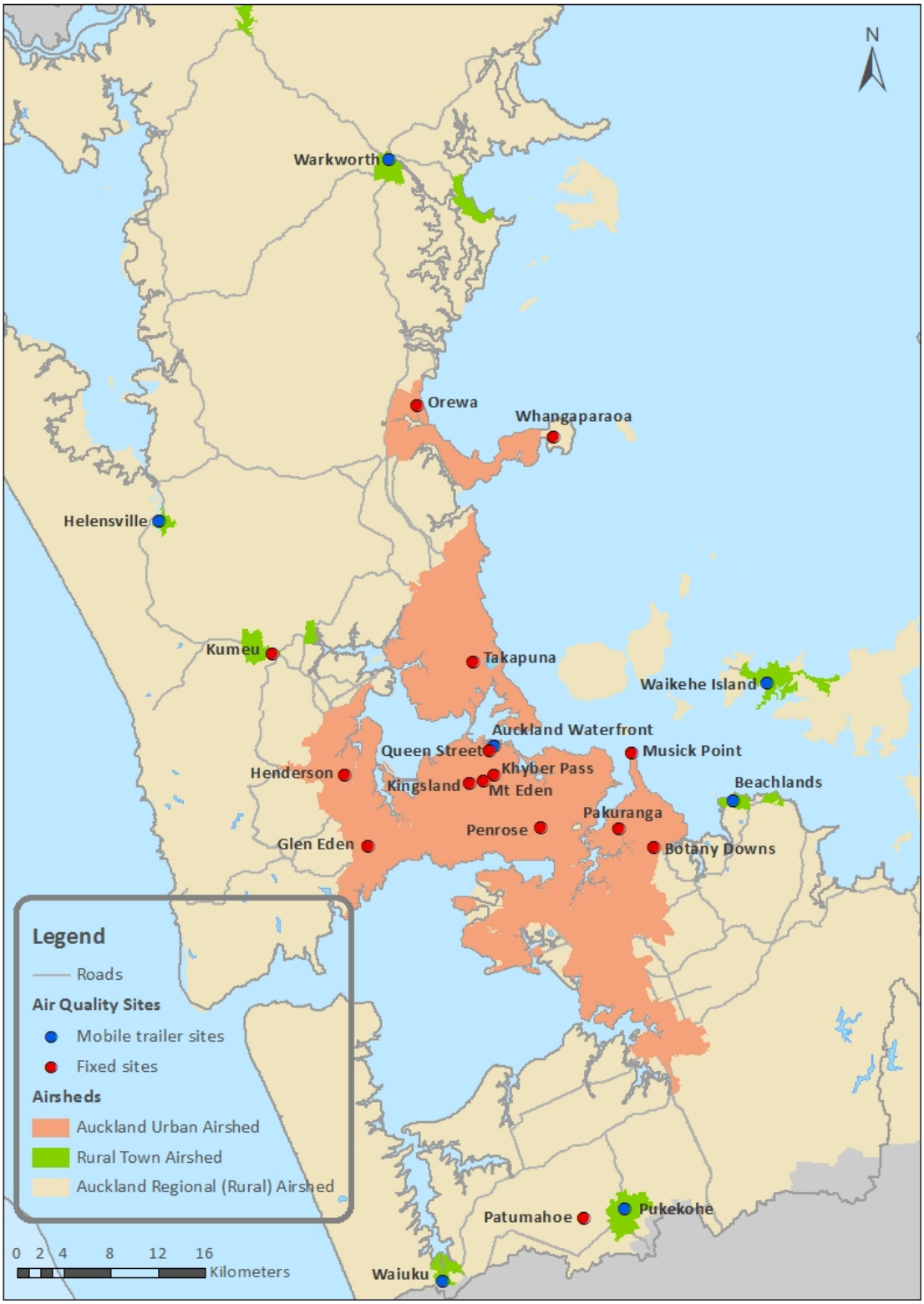


Figure 3.2
Location of Auckland Air Quality Monitoring Stations (as at Dec 2013)



3.3 Roadside locations

Industry located within the distances specified in Table 3.2 may be considered to be "roadside" locations. These locations should use the default values provided in Table 3.3 (carbon monoxide, sulphur dioxide and benzene). For nitrogen dioxide and particulate matter levels, the New Zealand Transport Agency air quality screening model should be used to estimate the transport contribution to downwind of the plant.

The air quality screening tool is designed to provide a conservative (worst case) assessment for emissions of nitrogen dioxide and PM_{10} from a single road. [3] The tool is available online at:

http://air.nzta.govt.nz/screening-model

To assess emissions of $PM_{2.5}$, users may use the screening model and assume that all PM_{10} is $PM_{2.5}$.

Table 3.2
Roadside locations where transport component requires consideration

Contaminant	Road [4]	Distance between industry and road edge
Nitrogen dioxide	Motorway or strategic arterial	300 m
	Regional arterial	150 m
PM_{10} and $PM_{2.5}$	Motorway or strategic arterial	150 m
	Regional arterial	70 m

Table 3.3
Background air quality default values for roadside locations

Contaminant	Airshed	Averaging Time	Default Value
Carbon monoxide	Auckland Urban	1-hour 8-hour	7.0 mg/m^3 4.5 mg/m^3
Sulphur dioxide	Auckland Urban	1-hour 24-hour	42 $\mu g/m^3$ 15 $\mu g/m^3$
Benzene	Auckland Urban	Annual	2.0 $\mu g/m^3$

[3] NB: To calculate the contribution from a single road, users should set background concentrations to zero. Further information about this tool is available on the NZTA website.

[4] Strategic arterial and regional arterial roads are defined in the Regional Arterial Road Plan (ARTA, 2009) and reproduced in full in Appendix 4.

4 Background air quality in detailed assessments

A detailed assessment should be carried out when the cumulative concentration predicted by a screening assessment exceeds relevant air quality assessment criteria. The detailed (Tier 3) assessment process is described in Section 8 of the Industry Good Practice Guide (MfE, 2008).

Detailed assessments typically use atmospheric dispersion models to predict maximum ground level concentrations of contaminants resulting from the industry. *Background* air quality data needs to be considered together with the *predicted* ambient concentrations to assess the *cumulative* impact of the industry.

For long-term (annual) averaging times, simple addition of the background air quality and the predicted ambient concentrations is appropriate. However, for short-term concentrations, the preferred approach is to add hourly background (from a suitable ambient monitoring site) to the hour-by-hour predicted industry contribution. This section describes the procedure and other issues to be addressed for a detailed assessment of background air quality for short-term concentrations.

4.1 Detailed assessment of background air quality

The location and timing of elevated background concentrations may not coincide with high concentrations from industrial sources. This means that, for short-term air quality criteria, simple addition of the maximum industrial contribution to peak background concentrations can overestimate cumulative concentrations. To address these issues, the Industry Good Practice Guide (MfE, 2008) states that the best predictive technique is to use hourly, sequential ambient air quality monitoring data that are recorded in the airshed of interest, and then add the hour-by-hour predicted concentrations.

It should be noted that this approach requires the use of meteorological data for the same year as the ambient air quality monitoring data.

For situations where a detailed assessment of background air quality is required, it is recommended that:

- The industry contribution should be estimated for 2005 and 2007, in accordance with the Industry Good Practice Guide (MfE 2008) as well as the ARC Meteorological Datasets User Guide (Gimson et al, 2010).
- A representative ambient monitoring site should be selected. Guidance on representative monitoring sites is provided in section 4.2. This includes consideration of the industry being assessed in relation to the monitoring site location to avoid ‘double-counting’.
- The assessment needs to justify the choice of representative monitoring site. If there are no representative ambient monitoring sites, options for estimating background air quality when there is no representative site are discussed in Section 4.3.

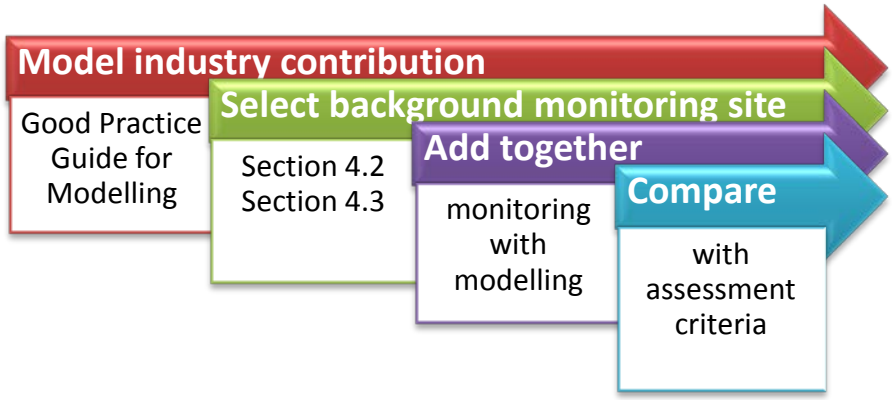
- Hourly background concentrations from the suitable ambient monitoring site (or sites) for the assessment year (2005 and 2007) should be added to the hour-by-hour predicted industry contribution for the same year.
- The predicted cumulative concentrations should be compared with the appropriate assessment criteria. Section 4.4 provides guidance on assessment criteria.

The above recommendations are summarised in Figure 4.1.

For pollutants that are formed downwind, or not addressed above, guidance is provided in the following sections (4.1.1 – 4.1.4):

- Downwind conversion of nitrogen oxides to nitrogen dioxide (section 4.1.1).
- Formation of secondary pollutants such as ozone and particles (section 4.1.2).
- Non-criteria pollutants (section 4.1.3).

Figure 4.1
Detailed Assessment of Background Air Quality



4.1.1 Nitrogen oxides

Ambient air contains around 78% nitrogen. The combustion of any fuel in the presence of air therefore, results in the formation of nitrogen oxides. Nitrogen oxides are emitted primarily as a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2). Nitric oxide usually makes up around 95 per cent (by volume) of combustion emissions from boilers with the remaining 5 per cent being nitrogen dioxide. With respect to human health, nitrogen dioxide is the pollutant of most concern.

The ratio of nitric oxide to nitrogen dioxide emissions from other sources can, however, vary significantly. Euro 4 diesel engines, fitted with diesel oxidation catalysts, can

contain up to 60% nitrogen dioxide.[5] Ultra-lean combustion in spark-ignited natural gas engines results in ratios greater than 0.5 whilst engines with emissions below 1 g/bhp-hr of nitrogen oxides yield a ratio greater than 0.90.[6]

Nitric oxide reacts with ozone (O_3) in the atmosphere to form nitrogen dioxide and oxygen.

$$NO + O_3 \rightarrow NO_2 + O_2$$

There are a number of methods for estimating the downwind conversion of nitric oxide to nitrogen dioxide. This guide recommends a tiered approach from simple to complex as shown in Figure 4.2. In simple terms, assessment should commence with the screening methodology (in which all nitric oxide is assumed to be nitrogen dioxide) and if this turns out to be too conservative then use more complex methodology as recommended later. If the more advanced assessment still results in elevated maximum predicted downwind concentrations, mitigation is recommended.

In practice, the reaction of nitric oxide to nitrogen dioxide is limited by the:

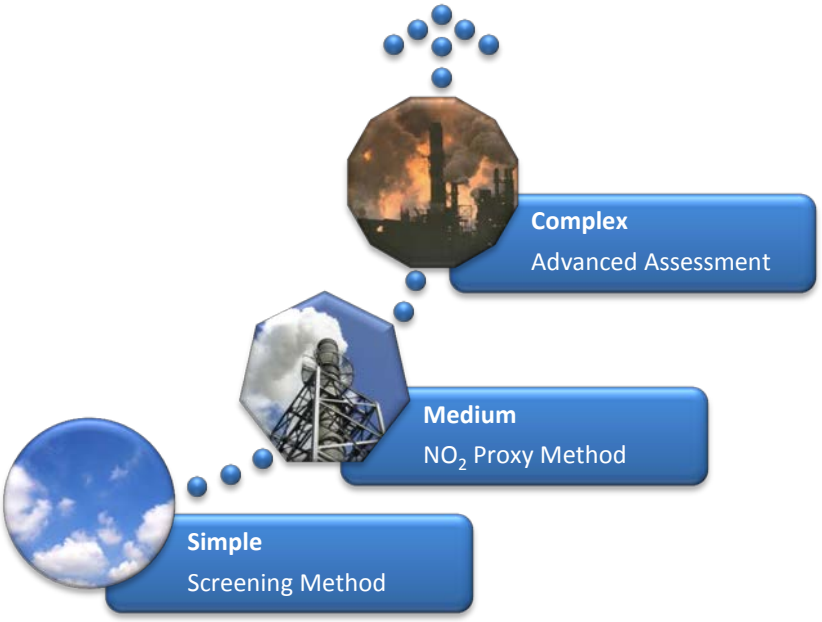
- amount of ozone and other reactive organic compounds available in the atmosphere;
- rate of mixing of ozone in the atmosphere with the plume of gases discharging from the stack;
- rate of chemical reaction;
- reverse reaction (from nitrogen dioxide back to nitric oxide).

The above factors mean that concentrations of nitrogen dioxide are normally less than nitric oxide (except at very low concentrations).

[5] Retrofit or renew the old diesel fleet: the NO_2 pollution in Hong Kong, Tian and Yu, May 2011. Available here: http://www.legco.gov.hk/yr10-11/english/panels/ea/ea_iaq/papers/ea_iaq0526cb1-2241-1-e.pdf

[6] Impact of oxidation catalysts on exhaust [NO2]/[NOx] ratio from lean-burn natural gas engines, Olsen et al, Journal of the Air & Waste Management Association 60.7 (July 2010): p867(8).

Figure 4.2
Methods for Assessing Conversion of Nitrogen Oxides to Nitrogen Dioxide



NO_2 Screening method

For a screening assessment it can be assumed that all nitrogen oxides from the modelled emission is nitrogen dioxide. The predicted ground level concentration of nitrogen dioxide is therefore;

$$[NO_2] = [NO_x]_{mod} + [NO_2]_{bkd}$$

Where:

$[NO_2]_{bkd}$ = background nitrogen dioxide

$[NO_x]_{mod}$ = is the nitrogen oxides concentration at the receptor estimated from the modelled nitrogen oxides emissions. In this very conservative screening approach, all NOx is assumed to be NO_2 (i.e. NOx as NO_2).

NO_2 Proxy method

Where the screening assessment predicts unacceptable concentrations, the 'proxy' method is recommended.

A comparison of the proxy method with the ozone limiting method that is recommended in the Industry Good Practice Guide (MfE, 2008) is provided in Appendix 3. In summary, the proxy method is considered appropriate for Auckland because it avoids double counting of background nitrogen dioxide and background ozone. The proxy method is

also the recommended 'baseline' method for assessment of nitrogen dioxide in the UK (Environment Agency, 2006b).

The proxy method assumes that all of the nitric oxide is converted into nitrogen dioxide, but that this process is limited by the availability of ozone as follows:

$$\mathbf{[NO_2] = [NO_x]_{mod} \times F(NO_2) + [Proxy\ NO_2]}$$

Where:

[Proxy NO_2] =	combined nitrogen dioxide with ozone (as nitrogen dioxide equivalents) from a suitable background monitoring site.
$[NO_x]_{mod}$ =	is the nitrogen oxides concentration at the receptor estimated from the modelled nitrogen oxides emission
$F(NO_2)$ =	is the mass fraction of nitrogen dioxide in the nitrogen oxides emissions from the source . Applicants should note that F varies depending on the source.

Default values for combined nitrogen dioxide with ozone [Proxy NO_2] as nitrogen dioxide equivalents have been derived for Auckland based on monitoring data from sites where these pollutants were monitored concurrently in 2005 and/or 2007. This is discussed further in Appendix 3. Default values are provided below in Table 4.1.

Table 4.1
Default background combined nitrogen dioxide with ozone [Proxy NO_2] concentrations

Contaminant	Location	Averaging Time	Default Value
Total $NO_2 + O_3$ [Proxy NO_2]	Roadside*	1-hour 24-hour	113 µg/m^3 75 µg/m^3
	All other locations	1-hour 24-hour	95 µg/m^3 75 µg/m^3

*As defined in Table 3.2

Alternatively, the hour by hour concentration of background combined nitrogen dioxide with ozone [Proxy NO_2] can be added to the hour by hour predictions of modelled nitrogen dioxide $[NO_x]_{mod} \times F(NO_2)$. Concurrent monitoring results for combined nitrogen dioxide with ozone are available for Musick Point, Patumahoe and Kingsland.

For hour by hour modelling in urban areas, the Kingsland data should be used because this is the only urban site with both nitrogen dioxide and ozone monitoring data. (NB: This site only has data for the year 2005). The Kingsland data should also be used for roadside locations.

NO_2 - Advanced assessments

Where the methods described above predict unacceptable concentrations of nitrogen dioxide, use of the chemistry modules provided with advanced dispersion models may be considered.[7] However this requires detailed input data and advanced knowledge of dispersion modelling. Any advanced assessment needs to be undertaken by a suitably qualified expert with relevant experience and the methodology should be agreed with Auckland Council staff before the assessment is undertaken.

Alternative methods, such as the empirical approach used in the US, also require Council approval prior to undertaking the assessment. To date this method has not been validated or rigorously assessed for the Auckland (or New Zealand) context.

Some historical air quality assessments for power plants have used the Janssen equation (Janssen et al, 1988) to calculate the conversion of nitrogen oxides to nitrogen dioxide. This equation has not been validated or rigorously assessed for its relevance in Auckland. It is not generally considered appropriate for Auckland.

4.1.2 Atmospheric chemistry

For large sources of combustion emissions, such as power plants, the applicant will also need to consider issues that are relevant to both atmospheric dispersion modelling of the proposed discharges and the assessment of background air quality including:

- the formation of the secondary contaminant ozone;
- the formation of secondary particles from sulphur and nitrogen discharges;

For these large sources, the approach to estimation of background air quality and dispersion modelling should be discussed with Auckland Council staff at an early stage of the assessment.

4.1.3 Recommended approach for other pollutants

This report focuses on the pollutants listed in Table 2.1. For other pollutants the overall approach for assessment of background concentrations is likely to be similar, and should consider the following:

- Is the modelled concentration significant compared to the assessment criteria?
- Are there any other nearby sources of the pollutant?

If there are local sources, background concentration will need to be estimated based on any available monitoring. Auckland Council staff should be consulted to confirm availability of monitoring information. If there are no available monitoring data, modelling or monitoring to estimate background concentrations of non-criteria pollutants may be necessary.

[7] For example, AERMOD, CALPUFF, ADMS.

The extent of assessment required will depend on the predicted maximum ground level concentration from the source, and how likely it is that the air quality assessment criteria could be exceeded. This will need to be assessed on a case by case basis. Auckland Council staff should be consulted prior to undertaking any detailed assessment.

4.1.4 Assessment of existing discharges

There is a risk of "double counting" the contribution of an existing industrial emission when the predicted industrial contribution is added to background air quality from a nearby monitoring site.

Most industrial emission sources have variable emission rates, and do not have continuous emissions monitoring. This means that the actual contribution of the industry to ambient air quality on any given day cannot be accurately quantified. In these cases, the industry contribution at the monitoring site cannot be easily removed from ambient air quality monitoring results.

Other approaches that are used internationally include:

- Wind rose analysis to remove the influence of the existing industry from the background air quality dataset, only on days when the plume coincides with the monitoring site. This approach is recommended in British Columbia, the United Kingdom and the United States. This would not be feasible if there were other significant sources in the same direction as the industry. There are very few scenarios where this approach would be appropriate in Auckland.
- For major sources that have well quantified emissions and are close to an ambient monitoring site, background air quality can be calculated by subtracting the modelled industry contribution from the measured concentration. This approach is recommended by the UK Environment Agency for major coal fired power stations and is unlikely to be applicable in Auckland.

For most assessments, the most practical way to address this issue is to undertake the assessment based on local background air quality results in addition to background air quality results from one or more other monitoring sites that most closely represent the site under consideration (as discussed in Section 4.3).

4.2 Representative ambient monitoring sites

The monitoring site should generally be in the same airshed and be representative of the assessment location. Parameters that should be considered include:

a. Local topography and meteorology,

b. Traffic volumes and distance to roads,

c. Likely emissions from domestic heating (related to population density and housing characteristics),

d. Location of the industry being assessed in relation to the representative monitoring site location,

e. Other industrial emission sources. To assist with the comparing emission sources, Auckland Council can provide emissions inventory information for the area surrounding ambient monitoring sites as well as the assessment location.

Table 4.2 lists representative air quality monitoring sites for different locations in Auckland, for each of the contaminants considered. Detailed information about the monitoring sites is available in *The Ambient Air Quality Monitoring Network in the Auckland Region* (ARC, 2006). Comparative analysis information is further available in three *Quality Reviews of ARC Meteorological Data Collected via Air Quality Monitoring* reports (Griffiths 2007, Griffiths 2008, and NIWA 2009). The information in these publications is useful for justifying the choice of a representative monitoring site. Updated site metadata is available on request from Auckland Council staff.

Table 4.2
Representative air quality monitoring sites

Contaminant	Location	Representative Monitoring Site(s)
Carbon monoxide	Roadside	Pakuranga, Penrose, Takapuna
	Urban	Henderson, Glen Eden
	Rural Town	Pukekohe
Nitrogen dioxide	Roadside	Penrose, Takapuna
	Urban	Glen Eden, Henderson, Kingsland, Mt Eden, Musick Point,
	Rural	Patumahoe, Waiheke Island
	Rural Town	Pukekohe, Warkworth, Waiuku
PM_{10}	Roadside	Pakuranga, Penrose, Takapuna
	Urban	Botany Downs, Glen Eden, Henderson, Kingsland, Mt Eden,
	Rural	Patumahoe, Waiheke Island, Whangaparaoa
	Rural Town	Helensville, Kumeu, Pukekohe, Orewa, Waiuku, Warkworth
$PM_{2.5}$	Roadside	Penrose, Takapuna
	Urban	Kingsland, Mt Eden
	Rural	Patamahoe, Whangaparoa
	Rural Town	Helensville, Pukekohe, Warkworth
Sulphur dioxide	Roadside	Penrose
	Port	Auckland Waterfront

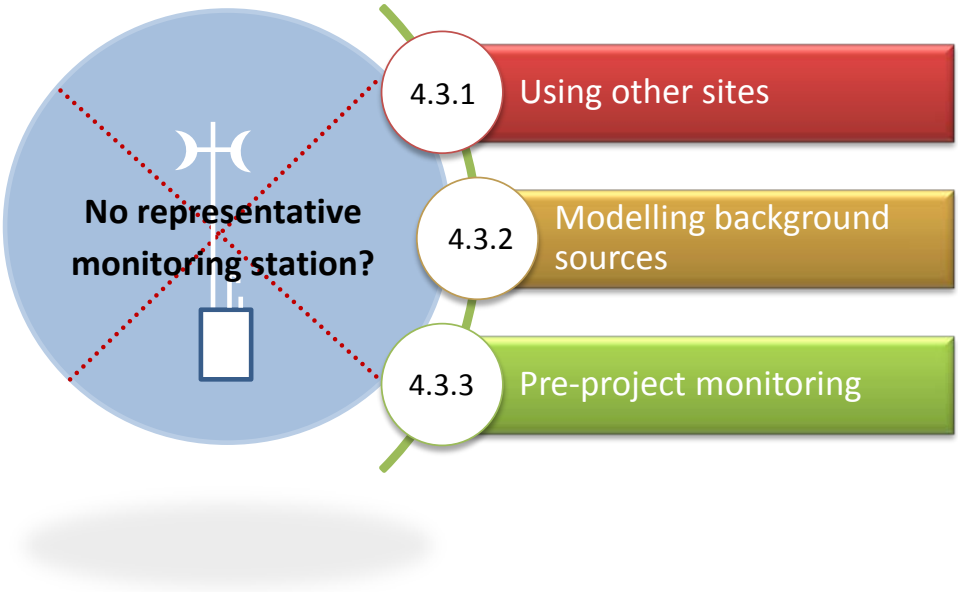
4.3 Options when there is no representative monitoring site

If there is no representative monitoring site, options include:

- Repeat the assessment for two or more sites that most closely represent the location
- Modelling other sources in the area,
- Pre-project monitoring.

These are summarised in Figure 4.3 and discussed in more detail below. Before proceeding with any of these options, the assessment of background air quality should be discussed with Auckland Council early in the assessment process.

Figure 4.3
Alternatives when there is no representative monitoring site



4.3.1 Repeat the assessment for two or more background monitoring sites

If there is not a representative ambient monitoring site, the assessment could be repeated for two or more ambient monitoring sites that most closely represent the industrial site under consideration.

The results should be presented for each site along with a qualitative, comparative assessment of the applicant's location and how this compares to the ambient monitoring sites. This should explicitly consider the following parameters for each monitoring site and the industrial location:

a. Local topography and meteorology,

b. Traffic volumes and distance to roads,

c. Likely emissions from domestic heating (related to population density and housing characteristics),

d. Location of the industry being assessed in relation to the representative monitoring site location,

e. Other industrial emission sources. To assist with comparing emission sources, Auckland Council can provide emissions inventory information for the area surrounding ambient monitoring sites as well as the assessment location.

If the conclusion of the assessment depends on which ambient monitoring site is selected, pre-project monitoring should be considered.

4.3.2 Dispersion modelling to estimate background concentrations

Modelling of transport and domestic emissions to estimate background air quality is not generally appropriate. This is because:

a. There is generally very good ambient monitoring data for most areas of Auckland already available; and

b. It would be a very large and costly exercise to model all sources with no guarantee of sufficient accuracy to establish background concentrations.

However, dispersion modelling may be a viable option in locations where:

- There are a small number of emissions sources in the area for which reliable emission data are available, and
- Any contribution to ambient levels from other hard-to-characterise sources (such as vehicle emissions, or domestic fires) is negligible (for example, pollutants such as hydrogen fluoride), or

- There is an ambient monitoring site that is representative of the background air quality in other respects (for example, it doesn't include impacts from industry).

For example, the contribution from other hard-to-characterise sources to background air quality might be negligible for certain non-criteria pollutants such as hydrogen fluoride.

For circumstances where there is a monitoring site that is representative of background air quality in other respects, the procedure would be:

- Identify the most appropriate representative monitoring site based on topography, meteorology, distance and traffic on nearby roads, and domestic heating emissions.
- Identify other industrial emission sources in the area based on review of Auckland Council consent records.
- Undertake dispersion modelling to estimate the likely industry contribution to ground level concentrations using the same methodology described in Section 4.1, but including all significant industrial sources in addition to the assessment site.

The onus would be on the applicant to obtain emission data for other sources and to undertake detailed dispersion modelling for these sources. Industrial emissions data are likely to be available from Auckland Council consent files but may require significant pre-processing before being suitable for use in an assessment.

This approach is relatively complex. It may be justified in industrial areas where the Penrose monitoring site is not considered to be representative of background air quality and there are other industrial sources present. This type of assessment should not be undertaken without prior consultation with Auckland Council staff.

4.3.3 Pre–project monitoring

In most situations it is expected that a quantitative assessment of background air quality can be obtained by considering the results of existing ambient air quality monitoring.

However, pre-project monitoring is likely to be necessary for:

- significant projects where there is no representative background monitoring, or
- projects where the conclusions of the assessment are dependent on the choice of ambient monitoring site, and there is no clear justification for selection of the most representative monitoring site.

For detailed assessment of background air quality, it is important that the background air quality data and meteorological data are measured at the same time. Therefore, it is expected that in most cases the pre-project monitoring will be used to determine the most representative background monitoring site (or sites) from Table 4.2. Dispersion modelling should then be undertaken based on 2005 and 2007 meteorological data and ambient monitoring data.

For significant projects where there is no representative monitoring data available from 2005 and 2007, a meteorological dataset for the pre-project monitoring period would also need to be developed. This is a complex and highly specialised task and should not be undertaken without consulting Auckland Council staff.

The Ministry for the Environment's Good Practice Guide on Air Quality Monitoring and Data Management (MfE, 2009) provides recommendations on ambient air quality monitoring. The monitoring should run continuously for at least 12 months, and preferably for 24 months, to account for variability in meteorological conditions.

Pre-project monitoring is typically only necessary for significant transport projects or large, industrial greenfield sites with no representative data. Parties considering pre-project monitoring should consult Auckland Council first.

4.4 Comparison of cumulative effects with assessment criteria

The predicted cumulative concentration should be compared with the assessment criteria specified in Table 2.1. The cumulative concentration should be reported as follows:

- For 8 hour, 24 hour and annual averages the maximum ground level concentration should be reported.
- For 1 hour averages the 99.9th percentile value of the predicted ground-level concentration should be reported as the maximum ground-level concentration likely to occur. Other percentile values (e.g., maximum, 99.5th and 99th percentile values) should be provided to provide an indication of the representativeness of the 99.9th percentile value ground-level concentration.
- To determine likely compliance with standards, it is not necessary to consider ambient background concentrations that occur during "exceptional events". This is described further in Appendix 5.

Reporting of the 99.9th percentile value for 1 hour averages is in accordance with the recommendations of the Good Practice Guide for Atmospheric Dispersion Modelling (MfE 2004) and is consistent with the Victorian EPA State Environment Protection Policy (Ambient Air Quality), which states "*The 99.9th percentile is selected because this avoids the possibility of setting expensive emission controls based on a single extreme set of meteorological conditions".*

It is common internationally to demonstrate compliance with assessment criteria by reporting against the number of exceedances allowed. So for example, if the assessment criteria allows for one exceedance, then the second highest result is reported.

This is not generally considered appropriate in the Auckland context.

While the NES includes allowable exceedances for some contaminants, these are not limits “to pollute up to”. Auckland Council considers it inappropriate to allow one industry to “use up” the allowable exceedances given that there are regulatory consequences across the whole airshed. The allowable exceedances provide some room for movement in the event that unforeseen or unusual pollution events occur.

4.5 What if the assessment predicts an exceedance?

It is likely that some assessments will predict exceedance of air quality assessment criteria, especially for PM_{10} and $PM_{2.5}$ because background levels are already close to the criteria. If this is the case, it is appropriate to provide additional information in order to adequately assess the actual or potential effects.

Some issues that should be discussed to support an assessment of *the actual or potential effect* where there is a predicted exceedance include:

- Relevant assessment criteria specified by the NES, for example whether the industry is a principal source of CO, NO_x or VOC.
- How many exceedances are predicted?
- What is the distribution of cumulative concentration results? Is the exceedance an outlier?
- What is the relative contribution of background vs. the industry to each exceedance?
- Is it likely that people will be exposed for the relevant averaging period? If the predicted exceedance is in an industrial area, what is the highest predicted result in an urban area?
- How many properties, or what area is affected by the predicted exceedance?
- Is the industry minimising emissions and achieving best practice?
- How likely is it that the exceedance will occur? This is discussed further in section 4.5.1.
- What are the options for mitigation? This is discussed further in section 4.5.2.

For further guidance on the matters that are considered in assessing discharges of contaminants to air, applicants are encouraged to talk to Auckland Council.

4.5.1 Assessing the likelihood of an exceedance

Most assessments of effects are based on maximum expected emission rates. This is appropriate and necessary to ensure compliance with standards. However, in some cases the maximum emission rate is much higher than the average emission rate, and it may be unlikely to occur on the same day that maximum ground level concentrations are predicted.

Where an assessment is based on maximum emission rates, it is recommended that the assessment should include a qualitative discussion of the conservatism in the predicted maximum. The probability of an exceedance occurring should also be calculated if this can be supported by quantitative data (including for example, emission test results and production records).

4.5.2 Mitigation

Mitigation options will need to be considered for any project where predictions indicate that the cumulative concentration is likely to exceed air quality assessment criteria. In some locations, relatively minor increases in ground level concentrations will be sufficient to cause unacceptable local impacts when added to elevated background concentrations. In these locations it may be prohibitively expensive to mitigate emissions to the extent required, and offsets may be the only realistic option.

4.6 Alternative approaches to assessment of background air quality

A number of alternative statistical approaches to consideration of background air quality have been reviewed in Appendix 1 (for example selection of percentile values of background air quality data, and the UK approach of doubling the annual average). However, validation of these approaches has not been undertaken in the New Zealand context.

In the Auckland region, detailed meteorological data and ambient air quality data are available for 2005 and 2007 (Gimson et al, 2010). Therefore it is feasible to add hourly background concentrations from the suitable ambient monitoring site (or sites) to the hour-by-hour predicted industry contribution **for the same year**.

Statistical approaches are generally not considered appropriate. This is because adding high percentiles of predicted industry contribution to percentiles of monitored background "*has no direct physical meaning*" (Environment Agency, 2006).

Background values for areas outside Auckland are provided in Ministry for the Environment, 2008 (industry) and Ministry for the Environment 2008b (land transport).

4.7 In summary - when to talk to Auckland Council first

There are a number of situations where liaison with Auckland Council is necessary before undertaking an assessment. These include:

- When advanced assessment of the downwind conversion of nitrogen oxides to nitrogen dioxide is required;

- Assessment is for a large combustion source (e.g. power plant) and the formation of secondary pollutants such as ozone and particulate matter from sulphates and nitrates will need to be addressed;
- Assessments for non-criteria pollutants (i.e. pollutants other than those provided in Table 2.1);
- When there is no representative monitoring site available (i.e. areas not covered by sites provided in Table 4.2).

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Appendix 1: Current approaches to assessment of background air quality

There is limited documentation or guidance available internationally on the use of background air quality in air quality assessments. This review reports briefly on what is available, as well as providing some examples of current approaches used in Auckland.

Auckland assessment approaches

In the preparation of this document five case studies of air quality assessments which used background air quality data were considered. This was not intended to be a comprehensive review - rather it served to highlight the variable and inconsistent approaches used in the Auckland region.

For three of those assessments, emissions of particulate matter (PM) were the primary air quality consideration, whereas for the other two it was emissions of nitrogen oxides (NO_x). There are significant differences in the background air quality values used in those five assessments.

For the four assessments that used background 24-hour average PM_{10} data the values were between 20 µg/m^3 and 30 µg/m^3. Three of those industrial premises are located in the same urban/industrial area of Auckland. For the three assessments that used background 1-hour average nitrogen dioxide data the values were between 25 µg/m^3 and 28 µg/m^3.

There are also significant differences in the specific indicator of air quality monitoring data that was used as the background concentration. Two of the assessments used the 90th percentile, one used “between the annual average and upper quartile”, one used the 70th percentile and one used the average. The difference between those various indicator levels is considerable for most air quality data sets.

Four of the assessments considered the results of ambient air monitoring at one site (considered the “most appropriate”), whereas one took the average of data for three sites.

Of particular interest is that none of these five assessments used the “examples of existing concentrations without project“, given in the Ministry for the Environment’s Good Practice Guide for Industry (MfE, 2008) as the background concentration.

International approaches to assessment of background air quality

As is often the case in the development of public policy, it is useful to consider approaches used internationally to assess background air quality. A review of available information on the approaches used by overseas jurisdictions has been carried out. These include for Canada, the United States, Australia, and the United Kingdom.

A review of available dispersion modelling guidance was undertaken. The following discussion focuses on the jurisdictions where relatively comprehensive and recent guidance has been published and is readily available via the internet. As well as review of the general approach to incorporation of background air quality, the review considered:

- Is there any international consistency or justification for the adoption of a particular percentile value from an ambient air quality monitoring data set to represent background air quality?
- Is there any international consistency or justification for the adoption of a particular percentile value from the cumulative concentration predicted by dispersion modelling for comparison with air quality assessment criteria?

Canada

Recent dispersion modelling guidance from British Columbia Ministry of Environment (BC MoE, 2008) includes guidance on the incorporation of background air quality. The British Columbia guide recommends the following approach:

- *If the monitoring data is deemed representative of the area under consideration, the background should be based on the most recent data available from the last year. A data record that is 75% complete in each quarter of the year is recommended.*
- *If the modelled source already exists, then periods when the source is impacting the monitoring location used to determine background can be removed from the data set. Use wind direction data to determine whether the plume location is within or outside the sector (as defined by a 45º sector downwind of the source). If an area is subject to frequent light wind conditions, then this rule does not apply and professional judgment is required to establish whether the existing source is contributing to the monitored levels. If the source in question is a new source, then the whole data set is eligible.*
- *The monitoring data can be pre-screened to exclude any periods when nearby, intermittent sources have an influence on the monitor, but have minimal influence on the wider area. For example, for PM_{10} concentrations measured at a monitor adjacent to a construction site, the period of record when the site was active should be eliminated from the data.*

- *For Level 1 assessments, select the maximum measured concentration (100th percentile) from the screened or unscreened data set as the background level.*
- *For Level 2 and 3 assessments, from the screened data set, select a background value not lower than the 98th percentile. The specific percentile depends on the level of uncertainty associated with establishing the background value. If there is large uncertainty, select a percentile in the upper range of the measured concentration distribution. The uncertainty depends on the following factors:*
- *the time representativeness (total period of record: the longer the period of record, the less uncertainty associated with the background selection)*
- *the area representativeness of the monitoring location (wider representativeness means less uncertainty associated with the background selection)*
- *the number of monitoring sites used (more measurement sites, less uncertainty)*
- *Select background levels for time averages that correspond to the modelled time averages (24-hour average background level for 24-hour model predicted time-average concentration).*
- *If there is more than one representative monitoring site, an acceptable approach is to follow the previous steps for each site, then take the arithmetic average of the selected background level to determine the background concentration that corresponds to each averaging period.*
- *In figures and/or tables that present the modelling results, provide the total air quality (background plus the increment due to the source modelled) and provide the modelled incremental air quality impacts (due to the source modelled).*
- *The process used to justify the selection of the background should be outlined in the model plan.*

The overall approach to dispersion modelling in British Columbia is similar to New Zealand with 3 levels of assessment depending on the level of detail required. As outlined above, the British Columbia guidance recommends selection of the maximum concentration from the relevant ambient monitoring records to represent background air quality in a level 1 assessment. This is similar to the approach recommended in this guide for a screening assessment in Auckland. The approach for detailed assessments is somewhat different, with the British Columbia guide recommending the selection of one value to represent background "*not lower than the 98th percentile*".

The British Columbia guidance was preceded by a critical review of a draft version (Hrebenyk., et al, (2003). This review considered incorporation of background air quality in United States and Canadian jurisdictions in general terms, as well as specific review of guidance from Alberta, Ontario and New Zealand (MfE, 2004). Based on this review, the guidance states: "*In situations where the prime interest is in determining compliance with ambient objectives/ guidelines for continuously emitting sources, regulatory agencies differ in their recommendations on establishing background concentrations.*

Examples include: a specific percentile (100th, 99th or 98th highest hourly value), a regionally dependent background level, sequence matching the hourly background concentration with the hour being modelled, or a specified process to establish a background level, or no guidance at all. Historically in B.C., percentile background levels used in air quality assessments have ranged from the 100th to 98th percentile".

The review (Hrebenyk., et al, 2003) found that "there has been little-to-no consistency in the practice of defining a background concentration in B.C, or elsewhere across Canada". The recommendation of *a background value not lower than the 98th percentile* for level 2 and 3 assessments is based on the recommendations of the review and is intended to improve consistency. The 98th percentile is generally intended to represent a conservative value which excludes "unusual" peaks.

A key difference between Canada and other jurisdictions (including New Zealand) is that there are no "legal or economic constraints for failure to achieve air quality objectives". This means that the percentiles adopted for background air quality, and reporting against assessment criteria are less critical than in the New Zealand context. For BC the critical issue is ensuring consistency so that all sources are considered on an equivalent basis.

In the Auckland context, background air quality may be a critical factor in determining whether or not national environmental standards for air quality are likely to be exceeded. It is not considered appropriate in this context to nominate an arbitrary percentile which is intended to eliminate "unusual" or "unrepresentative" peaks. The default screening assessment values provided in this Auckland guide are based on averages across and number of sites and years and therefore exclude unusual peaks. For detailed assessments the preferred approach is that recommended by the UK Environment Agency which is discussed below.

United States

The USEPA (2005) provides guidance for isolated single sources as follows:

- *Use air quality data collected in the vicinity of the source to determine the background concentration for the averaging times of concern. Determine the mean background concentration at each monitor by excluding values when the source in question is impacting the monitor. The mean annual background is the average of the annual concentrations so determined at each monitor. For shorter averaging periods, the meteorological conditions accompanying the concentrations of concern should be identified. Concentrations for meteorological conditions of concern, at monitors not impacted by the source in question, should be averaged for each separate averaging time to determine the average background value. Monitoring sites inside a 90° sector downwind of the source may be used to determine the area of impact. One hour concentrations may be added and averaged to determine longer averaging periods.*

- *If there are no monitors located in the vicinity of the source, a ''regional site'' may be used to determine background. A ''regional site'' is one that is located away from the area of interest but is impacted by similar natural and distant man-made sources.*

In multi-source areas, the USEPA describes procedures for modelling the contribution of other nearby sources as well as quantification of minor sources or distant major sources (effectively background) from ambient monitoring or modelling.

The USEPA guidance seems to be open to interpretation. The approach to incorporation of background air quality in the United States was discussed to some extent in the British Columbia review (Hrebenyk., et al, 2003). This found that there is no consistency between States.

In general terms the approach is similar to British Columbia where one value is nominated to represent background air quality. In some locations this is based on the annual average from ambient air quality monitors (e.g. Albuquerque (Stonesifer, 2006)), while in others a "conservative default" value is prescribed. (e.g. State of Conneticut).

A consultant working in the US advises the following:[8]

Tier 1 $NO_2 = NO_x$

Tier 2 $NO_2 = 0.8\ NO_x$

Tier 3 Ozone limiting method employed (AERMOD)

Background air quality is only considered if the facility exceeds significant impact levels.

United Kingdom

The UK Environment Agency has recently published updated guidance on consideration of background air quality and methods to combine these with process contributions (Environment Agency, 2006). The Environment Agency approach is particularly relevant to New Zealand, because UK legislation requires a similar "effects based" approach where cumulative concentrations are compared to assessment criteria.

The Environment Agency (2006) report states that "It is generally not appropriate to add high percentile PCs (process contributions) and background concentrations together because this has no direct physical meaning and in any case the meteorological conditions that lead to high PCs often do not coincide with the conditions associated with high background concentrations.

The recommended approach is to add the background concentration to the process contribution on an hour-by-hour basis. The relevant percentile for comparison with assessment criteria is then calculated directly from the cumulative (industry + background) concentration. This method is recommended for assessments that require detailed assessment of background air quality. This is the case when the cumulative concentration (industry + background) is close to or exceeding the assessment criteria.

[8] Personal comm. Jenny Barclay, 9 March 2012.

The approach recommended for Auckland is consistent with the recommendations of the Environment Agency for assessments that require detailed assessment of background air quality (tier 3 assessments).

The Environment Agency recommends a number of statistical approaches to be applied in cases where the hour-by-hour assessment is not feasible, or is not justified because there is little risk of air-quality objective limits being exceeded. These methods have not been evaluated for the Auckland context. The tier 2 assessment is intended to determine whether there is significant risk of air quality assessment criteria being exceeded. Where a tier 3 assessment is required, the statistical screening methodologies recommended by the Environment Agency are not considered appropriate. Auckland Council provides detailed meteorological and monitoring data so that detailed assessments are feasible.

Australia

Dispersion modelling guidance from Western Australia, South Australia and Queensland provides no specific guidance on the consideration of background air quality.

The State Environmental Protection Policy (Air Quality Management) for Victoria (SEPP) includes requirements for dispersion modelling. The SEPP states "*Proponents required to include background data where no appropriate hourly background data exists must add the 70th percentile of one year's observed hourly concentrations as a constant value to the predicted maximum concentration from the model simulation*." The rationale for selection of the 70th percentile is not provided.

For comparison of results against assessment criteria, the SEPP requires the 99.9th percentile to be reported for averaging times of one hour or less; or the highest value (100th percentile) for averaging times of longer than one hour. The SEPP states that "*the 99.9th percentile is selected because this avoids the possibility of setting expensive emission controls based on a single extreme set of meteorological conditions*".

New South Wales

The New South Wales Environment Protection Authority (NSW EPA) has Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales (NSW EPA, 2005). The New South Wales guidance for consideration of background air quality is broadly consistent with the recommended guidance for Auckland. New South Wales requires background air quality data to be based on ambient monitoring at the proposed site, or "*from a monitoring site that is as close as possible to the proposed location where the sources of pollution resemble the existing sources at the proposal site*".

The document outlines the process for incorporation of background air quality as follows:

Level 1 assessments

- *Obtain ambient monitoring data that includes at least one year of continuous measurements.*
- *Determine the maximum background concentration of the pollutant being assessed for each relevant averaging period.*
- *At the maximum exposed off-site receptor, add the maximum background concentration and the 100th percentile dispersion model prediction to obtain the total impact for each averaging period.*

Level 2 assessments

- *Obtain ambient monitoring data that includes at least one year of continuous measurements and is contemporaneous with the meteorological data used in the dispersion modelling.*
- *At each receptor, add each individual dispersion model prediction to the corresponding measured background concentration (e.g. add the first hourly average dispersion model prediction to the first hourly average background concentration) to obtain hourly predictions of total impact.*
- *At each receptor, determine the 100th percentile total impact for the relevant averaging period.*

The guidance also states that *"a licensee must demonstrate that no additional exceedances of the impact assessment criteria will occur as a result of the proposed activity".*

Discussion and Conclusions

The review of examples of Auckland air quality assessments found that there is currently wide variation in the specific indicator of air quality monitoring data used (for example, the percentile value) for the background air quality.

In the international review we found no consistency or justification for the adoption of any particular percentile to represent background air quality. Approaches range from adopting an average (US), the 70th percentile (Victorian EPA), the 98th percentile (British Columbia). The UK Environment Agency concludes that adding high percentiles of predicted industry contribution to percentiles of monitored background "*has no direct physical meaning".* We agree with this conclusion and do not consider it appropriate to base assessments on percentile values from ambient monitoring results.

The rationale for adoption of high percentiles to represent background air quality in other jurisdictions is generally to eliminate outliers or unusually high results.

The rationale for adoption of average background results (US) or the 70th percentile (Victoria) is unclear, however it seems likely that the rationale is similar to that for the

statistical approaches recommended in the UK (e.g. adding modelled peaks to double the annual average). In the UK, the statistical approaches are intended to compensate for time coincidence issues, and provide a conservative estimate of the result that would be obtained by addition of the hour by hour modelled result to the hour by hour background monitoring result.

In the Auckland context, background air quality may be a critical factor in determining whether or not national environmental standards for air quality are likely to be exceeded. It is not considered appropriate in this context to nominate an arbitrary percentile which is intended to eliminate “unusual” or “unrepresentative” peaks. The default screening assessment values provided in this Auckland guide are based on averages across a number of sites and years and therefore exclude unusual peaks. Where detailed assessment is required the approach recommended for Auckland is consistent with international best practice and the recommendations of the UK Environment Agency and the New South Wales EPA. The recommended approach will improve consistency for Auckland.

There is consistency in the international approach for comparison of predicted concentrations with assessment criteria. For jurisdictions where there is an allowable number of exceedances, it is normal practice to compare dispersion modelling results with the number of exceedances allowed. So for example, if the assessment criteria allows for one exceedance, the second highest result is reported to demonstrate compliance with the assessment criteria.

Appendix 2: Ambient air quality monitoring in Auckland

This appendix briefly reviews ambient air quality monitoring sites and the results of monitoring in the Auckland region. The contaminants of most concern for assessment of background air quality are identified as particulate and nitrogen dioxide because background concentrations of these contaminants are close to or exceeding air quality criteria. Further information relating to ambient monitoring in Auckland is available from the State of the Region report (ARC 2010a). Ambient air quality monitoring data is available upon request from Auckland Council.

In 2008 there were 15 ambient air quality monitoring sites in Auckland. The locations of key monitoring stations are shown in Figure 3.1 (Section 3) and the contaminants monitored at each site are given in Table A2-1 below. Full details of (most) monitoring sites are provided in the Ambient Air Quality Monitoring Network in the Auckland Region (ARC, 2006).

For the purpose of this document a relevant indicator of levels of contaminants in the Auckland air environment that are of most concern from a health perspective is the exceedances of air quality criteria. This is illustrated in Figure A2-1 (national standards only) and Table A2-2 (standards and regional targets).

The air quality criteria are given in Table 3.2. They are a combination of the national environmental standards for air quality and the Auckland Regional Air Quality Targets (ARC, 2010), with the allowable number of exceedances per year of the standards noted.

From recent (2006-2013) monitoring data, the air contaminants of most concern in Auckland are PM_{10}, $PM_{2.5}$ and nitrogen dioxide.

Table A2-1
Auckland air quality monitoring sites metadata

Site Name	Monitoring Period[9]	Contaminants Monitored
Auckland Waterfront	Feb 2011 –	CO, NOx, PM_{10}, (beta gauge), $PM_{2.5}$ (beta gauge), SO_2
Beachlands	May 2011 – Apr 2012	PM_{10}, $PM_{2.5}$ (beta gauges)
Botany Downs	Oct 2003 –	CO, PM_{10} (beta gauge)
Glen Eden – Ceramco Park	Dec 2005 –	CO, NO_x, PM_{10} (beta gauge)
Helensville	Jan 2010 – Dec 2010	PM_{10}, (beta gauge), $PM_{2.5}$ (beta gauge), NOx
Henderson 1(A) – Lincoln Road	Dec 1993 –	CO, NO_x, PM_{10} (beta gauge, partisol, minivol)
Kingsland	Apr 2004 – Sept 2005	PM_{10}, (beta gauge, partisol), $PM_{2.5}$ (partisol), NOx, TSP, lead, O_3
Khyber Pass Road	Oct 1996 –	CO, NO_x, PM_{10} (partisol), $PM_{2.5}$ (partisol), Benzene, 1,3 Butadiene
Kumeu	Jun 2006 – Jan 2013	PM_{10} (beta gauge)
Mt Eden	Feb 2001 – Jan 2006	PM_{10}, (beta gauge, partisol), $PM_{2.5}$ (partisol), NOx
Musick Point II – Telecom Building	Feb 1999 –	NO_x, O_3
Orewa	May 2007 –	PM_{10} (beta gauge)
Pakuranga	Jun 1998 –	CO, PM_{10} (beta gauge)
Patumahoe – Pukekohe Rural	Oct 1996 –	NO_x,, O_3, PM_{10} (beta gauge), $PM_{2.5}$ (beta gauge)
Penrose II(B) – Gavin St substation	Jan 1987 –	NO_x,, PM_{10} (beta gauge, hi-vol), $PM_{2.5}$ (beta gauge), SO_2
Pukekohe Urban – Mobile Trailer	Sep 2006 – Dec 2008	CO, NO_x, PM_{10} (beta gauge), $PM_{2.5}$ (partisol)
Queen Street II – CML Building	Dec 1982 –	CO, NO_x,, PM_{10} (partisol), $PM_{2.5}$ (partisol)
Takapuna I – Westlake	May 2005 –	CO, NO_x, PM_{10} (beta gauge, partisol), $PM_{2.5}$ (beta gauge)
Waiheke	Feb 2009 – Dec 2010	PM_{10}, $PM_{2.5}$ (beta gauge), NOx, O_3
Waiuku	Feb 2009 – Jan 2010	PM_{10}, $PM_{2.5}$ (beta gauge), NOx, O_3
Warkworth – Mobile Trailer	Apr 2007 – Nov 2008	NO_x, PM_{10} (beta gauge), $PM_{2.5}$ (beta gauge)
Whangaparaoa	Apr 1998 –	O_3, PM_{10} (beta gauge), $PM_{2.5}$ (beta gauge)

[9] No end date indicates monitoring was ongoing at time of drafting (June 2014).

Figure A2-1
Number of days national air quality standards were exceeded
(ARC, 2010a)

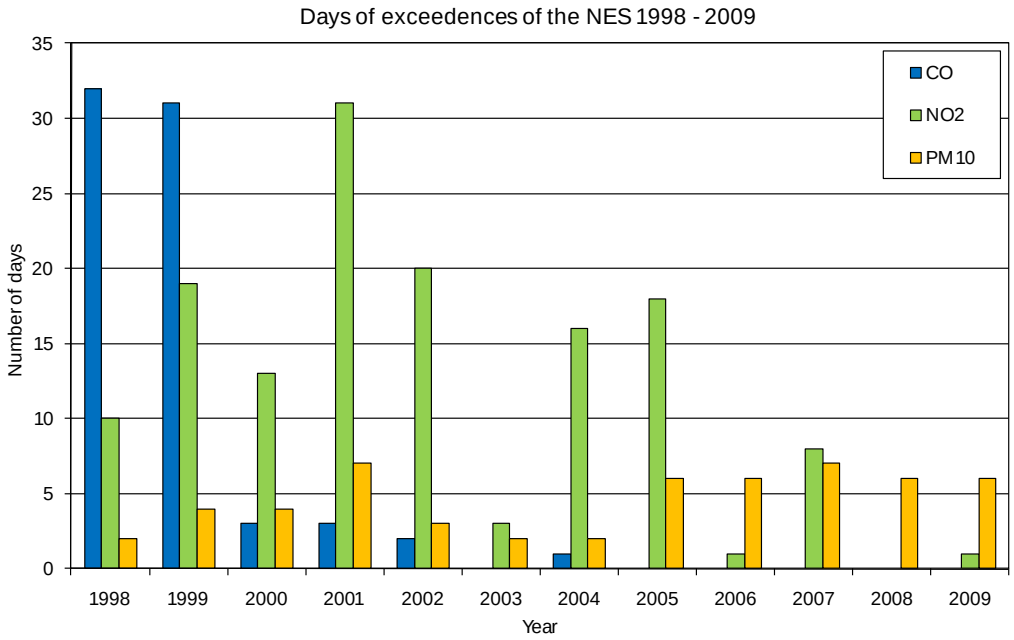


Table A2-2
Number of days air quality criteria were exceeded
(ARC, 2010a)

Year	Carbon monoxide		Nitrogen dioxide		PM_{10}**	$PM_{2.5}$**	Total***
	1-hour	8-hour	1-hour	24-hour	24-hour	24-hour	
1998	0	32	10	18	2	6	53
1999	1	31	19	15	4	3	57
2000	0	3	13	21	4	3	33
2001	0	3	27	18	7	4	46
2002*	0	2	20	21	3	1	36
2003	0	0	3	6	2	6	15
2004	0	1	16	20	2	5	37
2005	0	0	18	16	4	2	31
2006	0	0	1	0	6	5	8
2007	0	0	8	0	7	9	21
2008	0	0	0	0	6	3	6
2009	0	0	1	0	6	8	11

* An exceedance day of the ozone guideline was recorded in 2002.

** PM_{10} or $PM_{2.5}$ at some sites were sampled on every third day, therefore, the actual number of their exceedance days could be more than three times higher. All sites were upgraded to every day sampling between 2002 and 2005.

*** Total may not be the sum of individual pollutants as the exceedance days may overlap.

Appendix 3: Determining default background air quality values for screening assessments

This appendix outlines the data considered and the approach taken to determine the default values specified in Table 3.1. The basis of distances to roadsides specified in Table 3.2 is also briefly discussed.

Determining default values

Default values for screening assessments have been derived following an extensive review of Auckland air quality monitoring data from about 1991 to 2013. Recent publications on benzene and other volatile organic compounds in Auckland (ARC, 2009), and a report on sulphur dioxide monitoring (Watercare, 2007) were also considered.

The data considered for determining default background air quality values are summarised in Tables A3-1 to A3-5. Unless stated otherwise (in the following sections), the approach to determine default values was:

1. Identify air quality monitoring sites in Auckland that are representative of those areas. The monitoring sites considered for each area are listed in the “site” column of the tables.
2. Calculate averages of annual maximum values over available monitoring periods.[10] Trends in results were considered, and where necessary out of date results were excluded. The years for which monitoring data were included are listed in the “years” column of the tables.
3. The default value is the average from all of the sites, weighted by the number of years of monitoring at each site. The values are rounded up or down to the nearest whole number, except for carbon monoxide, which is rounded to the nearest 0.5.

This approach is consistent with the procedure recommended in by the Industry Good Practice Guide (MfE 2008) for tier 2 assessments. Averaging peak values across a number of sites and years will reduce the effect of any non-representative or localised peaks.

[10] The exception to this is particulate matter for which the average of the second highest value was calculated.

Carbon monoxide

This was the only contaminant with a significant trend over time (i.e. a decrease), and so the results prior to 2005 were excluded.

Results of the averages of annual maximum values for each of the two averaging times (1-hour and 8-hour) are:

Table A3-1
Data considered in the calculation of default CO values[11]

Location	Site	Years	Average		Default Values*	
			1-hour	8-hour	1-hr	8-hr
Roadside	Pakuranga	2005-2013	8.6	4.8	7.0	4.5
	Penrose	2005	6.6	4.2		
	Takapuna	2006-2013	6.1	4.5		
Urban	Henderson	2005-2013	4.5	2.4	5.0	3.0
	Glen Eden	2006-2013	5.4	3.1		
Rural Town	Pukekohe	2007-2008	5.1	2.4	5.0	2.0

*rounded to nearest 0.5

NB: Khyber Pass and Queen Street monitoring data were excluded from consideration of background air quality values for carbon monoxide. These sites are heavily influenced by street canyons (Queen Street) and large buildings (Khyber Pass) and had elevated levels of carbon monoxide that are not considered generally relevant to other locations in Auckland.

[11] The Khyber Pass and Queen Street monitoring sites were considered to be influenced by tall buildings and street canyons and not representative of other (less built up) areas in Auckland.

PM_{10}

PM_{10} data were either measured or estimated for each census area unit in the Auckland region as shown in Figure A3-1 (daily PM_{10}) and Figure A3-2 (annual PM_{10}).

Measured data reflects the second highest 24-hour average, and annual average, averaged over all years of available data as shown in Table A3-2.

Available data are years with >75% valid data.

For census area units without a monitoring station, **annual** PM_{10} default values were estimated using the exposure model developed for the updated HAPINZ study (Kuschel et all, 2012). The HAPINZ study developed a national exposure model that used:

1. Available monitoring data (2006 – 2008) in the first instance if a monitoring station happened to be located in that census area unit; or
2. For unmonitored areas, annual concentrations were estimated from emissions density[12]. This in turn was calculated from population and emissions sources in each census area unit.

For this document, ambient monitoring data was updated in the HAPINZ exposure model to include annual averages for each site listed in Table A3-2 (which follows). This expanded monitoring data uses all available monitoring data (e.g. back to 1995 for Penrose) up to and including 2013. Emissions density (based on population and emissions sources) and the regression analysis were not updated (and rely on the base data in the 2012 Updated HAPINZ exposure model).

For census area units without a monitoring station, **daily** PM_{10} default values were estimated using a correlation ($R^2 = 0.70$) developed for Auckland based on Auckland region data as shown in Formula A3-1 and Figure A3-3:

$$y = 0.4648\, x^{0.9683} \qquad \textbf{Formula A3-1}$$

This correlation is called the Auckland peak to mean PM_{10} correlation. Default PM_{10} values for all census area units in the Auckland Region are provided Appendix 6.

[12] PM_{10} concentration was estimated based on regression of emission density versus concentrations in census area units where monitoring was carried out.

Figure A3-1
Default daily PM_{10} by census area unit for the Auckland Region

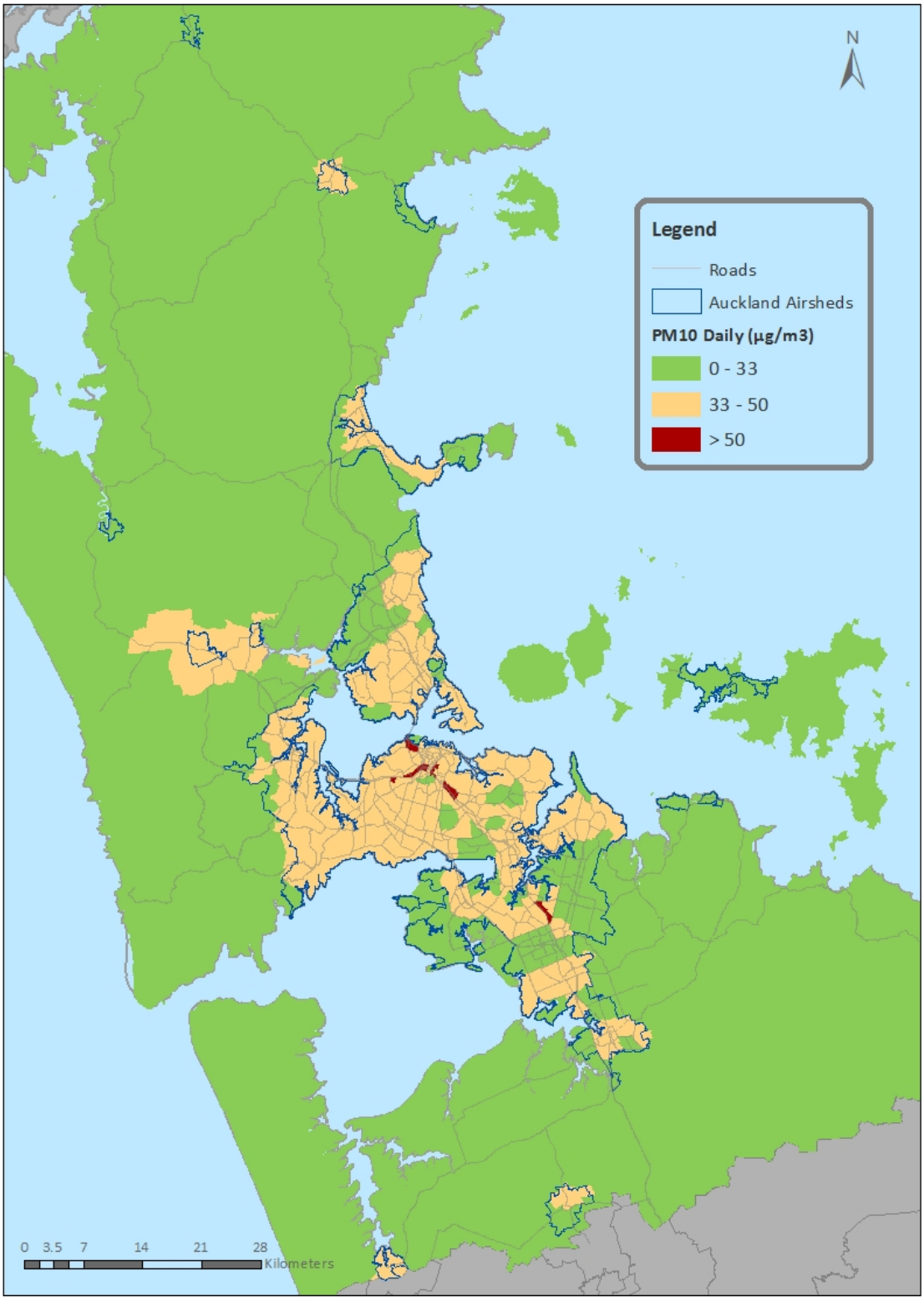


Figure A3-2
Default annual PM_{10} by census area unit for the Auckland Region

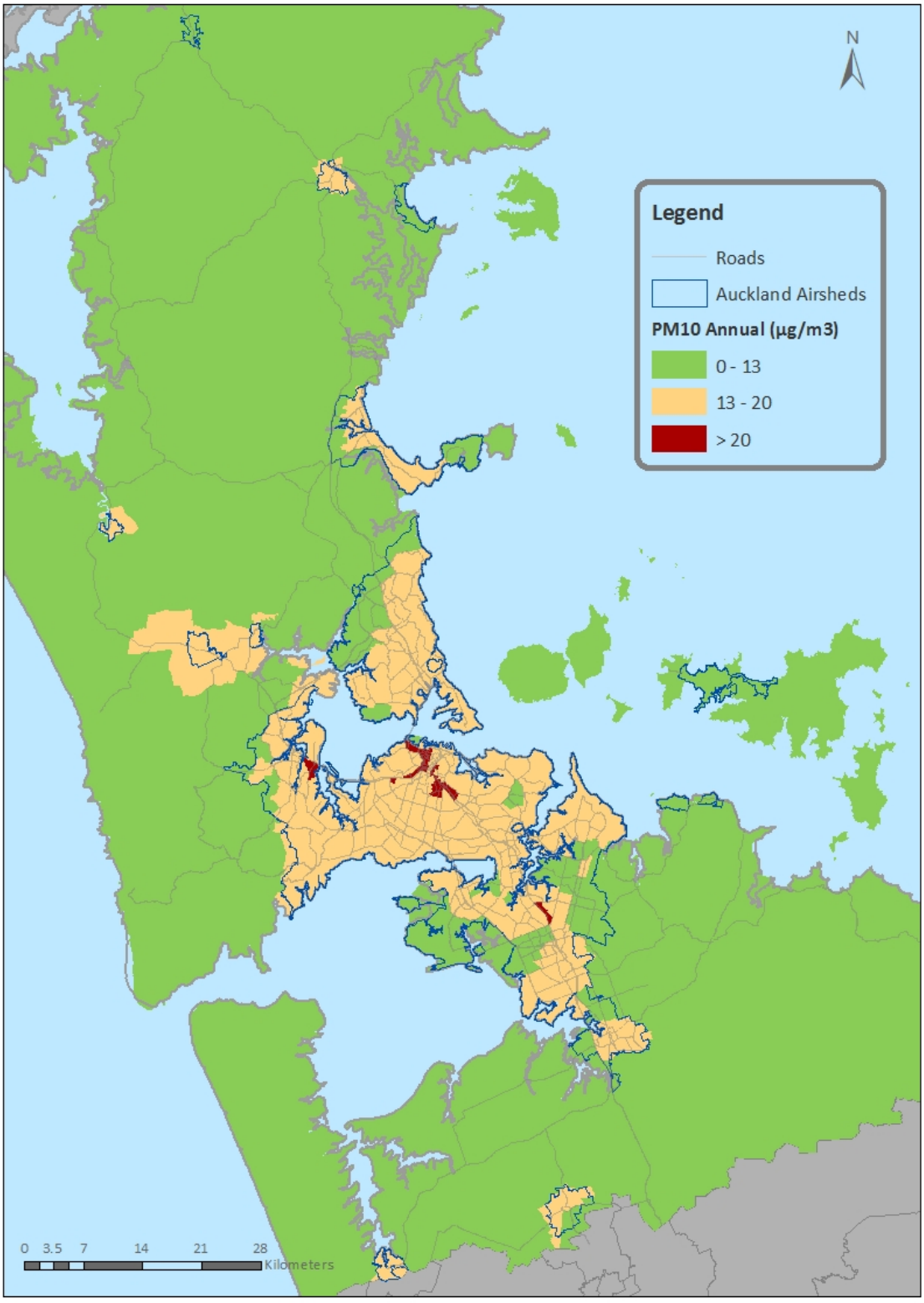
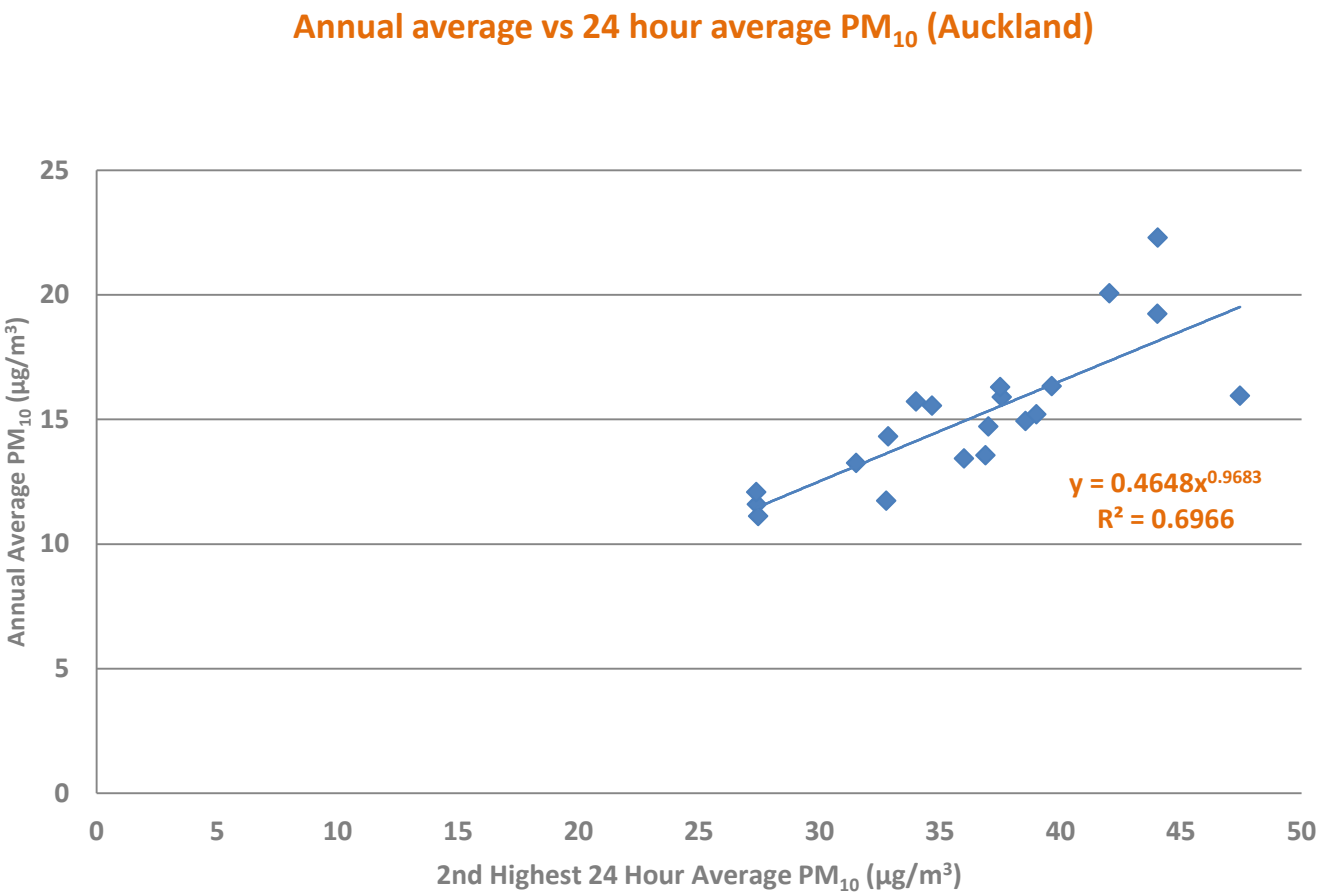


Table A3-2
Data used for census area units with PM_{10} monitoring stations

Location	Airshed	Monitoring Site	Census Area Unit	Years	Average	
					24-hr	Annual
Roadside	Auckland Urban	Pakuranga	Pakuranga North	2005-13	47	16
	Auckland Urban	Penrose	Ellerslie South	1995-2013	44	19
	Auckland Urban	Takapuna	Westlake	1997-2013	40	16
Roadside (tall buildings, street canyon)	Auckland Urban	Khyber Pass	Epsom North	1998-2013	44	22
	Auckland Urban	Queen St	Auckland Central West	1999-2013	42	20
Urban	Auckland Urban	Botany Downs	Millhouse	2004-13	27	12
	Auckland Urban	Glen Eden	Glen Eden East	2006-13	36	13
	Auckland Urban	Henderson	Fairdene	1999-2013	35	16
	Auckland Urban	Kingsland	Kingsland	2005-2006	39	15
	Auckland Urban	Mt Eden	Mt Eden North	2001-2005	33	14
Rural	Auckland Region	Patumahoe	Eden Road-Hill Top	2006-13	33[1]	12
	Waiheke Island	Waiheke Island	Waiheke Island	2009-10	27	12
	Auckland Region	Whangaparaoa	Army Bay	2008-13	28	11
Rural town	Helensville	Helensville	Helensville	2010	32	13
	Kumeu	Kumeu	Kumeu	2007-2012	38	16
	Pukekohe	Pukekohe	Pukekohe North	2007-08	39	15
	Auckland Urban	Orewa	Orewa	2008-3	37	14
	Waiuku	Waiuku	Waiuku	2009	37	15
	Warkworth	Warkworth	Warkworth	2008	38	16
Port	Auckland Urban	Auckland Waterfront	Auckland Harbourside	2011-2013	34	16

[1] Outliers, as identified in Appendix 5 are excluded from the average of annual maximum values for Patumahoe.

Figure A3-3
Auckland peak to mean correlation



$PM_{2.5}$

$PM_{2.5}$ data were either measured or estimated for each census area unit in the Auckland region as shown in Figure A3-4 (daily $PM_{2.5}$) and Figure A3-5 (annual $PM_{2.5}$).

Measured data reflects the second highest 24-hour average, and annual average, averaged over all years of available data as shown in Table A3-3. Available data are years with >75% valid data.

Estimated data are discussed in more detail below.

Default $PM_{2.5}$ values for all census area units in the Auckland Region are provided in Appendix 6.

Table A3-3
Data used for census area units with $PM_{2.5}$ monitoring stations

Location	Airshed	Monitoring Site	Census Area Unit	Years	Average	
					24-hour	Annual
Roadside	Auckland Urban	Penrose	Ellerslie South	2007 - 2013	23	7
	Auckland Urban	Takapuna	Westlake	2008 - 2013	27	7
Roadside (buildings, street canyon)	Auckland Urban	Khyber Pass	Epsom North	2003 - 2013	21	9
	Auckland Urban	Queen St	Auckland Central West	2003 - 2013	21	10
Urban	Auckland Urban	Kingsland	Kingsland	2005 - 2006	22	7
	Auckland Urban	Mt Eden	Mt Eden North	2001 - 2005	20	8
Rural	Auckland Region	Patumahoe	Eden Road-Hill Top	2009 - 2013	11	4
	Auckland Region	Whangaparoa	Army Bay	2009 - 2013	10	4
Rural town	Auckland Region	Helensville	Helensville	2010	13	5
	Pukekohe	Pukekohe	Pukekohe North	2008	21	6
	Auckland Region	Warkworth	Warkworth	2008	17	8

[1] Outliers, as identified in Appendix 2 are excluded from the average of annual maximum values for Patumahoe.

Estimated $PM_{2.5}$

For census area units without a monitoring station, daily $PM_{2.5}$ default values were estimated from daily PM_{10} values (either measured or estimated for each census area unit as outlined above). $PM_{2.5}$ was estimated based on the following correlations with PM_{10}.

Daily $PM_{2.5}$

$PM_{2.5}$ = 0.60 x PM_{10} – Urban

$PM_{2.5}$ = 0.37 x PM_{10} – Rural

These correlations represent the maximum of second highest $PM_{2.5}$ to second highest PM_{10} ratios averaged over all available years where monitors have been co-located for each site. Available data are years with >75% valid data. Urban/rural classifications are those from Statistics New Zealand.

The urban correlation for daily $PM_{2.5}$ is calculated below.

	Kingsland			Mt Eden		
	2nd highest			2nd highest		
Year	PM_{10}	$PM_{2.5}$	Ratio	PM_{10}	$PM_{2.5}$	Ratio
2001				42	27	0.66
2002				27	19	0.70
2003				33	20	0.62
2004				36	18	0.50
2005	38	16	0.43	26	14	0.54
2006	40	28	0.72			
Average	**39**	**22**	**0.57**	**33**	**20**	**0.60**

The rural correlation for daily $PM_{2.5}$ is calculated below.

	Patamahoe			Whangaparoa		
	2nd highest			2nd highest		
Year	PM_{10}	$PM_{2.5}$	Ratio	PM_{10}	$PM_{2.5}$	Ratio
2009	42	10	0.25	30	11	0.36
2010	31	9	0.29	25	9	0.36
2011	35	12	0.34	27	11	0.42
2012	29	14	0.47	28	10	0.36
2013	31	11	0.34	27	10	0.37
Average	**34**	**11**	**0.34**	**30**	**11**	**0.37**

Annual $PM_{2.5}$

$PM_{2.5}$ = 0.48 x PM_{10} – Urban

$PM_{2.5}$ = 0.37 x PM_{10} – Rural

These correlations represent the maximum of annual $PM_{2.5}$ to annual PM_{10} ratios, averaged over all available years where monitors have been co-located. Available data are years with >75% valid data. Urban/rural classifications are those from Statistics New Zealand.

The urban correlation for annual $PM_{2.5}$ is calculated below.

	Kingsland			Mt Eden		
	Annual			Annual		
Year	**PM_{10}**	**$PM_{2.5}$**	**Ratio**	**PM_{10}**	**$PM_{2.5}$**	**Ratio**
2001				15	9	0.58
2002				14	7	0.49
2003				14	6	0.43
2004				15	7	0.47
2005	15	6	0.42	13	5	0.43
2006	15	8	0.52			
Average	**15**	**7**	**0.47**	**14**	**7**	**0.48**

The rural correlation for annual $PM_{2.5}$ is calculated below.

	Patamahoe			Whangaparoa		
	Annual			Annual		
Year	**PM_{10}**	**$PM_{2.5}$**	**Ratio**	**PM_{10}**	**$PM_{2.5}$**	**Ratio**
2009	11	4	0.35	11	4	0.35
2010	11	4	0.34	10	4	0.38
2011	11	4	0.37	11	4	0.37
2012	11	4	0.38	11	4	0.37
2013	13	5	0.37	11	4	0.38
Average	**11**	**4**	**0.36**	**11**	**4**	**0.37**

Measured $PM_{2.5}$ compared with estimated $PM_{2.5}$

Figure A6-1 shows the estimated **daily** $PM_{2.5}$ values are generally more conservative than the measured values. Typically this difference is an overestimate within 30% but significant outliers are as follows:

- Under-estimate Takapuna (12%)
- More than 50% overestimate Helensville, Patamahoe and Whangaparoa.

The remainder of sites are a reasonably good fit.

Figure A6-2 shows the estimated **annual** $PM_{2.5}$ values are slightly more conservative than the measured values. Typically this difference is an overestimate within 30% but significant outliers are as follows:

- Underestimate Patamahoe (14%)
- Overestimate Mt Eden (41%)

The intent is to be reasonably conservative, so that assessments do not underestimate potential impacts. Overall, the selected correlations provide a reasonable fit for the majority of locations.

We investigated the maximum ratio of $PM_{2.5}$ to PM_{10} (averaged over available data) for other monitoring sites as shown below:

Maximum daily ratios $PM_{2.5}$: PM_{10}

Rural	0.37	Patamahoe (2009-13), Whangaparoa (2009-13)
Rural town	0.52	Helensville (2010), Pukekohe (2008), Warkworth (2008)
Urban	0.60	Kingsland (2005-06), Mt Eden (2001-05)
Roadside 1	0.74	Penrose (2007-13), Takapuna (2008-13)
Roadside 2	0.74	Penrose (2007-13), Takapuna (2008-13), Queen St (2003-13), Khyber Pass (2003-13)

Maximum annual ratios $PM_{2.5}$: PM_{10}

Rural	0.37	Patamahoe (2009-13), Whangaparoa (2009-13)
Rural town	0.49	Helensville (2010), Pukekohe (2008), Warkworth (2008)
Urban	0.48	Kingsland (2005-06), Mt Eden (2001-05)
Roadside 1	0.46	Penrose (2007-13), Takapuna (2008-13)
Roadside 2	0.52	Penrose (2007-13), Takapuna (2008-13), Queen St (2003-13), Kybher Pass (2003-13)

However, these significantly overestimated $PM_{2.5}$ compared with measured values when applied across Auckland so were not used.

We also investigated the ratio of $PM_{2.5}$ to PM_{10} on the day of the peak PM_{10}, **and** this ratio on the day of the peak $PM_{2.5}$ (for daily correlations). These both significantly overestimated $PM_{2.5}$ compared with measured values when applied across Auckland so were not used.

Figure A6-1

Comparison of Estimated and Measured Daily $PM_{2.5}$

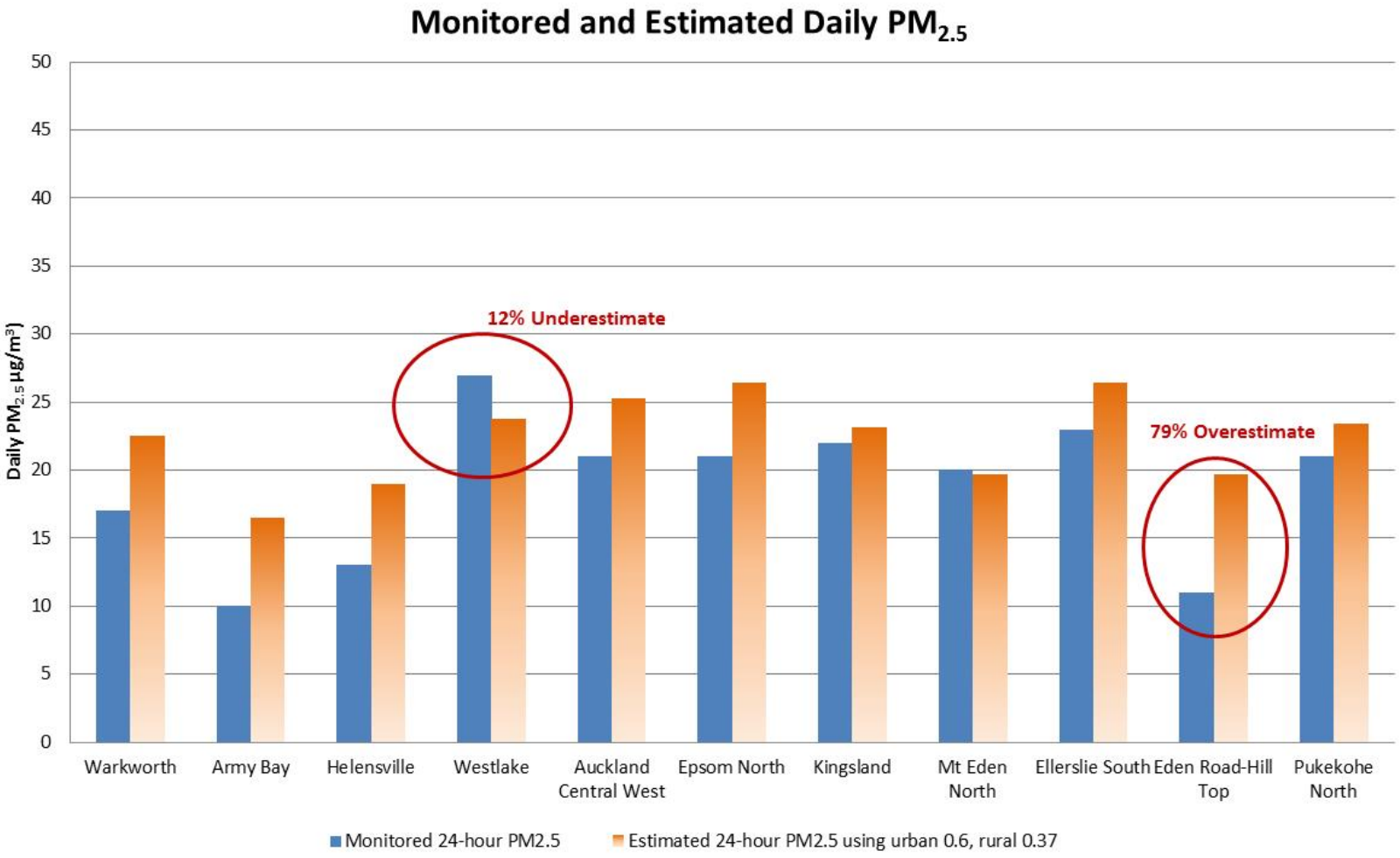


Figure A6-2
Comparison of Estimated and Measured Annual $PM_{2.5}$

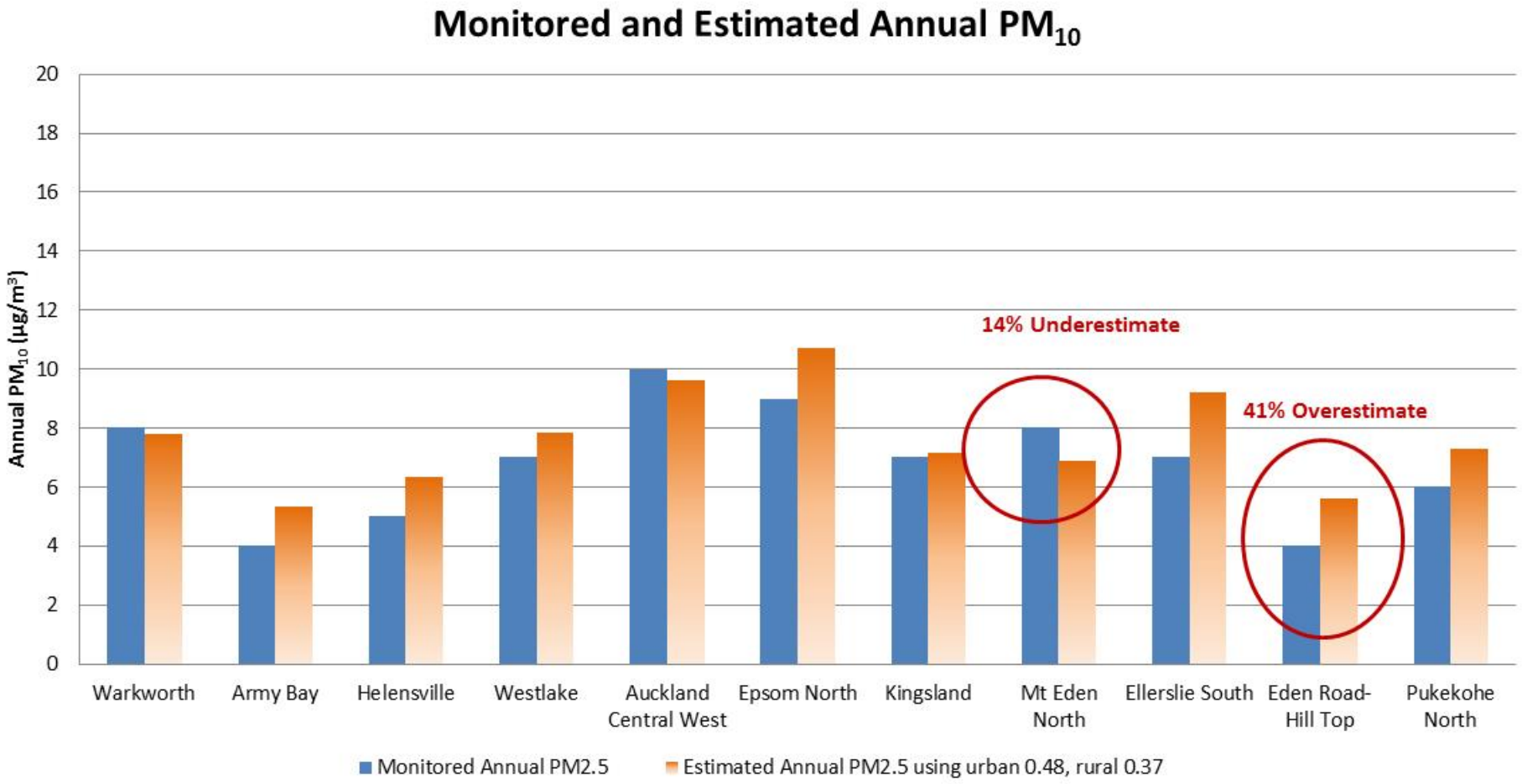


Figure A3-4
Default daily $PM_{2.5}$ by census area unit for the Auckland Region

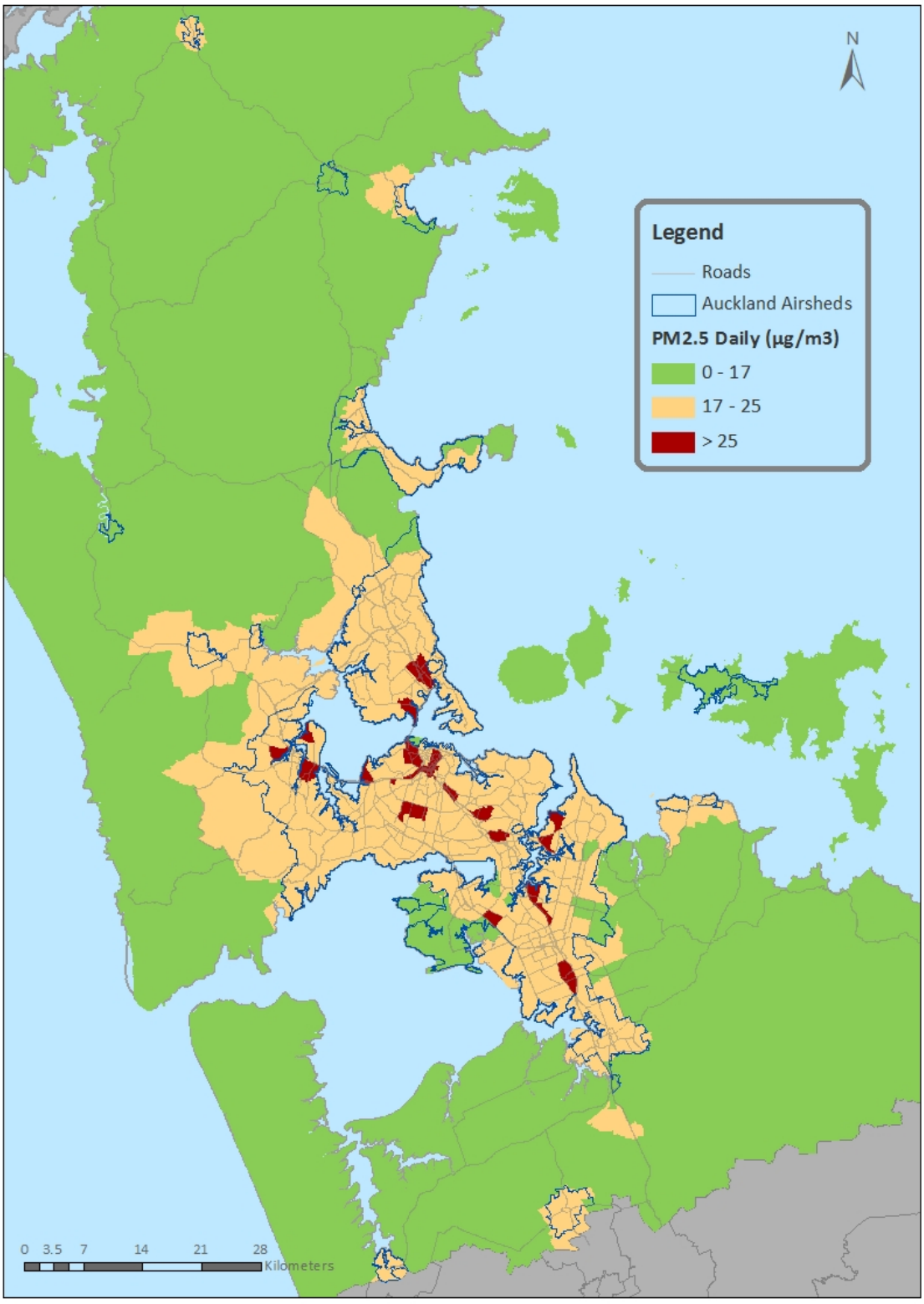
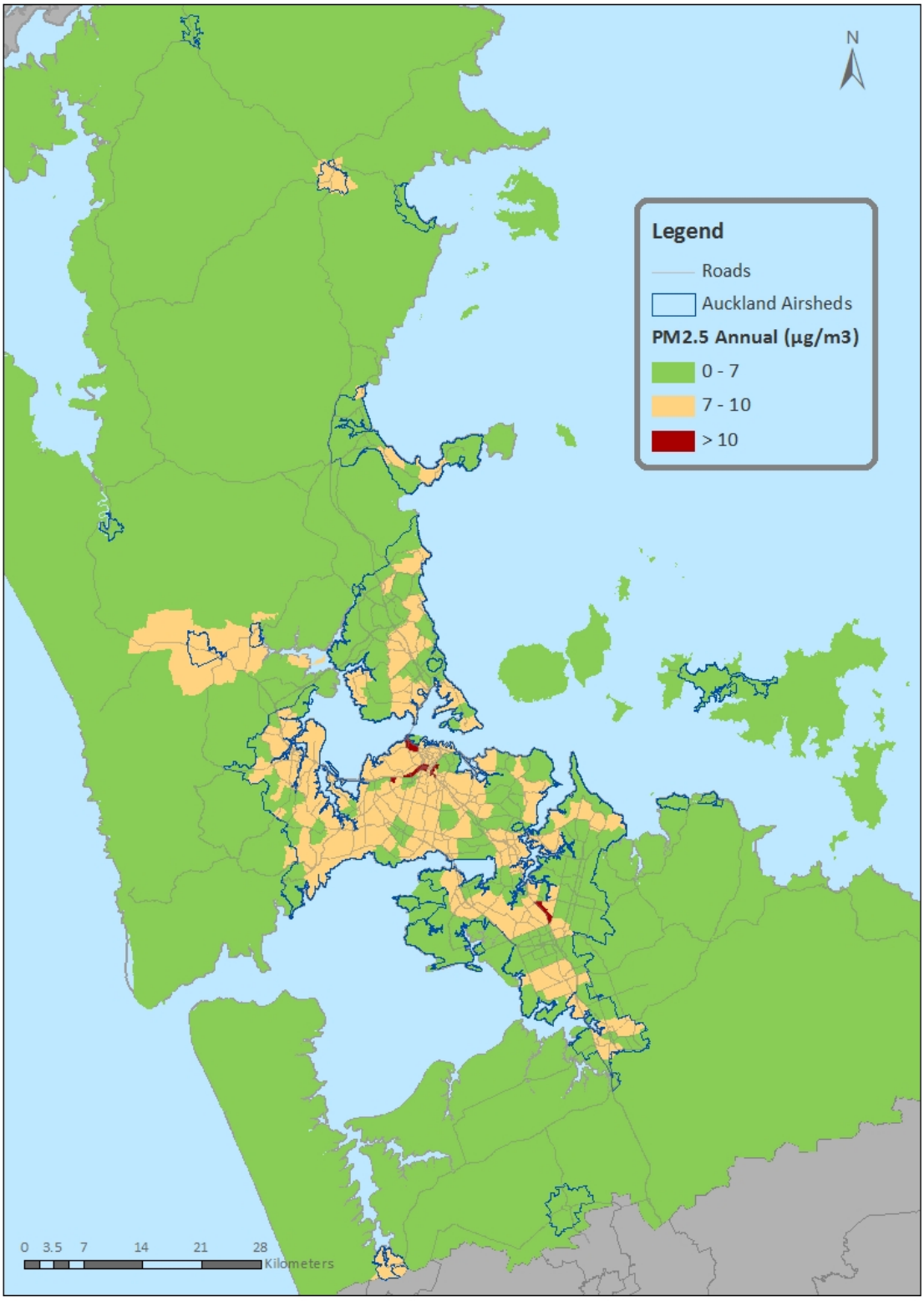


Figure A3-5
Default annual $PM_{2.5}$ by census area unit for the Auckland Region



Sulphur dioxide

The only site for which a long-term data record is available is Penrose. This is a roadside location as defined in Section 3.3.

Peak ambient levels of short-term sulphur dioxide measured at Penrose have dropped significantly over the last 30 years as shown in Figure A3-7. The last ten years have seen a more consistent trend in maximum daily levels and this period has been selected for representative background levels for the 24-hour average.

Table A3-4 provides peak averages and default values for roadside locations.

Monitoring commenced at the Auckland Waterfront in winter 2011. Elevated levels of sulphur dioxide recorded at this site indicate that the Penrose site may not be suitably conservative. Assessments for areas near the port, and areas where Penrose data is not applicable, should consult Auckland Council to determine an appropriate value for background air quality.

Comparing data for various sites, levels of 20 µg/m^3 (1-hour average), and 8 µg/m^3 (24-hour average) were chosen to apply in the Urban Airshed.

Figure A3-6
Long-term trends in sulphur dioxide at Penrose (1975-2013)

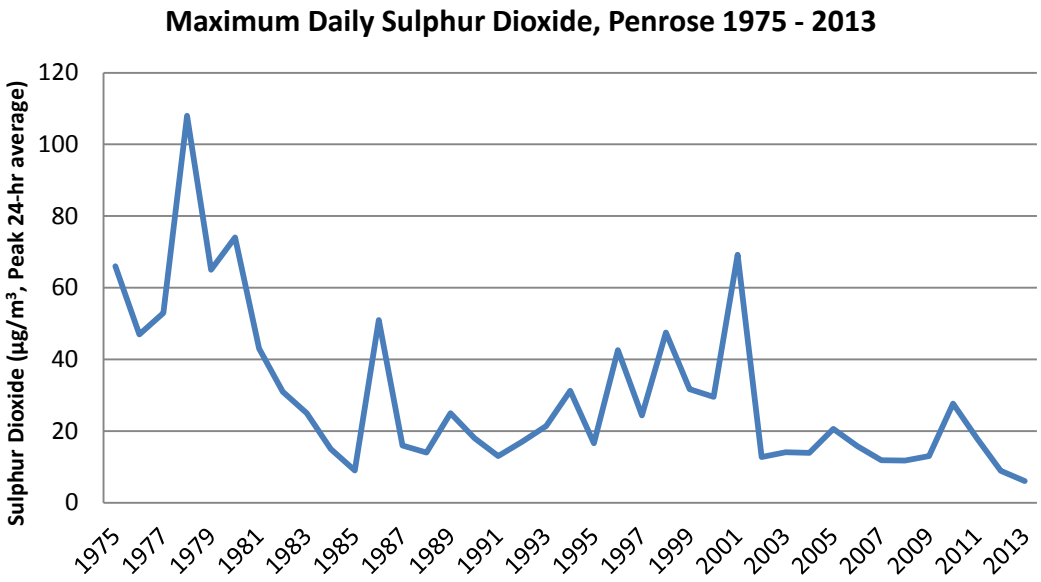


Table A3-4
Data considered in the calculation of default SO_2 values

Location	Site	1-hour		24-hour		Default Values	
		Years	Peak Average	Years	Peak Average	1-hr	24-hr
Roadside	Penrose	1975-2013	42.3	2003-2013	14.7	42	15

Benzene

Benzene concentrations have been measured in Auckland during various project campaigns (ARC, 2009). Because of the decrease in the benzene content of petrol in late 2005, data prior to 2006 was excluded. Considering available information, a value of 2 µg/m^3, annual average, was chosen for the Roadside Urban Airshed, and a value of 1 µg/m^3, annual average, for the Urban Airshed.

Nitrogen oxides

This guide has been developed with industrial applications in mind. Assessments for discharges from roads, or assessments for discharges from large combustion plant (e.g. power stations) should liaise with Auckland Council prior to commencing.

Results of the averages of annual maximum values for each of the two averaging times for nitrogen dioxide (1-hour and 24-hour), and annual average data are provided in Table A3-5.

It is important to note that measured nitrogen dioxide in residential areas is typically only a fraction of measured total nitrogen oxides. This is shown in Figure A3-7 which plots hourly concentrations of nitrogen dioxide against those of total nitrogen oxides as measured at Kingsland in 2005. Figure A3-7 shows that the maximum nitrogen dioxide measured is 103 µg/m^3 whereas the maximum total nitrogen oxides measured is 1,350 µg/m^3.

Review of the monitoring data confirms that, when nitrogen dioxide concentrations are high, the available ozone concentration is negligible. This is shown in Figure A3-8. Figure A3-8 plots hourly concentrations of nitrogen dioxide against those of ozone as measured at Kingsland in 2005. Figure A3-8 shows that the maximum hourly nitrogen dioxide concentration of 103 µg/m^3 is measured when ozone is only 3 µg/m^3.

Table A3-5
Data considered in the calculation of default 1-hr, 24-hr and annual nitrogen dioxide (NO_2) concentrations

Location	Site	Years	Peak Average		Annual	Default Values		
			1-hour	24-hour	Average	1-hr	24-hr	Annual
Roadside	Penrose	1990-2013	117	55	23	113*	55	23
	Takapuna	2002-2013	109	54	24			
Urban	Glen Eden	2006-2013	55	25	8	75	39	13
	Henderson	2004-2013	75	38	15			
	Kingsland	2005-2006	96	45	19			
	Mt Eden	1994-2005	82	47	18			
	Musick Point	2001-2013	68	39	8			
Rural	Patumahoe	2007-2013	43	17	4	41	16	4
	Waiheke	2009-2010	39	15	4			
Rural Town	Pukekohe	2007-2008	88	39	13	75	37	13
	Warkworth	2008	72[13]	34	18			
	Waiuku	2009	64	37	8			

*For use in assessments using proxy methodology

NB: Khyber Pass and Queen Street monitoring data were excluded from consideration of background air quality values for nitrogen dioxide. These sites are heavily influenced by street canyons (Queen Street) and large buildings (Khyber Pass) and had elevated levels of nitrogen dioxide that are not considered generally relevant to other locations in Auckland.

[13] Two outliers removed (roadworks).

Figure A3-7
Ambient levels of nitrogen dioxide (NO_2) are always significantly less than total nitrogen oxides (NOx) as measured at Kingsland (2005)

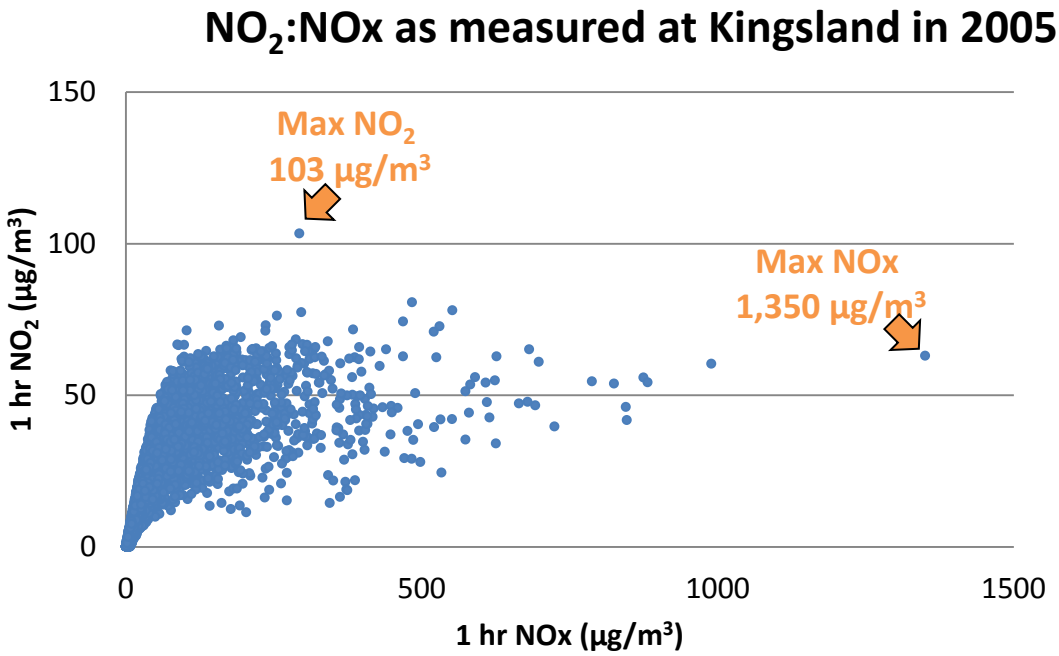


Figure A3-8
Ambient levels of nitrogen dioxide (NO_2) show negative correlation with ambient levels of ozone (O_3) as measured at Kingsland (2005)

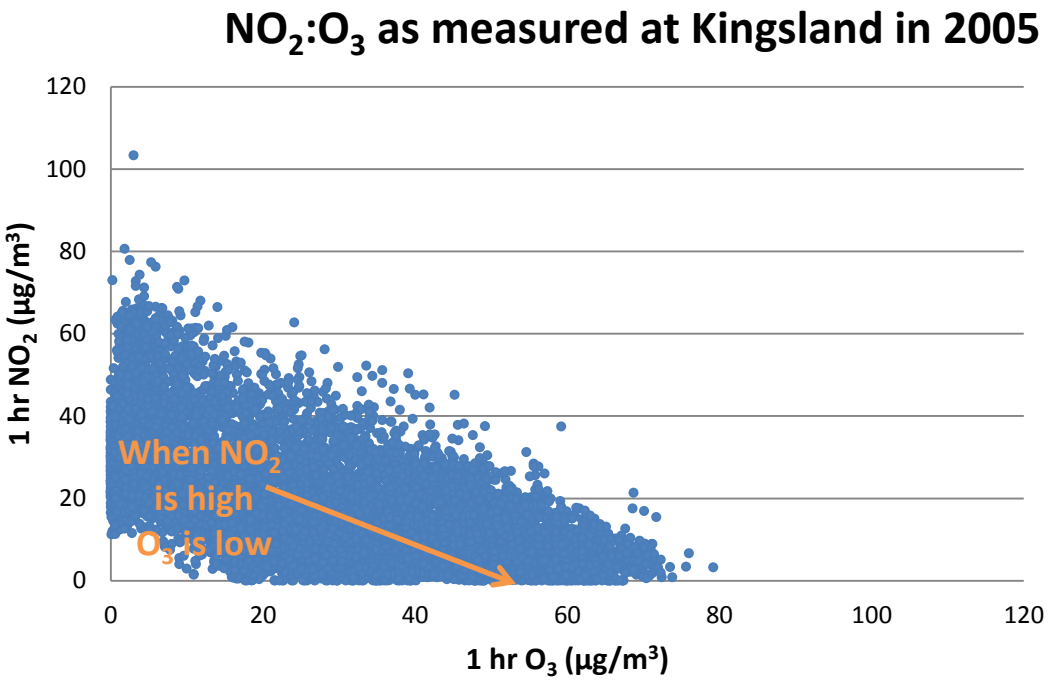
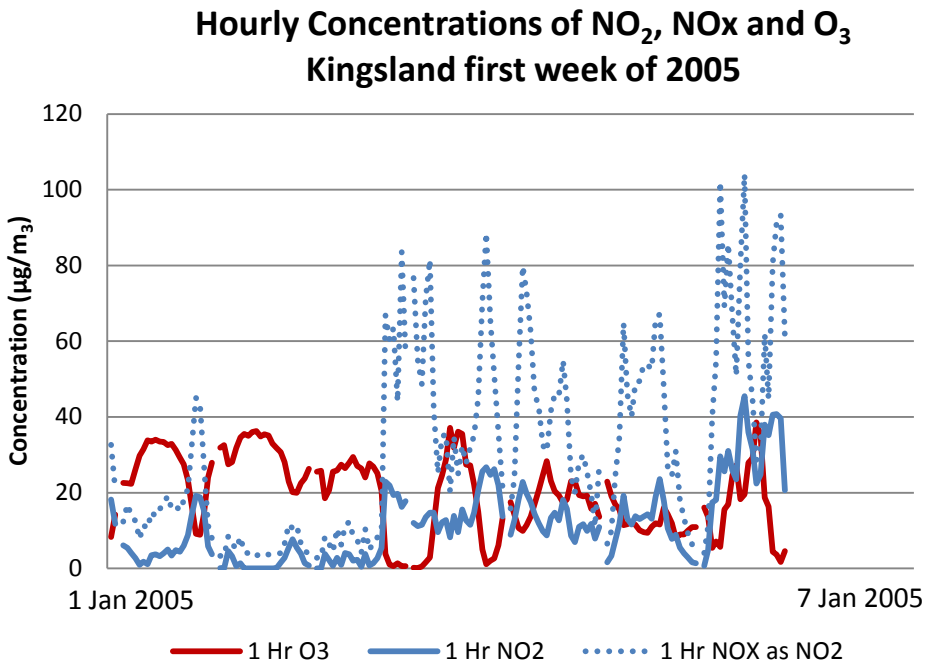


Figure A3-9 plots both nitrogen dioxide, nitrogen oxides and ozone for the first week of 2005 as measured at the Kingsland monitoring station. This shows how nitrogen dioxide is negatively correlated with ozone and always less than total nitrogen oxides.

Figure A3-9

Relative concentrations of nitrogen dioxide (NO_2), nitrogen oxides (NOx) and ozone (O_3) in the first week of 2005 at Kingsland



For assessing background concentrations with the proxy method (Section 4.1.1) default values for combined nitrogen dioxide with ozone [Proxy NO_2] have been derived (please refer Table A3-7).[14] These are based on monitoring data from sites where nitrogen dioxide and ozone were monitored concurrently in 2005 and/or 2007 (Kingsland, Patumahoe and Musick Point). Table A3-7 demonstrates that the peak nitrogen dioxide concentration and peak combined nitrogen dioxide with ozone [Proxy NO_2] are similar at the Kingsland monitoring site.

[14] Conversion of ozone to nitrogen dioxide equivalent is calculated by multiplying the ozone concentration by the ratio of molecular weights of nitrogen dioxide (46) to ozone (48) i.e. [O3] x 46/48 = [NO2] equivalent.

Table A3-7
Data considered in the calculation of default combined nitrogen dioxide with ozone [Proxy NO_2] concentrations

Airshed		Site	Year	1-hour		24-hour	Default (**Proxy NO_2)	
				Max	99.9th %ile	Max	1-hr	24-hr
Roadside		non available					113*	75
Urban	**Proxy NO_2	Kingsland	2005	106	84	74	95	
			2007	84	76	68		
	NO_2		2005	103	72	48		
			2007	81	69	44		
Rural	**Proxy NO_2	Musick Point	2005	102	92	75		
			2007	94	82	75		
		Patumahoe	2007	83	76	69		
	NO_2	Musick Point	2005	66	61	33		
			2007	71	58	40		
		Patumahoe	2007	43	36	16		

*For use in assessments using proxy methodology
**NO_2 + O_3 (as NO_2 equivalents)

In rural areas the background concentration of nitrogen dioxide is lower compared with urban areas. However the default combined nitrogen dioxide with ozone [Proxy NO_2] is the same for rural and urban areas, because rural areas have relatively high ozone concentrations. The combined nitrogen dioxide with ozone (as NO_2 equivalents) is similar in rural and urban areas. This provides some confidence that the proxy method is applicable in any location, except roadsides where direct emissions of nitrogen dioxide are likely to cause higher nitrogen dioxide concentrations.

It is reasonable to assume that there is no ozone available when the ambient nitrogen dioxide concentration is elevated (above 75 µg/m^3). On this basis, the default background value for roadside combined nitrogen dioxide with ozone [Proxy NO_2] is the same as the default background value for nitrogen dioxide (113 µg/m^3).

The roadside default values should be used for industry located within 300 m of motorways and strategic arterial, and 150 m of regional arterials (refer Table 3.2). These distances reflect research showing elevated levels of nitrogen dioxide out to significant distances (ARC, 2007).

Note: Comparison with the Good Practice Guide

The recommended (proxy) method for considering nitrogen oxides and nitrogen dioxide in this Guide differs from the ozone limiting method recommended by the Industry Good Practice Guide (MfE, 2008).

The ozone limiting method in the Industry Good Practice Guide is described as follows:

$$[NO_2] = [NO_2]_{est} + [NO_2]_{bkd}$$

And

$$[NO_2]_{est} = [NO_x]_{mod} \times F(NO_2) + 72$$

Where:

$[NO_2]_{bkd}$ = background nitrogen dioxide

$[NO_2]_{est}$ = the nitrogen dioxide concentration at the receptor due to the modelled nitrogen oxides emission

$[NO_x]_{mod}$ = the nitrogen oxides concentration at the receptor, due to the nitrogen oxides emission under consideration

$F(NO_2)$ = is the mass fraction of nitrogen dioxide in the nitrogen oxides emissions from the source under consideration

72 = the upper limit for nitrogen dioxide formed by oxidation of nitric oxide by the maximum background ozone concentration.

The ozone limiting method is too conservative for an assessment where high background concentrations of nitrogen dioxide are present (such as parts of Auckland). Figure A3-10 shows that peak 1-hour levels of nitrogen dioxide have not been decreasing as expected due to reductions in vehicle emission limits. Annual levels of nitrogen dioxide further appear to be increasing (Figure A3-11).

The following worked example for 1-hour average nitrogen dioxide in an urban area (i.e. non roadside location) compares the proxy method with the ozone limiting method:

Proxy Method

$[NO_2]$ = $[NO_x]_{mod} \times F(NO_2) + [\text{Proxy } NO_2]$ (Section 4.1.1)

= $[NO_x]_{mod} \times F(NO_2) + 95$ **(Table 4.1)**

Ozone Limiting Method

$[NO_2]$ = $NO_x]_{mod} \times F(NO_2) + 72 + [NO_2]_{bkd}$

= $NO_x]_{mod} \times F(NO_2) + 72 + 75$ **(Table 3.1)**

= $NO_x]_{mod} \times F(NO_2) + 147$

In locations where the background concentration of nitrogen dioxide is already higher than 72 µg/m^3 there will be little, if any, ozone available so the upper limit for nitrogen dioxide formed by oxidation of nitric oxide will be negligible.

In summary, the recommended proxy method avoids double counting of background nitrogen dioxide and background ozone. It is therefore, a more appropriate method for Auckland.

Figure A3-10
Long term trend of peak 1-hour concentrations of nitrogen dioxide as measured at Penrose, 1975 -2013

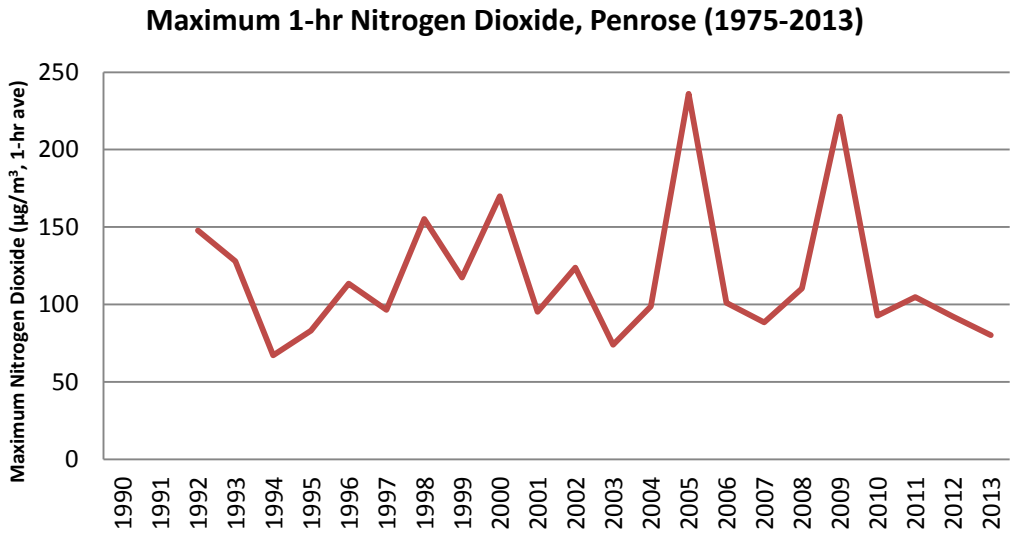
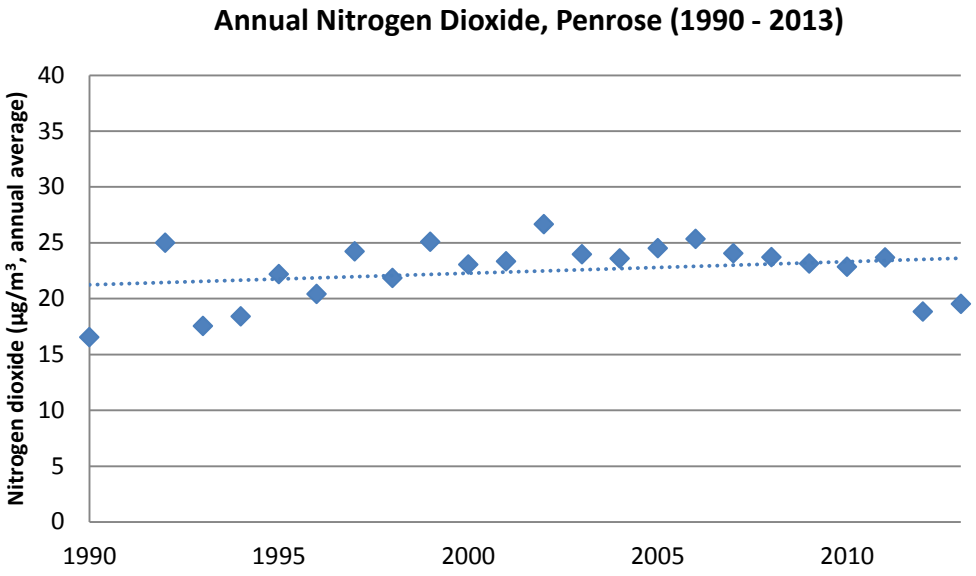


Figure A3-11
Long term trend of annual average concentrations of nitrogen dioxide as measured at Penrose, 1990 -2013



Appendix 4: Strategic and regional arterial road network

Roadside Locations

Roadside locations are based on consideration of pollutant concentrations measured at the Penrose, Takapuna and Pakuranga (for CO only).[15] The distance from these monitoring sites to major roads is described in Table A4-1 (ARC, 2006).

Table A4-1
Monitoring sites considered to determine roadside default values

Site	Distance to road
Penrose	106 m to Southern Motorway
Pakuranga	7.5 m to Pakuranga Highway (regional arterial)
Takapuna	60 m to motorway, 30m to Wairau Road (regional arterial)

Dispersion modelling suggests that the concentration of contaminants declines to levels that are close to background concentrations at approximately 100 to 150m from roadsides (MfE, 2008b). The roadside concentrations are assumed to apply within 150m of motorways on this basis. Arterial roads have substantially lower traffic volumes than motorways, however monitoring shows that concentration of contaminants close to arterials may be elevated. Therefore the roadside concentrations are assumed to apply within 60m of arterial roads.

Monitoring of roadside NO_2 in Auckland has shown that concentrations do not necessarily decline quickly with distance from the motorway (ARC, 2007). Further research is needed to understand the influence of emissions from a motorway on NO_2 concentrations, however it is reasonable to assume that NO_2 concentrations may be elevated up to 400m away from motorways.

Strategic arterials, state highways and regional arterials are defined in the Regional Arterial Road Plan (ARTA, 2009) and shown in Figure A4-1 and Table A4-2.

[15] The Queen Street and Khyber Pass monitoring sites were considered to be influenced by tall buildings and not considered representative of other (less built up) areas in Auckland.

Figure A4-1
The Auckland strategic route and regional arterial road network
(ARTA 2009 pg. 75)

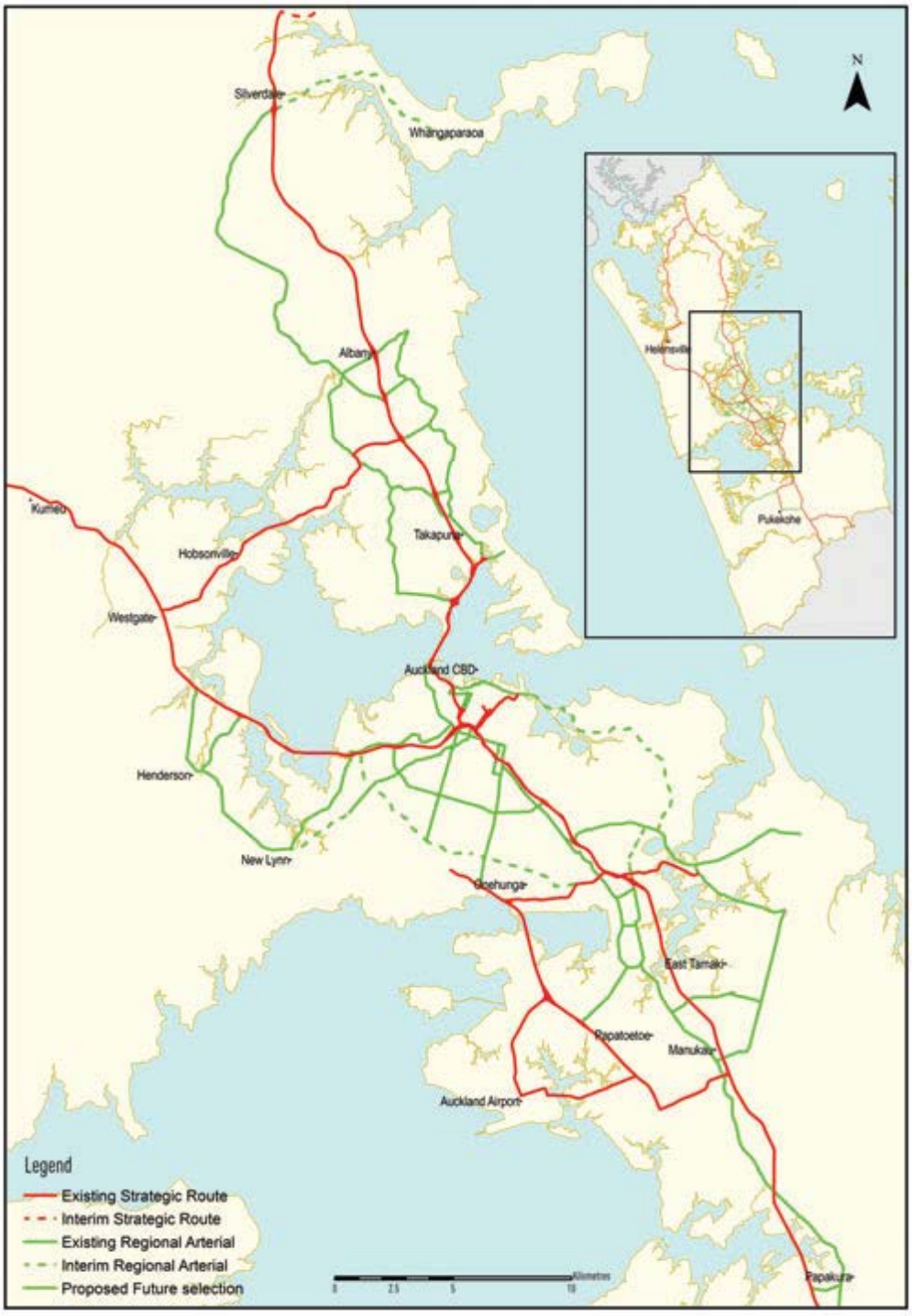


Table A4-2
Roads in the Regional Arterial Network
(ARTA 2009).

The list of roads that are included in the Regional Arterial Network shown in Figure A4-1 by Territorial Local Authority.

Auckland City Council		
Arterial	**From**	**To**
Alpers Avenue	Gillies Avenue	Broadway
Albert Street/Lower Albert Street	Quay Street	Wellesley Street
Apirana Avenue – Pilkington Road – Jellicoe Road	Merton Road	Panmure Roundabout
Ash Street	TLA boundary (Whau River)	Great North Road
Atkinson Avenue	Portage Road	Great South Road
Balmoral Road	Sandringham Road	Manukau Road
Broadway	Khyber Pass	Manukau Road
Carrington Road	Great North Road	Mt Albert Road
Church Street	Mays Road	Neilson Street
Church Street*	Neilson Street	South-eastern Highway
Customs Street East	Customs Street West	Anzac Avenue
Customs Street West	Fanshawe Street	Customs Street East
Dominion Road	SH20	New North Road
Ellerslie – Panmure Highway	Great South Road	Panmure Roundabout
Fanshawe Street	SH1 Interchange	Customs Street West
Gillies Avenue	Khyber Pass	Owens Road
Great North Road	Ash Street	Karangahape Road
Great South Road	Broadway	Portage Road
Great South Road	Atkinson Avenue	TLA boundary (Tamaki River)
Greenlane West and East	Balmoral Road	Remuera Road
Ian McKinnon Drive	Dominion Road	Upper Queen Street
Karangahape Road	Great North Road	Pitt Street
Kepa Road	Ngapipi Road	Kohimarama Road
Khyber Pass	Symonds Street	Broadway
Kohimarama Road	Kepa Road	St Heliers Bay Road
Lagoon Drive	Panmure Roundabout	TLA boundary (Tamaki River)
Lower Hobson Street	Quay Street	Fanshawe Street
Lower Queen Street	Customs Street	Quay Street
Maioro Street	New Windsor Road	SH20 Intersection
Mangere Road	TLA boundary (Railway)	Great South Road
Manukau Road	Broadway	Greenlane
Manukau Road – Pah Road	Manukau Road/Greenlane	Pah Road/Mt Albert Road

Table A4-1 (Cont.)
Roads in the Regional Arterial Network
(ARTA 2009).

Auckland City Council		
Arterial	**From**	**To**
Mayoral Drive	Wellesley Street	Cook Street
Mays Road	Mt Smart Road	Church Street
Mt Albert Road	Carrington Road	Royal Oak Roundabout
Mt Smart Road	Royal Oak Roundabout	Mays Road
Mt Wellington Highway	Ellerslie – Panmure Highway	Portage Road
Owens Road	Gillies Avenue	Manukau Road
Neilson Street*	SH20 Interchange	Church Street
Newton Road	Great North Road	Symonds Street
Ngapipi Road	Tamaki Drive	Orakei Road
Pah Road – Queenstown Road	Mt Albert Road	SH20 Interchange
Pitt Street	Vincent Street	Karangahape Road
Portage Road	Great South Road	Atkinson Avenue
Princes Street	Atkinson Avenue	SH1 Interchange
Quay Street	Tinley Street	The Strand
Quay Street	Lower Hobson Street	Lower Queen Street
Remuera Road	St Johns Road	Greenlane East
Saleyards Road – Walmsley Road	Great South Road	Mangere Road
South-eastern Highway	Church Street	Waipuna Road
St Heliers Bay Road – Apirana Avenue	St Johns Road	Merton Road
St Johns Road	Kohimarama Road – St Heliers Bay Road Intersection	Remuera Road
St Lukes Road	Great North Road	Sandringham Road
Sturdee Street	Fanshawe Street	Customs Street
Sylvia Park Road	Great South Road	Mt Wellington Highway
Symonds Street – Anzac Avenue	Khyber Pass	Beach Road
Tamaki Drive	The Strand	Ngapipi Road
The Strand*	Quay Street	SH16
Tiverton Road – New Windsor Road	Wolverton Road	Maioro Street
Vincent Street	Mayoral Drive	Pitt Street
Waipuna Road	Mt Wellington Highway	South-eastern Highway
Wolverton Street	TLA boundary (east of Portage Rd)	Blockhouse Bay Road

Franklin District Council		
Arterial	**From**	**To**
Glenbrook Rd – Glenbrook Waiuku Rd	Karaka Road	Kitchener Road
East Street – Pukekohe East Road	Stadium Drive	SH1 Bombay Interchange
Manukau Rd – Buckland Rd – Gorge St	East Street, Pukekohe	Whangarata Road, Tuakau
Paerata Road – Franklin Road	East Street, Pukekohe	South of end of SH22
Whangarata Road – Pokeno Road	Tuakau	Pokeno

Table A4-1 (Cont.)
Roads in the Regional Arterial Network
(ARTA 2009).

Manukau City Council		
Arterial	**From**	**To**
Cavendish Drive – Liverpool Street – Nesdale Street	SH1 Interchange	SH20 Interchange
East Tamaki Road	Preston Road	Great South Road
Great South Road	TLA boundary (Tamaki River)	TLA boundary (north of motorway)
Harris Road	Ti Rakau Drive	Smales Road
Highbrook Drive – Allens Road	SH1 Interchange	Harris Road
Massey Road	TLA boundary (railway)	SH20 Interchange
Ormiston Road	East Tamaki Road	Sandstone Road
Pakuranga Road	TLA boundary (Tamaki River)	Bucklands Beach Road
Sandstone Road – Whitford Road – Maraetai Road – Maraetai Drive	Ormiston Road	Rewa Road
Smales Road	Harris Road	Te Irirangi Drive
South-eastern Highway*	Waipuna Road	Ti Rakau Drive
Springs Road – East Tamaki Road	Harris Road	Preston Road
Te Irirangi Drive*	Ti Rakau Drive	SH1 Te Irirangi interchange
Ti Rakau Drive*	Pakuranga Road	Te Irirangi Drive

North Shore City Council		
Arterial	**Between**	**To**
Akoranga Drive	SH1 Esmonde interchange	Northcote Road
Albany Highway	Oteha Valley Road	Glenfield Road
Anzac Street	Fred Thomas Drive	Auburn Street
Barry's Point Road	Anzac Street	Esmonde Road
Constellation Drive	SH1 Interchange	East Coast Road
East Coast Road	Northcross Intersection	Forrest Hill Road
Esmonde Road	SH1 Esmonde Interchange	Lake Road
Forrest Hill Road	East Coast Road	Wairau Road
Glenfield Road	Sunset Road	Highbury Corner
Lake Road	Esmonde Road	Victoria Road
Northcote Road	Taharoto Road	Akoranga Drive
Onewa Road	Highbury Corner	SH1 Onewa Interchange
Oteha Valley Road	Albany Highway	Northcross Intersection
Taharoto Road	Wairau Road	Fred Thomas Drive
Tristram Avenue	Forrest Hill Road	Wairau Road
Upper Harbour Drive (SH18)**	Tauhinu Road, Greenhithe	Albany Highway
Wairau Road	Glenfield Road	Taharoto Road
SH17 (and Albany Expressway)**	TLA boundary (Albany Heights Road)	SH1 Greville Interchange

Table A4-1 (Cont.)
Roads in the Regional Arterial Network
(ARTA 2009).

Papakura District Council		
Arterial	**Between**	**To**
Beach Road	SH1 Interchange	Great South Road
Great South Road	TLA boundary (north of motorway)	SH1 Drury Interchange

Rodney District Council		
Arterial	**Between**	**To**
Coatesville Riverhead Highway	SH17	SH16
Kahikatea Flat Road	Pine Valley Road	SH16
Pine Valley Road	SH17	Kahikatea Road
SH17**	SH1 Silverdale Interchange	TLA boundary (Albany Heights Road)
Whangaparaoa Road	Hibiscus Coast Highway	Link Crescent
Hibiscus Coast Highway (SH1)**	SH1 Silverdale Interchange	West Hoe Road

Waitakere City Council		
Arterial	**Between**	**To**
Brigham Creek Road	Hobsonville Road	SH16
Don Buck Road	Hobsonville Road	Triangle Road
Edmonton Road	Sel Peacock Drive	Te Atatu Road
Great North Road	Swanson Road	Titirangi Road
Great North Road – Clark Street	Titirangi Road	Wolverton Street (TLA boundary)
Hobsonville Road (SH18)**	Don Buck Road	Eastern end of Hobsonville Road
Lincoln Road	Swanson Road	SH16 Interchange
Rata Street	Titirangi Road	Whau River (TLA boundary)
Swanson Road	Don Buck Road	Lincoln Road
SH16**	Hobsonville Road	Brighams Creek Road
Te Atatu Road	Edmonton Road	SH16 Interchange
Triangle Road	Lincoln Road	Don Buck Road

* Roads that are classified as strategic routes, but are not state highways, i.e. they are controlled by the relevant territorial authority.

** Roads that are state highways, and hence that are controlled by New Zealand Transport Agency, but are included in the regional arterial network.

Appendix 5: Exceptional events and outliers

As noted in Section 4.4, it is not necessary to consider ambient background concentrations that occur during “exceptional events”.

There are no specific results from 2005 and 2007 that are considered likely to have been affected by “exceptional events”.

In addition to “exceptional events”, it is appropriate to exclude outliers from consideration of background air quality, which are unlikely to be representative or repeatable. As such these outliers are not relevant to the consideration of potential future effects.

Henderson PM_{10}, 27 June 2007 (125 µg/m^3)

24 hour average is elevated due to a large elevation in concentrations in the middle of the day. Other sites are elevated, but not to the same extent. Concentrations on the day before and after this are not elevated. The cause is not known, however it is not considered likely to be a representative or repeatable peak.

Pakuranga PM_{10}, 11 October 2007 (137 µg/m^3)

24 hour average is elevated due to a large elevation in concentration for six hours in afternoon. Other sites are not elevated. Concentrations on the day before and after this are not elevated. The cause is not known, however it is not considered likely to be a representative or repeatable peak.

Patumahoe

Results from Patumahoe have been examined in some detail because peak concentrations are very high compared with the other rural monitoring site.

High concentrations were measured at this site in September 2008 due to open burning of vegetation in the vicinity of the monitoring site. High concentrations at this site are generally from activities that have localised effects, and are effectively **independent of meteorological conditions.** This means that the coincidence of high modelled concentrations and high background concentrations is random and extremely unlikely.

For consideration of background air quality it is considered appropriate to remove outliers from the Patumahoe data set. Outliers have been identified for all monitoring between 2005 and 2008 based on examination of the data.as illustrated in Figures A5-1 to A5-3. Outliers have been removed for calculation of default values in Appendix 4.

Patumahoe PM_{10} 15 March 2006 (49.3 µg/m^3)

Patumahoe PM_{10} 9 March 2007 (43.7 µg/m^3)

Patumahoe PM_{10} 15 September 2008 (84.9 µg/m^3)

Patumahoe PM_{10} 16 September 2008 (63.1 µg/m^3)

Patumahoe PM_{10} 21 September 2008 (87.5 µg/m^3)

Patumahoe $PM_{2.5}$ 15 September 2008 (71.9 µg/m^3)

Patumahoe $PM_{2.5}$ 16 September 2008 (42.4 µg/m^3)

Figure A5-1
Patumahoe 2006 PM_{10} monitoring results indicating results that are outliers for the purposes of background air quality assessment

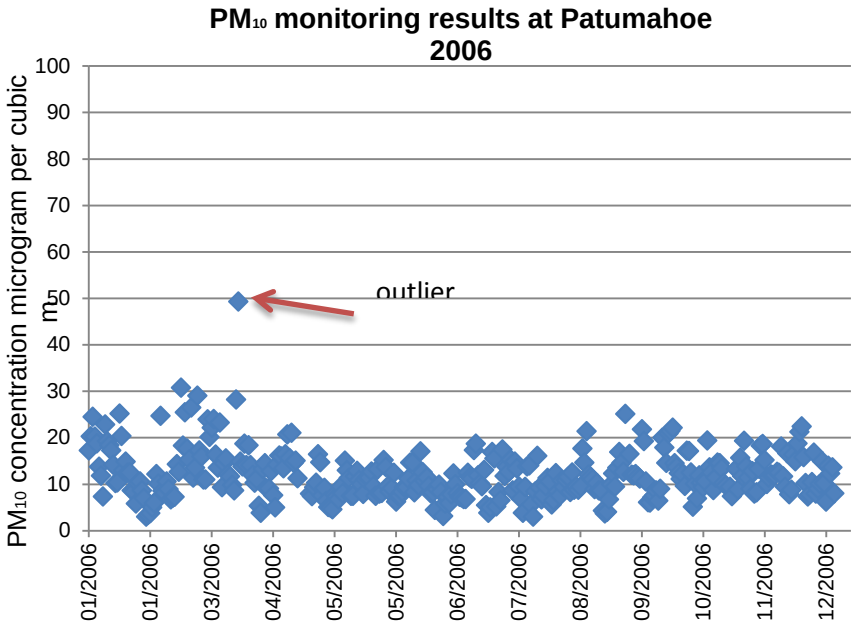


Figure A5-2
Patumahoe 2007 PM_{10} monitoring results indicating results that are outliers for the purposes of background air quality assessment

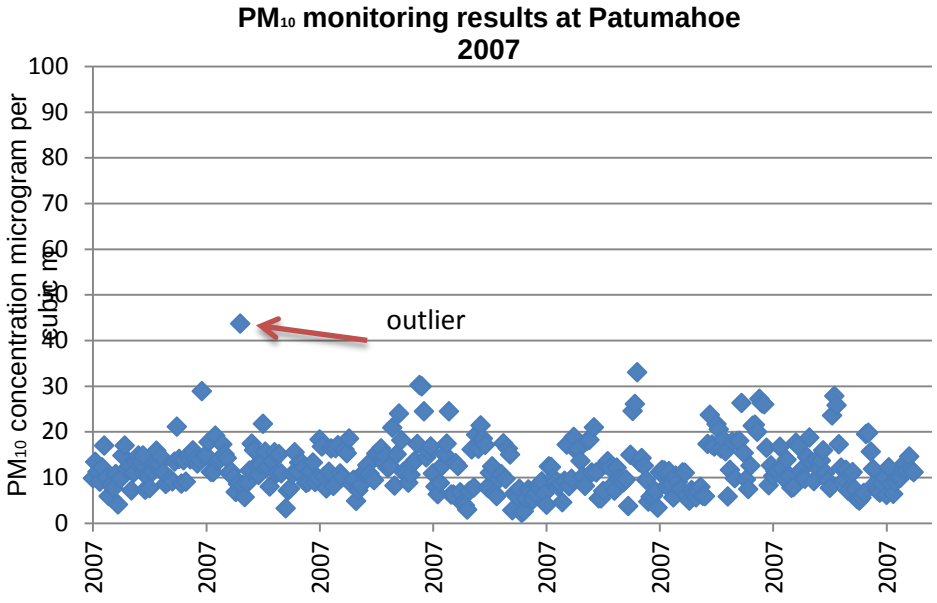
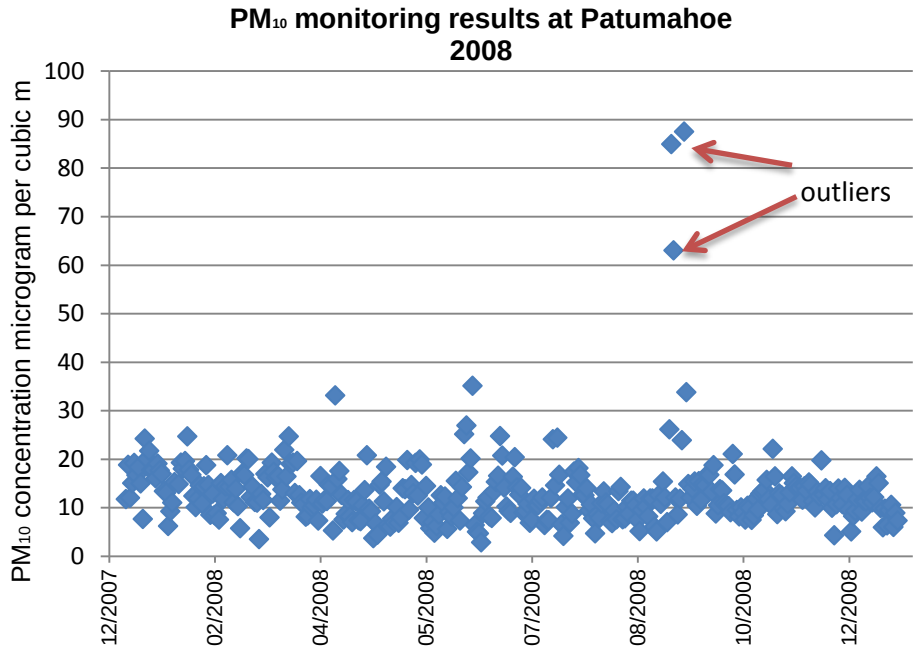


Figure A5-3
Patumahoe 2008 PM_{10} monitoring results indicating results that are outliers for the purposes of background air quality assessment



Warkworth NO_2, 2008 1-hr average (159 µg/m^3)

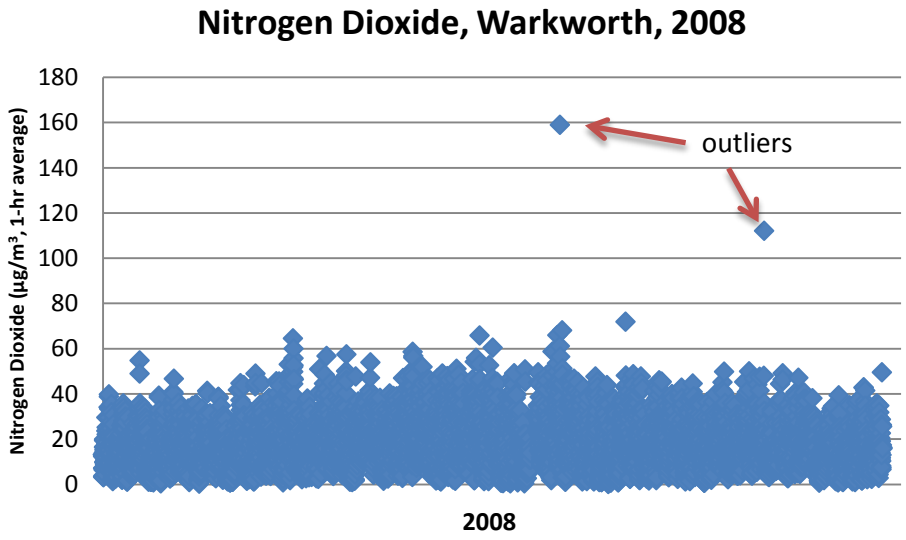
Warkworth NO_2, 2008 1-hr average (112 µg/m^3)

The maximum and second highest results from Warkworth have been removed as they are considered to be outliers based on examination of the data as illustrated in Figure A5-4. Warkworth was known to be experiencing significant congestion due to roadworks during this monitoring period.

Outliers have been removed for calculation of default values in Appendix 4.

Figure A5-4

Warkworth 2008 NO_2 monitoring results indicating results that are outliers for the purposes of background air quality assessment



Appendix 6: PM_{10} and $PM_{2.5}$ by Census Area Unit

Table A6-1 presents measured and estimated default values for PM_{10} and $PM_{2.5}$ for all census area units in the Auckland Region. Where monitored values are available, these are used as default background concentrations.

The census area units are those defined by Statistics New Zealand in 2006 (because this document was originally drafted in 2011). In the 2013 census, Statistics New Zealand made some amendments to the census area units defined for the Auckland Region. However, background values have been assigned using the Updated HAPINZ 2012 study (Kuschel *et al*., 2012) which similarly relies on the 2006 census area units.

This document therefore, continues to refer to the 2006 census area units. Readers are advised there may be slight differences between current census area unit boundaries and those listed here.

Statistics New Zealand hosts an interactive boundary map that provides the name of each census area unit for a searchable address:

http://apps.nowwhere.com.au/StatsNZ/Maps/default.aspx

Table A6-1

Estimated and Measured PM_{10} and $PM_{2.5}$ by census area unit in Auckland

TLA	Census Area Unit Description	Monitored 24-hour PM_{10}	Estimated or Monitored 24-hour PM_{10}	Monitored 24-hour $PM_{2.5}$	Estimated 24-hour $PM_{2.5}$ using urban 0.6, rural 0.37	Monitored Annual PM_{10}	Estimated or Monitored Annual PM_{10}	Monitored Annual $PM_{2.5}$	Estimated Annual $PM_{2.5}$ using urban 0.48, rural 0.37
Rodney District	Wellsford		30		18		12		6
Rodney District	Leigh		31		11		13		5
Rodney District	Warkworth	38	38	17	23	16	16	8	8
Rodney District	Kumeu	38	38		23	16	16		8
Rodney District	Waipareira West		28		17		12		6
Rodney District	Red Beach		34		20		14		7
Rodney District	Waiwera		28		10		12		4
Rodney District	Hatfields Beach		36		22		15		7
Rodney District	Orewa	37	37		22	14	14		7
Rodney District	Manly		37		22		15		7
Rodney District	Army Bay	27	27	10	16	11	11	4	5
Rodney District	Vipond		36		22		15		7
Rodney District	Stanmore Bay West		37		22		15		7
Rodney District	Stanmore Bay East		34		20		14		7
Rodney District	Wade Heads		32		19		13		6
Rodney District	Gulf Harbour		29		17		12		6
Rodney District	Gulf Harbour Marina		27		10		11		4
Rodney District	Silverdale South		28		17		12		6
Rodney District	Silverdale North		28		17		12		6
Rodney District	Dairy Flat-Redvale		29		18		12		6
Rodney District	Paremoremo West		28		17		12		6
Rodney District	Tauhoa-Puhoi		28		10		12		4
Rodney District	Tahekeroa		28		10		12		4
Rodney District	Cape Rodney		28		10		12		4
Rodney District	Matheson Bay		31		11		13		5
Rodney District	Kawau		28		10		12		4

TLA	Census Area Unit Description	Monitored 24-hour PM_{10}	Estimated or Monitored 24-hour PM_{10}	Monitored 24-hour $PM_{2.5}$	Estimated 24-hour $PM_{2.5}$ using urban 0.6, rural 0.37	Monitored Annual PM_{10}	Estimated or Monitored Annual PM_{10}	Monitored Annual $PM_{2.5}$	Estimated Annual $PM_{2.5}$ using urban 0.48, rural 0.37
Rodney District	Snells Beach		29		18		12		6
Rodney District	Algies Bay-Mahurangi		28		10		12		4
Rodney District	Parakai		28		10		12		4
Rodney District	South Head		27		10		12		4
Rodney District	Kaukapakapa		28		10		12		4
Rodney District	Muriwai Beach		28		10		12		4
Rodney District	Rewiti		28		10		12		4
Rodney District	Riverhead		28		10		12		4
Rodney District	Helensville	32	32	13	19	13	13	5	6
North Shore City	Awaruku		34		20		14		7
North Shore City	Glamorgan		36		22		15		7
North Shore City	Torbay		35		21		15		7
North Shore City	Waiake		37		22		15		7
North Shore City	Browns Bay		34		20		14		7
North Shore City	Oaktree		35		21		15		7
North Shore City	Rothesay Bay		35		21		14		7
North Shore City	Murrays Bay		35		21		15		7
North Shore City	Mairangi Bay		36		21		15		7
North Shore City	Campbells Bay		32		19		13		6
North Shore City	Castor Bay		35		21		15		7
North Shore City	Crown Hill		36		22		15		7
North Shore City	Lake Pupuke		34		21		14		7
North Shore City	Westlake	40	40	27	24	16	16	7	8
North Shore City	Takapuna Central		31		19		13		6
North Shore City	Hauraki		36		22		15		7
North Shore City	Seacliffe		36		22		15		7
North Shore City	Bayswater		37		22		15		7
North Shore City	Kaipatiki		35		21		15		7
North Shore City	Windy Ridge		35		21		14		7
North Shore City	Glenfield Central		36		22		15		7

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North Shore City	Glenfield North		37		22		15		7
North Shore City	Glendhu		35		21		14		7
North Shore City	Witheford		34		20		14		7
North Shore City	Target Road		38		23		16		8
North Shore City	Forrest Hill		41		25		17		8
North Shore City	Sunnynook		38		23		16		8
North Shore City	Monarch Park		37		22		15		7
North Shore City	Sunnybrae		35		21		14		7
North Shore City	Albany		30		18		12		6
North Shore City	Fairview		30		18		13		6
North Shore City	Northcross		36		21		15		7
North Shore City	Unsworth Heights		32		19		13		6
North Shore City	Pinehill		33		20		14		7
North Shore City	Windsor Park		32		19		13		6
North Shore City	North Harbour West		29		17		12		6
North Shore City	North Harbour East		31		18		13		6
North Shore City	Long Bay		28		17		12		6
North Shore City	Paremoremo East		29		17		12		6
North Shore City	Greenhithe		30		18		13		6
North Shore City	Narrow Neck		35		21		14		7
North Shore City	Mt Victoria		38		23		16		8
North Shore City	Stanley Bay		34		20		14		7
North Shore City	Ocean View		37		22		15		7
North Shore City	Tuff Crater		41		24		17		8
North Shore City	Northcote South		44		26		18		9
North Shore City	Beachhaven North		37		22		15		7
North Shore City	Beachhaven South		35		21		15		7
North Shore City	Birkdale North		37		22		15		7
North Shore City	Birkdale South		35		21		14		7
North Shore City	Kauri Park		35		21		14		7

TLA	Census Area Unit Description	Monitored 24-hour PM_{10}	Estimated or Monitored 24-hour PM_{10}	Monitored 24-hour $PM_{2.5}$	Estimated 24-hour $PM_{2.5}$ using urban 0.6, rural 0.37	Monitored Annual PM_{10}	Estimated or Monitored Annual PM_{10}	Monitored Annual $PM_{2.5}$	Estimated Annual $PM_{2.5}$ using urban 0.48, rural 0.37
North Shore City	Chelsea		31		18		13		6
North Shore City	Birkenhead East		36		21		15		7
Waitakere City	Henderson North		37		22		15		7
Waitakere City	Henderson South		33		20		14		7
Waitakere City	Tangutu		35		21		14		7
Waitakere City	Woodglen		38		23		16		7
Waitakere City	Glen Eden East	36	36		22	13	13		6
Waitakere City	New Lynn North		36		22		15		7
Waitakere City	New Lynn South		40		24		17		8
Waitakere City	Lynnmall		35		21		15		7
Waitakere City	Fruitvale		41		25		17		8
Waitakere City	Rewarewa		41		25		17		8
Waitakere City	Glendene North		40		24		16		8
Waitakere City	Glendene South		36		21		15		7
Waitakere City	Kelston Central		40		24		16		8
Waitakere City	Sunnyvale		36		21		15		7
Waitakere City	Kaurilands		41		25		17		8
Waitakere City	Crum Park		41		25		17		8
Waitakere City	Titirangi South		35		21		15		7
Waitakere City	Green Bay		38		23		16		8
Waitakere City	Matipo		45		27		18		9
Waitakere City	Durham Green		40		24		16		8
Waitakere City	Te Atatu Central		38		23		16		8
Waitakere City	Edmonton		47		28		19		9
Waitakere City	Wakeling		49		30		20		10
Waitakere City	Mcleod		40		24		17		8
Waitakere City	Konini		35		21		15		7
Waitakere City	Waima		34		21		14		7
Waitakere City	Laingholm		33		20		14		7
Waitakere City	Armour Bay		30		18		13		6

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Waitakere City	Parrs Park		34		20		14		7
Waitakere City	Otimai		29		17		12		6
Waitakere City	Henderson West		41		25		17		8
Waitakere City	Palm Heights		30		18		13		6
Waitakere City	McLaren Park		41		25		17		8
Waitakere City	Opanuku		28		17		12		6
Waitakere City	Swanson		29		17		12		6
Waitakere City	Urlich		36		22		15		7
Waitakere City	Starling Park		41		25		17		8
Waitakere City	Ranui Domain		40		24		16		8
Waitakere City	Ranui South		39		23		16		8
Waitakere City	Sturges North		30		18		13		6
Waitakere City	Kingdale		37		22		15		7
Waitakere City	Fairdene	35	35		21	16	16		7
Waitakere City	Whenuapai West		29		17		12		6
Waitakere City	Herald		35		21		15		7
Waitakere City	Hobsonville		32		19		13		6
Waitakere City	Westgate		34		21		14		7
Waitakere City	Royal Road West		41		25		17		8
Waitakere City	West Harbour		41		24		17		8
Waitakere City	Lucken Point		35		21		14		7
Waitakere City	Royal Heights		39		23		16		8
Waitakere City	Massey West		29		17		12		6
Waitakere City	Birdwood		29		18		12		6
Waitakere City	Waimumu North		40		24		16		8
Waitakere City	Waimumu South		42		25		17		8
Rodney District	Taupaki		28		17		12		6
Waitakere City	Waitakere		29		17		12		6
Waitakere City	Karekare		28		10		12		4
Auckland City	Freemans Bay		43		26		18		9

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Auckland City	Auckland Harbourside	34	34		20	16	16		8
Auckland City	Auckland Central West	42	42	21	21	20	20	10	10
Auckland City	Auckland Central East		43		26		18		9
Auckland City	Newton		62		37		25		12
Auckland City	Grafton West		48		29		20		10
Auckland City	Grafton East		55		33		22		11
Auckland City	Roberton		38		23		16		8
Auckland City	Glenavon		37		22		15		7
Auckland City	New Windsor		39		23		16		8
Auckland City	Avondale South		37		22		15		7
Auckland City	Blockhouse Bay		36		21		15		7
Auckland City	Rosebank		37		22		15		7
Auckland City	Avondale West		35		21		14		7
Auckland City	Waterview		41		24		17		8
Auckland City	Point Chevalier West		42		25		18		8
Auckland City	Point Chevalier East		38		23		16		7
Auckland City	Point Chevalier South		34		21		14		7
Auckland City	Westmere		39		23		16		8
Auckland City	Herne Bay		37		22		15		7
Auckland City	St Marys		55		33		23		11
Auckland City	Ponsonby West		41		25		17		8
Auckland City	Ponsonby East		43		26		18		8
Auckland City	Grey Lynn West		40		24		16		8
Auckland City	Grey Lynn East		40		24		17		8
Auckland City	Surrey Crescent		41		24		17		8
Auckland City	St Lukes North		51		31		21		10
Auckland City	Arch Hill		56		34		23		11
Auckland City	Eden Terrace		39		23		16		8
Auckland City	Epsom North	44	44	21	21	22	22	9	9
Auckland City	Epsom Central		37		22		15		7

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Auckland City	Epsom South		37		22		15		7
Auckland City	Parnell East		34		21		14		7
Auckland City	Parnell West		34		20		14		7
Auckland City	Mt Hobson		51		30		21		10
Auckland City	Remuera South		40		24		17		8
Auckland City	Abbotts Park		38		23		16		8
Auckland City	Remuera West		36		22		15		7
Auckland City	Waitaramoa		36		22		15		7
Auckland City	Orakei South		36		22		15		7
Auckland City	Waiata		37		22		15		7
Auckland City	Meadowbank North		35		21		15		7
Auckland City	Meadowbank South		32		19		13		6
Auckland City	Orakei North		36		22		15		7
Auckland City	Mission Bay		34		21		14		7
Auckland City	Kohimarama West		35		21		14		7
Auckland City	Kohimarama East		36		21		15		7
Auckland City	St Heliers		34		20		14		7
Auckland City	Glendowie		34		20		14		7
Auckland City	Glen Innes North		34		20		14		7
Auckland City	Glen Innes West		37		22		16		7
Auckland City	Glen Innes East		36		21		15		7
Auckland City	Point England		35		21		15		7
Auckland City	St Johns		30		18		13		6
Auckland City	Newmarket		38		23		16		8
Auckland City	Kingsland	39	39	22	22	15	15	7	7
Auckland City	St Lukes		39		23		16		8
Auckland City	Sandringham North		41		25		17		8
Auckland City	Sandringham West		39		23		16		8
Auckland City	Sandringham East		43		26		18		8
Auckland City	Mt Albert Central		37		22		15		7

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Auckland City	Springleigh		37		22		15		7
Auckland City	Owairaka West		40		24		16		8
Auckland City	Owairaka East		39		23		16		8
Auckland City	Mt Eden North	33	33	20	20	14	14	8	8
Auckland City	Sherbourne		38		23		16		7
Auckland City	Balmoral		40		24		17		8
Auckland City	Mt Eden East		41		24		17		8
Auckland City	Maungawhau		45		27		18		9
Auckland City	Mt Eden South		42		25		17		8
Auckland City	Three Kings		39		24		16		8
Auckland City	Royal Oak		39		23		16		8
Auckland City	Hillsborough West		38		23		16		8
Auckland City	Hillsborough East		37		22		15		7
Auckland City	Walmsley		37		22		15		7
Auckland City	Wesley		34		21		14		7
Auckland City	Akarana		35		21		14		7
Auckland City	Lynfield North		37		22		15		7
Auckland City	Lynfield South		35		21		14		7
Auckland City	Waikowhai West		34		21		14		7
Auckland City	Waikowhai East		36		22		15		7
Auckland City	Mt St John		37		22		15		7
Auckland City	One Tree Hill Central		31		19		13		6
Auckland City	One Tree Hill East		37		22		16		7
Auckland City	Penrose		31		19		13		6
Auckland City	Onehunga North West		37		22		15		7
Auckland City	Onehunga North East		37		22		15		7
Auckland City	Onehunga South West		38		23		16		8
Auckland City	Onehunga South East		37		22		15		7
Auckland City	Oranga		39		23		16		8
Auckland City	Te Papapa		32		19		13		6

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Auckland City	Ellerslie North		44		26		18		9
Auckland City	Ellerslie South	44	44	23	23	19	19	7	7
Auckland City	Mt Wellington North		34		20		14		7
Auckland City	Ferndale		33		20		14		7
Auckland City	Hamlin		47		28		19		9
Auckland City	Mt Wellington South		38		23		16		8
Auckland City	Tamaki		39		23		16		8
Auckland City	Panmure Basin		34		20		14		7
Auckland City	Waiheke Island	27	27		16	12	12		6
Area Outside Territorial Authority	Bays-Waiheke Island		27		16		11		5
Auckland City	Islands-Motutapu, Rangitoto, Rakino		27		16		11		5
Auckland City	Great Barrier Island		27		16		11		5
Franklin District	Paerata-Cape Hill		28		17		12		6
Franklin District	Eden Road-Hill Top	33	33	11	11	12	12	4	4
Franklin District	Patumahoe		28		10		12		4
Franklin District	Kingseat		28		10		12		4
Franklin District	Hunua		28		10		12		4
Franklin District	Awhitu		28		10		12		4
Franklin District	Glenbrook		28		10		12		4
Franklin District	Bombay		28		11		12		4
Papakura District	Hingaia		29		17		12		6
Franklin District	Whangapouri Creek		28		17		12		6
Papakura District	Bremner		28		17		12		6
Papakura District	Drury		28		17		12		6
Franklin District	Runciman		29		17		12		6
Manukau City	Mellons Bay		35		21		14		7
Manukau City	Cockle Bay		36		22		15		7
Manukau City	Howick West		38		23		16		8
Manukau City	Howick Central		38		23		16		8

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Auckland City	Otahuhu North		39		23		16		8
Auckland City	Fairburn		35		21		15		7
Auckland City	Otahuhu East		39		24		16		8
Auckland City	Otahuhu West		35		21		15		7
Manukau City	Middlemore		28		17		12		6
Manukau City	Papatoetoe West		39		23		16		8
Manukau City	Papatoetoe North		39		24		16		8
Manukau City	Papatoetoe Central		38		23		16		8
Manukau City	Dingwall		39		23		16		8
Manukau City	Papatoetoe East		40		24		17		8
Manukau City	Puhinui		39		24		16		8
Manukau City	Bucklands and Eastern Beaches		32		19		13		6
Manukau City	Bleakhouse		35		21		14		7
Manukau City	Bucklands Beach South		33		20		14		7
Manukau City	Pigeon Mountain North		35		21		15		7
Manukau City	Murvale		36		22		15		7
Manukau City	Pigeon Mountain South		39		23		16		8
Manukau City	Aberfeldy		34		21		14		7
Manukau City	Elsmore Park		33		20		14		7
Manukau City	Half Moon Bay		34		20		14		7
Manukau City	Pakuranga North	47	47		28	16	16		8
Manukau City	Sunnyhills		35		21		14		7
Manukau City	Pakuranga Central		42		25		17		8
Manukau City	Edgewater		38		23		16		8
Manukau City	Pakuranga East		38		23		16		8
Manukau City	Botany Downs		35		21		15		7
Manukau City	Maungamaungaroa		32		19		13		6
Manukau City	Golfland		31		18		13		6
Manukau City	Millhouse	27	27		16	12	12		6
Manukau City	Burswood		32		19		13		6

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Manukau City	East Tamaki		29		18		12		6
Manukau City	Dannemora		32		19		13		6
Manukau City	Kilkenny		31		18		13		6
Manukau City	Point View		30		18		12		6
Manukau City	Shelly Park		34		20		14		7
Manukau City	Turanga		28		17		12		6
Manukau City	Beachlands-Maraetai		29		18		12		6
Manukau City	Grange		32		19		13		6
Manukau City	Otara West		42		25		17		8
Manukau City	Otara North		33		20		14		7
Manukau City	Otara East		39		23		16		8
Manukau City	Otara South		55		33		23		11
Manukau City	Ferguson		36		22		15		7
Manukau City	Flat Bush		32		19		13		6
Manukau City	Donegal Park		30		18		12		6
Manukau City	Ormiston		28		17		12		6
Manukau City	Clover Park		36		21		15		7
Manukau City	Redoubt North		38		23		16		8
Papakura District	Ardmore		28		17		12		6
Manukau City	Totara Heights		33		20		14		7
Manukau City	Wairere		29		17		12		6
Manukau City	Randwick Park		38		23		16		7
Manukau City	Hyperion		35		21		14		7
Manukau City	Redoubt South		32		19		14		6
Papakura District	Takanini North		30		18		12		6
Papakura District	Takanini South		30		18		13		6
Papakura District	Takanini West		37		22		15		7
Manukau City	Ambury		32		19		13		6
Manukau City	Mangere Bridge		36		22		15		7
Manukau City	Mangere Central		37		22		15		7

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Manukau City	Mascot		37		22		15		7
Manukau City	Arahanga		37		22		15		7
Manukau City	Viscount		37		22		15		7
Manukau City	Mangere South		28		17		12		6
Manukau City	Mangere East		38		23		16		8
Manukau City	Aorere		42		25		17		8
Manukau City	Kohuora		36		22		15		7
Manukau City	Mangere Station		29		11		12		4
Manukau City	Favona West		35		21		14		7
Manukau City	Favona North		33		20		14		7
Manukau City	Favona South		31		19		13		6
Manukau City	Harania North		35		21		15		7
Manukau City	Harania West		36		22		15		7
Manukau City	Harania East		36		21		15		7
Manukau City	Manukau Central		30		18		12		6
Manukau City	Wiri		32		19		13		6
Manukau City	Burbank		39		24		16		8
Manukau City	Homai West		41		25		17		8
Manukau City	Rowandale		37		22		15		7
Manukau City	Homai East		40		24		17		8
Manukau City	Weymouth West		34		20		14		7
Manukau City	Weymouth East		35		21		14		7
Manukau City	Clendon North		36		21		15		7
Manukau City	Clendon South		33		20		14		7
Manukau City	Hillpark		43		26		18		9
Manukau City	Manurewa East		44		26		18		9
Manukau City	Manurewa Central		40		24		16		8
Manukau City	Beaumont		39		23		16		8
Manukau City	Leabank		37		22		15		7
Manukau City	Wattle Farm		33		20		14		7

TLA	Census Area Unit Description	Monitored 24-hour PM_{10}	Estimated or Monitored 24-hour PM_{10}	Monitored 24-hour $PM_{2.5}$	Estimated 24-hour $PM_{2.5}$ using urban 0.6, rural 0.37	Monitored Annual PM_{10}	Estimated or Monitored Annual PM_{10}	Monitored Annual $PM_{2.5}$	Estimated Annual $PM_{2.5}$ using urban 0.48, rural 0.37
Manukau City	Clevedon		28		10		12		4
Manukau City	Kawakawa-Orere		28		10		12		4
Papakura District	Papakura Central		35		21		15		7
Papakura District	Papakura North		36		22		15		7
Papakura District	Papakura South		31		19		13		6
Papakura District	Opaheke		38		23		16		8
Papakura District	Rosehill		37		22		15		7
Papakura District	Pahurehure		38		23		16		8
Papakura District	Papakura East		38		23		16		8
Papakura District	Massey Park		41		25		17		8
Papakura District	Papakura North East		40		24		17		8
Papakura District	Red Hill		33		20		14		7
Franklin District	Pukekohe North	39	39	21	21	15	15	6	6
Franklin District	Pukekohe West		33		20		14		7
Franklin District	Bledisloe Park		30		18		12		6
Franklin District	Waiuku	37	37		22	15	15		7
Auckland City	Mokohinau Island		27		16		11		5
Auckland City	Little Barrier Island		27		16		11		5
Auckland City	Kaikoura and Rangiahua Islands		27		16		11		5
Area Outside Territorial Authority	Inlet-Waitemata Harbour		27		16		11		5
Auckland City	Auckland City-Marinas		27		16		11		5