Auckland's Air Quality Monitoring Plan

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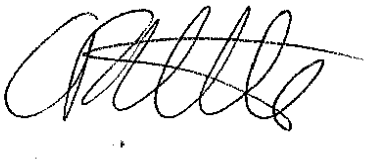
Approved for Auckland Council publication by:    Name: Greg Holland Position: Manager, Research Investigations and Monitoring Unit
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Auckland’s Air Quality Monitoring Plan

Surekha Sridhar

Emission Impossible Ltd

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Executive Summary

Auckland generally experiences good air quality throughout the year. However, Auckland's urban setting means that emissions from transport, domestic fires (the use of solid fuels such as wood and coal) and industry combine to add pressure upon the environment and degrade air quality, particularly during winter (Auckland Regional Council, 2010a). This mixture of gases and particles can affect human health and well-being. In order to assess these effects, a comprehensive air quality monitoring programme needs to be in place.

The purpose of the air quality monitoring programme is to ensure that there is a good scientific understanding of pollutant levels, trends and sources, in order for Auckland Council to manage air quality and reduce pollutant levels. The monitoring programme also enables council to assess the cumulative effects and potential impacts these pollutants have on health and the environment.

This report outlines the Auckland Council's air quality monitoring programme currently in place (as at December 2012) and briefly discusses the priorities identified by Auckland Council and the 2012 review of the monitoring programme (Rolfe, 2013) in order to determine the future direction of the programme.

The following strategic plans and statutory regulations require Auckland Council to ensure ambient air is clean and healthy to breathe:

- The Resource Management Act 1991;
- The National Environmental Standards for Air Quality 2004;
- The Auckland Plan; and
- The Auckland Unitary Plan (which will replace the current Auckland Council Regional Plan: Air, Land and Water and the Auckland Council Regional Policy Statement).

The main sources of air pollution in Auckland are from transport, domestic sources and industrial discharges, with a smaller contribution from rural activities. These sources produce a range of pollutants which cause adverse effects on health, making asthma, and lung and heart conditions worse. Every year, air pollution causes more than 300 premature deaths in Auckland, and results in increased numbers of reduced activity days and hospital visits, and higher usage of medications. It is estimated that the social cost from air pollution in Auckland is $1.07 billion per year (Auckland Council, 2012c).

Auckland Council's air quality monitoring programme uses a combination of monitoring methods (as outlined below) to capture emissions from various sources in order to measure environmental and health effects and meet the statutory obligations:

- A continuous monitoring programme which measures particulates smaller than 10 and 2.5 micrometres in size (PM_{10} and $PM_{2.5}$), oxides of nitrogen, carbon monoxide,

ozone, sulphur dioxide, benzene and 1,3-butadiene at 14 monitoring sites (13 permanent sites and one mobile monitoring site) across Auckland.

- A gravimetric monitoring programme that measures particulates, specifically total suspended particulates (TSP), $PM_{10,}$ $PM_{2.5}$ and lead (in particles) at five monitoring sites across Auckland.
- A passive monitoring programme which is designed to screen levels of specific pollutants such as:
    - Benzene, toluene, ethylbenzene and xylene (BTEX) at Khyber Pass Road and Crowhurst Street in Newmarket, and other volatile organic compounds at Penrose to assess the effects of industry and transport; and
    - Passive sampling of nitrogen dioxide and sulphur dioxide (at the Auckland Waterfront) to understand the impact of motor vehicles and port related activities on the air quality in Auckland's central business area.
- A meteorological monitoring programme co-located with 11 air quality monitoring sites and an additional three stand-alone meteorological sites to better understand regional meteorological conditions and provide input into air emissions modelling.
- Other monitoring programmes which include:
    - Particulate monitoring using non-standard monitoring methods;
    - Air quality monitoring conducted by individual industrial sites (not council) as part of their resource consent applications and consent conditions; and
    - Other special projects that quantify the contribution of sources to the particulate loading of Auckland's air (source apportionment and secondary organic aerosol studies).

A recent review of Auckland Council's air quality monitoring programme (Rolfe, 2013) found that Auckland's programme was fit for purpose and comparable against the air quality monitoring programmes of eight international cities. However, the review also identified some gaps in the programme, and made recommendations for the future development of the programme. Auckland Council is already in the process of addressing some of these recommendations and has identified priority areas for the future direction of the air quality monitoring programme.

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1.0 Introduction

Auckland Council is responsible for the management of air quality in the Auckland region. In order to achieve this, the council runs an air quality monitoring programme to gather a good scientific understanding of pollutant levels, trends and sources. The monitoring programme also enables council to assess the cumulative effects and potential impacts these pollutants have on health and the environment. Information obtained from the monitoring programme is used to support the development of policies, plans and rules in order to reduce air pollution (Auckland Council, 2013a).

This report outlines the Auckland Council's air quality monitoring programme currently in place (as at December 2012).

1.1 Why monitor air quality

Auckland generally experiences good air quality throughout the year. However, Auckland's urban setting means that emissions from transport, domestic fires (the use of solid fuels such as wood and coal) and industry combine to add pressure upon the environment and degrade air quality, particularly during winter (Auckland Regional Council, 2010a). This mixture of gases and particles can affect human health and well-being.

There are a suite of strategic plans and statutory regulations in place (both at the national and regional level) which require Auckland Council to ensure that ambient (outdoor) air is clean and healthy to breathe. These documents are briefly discussed below.

- The Resource Management Act (RMA) 1991 is the key piece of legislation for managing environmental resources (including air quality) in New Zealand. The Minister for the Environment is responsible for recommending national environmental standards to guarantee a level of protection for the health of all New Zealanders. Under the RMA, regional councils and unitary authorities have the responsibility to manage air quality within their regions.
- The Ministry for the Environment promulgated the *Resource Management (National Environmental Standards for Air Quality) Regulations 2004* to improve air quality and protect the health of the general population. These regulations are issued under the RMA 1991, which means that regional councils have to monitor air quality in areas where it is likely to be degraded. These areas are gazetted with the Ministry for the Environment as an airshed.
- The Auckland Plan is a 30 year plan which sets out a long-term strategy for the growth and development of Auckland, including the social, economic, environmental and cultural aspects of the region in order to achieve the vision for Auckland to become "the world's most liveable city" (Auckland Council, 2012a). The plan

commits to improving Auckland's quality of living and housing, public transport, social and economic well-being as well as protecting the city's environment and heritage. Improving or maintaining air quality is crucial to achieving this goal and the Auckland Plan clearly sets a directive to *reduce emissions from home heating, transport and other sources to improving air quality* (Directive 7.6, Auckland Council 2012a, p. 186).

- The Draft Auckland Unitary Plan[1] is Auckland Council's principal planning document and mode of applying the Resource Management Act 1991. The Auckland Unitary Plan will replace existing regional and district plans, specifically the Auckland Council Regional Plan: Air, Land and Water (2012) (Auckland Council, 2012b) which manages activities with discharges to air, land and water, and the Auckland Council Regional Policy Statement (Auckland Council, 2012d) which sets out policy for the sustainable management of resources in the Auckland region. These two documents define policies and rules around activities that require resource consent from discharges to air, while the Auckland Regional Council Plan: Air, Land and Water 2012 sets regional air quality targets. The regional air quality targets aim to maintain air quality in areas of the region (classified into urban, industrial or rural air quality management areas) where it is already good and improve air quality in areas where it is degraded or unacceptable. The rules of the Auckland Council Regional Plan: Air, Land and Water and the regional air quality targets are applicable until the Auckland Unitary Plan is adopted.

1.2 Air quality in the Auckland context

The quality of air is affected by emissions discharged into the air, weather conditions and the topography of the land. Auckland experiences a temperate climate with warm, humid summers and mild, damp winters (Auckland Regional Council, 2010a). The region's urban area is situated in a low undulating isthmus between mountain ranges in the west and south east. Air quality can vary considerably across Auckland due to the undulating topography of the region and can be made worse in low or light wind conditions and on cold winter days.

There are three main sources of air pollution in Auckland. Emissions from transport are the primary source of air pollution throughout the year (especially motor vehicles) while emissions from domestic fires are the highest source during the winter months of June, July and August (Auckland Council, 2012c). Industrial discharges also contribute to

[1] Feedback on the Draft Auckland Unitary Plan is currently being reviewed following public consultation (draft March 2013 – see Auckland Council, 2013b).

Auckland's air pollution, however industry has been heavily regulated over the past decade so emissions contribute to a much lesser extent than domestic fires and transport, and generally have a local rather than regional effect. All these sources produce different pollutants, some of which are dangerous and hazardous to human health (Auckland Council, 2012c).

According to the 2006 Census, the Auckland region is home to over 1.3 million people, which accounts for almost one third of New Zealand's population, and it is projected to grow to up to 2.5 million by 2041 (Auckland Council, 2012a). This high growth affects transport use (increasing car ownership, and more vehicles trips and of longer distances) and the domestic sector (causing an increase in the number of domestic fire appliances discharging emissions into the air). Aside from transport and domestic sources, industrial and rural activities such as outdoor burning also contribute to Auckland's emissions.

The most common pollutants in the region from these sources are similar to those found everywhere else in the world (WHO, 2006):

- Particulates smaller than 10 micrometres (PM_{10}), 2.5 micrometres ($PM_{2.5}$) and one micrometre (PM_1) in diameter – these are particles that are suspended in the air and are not visible to the human eye. PM_{10} particles are produced naturally (from pollen, bushfires etc.), and from anthropogenic activities (domestic fires, industries and motor vehicles) while the smaller fractions of $PM_{2.5}$ and PM_1 are predominantly from anthropogenic activities. The coarser fraction (particulates smaller than 100 micrometres in diameter) are referred to as total suspended particulates (TSP).
- Nitrogen dioxide (NO_2) – a brown acidic gas which is mainly formed from the reaction of nitric oxide (NO) with ozone (O_3). Nitric oxide and nitrogen dioxide are collectively referred to as nitrogen oxides (NO_x). Nitrogen oxides are formed by the combustion of fossil fuels (coal, oil and gas) and contribute towards the formation of photochemical smog. Motor vehicles are a large source of nitrogen dioxide in urban areas.
- Carbon monoxide (CO) – a colourless, odourless gas formed by both natural processes (such as volcanic activity) and human activities (mostly from motor vehicles)
- Ozone (O_3) - a colourless gas naturally found in the outer atmosphere but is a pollutant when formed at ground level from reactions with other pollutants produced by motor vehicles, industrial activities and domestic sources. Ozone is a main component of photochemical smog.
- Sulphur dioxide (SO_2) – a colourless, acidic gas largely produced by industrial processes but also produced from transport fuels that contain sulphur.
- Volatile organic compounds (VOCs) – organic chemical compounds that are both naturally occurring and human-made (such as benzene and 1,3-butadiene).

- Benzene (C_6H_6) – a colourless, flammable gas with a sweet odour produced by motor vehicles and domestic fires.
- 1,3-Butadiene (C_4H_6) – a colourless, highly reactive gas with a mild odour primarily produced by motor vehicle exhaust emissions.
- Lead (Pb) – a metal found naturally in the environment as well as in human-made products. Historically, the major source of lead emissions have been from fuels used by motor vehicles, specifically, leaded petrol.

Exceedances in the Auckland region for PM_{10}, NO_2 and CO have occurred in the past due to traffic, domestic fires, road works, construction activities, outdoor burning, or from special events such as fireworks displays (S. Xie, Scientist – Air Quality, personal communications, 3 April 2013).

Pollutants cause adverse effects on health, making asthma, lung and heart conditions worse. The worst air pollutant are the particulates PM_{10}, $PM_{2.5}$ and PM_1 as they are made up of a mixture of different chemical substances (eg, polyaromatic hydrocarbons) and heavy metals (eg, chromium, copper, or nickel) depending upon the season, weather conditions and sources producing them, and can stay suspended in the air for up to 40 days. It is for these reasons that particulates are considered a surrogate for health effects and associated costs from air pollution (Auckland Regional Council, 2007a). Every year, air pollution causes more than 300 premature deaths, and results in increased numbers of reduced activity days and hospital visits, and higher usage of medications. It is estimated that the social cost from air pollution in Auckland is estimated to be $1.07 billion per year (Auckland Council, 2012c).

1.3 Background to Auckland's air quality monitoring programme

Air quality monitoring began in the Auckland region in the mid-1950s to monitor "fumes" from the Manukau mudflats (Auckland Regional Council, 1997). The former Department of Health was responsible for monitoring air pollution issues which were primarily from localised sources. The Department of Health monitored air quality at two sites (Mount Albert and Penrose) measuring total suspended particles (TSP) and lead (Pb), which contributed towards the World Health Organisation's Global Environmental Monitoring System (GEMs).

In 1972, central government passed the Clean Air Act in response to growing public concern over air pollution issues in both Auckland (caused by increased transport and industrial activities) and in Christchurch (resulting from increased transport and domestic fires). The Clean Air Act regulated emissions from industrial and trade processes, and classified pollution based on the type and rate of heat released into the air. Consequently, the Department of Health's air quality monitoring programme expanded in 1975 with the

addition of sulphur dioxide (SO_2) and smoke, and oxides of nitrogen (NO_x) in 1987 (Auckland Regional Council, 2007b).

In 1991, the Resource Management Act (RMA) was introduced to promote the sustainable management of natural and physical resources. The RMA 1991 repealed the Clean Air Act of 1972 and transferred the responsibility of managing air pollution to regional councils and unitary authorities. The Auckland Council (formerly the Auckland Regional Council) took over the monitoring of air quality in 1993 and began further expanding and upgrading the network.

The RMA 1991 does not set air quality standards and allows for each authority to determine suitable thresholds for region, however the Act does require the Ministry for the Environment to provide guidance to councils with statutory or non-statutory guidelines. In response to this, the Ministry for the Environment issued Ambient Air Quality Guidelines (AAQGs) in 1994 (later updated in 2002) (Ministry for the Environment, 2002a) which were developed largely based on the World Health Organisation (WHO) Guidelines for the most common and widespread air pollutants.

As mentioned earlier, the Ministry for the Environment promulgated the *Resource Management (National Environmental Standards for Air Quality) Regulations 2004* (the regulations) under sections 43 and 44 of the RMA 1991. The regulations establish maximum concentration limits for five ambient air pollutants (as shown in Table 1-1), which came into effect on 1st September 2005. Regional councils are required to publicly report exceedances of the standards and guidelines that occur in each airshed.

Table 1-1 National Environmental Standards for Air Quality for the five ambient air pollutants.

Pollutant	Standard	Time average	Allowable exceedances per year
Particulates <10µms (PM_{10})	50 µg/m^3	24-hours	1
Nitrogen dioxide (NO_2)	200 µg/m^3	1-hour	9
Carbon monoxide (CO)	10 mg/m^3	8-hours (running mean)	1
Ozone (O_3)	150 µg/m^3	1-hour	0
Sulphur dioxide (SO_2)	350 µg/m^3 570 µg/m^3	1-hour 1-hour*	9 0

* Maximum concentration limit for SO_2 (1-hour average)

1.4 Changes to the air quality monitoring programme

The nature and overall objectives of the monitoring programme have changed over the years to keep up with and reflect international trends. This includes increasing concern over smaller particulates, improvements in technology, and a better understanding of air quality. A number of factors have influenced the changes in air quality monitoring in the Auckland region (Auckland Regional Council, 2006):

- An increased concern over the smaller fraction of particulates influenced the move away from the monitoring of TSP to measuring PM_{10}, $PM_{2.5}$ and now PM_1.
- The monitoring of lead (in particulates) also reduced as petrol became unleaded in 1996.
- A change in the focus of gaseous pollutants, from sulphur dioxide from industrial coal burning and carbon monoxide from older motor vehicles, to nitrogen oxides from the combustion of gas and diesel, and hazardous air pollutants such as benzene and 1,3-butadiene.
- Concern over the formation of photochemical smog on warm summer days.
- A change towards more frequent and continuous monitoring (from one day in six, to one day in three and daily monitoring) due to improvements in instrument technology which resulted in better quality data and interpretation of trends.
- Development of and changes to air quality standards and guidelines.

Passive monitoring programmes and short surveys have been conducted over the years to provide a better understanding of localised effects and the spatial distribution of pollutants in relation to specific sources.

1.5 Report structure

This air quality monitoring plan is structured as follows:

Section 2 describes the current air quality monitoring programmes operating at Auckland Council.

Section 3 details the management of the air quality monitoring sites.

Section 4 details the collection and management process of data.

Section 5 describes the various reporting types and requirements.

Section 6 briefly discusses the recent review of the air quality monitoring programme and summarises the priority areas for the future development of the programme.

2.0 The air quality programme

The Auckland Council's air quality monitoring programme consists of a combination of continuous monitoring of pollutants at permanent and mobile sites, gravimetric particulate monitoring, meteorological monitoring, survey-type monitoring, passive monitoring, a visibility programme and special projects that include source apportionment studies and secondary carbon analysis. Each of these are described in the following sections.

2.1 Continuous ambient air quality monitoring programme

Continuous monitoring methods provide continuous records for each pollutant and can operate over extended periods (for weeks, months or years) (Ministry for the Environment, 2009). Auckland Council has used continuous sampling methods for more than 10 years (Auckland Council, 2013c). After the national environmental standards for air quality were introduced in 2004, the Ministry for the Environment issued mandatory regulatory continuous monitoring methods (in accordance with Australia/New Zealand standards, and US Environment Protection Agency standards) (Ministry for the Environment, 2009). These regulatory methods have a high degree of measurement precision but are the most expensive type of monitoring as they need a high standard of site and instrument management to obtain good quality data. It is therefore preferred to use non-regulatory monitoring methods when undertaking screening surveys or short-term monitoring surveys to identify areas with air quality issues.

The Auckland Council monitor several pollutants at 14 sites around the Auckland region (13 permanent sites and one mobile site) as part of Auckland's continuous ambient air quality monitoring programme. The sites range in their scope and represent a variety of sources and exposures (from suburban residential areas to peak traffic areas). Most monitoring sites in the region are influenced by multiple sources. Some sites are set up to monitor a single pollutant while others measure a suite of pollutants all on a continuous basis.

2.1.1 Permanent sites

The permanent air quality monitoring sites have fixed sheds at the monitoring locations which house the continuous sampling instrumentation. These sites are set up with the intention of measuring pollutants from particular sources on a long-term basis. Table 2-1 lists the permanent monitoring sites and the predominant sources and pollutants measured at each site.

Carbon monoxide (CO) is measured at six sites, oxides of nitrogen (NO_x) at eight sites, ozone (O_3) at three sites, sulphur dioxide (SO_2) at one site, PM_{10} at 11 sites and $PM_{2.5}$ at

four sites. Auckland Council also began continuously monitoring benzene and 1,3-butadiene at one permanent site (Khyber Pass) in 2005. Details on the instrumentation and methods used, and applicable standards are provided in Appendix A.

Table 2-1 Permanent ambient air quality monitoring sites in Auckland and pollutants measured at each site.

Site name	Predominant source(s)	Pollutants measured					
		CO	NO_x	O_3	SO_2	PM_{10}	$PM_{2.5}$
Botany Downs	Vehicles and domestic heating					✓	
Glen Eden	Domestic heating and vehicles	✓	✓			✓	
Henderson	Vehicles and domestic heating	✓	✓			✓	
Khyber Pass Road	Vehicles	✓	✓			✓	
Kumeu**	Vehicles and domestic heating					✓	
Musick Point	Urban plume*		✓	✓			
Orewa	Domestic heating and vehicles					✓	
Pakuranga	Vehicles and domestic heating	✓				✓	
Patumahoe	Rural and urban plume*		✓	✓		✓	✓
Penrose	Industry and vehicles		✓		✓	✓	✓
Queen Street	Vehicles	✓	✓				
Takapuna	Vehicles and domestic heating	✓	✓			✓	✓
Whangaparaoa	Rural and urban plume*			✓		✓	✓

* Related to measuring the development of ozone (as a secondary pollutant)

** Site decommissioned in March 2013.

2.1.2 Mobile sites

The mobile air quality monitoring sites are mobile trailer units which house the continuous monitoring equipment and are a portable option for undertaking short-term monitoring. This is particularly useful in areas where setting up a permanent site is not possible or necessary. Auckland Council owns two mobile trailer units, one of which is currently operating at the Auckland Waterfront within the grounds of Ports of Auckland Limited.

The Auckland Waterfront mobile site was commissioned in April 2012 to measure and assess the effect of shipping activities on air quality near the central business area. Table 2-2 lists the pollutants measured at the Auckland Waterfront mobile monitoring site.

Table 2-2 Mobile monitoring sites in Auckland and the pollutants measured at the site.

Site name	Predominant source(s)	Pollutants measured					
		CO	NO_x	O_3	SO_2	PM_{10}	$PM_{2.5}$
Auckland Waterfront	Port activities and vehicles	✓	✓		✓	✓	✓

The second mobile trailer unit is currently not in use. However, the unit has instrumentation available to measure the same pollutants as monitored at the Auckland Waterfront mobile site (shown in Table 2-2).

In the past, the mobile trailers have been used for monitoring air quality in different parts of Auckland for either a one or two year period. This was particularly effective in gathering air quality data for the rural town airsheds such as Helensville, Pukekohe, Warkworth, Waiheke Island, Waiuku and most recently, Beachlands. The air quality at four rural town airsheds (Wellsford, Riverhead, Snells Beach and Maraetai) are yet to be monitored.

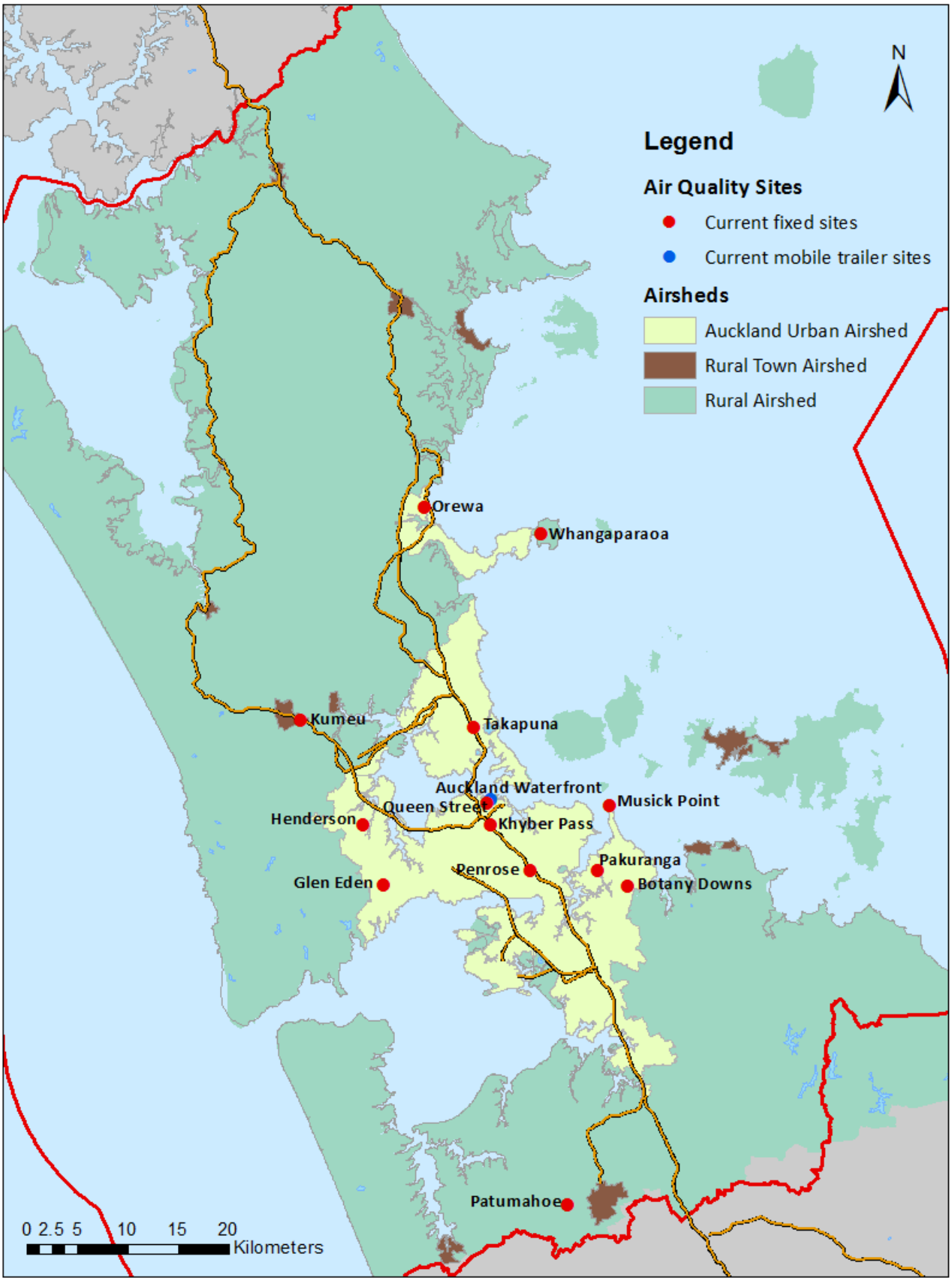
2.1.3 Spatial distribution

The 14 monitoring sites (both permanent and mobile sites) are spatially distributed from Whangaparaoa in the north to Pukekohe in the south and from Henderson in the west to Botany Downs in the east as shown in Figure 1. These sites are spatially distributed to capture emissions from motor vehicles, industry and domestic fires in urban areas, and from activities in the rural areas and towns.

A recent review of the ambient air monitoring programme (Rolfe, 2013) found that the number of monitoring sites across Auckland compared well against monitoring programmes undertaken internationally in eight cities with similar geo-socio situations.

2.2 Gravimetric monitoring programme

The gravimetric particulate monitoring method involves a known volume of air being passed through a filter that is weighed pre and post sampling for a determined length of time (usually 24 hours). Both gravimetric and continuous methods have been used by Auckland Council to monitor particulates for many years (Auckland Council, 2013c). Continuous monitoring methods have become more common and cost effective in recent years, especially since the implementation of the national environmental standards for air quality. The Auckland Council uses gravimetric particulate monitoring methods to collect filters which are analysed in a laboratory for particulates, airborne lead and other studies. Results from the analysed filter samples provide Auckland Council with an indication of localised air pollution sources across the region.



Gazetted Airsheds and Air Quality Monitoring Sites

Figure 2-1 Map showing the 13 permanent sites and one mobile site in Auckland's airsheds.

2.2.1 Particulate sampling

Auckland Council samples particulates using gravimetric particulate monitoring methods at five sites across Auckland (as shown in Table 2-3). The samplers are all contained in the permanent monitoring site sheds along with the continuous monitors (with the exception of the sampler at Khyber Pass which is mounted on a pole). Filters used for gravimetric particulate sampling undergo further laboratory analysis to identify and quantify the types particulates (TSP, PM_{10} or $PM_{2.5}$ speciation and lead) found on each filter in addition to measuring the mass concentrations of particulates in the air (as described in section 2.1).

Table 2-3 Gravimetric particulate sampling locations in Auckland.

Site name	PM_{10}	$PM_{2.5}$	TSP	Pb
Henderson	✓			
Khyber Pass[+]	✓	✓		
Queen Street	✓	✓		
Penrose	✓		✓	✓
Takapuna	✓			

* Auckland Council's gravimetric particulate sampling use Partisol samplers which follow a one in three day sampling regime except for Queen Street which uses a sequential Partisol sampler and collects samples daily.

[+]Khyber Pass sampler is not contained within a shed and is mounted on a pole.

Filters analysed from the Penrose and Takapuna sites are sent to GNS Science for elemental analysis and CSIRO (Australia) for ion analysis and organic carbon and elemental carbon analysis (OC/EC) (discussed further in section 2.7).

TSP and lead are measured at the Penrose permanent monitoring site. TSP is sampled gravimetrically throughout the year and reported monthly, while lead is sampled only during the winter months (June, July and August) using the same samples that were used to analyse for TSP.

2.3 Passive monitoring programme

Passive monitoring method diffuses contaminants into a tube or badge which contains reactive or adsorbent material. A time averaged contaminant concentration is established by analysing the tubes or badges after a known amount of exposure time. The only difference between the diffusion tubes and badges is that the badges have a higher uptake rate of contaminants. Badges are therefore more commonly used across New Zealand (Ministry for the Environment, 2009). Passive samplers are low in cost and easy to use, so they can be used as a screening tool to give a good indication of the spatial variation in air

quality across a wide area. However, they do have lower accuracy compared to other methods.

Auckland Council currently has three passive monitoring projects underway which are detailed in the following sections.

2.3.1 VOC passive sampling

Passive sampling of volatile organic compounds (VOCs) is undertaken at the Penrose permanent monitoring site using passive 3M organic vapour monitor badges. The badges are exposed for three month periods (July to September, October to December, January to March and April to June). The VOCs diffuse onto the badges and are later analysed using gas chromatography-mass spectrometry (GC-MS). Sampling began in April 2001 as part of the Ministry for the Environment's reporting towards the World Health Organisation's Global Environmental Monitoring Systems (GEMs) program (Ministry for the Environment, 2002b).

Passive sampling of VOCs provides Auckland Council with additional information on the impact of motor vehicles and industry on ambient air quality. This data is also useful for the application and processing of resource consents, as well as monitoring trends in VOCs (specifically, benzene). With the exception of the BTEX passive sampling along Khyber Pass (see section 2.3.2 below), concentrations of VOCs are not measured at any other site around Auckland.

2.3.2 BTEX passive sampling

Passive sampling of benzene, toluene, ethylbenzene and xylene (commonly called BTEX) began in 2011 at two sites in Auckland. These are at the Khyber Pass permanent monitoring site and Crowhurst Street in Newmarket, approximately 400 metres east of the Khyber Pass permanent monitoring site. Passive sampling badges are exposed on a monthly basis, where BTEX are adsorbed onto an activated carbon filter, and then analysed using gas chromatography-mass spectrometry (GC-MS).

Continuous monitoring of benzene (and 1,3-butadiene) began at the Khyber Pass permanent monitoring site in 2005. Results indicate that the passive samplers under read benzene concentrations. The BTEX passive sampling results are used not only to gain a better understanding of the impacts of motor vehicles on air quality along busy transport corridors, but to also benchmark against the benzene concentrations measured using the continuous sampler at the Khyber Pass permanent site.

2.3.3 NO_2 and SO_2 passive sampling

Auckland Council began monitoring nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) using diffusion tube passive samplers at the Auckland Waterfront mobile site in May 2011.

Passive sampling of NO_2 provides a snapshot of the impact of motor vehicles on air quality, while passive sampling of SO_2 allows Auckland Council to better understand the impact shipping activities have on the air quality around the central business area.

2.4 Meteorological monitoring programme

Weather conditions can significantly influence the concentrations of air pollutants. It is therefore essential to monitor meteorological conditions along with ambient air pollutants at air quality monitoring sites to better understand pollutant sources, short-term pollution events, chemical reactions, trends in data and why exceedances of guidelines and standards have occurred.

2.4.1 Meteorological site locations

Meteorological monitoring is co-located at all permanent and mobile sites along with the ambient air quality monitoring (with the exception of the Queen Street and Whangaparaoa permanent sites). Sites are fitted with meteorological masts (usually six metres in height although this does vary from site to site – see Auckland Council, 2013c for further details) and the meteorological parameters of wind speed, wind direction, ambient temperature, relative humidity, solar radiation and rainfall are measured at most sites. Table 2-4 shows the meteorological parameters measured at each site.

Table 2-4 Meteorological parameters measured at each meteorological co-located site.

Site name	Wind speed	Wind direction	Ambient temperature	Relative humidity	Solar radiation	Rainfall
Botany Downs	✓	✓	✓	✓	✓	✓
Glen Eden	✓	✓	✓	✓	✓	✓
Henderson	✓	✓	✓	✓	✓	
Khyber Pass	✓	✓	✓	✓	✓	✓
Kumeu	✓	✓	✓	✓	✓	✓
Musick Point	✓	✓	✓	✓	✓	
Orewa	✓	✓	✓	✓	✓	
Pakuranga	✓	✓	✓	✓	✓	✓
Penrose	✓	✓	✓	✓	✓	✓
Takapuna	✓	✓	✓	✓	✓	✓
Auckland Waterfront*	✓	✓	✓	✓	✓	✓

* Mobile monitoring site

In addition to the co-located meteorological monitoring sites, Auckland Council also collects data from three other stand-alone meteorological sites across Auckland. These

sites provide additional data to better understand regional meteorological conditions and are used for input into air emissions modelling. The stand-alone meteorological sites are fitted with a 10 metre meteorological mast and measure most parameters except rainfall as shown in Table 2-5.

Table 2-5 Parameters measured at the meteorological sites by Auckland Council.

Site name	Wind speed	Wind direction	Ambient temperature	Relative humidity	Solar radiation	Rainfall
Henderson Te Pai Met	✓	✓	✓	✓	✓	
Onehunga Met	✓	✓	✓	✓	✓	
Wiri Met	✓	✓	✓	✓	✓	

2.5 Other monitoring

2.5.1 GRIMM particulate monitoring programme

GRIMM samplers are light scattering instruments used to estimate particle numbers and mass, but have mostly been used to monitor dust in the workplace. The method is not accurate as there is no direct relationship between light scattering and mass (Ministry for the Environment, 2009). It is therefore not used as a standard method for ambient or compliance monitoring, but is suited more towards undertaking low-level survey work. However, instruments that use light scattering techniques can measure particles smaller than $PM_{2.5}$. The GRIMM sampler is the only instrument available to Auckland Council that can measure these finer particles. The Auckland Council therefore uses the GRIMM sampler to identify mass concentrations of PM_{10}, $PM_{2.5}$ (along with the methods described in section 2.1) and PM_1, and count particle numbers which are used to ascertain trends in particulates in Auckland's air.

2.5.2 Industrial monitoring

There are approximately 270 regulated industrial sites across Auckland that requires resource consent. Almost 200 of these sites are required to undertake some form of air quality monitoring for the application process (as part of an assessment of environmental effects) and/or as part of their resource consent conditions (undertaken by other independent organisations). In addition to this, some sites (depending upon the activity) have to also undertake stack and odour testing (J. Jolliffe, Team Leader – Air Quality, personal communications, 2 April 2013).

Data collected from the air quality monitoring programme is also used by Auckland Council regulatory officers to process air discharge consents.

2.5.3 Transport projects

There are numerous air quality monitoring projects conducted by other government organisations in addition to Auckland Council's programme:.

- NZ Transport Agency's (NZTA) NO_2 passive sampling network located near roads in order to capture the impact of road transport on air quality.
- NZTA's project monitoring before, during and after construction of major state highway projects (the State Highway 20 Waterview Connection project and the Victoria Park Tunnel project are both examples of these).
- Auckland Transport's project monitoring (formerly conducted by Auckland City Council) before, during and after construction on major roads in the region. The Central Connector project (formerly the Auckland Central Transit Connector) is an example of this.

Air quality monitoring data from these projects provide additional information on the state of air quality in Auckland.

2.6 Visibility camera network

Auckland Council operates visibility cameras which capture half hourly images of the city's skyline. The images captured by these cameras are used to monitor the development of brown haze and assess the number of brown haze days in a year for reporting under the Auckland Plan (Strategic Direction 7, Auckland Plan 2012a, pg. 365) and for the State of the Environment report.

There are three cameras located across Auckland at the following sites:

- Como Street in Takapuna, established in August 2000 and faces south towards the city;
- Arataki Visitors Centre in the Waitakere Ranges, established in June 2003 and faces east towards the city; and
- Central Park on Great South Road in Penrose, established in December 2005 and faces south towards Mangere.

Auckland Council's Research, Investigations and Monitoring Unit (RIMU) took over responsibility from NIWA to manage the sites, visibility camera devices and data in 2011, and subsequently upgraded the devices and software across all three sites in 2012. The cameras are all currently offline and undergoing maintenance.

2.7 Special projects

Measuring the mass concentrations of particulate matter provides little information on the contributing sources. The chemical composition and size of particulates can provide valuable details about the sources of these particles (AQEG, 2005). In addition to routine monitoring activities, specialised monitoring projects are also undertaken by Auckland Council to help determine sources and pollutants that could pose a potential issue for air quality, and identify areas for further or future monitoring. Filter analyses and source apportionment techniques provide a means to determine the contribution of particles from various sources. These methods also assist councils in assessing localised air pollution sources, developing policy, and research and monitoring strategies.

2.7.1 Laboratory analysis programme

This programme involves the laboratory analysis of particulate matter collected on filters by the gravimetric monitoring programme (detailed in section 2.2) using the techniques described below.

Elemental analysis

Elemental analysis is a process where a sample of particulate matter is analysed for its elemental composition using various ion bean analysis (IBA) techniques. IBA is based on measuring X-rays and gamma rays (γ-rays) that are characteristic of an element (such as lead) and uses the techniques of particle-induced X-ray emission (PIXE), particle induced gamma-ray emission (PIGE) and particle elastic scattering analysis (PESA) to identify and quantify the element found in particulate matter (refer to Davy *et al*. 2011 for further details).

Auckland Council engaged GNS Science and CSIRO (Australia) in 2004 to conduct elemental analysis of filter samples collected at Auckland's ambient air quality monitoring sites. The current project is to analyse 10 sets of filters of particulate matter collected at the sites listed in Table 2-6. The programme began in March 2012 and will continue until July 2015.

Ion analysis

Ion analysis is similar to elemental analysis in that it is a process where a sample of particulate matter is analysed for its ionic concentration, such as ammonium, sulphates and nitrates. Teflon filters (collected using gravimetric methods) are analysed for ions using suppressed ion chromatography method.

Auckland Council engaged CSIRO in 2008 to conduct ion analysis of filter samples collected from Auckland's air quality monitoring sites. The current programme began in

2011 and involves the analysis of almost 260 filter samples collected each year for three years at the Takapuna and Penrose monitoring sites.

Black carbon analysis

Black carbon is the term used for the strongest light absorbing fraction of particulate matter and is formed by the incomplete combustion fossil fuels and biomass (DEFRA, 2013). Black carbon is quantified by applying optical light absorbing techniques to filters (collected using the gravimetric programme). The amount of light absorption is indicative of the amount of black carbon present on the filter.

GNS Science began analysing black carbon for Auckland Council in 2004 along with the elemental analysis project. The current project analyses filter samples collected at the monitoring sites detailed in Table 2-6 which began in 2012 and will continue until 2015.

Organic and elemental carbon analysis

Elemental carbon (EC) is a primary pollutant in the air from the incomplete combustion of anthropogenic (combustion of fossil fuels) or natural sources (such as bush fires). Organic carbon (OC) is a complex mix of compounds that are derived from both primary and secondary sources (Keywood *et al.* 2011). The ratio of OC to EC is calculated and used to determine secondary organic aerosol concentrations (described in section 2.7.2) and improve source apportionment estimates.

Auckland Council engaged CSIRO in 2011 to carry out OC/EC analysis on filter samples collected at the Takapuna and Penrose monitoring sites using gravimetric samplers.

2.7.2 Source apportionment programme

This programme involves the apportionment of sources from particulate matter collected on filters under the gravimetric monitoring programme (detailed in section 2.2) using the source apportionment methods or secondary organic aerosol methods, described below.

Source apportionment analysis

Source apportionment is a type of receptor modelling which provides a way to quantify the contribution of sources on particulate matter (Davy *et al*. 2011). This is conducted by collecting filter samples of particulate matter at monitoring sites (using gravimetric particulate monitoring methods as described in section 2.2) and then analysed using statistical methods (such as the principle component analysis and positive matrix factorisation) for the identification of sources.

Auckland Council engaged GNS Science in 2006 to undertake source apportionment studies of filter samples collected at Auckland's ambient air quality monitoring sites. The current source apportionment programme is to analyse 10 sets of filters of particulate

matter collected at the sites listed in Table 2-6. The programme began in March 2012 and it is planned to continue until July 2015.

Table 2-6 Monitoring sites collecting filters for source apportionment analysis.

Particle fraction analysed (and filter sampling method)	Henderson	Khyber Pass	Queen Street	Penrose	Takapuna
PM_{10} (Speciation)				✓	
PM_{10} (Sequential)			✓		
PM_{10} (Partisol)	✓	✓		✓	✓
$PM_{2.5}$ (Speciation)				✓	✓
$PM_{2.5}$ (Partisol)		✓	✓		

Secondary organic aerosol analysis

Secondary organic aerosol is formed in the atmosphere by the oxidation of VOCs (from natural or anthropogenic sources). When this mixes with sunlight, ozone, oxides of nitrogen and sulphur, semi volatile compounds are produced which split to form particulate matter in the air. Combinations of these pollutants exist in Auckland's air, but current measurement capabilities make it difficult to predict the amount of secondary organic aerosol found in particulate matter.

The ratios of organic carbon and elemental carbon (OC/EC) evaluated from the laboratory analysis programme are used to determine the secondary organic aerosol concentrations. CSIRO are conducting the secondary organic aerosol analysis for Auckland Council (which began in September 2011 and will run until June 2014) using the teflon and quartz filter samples collected at the Takapuna and Penrose sites during 2011, 2012 and 2013. This data is used to improve the source apportionment estimates (carried out by GNS Science) and provide quantitative estimates of the contribution of secondary organic aerosol to the particulate loading of Auckland's air.

3.0 Site management

Site management involves regular inspection, servicing and calibration of monitoring instrumentation, sample inlets and filters, and electronics, and also includes general site maintenance (Ministry for the Environment, 2009). Most of Auckland Council's air quality monitoring sites are currently managed by Watercare Services Limited except for the Kumeu monitoring site, meteorological monitoring at the Khyber Pass monitoring site, and the three stand-alone meteorological monitoring sites which are managed by Auckland Council's Research Investigations and Monitoring Unit (RIMU).

Watercare Services Limited's Air Quality Unit is accredited by International Accreditation New Zealand (IANZ) for monitoring ambient air, odour emissions, industrial stack emissions and workplace environments. Auckland Council's RIMU is accredited under the International Organisation for Standardization for meteorological monitoring as part of hydrological monitoring program (ISO 9001), but is not yet formally certified for meteorological monitoring (N. Reid, Environmental Specialist, personal communications, 29 July 2013). Both Watercare Services Limited and RIMU manage the sites in accordance with the Ministry for the Environment's *Good Practice Guide for Air Quality Monitoring and Data Management 2009* and where applicable, the relevant Australia/New Zealand, US Environment Protection Authority standardised monitoring methods and the World Meteorological Organisation's *Guide to Meteorological Instruments and Methods of Observation* (WMO, 2008).

3.1 Site management

3.1.1 Permanent and mobile sites

All permanent sites (except Kumeu) and the current mobile site at the Auckland Waterfront are managed by Watercare Services Limited's Air Quality Unit under contract with Auckland Council until the end of June 2014. Watercare Services Limited is responsible for the set up and commissioning of the site, maintenance and calibration of sampling instrumentation, and decommissioning of the sites. RIMU is responsible for the maintenance and calibration of sampling instrumentation, and site decommission at Kumeu.

3.1.2 Gravimetric sampling sites

The gravimetric instruments are housed at the permanent sites mentioned in Table 2-1 (except at the Khyber Pass monitoring site which is mounted on a pole). Watercare Services Limited is responsible for the instrument maintenance and calibration, collection

and replacement of filters, weighing the filters, TSP and lead analysis (undertaken at Watercare Services Limited's Laboratory Services General Chemistry Unit).

3.1.3 Passive sampling sites

Watercare Services Limited is responsible for the supply and exchange of samples at the:

- Penrose permanent site (badges exchanged quarterly) for the passive sampling of VOCs.
- Khyber Pass permanent site and Crowhurst Street passive site (badges exchanged monthly) for the passive sampling of BTEX.
- Auckland Waterfront mobile site (filters are exchanged monthly) for the passive sampling of NO_2 and SO_2.

AsureQuality (IANZ accredited) are subcontracted by Watercare Services Limited to undertake the extraction and analysis of VOCs and BTEX from the badges.

Staffordshire Scientific Services are subcontracted by Watercare Services Limited to analyse the NO_2 and SO_2 samples collected. Staffordshire Scientific Services are accredited under the United Kingdom Accreditation Service (UKAS) for Quality Standard ISO/IEC 17025 for such analyses.

3.1.4 Meteorological sites

Watercare Services Limited is responsible for the management of all the co-located meteorological instruments at the sites listed in Table 2-4 (except for the meteorological instruments at the Kumeu and Khyber Pass permanent sites). Auckland Council's RIMU is responsible for managing the meteorological instruments at the Khyber Pass and Kumeu permanent sites and are also responsible for site management of the stand-alone meteorological monitoring sites listed in Table 2-5.

3.1.5 Other monitoring

The GRIMM sampler is located at the Penrose permanent site which is managed by Watercare Services Limited.

Air quality data monitored by industry is managed independently by external providers (not Auckland Council) contracted to the industrial site as this is part of the industrial site's resource consent conditions.

NZTA's NO_2 passive monitoring sites are managed by Watercare Services Limited. Monitoring sites used for transport project monitoring are managed by external independent providers (not Auckland Council).

3.1.6 Special projects

Watercare Services Limited is responsible for the collection and exchange of filters from the monitoring sites and for the management of the site and instrumentation. They are also responsible for sending the filter samples to GNS Science and CSIRO (Australia) for further analysis.

4.0 Information and data collection and management

4.1 Data collection

Air quality and meteorological data is collected at different (but regular) time periods depending upon the type of monitoring programme. Data collection is carried out by Auckland Council's RIMU and by the Air Quality Unit at Watercare Services Limited (detailed in Table 4-1).

Watercare Services Limited use Envitech Envidas data loggers for all continuous air quality and meteorological monitoring data on site. This data is then uploaded into Envista for storage and data analysis.

Auckland Council currently receive data from Watercare Services Limited as MS Excel spreadsheets. The council is currently in the process of acquiring Envitech Envista for storing and analysing air quality data, however until then, Auckland Council will continue to store air quality monitoring data in MS Excel spreadsheets. Auckland Council use HydroTel to collect meteorological data which is archived in Hydstra.

Both the Auckland Council's RIMU and the Air Quality Unit at Watercare Services Limited have in house quality control procedures for data collection and management in accordance with the Ministry for the Environment's *Good Practice Guide for Air Quality Monitoring and Data Management 2009* (Ministry for the Environment, 2009) and the WMO's *Guide to Meteorological Instruments and Methods of Observation* (WMO, 2008).

Table 4-1 Data collection details for air quality monitoring programmes

Monitoring programme	Sub-programme	Sampling frequency	Data collection by	Database	Notes
Continuous monitoring	Gaseous pollutants	<1 second*	WSL [1] AC EM[2]	WSL: Envitech Envidas data loggers and stored on Envista AC EM: MS Excel	AC EM collects data from Kumeu monitoring site. WSL collect data from all other sites
	Particulates	10 minutes	WSL AC EM	WSL: Envitech Envidas data loggers and stored on Envista AC EM: MS Excel	AC EM collects data from Kumeu monitoring site. WSL collect data from all other sites
Gravimetric monitoring	Particulate speciation	1 in 3 days	WSL	Envitech Envidas data loggers and stored on Envista	Except at Queen Street monitoring site which is sampled daily
	TSP and lead	TSP – weekly Lead – weekly over June, July and August	WSL	MS Excel	
Passive monitoring	VOC	3-monthly	WSL	MS Excel	
	BTEX	Monthly	WSL	MS Excel	
	NO_2 and SO_2	Monthly	WSL	MS Excel	
Meteorological monitoring		10 minutes (WSL) 10 minutes (AC EM)	WSL AC EM	WSL: Envitech Envidas data loggers and stored on Envista AC EM: Collected in HydroTel and stored in Hydstra	AC EM collects data from Kumeu and Khyber Pass monitoring sites, Onehunga met, Henderson met and Wiri met sites. WSL collect data from all other sites
Other monitoring**	GRIMM particulates	10 minutes	WSL	MS Excel	
Visibility cameras		30 minutes	AC EM	AC FTP access	

[1] WSL – Watercare Services Limited [2] AC EM – Auckland Council Environmental Monitoring

* Sampling is conducted at less than one second frequency but stored in 10 minute averages.

** Air quality monitored by industry, other organisations and data collected for special projects are not included here.

5.0 Reporting

The data collected by Auckland Council's monitoring programmes are reported in different formats depending upon the target audience. Reporting can be in the form of public notices, fact sheets, report cards, internal reports, technical publications, state of the environment reporting and web based online reporting.

5.1 Data reporting

Data collected and stored by Auckland Council and Watercare Services Limited is treated as raw data until the data is validated. Once validated, the data is issued as a provisional dataset until it is externally audited and quality assured. All data (raw, provisional and quality assured/audited data) is accessible from Auckland Council to respond to specific requests from the public or for internal projects.

5.1.1 Raw data

Raw data is stored in the Envista database at Watercare Services Limited, and in MS Excel spreadsheets or HydroTel (for meteorological monitoring and particulate monitoring at Kumeu) at Auckland Council. The raw data is screened for exceedances of the standards, invalid values (such as invalid concentrations logged due instrument error) and then subsequently validated. Watercare Services Limited issues a notice to Auckland Council when an exceedance of a standard has occurred and provides additional relevant information on the exceedance. Auckland Council are required to publicly report any exceedance (see section 5.2.4).

5.1.2 Provisional data

Validated data is compiled into a monthly dataset by Watercare Services Limited and provided to Auckland Council via an FTP site. The datasets are subjected to a review and quality assurance in-house at Watercare Services Limited before being issued.

A monthly report is issued along with the monthly dataset, which includes statistics, graphs, any exceedances of the Auckland Council targets, ambient air quality guidelines and national environmental standards, and all meta data (such as explanations for all missing and invalidated data, summaries of automated and manual instrument calibrations and maintenance, any changes to site and data management procedures etc.).

An annual dataset for a calendar year is issued to Auckland Council by Watercare Services Limited in February the following year (ie, an annual dataset for the year 2011 is supplied to Auckland Council in February 2012).

Similarly, data collected by RIMU at Auckland Council is subject to in-house quality assurance processes for both air quality and meteorological data and forms part of the final provisional dataset for the year.

5.1.3 Dataset auditing and quality assurance

The annual datasets (collected by Watercare Services Limited and by Auckland Council) undergoes an external audit and quality assurance process to identify outliers, ensure consistency in the data validation process and to check for data completeness. Once the data has been audited and quality assured, it is submitted back to council.

Data from other monitoring projects and industry collect and apply quality control procedures on the data themselves, or contract this process to external providers. Industry provides monitoring data and reports to Auckland Council on a monthly, quarterly or annual basis depending upon their individual consent conditions.

5.1.4 Annual dataset

Once the audited dataset is provided back to Auckland Council, this data is stored as the finalised annual dataset, available for official use. Data CDs are issued by Auckland Council on an ad-hoc basis to individuals or organisations upon request. The finalised datasets are also used in Auckland Council's annual reports and Auckland Plan status reporting.

5.2 Technical reporting

Auckland Council reports technical information on an ad-hoc basis for the various air quality monitoring programmes. These range from fact sheets and report cards to more technically detailed reports and publications. These forms of reporting aim to make the data collected more publicly accessible.

5.2.1 Fact sheets and report cards

Fact sheets and report cards are published occasionally by Auckland Council to provide the public with information that ranges from general air quality information (such as information on the types of air pollutants) to specific issues that the council are targeting (eg, emissions from domestic fires).

The Auckland Council currently producing a series of report cards on the *State of Auckland's Air* (see Auckland Council, 2012c for the first issue).

5.2.2 Air quality technical publications

Air quality technical publications are produced by Auckland Council as and when projects are completed. The technical publications provide detailed descriptions of monitoring results or the results of various special projects. In the past, Auckland Council has published monitoring reports on the NO_2 passive sampling results (Auckland Regional Council, 2007c), VOC passive sampling results (Auckland Regional Council, 2009), monitoring results from the continuous monitoring network (Auckland Regional Council, 1997), and also site metadata details on the continuous monitoring programme (Auckland Regional Council, 2006). Monitoring data has also been used to provide guidance on the use of background air quality data (Auckland Council, 2012e) or the use of meteorological datasets (Auckland Regional Council, 2010b) for air quality resource consent assessments of industrial activities and transport projects in Auckland.

5.2.3 State of the Environment reporting

The State of the Environment reporting contains detailed information on the condition of the environment is prepared as a requirement under section 35 of the Resource Management Act 1991. A suite of air quality indicators and monitoring results are presented as part of the reporting, from the number of exceedances and brown haze days to reporting trends of various pollutants. The State of the Environment is reported every five years, with the most recent report produced for 2009 (Auckland Regional Council, 2010a).

5.2.4 Reporting of exceedances

Exceedances occur when concentrations of a pollutant measure above the maximum acceptable concentration set by the national environmental standards for air quality. There are a limited number of allowable exceedances set by the national environmental standards (as detailed in Table 1-1, section 1.3). A *breach* of the standards occurs when an exceedance occurs in addition to the maximum number of allowable exceedances in a rolling 12-month period in an airshed. Auckland Council is statutorily required under the regulations to publicly report any exceedance of the standards when an airshed is in breach. The exceedance is reported by public notice in the New Zealand Herald within a month of the occurrence.

If an exceedance occurs and the Auckland Council lodges an application with the Ministry for the Environment for the exceedance to be considered as an *exceptional event*, air quality and meteorological monitoring data, and source apportionment results are all used to justify the application.

5.2.5 Other reports

Data from the air quality monitoring programme is also used in Auckland Council's annual reports and against directives set in the Auckland Plan.

5.3 Spatial and web based reporting

Auckland Council is currently scoping out mechanisms to directly report air quality monitoring data online from the continuous and meteorological monitoring programmes. Raw data collected from the stand alone meteorological monitoring sites (Henderson Te Pai met, Onehunga met and Wiri met) are fed directly to an Environmental Monitoring tool on Auckland Council's online GIS viewer. It is anticipated that once Envista is established at Auckland Council, the air quality monitoring data will also be incorporated and accessible via the Environmental Monitoring tool on the GIS viewer.

All technical reports and report cards are available online via the Auckland Council website.

6.0 Moving air quality monitoring forward

The air quality monitoring programme has been developed over the years to capture a variety of pollutants from various sources. There is some degree of flexibility in the design of the programme so that new emerging sources and pollutants can be screened using passive sampling techniques, while potential problem pollutants can be monitored further using gravimetric type sampling or continuous monitoring.

6.1 Monitoring programme review

Individual programmes are reviewed internally to gauge the status of the programme, the need for further monitoring and assess whether the programmes are fit for purpose. The mobile sites of the continuous monitoring programme and the passive sampling programmes are reviewed most often due to the nature of sampling undertaken. The types of sampling equipment and the methods used for monitoring across all programmes are also regularly reviewed to ensure that they are reliable, current and comparable internationally.

In addition to the internal reviews, the air quality monitoring programme has also been externally reviewed to benchmark against international monitoring programmes with intermittent technical reviews also being conducted.

The most recent review of Auckland Council's air quality monitoring programme was conducted in 2012 (Rolfe, 2013) and assessed the air quality monitoring activities carried out by Auckland Council. The review presents a range of recommendations in terms of monitoring site locations, the pollutants monitored, monitoring methods etc. Auckland Council had already begun discussions around some of these recommendations independent of the review, however the decisions are not detailed here as they are yet to be finalised.

6.2 Moving air quality monitoring forward

The following recommendations present the priority areas for Auckland Council to ensure that the air quality monitoring programme is kept up-to-date. These are based on discussions with Auckland Council and the 2012 review of the monitoring programme (Rolfe, 2013):

- Continue monitoring pollutants at the Auckland Waterfront site at least until June 2014.
- Expand the $PM_{2.5}$ monitoring network.

- Investigate the options for sampling other hazardous air pollutants in Auckland, particularly arsenic and benzo(a)pyrene.
- Continue monitoring in rural town airsheds that are yet to be monitored.
- Establish a real-time monitoring database (or near real-time) so that data can be accessed online via Auckland Council's GIS viewer.
- Consolidate data collected across Auckland for various projects (such as data from NZTA's NO_2 passive sampling network, NZTA's Waterview Connection and Victoria Park Tunnel projects, Auckland Transport's Central Connector project etc.).
- Develop procedures for the management of air quality data, the peer review of air quality and meteorological data, and a plan for the regular reporting of these results.

Currently, there is an international debate regarding the monitoring of PM_{10}, $PM_{2.5}$ and whether the fraction of $PM_{10-2.5}$ should also be monitored. In addition, there is also debate regarding the measurement of particles smaller than $PM_{2.5}$, black carbon and particle numbers, and the chemical composition of particles (DEFRA, 2013). The outcomes of these debates will influence and impact the future direction of the air quality monitoring programme.

The air quality monitoring programme also needs to be integrated to some extent with the other environmental monitoring and research programmes available at Auckland Council. Air pollutants can deposit on land, soil and water and contaminate these resources. It is advantageous to integrate the monitoring programmes so that sampling can be coordinated between these resources when necessary.

This plan will need to be reviewed in 2014 as the contractual agreements for some of the programmes come to a close and changes are made to the monitoring network.

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8.0 Glossary

Term	Description
ACRP: ALW	Auckland Council Regional Plan: Air, Land and Water
Airshed	A geographic area established to manage air pollution within the area as defined by the national environmental standard for air quality and gazetted by the Minister for the Environment.
Anthropogenic sources	Sources resulting from human activity (not natural sources).
ARC	Auckland Regional Council (which merged with other territorial authorities in November 2010 to become the Auckland Council).
Background	The amount of contaminant existing in the air across the airshed from all sources (natural and human-made).
Breach	When an exceedance occurs in addition to the maximum number of allowable exceedances as determined by the national environmental standards for air quality.
BTEX	Benzene, toluene, ethylbenzene and xylenes. A group of volatile organic compounds.
CO	Carbon monoxide
DoH	Department of Health
Exceedance	When the concentration of a pollutant measures above the maximum acceptable concentration set by the national environmental standard for air quality.
Exceptional event	An exceptional event is when an unforeseen event (such as a dust storm or volcanic activity) causes an exceedance of the standard. Provisions are made in NES-AQ for the exclusion of exceptional events.
MfE	Ministry for the Environment
NES-AQ	National Environmental Standards for Air Quality
NO_x	Oxides of nitrogen
O_3	Ozone
OC/EC	Organic carbon and elemental carbon
Photochemical smog	Photochemical smog is formed by reactions between NO_x and VOCs in the presence of sunlight, and severely reduces visibly.
PCA	Principal component analysis
PIXE	Particle (or proton) induced X-ray emission. A technique used to determine the elemental composition of a material or sample.
PM_1	Particulate matter smaller than 1 micrometre in size
$PM_{2.5}$	Particulate matter smaller than 2.5 micrometres in size
PM_{10}	Particulate matter smaller than 10 micrometres in size
PMF	Positive matrix factorisation
RMA	Resource Management Act 1991
SA	Source apportionment
SOA	Secondary organic analysis
VOC	Volatile organic compounds

Appendix A Monitoring methods

Auckland Council use different types of monitoring instruments and methods to measure air quality across Auckland. The types of monitoring methods and relevant standards are detailed below.

Continuous monitoring methods

Table A-1 Continuous monitoring methods (Rolfe, 2013)

Pollutant	Method	Standard*
CO	Gas filter correlation infrared (GFC-IR) absorption	AS3580.7.1:2011
NO_x	Chemiluminescence from reaction of NO (both directly and after catalytic reduction of NO_2 to NO) with O_3	AS3580.5.1:2011
SO_2	Molecular ultraviolet (UV) fluorescence	AS3580.4.1:2008
O_3	Ultraviolet (UV) absorption	AS3580.6.1:2011
PM_{10}	Beta Attenuation Monitor (BAM) with PM_{10} inlet	NZS/AS3580.9.11:2008
$PM_{2.5}$	Beta Attenuation Monitor (BAM) with $PM_{2.5}$ inlet	US CFR Title 40, Volume 2, Part 50, Appendix J

* AS is Australian Standard; NZS is New Zealand Standard; US CFR is United States Code of Federal Regulations

Gravimetric monitoring methods

Table A-2 Gravimetric particulate sampling methods

Pollutant	Method
PM_{10}	Partisol instruments with one in three day sampling regime, producing 24-hour averages with a PM_{10} inlet (except at Queen Street).
PM_{10}	Sequential Partisol instrument with a daily sampling regime, producing 24-hour averages (at Queen Street).
$PM_{2.5}$	Partisol instruments with one in three day sampling regime, producing 24-hour averages with a $PM_{2.5}$ inlet.
TSP	Medium volume instrument with a seven day sampling regime (non-standard method).
Pb (in TSP)	Medium volume instrument with a seven day sampling regime (non-standard method) to measure TSP. Lead analysed from TSP filters in winter.

Table A-3 Gravimetric speciation sampling methods

Pollutant	Method
PM_{10}*	Partisol 2300 instrument with four channels used to hold sampling cartridges (using one channel with a Teflon filter), sampling on a one in three day sampling regime situated at Penrose.
$PM_{2.5}$**	Partisol 2300 instrument with four channels used to hold sampling cartridges (using two channels with a Teflon filter and one channel with a Tissuequartz filter), sampling on a one in three day sampling regime situated at Penrose.
$PM_{2.5}$**	RAAS 400 instrument with four channels used to hold sampling cartridges (using two channels with a Teflon filter and one channel with a Tissuequartz filter), sampling on a one in three day sampling regime situated at Takapuna.

* One Teflon filter is sent to GNS for elemental analysis.

** One Teflon filter is sent to GNS for elemental analysis. Two filters (one Teflon and one Tissuequartz) are sent to CSIRO for ion and organic and elemental carbon (OC/EC) analysis.

Passive monitoring methods

Table A-4 Passive monitoring methods

Pollutant	Method
VOC	3M organic vapour badges used to sample on a three monthly basis, and analysed using gas chromatography- mass spectrometry (GC-MS).
BTEX	3M organic vapour badges used to sample monthly, and analysed using gas chromatography- mass spectrometry (GC-MS).
NO_2	Diffusion tubes used to analyse NO_2 on a monthly sampling regime and analysed using standard laboratory techniques (by Staffordshire Scientific Services - UKAS Quality Standard ISO/IEC 17025 accredited for such analyses.
SO_2	Diffusion tubes used to analyse SO_2 on a monthly sampling regime and analysed using standard laboratory techniques (by Staffordshire Scientific Services - UKAS Quality Standard ISO/IEC 17025 accredited for such analyses.