Waikato Regional Council Technical Report 2017/03

Ambient air quality monitoring report for the Waikato region - 2016

www.waikatoregion.govt.nz
ISSN 2230-4355 (Print)
ISSN 2230-4363 (Online)

Waikato
REGIONAL COUNCIL
Te Kaunihera ā Rohe o Waikato

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10 January 2018

Document #: 9793067

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Acknowledgement

The Environmental Monitoring team, particularly Kane Lynn and Kevin Mullane, are gratefully acknowledged for the supply, collection and management of the monitoring data used in this report and servicing and maintenance of the monitoring stations used. Asaeli Tulagi is also thanked for coordinating laboratory services.

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Executive summary

The main air contaminant of concern in the Waikato Region is PM_{10} (particles in the air 10 microns in diameter or less). Monitoring of PM_{10} was undertaken in the Hamilton, Tokoroa, Taupo, Te Kuiti, Putaruru, Turangi, Cambridge, Te Awamutu-Kihikihi, Morrinsville and Thames airsheds during 2016. In addition to this, $PM_{2.5}$ (particles in the air 2.5 microns in diameter or less) was monitored in Tokoroa. This particulate monitoring was targeted mainly at identifying the impacts from domestic home heating sources.

The National Environmental Standards for Air Quality (NESAQ) has set a maximum concentration limit for PM_{10} of 50 $\mu g/m^3$ as a 24 hour average. The NESAQ allows for one exceedance of this standard per rolling 12 month period. More than one exceedance within a rolling 12 month period is a breach of the standard and an airshed becomes classified as polluted as a result. A national guideline of 20 $\mu g/m^3$ as an annual average for PM_{10} is also used for assessment purposes. There is currently no New Zealand based guideline or standard applicable to $PM_{2.5}$ and therefore the World Health Organisation (WHO) guideline of 25 $\mu g/m^3$ as a 24 hour average and 10 $\mu g/m^3$ as an annual average is used for assessment purposes.

In 2016 the 24 hour average standard for PM_{10} of 50 $\mu g/m^3$ was exceeded five times in Tokoroa which is the equivalent of four breaches (based on one allowable exceedance per 12 month period). There were no exceedances in any of the other airsheds. Annual average concentrations of PM_{10} were all within the annual average guideline of 20 $\mu g/m^3$ in all airsheds.

A total of 70% of gazetted airsheds (14 out of 20) in the Waikato region have now been monitored for PM_{10}. Five of these airsheds have been identified as requiring ongoing monitoring based on the identification of previous PM_{10} exceedances, namely Tokoroa, Taupo, Te Kuiti, Putaruru and Hamilton.

In Tokoroa, $PM_{2.5}$ concentrations exceeded the WHO guideline of 25 $\mu g/m^3$ as a 24 hour average on 41 occasions during 2016. An annual average $PM_{2.5}$ concentration of 12 $\mu g/m^3$ was estimated for Tokoroa which also exceeds the WHO annual average guideline of 10 $\mu g/m^3$.

A statistical trends analysis of PM_{10} concentrations in Hamilton, Tokoroa, Te Kuiti, Putaruru and Taupo indicates that concentrations have decreased over the previous six or more year period. The improving trends identified in Tokoroa, Taupo, Te Kuiti and Putaruru have mainly been attributed to reductions in emissions from home heating sources.

Tokoroa is unlikely to comply with its specified NESAQ target of no more than three exceedences of the 24 hour average PM_{10} standard of 50 $\mu g/m^3$ from September 2016. Taupo and Putaruru may comply with the less stringent NESAQ target of no more than one exceedance of 50 $\mu g/m^3$ from September 2016. However, this is likely to depend on meteorological conditions and is unlikely to be sustained long term unless further decreases in emissions occur. Te Kuiti now meets the criteria of “not polluted” having been compliant with the NESAQ for five years which is a pre-requisite for achieving this status under the NESAQ. The Tokoroa, Taupo, and Putaruru airsheds remain classified as polluted.

While woodburners for domestic home heating have been identified as the main source of poor air quality in all airsheds, traffic sources in Hamilton have been identified as significant contributors to poor air quality in localised areas close to busy traffic routes and intersections based on the results of nitrogen dioxide (NO_2) monitoring.

Monitoring of NO_2 was undertaken in Hamilton, Cambridge, Te Awamutu, Taupo, Tokoroa and Matamata in 2016 for purposes of identifying the impacts from traffic related emissions. Monitoring of benzene, toluene, xylenes and ethylbenzene (BTEX) were also undertaken in Hamilton in 2016 as additional indicators of traffic related emissions.

The results from NO_2 monitoring indicate that the Lorne Street/Ohaupo Road site and Greenwood Road/Killarney Road site in Hamilton continue to exceed the WHO annual guideline of 40 $\mu g/m^3$ for NO_2. While there have been no exceedances of the WHO annual guideline for NO_2 at the other Hamilton sites and the Cambridge, Te Awamutu, Taupo, Tokoroa or Matamata sites a long term trend analysis of the annual averages indicates a worsening trend for the Cambridge Road/Morrinsville Road and the Avalon Drive/Grandview Drive sites in Hamilton and an improving trend for the Bridge Street/Anglesea Street site in Hamilton. In Cambridge, an improvement has been identified for 2016 compared with the previously identified worsening trend which is assumed to be related to the opening of the Cambridge expressway at the end of 2015.

Concentrations of benzene in Hamilton were within the national guideline of 3.6 $\mu g/m^3$ at all sites and show evidence of a decreasing trend. The highest annual concentration was measured at the Greenwood Street monitoring site and was 2.2 $\mu g/m^3$. Concentrations of toluene, ethylbenzene and xylene were also well within acceptable international criteria.

1 Introduction

1.1 Background

New Zealand (and the Waikato region) enjoys good air quality most of the time due to the country's long narrow shape, exposure to strong eastward winds, and typically low population density. However, during the winter months when temperature inversions form on cold, still days, air pollutants can become trapped close to the ground leading to poor air quality in some towns and cities.

Air quality within towns and cities can be affected by a number of activities including natural causes such as sea spray, pollen and volcanic activity and human created causes such as home heating, traffic and industrial discharges.

Although air pollution is a complex mixture of contaminants and particles, the majority of health effects in New Zealand are associated with particulate matter less than 10 micrometres in size – commonly known as PM_{10}. It is also a good indicator of the sources and effects of other air pollutants. However, while PM_{10} levels pose a risk to human health, it is now well established internationally, that the finer particle range, referred to as $PM_{2.5}$, provides better evidence of effects on human health and is more indicative of the problem source, which is combustion related.

The Health and Air Pollution in New Zealand Study (Kushel et al., 2012) identified that domestic fires (open fires and wood and coal burners used for home heating) dominate the health impacts associated with PM_{10} in every location in New Zealand except Auckland.

Emissions from motor vehicles are also sources of air pollutants that have adverse health effects. Exhaust emissions include fine particulate matter, volatile organic compounds (such as benzene) and the gases carbon monoxide and nitrogen oxides. Nitrogen dioxide emissions can occur directly from combustion processes and as a result of the conversion of nitric oxide gas (also produced from combustion processes) reacting in the atmosphere in the presence of ozone. In New Zealand, motor vehicle emissions are the main source of nitrogen dioxide in urban areas.

Other gases (such as ozone and sulphur dioxide) and secondary particulate (sulphates and nitrates) can form in the atmosphere from reactions involving some of these primary emissions. Sulphur dioxide is typically associated with combustion of fuels containing high levels of sulphur such as coal from industry and heavy fuel oils used in shipping.

Ambient air quality monitoring has been carried out in the Waikato region by the Waikato Regional Council (WRC) since 1998. The US EPA define ambient air monitoring as the systematic, long-term assessment of pollutant levels by measuring the quantity and types of certain pollutants in the surrounding, outdoor air.

1.2 Regulatory requirements and assessment criteria

In New Zealand, monitoring and management of air quality is undertaken within defined air quality management areas referred to as airsheds. Airshed boundaries are officially identified by regional councils and approved and made public by the Ministry for the Environment (MfE).

Regional councils have a responsibility to monitor and manage outdoor air quality under the Resource Management Act 1991 (RMA). The National Environmental Standards for Air Quality (NESAQ) are mandatory environmental regulations made under the RMA that:

- direct regional councils to focus on monitoring of PM_{10} as the main contaminant of concern and on managing the main source of PM_{10} emissions, namely woodburners used for domestic home heating;
- include ambient air quality standards for PM_{10}, carbon monoxide, nitrogen dioxide, sulphur dioxide and ozone for protecting human health;
- require regional councils to monitor air quality if it is likely that the ambient air quality standard for a contaminant will be breached in an airshed;
- state that an airshed is classified as polluted if it has more than one PM_{10} exceedance per 12 month period; and
- state that an airshed ceases to be polluted when the PM_{10} standard has not been breached in the airshed for five years.

The air quality standard for PM_{10} is 50 micrograms per cubic metre of air (50 $\mu g/m^3$) averaged over a 24-hour period (from midnight to midnight), with one allowable exceedance per 12-month period. The standards for PM_{10}, carbon monoxide, nitrogen dioxide, sulphur dioxide and ozone along with averaging periods and number of allowable exceedances are provided in Table 1.1. A breach of the standards occurs when more than the allowable number of exceedances occurs within the specified period.

Table 1.1 National Environmental Standards for Air Quality.

Contaminant	Standard Concentration	Standard Averaging period	Allowable exceedances per year
Carbon monoxide	10 mg/m^3	8-hour	1
Particles (PM_{10})	50 $\mu g/m^3$	24-hour	1
Nitrogen dioxide	200 $\mu g/m^3$	1-hour	9
Sulphur dioxide	350 $\mu g/m^3$	1-hour	9[a]
Sulphur dioxide	570 $\mu g/m^3$	1-hour	0[a]
Ozone	150 $\mu g/m^3$	1-hour	0

a. Note that the 1-hour average concentration of sulphur dioxide can exceed 350 $\mu g\ m^{-3}$ up to 9 times within any 12-month period but can never exceed a 1-hour average of 570 $\mu g\ m^{-3}$.

For the assessment of other air contaminants not included under the NESAQ, the National Ambient Air Quality guidelines (MfE, 2002) and the World Health Organisation guidelines (WHO, 2005) are used. A subset of ambient air quality guidelines relevant to WRC's air quality monitoring programme are provided in Table 1.2.

Table 1.2 Ambient air quality guidelines.

Contaminant	Guideline Concentration	Guideline Averaging period	Source
Benzene (year 2002)	10 $\mu g/m^3$	Annual	MfE, 2002
Benzene (year 2010)	3.6 $\mu g/m^3$	Annual	MfE, 2002
Particles (PM_{10})	20 $\mu g/m^3$	Annual	MfE, 2002
Particles ($PM_{2.5}$)	25 $\mu g/m^3$	24-hour	WHO, 2005
Particles ($PM_{2.5}$)	10 $\mu g/m^3$	Annual	WHO, 2005
Nitrogen dioxide	40 $\mu g/m^3$	Annual	WHO, 2005

There are 20 airsheds in the Waikato region that have been officially gazetted by MfE for monitoring and management purposes (refer to Figure 1). To date, a total of 14 of these airsheds have been monitored for PM_{10}. A combination of long-term monitoring and short-term surveys are undertaken as described below:

- Long-term monitoring is undertaken for airsheds that are shown to either breach or have the potential to breach the ambient air quality standards. There are currently three polluted airsheds in the Waikato region, namely Putaruru, Taupo, and Tokoroa. Te Kuiti and Hamilton, although not currently classified as polluted, are also included for long-term monitoring purposes due to previous breaches and or ongoing potential for future breaches.
- A three-yearly "rolling" survey is undertaken for airsheds that have not yet been monitored. In these cases, WRC's monitoring stations are moved to new locations according to a three year rotation subject to the airshed having had no exceedances of the 24 hour average PM_{10} standard over that three year period.

Figure 1.1 **Map of Waikato Region indicating the 20 urban centres that have been gazetted as airsheds.**

The NESAQ also sets PM_{10} compliance targets for polluted airsheds. Polluted airsheds which have had less than 10 exceedances per year, must not breach the standard after September 2016 (i.e. Taupo, and Putaruru). Airsheds that have had 10 or more exceedances per year, must have no

more than three exceedances after September 2016 and no more than one exceedance after September 2020 (i.e. Tokoroa). As of December 2016, the Te Kuiti airshed is now classified as non-polluted as it has not had a breach of the NESAQ for five years. The Hamilton airshed is also not classified as polluted as it has not had any breaches of the standard since 2009 apart from a series of breaches in 2013 which were considered exceptional circumstances and were discounted by MfE[1].

1.3 Monitoring objectives

The objectives of Waikato Regional Council's ambient air quality monitoring programme are to:

1. Determine compliance with national ambient air quality standards and guidelines.
2. Identify trends in ambient air quality and sources contributing to poor air quality.
3. Provide information to support the implementation of our regional plan and regional policies on air quality, including consent processing and consented and permitted activity compliance.

1.4 Airsheds and contaminants monitored in 2016

Ambient air quality and meteorological monitoring for 2016 was undertaken in the following airsheds:

- Hamilton (PM_{10}, NO_2, benzene, ethyl benzene, toluene, xylenes and meteorology)
- Taupo (PM_{10}, NO_2 and meteorology)
- Tokoroa (PM_{10}, $PM_{2.5}$, NO_2 and meteorology)
- Te Kuiti (PM_{10} and meteorology)
- Putaruru (PM_{10})
- Turangi (PM_{10})
- Cambridge (PM_{10} and NO_2)
- Te Awamutu-Kihikihi (PM_{10} and NO_2)
- Morrinsville (PM_{10})
- Thames (PM_{10})
- Matamata (NO_2 and meteorology)

Refer to Figures 1.2 to 1.5 for maps of the airsheds monitored in 2016. All stations, except Hamilton's Bloodbank station are set up for assessing the impacts of residential solid fuel heating. The Bloodbank station is located 10 metres away from a busy roadway (Ohaupo Road) and is near to industry discharges (e.g. Waikato Hospital boilers) and is therefore expected to be more influenced by traffic and industry sources compared with the other Hamilton station at Claudelands.

[1] An application was made to the Minister for the Environment in August 2013 and an exemption for the eight exceedances was provided by the Minister in November 2013. As a result, the exceedances do not count towards determining the polluted status of the Hamilton airshed i.e. Hamilton remains a non-polluted airshed and the industry offset and open fire place ban regulations of the NESAQ are not triggered.

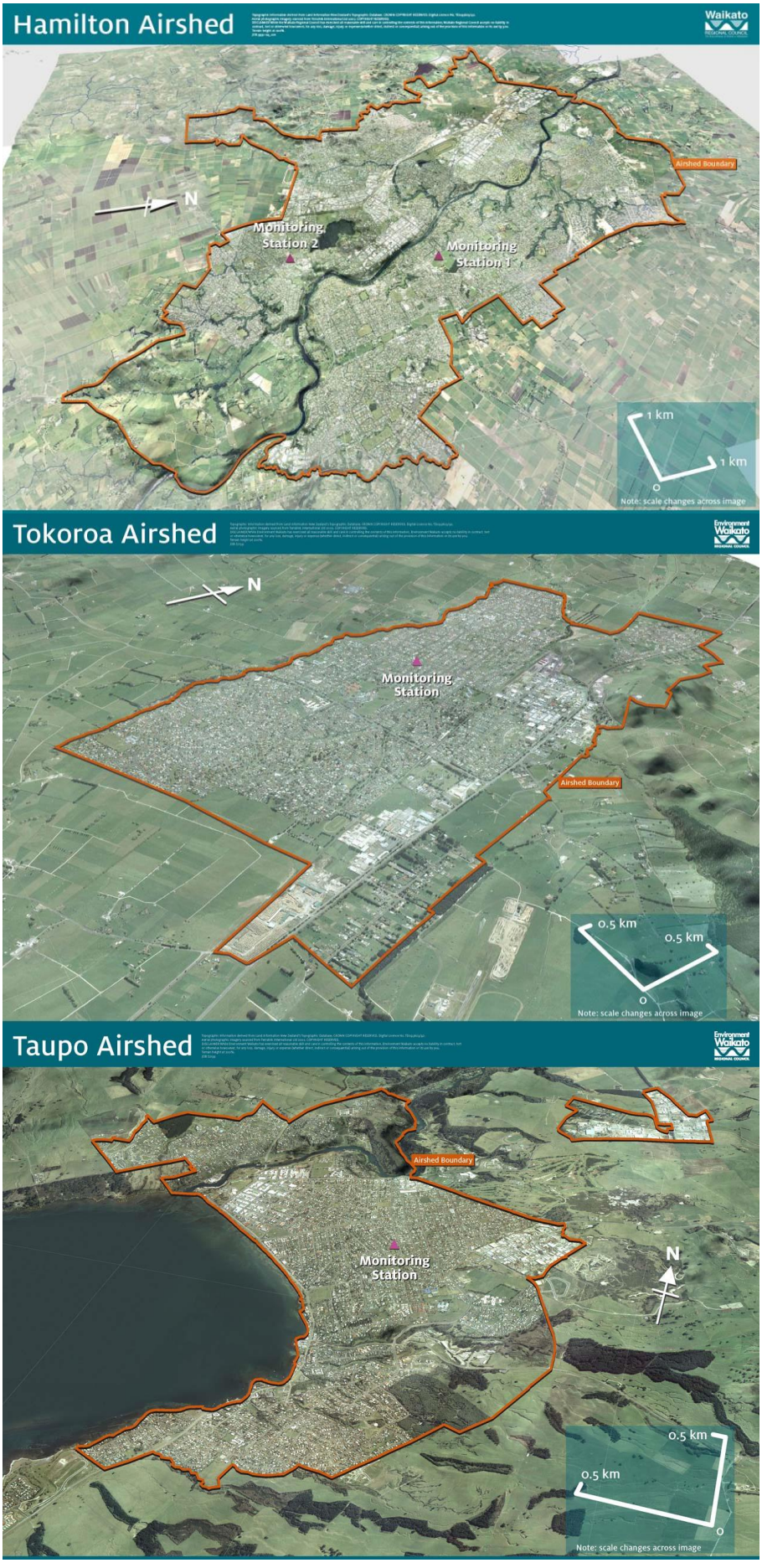

Figure 1.2 **Hamilton, Tokoroa and Taupo airsheds with monitoring stations identified by pink triangle.**

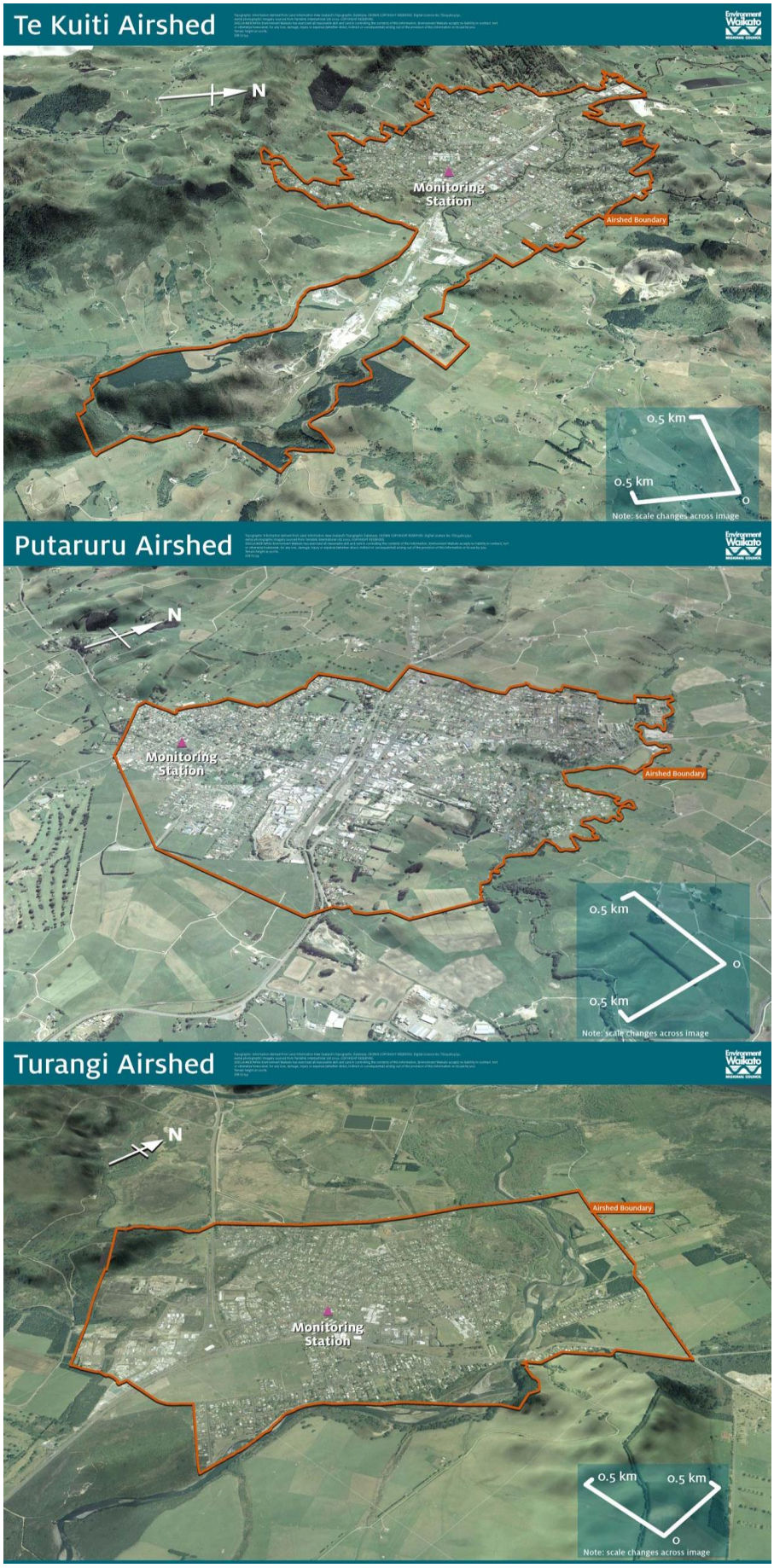

Figure 1.3 **Te Kuiti, Putaruru and Turangi airsheds with monitoring stations identified by pink triangle.**

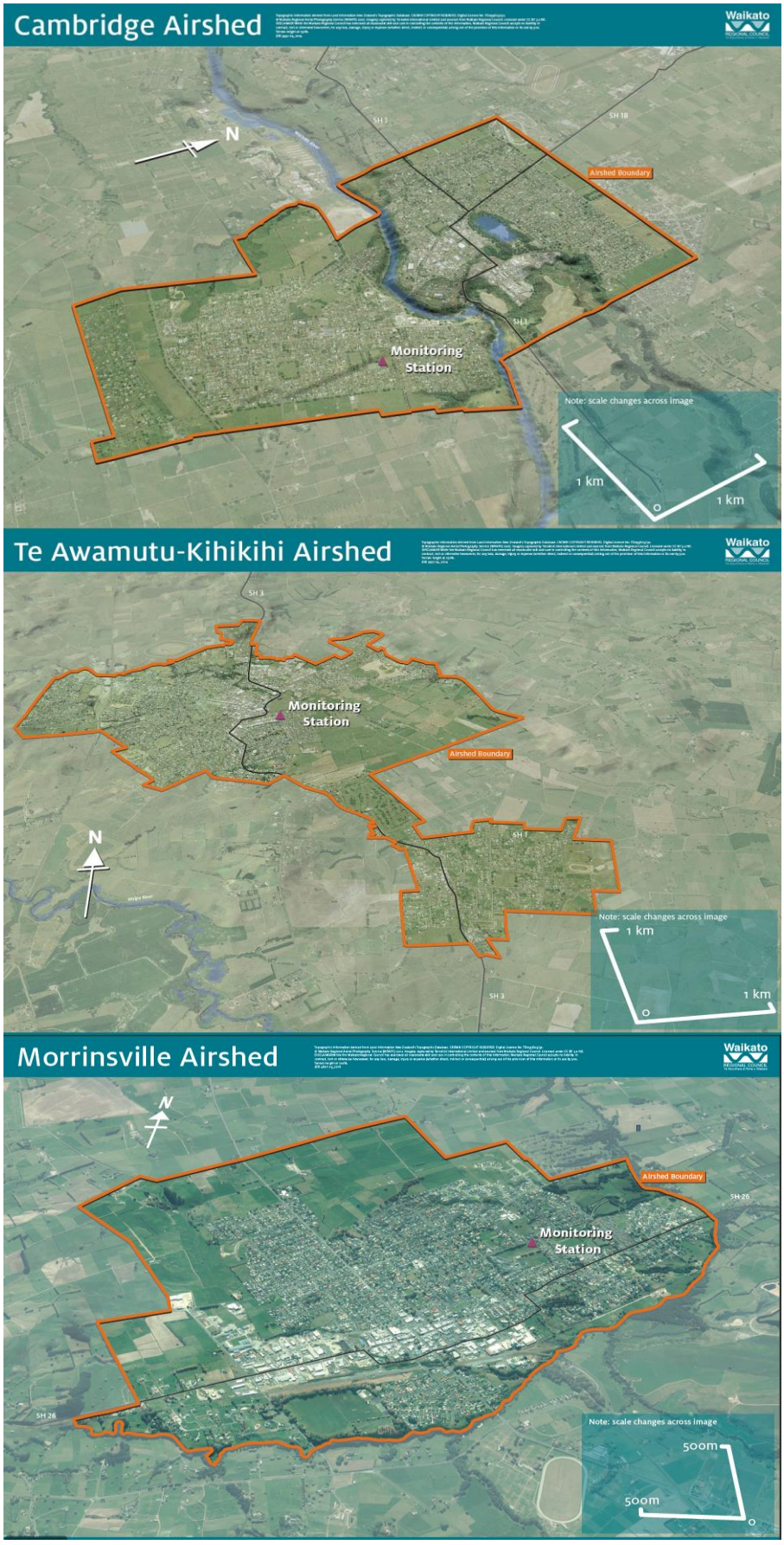

Figure 1.4 **Cambridge, Te Awamutu-Kihikihi and Morrinsville airsheds with monitoring stations identified by pink triangle.**

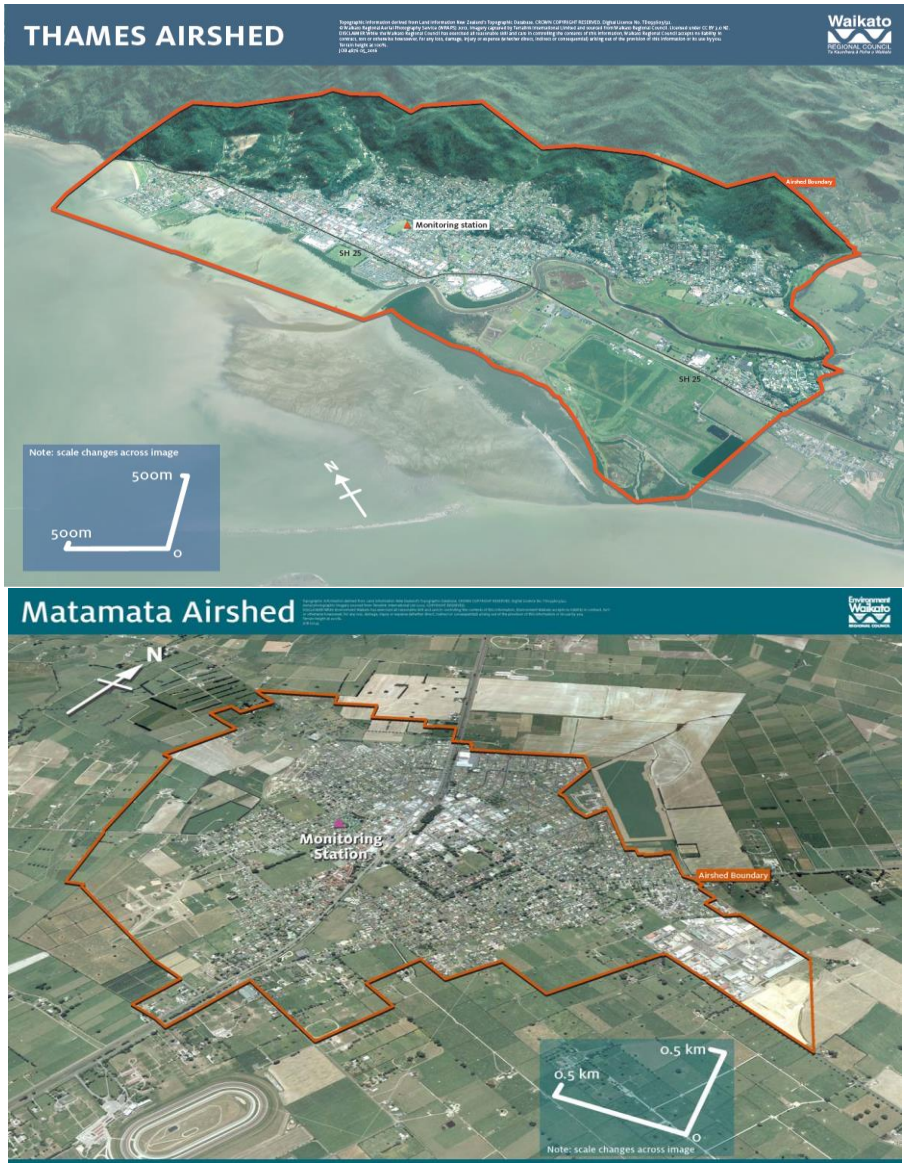

Figure 1.5 Thames and Matamata airsheds with monitoring station identified by pink triangle.

Hamilton is the Waikato region's main urban area, with a population of 141,612. The airshed extends across both the eastern and western sides of the Waikato River. The main source of poor air quality during winter is from home heating using wood. However, traffic can also be a significant source of poor air quality especially in the vicinity of busy intersections. Hamilton currently has two active residential PM_{10} monitoring stations and six traffic BTEX monitoring sites. The main residential station is at the Claudelands Event Centre on Heaphy Terrace on the eastern side of Hamilton. The Bloodbank station is a secondary air quality monitoring station, more influenced by traffic and industry sources. It is next to the NZ Blood Service at the Waikato Hospital on the corner of Ohaupo Road and Lorne Street on the western side of Hamilton. From November 1997 to October 2013, the main air quality monitoring station was located on Peachgrove Road on the eastern side of Hamilton. The station was decommissioned in October 2013 because the property changed ownership.

Tokoroa is located mid-way between Hamilton and Taupo on State Highway One, close to the foot of the Mamaku Ranges with a population of 12,243. The main source of poor air quality during winter is home heating using wood. Tokoroa's one active residential air quality and meteorological monitoring station is located at the Billah Street Reserve and was established in March 2001. In April 2015, the station was shifted (within the same site) to a new enclosure 25 metres from its previous location because of concern about potential impacts from the lime

dosing process used on site by South Waikato District Council for treating drinking water at the Billah Street reservoir.

Taupō, with a population of around 23,700, is the Waikato region's second largest urban area after Hamilton. It is located within the Taupō Volcanic Zone at the northeastern end of Lake Taupō. The main source of poor air quality during winter is from home heating using wood. Because of its location within the Taupō Volcanic zone, there will be a larger contribution from volcanic/geothermal activity at times. The surrounding pumice soils are also likely to contribute to a higher summertime dust source. Taupō's one active residential air quality and meteorological monitoring station, located at Gillies Avenue Reserve, was established in November 2000.

Te Kuiti is located approximately 78km south of Hamilton within a confined valley that is aligned along an approximately southeasterly to northwesterly direction. The town is located within the Waitomo District and has a population of 4221. The main source of poor air quality during winter is home heating using wood but there are also three significant industrial sources including a lime processing plant and two woodfired combustion plants associated with two separate sawmilling operations. Te Kuiti's residential air quality monitoring and meteorological station was established at the Waitomo District Council offices on Queen Street in May 2003.

Matamata, approximately 41km east of Hamilton near the western base of the Kaimai Ranges, has a population of around 7500. The main source of poor air quality is considered to be home heating. Air quality was monitored at the playcentre grounds on Farmers Road from June 2005 to April 2013, when the monitoring of air quality was disestablished. Since that time, the residential based station has continued to be used for monitoring of meteorology.

Putaruru is located 65 kilometres southeast of Hamilton and is close to Lake Arapuni on the Waikato River. It is situated midway between Tokoroa and Tirau on State Highway One, in the South Waikato District and has a population of 3777. Putaruru occupies a flat to gently undulating site, and to the east the land rises to the Mamaku Range. The main source of poor air quality is considered to be home heating. Putaruru's residential air quality monitoring station was established at the Bowling Club on Arapuni Street, in July 2006.

Turangi, at the southern end of Lake Taupō, has a population of 2952. The main source of poor air quality is considered to be home heating. Due to its location within the Taupo Volcanic zone, at times volcanic/geothermal activity has been identified as contributing to PM_{10} concentrations.Turangi's residential air quality monitoring station was established at the Turangi Fire Station on Ohuanga Road in March 2009.

Cambridge, approximately 23km southeast of Hamilton, has a population of approximately 18,000. The airshed extends across both the eastern and western sides of the Waikato River. The main source of poor air quality is considered to be home heating. Cambridge currently has one residential air quality monitoring station located at Leamington Domain on Scott Street. The station was established in May 2013.

Te Awamutu, approximately 30km south of Hamilton, has a population of 10,305. The main source of poor air quality is considered to be home heating but there are also significant industrial emissions associated with the Fonterra dairy factory which has milk powder driers and gas and coal fired boilers. Te Awamutu's residential air quality monitoring station was established at Albert Park on Albert Park Drive in June 2013.

Morrinsville, approximately 30km northeast of Hamilton, has a population of approximately 7000. The main source of poor air quality is considered to be from home heating. Morrinsville's residential air quality monitoring station was established at Morrinsville College in the vicinity of North Street in May 2015.

Thames is located at the southeastern end of the Firth of Thames on the banks of the Kauaeranga River. Most of the urban area occupies a coastal strip of flat land at the western base of the Coromandel Range. Thames has a population of 7,518. The main source of poor air quality is considered to be from home heating. Thame's residential air quality monitoring station was established at Thames High School in the vicinity of Richmond Street in March 2016.

2 Methodology

2.1 PM_{10} & $PM_{2.5}$ monitoring

There are many different ways of measuring particle concentrations (e.g. PM_{10} or $PM_{2.5}$ etc.) in air and each method can provide varying levels of accuracy. One of the most common methods used by Regional Councils around New Zealand is the BAM. BAM stands for Beta Attenuation Monitor. This instrument type measures particle concentrations continuously. Sampled air is drawn through a filter which collects particles. A beam of beta radiation (electrons) is passed though the filter and counted on the other side of the filter by a detector. As the mass of particles on the filter increases the beta count is reduced and from this the mass of particles can be determined. This method is a US EPA equivalent method which is therefore accepted for compliance purposes under the NESAQ.

All air quality monitoring stations in the Waikato region used a BAM for monitoring particulate concentrations in 2016. Refer to table 2.1 for details of monitoring station locations and instruments used for 2016. All stations, except Hamilton's Bloodbank station are set up for assessing the impacts of residential solid fuel heating. The Bloodbank station is located 10 metres away from a busy roadway (Ohaupo Road) and is near to industry discharges (e.g. Waikato Hospital boilers) and is therefore expected to be more influenced by traffic and industry sources compared with the other Hamilton station at Claudelands.

Table 2.1 PM_{10} and $PM_{2.5}$ monitoring stations and instruments for 2016.

Station	Location	Airshed	Instrument
Claudelands[1]	Claudelands Event Centre, Heaphy Tce, Hamilton	Hamilton	Thermo FH62 BAM (PM_{10})
Bloodbank	Waikato Hospital, Ohaupo Road, Hamilton	Hamilton	Thermo FH62 BAM (PM_{10})
Billah Street	Billah St Reserve, Billah St, Tokoroa	Tokoroa	Thermo FH62 BAM (PM_{10}) & Thermo 5014i BAM ($PM_{2.5}$)
Bowling Club	Bowling Club, Arapuni St, Putaruru	Putaruru	Thermo FH62 BAM (PM_{10})
Gillies Avenue	Gillies Ave Reserve, Taupo	Taupo	Thermo FH62 BAM (PM_{10})
Waitomo DC	Waitomo District Council, Queen St, Te Kuiti	Te Kuiti	Thermo FH62 BAM (PM_{10})
Firestation	Fire Station, Ohuanga Rd, Turangi	Turangi	Thermo FH62 BAM (PM_{10})
Albert Park	Albert Park, Albert Park Drive, Te Awamutu	Te Awamutu	Thermo FH62 BAM (PM_{10})
Leamington	Leamington Domain, Scott St, Cambridge	Cambridge	Thermo FH62 BAM (PM_{10})
Morrinsville College	Morrinsville College, North St, Morrinsville	Morrinsville	Thermo 5014i BAM (PM_{10})
Thames	Thames High School, Richmond St, Thames	Thames	Thermo 5014i BAM (PM_{10})

1. Note that prior to 2014, the main monitoring station in the Hamilton airshed was located 160 Peachgrove Road from 1997 to 2013. The Claudelands site is a replacement for this earlier "Peachgrove Rd" site.

PM_{10} and $PM_{2.5}$ data from the BAM monitors are recorded and logged by iQuest iRIS 320 dataloggers and telemetered hourly to Waikato Regional Council and stored in the hydrotel database. Subsequent data processing and archiving is undertaken in the WISKI database.

Over the period 2006 to 2010, several air quality monitoring stations in the Waikato region had Thermo Sequential Partisol gravimetric samplers run in conjunction with existing BAM instruments in order to determine the need to apply site-specific corrections to the BAM PM_{10} data. As a result, it was determined that site-specific corrections were required for BAM PM_{10} data collected at Tokoroa, Taupo and Putaruru. Monitoring data has therefore been adjusted accordingly, at those sites. Table 2.2 provides details of the formulae used for applying the corrections. Additional assessments using a sequential partisol have been undertaken in Tokoroa in 2014 and 2016 and indicate that the currently applied correction factor for BAM PM_{10} data for Tokoroa is still valid. No corrections are applied to the $PM_{2.5}$ data.

Table 2.2 Site-specific corrections applied to BAM PM_{10} data.

Station	Correction factor
Tokoroa	Corrected $PM_{10} = 10^{(1.09945 \log BAM - 0.08595)}$
Taupo	Corrected $PM_{10} = 1.255BAM – 1.538$
Putaruru	Corrected $PM_{10} = 1.106BAM - 2.38$

2.2 BTEX monitoring

Passive sampling for the volatile organic compounds benzene, ethyl-benzene, toluene and xylenes (BTEX) was undertaken in Hamilton at six sites in 2016 using 3M Passive axial diffusion samplers. Two of the six sites are located on Peachgrove Road adjacent to Countdown supermarket and Hamilton Intermediate School. The other four sites are located at Bridge Street/Grey Street intersection, Claudelands Road/Victoria Street intersection, Tristram Street and Greenwood Street (refer to Figure 2.1).

Motor vehicles are the main sources of BTEX in urban areas. Pollutants such as benzene are typically monitored using a passive sampling methodology where small plastic badges containing activated carbon are attached to a power pole, for example, in proximity to a busy street or intersection and are exposed for a certain period to the ambient air. The benzene is adsorbed to the carbon over this period and can then be analysed in a laboratory at the end of the exposure period.

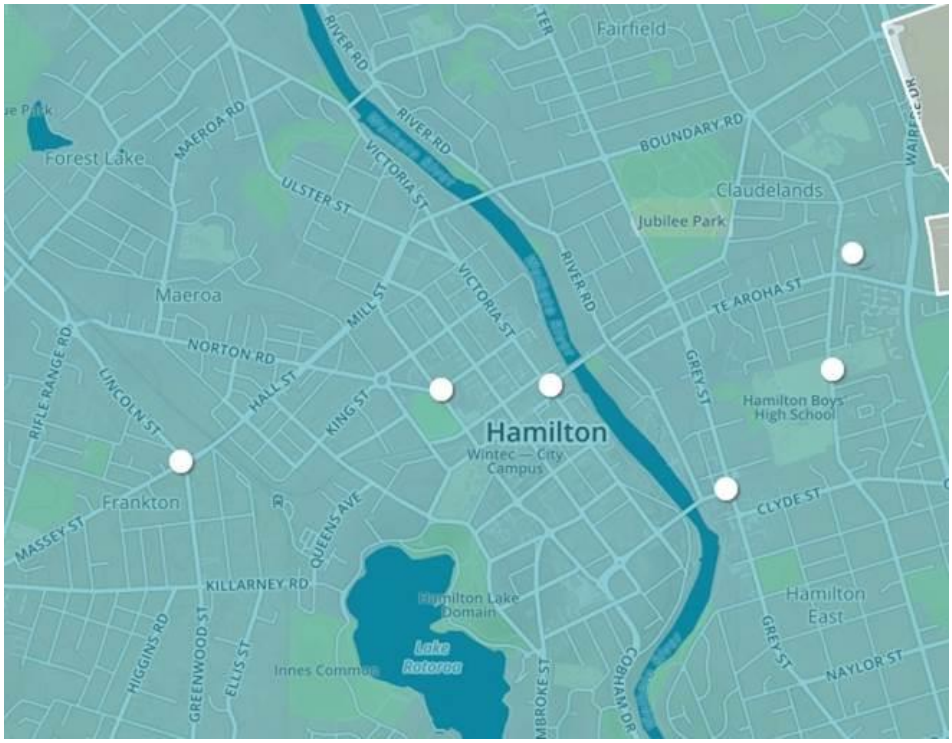

Figure 2.1 Map of BTEX sites in Hamilton.

The method used is as described in Stevenson and Narsey (1999) with passive axial samplers being deployed for periods of three months. The BTEX compounds are extracted from the samplers using carbon disulphide and then analysed using Gas Chromatography Mass Spectrometry by Hill Laboratories in Hamilton. While this type of passive sampling is recommended as a screening method only, it is the most common approach to BTEX monitoring in New Zealand and is significantly more cost effective than the radial passive sampler method recommended by the Ministry for the Environment's ambient air quality guidelines (MfE 2002).

Validation of this axial sampler method with the MfE recommended method was undertaken in 2010 by Waikato Regional Council. It was determined that the accuracy of the 3M passive axial samplers is likely to be sufficient for monitoring purposes provided the deployment duration is not excessive (Mathieson, 2010).

The 2016 monitoring period for BTEX covered the period 18 December 2015 to 4 January 2017. Aligning the reporting period for BTEX with an exact calendar year is not always feasible as it would require staff to deploy passive sampling equipment on 1 January. This misalignment with the calendar year is of little concern when reporting annual averages and it is not expected that there would be any difference in the annual averages if the passive samplers were instead deployed on 1 January each year.

2.3 Nitrogen dioxide monitoring

Nitrogen dioxide (NO_2) monitoring is used as a general proxy for air pollution from motor vehicles. The NZ Transport Agency undertakes passive NO_2 monitoring near to state highways across New Zealand. The Waikato Regional Council partners with NZTA to collect additional NO_2 data at selected sites in the Waikato region including Hamilton, Te Awamutu, Taupo and Cambridge. Monitoring was undertaken in these four airsheds in 2016 for a full 12 month period. An additional six month passive monitoring survey of NO_2 was undertaken in Tokoroa and Matamata adjacent to State Highway 1 and 24 respectively over the period 3 December 2015 to 7 June 2016. This monitoring survey (independent of NZTA's programme) was managed by Watercare Services Ltd on behalf of Waikato Regional Council. The locations of monitoring sites are provided in Table 2.3 and Figures 2.2 to 2.4.

Table 2.3 Site locations for passive NO_2 monitoring in 2016.

Airshed	Location
Hamilton	Cambridge Rd/Morrinsville Rd
Hamilton	Bridge St/Cobham Dr
Hamilton	Brooklyn Rd/Peachgrove Rd
Hamilton	Victoria St/Ulster St
Hamilton	Greenwood St/Killarney Rd
Hamilton	Lorne St/Ohaupo Rd
Hamilton	Avalon Dr/Grandview Rd
Hamilton	Seamer Pl
Hamilton	Te Rapa Rd/Ann Michele St
Cambridge	Victoria St/Queen St
Te Awamutu	Ohaupo Rd/Albert Dr
Taupo	Tongariro St/Norman Smith St
Matamata	SH24 (Broadway)/Firth St
Matamata	SH24 (Broadway)/Arawa St
Tokoroa	Bridge St/Leith Pl
Tokoroa	SH1/Swanston St

Passive nitrogen dioxide samplers (similar to the BTEX samplers described above) are easy to operate and relatively cheap, so they can be installed in large numbers (usually attached to power poles for example) over a wide area giving good spatial coverage. The sampler tubes contain triethanolamine which reacts with nitrogen dioxide to form nitrite ions. The tubes are typically exposed for a one month duration and then analysed at a laboratory using UV spectroscopy.

The results are indicative only and provide monthly rather than daily averages. Passive sampling is therefore useful as a screening method rather than a regulatory method, for which continuous monitors are used.[2]

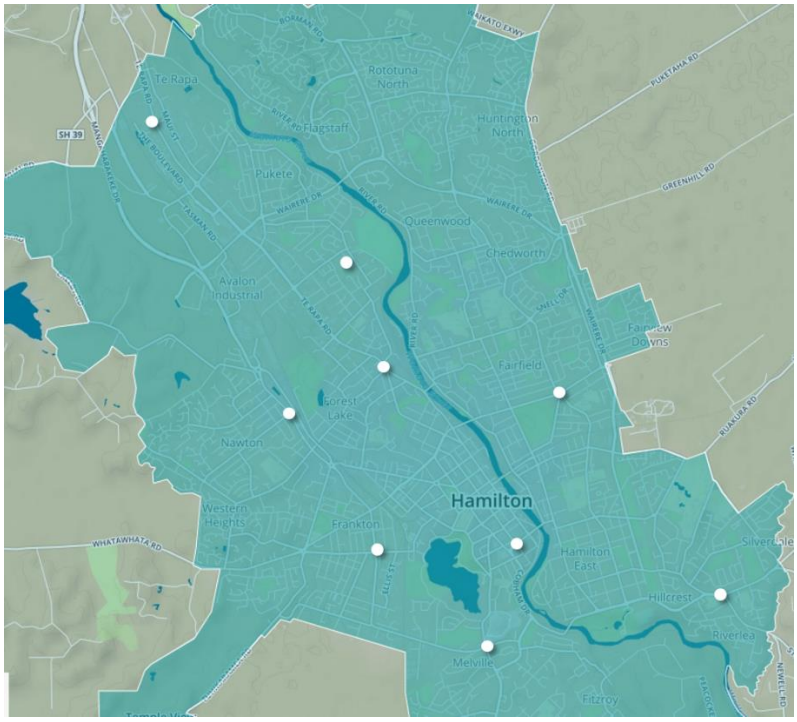

Figure 2.2 Map of passive NO_2 monitoring sites in Hamilton.

[2] Ambient air quality (nitrogen dioxide) monitoring network report 2007 – 2009, NZTA

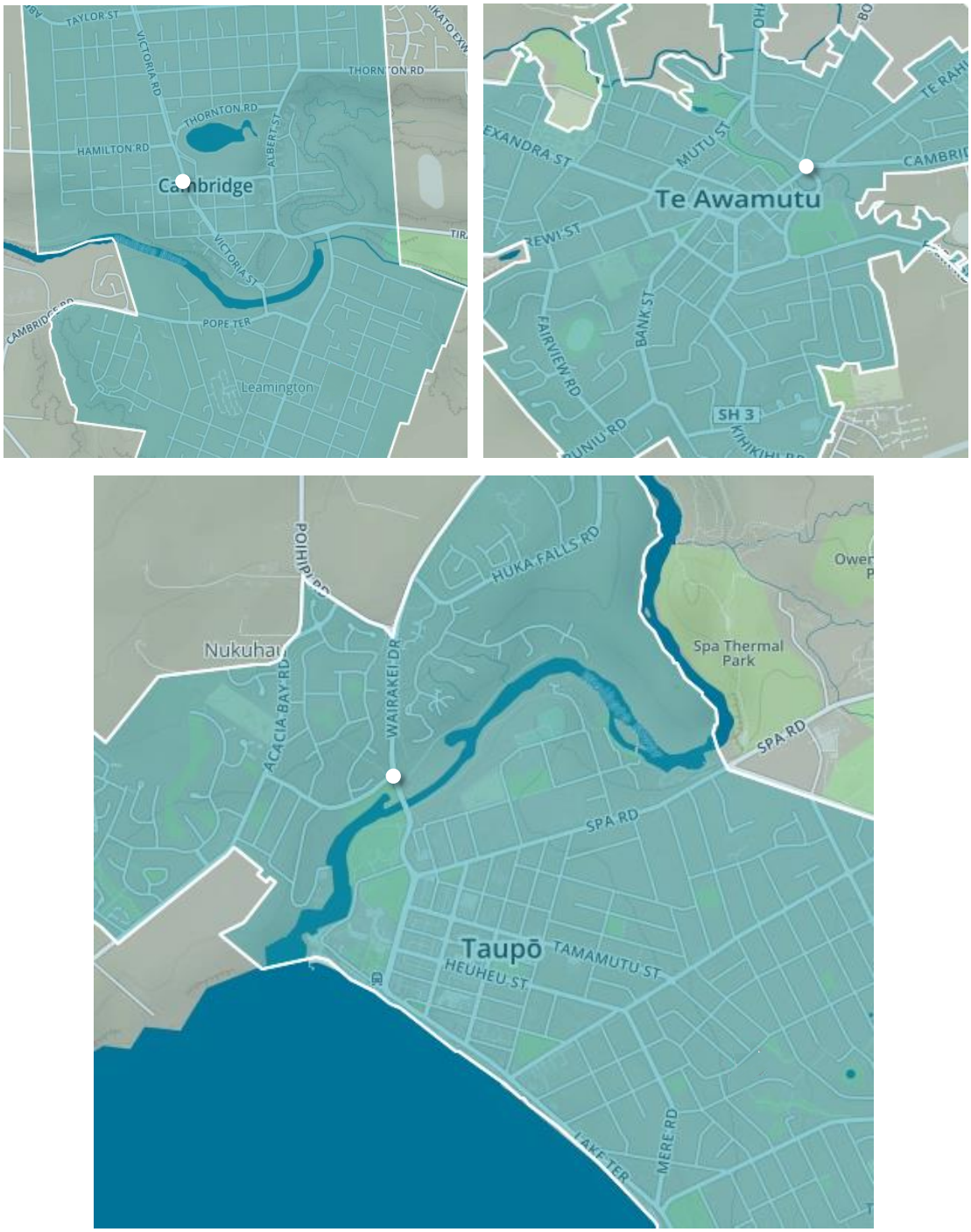

Figure 2.3 Map of passive NO_2 monitoring sites in Cambridge. Te Awamutu and Taupo.

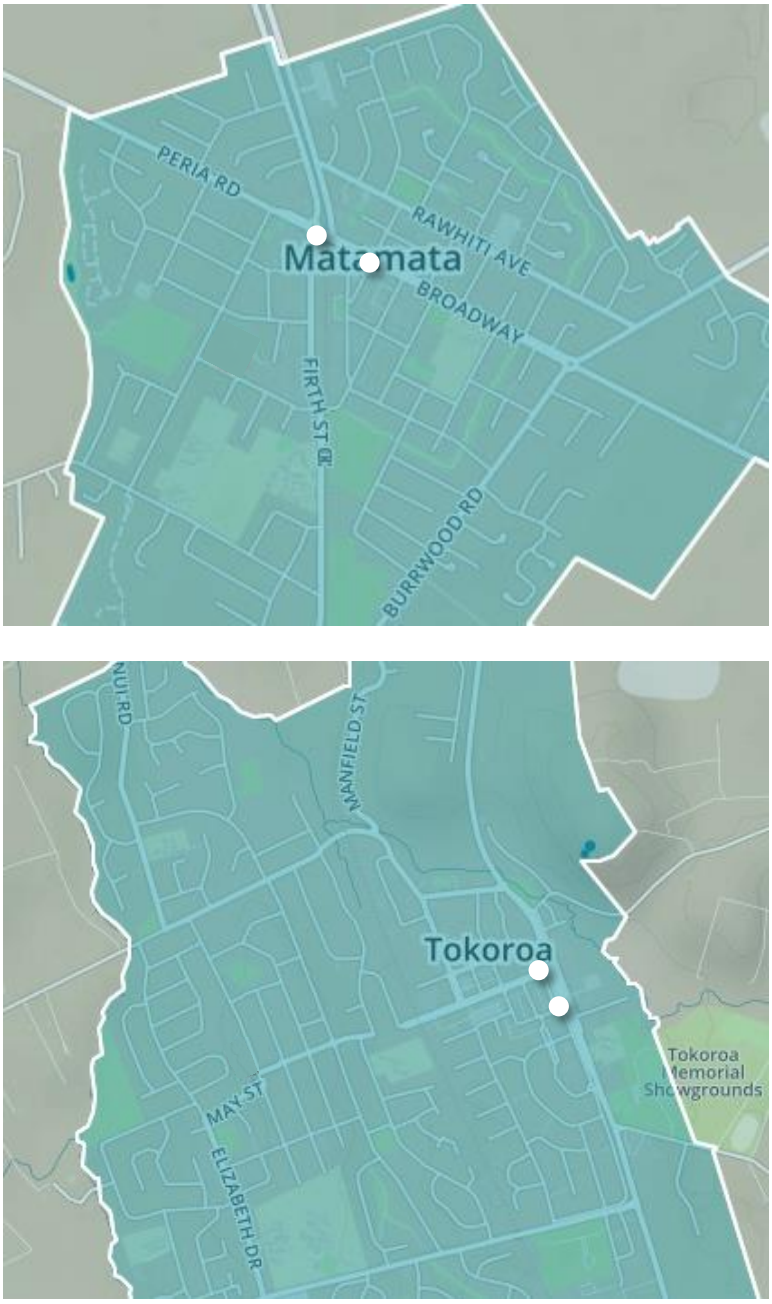

Figure 2.4 **Map of passive NO_2 monitoring sites in Matamata and Tokoroa.**

2.4 Meteorological monitoring

In 2016, meteorological data, including ambient air temperature, wind speed and wind direction were collected at Hamilton (Claudelands), Tokoroa, Taupo, Matamata and Te Kuiti monitoring stations. Relative humidity data was also collected at Hamilton (Claudelands) and Taupo. All meteorological data is collected at a height of six metres above ground level except for Tokoroa where meteorological data is collected from the top of an existing water reservoir tower at a height of 10 metres. Details of the meteorological instrumentation used is provided in Table 2.4.

The meteorological data is recorded and logged by iQuest iRIS 320 dataloggers and telemetered hourly to Waikato Regional Council and stored in the hydrotel database. Subsequent data processing and archiving is undertaken in the WISKI (by Kisters) database.

Table 2.4 Meteorological monitoring instrument details.

Airshed	Windspeed	Wind direction	Air temperature	Relative humidity	Height above ground level (m)
Tokoroa	Vector A101M	Vector W200P	PT100	–	10
Taupo	Young Ultrasonic 85000	Young Ultrasonic 85000	Vaisala HMP45A	Vaisala HMP45A	6
Te Kuiti	Young Ultrasonic 81000	Young Ultrasonic 81000	Young Ultrasonic 81000	–	6
Hamilton	Young Ultrasonic 85000	Young Ultrasonic 85000	Vaisala HMP60	Vaisala HMP60	6
Matamata	Vaisla WMT52	Vaisla WMT52	Vaisla WMT52	Vaisla WMT52	6

The frequency and extent of NES breaches from year to year depends largely on the prevalence of meteorological conditions conducive to elevated pollution, in particular low wind speeds, cooler temperatures and temperature inversions.

A graphical comparison of hourly average PM_{10} concentrations on days where the 24-hour average is elevated or exceeds the standard relative to the hourly average wind direction, wind speed and air temperature provides a means of identifying contributing meteorological influences. This type of comparative assessment has been applied to PM_{10} and meteorological data for Hamilton, Taupo, Te Kuiti and Tokoroa for 2016.

A wind rose is a diagram that shows the relative frequency and speed of winds from different directions at a specific location. They provide a useful means of visually identifying prevailing wind directions and windspeed frequencies. The application, WRPLOT View (Version 7.0.0) by Lakes Environmental, has been used to generate wind roses for Hamilton, Tokoroa, Taupo, Te Kuiti and Matamata.

2.5 Trend analysis

Analysis of trends in PM_{10} concentrations requires an assessment of the variability from year to year occurring because of meteorological conditions. For example, higher PM_{10} and more exceedances might be expected if a winter has a greater number of days when the wind speed is low and there is vertical stability in the lower atmosphere. Over the short term this inter-annual variability will mask any genuine underlying trend toward better or worse air quality. A reasonably long monitoring record is therefore needed to confirm or exclude the possibility of any underlying trend.

Seasonal Mann-Kendall test for monotonic trends (consistently increasing or decreasing trends) can be used for detecting underlying trends in variable environmental time-series data sets, and may suggest presence of an underlying trend which is not evident from visual inspection of the PM_{10} record or summary statistics. This method generates probability (p) values that are used to assess the likelihood that the apparent relationship is real or a result of chance. The conventional threshold for deciding whether a relationship is likely to be genuine is at a probability value of $p = 0.05$ or lower, which corresponds to a 95% confidence level and greater. A negative MK-Stat indicates a decreasing trend.

Seasonal Mann-Kendall trend analysis was undertaken for Hamilton, Tokoroa, Taupo, Te Kuiti and Putaruru PM_{10} datasets for 2016.

3 Results

3.1 PM_{10} monitoring in Hamilton

The Hamilton airshed remains compliant with the NES with no exceedances of the PM_{10} standard of 50 µg/m^3 as a 24-hour average. The maximum 24-hour average PM_{10} concentration measured was 32 µg/m^3 at the Claudelands site on 4 June 2016 and 31 µg/m^3 at the Ohaupo Road (Bloodbank) site on 3 June 2016.

The 24-hour average PM_{10} concentrations measured at Hamilton during 2016 are shown in Figures 3.1 and 3.2.

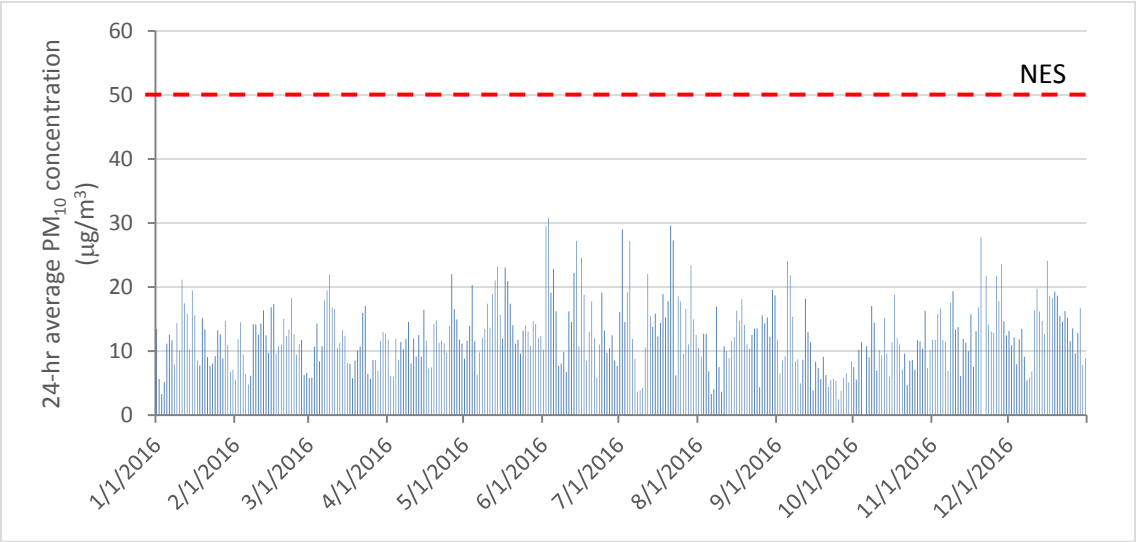

Figure 3.1 24-hour average PM_{10} concentrations measured at Ohaupo Road during 2016.

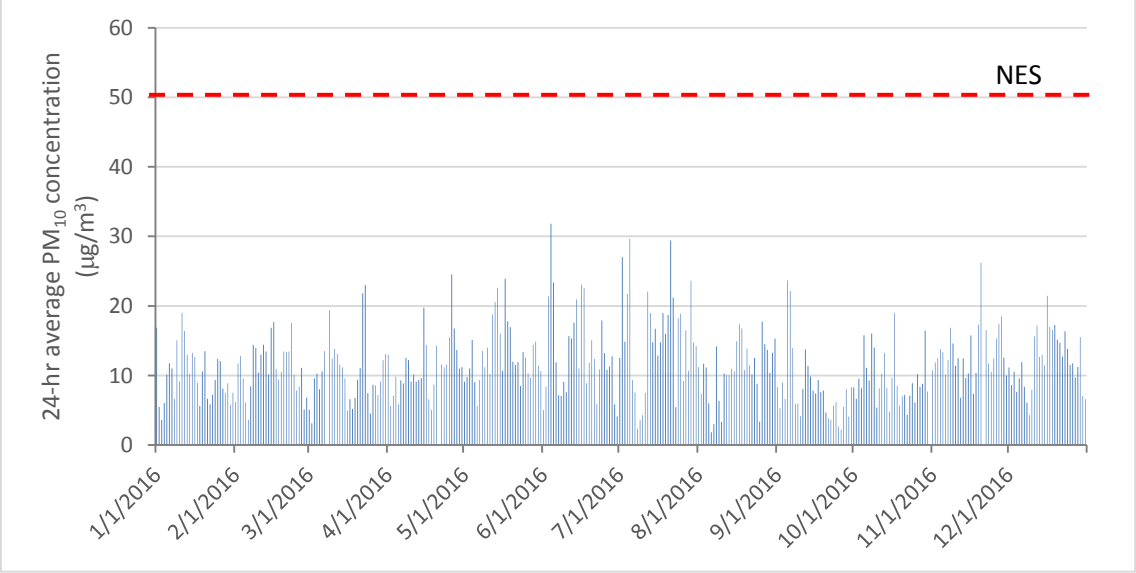

Figure 3.2 24-hour average PM_{10} concentrations measured at Claudelands during 2016.

Figure 3.3 shows year to year variability in 24-hour average PM_{10} concentrations relative to MfE air quality indicator categories from 2000 to 2016 for the Claudelands site and its predecessor, the Peachgrove Rd site (decommissioned at end of 2013). The proportion of 24-hour average

PM_{10} concentrations less than 33% of the guideline (standard) for 2016 is similar to the proportion determined for 2015, both of which represent better air quality than previous years.

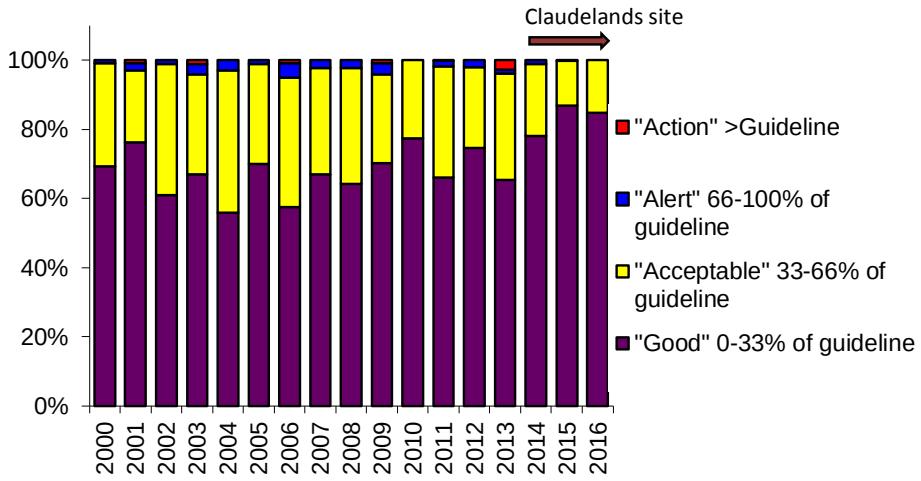

Figure 3.3 **Comparison of 24- hour average PM_{10} concentrations measured at Peachgrove Road and the replacement Claudelands site in Hamilton from 2000 to 2016 relative to air quality indicator categories.**

A comparison of PM_{10} concentrations at the Ohaupo Rd site from 2012 to 2016 relative to the MfE air quality indicator categories are shown in Figure 3.4. As with previous years, the majority (approximately 80%) of the 24-hour average PM_{10} concentrations for 2016 were less than 33% of the air quality guideline and is similar to the proportion (approximately 85%) of data less than 33% of the guideline determined for the Claudelands site.

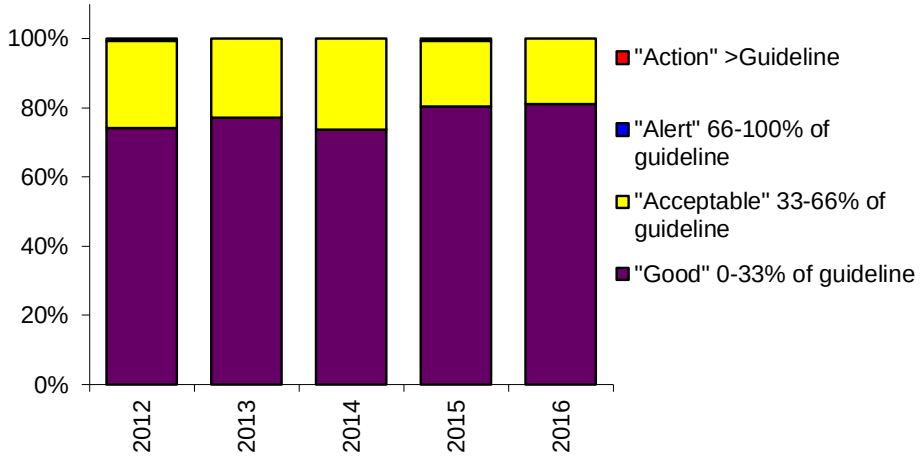

Figure 3.4 **Comparison of 24-hour average PM_{10} concentrations measured at Ohaupo Road site in Hamilton from 2012 to 2016 relative to air quality indicator categories.**

A comparison of monthly average PM_{10} concentrations at Ohaupo Road and Claudelands for 2016 (Figure 3.5) indicates slightly higher overall concentrations at the Ohaupo Road site but with a similar seasonal distribution. In 2015 the Ohaupo Road concentrations were around 14% higher on average than Claudelands compared with 8% higher in 2016.

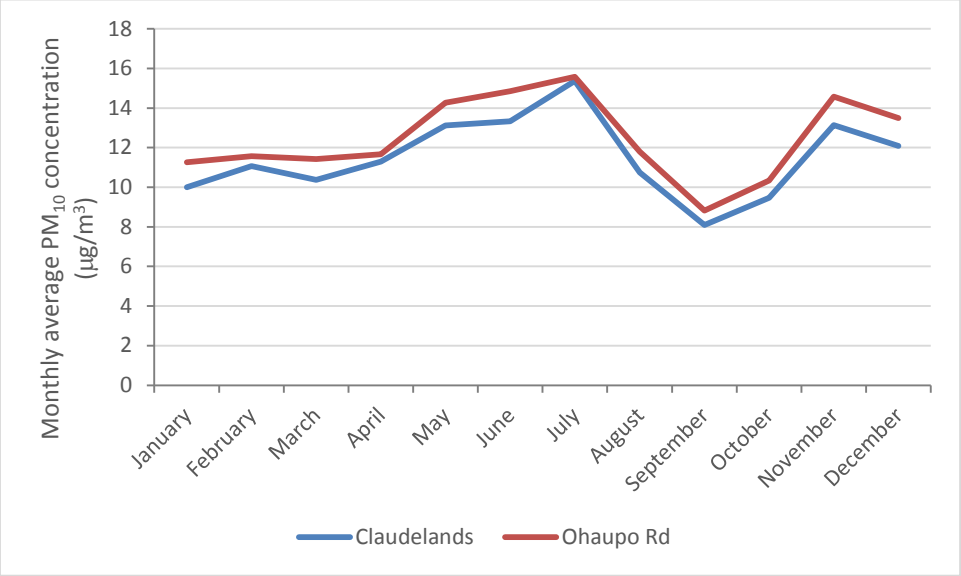

Figure 3.5 **Comparison of monthly average PM_{10} concentrations measured at Claudelands and Ohaupo Rd sites in Hamilton in 2016.**

The annual average PM_{10} concentrations for Ohaupo Road and Claudelands for 2016 were 12.5 µg/m^3 and 11.5 µg/m^3 respectively which is well below the annual average guideline for PM_{10} of 20 µg/m^3 (MfE, 2002). An annual average PM_{10} concentration is not specified in the NES. Refer to Appendix 1 for a full summary of PM_{10} monitoring statistics for Hamilton for the period 2002 to 2016.

A wind rose for 2016 showing the relative frequency and speed of winds from different directions for 2016, as measured at the Claudelands station, is provided in Figure 3.6. The wind rose indicates a prevailing wind direction from the west and west-southwest with a high frequency of low to moderate windspeeds.

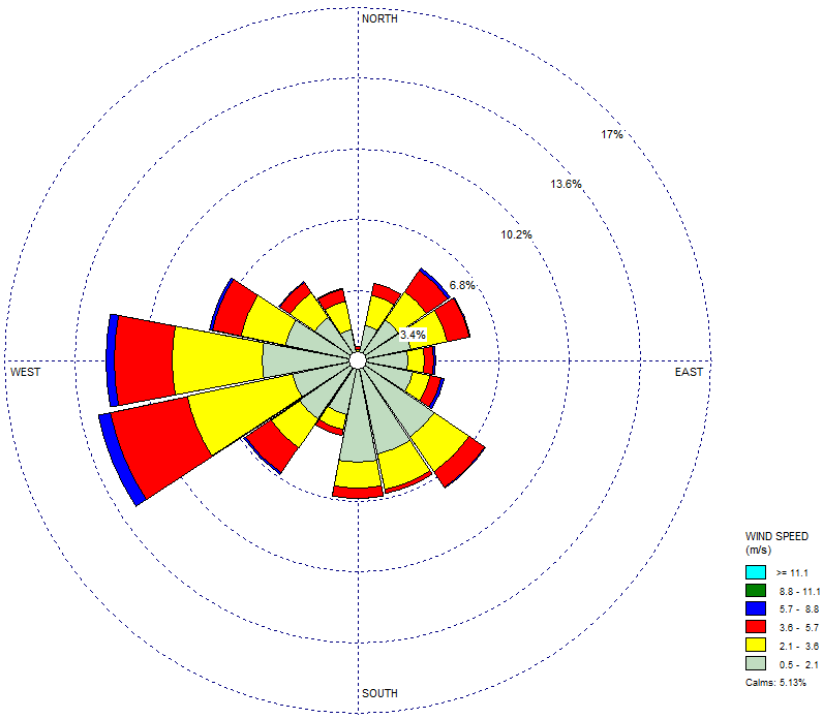

Figure 3.6 **Windrose of wind direction and windspeed data as measured at Claudelands station in Hamilton in 2016.**

A comparison of meteorological parameters with hourly average variations in PM_{10} on the three days during 2016 which had the highest 24-hour average PM_{10} concentrations at the Claudelands site is provided in Figure 3.7. These days were 4 June, 5 July and 21 July (PM_{10} = 31.8 µg/m^3, 29.6 µg/m^3 and 29.4 µg/m^3).

Concentrations of PM_{10} on the 4 June and 5 July are typical of daily variations in concentrations that occur in urban areas of New Zealand primarily because of solid fuel burning for domestic heating (Trompetter *et al.*, 2010). The average wind speeds on these days were less than 2 m/s. In comparison on 21 July (PM_{10} = 29.4 µg/m^3) concentrations were slightly elevated throughout the day and the wind speed was around 4 m/s for most of the day. The wind speed dropped to less than 1 m/s in the evening and PM_{10} concentrations increased accordingly in a manner consistent with domestic heating. The temperature was also warmer during the daytime only dropping to below 10 degrees in the early evening. It is likely that the source of PM_{10} concentrations on 21 July occurred primarily as a combination of windblown sources and domestic heating.

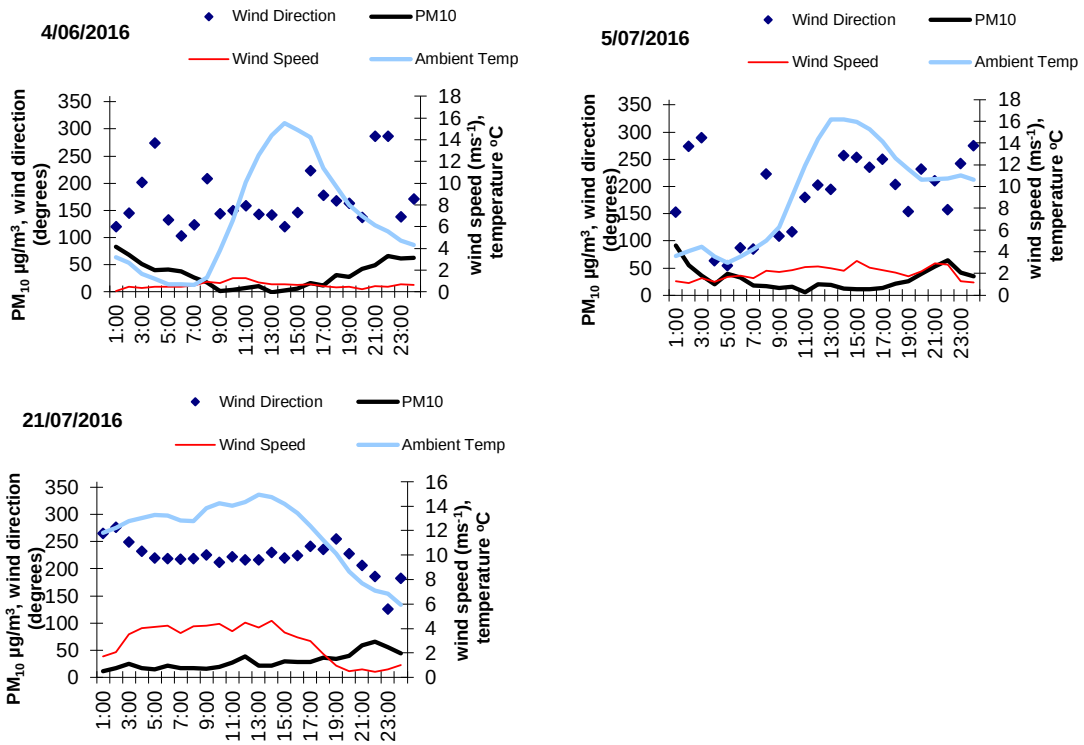

Figure 3.7 **Variation in hourly average PM_{10} concentrations, wind speed, wind direction and temperature at Claudelands on 4 June (PM_{10} = 31.8µg/m^3), 5 July (PM_{10} = 29.6 µg/m^3) and 21 July (PM_{10}= 29.4 µg/m^3).**

Seasonal Mann Kendall test results for monthly average PM_{10} concentrations from the decommissioned Peachgrove Rd station (MK-Stat of -2.05 and p-value of 0.04) provided possible evidence that PM_{10} concentrations in Hamilton were decreasing over the period 2006 to 2013 (Caldwell 2015). The analysis has not been updated to include the Claudelands site PM_{10} data (2014-2016). Analysis of trends for this site will commence once four years of PM_{10} data is available. Seasonal Mann Kendall test results for monthly average PM_{10} concentrations from the Ohaupo Road site for the period 2012 to 2016 indicate no statistically evident change (MK-Stat of -0.93 and p-value of 0.35).

Data suggests that Hamilton is likely to continue to meet the NES target of no more than one exceedance per 12-month period of the 24-hour average PM_{10} concentration standard of 50 µg/m^3. However, it is possible that poor meteorological conditions i.e., a particularly cold and

calm winter could still result in more than one exceedance with in a 12-month period. This would result in Hamilton being classified as a polluted airshed.

3.2 BTEX monitoring in Hamilton

Benzene concentrations measured at all locations in Hamilton during 2016 were lower than the Ministry for the Environment's annual average guideline of 3.6 µg/m^3. The guideline prior to 2010 was 10 µg/m^3 (annual average). The highest annual average benzene concentration of 2.2 µg/m^3 was measured at the Greenwood Street monitoring site. An improving or "levelling" trend is evident for annual average concentrations of benzene at all sites particularly between 2011 and 2013 (Figure 3.8). The main exception is Peachgrove Road which shows an increase for 2016. A new supermarket opening on this road, near to the monitoring site location at the end of 2015 is the likely cause of the increase.

Large decreases in benzene concentrations were observed over the period 2003 to 2007. These earlier decreases were attributed to changes in fuel specifications and improved vehicle technology (Smith, 2007).

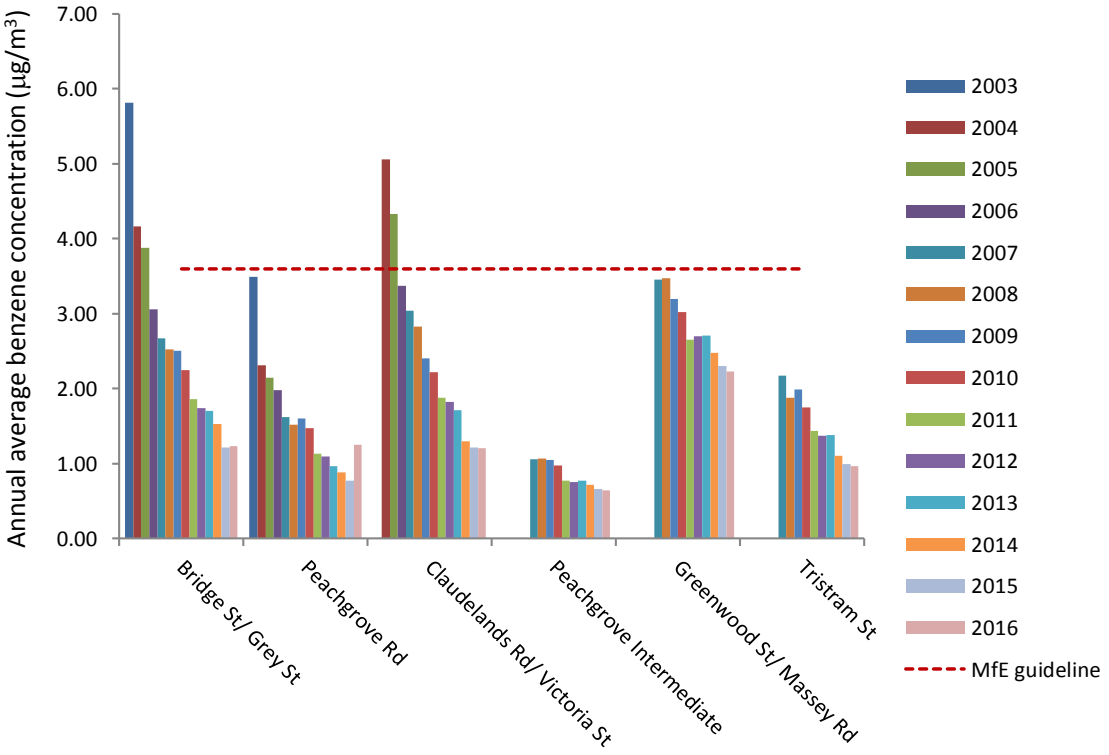

Figure 3.8 Annual average benzene measured at Hamilton sites (2003 to 2016).

Ethyl-benzene, toluene and xylene were also measured at the BTEX monitoring sites for each year. Results are shown in Table 3.1. An MfE document discussing amendments to the 1994 ambient air quality guidelines suggests an annual threshold of 190 µg/m^3 and 950 µg/m^3 for toluene and total xylenes respectively (MfE, 2000). The United States EPA Reference Concentration for ethyl-benzene is 1000 µg/m^3 as an annual average. Concentrations of toluene, total xylenes and ethyl-benzene measured in Hamilton at all sites were significantly lower than the suggested MfE thresholds and USEPA Reference Concentration.

Table 3.1 **Annual average concentrations of volatile organic compounds (VOCs) at Hamilton sites between 18 December 2014 to 18 December 2016.**

VOC	Bridge St	Peachgrove Rd	Claudelands Rd	Peachgrove Intermediate	Greenwood St	Tristram St	Guideline[a]
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Benzene	1.24	1.25	1.21	0.65	2.23	0.97	3.6
Ethyl-benzene	5.01	3.94	5.01	2.39	13.39	5.16	1000[a]
Toluene	1.05	0.77	1.05	0.63	1.72	0.95	190[a]
Total Xylenes	4.59	3.60	4.61	2.37	7.47	3.90	950[a]

[a] There are currently no guideline values for ethyl-benzene, toluene and xylenes. Threshold values for toluene and total xylenes used here are from proposed amendments to the 1994 ambient air quality guidelines. For ethyl-benzene, the US EPA Reference Concentration has been used.

3.3 NO_2 monitoring in Hamilton

The results from NZTA's passive NO_2 monitoring programme for 2016 (Figure 3.9) indicate that the Lorne Street/Ohaupo Road site and Greenwood Road/Killarney Road site in Hamilton have some of the highest readings in New Zealand. Both sites have exceeded the World Health Organisation (WHO) annual guideline of 40 µg/m^3 for NO_2. A long term trend analysis of the annual averages indicates a worsening trend for the Cambridge Road/Morrinsville Road and the Avalon Drive/Grandview Drive sites but an improving trend for the Bridge Street/Anglesea Street site. A trend analysis of all other Hamilton sites indicates no statistically evident change.

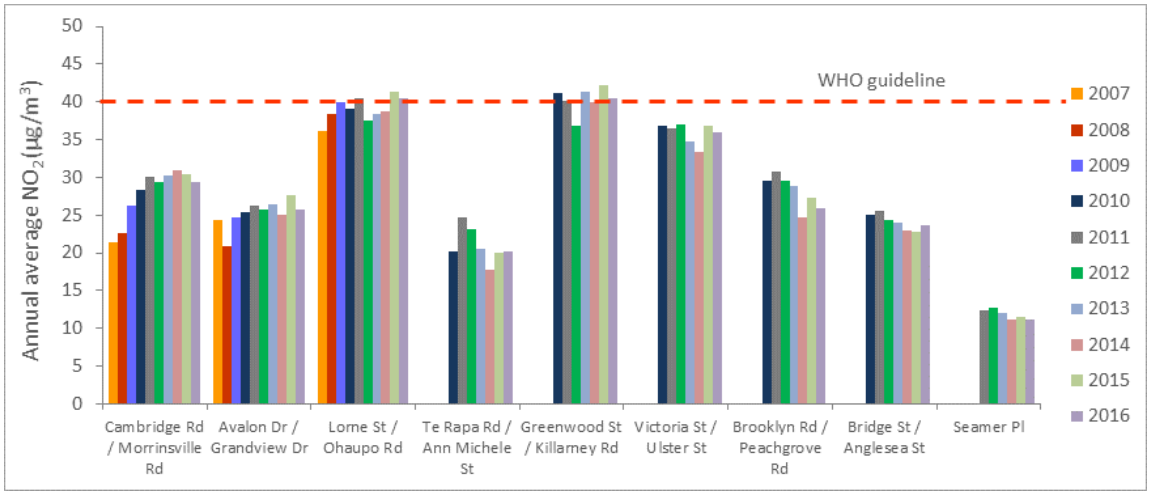

Figure 3.9 **Annual average NO_2 measured at Hamilton sites (2007 to 2016).**

3.4 PM_{10} and $PM_{2.5}$ monitoring in Tokoroa

Concentrations of PM_{10} in Tokoroa exceeded the PM_{10} standard of 50 µg/m^3 as a 24-hour average on five occasions during 2016 (Table 3.2). The maximum 24-hour average PM_{10} concentration measured was 60 µg/m^3 on 3 July 2016 and is the lowest maximum 24-hour average concentration recorded since 2013.

Table 3.2 **Dates and concentrations for exceedences of the PM_{10} standard of 50 µg/m^3 as a 24-hour average in Tokoroa during 2016.**

Date	PM_{10} µg/m^3	Rank
3 July	60 µg/m^3	1
4 July	56 µg/m^3	2
17 June	55 µg/m^3	3
2 July	54 µg/m^3	4
26 July	54 µg/m^3	5

During 2016 $PM_{2.5}$ concentrations in Tokoroa exceeded the World Health Organisation (WHO) guideline of 25 µg/m^3 (24-hour average) on 41 occasions. The maximum 24 hour average $PM_{2.5}$ concentration of 65 µg/m^3 was measured on 3 July 2016. This corresponded with the date of the maximum 24 hour average PM_{10} concentration. As $PM_{2.5}$ is a subset of PM_{10} the $PM_{2.5}$ concentration should typically be lower but some small discrepancies like this can occur when different instruments are being used to monitor the different particulate size fractions[3]. However, an evaluation of the relationship for winter 2016 (Figure 3.12) suggests $PM_{2.5}$ concentrations were consistently higher than PM_{10} when concentrations were elevated and caution is advised in using these data.

Daily PM_{10} and $PM_{2.5}$ concentrations measured at Tokoroa during 2016 are shown in Figures 3.10 and 3.11. Figure 3.12 shows the relationship between PM_{10} and $PM_{2.5}$ concentrations for Tokoroa for winter 2015 compared with winter 2016. A good correlation between $PM_{2.5}$ and PM_{10} is observed for both years (r^2=0.98 and r^2 = 0.92). However, the slope changes between 2015 and 2016 with the latter year consistently reporting higher $PM_{2.5}$ concentrations than PM_{10} when concentrations are elevated. The cause of the discrepancy in the relationship is unclear.

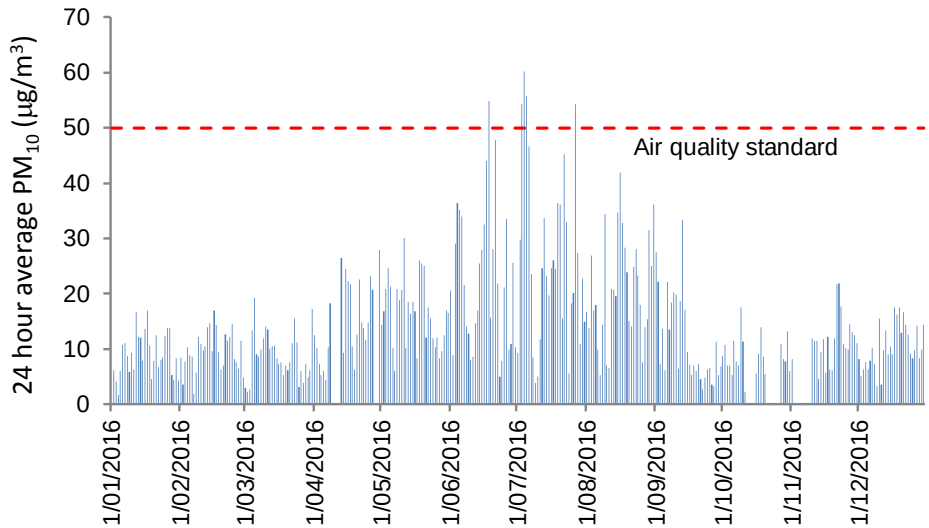

Figure 3.10 **24 hour average PM_{10} concentrations measured in Tokoroa during 2016.**

[3] A particulate monitoring instrument with a PM_{10} sampling head will collect particles 10 microns in size and smaller including particles 2.5 microns in size and smaller whereas an instrument with a $PM_{2.5}$ sampling head will only collect particles 2.5 microns in size and smaller. The BAM FH62 used for PM_{10} has relative humidity control on the sampler inlet compared to the BAM 5014i used for $PM_{2.5}$ at Tokoroa which has temperature control on the sampler inlet.

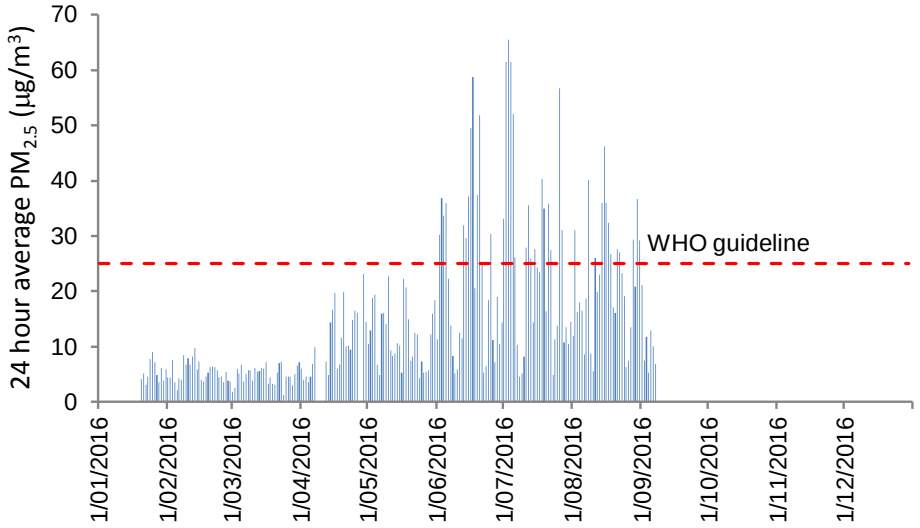

Figure 3.11 **24 hour average $PM_{2.5}$ concentrations measured in Tokoroa during 2016.**

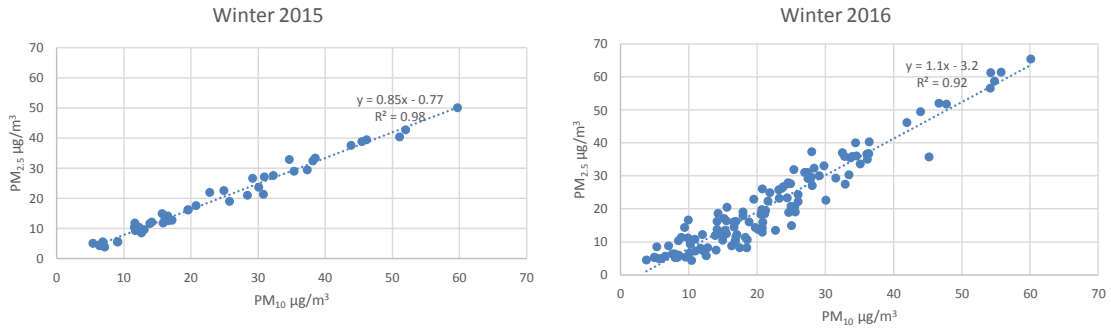

Figure 3.12 **Relationship between 24 hour average PM_{10} and $PM_{2.5}$ concentrations measured in Tokoroa for winter 2015 and winter 2016.**

Tokoroa PM_{10} concentrations from 2006 to 2016 are presented relative to air quality indicator categories in Figure 3.13. The proportion of concentrations within the "action" category was the lowest in 2016 at 1.5%. The typical range for previous years is between 3% and 6% of the daily averages.

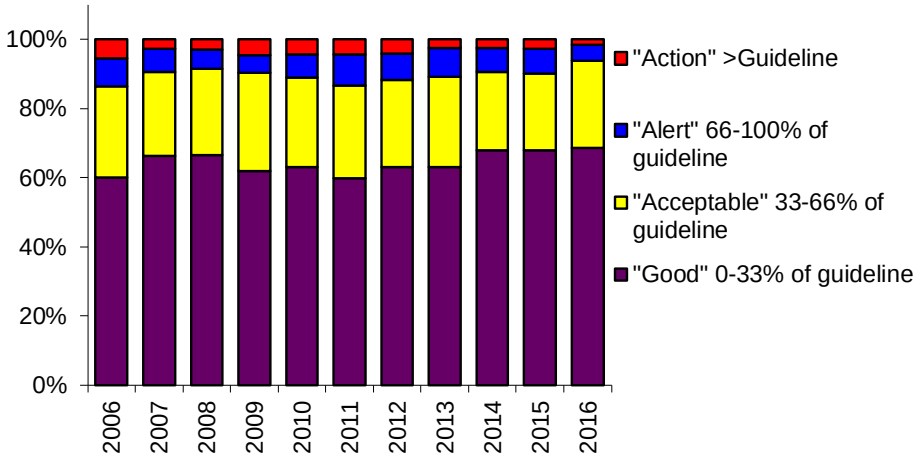

Figure 3.13 **Comparison of 24 hour average PM_{10} concentrations measured in Tokoroa from 2006 to 2016 to air quality indicator categories.**

Figure 3.14 shows the seasonal variations in the distribution of 24 hour average PM_{10} concentrations for each month relative to the air quality indicator categories. Worst PM_{10} concentrations are measured during the winter months when emissions from solid fuel burning coincides with meteorological conditions conducive to elevated concentrations.

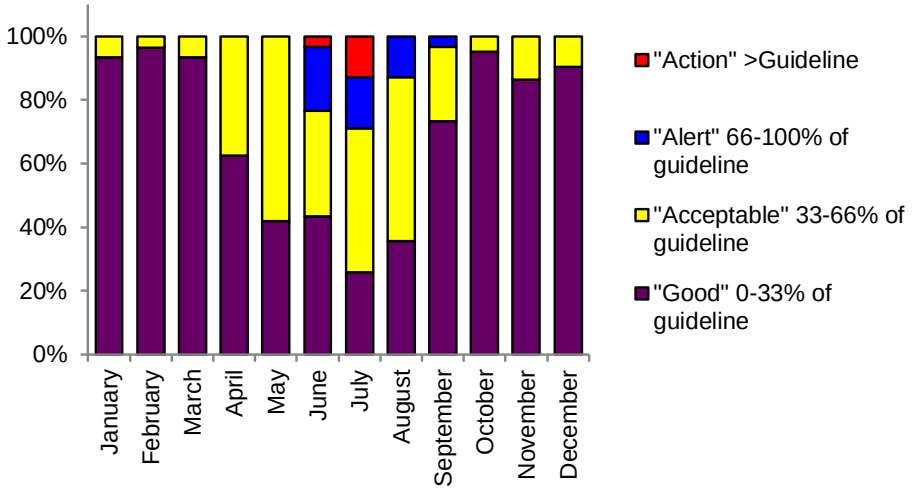

Figure 3.14 Comparison of 24 hour average PM_{10} concentrations each month during 2016 to air quality indicator categories.

The number of days when the PM_{10} standard of 50 µg/m^3 as a 24 hour average was exceeded, the maximum 24 hour average concentration and the 2nd highest 24 hour average concentration over the period 2006 to 2016 is shown in Figure 3.15. The NES compliance targets for Tokoroa are no more than three exceedances after 1 September 2016 and no more than one exceedance after 1 September 2020. It is unlikely that either target would be met in the absence of additional air quality management measures.

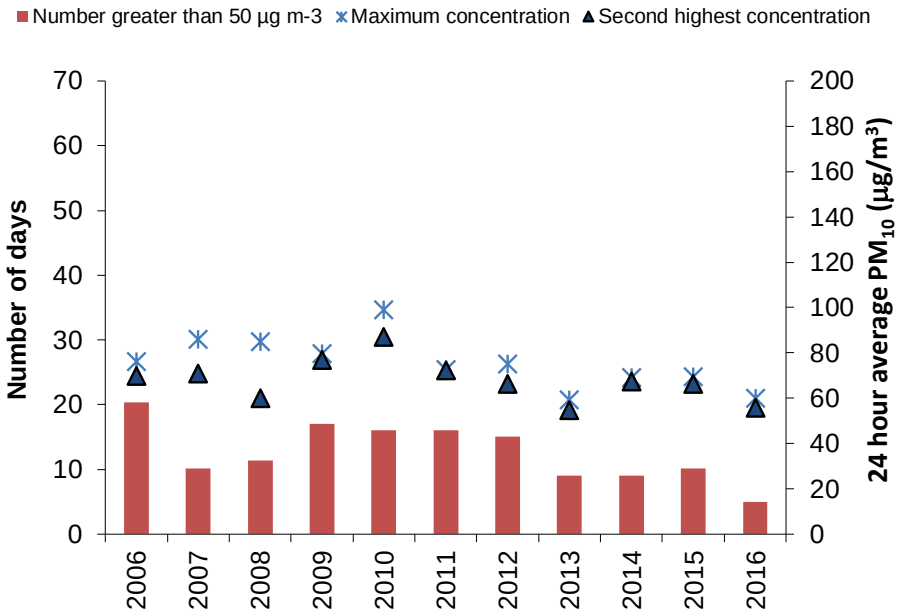

Figure 3.15 Number of days (left axis) when when the PM_{10} standard of 50 µg/m^3 as a 24 hour average was exceeded compared with the maximum 24 hour average concentration and the 2nd highest 24 hour average concentration (right axis) measured from 2006 to 2016.

The annual average PM_{10} concentration for Tokoroa for 2016 was 14.5 µg/m^3 and is slightly lower than annual average concentrations recorded at the site since 2006 (range 15.8 to 18.8 µg/m^3). The Ministry for the Environment specifies an annual average guideline for PM_{10} of 20 µg/m^3 (MfE, 2002). The annual average $PM_{2.5}$ concentration for the year from 1 September 2015 to 30 August 2016 was 12 µg/m^3. This is higher than the WHO guidelines for annual average $PM_{2.5}$ of 10 µg/m^3. Refer to Appendix 2 for a full summary of PM_{10} monitoring statistics for Tokoroa for the period 2006 to 2016.

A wind rose for 2016 showing the relative frequency and speed of winds from different directions for 2016, as measured at the Tokoroa station, is provided in Figure 3.16. The wind rose indicates two distinct prevailing wind directions, one from the west-northwest and another from the southeast with a high frequency of low to moderate windspeeds.

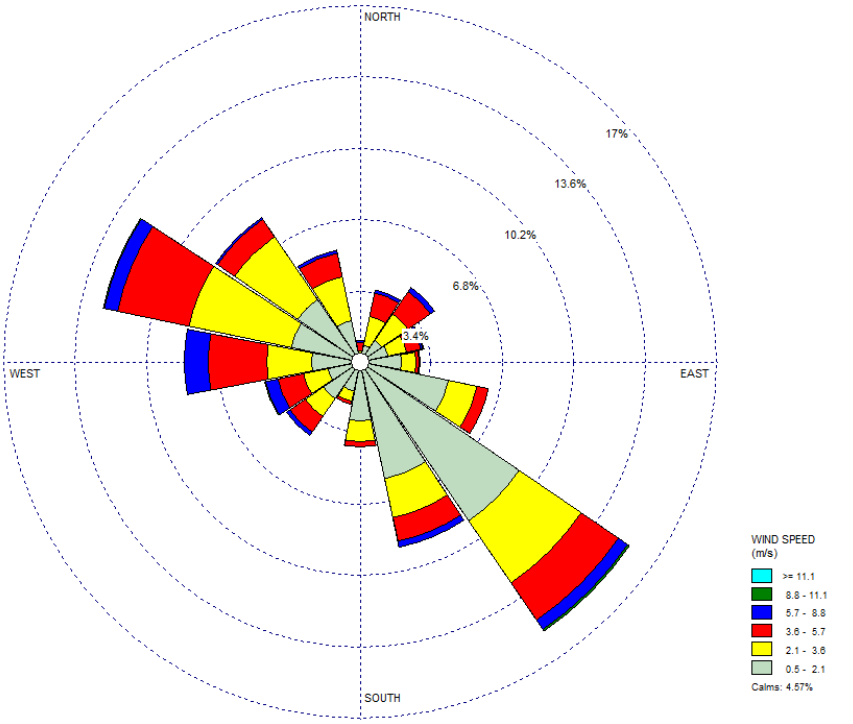

Figure 3.16 Windrose of wind direction and windspeed data as measured at the Tokoroa station in 2016.

Summary statistics for wind speed and temperature from 2006 to 2016 are shown in Figure 3.17. Data suggest wind speeds for 2016 were similar to 2014 and 2015, slightly higher than the period from 2010 to 2013 and similar to pre-2010. Air temperature during 2016 was highest for all indicators examined for the 10 year period.

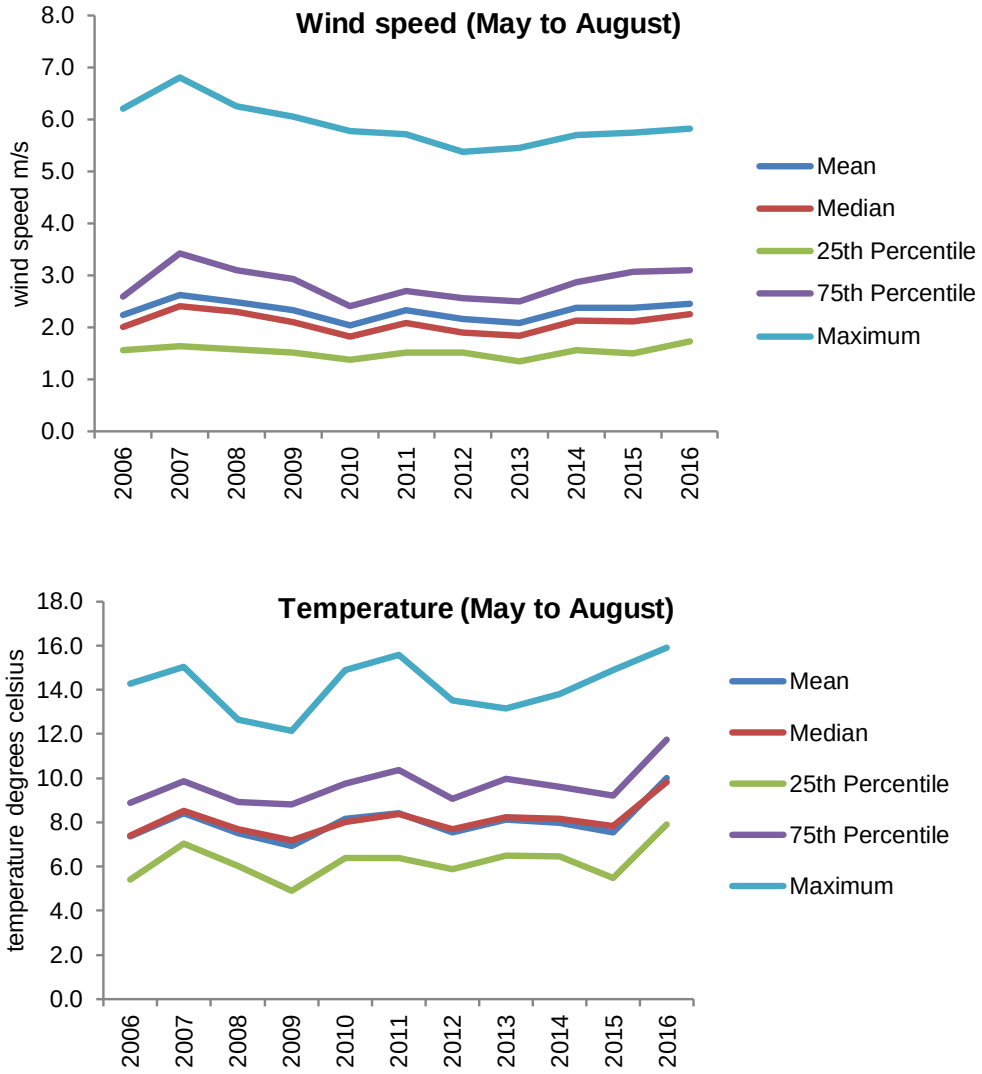

Figure 3.17 Summary wind speed and temperature data from 2006 to 2016 in Tokoroa.

Daily variations in meteorological conditions and hourly average PM_{10} and $PM_{2.5}$ concentrations on the five days when the 24 hour average PM_{10} concentrations exceeded 50 µg/m^3 during 2016 are shown in Figure 3.18. The daily variations in PM_{10} and $PM_{2.5}$ concentrations presented in Figure 3.18 are typical of small urban towns in New Zealand where domestic home heating is the main contributor to elevated PM_{10} concentrations. Meteorological conditions for Tokoroa include low wind speeds and air temperatures, a southeast wind direction during the evening/ overnight and morning and a west to northwest wind during the afternoon as indicated by the prevailing wind directions identified by the windrose in Figure 3.16.

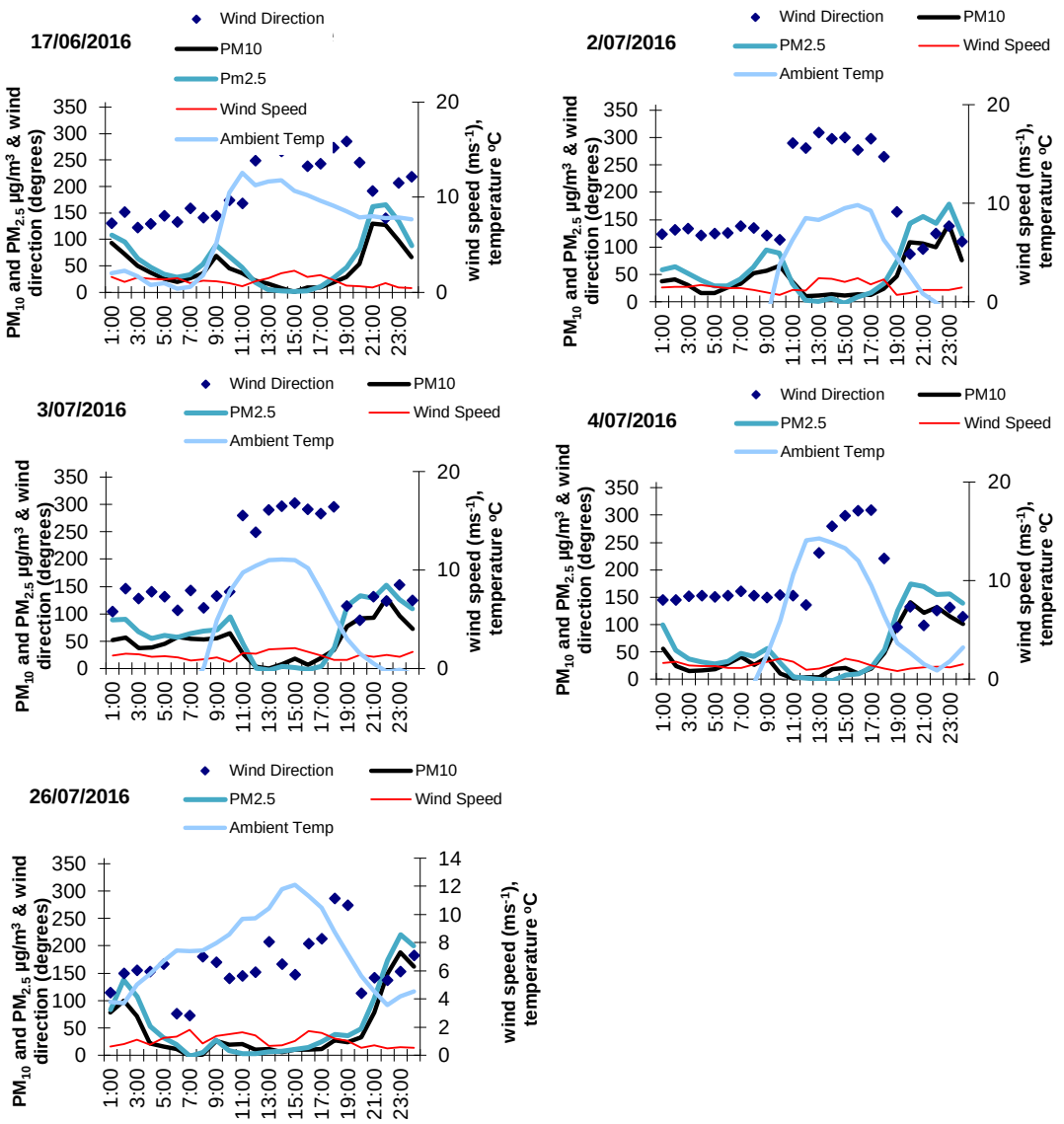

Figure 3.18 **Hourly average PM_{10}, $PM_{2.5}$, wind speed, wind direction and temperature on days when PM_{10} concentrations exceeded the NES in Tokoroa.**

The Seasonal Mann Kendall test results for Tokoroa with the inclusion of 2016 data indicate a significant reduction in PM_{10} concentrations for the period 2009 to 2016 (MK-Stat of -2.0 and a p-value of 0.04). For the period 2006 to 2016 the trend is not quite significant (MK-Stat of -1.9 and a p-value of 0.06) suggesting that more consistent reductions have occurred post 2009.

A 32% reduction in wintertime PM_{10} emissions was estimated to have occurred between 2012 and 2016 based on air emission inventory information (Wilton, 2016). The majority of emission reductions were as a result of reductions in emissions from domestic home heating (mainly woodburners and open fires).

Additional analysis has also been undertaken using methodologies which account for the impacts of varying meteorology in Tokoroa (Wilton, 2013a). Meteorological conditions conducive to high pollution in Tokoroa include days which have both low wind speeds and low temperatures over a specific period of the day, namely:

- Days with more than 15 hours when the hourly average wind speed was less than 2 metres per second; and
- Days where the average temperature from 8 pm to midnight is less than 5.36 degrees Celsius.

In summary, if these criteria are met then these are the days you would expect most exceedances to occur. Figure 3.19 provides a summary of the year-to-year variation of the proportion of high pollution potential days which resulted in exceedances in Tokoroa. Figure 3.20 provides a summary of the year-to-year variation of the absolute number of high pollution potential days compared with the number of exceedance days. It shows that 2016 recorded the lowest number of days qualifying as high pollution potential.

If PM_{10} concentrations were decreasing, a consistent reduction in the proportion of high pollution potential days that resulted in breaches would be evident. Between 2006 and 2012 breaches occurred on 39-70% of days when meteorological conditions conducive to elevated PM_{10} occurred. From 2013-2016 the proportion ranges from 20-36% but with an indication that the proportion of days with a breach has been increasing rather than decreasing. The reason for this is unclear.

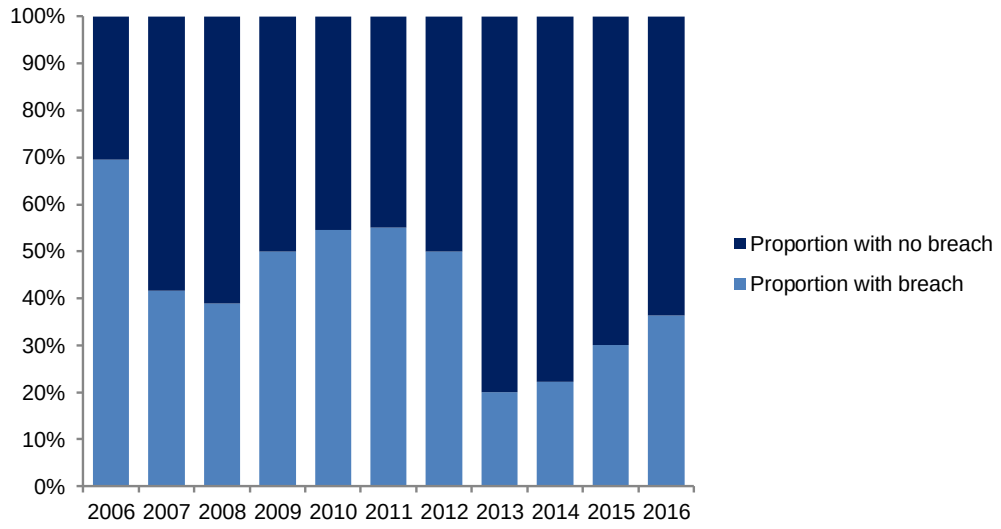

Figure 3.19 **Year-to-year variation of the proportion of high pollution potential days which resulted in exceedances.**

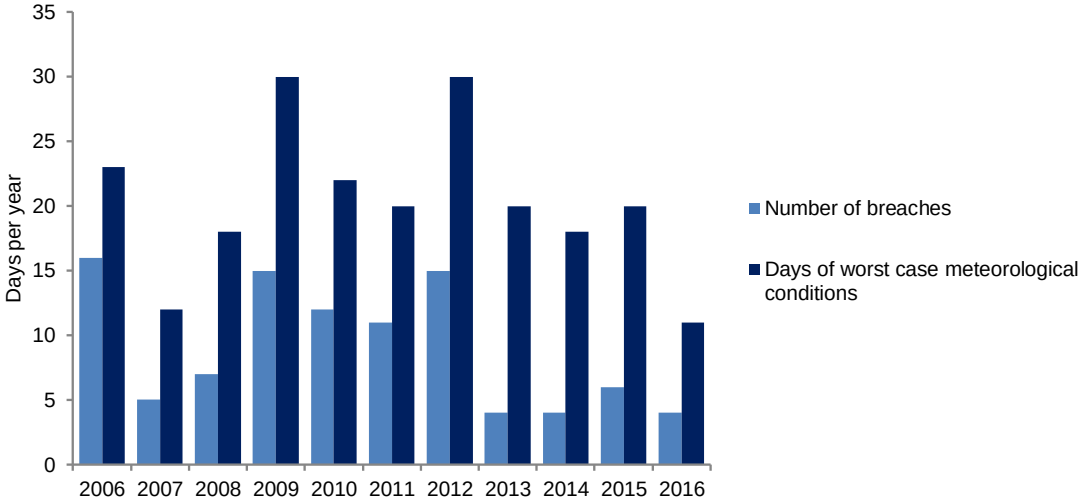

Figure 3.20 **Year-to-year variation of the absolute number of high pollution potential days compared with the total number of exceedance days.**

Wilton (2013) outlines a method for adjusting PM_{10} concentrations for some of the impact of meteorological conditions. Figure 3.21 shows the normalised PM_{10} concentrations for Tokoroa

using that method to minimise the impact of meteorology. Concentrations of PM_{10} appear to have reduced since around 2013. However, when considering the data adjusted for the impact of meteorology, reductions for 2016 appear less significant and the evaluation suggest that some of the improved results for 2016 occur as a result of meteorological conditions being less favourable to high pollution episodes.

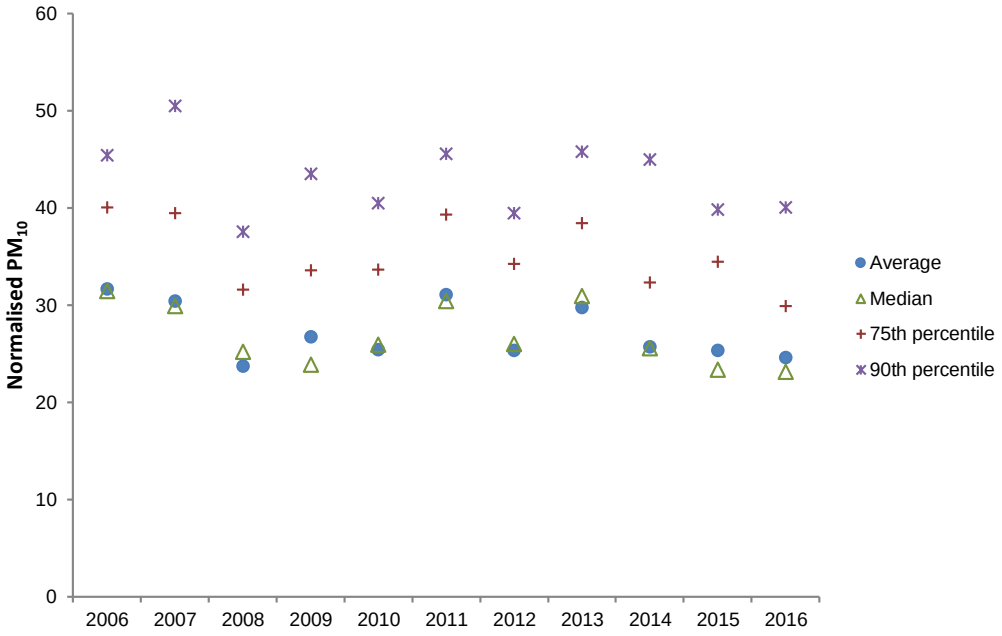

Figure 3.21 **Average, 75th percentile, 90th percentile and median PM_{10} concentrations for the days when the impacts of meteorological variability have been minimised.**

Another way of comparing changes in air quality over time is to compare the five year exceedance average from year to year (Figure 3.22). The use of a five year average removes some of the impact of the year to year variability in meteorological conditions whilst targeting the indicator of most concern, the number of exceedences of the 24 hour average PM_{10} standard of 50 µg/m^3. Figure 3.22 provides some indication of a reduction in exceedences at Tokoroa with a consistent decrease in the five year rolling average exceedences from 2008-2012 (15 days) to 2012-2016 (9.6 days), noting that some of the reduction observed between the last two data points (11.8 and 9.6) likely occurs as a result of favourable meteorological conditions during 2016.

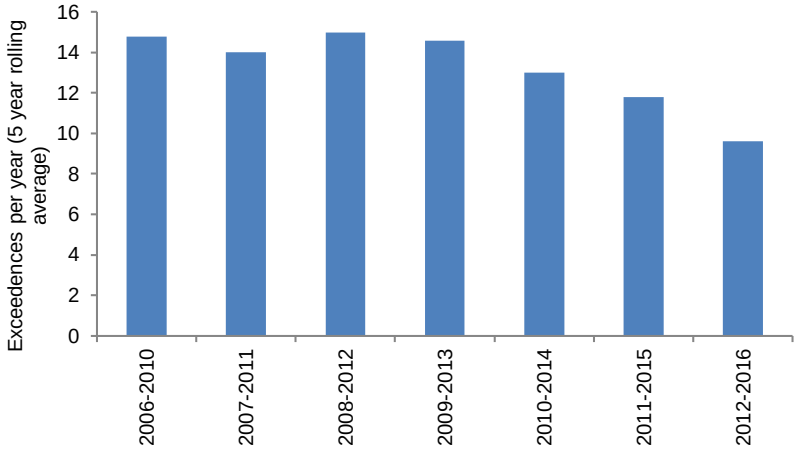

Figure 3.22 **Comparison of the five-year exceedance averages for the period 2006 to 2016.**

It is clear from the data that despite reductions in PM_{10} concentrations in Tokoroa in recent years the interim NES target of no more than three exceedances by September 2016 will not be met and significant intervention would be required to meet the September 2020 target of no more than one exceedence per year. It has been estimated that an emission reduction of around 24% of 2007 emission levels is required to meet the 2016 target and around 43% to meet the 2020 target (Wilton, 2011).

3.5 NO_2 monitoring in Tokoroa

The results from a six month passive NO_2 monitoring survey at the intersection of Bridge Street and Leith Place and the intersection of State Highway 1 and Swanston Street in Tokoroa for 2016 (refer to Figure 3.23) indicates that the average concentrations for that period were well below the WHO annual average guideline of 40 µg/m^3.

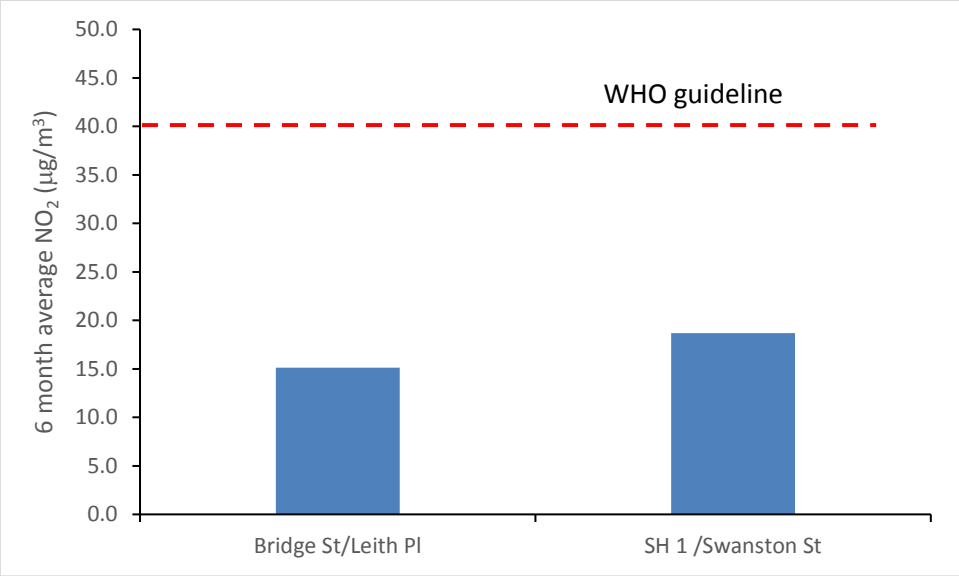

Figure 3.23 Six month average NO_2 concentrations measured in Tokoroa during 2016.

3.6 PM_{10} monitoring in Taupo

There were no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 for 2016. The maximum 24 hour average concentration was 50 µg/m^3 and was measured on 7 June 2016. The last breach of the NES at this site was 2013 when two exceedances of the 24 hour average standard (65 µg/m^3 and 62 µg/m^3) were measured. The years 2011 and 2012 were both compliant with the NES with only one exceedance of the 24 hour average standard occurring in each year. Figure 3.24 shows the 24 hour average concentrations of PM_{10} for 2016 compared to the NES value of 50 µg/m^3.

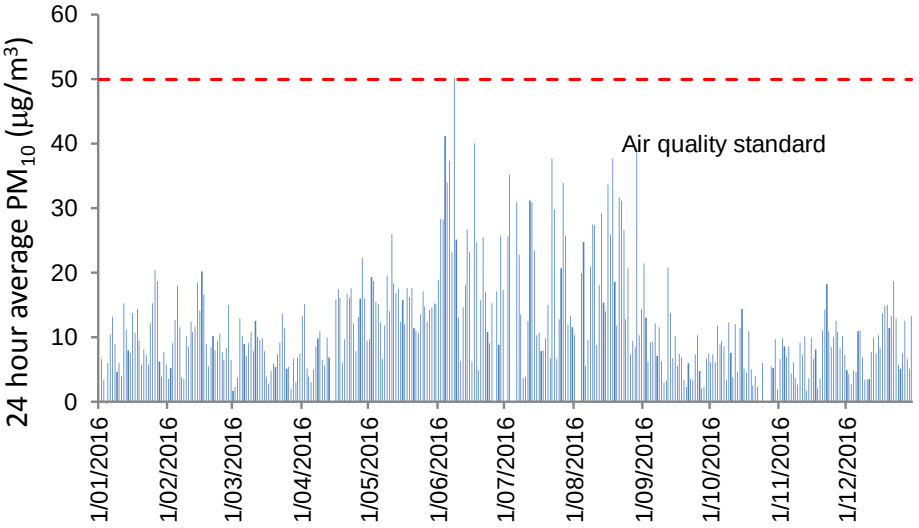

Figure 3.24 **24 hour average PM_{10} concentrations measured at Taupo during 2016.**

Figure 3.25 shows the changes in 24 hour average PM_{10} concentrations relative to air quality indicator categories at the Taupo site from 2006 to 2016. Data are adjusted for gravimetric equivalency only since 2007 so comparison of trends with pre 2006 data are limited[4]. There has been a gradual increase in the proportion of PM_{10} concentrations in the 'good' category since 2007.

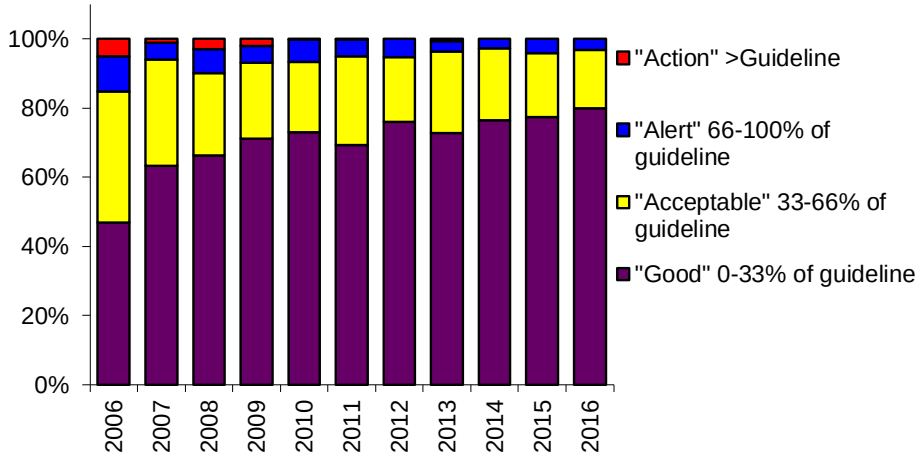

Figure 3.25 **Comparison of 24 hour average PM_{10} concentrations measured at the Taupo site from 2006 to 2016 to air quality indicator categories.**

Figure 3.26 shows the number of days when the 24 hour average PM_{10} standard of 50 µg/m^3 was exceeded, the maximum concentration and the 2nd highest concentration for 2006 to 2016. Data suggests improvements in PM_{10} concentrations particularly between the years 2006 and 2011. Data suggests a high likelihood of ongoing compliance with the NES for PM_{10} if meteorological conditions similar to 2014-2016 prevail.

[4] For 2006 the gravimetric partisol data from Gillies Ave were used in preference to the BAM primary school data.

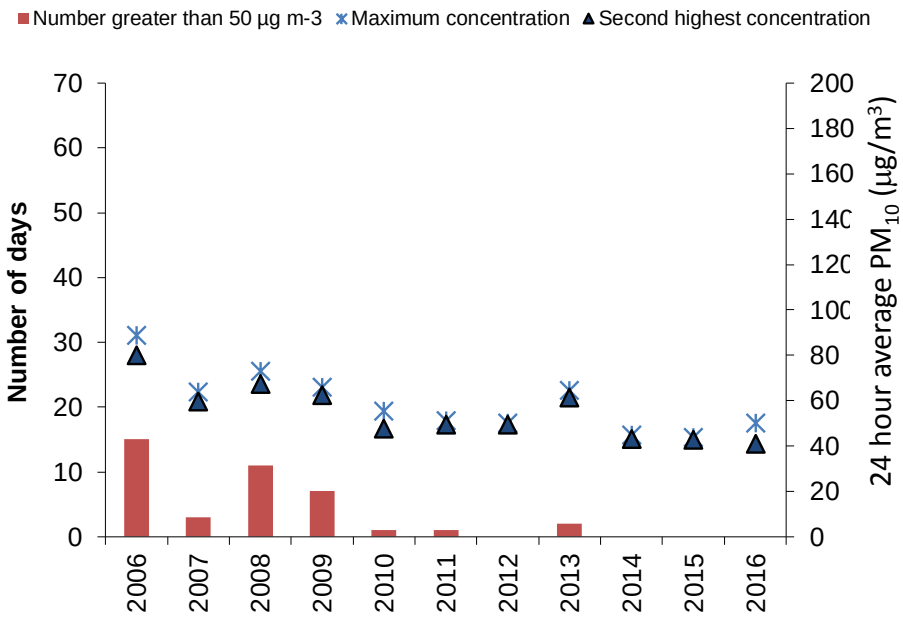

Figure 3.26 **Number of days (left axis) when the 24 hour average standard of 50 µg/m³ was exceeded compared with the maximum concentration and the 2nd highest concentration (right axis) measured from 2006 to 2016.**

The annual average PM_{10} concentration for Taupo for 2016 was 11.9 µg/m³ and is the lowest annual average concentration recorded. Figure 3.27 shows a decreasing trend in annual average PM_{10} concentrations. Refer to Appendix 3 for a full summary of PM_{10} monitoring statistics for Taupo for the period 2001 to 2016.

Figure 3.27 **Comparison of annual averages measured at the Taupo site from 2006 to 2016.**

A wind rose for 2016 showing the relative frequency and speed of winds from different directions for 2016, as measured at the Taupo station, is provided in Figure 3.28. The wind rose indicates one distinct prevailing wind direction from the northeast and a second broader wind direction spanning the northwest to southwest quadrant. The windrose for Taupo also indicates a high frequency of low windspeeds (0.5 to 2.1 m/s) compared to windroses for Tokoroa and Hamilton.

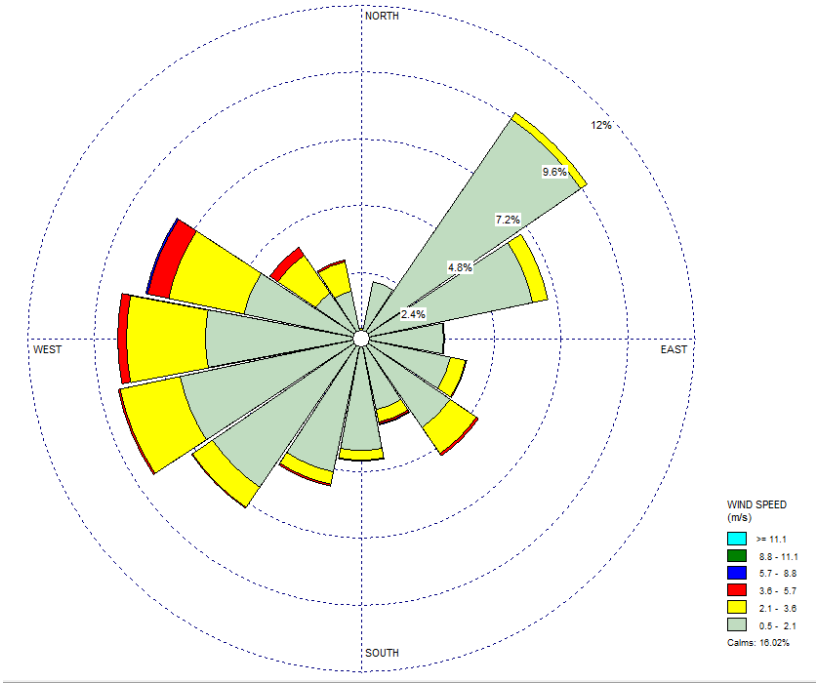

Figure 3.28 **Windrose of wind direction and windspeed data as measured at the Taupo station in 2016.**

The highest 24 hour average PM_{10} concentration during 2016 was recorded on 7 June. Figure 3.29 shows variations in PM_{10} concentrations and meteorological data on this day. This shows a small morning peak in PM_{10} concentrations around 8am and an increase in PM_{10} concentrations around 5pm with elevated concentrations for the duration of the evening. The variations are typical of those in small urban areas of New Zealand where emissions from solid fuel burning for domestic heating the dominant source of PM_{10}.

In Taupo, high PM_{10} concentrations typically occur when the wind is from an easterly or south easterly direction and wind speeds are low. During the daytime the wind shifts to westerly, returning to east/south east during the evening (Wilton & Baynes, 2010). Meteorological conditions on 7 June were reasonably consistent with these conditions. The daytime shift to westerly appears only for a short duration but otherwise match these described conditions very well.

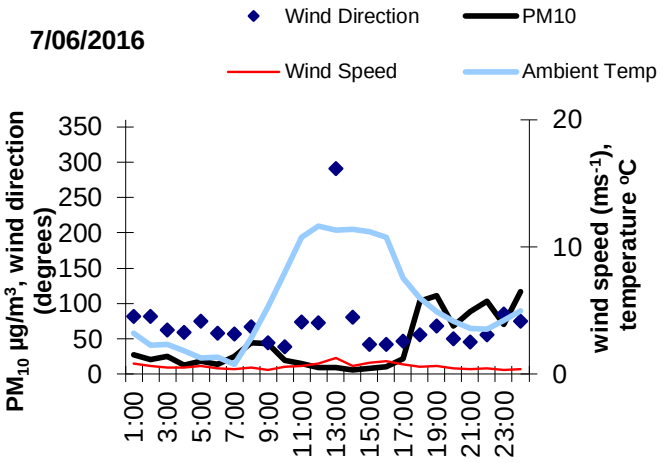

Figure 3.29 **Hourly average PM_{10}, wind speed, wind direction and temperature on the 7 June when the highest 24-hour average PM_{10} concentration of 50 µg/m^3 was recorded at Taupo.**

Seasonal Mann Kendall test results (MK-Stat of -2.4 and p-value of 0.01) provides evidence that PM_{10} concentrations in Taupo have been decreasing over the period 2006 to 2016.

A 23% reduction in wintertime PM_{10} emissions was estimated to have occurred between 2009 and 2014 based on air emission inventory information (Wilton, 2015a). The majority of emission reductions were as a result of reductions in emissions from domestic home heating (mainly woodburners and open fires).

Meteorological conditions conducive to high pollution in Taupo include days which have both low wind speeds and low temperatures over a specific period of the day (Wilton 2013), namely:

- Days with more than 16 hours when the hourly average wind speed was less than 1 metres per second; and
- Days where the average temperature between 5 pm to midnight is less than 7.7 degrees Celsius.

In summary, if both criteria are met then these are the days you would expect exceedances to occur. Figure 3.30 provides a summary of the year-to-year variation of the proportion of high pollution potential days which resulted in exceedances in Taupo. This suggests a decrease in the proportion of high pollution potential days that resulted in exceedences of the 24 hour average standard of 50 $\mu g/m^3$, with around 20% of high pollution potential days having exceedences between 2007 and 2009 compared with 0% from 2014-2016.

Figure 3.31 provides a summary of the year-to-year variation of the absolute number of high pollution potential days compared with the number of exceedance days. This shows that for 2016 there were more high pollution potential days than for 2013, 2011 and 2007, all of which experienced in exceedences of the NES. This is a strong indicator that PM_{10} concentrations have reduced in Taupo.

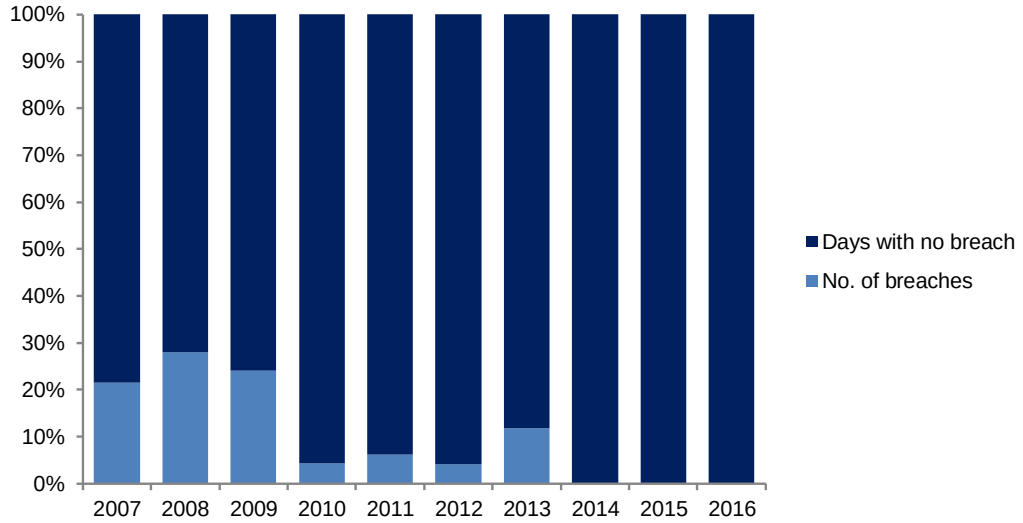

Figure 3.30 **Year-to-year variation in the proportion of high potential pollution days which resulted in exceedances.**

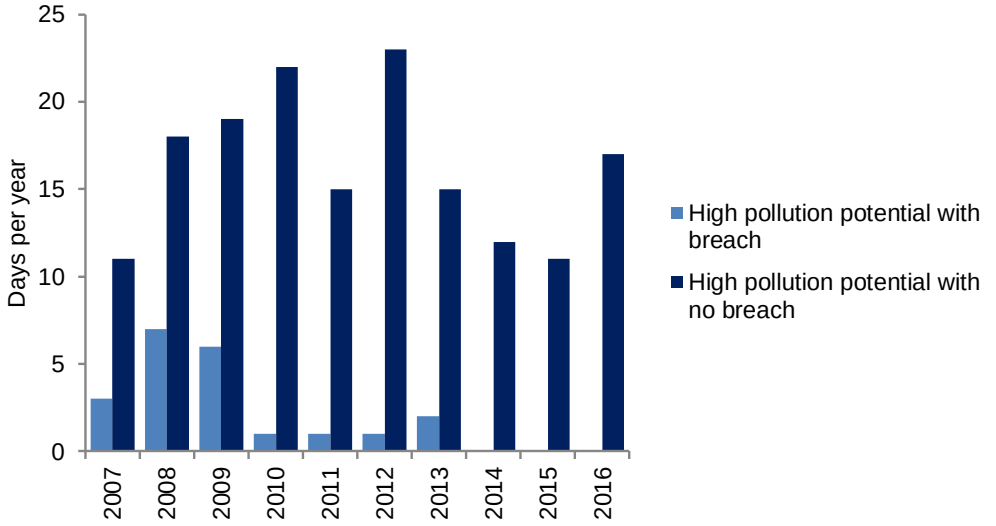

Figure 3.31 **Year-to-year variation in the absolute number of high pollution potential days compared with the total number of exceedance days.**

Wilton (2013) outlines a method for adjusting PM_{10} concentrations for some of the impact of meteorological conditions. Figure 3.32 shows the normalised PM_{10} concentrations for Taupo using that method to minimise the impact of meteorology. Data for 2016 are supportive of an ongoing downward trend in PM_{10} concentrations in Taupo.

Management measures to further reduce PM_{10} by around 20% were recommended in 2014 for on-going NES compliance (Wilton, 2014). Figure 3.32 suggests a portion of this required reduction may already have occurred in the absence of additional management measures.

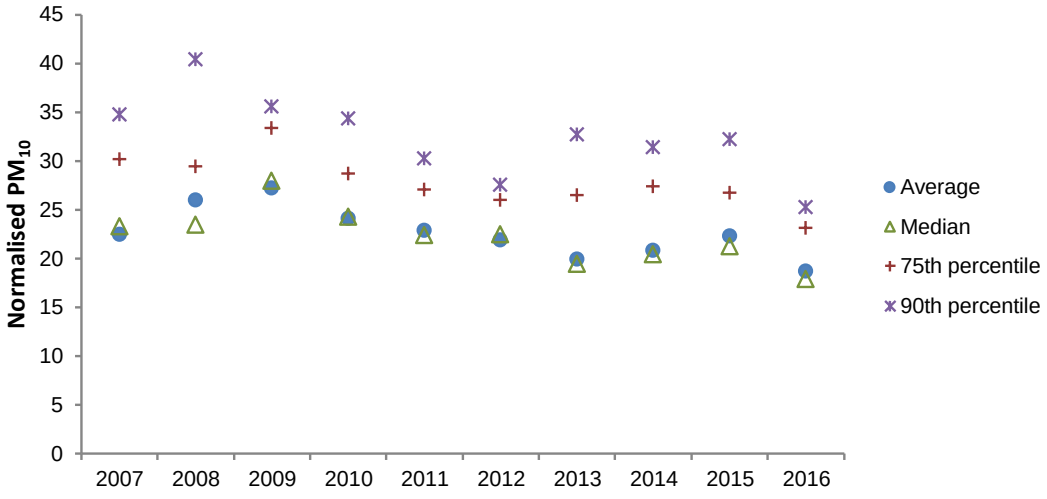

Figure 3.32 **Average, 75th percentile, 90th percentile and median of the 24 hour average PM_{10} concentrations for the days when the impacts of meteorological variability have been minimised.**

The 5 year average of exceedances per year from 2006 to 2016 is shown in Figure 3.33. Comparing averages over many years is another way of reducing some of the impact of year to year variability in meteorological conditions. There has been a consistent downwards trend in the 5 year exceedance average over the period 2006 to 2016.

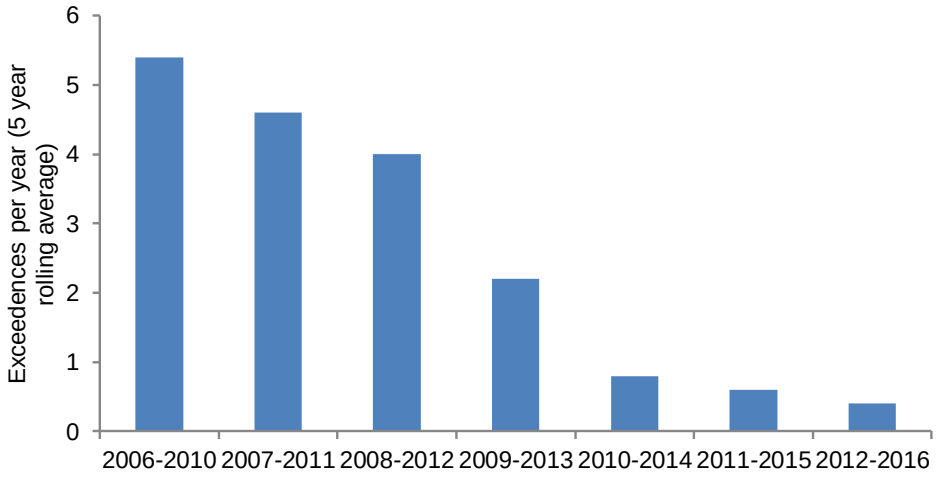

Figure 3.33 Comparison of the five year exceedance averages for the period 2006 to 2016.

Based on these analyses and the current previous five year exceedance average of less than 1, it is likely that Taupo will meet the NES 2016 target of no more than one exceedance per 12 month period. But this will still be dependent on meteorological conditions i.e. a particularly cold and calm winter could still result in more than one exceedance with in a 12 month period. Further reductions in emissions would provide a "safeguard" against future impacts of changes in meteorology.

3.7 NO_2 monitoring in Taupo

The results from NZTA's passive NO_2 monitoring programme for 2016 (refer to Figure 3.34) indicates that the annual average NO_2 concentration continues to remain well below the WHO annual average guideline of 40 μg/m^3. A long term trend analysis of the annual averages for the the Taupo site at the intersection of Tongariro Street and Norman Smith Street indicates no statistically evident change.

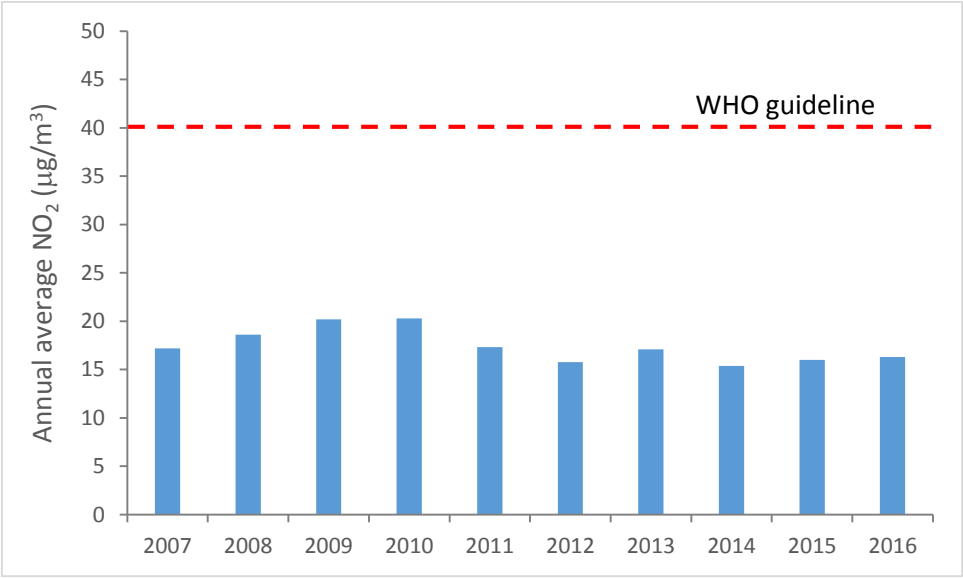

Figure 3.34 Annual average NO_2 concentrations measured in Taupo (2007 to 2016).

3.8 PM_{10} monitoring in Te Kuiti

There were no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 for 2016. Figure 3.35 shows 24 hour average PM_{10} concentrations measured in Te Kuiti during 2016. The maximum measured 24 hour average PM_{10} concentration was 41 µg/m^3. No exceedances have been recorded in Te Kuiti since 2012 when one exceedance of 50 µg/m^3 (61 µg/m^3) occurred. The airshed has now been fully compliant with the NES for five years and is no longer classified as "polluted" under the NES.

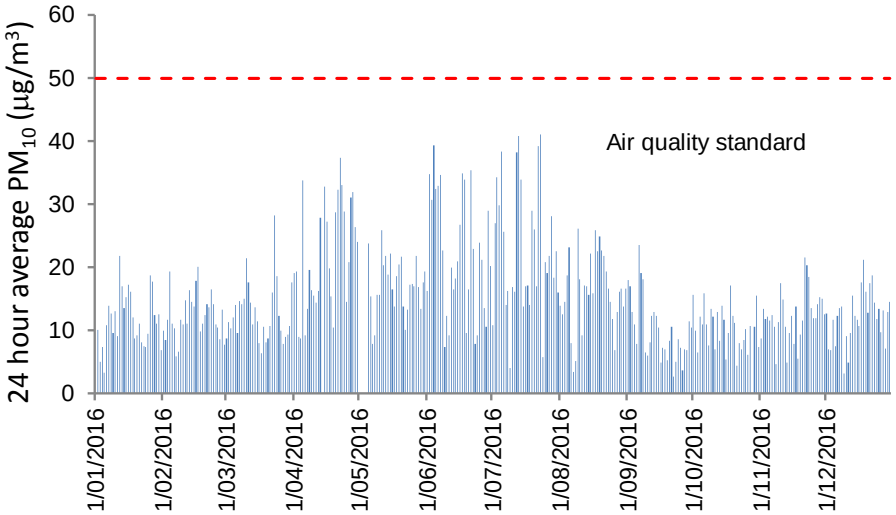

Figure 3.35 24 hour average PM_{10} concentrations measured in Te Kuiti during 2016.

Figure 3.36 shows variations in the 24 hour average PM_{10} concentrations relative to air quality indicator categories in Te Kuiti from 2006 to 2016. A gradual increase in the proportion of PM_{10} concentrations in the 'good' category and decreases in the proportion of concentrations in the "action" and "alert" categories are an illustration of improvements in air quality in Te Kuiti.

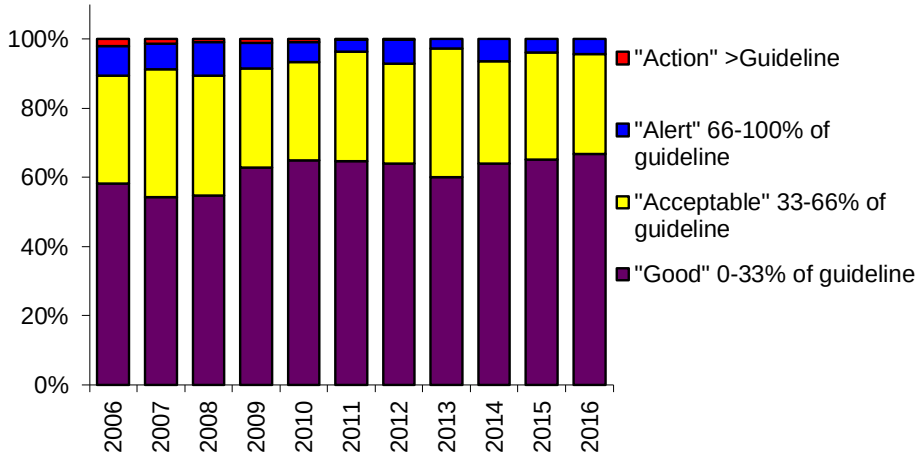

Figure 3.36 Comparison of 24 hour average PM_{10} concentrations measured at the Te Kuiti site from 2006 to 2016 relative to air quality indicator categories.

The number of days when the 24 hour average PM_{10} standard of 50 µg/m^3 was exceeded, the maximum concentration and the 2nd highest concentration from 2006 to 2016 are shown in Figure 3.37. Data is indicative of improvements in PM_{10} concentrations since 2006.

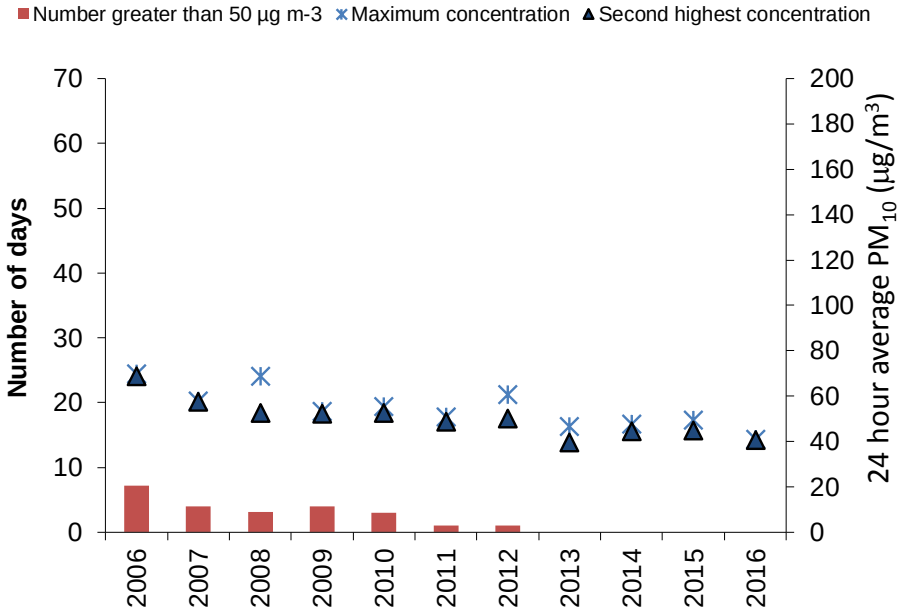

Figure 3.37 **Number of days (left axis) when the 24 hour average PM_{10} standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd Highest concentration (right axis) measured from 2006 to 2016.**

The annual average PM_{10} concentration for 2016 was 15.2 µg/m^3. This is consistent with the last four to five years and lower than the typical average of approximately 18 µg/m^3 prior to 2009. The Ministry for the Environment specifies an annual average guideline for PM_{10} of 20 µg/m^3 (MfE, 2002). Refer to Appendix 4 for a full summary of PM_{10} monitoring statistics for Te Kuiti for the period 2003 to 2016.

A wind rose for 2016 showing the relative frequency and speed of winds from different directions for 2016, as measured at the Te Kuiti station, is provided in Figure 3.38. The wind rose indicates one distinct prevailing wind direction from the northeast and a second broader wind direction spanning the northwest to southwest quadrant, similar to that indicated for Taupo. The windrose for Te Kuiti also indicates a high frequency of low to moderate windspeeds, with a lower frequency of higher windspeeds than Hamilton and Tokoroa but a higher frequency of higher windspeeds than Taupo.

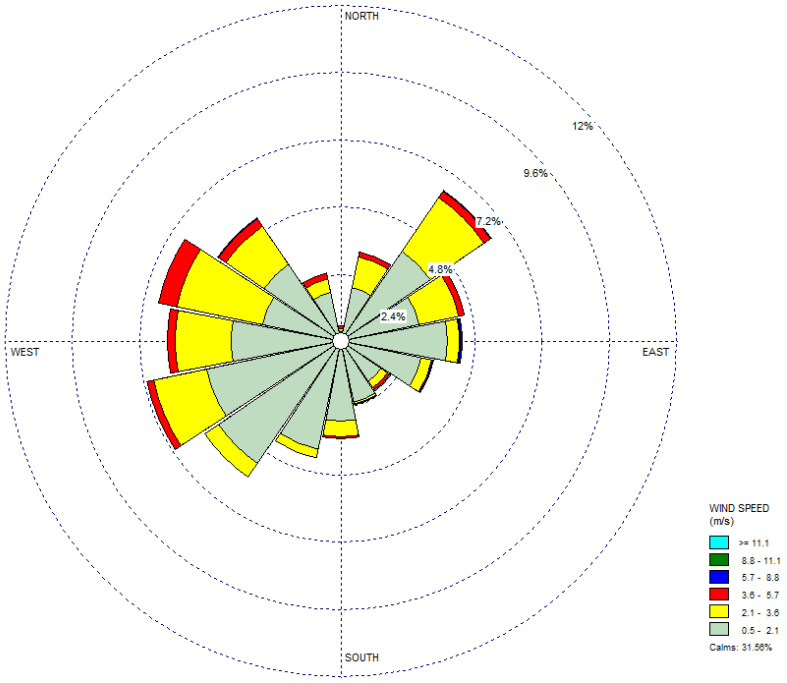

Figure 3.38 **Windrose of wind direction and windspeed data as measured at the Te Kuiti station in 2016.**

Hourly variations in PM_{10} concentrations and meteorological variables on 12 and 22 July when the maximum 24 hour average PM_{10} concentrations of 41 µg/m^3 were measured are shown in Figure 3.39. On 12 July the hourly PM_{10} profile is fairly typical of an urban PM_{10} pollution event with an elevated broad peak extending from the previous night and slowly reducing over the early hours of the morning followed by a peak in concentrations around 9 am, a drop off to around zero during the middle of the day and then a gradual increase again from about 5 pm. On the 22 July concentrations decrease after the previous night but remain slightly elevated during the afternoon and increase only slightly during the evening.

Morning temperatures of around zero degrees were experienced on 12 July indicating likely temperature inversions. The wind speed was low throughout the day on both days and temperatures peaked at between 10 and 15 degrees in the early afternoon.

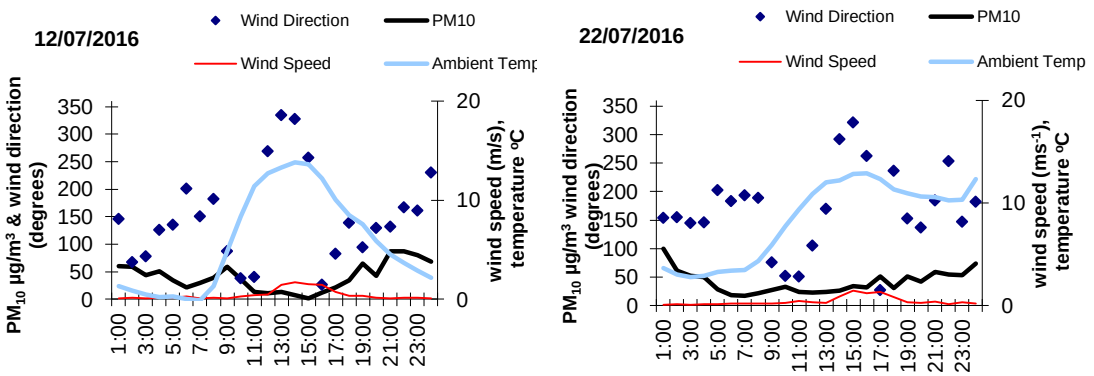

Figure 3.39 **Hourly average PM_{10}, wind speed, wind direction, and temperature on 12 and 22 July when the maximum 24 hour average PM_{10} concentrations of 41 µg/m^3 were recorded at Te Kuiti.**

Seasonal Mann Kendall test results (MK-Stat of -3.0 and p-value of 0.003) provides strong evidence that PM_{10} concentrations in Te Kuiti have been decreasing over the period 2005 to 2016.

Another indicator of trends over time is the 5 year exceedance average (Figure 3.40) as averaging over a longer time period will remove some of the variation that occurs from year to year. A consistent downwards trend in the 5 year exceedance average over the period 2006 to 2016 is apparent.

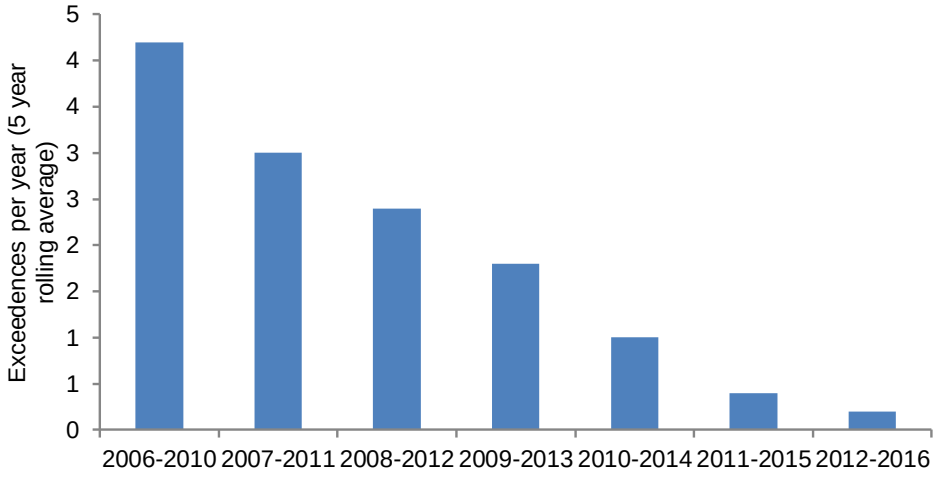

Figure 3.40 Comparison of the five year exceedance averages for the period 2006 to 2016.

On a calendar year basis, Te Kuiti has had no more than one exceedance per year since 2011. However, two exceedances occurred in Te Kuiti over a 12 month period that straddled the period 2011 to 2012. The first exceedance of the breach occurred on 9 December 2011 and the second exceedance occurred on 2 July 2012.

An airshed ceases to be polluted when the PM_{10} standard has not been breached in the airshed for five years. That is only one exceedance of the 24 hour average within any 12-month period during that five years. Therefore, the compliance period for Te Kuiti starts from 10 December 2011, the day after the first exceedance of the breach that occurred between 2011 and 2012. Because no exceedences of the 24 hour average standard of 50 $\mu g/m^3$ occurred during 2016 as of 11 December 2016 the Te Kuiti airshed qualifies as a non-polluted airshed.

An air emission inventory undertaken in Te Kuiti in 2015 indicates that there has been a 14% reduction in PM_{10} emissions since 2007 as a result of reductions in both domestic heating and industrial emissions (Wilton 2015b). While it appears emissions have reduced sufficient that further breaches may seem unlikely, it is possible that the NES for PM_{10} could still be breached in the airshed if particularly conducive meteorological conditions were experienced.

3.9 PM_{10} monitoring in Putaruru

There were no exceedances of the 24 hour average PM_{10} standard of 50 $\mu g/m^3$ for 2016. Figure 3.41 shows 24 hour average PM_{10} concentrations measured in Putaruru during 2016. The maximum measured 24 hour average PM_{10} concentration was 43 $\mu g/m^3$ on 5 July. This result is similar to 2015 when no exceedences of 50 $\mu g/m^3$ were recorded. During 2014 two exceedances of the 24 hour average standard of 50 $\mu g/m^3$ were recorded but occurred outside of the typical wintertime season (March/ early April) and had hourly profiles inconsistent with the typical

diurnal pattern indicative of a home heating source. Prior to 2014 the previous NES breach occurred in 2009 when three exceedences of the 24 hour average PM_{10} standard occurred.

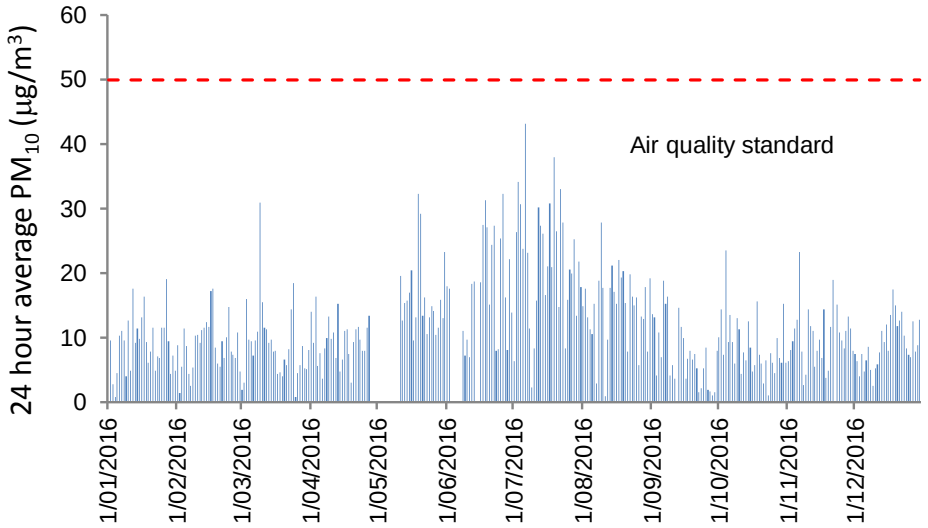

Figure 3.41 24 hour average PM_{10} concentrations measured at the Putaruru site during 2016.

Figure 3.42 compares variations in the 24 hour average PM_{10} concentrations relative to air quality indicator categories in Putaruru from 2006 to 2016. Data for 2016 indicates an improvement from previous years with less than 20% of concentrations being higher than a 24 hour average concentration of 16.5 µg/m^3 (33% of the NES standard).

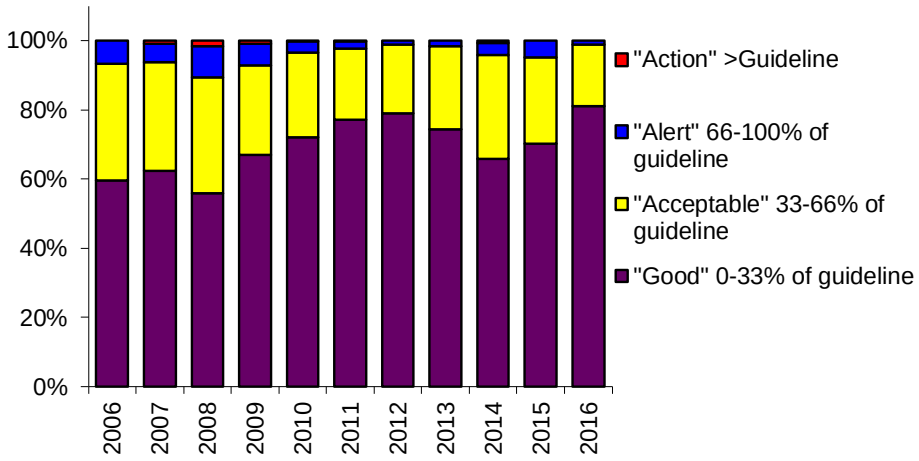

Figure 3.42 Comparison of 24 hour average PM_{10} concentrations measured at the Putaruru site from 2006 to 2016 relative to air quality indicator categories.

Figure 3.43 shows the number of days when the 24 hour average PM_{10} standard of 50 µg/m^3 was exceeded, the maximum concentration and the 2nd highest concentration from 2007 to 2016. The 2006 data has been excluded from the comparison as monitoring only began half way through the winter season. The greatest number of exceedances and the highest PM_{10} concentrations occurred during 2008. However, it is worth noting that in 2008, two of the four recorded exceedances were in summer (February) and came about as a result of dust created by roadworks during the unusual drought conditions. The two exceedances that occurred during 2014 are also atypical and occurred out of season.

Data indicates no breaches of the NES for PM_{10} that occur as a result of typical winter air pollution since 2009. This suggests that in the absence of the atypical sources, Putaruru would be in compliance with the NES. However, because the atypical sources have not been identified it is possible that they could result in future breaches at the site.

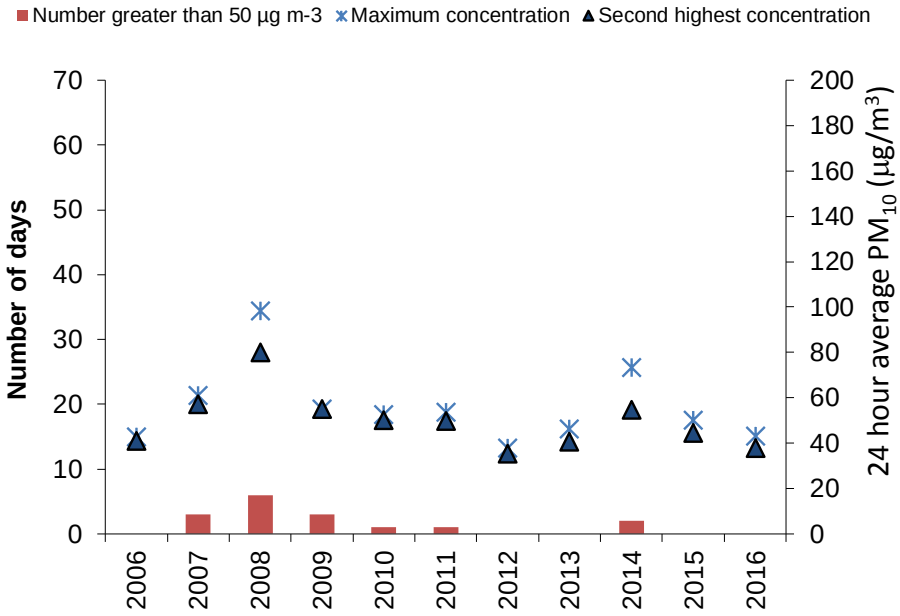

Figure 3.43 **Number of days when the 24 hour average standard of 50 µg/m^3 was exceeded compared with the maximum concentration and the 2nd highest concentration measured from 2007 to 2016.**

The annual average PM_{10} concentration for Putaruru for 2016 was 12 µg/m^3 and is lower than previous annual averages recorded at the site. Refer to Appendix 5 for summary PM_{10} monitoring statistics for Putaruru for the period 2006 to 2016.

Seasonal Mann Kendall test results for Putaruru (MK-Stat of -2.1 and p-value of 0.03) now indicate that PM_{10} concentrations have been improving over the period 2007-2016. This is consistent with the assessment for the period 2007 to 2013 (Caldwell 2015) (MK-Stat of -1.98 and p-value of 0.048) and the visual observation in Figure 3.38 of an improvement in PM_{10} in the "good" and "acceptable" air quality indicator categories over the period 2008 - 2012. However, analysis for the years 2007-2014 and 2007-2015 did not indicate a significant trend, nor does Figure 3.38 indicate a reduction in concentrations when these years are considered. It is unclear whether the reversal of this trend over the years 2014-2015 occurs as a result of a couple of years of worst case meteorological conditions or an increase in PM_{10} emissions.

A comparison of winter PM_{10} averages (May to August) are illustrated in Figure 3.44. A decrease in the winter averages was evident around 2011 and 2012. However, winter average concentrations were higher from 2013-2015, although still lower than the pre 2010 averages. In 2016 the winter average concentration was 18 µg/m^3 which is similar to the 2011 and 2012 averages. A comparison of annual averages as illustrated in Figure 3.44 shows a similar pattern with the lowest annual averages recorded in 2011 and 2012 and 2016.

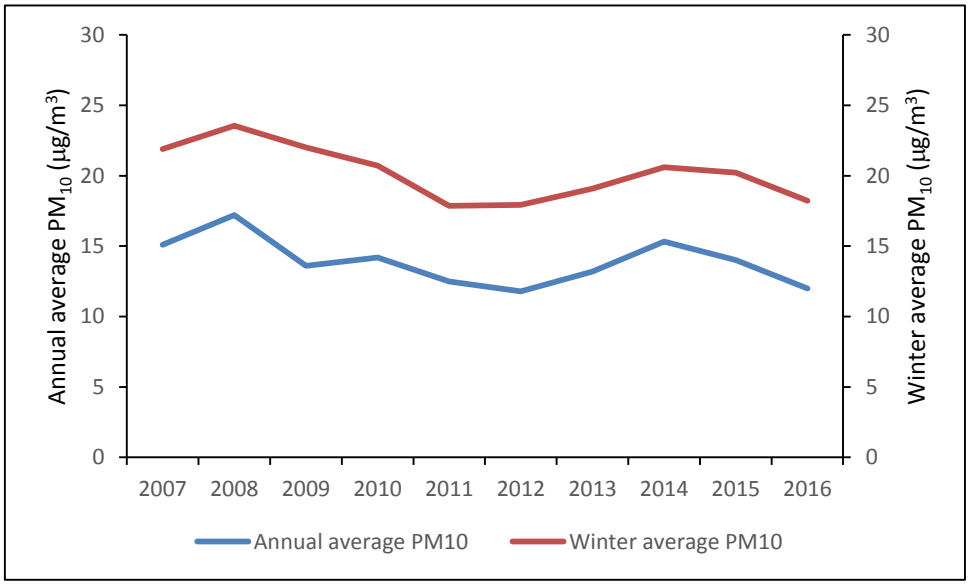

Figure 3.44 **Comparison of the winter PM_{10} averages (May to August) and annual PM_{10} averages for the period 2007 to 2016.**

The key area of interest in terms of trends is the worst-case concentrations which can result in exceedences during the winter months. Figure 3.45 shows a consistent downward trend in the rolling average exceedences per year from 2006 to 2016.

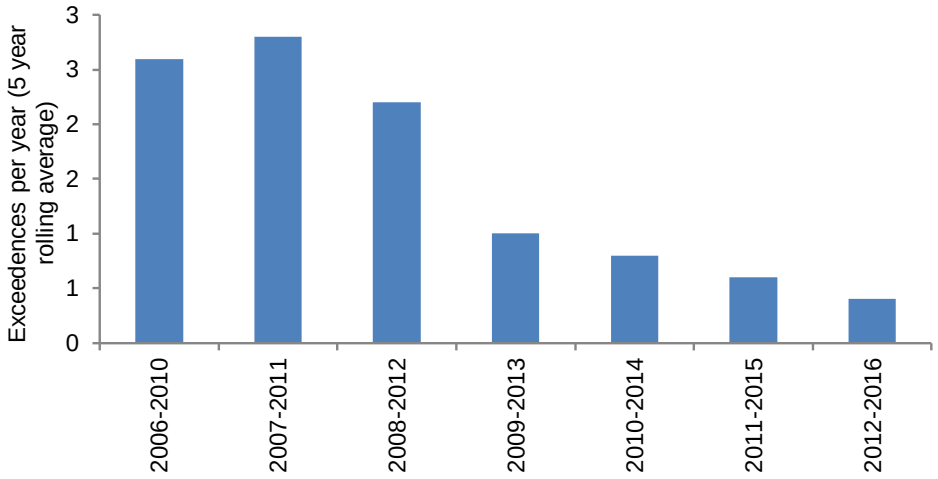

Figure 3.45 **Comparison of the five-year exceedance averages for the period 2006 to 2016.**

An air emission inventory undertaken in Putaruru in 2015 indicates that there has been a 62% reduction in PM_{10} emissions since 2006 as a result of reductions in both domestic heating and industrial emissions (Wilton 2015b).

The overall indication for Putaruru is that exceedance numbers are tracking downwards. However, non-winter exceedances in 2014 indicate the presence of an unidentified localised source of PM_{10} that could result in further exceedances in future.

3.10 PM_{10} monitoring in Turangi

There were no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 for 2016. Figure 3.46 shows 24 hour average PM_{10} concentrations measured in Turangi during 2016. The maximum 24 hour average PM_{10} concentration of 29 µg/m^3 was recorded on 10 August which is less than the maximum 24 hour average PM_{10} concentration of 41 µg/m^3 recorded for 2015 in June.

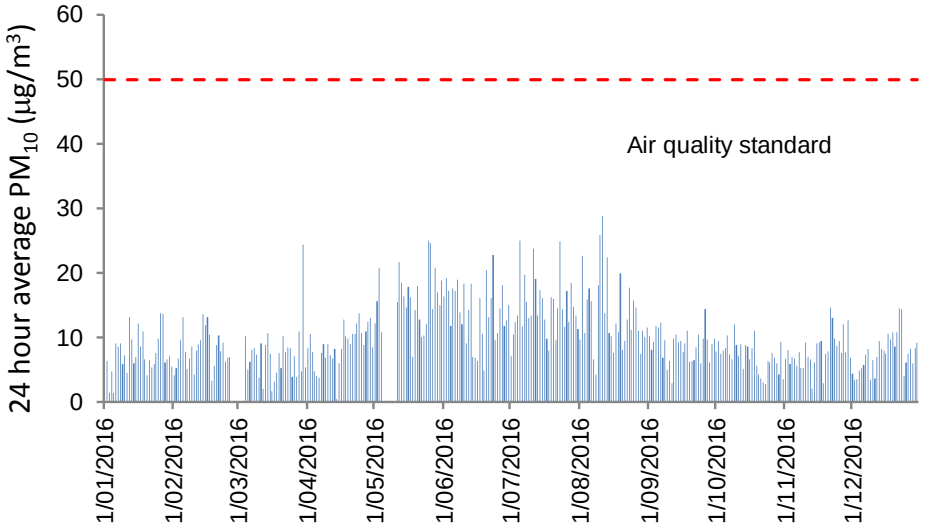

Figure 3.46 Daily average PM_{10} concentrations measured at the Turangi site for 2016.

Figure 3.47 shows 24 hour average concentrations of PM_{10} relative to air quality indicator categories at Turangi from 2009 to 2016. In 2016, 90% of days experienced 24 hour average PM_{10} concentrations within the 'good' category. On all other days PM_{10} was within the "acceptable" category.

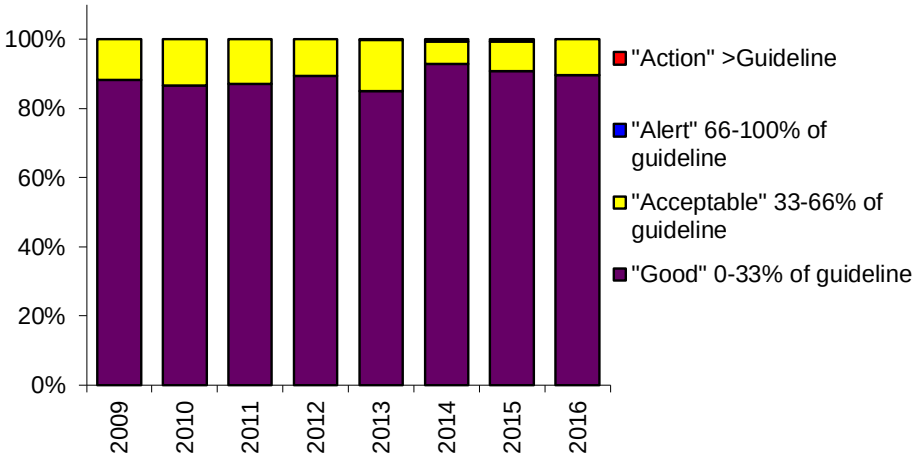

Figure 3.47 Comparison of 24 hour average PM_{10} concentrations measured at the Turangi site from 2009 to 2016 relative to air quality indicator categories.

Figure 3.48 shows that there have been no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 over the monitoring period 2009 to 2016. While the maximum 24 hour average PM_{10}

concentrations measured at the site of 40 and 41 µg/m^3 have occurred recently in 2014 and 2015, a visual comparison of the data (Figure 3.43 and 3.44) does not indicate a worsening trend.

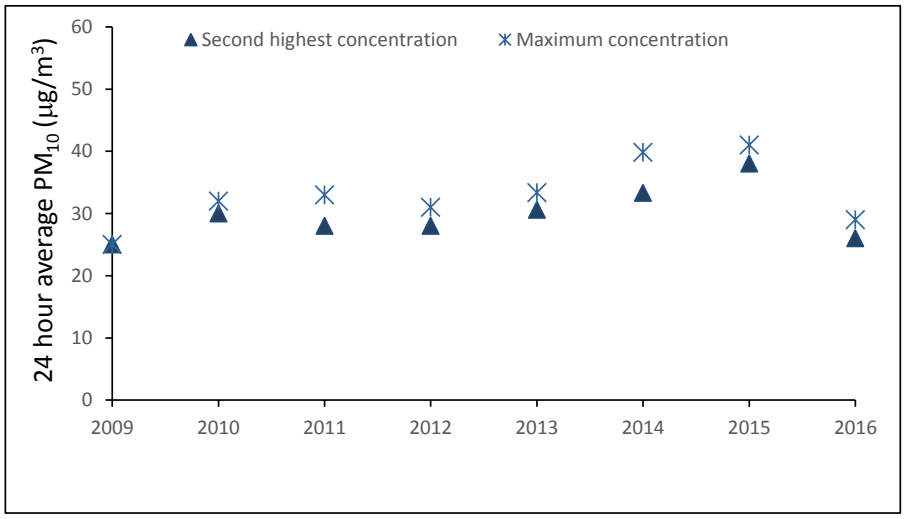

Figure 3.48 **Comparison of the maximum 24 hour average PM_{10} concentration and the 2nd highest average PM_{10} concentration measured from 2009 to 2016.**

The annual average PM_{10} concentration for Turangi for 2016 was 10 µg/m^3 and is consistent with previous years. The Ministry for the Environment specifies an annual average guideline for PM_{10} of 20 µg/m^3 (MfE, 2002). Refer to Appendix 6 for a full summary of PM_{10} monitoring statistics for Turangi for the period 2009 to 2016.

3.11 PM_{10} monitoring in Cambridge

There were no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 for 2016. Figure 3.49 shows 24 hour average PM_{10} concentrations measured in Cambridge during 2016. The maximum 24 hour average PM_{10} concentration was 39 µg/m^3 and was measured on 1 July. This compares with previous maximum 24 hour average concentrations ranging from 28-42 µg/m^3. No exceedances of 50 µg/m^3 have been recorded since monitoring commenced in 2013.

The Cambridge station was scheduled to be decommissioned at the end of 2016 as a result of three or more years monitoring without evidence of an exceedance. However, due to instrument failure it was decided that the station would be decommissioned early in August 2016.

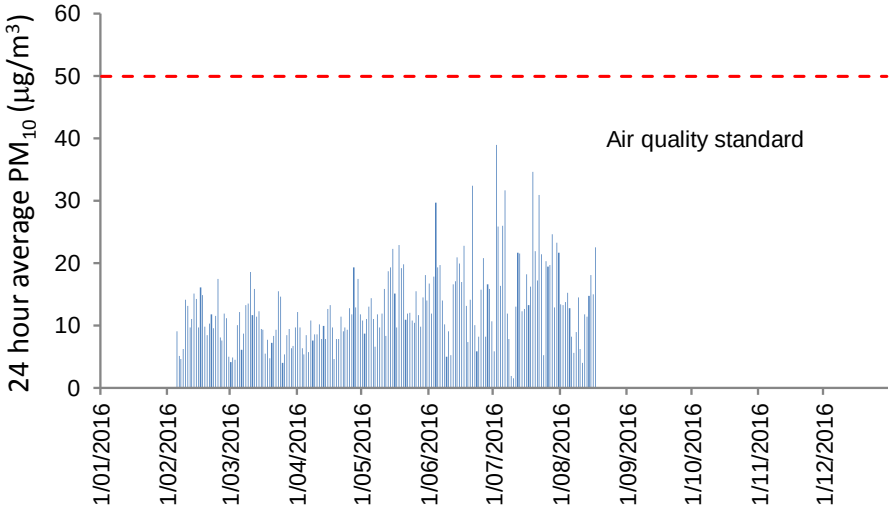

Figure 3.49 24 hour average PM_{10} concentrations measured at Cambridge during 2016.

Figure 3.50 shows 24 hour average concentrations of PM_{10} relative to air quality indicator categories at Cambridge from 2013 to 2016. The slightly higher proportion of concentrations that fall outside of the "good" air quality category in 2016 occurs as a result of bias caused from missing data during the summer months when PM_{10} concentrations are typically lower.

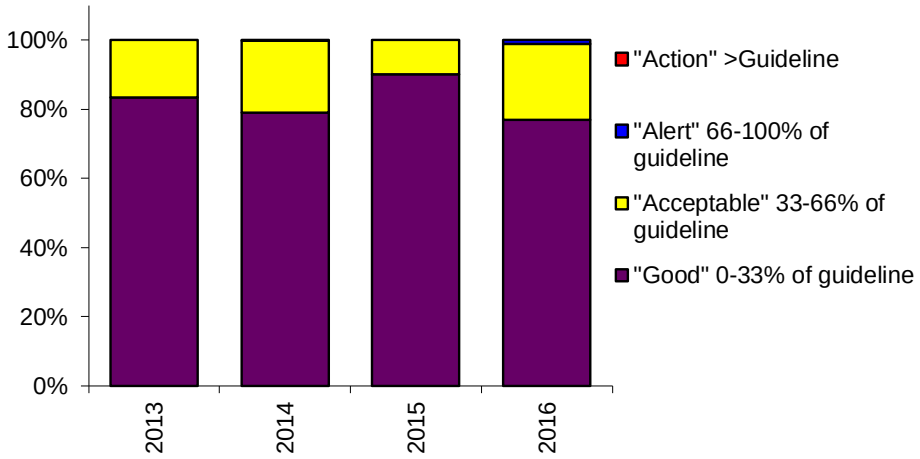

Figure 3.50 Comparison of 24 hour average PM_{10} concentrations measured at the Cambridge site from 2013 to 2016 relative to air quality indicator categories.

An estimate of the annual average PM_{10} concentration for 2016 was made using the assumption that the average of the months January to April would apply for the months September to December. The estimated annual average PM_{10} concentration for 2016 was 11.7 µg/m^3. Refer to Appendix 7 for a full summary of PM_{10} monitoring statistics for Cambridge for the period 2013 to 2016.

3.12 NO_2 monitoring in Cambridge

The results from NZTA's passive NO_2 monitoring programme for 2016 (refer to Figure 3.51) indicate that the annual average NO_2 concentration continues to remain below the WHO annual

average guideline of 40 µg/m^3. A long term trend analysis of the annual averages for the Cambridge site at the intersection of Victoria Street and Queen Street prior to 2016 indicated a worsening trend. However, an improvement has been identified for 2016 which is assumed to be related to the opening of the Cambridge expressway at the end of 2015.

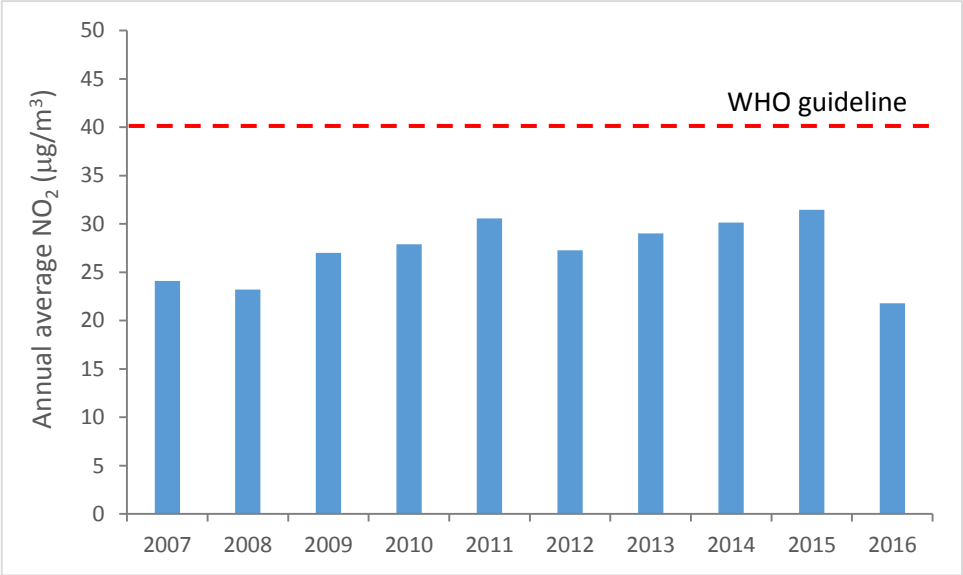

Figure 3.51 Annual average NO_2 measured in Cambridge (2007 to 2016).

3.13 PM_{10} monitoring in Te Awamutu-Kihikihi

There were no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 for 2016. Figure 3.52 shows 24 hour average PM_{10} concentrations measured in Te Awamutu-Kihikihi during 2016. The maximum 24 hour average PM_{10} concentration was 45 µg/m^3 and was measured on 20 April. It is slightly higher than the 2013 and 2014 maximum 24 hour averages which were in the mid-thirties. No exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 have been recorded at the site since monitoring commenced in 2013.

The Te Awamutu station was scheduled to be decommissioned at the end of 2016 as a result of three or more years monitoring without evidence of an exceedance. However, due to instrument problems occurring in late October it was decided that the station would be decommissioned early.

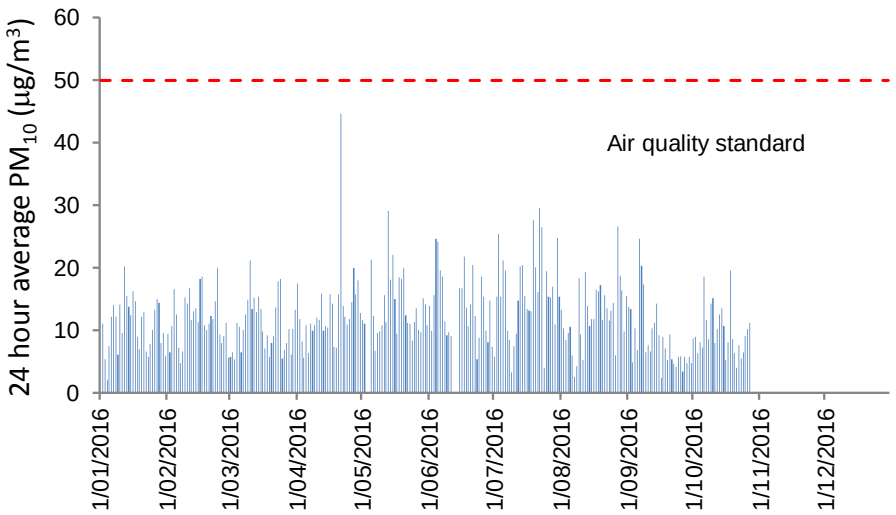

Figure 3.52 24 hour average PM_{10} concentrations measured at Te Awamutu during 2016.

Figure 3.53 shows 24 hour average concentrations of PM_{10} relative to air quality indicator categories at Te Awamutu from 2013 to 2016. In 2016, 82% of days experienced PM_{10} concentrations within the 'good' category. On one day PM_{10} concentrations fell within the "alert" category and on all other days PM_{10} was within the "acceptable" category.

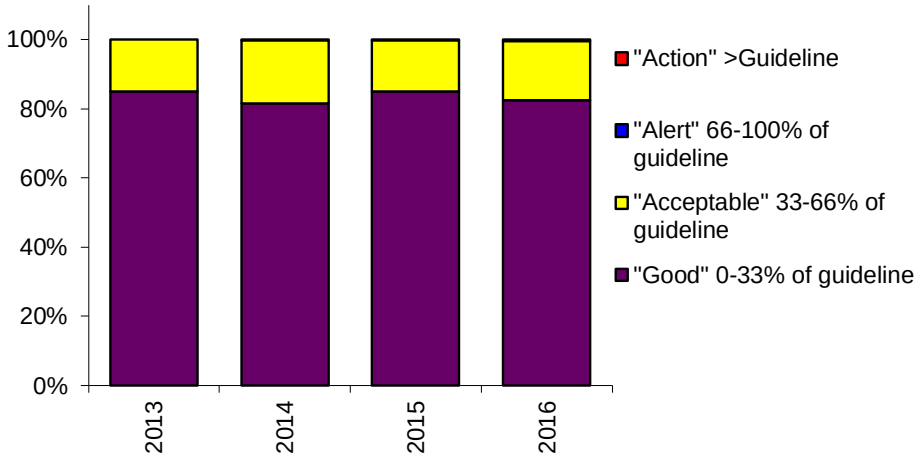

Figure 3.53 Comparison of 24 hour average PM_{10} concentrations measured at the Te Awamutu site from 2013 to 2016 relative to air quality indicator categories.

The annual average PM_{10} concentration for 2016 of 11.7 $\mu g/m^3$ is similar to the 2015 average and is at the low end of the range of annual averages determined for airsheds in the Waikato region. Refer to Appendix 8 for a full summary of PM_{10} monitoring statistics for Te Awamutu for the period 2013 to 2016.

3.14 NO_2 monitoring in Te Awamutu

The results from NZTA's passive NO_2 monitoring programme for 2016 (refer to Figure 3.54) indicates that the annual average NO_2 concentration continues to remain below the WHO annual average guideline of 40 $\mu g/m^3$. A long term trend analysis of the annual averages for the Te Awamutu site at the intersection of Ohaupo Road and Albert Park Drive indicates no statistically evident change.

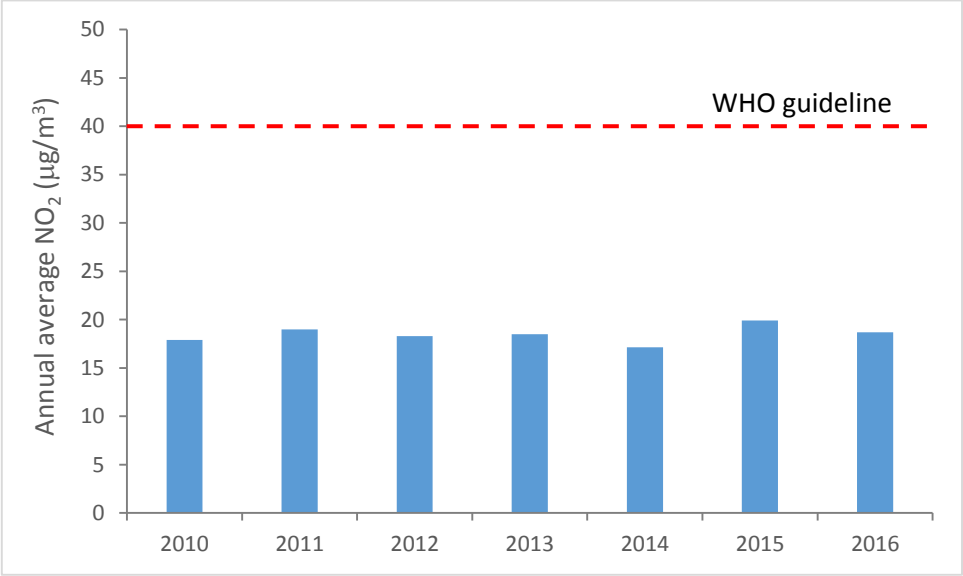

Figure 3.54 Annual average NO_2 measured in Te Awamutu (2007 to 2016).

3.15 PM_{10} monitoring in Morrinsville

There were no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 for 2016. Figure 3.55 shows 24 hour average PM_{10} concentrations measured in Morrinsville during 2016. The maximum 24 hour average PM_{10} concentration was 36 µg/m^3 and was measured on 20 November. The second highest 24 hour average PM_{10} concentration of 33 µg/m^3 was measured during June. In 2015 a maximum 24 hour average PM_{10} concentration of 45 µg/m^3 was measured during July. No exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 have been recorded at the site since monitoring commenced in 2015.

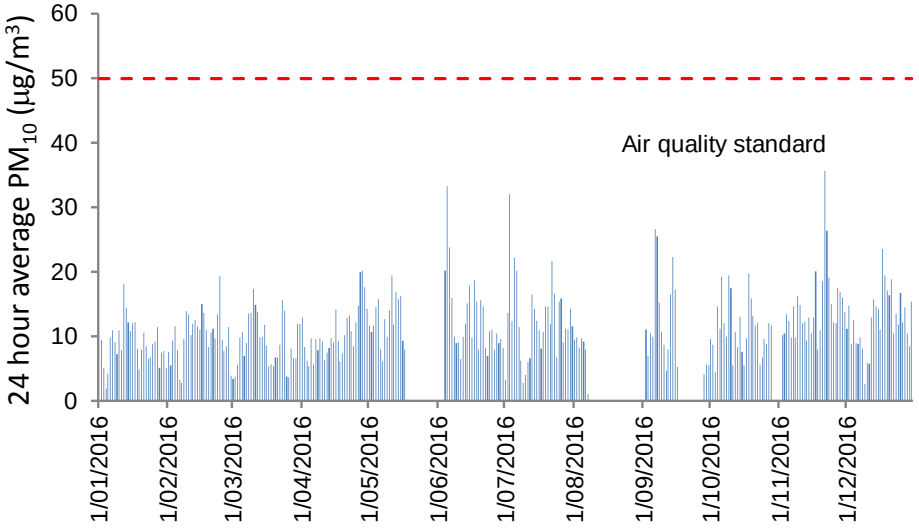

Figure 3.55 24 hour average PM_{10} concentrations measured at Morrinsville during 2016.

A comparison of 24 hour average concentrations of PM_{10} relative to air quality indicator categories at Morrinsville for 2016 indcates around 88% of days experienced PM_{10} concentrations within the 'good' category, 12% within the acceptable category and 1% within the alert category.

The annual average PM_{10} concentration for 2016 for Morrinsville was 11.5 µg/m^3 and is at the low end of the range of annual averages determined for airsheds in the Waikato region. Refer to Appendix 9 for a full summary of PM_{10} monitoring statistics for Morrinsville for 2015 and 2016.

3.16 PM_{10} monitoring in Thames

There were no exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 for 2016. Figure 3.56 shows 24 hour average PM_{10} concentrations measured in Thames during 2016. The maximum 24 hour average PM_{10} concentration was 34 µg/m^3 and was measured on 1 July.

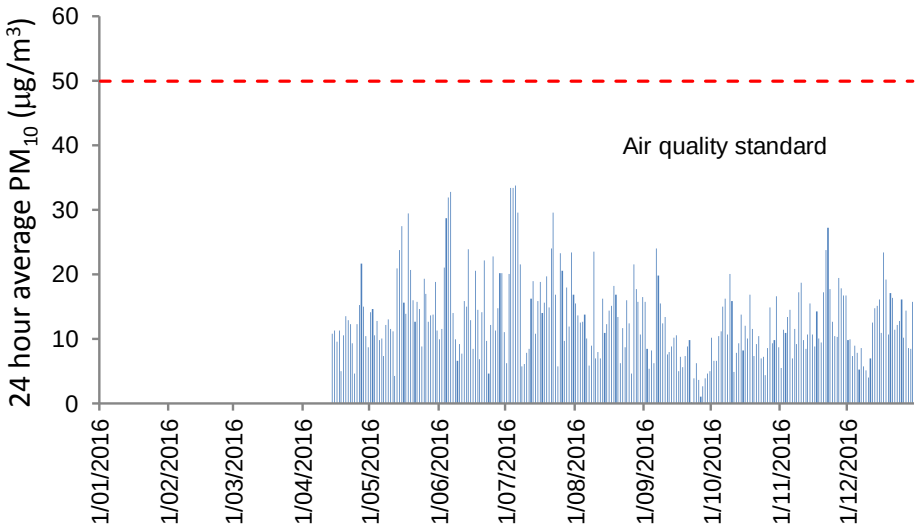

Figure 3.56 Daily average PM_{10} concentrations measured at Thames during 2016.

A comparison of 24 hour average concentrations of PM_{10} relative to air quality indicator categories at Thames for 2016 indicates around 77% of days experienced PM_{10} concentrations within the 'good' category, 22% within the acceptable category and 1% within the alert category.

The annual average PM_{10} concentration for 2016 for Thames was 12.6 µg/m^3. Refer to Appendix 10 for a full summary of PM_{10} monitoring statistics for Thames for 2016.

3.17 NO_2 monitoring in Matamata

The results from a six month passive NO_2 monitoring survey at the intersection of State Highway 24 and Firth Street and State Highway 24 and Arawa Street in Matamata for 2016 (refer to Figure 3.57) indicates that the average concentrations for that period were well below the WHO annual average guideline of 40 µg/m^3.

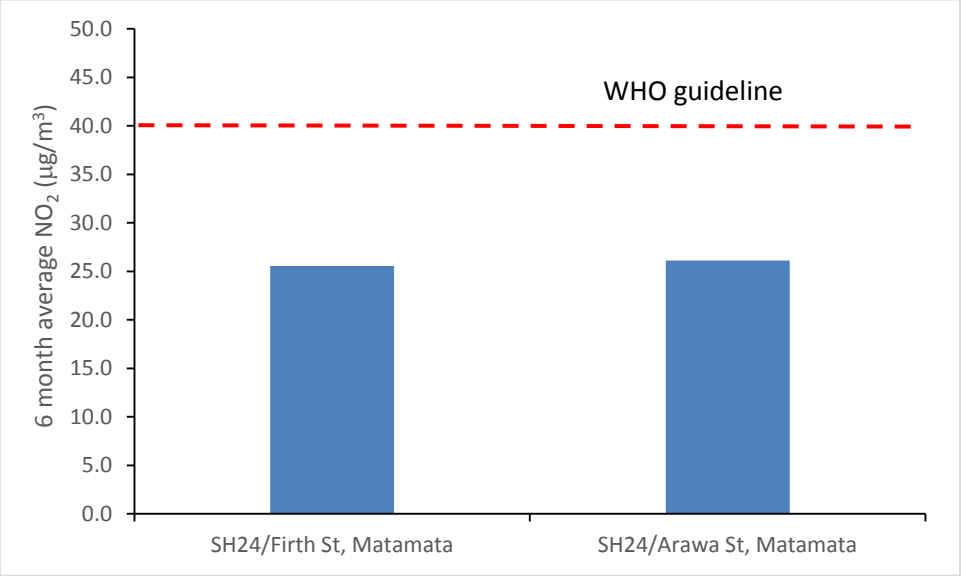

Figure 3.57 Six month average NO_2 concentrations measured in Matamata during 2016.

A wind rose for 2016 showing the relative frequency and speed of winds from different directions for 2016, as measured at the Matamata station, is provided in Figure 3.58. The wind rose indicates one distinct prevailing wind direction from the south-southeast and a second broader wind direction spanning the northwest to southwest quadrant. The windrose for Matamata also indicates a similar frequency of low to moderate windspeeds as was indicated for Te Kuiti.

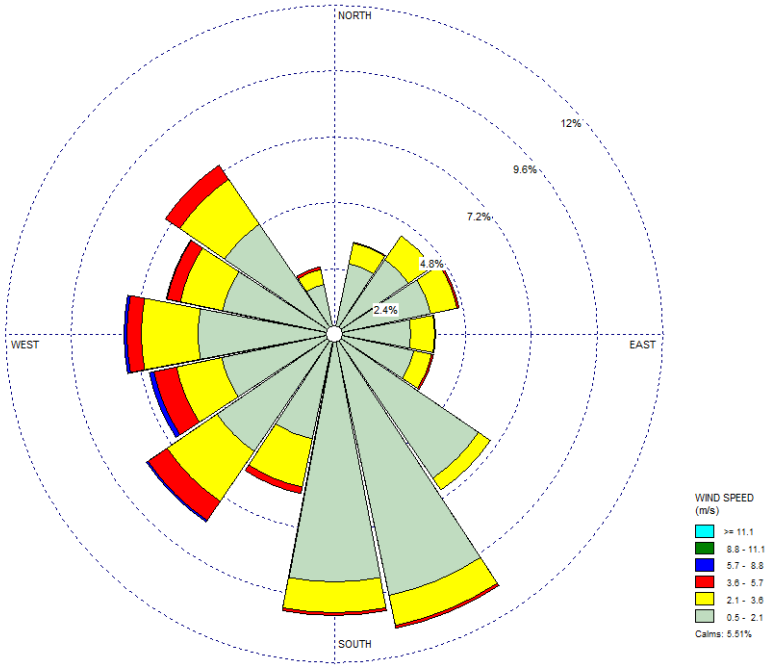

Figure 3.58 Windrose of wind direction and windspeed data as measured at the Matamata station in 2016.

4 Summary and conclusions

Monitoring of PM_{10} was undertaken in Hamilton, Tokoroa, Taupo, Te Kuiti, Putaruru, Turangi, Cambridge, Te Awamutu, Morrinsville and Thames during 2016. In addition to this, $PM_{2.5}$ was monitored in Tokoroa. This monitoring was targeted mainly at identifying the impacts from domestic home heating sources.

Monitoring of NO_2 was undertaken in Hamilton, Cambridge, Te Awamutu, Taupo, Tokoroa and Matamata for purposes of identifying the impacts from traffic related emissions. Monitoring of benzene, toluene, xylenes and ethylbenzene (BTEX) were also undertaken in Hamilton as additional indicators of traffic related emissions.

In 2016 the 24 hour average standard for PM_{10} of 50 µg/m^3 was exceeded five times in Tokoroa which is the equivalent of four breaches (based on one allowable exceedance per 12 month period). There were no exceedances in any of the other airsheds. Annual average concentrations of PM_{10} were also all within the annual average guideline of 20 µg/m^3 in all airsheds.

Table 4.1 summarises the maximum 24 hour average PM_{10} concentration recorded, the number of exceedances of the 24 hour average PM_{10} standard of 50 µg/m^3 and the annual average PM_{10} concentration in all airsheds.

Table 4.1 Summary of PM_{10} monitoring results for 2016.

Site	Maximum 24 hour average concentration (µg/m^3)	Number exceedances NES 24 hour average	Number breaches NES 24 hour average	Annual average concentration (µg/m^3)	Number exceedances annual guideline
Hamilton (Claudelands)	32	0	0	11.5	0
Hamilton (Ohaupo Rd)	31	0	0	12.5	0
Tokoroa	60	5	4	14.2	0
Taupo	50	0	0	11.9	0
Te Kuiti	41	0	0	15.2	0
Putaruru	43	0	0	12.0	0
Turangi	29	0	0	10.1	0
Cambridge	39	0	0	11.7	0
Te Awamutu-Kihikihi	45	0	0	11.7	0
Morrinsville	36	0	0	11.5	0
Thames	34	0	0	12.6	0

Table 4.2 shows the average number of exceedences of the 24 hour average PM_{10} standard at Hamilton, Tokoroa, Taupo, Putaruru and Te Kuiti over a five-year period and the trend in monthly average PM_{10} concentrations determined by Mann Kendall analysis. Based on historical monitoring, these five airsheds have the greatest potential for particulate pollution.

The trend analysis indicates that PM_{10} concentrations have decreased in Te Kuiti, Tokoroa, Putaruru and Taupo over the previous five or more year period. No change has been identified for the Hamilton monitoring station based at Ohaupo Road.

Table 4.2 **Five-year exceedance average and trend analysis for the five worst airsheds.**

Airshed	Five year exceedance average (2012 to 2016)	Trend
Hamilton	0	No change[1]
Tokoroa	9.6	Decrease
Taupo	0.4	Decrease
Te Kuiti	0.2	Decrease
Putaruru	0.4	Decrease

1. Based on data collected from Ohaupo Rd monitoring station. There is insufficient data for trend analysis for the Claudelands station.

A comparison of the changes in the five year exceedance average for PM_{10} for these five airsheds is also provided in Figure 4.1 which provides additional evidence of improvements for Tokoroa, Taupo, Te Kuiti and Putaruru.

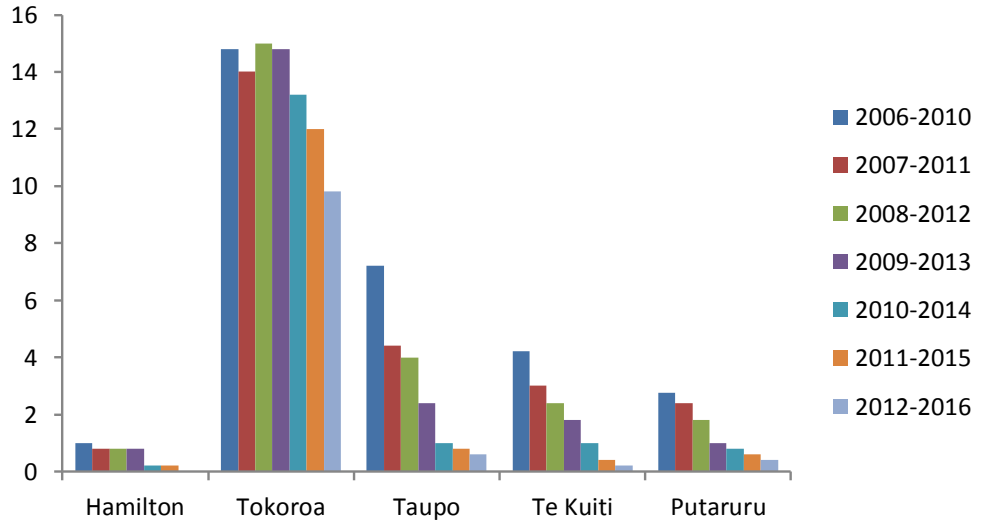

Figure 4.1 **Comparison of changes in the annual exceedance averages (per 5 year period) for Hamilton, Tokoroa, Taupo, Te Kuiti and Putaruru.**

During 2016 the 24 hour average $PM_{2.5}$ concentration in Tokoroa exceeded the WHO guideline of 25 µg/m^3 on 41 occasions. The annual average $PM_{2.5}$ concentration for Tokoroa was 12 µg/m^3 which also exceeds the WHO annual average guideline of 10 µg/m^3.

The results from passive NO_2 monitoring indicate that the Lorne Street/Ohaupo Road site and Greenwood Road/Killarney Road site in Hamilton continue to exceed the World Health Organisation (WHO) annual guideline of 40 µg/m^3 for NO_2. While there have been no exceedances of the WHO annual guideline for NO_2 at the other Hamilton sites and the Cambridge, Te Awamutu, Taupo, Tokoroa or Matamata sites a long term trend analysis of the annual averages indicates a worsening trend for the Cambridge Road/Morrinsville Road and the Avalon Drive/Grandview Drive sites in Hamilton and an improving trend for the Bridge Street/Anglesea Street site in Hamilton. In Cambridge, an improvement has been identified for 2016 compared with the previously identified worsening trend which is assumed to be related to the opening of the Cambridge expressway at the end of 2015.

The highest annual average concentration for benzene of 2.2 µg/m^3 was measured at the Greenwood Street monitoring site in Hamilton and is lower than the Ministry for the Environment's annual guideline of 3.6 µg/m^3. An improving or "levelling" trend is evident for

annual average concentrations of benzene at all sites. Concentrations of toluene, xylene and ethylbenzene were also well within acceptable levels.

A total of 70% of gazetted airsheds in the Waikato region have now been monitored for PM_{10}. Five of these airsheds have been identified as requiring ongoing monitoring based on the identification of previous PM_{10} exceedances, namely Tokoroa, Taupo, Te Kuiti, Putaruru and Hamilton. Improving trends have been identified in Tokoroa, Taupo, Te Kuiti and Putaruru which have mainly been attributed to reductions in emissions from home heating sources. The Tokoroa airshed, however, is unlikely to meet the NESAQ compliance target by September 2020 without additional or alternative intervention. Monitoring of $PM_{2.5}$ over the last two years in Tokoroa indicates that compliance with the WHO annual average guideline, if adopted as a national standard, is also unlikely to be met.

While woodburners for domestic home heating have been identified as the main source of poor air quality, traffic sources in Hamilton have been identified as significant contributors to poor air quality in localised areas close to busy traffic routes and intersections based on the passive NO_2 monitoring data.

References

Ancelet T, Davy P 2015. Multi-elemental analysis of PM_{10} and apportionment of contributing sources – Tokoroa 2014. Waikato Regional Council Technical Report 2017/29. Hamilton, Waikato Regional Council.

Caldwell J 2015. Air quality monitoring report for Hamilton, Tokoroa, Taupo, Te Kuiti, Putaruru, Turangi, Cambridge and Te Awamutu-Kihikihi – 2014. Waikato Regional Council Technical Report 2015/ 05. Hamilton, Waikato Regional Council.

Fisher G, Rolfe K, Kjellstrom T, Woodward A, Hales S, Sturman A, Kingham S, Peterson J, Shrestha R. King D 2002. Health effects due to motor vehicle air pollution in New Zealand. Report to the Ministry of Transport. Wellington, Ministry of Transport.

Mathieson T 2010. Validation of Environment Waikato BTEX monitoring by comparison of approaches. Environment Waikato Internal Series 2010/16. Hamilton, Waikato Regional Council (Environment Waikato).

Ministry for the Environment 2000. Proposals for revised and new ambient air quality guidelines: Discussion document. Air Quality Technical Report 16. Wellington, Ministry for the Environment.

Ministry for the Environment 2002. Ambient air quality guidelines. Wellington, Ministry for the Environment.

Ministry for the Environment 2004. The Resource Management (National Environmental Standards for Air Quality) Regulations 2004. Wellington, Ministry for the Environment.

Ministry for the Environment 2009. Good practice guide for air quality monitoring and data management. Wellington, Ministry for the Environment.

Smith J 2006. Air quality monitoring report 2006. Environment Waikato Technical Report 2006/52. Hamilton, Waikato Regional Council (Environment Waikato).

Smith J, Lee K 2003. Soil as a source of dust and implications for human health. Advances in Agronomy 80: 1-32.

Stevenson C, Narsey H 1999. Benzene and other toxic organics. Report prepared for the Ministry of Health. Wellington, Ministry of Health.

Trompetter WJ, Davy PK. Markwitz A 2010. Influence of environmental conditions on carbonaceous particle concentrations within New Zealand. *Journal of Aerosol Science*, 41(1), 134-142.

Wilton E, Baynes M 2008. Air quality monitoring 2007 for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata and Putaruru. Environment Waikato Technical Report 2008/11. Hamilton, Waikato Regional Council (Environment Waikato).

Wilton E, Baynes M 2009. Air quality monitoring 2008 for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata, Putaruru, Nguaruwahia, Waihi. Environment Waikato Technical Report 2009/04. Hamilton, Waikato Regional Council (Environment Waikato).

Wilton E, Baynes M 2010. Air quality monitoring 2009 for Hamilton, Tokoroa, Taupo,Te Kuiti, Matamata, Putaruru, Nguaruwahia, Waihi, and Turangi. Waikato Regional Council Technical Report 2010/14. Hamilton, Waikato Regional Council.

Wilton E 2011. Solid fuel replacements in Tokoroa, Taupo, Te Kuiti and Putaruru – meeting the NES for air quality. Report prepared for Waikato Regional Council. Doc#1978150.

Wilton E 2013a. Assessing trends in PM10 concentrations at Tokoroa. Report prepared for Waikato Regional Council. Doc#3141882.

Wilton E 2013b. Assessing trends in PM10 concentrations at Taupo. Report prepared for Waikato Regional Council. Doc#11834434.

Wilton E 2014. Personal communication based on reassessment of Assessing trends in PM_{10} concentrations at Taupo Report using second highest concentration recorded in 2013. 14 April 2014.

Wilton E 2015a. Air emission inventory – Taupo 2014. Waikato Regional Council Technical Report 2015/01. Hamilton, Waikato Regional Council.

Wilton E 2015b. Air emission inventory – Te Kuiti and Putaruru 2015. Waikato Regional Council Technical Report 2015/29. Hamilton, Waikato Regional Council.

Wilton E 2016. Air emission inventory – Tokoroa and Morrinsville 2016. Waikato Regional Council Technical Report 2016/31. Hamilton, Waikato Regional Council.

Appendix 1

Summary of PM_{10} concentrations measured at Ohaupo Road station in Hamilton for 2012 to 2016.

Indicator	2012	2013	2014	2015	2016
"Good" 0-33% of guideline	74%	77%	74%	80%	81%
"Acceptable" 33-66% of guideline	25%	23%	26%	19%	19%
"Alert" 66-100% of guideline	0.8%	0%	0%	1%	0%
“Action” >Guideline	0%	0%	0%	0%	0%
Percentage of valid data	73%	100%	100%	100%	99%
Annual average (µg/m^3)	13.5	13.3	13.4	12.9	12.5
Measured exceedances	0	0	0	0	0
2nd highest 24 hr average (µg/m^3)	35	30	31	37	30
Maximum 24 hr average (µg/m^3)	41	32	32	39	31
Number of records	266	365	364	364	363

Summary of PM_{10} concentrations measured at Claudelands Event Centre station in Hamilton for 2014 to 2016.

Indicator	2014	2015	2016
"Good" 0-33% of guideline	78%	87%	85%
"Acceptable" 33-66% of guideline	21%	13%	15%
"Alert" 66-100% of guideline	1%	0%	0%
“Action” >Guideline	0%	0%	0%
Percentage of valid data	69%	99%	99%
Annual average (µg/m^3)	14.1[1]	11.3	11.5
Measured exceedances	0	0	0
2nd highest 24 hr average (µg/m^3)	37	33	30
Maximum 24 hr average (µg/m^3)	46	35	32
Number of records	252	361	361

1. Winter average rather than annual average due to limited dataset.

Summary of PM_{10} concentrations measured using a TEOM at Peachgrove Road station in Hamilton from 1998 to 2005.

Indicator	1998	1999	2000	2001	2002	2003	2004	2005
"Good" 0-33% of guideline	57%	67%	72.5%	78.5%	61%	67%	56%	70%
"Acceptable" 33-66% of guideline	42%	31%	25.4%	17.6%	38%	29%	41%	29%
"Alert" 66-100% of guideline	1%	3%	2.1%	2.3%	1%	3%	3%	1%
"Action" >Guideline	0%	0%	0%	1.2%	0%	1%	0%	0%
Percentage of valid data	47%	99%	91.3%	69.9%	93%	91%	94%	77%
Annual average ($\mu g/m^3$)	15.2	15.7	14.7	15.5	15.3	16.9	15.5	16.3
Measured exceedances	0	0	0	3	0	4	1	0
2nd highest 24 hr average ($\mu g/m^3$)	33	43	36	64	34	54	43	34
Maximum 24 hr average ($\mu g/m^3$)	35	44	48	76	36	62	55	37
Number of records	172	361	334	256	340	331	344	281

Summary of PM_{10} concentrations measured using a TEOM at Peachgrove Road station in Hamilton from 2006 to 2013 (gravimetric correction of data applied[1]).

Indicator	2006	2007	2008	2009	2010	2011	2012	2013
"Good" 0-33% of guideline	58%	67%	64%	70%	77%	66%	75%	65%
"Acceptable" 33-66% of guideline	38%	31%	34%	26%	23%	32%	23%	31%
"Alert" 66-100% of guideline	4%	2%	2%	3%	0%	2%	2%	1%
"Action" >Guideline	1%	0%	0%	0.8%	0%	0.3%	0%	3%
Percentage of valid data	99%	100%	100%	100%	99%	100%	100%	80%
Annual average ($\mu g/m^3$)	16.6	14.7	15.3	14.4	13.1	14.4	13.4	13.7[2]
Measured exceedances	2	0	0	3	0	1	0	8
2nd highest 24 hr average ($\mu g/m^3$)	58	45	46	52	30	37	37	127
Maximum 24 hr average ($\mu g/m^3$)	66	46	48	101	30	64	42	136
Number of records	363	364	364	363	361	364	364	291

1. Corrected PM_{10} data = 1.19975 x RawTEOMdata - 3.9182.
2. Winter average rather than annual average due to limited dataset.

Appendix 2

Summary of PM_{10} concentrations measured at the Tokoroa monitoring station from 2001 to 2008[1].

Indicator	2001	2002	2003	2004	2005	2006	2007	2008
"Good" 0-33% of guideline	12%	15%	25%	12%	28%	60%	66%	67%
"Acceptable" 33-66% of guideline	64%	71%	58%	54%	49%	26%	24%	25%
"Alert" 66-100% of guideline	17%	9%	13%	23%	13%	8%	7%	6%
“Action” >Guideline	8%	4%	4%	11%	9%	6%	3%	3%
Percentage of valid data	47%	97%	55%	96%	88%	99%	99%	99%
Annual average ($\mu g/m^3$)	26.6	24.0	24.1	31.0	24.8	18.6	16.3	16.5
Measured exceedances	13	14	8	38	33	20	10	11
2nd highest 24 hr average ($\mu g/m^3$)	66	66	57	92	83	70	71	60
Maximum 24 hr average ($\mu g/m^3$)	75	70	62	97	89	76	86	85
Number of records	173	353	199	349	321	360	360	360

1. Gravimetric correction of data applied from 2006 onwards.

Summary of PM_{10} concentrations measured at the Tokoroa monitoring station from 2009 to 2016[1].

Indicator	2009	2010	2011	2012	2013	2014	2015	2016
"Good" 0-33% of guideline	61%	63%	60%	63%	63%	68%	68%	69%
"Acceptable" 33-66% of guideline	29%	26%	27%	25%	26%	23%	22%	25%
"Alert" 66-100% of guideline	5%	7%	9%	8%	8%	7%	7%	5%
“Action” >Guideline	5%	4%	4%	4%	3%	2%	3%	1.5%
Percentage of valid data	100%	99%	99%	100%	100%	100%	100%	93%
Annual average ($\mu g/m^3$)	17.5	18.0	18.0	17.2	16.8	15.9	16.6	14.5
Measured exceedances	17	16	16	15	10	9	10	5
2nd highest 24 hr average ($\mu g/m^3$)	77	87	72	66	59	67	66	56
Maximum 24 hr average ($\mu g/m^3$)	80	99	73	75	59	69	69	60
Number of records	364	360	362	366	364	365	364	341

1. Gravimetric correction of data applied from 2006 onwards.

Appendix 3

Summary of PM_{10} concentrations measured at the Taupo monitoring station from 2001 to 2008[1].

Indicator	2001	2002	2003	2004	2005	2006	2007	2008
"Good" 0-33% of guideline	43%	59%	52%	55%	56%	47%	65%	66%
"Acceptable" 33-66% of guideline	36%	33%	32%	30%	36%	38%	29%	24%
"Alert" 66-100% of guideline	18%	7%	12%	12%	7%	10%	5%	7%
“Action” >Guideline	2%	1%	4%	2%	1%	5%	1%	3%
Percentage of valid data	12%	21%	29%	29%	30%	27%	83%	99%
Annual average[2] ($\mu g/m^3$)	19.7	15.9	18.5	17.8	15.8	20.4	15.4	16.7
Measured exceedances[3]	1 (7)	1 (6)	4 (12)	2 (6)	1 (3)	5 (15)	3	10
Maximum 24 hr average ($\mu g/m^3$)	57	54	62	65	52	89	64	73
2nd highest 24 hr average ($\mu g/m^3$)	55	51	62	62	50	80	60	68
Number of records	44	76	106	105	111	98	303	362

Summary of PM_{10} concentrations measured at the Taupo monitoring station from 2009 to 2016[1].

Indicator	2009	2010	2011	2012	2013	2014	2015	2016
"Good" 0-33% of guideline	71%	73%	69%	76%	73%	77%	77%	80%
"Acceptable" 33-66% of guideline	22%	20%	26%	19%	24%	21%	19%	17%
"Alert" 66-100% of guideline	5%	6%	5%	5%	3%	3%	4%	3%
“Action” >Guideline	2%	0%	0%	0%	1%	0%	0%	0%
Percentage of valid data	99%	100%	99%	99%	99%	98%	99%	97%
Annual average[2] ($\mu g/m^3$)	14.7	14.0	14.2	12.9	13.4	12.4	12.6	11.9
Measured exceedances[3]	7	1	1	1	2	0	0	0
Maximum 24 hr average ($\mu g/m^3$)	66	55	51	51	65	45	44	50
2nd highest 24 hr average ($\mu g/m^3$)	66	48	50	50	62	43	43	41
Number of records	363	364	361	362	363	358	362	353

1. 2007 - 2008 data have been updated from that reported in the 2007 and 2008 reports based on a more recent (2009) adjustment factor. 2006 data were gravimetric at Gillies Ave. Data post 2006 has been adjusted for gravimetric equivalency. Note the 2008 monitoring report used a different equation and reported six exceedances of 50 $\mu g\ m^{-3}$ for 2007 compared with three exceedances reported here.
2. To avoid seasonal bias in missing data, annual averages for gravimetric data collected prior to 2007 have been calculated based on the average of the individual seasonal averages (i.e. Jan to Apr, May to Aug, Sep to Dec). Annual average calculations from 2007 onwards have been based on averaging of all data (it makes no difference which method is used because there is very little missing data).
3. For the years 2001 to 2006 both measured and reported exceedences are shown (in brackets). Reported exceedences are a statistical extrapolation of measured exceedences after accounting for non sample days.

Appendix 4

Summary of PM_{10} concentrations measured at the Te Kuiti monitoring station from 2003 to 2009.

Indicator	2003	2004	2005	2006	2007	2008	2009
Good 0-33% of Guideline	48%	51%	59%	58%	54%	55%	63%
Acceptable 33-66% of guideline	32%	40%	34%	31%	38%	35%	29%
Alert 66-100% of guideline	17%	8%	7%	9%	7%	9%	8%
Action >Guideline	2%	1%	1%	2%	1%	1%	1%
Percentage of valid data	63%	95%	92%	100%	99%	99%	99%
Annual average (µg/m3)	18.0	18.0	17.0	17.7	17.8	18.2	16.8
Number exceedances	4	5	2	7	4	3	4
Maximum 24 hr average (µg/m^3)	59	61	54	69	58	74	53
2nd highest 24 hr average (µg/m^3)	56	56	52	67	58	53	52
Number records	229	346	337	363	360	362	360

Summary of PM_{10} concentrations measured at the Te Kuiti monitoring station from 2010 to 2016.

Indicator	2010	2011	2012	2013	2014	2015	2016
Good 0-33% of Guideline	65%	65%	64%	60%	64%	65%	67%
Acceptable 33-66% of guideline	28%	32%	29%	37%	30%	31%	29%
Alert 66-100% of guideline	6%	3%	7%	3%	6%	4%	4%
Action >Guideline	1%	0%	0%	0%	0%	0%	0%
Percentage of valid data	99%	100%	99%	98%	100%	100%	98%
Annual average (µg/m^3)	16.1	15.1	16.4	16.3	15.9	15.4	15.2
Number exceedances	3	1	1	0	0	0	0
Maximum 24 hr average (µg/m^3)	56	51	61	47	48	49	41
2nd highest 24 hr average (µg/m^3)	53	41	50	40	44	45	41
Number records	360	363	363	358	364	364	359

Appendix 5

Summary of PM_{10} concentrations measured at the Putaruru monitoring station from 2006 to 2016.

Indicator	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Good 0-33% of Guideline	65%	67%	61%	71%	72%	78%	79%	74%	66%	70%	81%
Acceptable 33-66% of guideline	30%	27%	31%	23%	25%	20%	20%	24%	30%	25%	18%
Alert 66-100% of guideline	5%	5%	7%	6%	3%	2%	1%	2%	4%	5%	1%
Action > Guideline	0%	1%	1%	1%	0.3%	0.3%	0%	0%	1%	0%	0%
Percentage of valid data	46%	100%	100%	100%	100%	95%	99%	99%	98%	93%	94%
Annual average (µg/m^3)	n/a	15.1	17.2	13.6	14.2	12.5	11.8	13.2	15.3	14.0	12.0
Number exceedances	0	3	4	3	1	1	0	0	2	0	0
Maximum 24 hr average (µg/m^3)	42	60	78	54	53	54	38	46	73	50	43
2nd highest 24 hr average (µg/m^3)	40	56	60	54	50	50	35	41	55	45	38
Number records	166	365	364	364	363	346	361	360	359	340	343

Appendix 6

Summary of PM_{10} concentrations measured at the Turangi monitoring station from 2009 to 2016.

Indicator	2009	2010	2011	2012	2013	2014	2015	2016
Good (0-33% of guideline)	88%	87%	87%	90%	85%	89%	91%	90%
Acceptable (33-66% of guideline)	12%	13%	13%	10%	15%	7%	9%	10%
Alert (66-100% of guideline)	0%	0%	0%	0%	0%	1%	1%	0%
Action > guideline	0%	0%	0%	0%	0%	0%	0%	0%
Percentage of valid data	79%	84%	85%	99%	100%	95%	99%	97%
Annual average (µg/m3)	9.8	10.8	10.2	10.0	10.8	9.9	10.0	10.1
Measured exceedances	0	0	0	0	0	0	0	0
Maximum 24 hr average (µg/m^3)	25	32	33	31	33	40	41	29
2nd highest 24 hr average (µg/m^3)	25	30	28	28	31	33	38	26
Number of records	288	305	312	362	363	346	362	353

Appendix 7

Summary of PM_{10} concentrations measured at the Cambridge monitoring station from 2013 to 2016.

Indicator	2013	2014	2015	2016
Good (0-33% of guideline)	83%	79%	90%	77%
Acceptable (33-66% of guideline)	17%	21%	10%	22%
Alert (66-100% of guideline)	0%	0.3%	0%	1%
Action (> guideline)	0%	0%	0%	0%
Percentage of valid data	59%	99%	98%	53%
Annual average (µg/m^3)	11.8	12.4	10.8	11.7
Measured exceedances	0	0	0	0
Maximum 24 hr average (µg/m^3)	28	42	31	39
2nd highest 24 hr average (µg/m^3)	26	30	27	36
Number of records	216	361	357	195

Appendix 8

Summary of PM_{10} concentrations measured at the Te Awamutu monitoring station from 2013 to 2016.

Indicator	2013	2014	2015	2016
Good (0-33% of guideline)	85%	82%	85%	82%
Acceptable (33-66% of guideline)	15%	18%	15%	17%
Alert (66-100% of guideline)	0%	0.3%	0%	0%
Action (> guideline)	0%	0%	0%	0%
Percentage of valid data	51%	99%	98%	81%
Annual average (µg/m^3)	11.8	12.3	11.8	11.7
Measured exceedances	0	0	0	0
Maximum 24 hr average (µg/m^3)	32	38	34	45
2nd highest 24 hr average (µg/m^3)	25	30	30	30
Number of records	186	362	356	295

Appendix 9

Summary of PM_{10} concentrations measured at the Morrinsville monitoring station from 2015 to 2016.

Indicator	2015	2016
Good (0-33% of guideline)	80%	88%
Acceptable (33-66% of guideline)	18%	12%
Alert (66-100% of guideline)	2%	1%
Action (> guideline)	0%	0%
Percentage of valid data	59%	84%
Annual average (µg/m^3)	12	11.5
Measured exceedances	0	0
99.7 %ile PM_{10} conc. (µg/m^3)	41	33
Maximum 24 hr average (µg/m^3)	45	36
2nd highest 24 hr average (µg/m^3)	38	33
Number of records	217	308

Appendix 10

Summary of PM_{10} concentrations measured at the Thames monitoring station for 2016.

Indicator	2016
Good (0-33% of guideline)	77%
Acceptable (33-66% of guideline)	22%
Alert (66-100% of guideline)	1%
Action (> guideline)	0%
Percentage of valid data	72%
Annual average (µg/m^3)	12.6
Measured exceedances	0
Maximum 24 hr average (µg/m^3)	34
2nd highest 24 hr average (µg/m^3)	33
Number of records	262