greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Air quality monitoring programme

Annual data report, 2017

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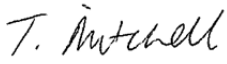
Report prepared by:	T Mitchell	Senior Environmental Scientist, Air Quality	
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Contents

1. Introduction

This report summarises the key results from the air quality monitoring programme for the period 1 January to 31 December 2017 inclusive. This programme includes:

i) continuous monitoring of air quality indicators using reference methods and selected meteorological variables at six sites across the Wellington Region; and

ii) traffic-related air quality monitoring based on nitrogen dioxide measured by passive diffusion tubes.

2. Background

Air quality has been monitored in the Wellington Region since 1998, when a series of pilot investigations were carried out. The first long-term site was established in Upper Hutt in 2000. Other sites have been progressively added to the monitoring network, which now comprises five long-term sites (Wellington central, Lower Hutt, Wainuiomata, Upper Hutt and Masterton West).

Shorter-term monitoring sites are occasionally established to assist with targeted investigations relating to specific air quality issues. For example, a second monitoring site was set up in Masterton East in 2012 to assist with understanding how air quality varies across the Masterton urban area.

A regional network of low cost monitoring sites to measure trends in traffic-related air quality was set up in July 2016. This network was progressively installed over a two year period and will be reviewed in 2019/20.

2.1 Monitoring objectives

The objectives of Greater Wellington Regional Council's (GWRC) monitoring programme are to:

1. Determine compliance with national guidelines and standards designed to protect human health and the environment;

2. Detect spatial and temporal trends in air quality;

3. Contribute to our understanding of air quality processes and impacts in the Wellington Region;

4. Provide information required to determine the effectiveness of regional plans and policies; and

5. To enable reporting on annual reporting on an outcome in the *Regional Land Transport Plan* (2015) for reduced harmful emissions from transport using a measure of concentrations of harmful transport generated pollutants.

2.2 Monitoring networks

2.2.1 Air quality reference monitoring sites

The Wellington Region has eight airsheds located in valleys between steep hills or mountains (Figure 2.1); Kapiti Coast, Porirua Basin, Wellington City, Karori, Lower Hutt Valley, Wainuiomata, Upper Hutt Valley and Masterton Urban.

Each airshed has its own distinct microclimate, meteorological conditions and air quality pressures. Apart from the Masterton Urban airshed, these airsheds were formally gazetted in 2005 in accordance with the National Environmental Standards for Air Quality (NES-AQ)[1] (Davy, 2005). The Masterton Urban

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

airshed replaced the former Wairarapa Valley airshed as of 1 September 2014. Not all airsheds are currently monitored as the NES-AQ only requires airsheds to be monitored where air quality standards are likely to be breached.

A new Wellington central site was established in 2015 on the corner of Willis Street and SH1. A mobile monitoring station was deployed at this site from January to early September 2015. It was replaced in January 2016 by a permanent monitoring station.

Site metadata are presented in Appendix 1.

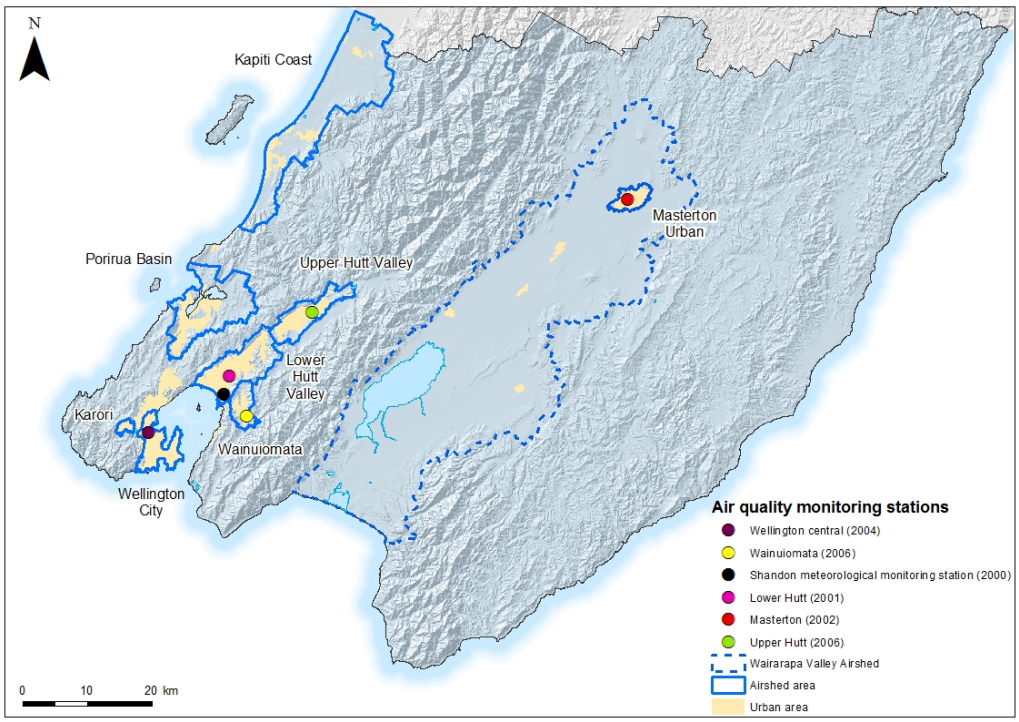

Figure 2.1: Airshed boundaries and location of GWRC permanent air quality monitoring stations (former Wairarapa airshed boundary shown as dashed blue line).

2.2.2 Traffic-related air quality monitoring

A regional network of low cost monitoring sites was established in July 2016 to measure trends in traffic-related air pollutants. This indicator is based on levels of nitrogen dioxide (a harmful pollutant arising from vehicle emissions) and is designed to allow reporting against the Regional Land Transport Plan 2015 (RLTP) outcome of reduced harmful emissions from transport. The regional network is a subset of the NZTA's National air quality (NO_2) monitoring network[2] and includes a mix of NZTA sites and new sites installed by GWRC shown in Table 2.1. The traffic-related air quality monitoring network and monitoring method is described in the report *Traffic-related air quality monitoring in the Wellington Region 2016/17*[3].

[2] https://www.nzta.govt.nz/resources/air-quality-monitoring/
[3] http://www.gw.govt.nz/assets/council-publications/Traffic-related-air-quality-indicator-201617.pdf

Table 2.1: Monitoring sites with NZTA site identification numbers

Area	Urban background	Roadside	Peak	Total
Wellington (central)	NA	WEL084 WEL086	WEL050 WEL008 WEL049 WEL073[4] WEL081 WEL083	8
Wellington (outer)	WEL048 WEL094	WEL085		3
Lower Hutt	WEL091 WEL054[5]	WEL079 WEL078 WEL003 WEL052	WEL090 WEL053	8
Upper Hutt	WEL092		WEL093	2
Kāpiti Coast/Ōtaki	NA	WEL063	WEL087	2
Porirua	WEL072	WEL080 WEL088		3
Masterton	WEL096	WEL089	WEL095	3
Total	7	11	11	29

Site locations are provided in Appendix 4.

2.3 Monitoring variables

The air quality indicators currently monitored in the Wellington Region are particulate matter (PM_{10} and $PM_{2.5}$), carbon monoxide (CO) and nitrogen oxides (NOx) which include nitrogen dioxide (NO_2) and nitric oxide (NO). These contaminants can have adverse human health impacts when concentrations in air are elevated. The air quality indicators measured at each site are shown in Table 2.2.

The two other pollutants that are regulated by national standards, sulphur dioxide (SO_2) and ozone (O_3), are not presently monitored in the Wellington Region. Meteorological conditions in the region are not conducive to the formation of ozone and there are no known significant point source emissions of sulphur dioxide.

Meteorological instruments for recording variables such as wind speed, wind direction and temperature are co-located at each monitoring site to assist with the interpretation of air quality data.

Further information on air quality indicators monitored and measurement methods are provided in Appendix 2.

[4] Co-located at GWRC air quality monitoring station (Willis Street/Urban Motorway, Wellington CBD)
[5] Co-located GWRC air quality monitoring station (Phil Evans Reserve, Waterloo, Lower Hutt)

Table 2.2: Air quality monitoring sites and indicators monitored

Site	Station	Airshed	Indicators monitored	Data available from
Wellington central	Willis Street (intersection of Willis Street and SH1)	Wellington City	PM_{10}, $PM_{2.5}$, CO, NOx	2015
			Black carbon	2017
Lower Hutt	Birch Lane (Phil Evans Reserve)	Lower Hutt Valley	PM_{10}	2001
			CO, NOx	2001-2011
Wainuiomata	Wainuiomata Bowling Club (Moohan Street)	Wainuiomata	PM_{10}	2006
			$PM_{2.5}$	2012
Upper Hutt	Savage Park (Savage Crescent)	Upper Hutt Valley	PM_{10}, CO, NOx	2006
Masterton West (permanent site)	Wairarapa College (Pownall Street)	Masterton Urban	PM_{10}, CO	2002
			NOx	2003
			$PM_{2.5}$	2011
Masterton East (non-permanent site)	Herbert Street (Herbert Street)	Masterton Urban	PM_{10}	2012
			$PM_{2.5}$	2013
Shandon	Shandon golf course (Gear Island, Petone)	Lower Hutt Valley	Meteorological parameters	2000

2.4 Air quality assessment criteria and reporting

2.4.1 National environmental standards and guidelines for air quality

National ambient air quality guidelines (NAAQG) were established by the Ministry for the Environment (MfE) in 1994 and revised in 2002 (Ministry for the Environment, 2002). Some of these guideline values were adopted as part of the NES-AQ in 2004. The NES-AQ specifies minimum requirements for outdoor air quality to provide a nationally consistent level of protection for human health and the environment.

There are no national standards for $PM_{2.5}$, although a value of 25µg/m^3 (24-hour average) can be used for assessing monitoring results (Ministry for the Environment, 2002). In the absence of New Zealand standards, World Health Organization (WHO) guidelines are used for assessing the significance of $PM_{2.5}$ monitoring results (World Health Organization, 2006).

The relevant standards and guidelines for air quality indicators measured in the Wellington Region are shown in Table 2.3. Nitrogen dioxide measured by passive diffusion tube is not a reference method and therefore results are indicative only and cannot be directly compared to standards and guidelines.

Table 2.3: Air quality standards and guidelines

Indicator	Standard or Guideline	Threshold concentration	Averaging period	Permissible exceedances per year
PM_{10}	NES-AQ	50 µg/m^3	24-hour	1
	NAAQG	20 µg/m^3	Annual	NA
$PM_{2.5}$	WHO Guideline	25 µg/m^3	24-hour	3
	WHO Guideline	10 µg/m^3	Annual	NA
Carbon monoxide (CO)	NES-AQ	10 mg/m^3	8-hour moving	6
	NAAQG	30 mg/m^3	1-hour	0
Nitrogen dioxide (NO_2)	NES-AQ	200 µg/m^3	1-hour	9
	NAAQG	100 µg/m^3	24-hour	0
	WHO Guideline	40 µg/m^3	Annual	NA

3. Results

3.1 Reference monitoring network

Summary statistics for air quality indicators measured during the 2017 calendar year at fixed reference monitoring stations are presented in Table 3.1. For sites where there is less than 75 percent data capture for the calendar year no summary statistics are reported apart from the maxima.

PM_{10} was the only pollutant that failed to meet the NES-AQ, and only at the Masterton East site. During winter there were numerous days in Masterton and some days in Wainuiomata where levels of $PM_{2.5}$ failed to meet the World Health Organization (WHO) guideline. These exceedances are shown in Table 3.1 in red.

Masterton East had a greater number PM_{10} exceedances and days above the $PM_{2.5}$ guideline than Masterton West. Poorer air quality is found at Masterton East because on cold and cloudless nights cold air slowly drains across Masterton from the west carrying fine particles from home fires towards the lower lying area on the east side leading to a build-up of air pollution.

Wind roses showing summaries of wind speeds and wind direction observations at selected sites are presented in Appendix 3.

Table 3.1: 2017 air quality indicator summary statistics

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
PM_{10} 24-hour average µg/m^3						
Mean (annual)	11.3	11.4	10.7	13.9	15.3	11.3
Maximum	25	30	30	56	70	40.0
Median	10.5	10.6	9.6	10.8	10.6	10.2
Std deviation	4.3	4.5	5.0	9.5	12.0	5.9
25th percentile	8.1	8.3	7.4	7.6	8.0	7.5
75th percentile	14.0	13.8	13.5	16.6	18.9	13.7
95th percentile	19.4	20.3	19.9	34.5	43.9	22.2
99th percentile	22.7	24.6	25.5	46.7	55.5	32.0
No. > 50 µg/m^3	0	0	0	3	5	0
Data capture	99.7%	97.8%	99.0%	97.5%	87.7%	96.4%
$PM_{2.5}$ 24-hour average µg/m^3						
Mean (annual)	5.4			9.7	11.0	6.4
Maximum	17			46	61	37
Median	5.2			6.2	6.0	4.7
Std deviation	2.2			8.7	11.1	5.6
25th percentile	4.0			4.0	4.4	3.2
75th percentile	6.5			12.7	13.9	7.1
95th percentile	9.6			27.1	35.2	19.5

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
99th percentile	11.2			39.8	53.3	29.4
No. > 25 µg/m3	0			28	43	6
Data capture	93.4%			99.5%	95.9%	99.2%
Carbon monoxide 8-hour moving average mg/m3						
Mean (annual)	0.19		0.19	0.21		
Maximum	0.82		1.57	2.44		
Median	0.17		0.13	0.11		
Std deviation	0.11		0.20	0.28		
25th percentile	0.12		0.07	0.07		
75th percentile	0.23		0.22	0.21		
95th percentile	0.43		0.64	0.85		
99th percentile	0.60		0.99	1.32		
No. > 10 mg/m3	0		0	0		
Data capture	99.1%		98.8%	98.2%		
Carbon monoxide 1-hour average mg/m3						
Mean (annual)	0.19		0.19	0.21		
Maximum	1.49		2.06	3.25		
Median	0.16		0.11	0.10		
Std deviation	0.15		0.24	0.34		
25th percentile	0.10		0.06	0.06		
75th percentile	0.23		0.21	0.18		
95th percentile	0.48		0.68	0.91		
99th percentile	0.81		1.24	1.75		
No. > 30 mg/m3	0		0	0		
Data capture	98.6%		98.8%	97.5%		
Nitrogen dioxide 1-hour average µg/m3						
Mean (annual)	14.1		6.3	5.4		
Maximum	67.9		53.5	48.2		
Median	12.0		3.5	3.2		
Std deviation	10.6		7.1	5.8		
25th percentile	6.0		1.5	1.7		
75th percentile	19.2		8.4	6.6		
95th percentile	35.4		21.7	17.5		
99th percentile	47.6		33.2	30.2		
No. > 200 µg/m3	0		0	0		
Data capture	97.9%		97.2%	97.8%		

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
Nitrogen dioxide 24-hour average µg/m^3						
Mean (annual)	14.1		6.3	5.4		
Maximum	36.6		25.5	17.6		
Median	13.3		5.3	4.3		
Std deviation	6.6		4.4	3.4		
25th percentile	9.1		2.7	2.8		
75th percentile	17.9		9.2	6.8		
95th percentile	26.2		14.6	12.3		
99th percentile	31.2		17.7	15.3		
No. > 100 µg/m^3	0		0	0		
Data capture	99.5%		98.9%	99.5%		

3.2 PM_{10} and $PM_{2.5}$ compliance monitoring

3.2.1 PM_{10} exceedances of National Environmental Standard

The NES-AQ for PM_{10} allows an airshed to exceed the threshold concentration of 50 µg/m^3 (24-hour average) on one day per 12 month period – known as a 'permissible exceedance'. Airsheds that average more than one exceedance per year are designated as polluted by the NES-AQ and new industries that seek resource consent to discharge PM_{10} into these airsheds may face restrictions.

The Masterton Urban airshed is the only one in the region that is designated as polluted (due to poor air quality in winter as a result of emissions from home fires). Table 3.2 shows the exceedance dates and concentrations measured at the two monitoring sites in Masterton. A total of six exceedance days meant there were five breaches of the NES-AQ in the airshed.

Table 3.2: PM_{10} NES-AQ exceedance days recorded in 2017

Date	Masterton (East) 24-hour average (µg/m^3)	Masterton (West) 24-hour average (µg/m^3)
22 May	56	
16 June		51
18 June	67	56
6 July	51	
11 July	70	56
30 July	57	
No. exceedances per site	5	3
TOTAL AIRSHED EXCEEDANCES	6	

3.2.2 $PM_{2.5}$ days above the WHO guideline

The WHO guideline value for $PM_{2.5}$ is 25 µg/m^3 expressed as a 24-hour average. Table 3.3 shows the dates when the concentration of $PM_{2.5}$ exceeded the 24-hour WHO guideline value. The WHO guideline allows three days per year to exceed the 24-hour guideline limit.

Over the 2017 winter period Masterton failed to meet the daily WHO guideline for $PM_{2.5}$ more frequently than the daily PM_{10} standard. Wood smoke mainly contains the smaller $PM_{2.5}$ sized particles so most of the PM_{10} measured on still winter nights is actually $PM_{2.5}$ particles, meaning it is easier to exceed the $PM_{2.5}$ daily limit of 25 µg/m^3 than the PM_{10} limit of 50 µg/m^3. $PM_{2.5}$ is a better indicator of health impacts across the population than PM_{10} because smaller particles are more damaging to health (World Health Organization, 2006).

Table 3.3: $PM_{2.5}$ days above WHO 24-hour guideline value recorded in 2017

Date	Masterton (East) 24-hour average (µg/m^3)	Masterton (West) 24-hour average (µg/m^3)	Wainuiomata 24-hour average (µg/m^3)
2 May	28.2		
7 May	27.5		
8 May	30.2		
14 May	35.9	26.0	
22 May	43.4	26.4	29.2
23 May	37.5	36.1	
25 May	30.2		
31 May		27.4	
4 June	26.0		
9 June	34.4	32.4	
10 June	26.5	25.8	
11 June	48.7	25.5	26.7
15 June	29.2	25.9	
16 June	39.2	39.1	
17 June	55.1		36.9
18 June	57.6	43.4	
19 June	31.0	26.9	
20 June	32.6		31.6
25 June	26.6		30.5
26 June	29.8		29.6
27 June	45.5	33.8	
28 June	26.3	26.8	
29 June	26.7		
3 July	34.4		

Date	Masterton (East) 24-hour average ($\mu g/m^3$)	Masterton (West) 24-hour average ($\mu g/m^3$)	Wainuiomata 24-hour average ($\mu g/m^3$)
4 July	31.6	25.9	
5 July	51.0	42.0	
6 July	54.7	38.1	
7 July	37.0	32.1	
8 July	36.1		
9 July	31.4	27.5	
10 July	25.8		
11 July	61.0	45.7	
15 July	30.0		
16 July	43.7	37.1	
18 July	26.6		
19 July	26.2		
24 July	36.6	28.3	
25 July	38.7	32.6	
26 July	28.0		
30 July	51.4	41.0	
3 August	31.0	27.1	
7 August		26.3	
24 August	37.9	29.5	
25 August	32.3	37.0	
26 August	28.2	30.8	
No. days above guideline per site	43	28	6
No. days above guideline per airshed	45		6
TOTAL BREACHES	42		3

3.3 Passive nitrogen dioxide monitoring results

Annual averages for nitrogen dioxide grouped by site type and monitoring zone are presented in Table 3.4. Monthly results for all sites monitored in 2017 are shown in Appendix 5.

Table 3.4: Annual average nitrogen dioxide (µg/m^3) by site type and zone (2017). Number of sites reported in brackets.

Zone	Urban background	Roadside	Peak	Average
Wellington	6.9 (2)	19.6 (3)	32.6 (6)	23.9 (11)
Hutt Valley	9.6 (3)	18.2 (4)	22.5 (3)	15.4 (10)
Porirua & Kāpiti	7.4 (1)	21.7 (3)	23.3 (1)	19.2 (5)
Masterton		16.2 (1)	13.5 (1)	14.9 (2)
Average	8.4 (6)	19.4 (11)	27.3 (11)	18.4 (28)

Acknowledgements

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Appendix 1: Air quality monitoring site metadata

Site Name	Lower Hutt			
Station	Birch Lane			
Hilltop site ID	108			
Location				
Address	Phil Evans Reserve, 46 Oxford Tce, Waterloo, Lower Hutt			
Map reference	Easting	Northing		
NZTM	1761032	5435863		
NZMG	2671054	5997577		
WGS84	Lat: -41.212603	Long: 174.920871		
Site details				
Site type	Residential / Commerical			
Airshed	Lower Hutt Valley			
Altitude	0 m			
Nearest Road	100 m			
Nearest Tree	10 m			
Site Classification (MfE, 2009)	Residential			
(AS/NZ 3580.1.1:2007)	Neighbourhood			
Parameters measured				
	Instrument		Start date	End date
PM_{10} (µg/m^3)	FH62		14/12/2010	
PM_{10} (µg/m^3)	TEOM		5/04/2001	13/12/2011
Carbon monoxide (ppm)	M300E		25/10/2001	11/01/2012
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E		13/08/2001	11/01/2012
Meteorological	RH, Temp, WS, WD, global solar radiation, rain, Barometric Pressure		25/10/2001	
Mast height	10m			
Internal temperature	25°C			
Data acquisition				
Sampling rate	AQ - 10 seconds, Met - 3 seconds			
Logger average	10-minute			
Logger	iQuest DS-4483		5/04/2001	2/06/2015
Logger	Campbell CR1000		2/06/2015	
Telemetry	GPRS			
Modem	iQuest ICE3			
ICP	0001395574UN55D			
Monitoring notes				
Passive NO_2 in triplicate measured by NZTA			Start date	End date
			1/03/2010	

Site Name	Masterton East		
Station	Chanel College		
Hilltop site ID	3579		
Location			
Address	Herbert Street	Masterton	
Map reference	Easting	Northing	
NZTM	1823279.81	5462375.21	
NZMG	2733294.01	6024095.93	
WGS84	Lat: -40.959262	Long: 175.653116	
Site details			
Site type	Type: Residential	Scale: Neighbourhood	
Airshed	Masterton Urban		
Altitude	105m		
Nearest Road	75m		
Nearest Tree	15m		
Site Classification (MfE, 2009)	Residential (peak)		
Parameters measured			
	Instrument	Start date	End date
PM_{10} (µg/m^3)	5014i	17/05/2012	
$PM_{2.5}$ (µg/m^3)	5014i + VSCC	2/12/2013	
Meteorological	RH, Temp, BP, WS, WD	11/05/2012	
Mast height	6m		
Internal temperature	25°C		
Data acquisition			
Sampling rate	AQ - 10 seconds, Met - 5 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483	11/05/2012	17/11/2015
Logger	Campbell CR1000	17/11/2015	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP			
Monitoring notes			
		Start date	End date
Fine and coarse PM measured by GNS Science	GENT	1/07/2010	1/09/2010

Site Name	Masterton West		
Station	Wairarapa College		
Hilltop site ID	2637		
Location			
Address	83 Pownall Street	Masterton	
Map reference	Easting	Northing	
NZTM	1822756	5463164	
NZMG	2732764	5463158	
WGS84	Lat: -40.952364	Long: 175.646546	
Site details			
Site type	Type: Residential	Scale: Neighbourhood	
Airshed	Masterton Urban		
Altitude	161m		
Nearest Road	124m		
Nearest Tree	5m		
Site Classification (MfE, 2009)	Residential		
(AS/NZ 3580.1.1:2007)	Neighbourhood		
Parameters measured			
	Instrument	Start date	End date
PM_{10} (µg/m^3)	5014i	17/12/2015	
	FH62 (inlet 40°C)	18/06/2007	16/12/2015
	5014i	25/05/2012	2/12/2013
	TEOM	9/10/2002	1/01/2011
	High Volume Sampler	17/04/2003	30/03/2005
$PM_{2.5}$ (µg/m^3)	5014i	11/12/2015	
	SHARP 5030	28/01/2011	10/12/2015
Carbon monoxide (ppm)	M300E	9/10/2002	
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E	1/01/2003	
Meteorological	Temp, WS, WD, RH, BP, soil moisture, soil temperature, rainfall, net solar radiation	4/06/2002	
Mast height	15m		
Internal temperature	25°C		
Data acquisition			
Sampling rate	AQ -10 seconds, Met-5 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483	9/10/2002	3/02/2014
Logger	Campbell CR1000	4/02/2014	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP			
Monitoring notes			
Fine and coarse PM measured by GNS Science	GENT	Start date	End date
		27/06/2002	3/11/2004

Site Name	Upper Hutt			
Station	Savage Park			
Hilltop site ID	2468			
Location				
Address	15 Savage Cres, Upper Hutt			
Map reference	Easting	Northing		
NZTM	1773804	5445684		
NZMG	2683825	6007400		
WGS84	Lat: -41.121549	Long: 175.070348		
Site details				
Site type	Type: Residential	Scale: Neighbourhood		
Airshed	Upper Hutt Valley			
Altitude	43 m			
Nearest Road	69 m			
Nearest Tree	11 m			
Site Classification (MfE, 2009)	Residential			
Parameters measured				
	Instrument		Start date	End date
PM_{10} ($\mu g/m^3$)	FH62		8/11/2005	
Carbon monoxide (ppm)	M300E		30/09/2005	
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E		19/09/2005	
Meteorological	RH, Air Temp, Soil Temp, WS, WD, solar radiation, rain, Barometric Pressure		14/09/2005	
Mast height	10m			
Internal temperature	25°C			
Data acquisition				
Sampling rate	AQ - 10 seconds, Met - 5 seconds			
Logger average	10-minute			
Logger	iQuest DS-4483		14/09/2005	27/06/2013
	Campbell CR1000		28/06/2013	
Telemetry	GPRS			
Modem	iQuest ICE3			
ICP				
Monitoring notes				
Passive NO_2 in triplicate measured by NZTA			Start date	End date
			1/03/2010	1/11/2012

Site Name	Wainuiomata	
Station	Wainuiomata Bowling Club	
Hilltop site ID	2579	

Location		
Address	Moohan Street	Wainuiomata
Map reference	Easting	Northing
NZTM	1763651	5429685
NZMG	2673674	5991399
WGS84	Lat: -41.267695	Long: 174.953745

Site details		
Site type	Type: Residential	Scale: Neighbourhood
Airshed	Wainuiomata	
Altitude	80m	
Nearest Road	20m	
Nearest Tree	10m	
Site Classification (MfE, 2009)	Residential	

Parameters measured	Instrument	Start date	End date
PM_{10} (µg/m^3)	FH62 (inlet 40°C)	30/06/2006	
$PM_{2.5}$ (µg/m^3)	FH62 + VSCC (inlet 40°C)	1/05/2012	
PM_{10} (µg/m^3)	High Volume Sampler	20/09/2000	6/10/2007
Meteorological	RH, Aiir Temp, Soil Temp, WS, WD, BP, solar radiation, soil moisture	1/01/2005	
Mast height	10m		
Internal temperature	25°C		

Data acquisition			
Sampling rate	AQ - 10 seconds, Met - 3 seconds		
Logger average	10-minute		
Logger - Met	iQuest DS-4483	20/09/2000	23/06/2015
Logger - Met	Campbell CR1000	23/06/2015	
Logger - AQ	iQuest DS-4483	30/06/2006	6/07/2015
Logger - AQ	Campbell CR1000	6/07/2015	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP	0001454109UN341		

Monitoring notes		Start date	End date
Fine and coarse PM measured by GNS Science	GENT	1/09/2006	25/09/2008
Inorganic arsenic	High Volume sampler PM_{10}	25/10/2011	31/10/2013

Site Name	Wellington central		
Station	Willis Street AQ		
Hilltop site ID	4795		
Location			
Address	Intersection Wellington urban motorway and Willis Street, Te Aro, Wellington		
Map reference	Easting	Northing	
NZTM	1748360	5427132	
NZMG	2658382	5988844	
WGS84	Lat: -41.293625	Long: 174.771919	
Site details			
Site type	Peak transport		
Airshed	Wellington City		
Altitude	24m		
Nearest Road	8m		
Nearest Tree	30m		
Site classification (MfE, 2009)	Traffic		
(AS/NZ 3580.1.1:2007)	Peak transport		
	Mobile station	*Fixed station*	
Parameters measured			
	Instrument	Start date	End date
PM_{10} (µg/m^3)	FH62 (mobile station)	20/01/2015	14/09/2015
PM_{10} (µg/m^3)	SHARP 5030 (fixed station)	8/01/2016	
$PM_{2.5}$ (µg/m^3)	SHARP 5030 (fixed station)	8/01/2016	
Carbon monoxide (ppm)	M300E (mobile station)	20/01/2015	14/09/2015
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E (mobile station)	20/01/2015	14/09/2015
Carbon monoxide (ppm)	M300E (fixed station)	17/12/2015	
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E (fixed station)	16/12/2015	
Black carbon (ng/m3)	AE33 (fixed station)	5/10/2016	
Meteorological	RH (%), Temperature (°C), Wind speed (m/s), Wind direction (degrees), Barometric Pressure	5/01/2016	
Mast height	4m		
Internal temperature	25°C		
Data acquisition			
Sampling rate	AQ -10 seconds, Met - 3 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483	20/01/2015	14/09/2015
Logger	Campbell CR1000	3/12/2015	
Telemetry	GPRS		
Modem	iQuest ICE3		
ICP	0001441727UN448		
Monitoring notes			
Passive NO_2 in triplicate measured by NZTA		1/01/2015	
Black carbon measured by NIWA		10/03/2015	

Appendix 2: Air quality indicators, methods and reporting units

Carbon monoxide

Carbon monoxide (CO) is a colourless and odourless gas produced by the incomplete combustion of carbon-containing fuels such as petrol and diesel used in motor vehicles, or wood and coal used for domestic heating or in industrial boilers. Motor vehicles are the main source of carbon monoxide in urban areas.

When inhaled, carbon monoxide reduces the oxygen carrying capacity of the blood and, depending on its concentration, causes a range of adverse health effects.

Nitrogen dioxide

Nitrogen dioxide (NO_2) arises from combustion processes, with vehicle emissions being the main source in urban areas. Vehicle exhausts contain a mixture of nitrogen dioxide and nitric oxide (NO), collectively known as oxides of nitrogen (NOx). Most of the NOx discharged from vehicle exhausts is in the form of nitric oxide which is subsequently converted to nitrogen dioxide by oxidation.

Nitrogen dioxide appears as a brown gas in the atmosphere and can be seen as a haze over some cities during periods of calm weather and heavy traffic congestion. As well as contributing to poor visibility, nitrogen dioxide has adverse health effects such as lung inflammation and eye, nose and throat irritation.

Particulate matter

Particulate matter (PM) is a mixture of airborne solid particles and liquid droplets. Particulate matter concentrations are typically classified by particle size. PM_{10} includes all particles smaller than 10 microns (μm) in diameter and $PM_{2.5}$ includes all particles smaller than 2.5 μm in diameter.

PM arises from human activities and natural sources. Sources of PM in the Wellington Region include:

- Domestic solid fuel heating (eg, wood burners)
- Motor vehicles, particularly diesel vehicles
- Industrial combustion processes
- Quarrying activities
- Natural sources such as sea salt and wind-blown soil particles.

Domestic fires and vehicles produce very fine particles less than 2.5 microns in diameter ($PM_{2.5}$). Road dust and natural sources (such as sea salt and soil) produce particles that are typically larger than 2.5 microns and are commonly described as the 'coarse' fraction of PM_{10}.

Epidemiological studies show adverse health effects from both short-term and long-term exposure to PM_{10}. However, a threshold below which there are no observed adverse effects has not been reliably established to date (World Health Organization, 2006). The adverse health effects associated with exposure to PM_{10} range from increases in the number of restricted activity days to increases in hospital admissions and premature deaths for people with existing lung and heart disease. The fine component of PM_{10} (ie,

$PM_{2.5}$) is more strongly associated with harmful health impacts because the smaller the particle the deeper it can penetrate into the lungs.

Data capture and reporting

All pollutants are measured continuously with instruments that are connected by digital interface to data loggers. Ambient air is sampled at 10 to 20 second intervals (depending on the number of instruments at a site) and these measurements are reported as 10-minute averages at New Zealand Standard Time (NZST). These 10-minute averages are then aggregated to hourly averages where there is at least 75% data capture (ie, at least five 10-minute averages must be present for a 1-hour average to be considered valid and included in the data set). Hourly averages apply to the preceding hour (eg, a 1-hour average at 17:00 refers to data collected between 16:00 and 16:59).

PM_{10} 24-hour averages are calculated from 1-hour averages between midnight to midnight (00:00 to 23:59) and require at least 18 hours of data for each 24-hour period to be included in the data set. PM_{10} values are rounded up to the nearest whole number for reporting purposes in accordance with MfE (Ministry for the Environment, 2009) recommendations. An exceedance of the NES-AQ is therefore 51 $\mu g/m^3$ or higher.

For comparison with the NES-AQ for carbon monoxide, 8-hour moving means are calculated on the hour for the preceding 8-hour period using 1-hour averages. At least 6 hours (ie, at least 75% data capture) must be present for an 8-hour mean to be considered valid and included in the data set. Carbon monoxide 8-hour moving means and nitrogen dioxide 1-hour averages are rounded to one decimal place for reporting purposes in accordance with MfE (Ministry for the Environment, 2009) recommendations.

Measurement methods

Variable	Instrument	Method	Units
PM_{10}	Thermo Andersen series FH62 C14 beta attenuation monitor and Thermo Scientific 5014i beta attenuation monitor	Automated method equivalent to the United States Code of Federal Regulations (CFR)[6] EQPM-1102-150 Method 9.11: Determination of suspended particulate matter – PM_{10} beta attenuation monitors in accordance with AS/NZS 3580.9.11:2008	$\mu g/m^3$
$PM_{2.5}$	Thermo Scientific 5030 SHARP monitor + Very Sharp Cut Cyclone particle size separator	EQMP-0609-184[7] Method 9.12: Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors in accordance with AS/NZS 3580.9.12:2013	$\mu g/m^3$
$PM_{2.5}$	Thermo Andersen series FH62 C14 beta attenuation monitor + Very Sharp Cut Cyclone particle size separator.	Does not have USEPA equivalency	$\mu g/m^3$

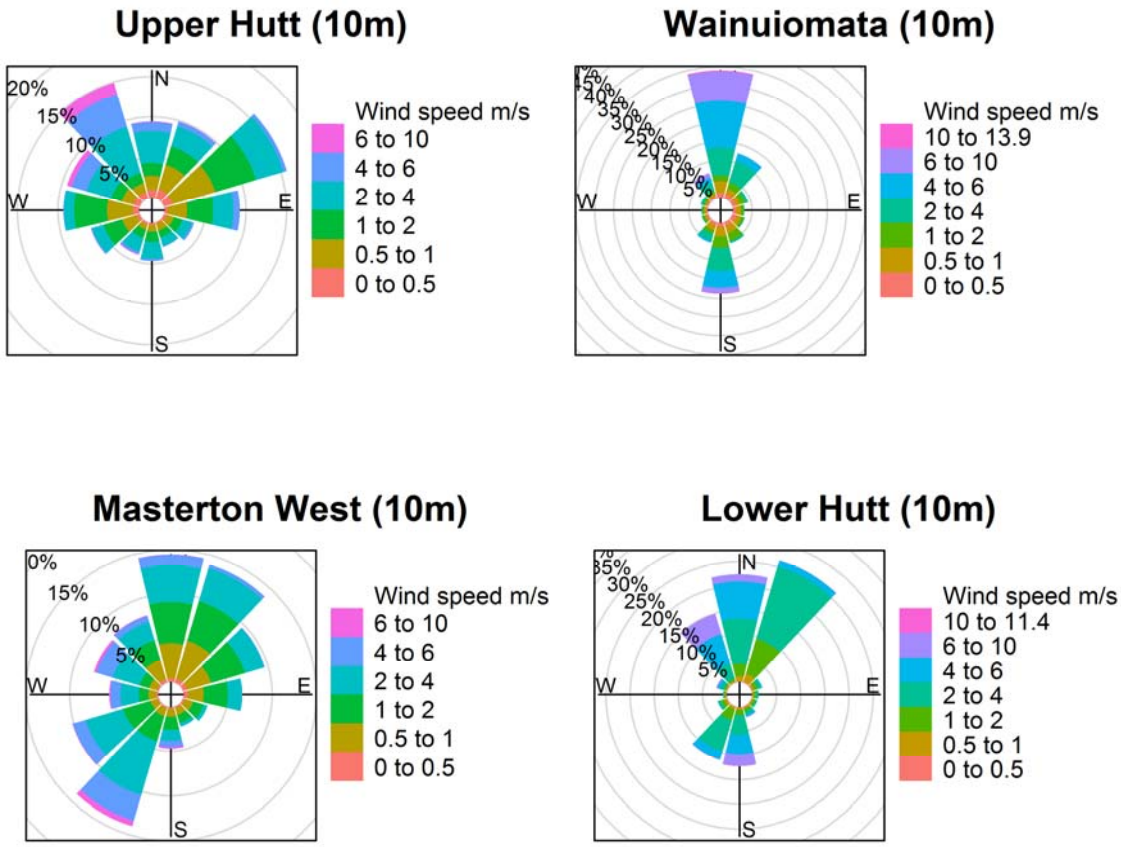
[6] Title 40 – Protection of the Environment, Volume 2, Part 50, Appendix J: Reference Method for the Determination of Particulate Matter as PM_{10} in the Atmosphere.
[7] Title 40 – Protection of the Environment, Volume 2, Part 50, Appendix L: Reference Method for the Determination of Fine Particulate Matter as $PM_{2.5}$ in the Atmosphere.

$PM_{2.5}$	Thermo Andersen 5014i + Very Sharp Cut Cyclone particle size separator.	EQPM-0609-183 Method 9.12: Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors in accordance with AS/NZS 3580.9.12:2013	µg/m^3
Carbon monoxide	API 300 series analysers	Gas Filter Correlation Infrared in accordance with AS 3580.7.1:2011 Method 7.1: Determination of carbon monoxide – Direct-reading instrumental method	Parts per million (ppm) converted to mg/m^3 by multiplying by 1.25 (0^oC)
Nitrogen dioxide	API 200 series analysers	Chemiluminescence in accordance with AS 3580.5.1:2011 Method 5.1: Determination of oxides of nitrogen – Direct-reading instrumental method	Parts per billion (ppb) and is converted to µg/m^3 by multiplying by 2.05 (0^oC)

Appendix 3: Wind roses

The below wind roses were created using R statistical software (R Core Team, 2015) and the 'openair' package (Carslaw and Ropkins, 2015). They show the proportion (percentage) of time that the wind is coming from a particular angle (30^{o} increments) and wind speed range (shown on the right-hand scale in metres per second). The wedge points towards the direction the wind is blowing from.

Figure A3.1: Wind roses showing wind speed (m/s) and direction recorded at air quality monitoring stations during 2017 (mast height is shown in brackets)



Appendix 4: Passive NO_2 monitoring sites 2017

NZTA site Identifier	Area	Location	GWRC classification	Site sponsor	NZTM E	NZTM N
WEL003	Lower Hutt	Riddlers Cres, Petone	Roadside	NZTA	1757206	5435187
WEL008	Wellington	Basin Reserve	Peak	NZTA	1748917	5426328
WEL048	Wellington	Island Bay	Urban background	NZTA	1748544	5422507
WEL049	Wellington	Riddiford/Mein Street	Peak	NZTA	1748907	5425194
WEL050	Wellington	Kilbirnie (on SH1)	Peak	NZTA	1750102	5425039
WEL052	Lower Hutt	Boulcott	Roadside	NZTA	1759667	5436831
WEL053	Lower Hutt	Knights Road	Peak	NZTA	1759934	5436058
WEL054	Lower Hutt	Birch Lane, GWRC site	Urban background	NZTA	1761034	5435864
WEL063	Kapiti	Rimutaka Street, Paraparaumu	Roadside	NZTA	1769627	5469035
WEL072	Porirua	Papakowhai, Porirua	Urban background	NZTA	1756584	5446972
WEL073	Wellington	Willis Street/urban motorway	Peak	NZTA	1748360	5427134
WEL078	Lower Hutt	Manor Park	Roadside	NZTA	1766009	5441920
WEL079	Lower Hutt	Cuba Street, Petone	Roadside	GWRC	1758286	5434987
WEL080	Porirua	Titahi Bay Rd	Roadside	GWRC	1754261	5444566
WEL081	Wellington	Lambton Quay, CBD	Peak	GWRC	1748671	5428257
WEL082*	Wellington	Manners Street, CBD	Special	GWRC	1748752	5427413
WEL083	Wellington	Courtney Place, CBD	Peak	GWRC	1748971	5427223
WEL084	Wellington	Thorndon Quay, Pipitea	Roadside	GWRC	1749266	5429488
WEL085	Wellington	Morefield Rd, Johnsonville	Roadside	GWRC	1751000	5434368
WEL086	Wellington	Wakefield St, CBD	Roadside	GWRC	1748788	5427570

WEL087	Otaki	Rahui Road/SH intersection, Otaki	Peak	GWRC	1782151	5485622
WEL088	Porirua	Johnsonville-Porirua motorway (SH1)	Roadside	GWRC	1756620	5447614
WEL089	Masterton	High Street, Masterton	Roadside	GWRC	1822056	5462296
WEL090	Lower Hutt	High St, Lower Hutt	Peak	GWRC	1759910	5436507
WEL091	Lower Hutt	Mills St, Lower Hutt	Urban background	GWRC	1760457	5437045
WEL092	Upper Hutt	Clyma St, Upper Hutt	Urban background	GWRC	1772716	5445683
WEL093	Upper Hutt	Main St, Upper Hutt	Peak	GWRC	1773935	5445382
WEL094	Wellington	Rudyard Cres, Johnsonville	Urban background	GWRC	1750737	5434617
WEL095	Masterton	Queen St, Masterton	Peak	GWRC	1823884	5463277
WEL096	Masterton	Masters Cres, Masterton	Urban background	GWRC	1822228	5463481
WEL097*	Wellington	Stewart Duff Dr, Airport	Special	GWRC	1751411	5422387
WEL098*	Wellington	Moa Point Rd, Airport	Special	GWRC	1751295	5422399

*Not included in annual GWRC RLTP reporting summary

Appendix 5: Passive NO_2 monitoring results 2017

Table A5.1: Passive NO_2 monitoring results 2017, with estimated annual averages* where data capture below 75%. Note data from these sites is provisional until NZTA publishes the Annual ambient air quality (nitrogen dioxide) monitoring network annual report 2007-17.

NZTA site Identifier	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
WEL003	9.5	14.0	16.4	18.0	22.6	27.7	18.0	16.7	16.0	13.1	12.8	Missing	16.8
WEL008	31.8	42.5	40.0	41.6	47.4	49.8	Missing	40.6	39.2	41.0	29.1	Missing	40.3
WEL048	5.7	7.9	7.9	8.9	11.2	13.1	10.3	9.2	Missing	6.3	6.4	6.0	8.4
WEL049	26.6	37.6	42.9	42.2	48.1	51.4	45.2	39.8	22.7	36.4	40.6	23.1	38.1
WEL050	13.1	20.1	17.0	20.5	25.2	27.4	20.4	19.9	12.5	17.0	20.0	13.8	18.9
WEL052	12.0	16.7	25.3	26.6	29.0	37.5	24.8	25.4	23.0	18.2	17.5	14.6	22.6
WEL053	19.1	20.1	20.9	23.4	30.8	32.1	23.8	27.4	24.6	22.2	18.0	13.1	23.0
WEL054	6.7	7.7	13.3	13.1	19.3	20.3	15.5	13.3	11.7	6.0	9.1	7.4	12.0
WEL063	13.4	10.7	8.8	Invalid	13.1	13.7	9.5	9.0	8.1	Missing	7.9	5.5	10.0
WEL072	5.1	7.1	7.3	8.0	10.0	11.3	8.9	7.0	7.6	5.4	5.7	5.6	7.4
WEL073	15.2	20.7	23.8	23.0	26.3	31.0	24.8	19.7	20.6	19.7	16.3	14.1	21.3
WEL078	8.9	13.6	15.6	15.3	22.5	25.3	16.8	16.2	13.3	10.0	10.6	8.6	14.7
WEL079	11.2	17.8	18.6	20.9	24.8	26.4	24.7	18.5	19.3	16.4	14.5	12.2	18.8
WEL080	12.2	20.4	24.7	24.9	28.0	30.2	23.2	25.3	22.9	19.2	15.8	14.3	21.8
WEL081	29.3	39.9	38.7	37.8	45.5	49.1	50.7	Missing	45.1	38.3	31.2	27.5	39.4
WEL082	33.2	42.0	41.7	43.9	44.8	50.3	47.4	Missing	45.5	41.4	40.4	35.2	42.3
WEL083	26.5	37.0	37.1	40.8	43.6	46.7	43.2	36.7	39.8	34.6	33.3	29.9	37.4
WEL084	14.8	23.0	25.4	22.0	28.6	33.1	30.8	24.8	24.2	22.3	18.1	16.6	23.6

WEL085	7.1	12.3	12.8	13.4	16.1	17.6	15.6	11.8	12.0	8.1	8.7	8.1	12.0
WEL086	14.2	21.5	25.6	22.3	27.7	30.5	27.9	23.7	21.1	20.4	19.2	Missing	23.1
WEL087	19.0	20.1	22.6	24.5	25.4	24.3	26.7	26.7	26.2	26.0	15.7	22.0	23.3
WEL088	21.6	Missing	32.8	35.8	38.7	39.5	37.8	35.8	34.9	30.7	34.1	26.1	33.4
WEL089	7.9	14.0	17.2	16.8	20.9	26.0	20.3	19.5	13.9	13.8	13.7	10.1	16.2
WEL090							32.0	30.6	27.2	24.9	25.1	21.1	27.6*
WEL091							14.9	11.1	9.0	8.4	8.8	6.8	10.0*
WEL092							10.3	9.0	7.2	4.8	6.4	4.7	7.1*
WEL093							19.8	19.7	17.8	15.9	15.3	Missing	17.2*
WEL094								6.5	5.4	5.5	6.6	5.6	5.4*
WEL095								22.8	17.5	16.1	15.9	5.8	13.5*
WEL096								9.6	6.8	7.0	Missing	12.8	NA
WEL097									19.6	19.4	12.2	9.6	NA
WEL098											12.3	13.8	NA