greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Air Quality State of the Environment monitoring programme

Annual data report, 2014

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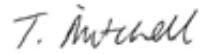
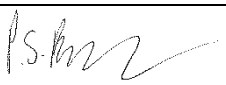
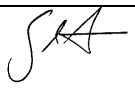
Report prepared by:	T Mitchell	Team Leader, Air and Climate	
Report reviewed by:	P Fairbrother	Senior Science Coordinator	
Report approved for release by:	G Sevicke-Jones	Manager, Environmental Science	 **Date**: June 2015

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Contents

1. Introduction

This report summarises the key results from the Air Quality State of Environment (AQSoE) monitoring programme for the period 1 January to 31 December 2014 inclusive. The core programme is based on continuous monitoring of air quality indicators and selected meteorological variables at five permanent sites across the Wellington region.

2. Overview of AQSoE monitoring programme

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 urban area.

2.1 Monitoring objectives

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

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

2. Detect of spatial and temporal trends in air quality;

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

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

2.2 Monitoring network

2.2.1 Regional airsheds

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

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

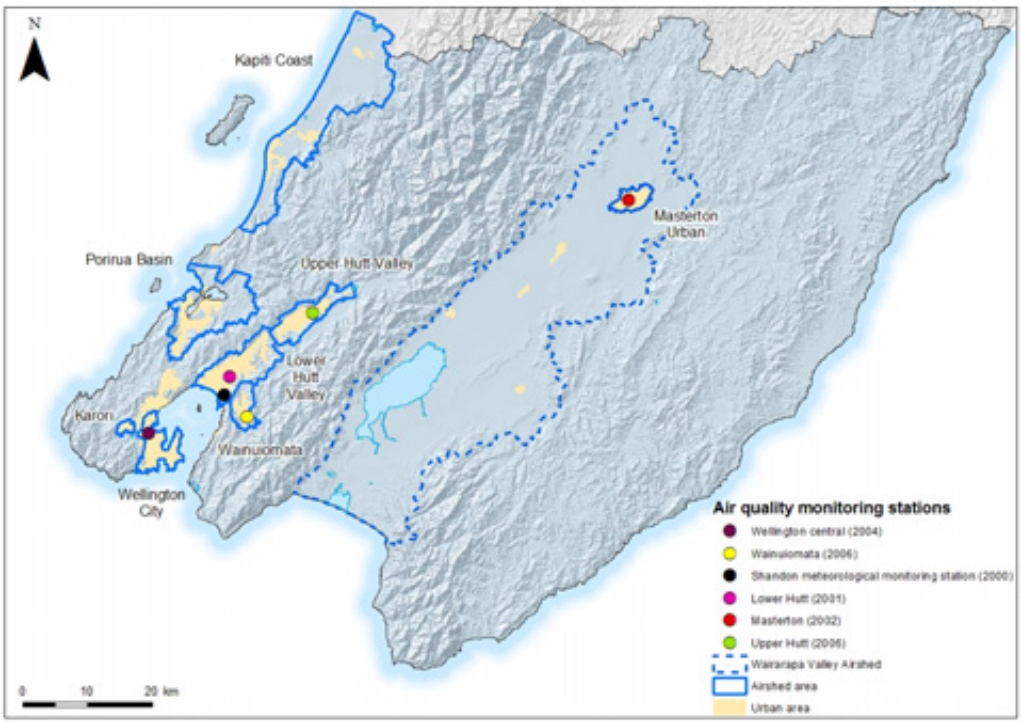

Figure 2.1: Location of GWRC air quality and meteorological monitoring sites and airshed boundaries

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 are have adverse human health effects when concentrations in air are elevated. The air quality indicators measured at each site are shown in Table 2.1.

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.

Table 2.1: Air quality monitoring sites operated in the 2014 calendar year

Site	Station	Airshed	Location	Indicators monitored	Valid data from
Wellington central	Corner V	Wellington City	Corner Victoria & Vivian Streets	PM_{10}, CO	2004-2014
				NOx	2005-2014
Lower Hutt	Birch Lane	Lower Hutt Valley	Phil Evans Reserve	PM_{10}	2001
				CO, NOx	2001-2011
Wainuiomata	Wainuiomata Bowling Club	Wainuiomata	Moohan Street	PM_{10}	2006
				$PM_{2.5}$	2012
Upper Hutt	Savage Park	Upper Hutt Valley	Savage Crescent	PM_{10}, CO, NOx	2006
Masterton West (permanent site)	Wairarapa College	Wairarapa Valley	Cornwell Street	PM_{10}, CO	2002
				NOx	2003
				$PM_{2.5}$	2011
Masterton East (non-permanent site)	Chanel College	Wairarapa Valley	Herbert Street	PM_{10}	2012
				$PM_{2.5}$	2013
Shandon	Shandon golf course	Lower Hutt Valley	Gear Island, Petone	Meteorological parameters only	2000

The Wellington central site was decommissioned in November 2014 as Wellington City Council required the site as part of the Victoria Street improvement project. A mobile monitoring station was set up in January 2015 on the corner of Willis Street and the urban motorway. Site metadata are presented in Appendix 1. Further information on air quality indicators monitored and measurement methods are provided in Appendix 2. Wind roses showing summaries of wind speeds and wind direction observations at each site are presented in Appendix 3.

2.4 Air quality assessment criteria and reporting

2.4.1 National environmental standards and guidelines for air quality

National ambient air quality guidelines[2] (NAAQG) were established by the Ministry for the Environment (MfE) in 1994 and revised in 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 or guidelines currently available for $PM_{2.5}$, although a monitoring value of 25 $\mu g/m^3$ (24-hour average) can be used for assessing monitoring results (MfE 2002). In the absence of New Zealand

[2] Ambient air quality guidelines 2002 update

health-based guidelines, World Health Organisation (WHO) guidelines[3] are used for assessing the environmental significance of $PM_{2.5}$ monitoring results.

The relevant standards and guidelines for air quality indicators measured in the Wellington region are shown in Table 2.2.

Table 2.2: 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
PM_{10}	NAAQG	20 µg/m^3	Annual	NA
$PM_{2.5}$	WHO Guideline	25 µg/m^3	24-hour	3
$PM_{2.5}$	WHO Guideline	10 µg/m^3	Annual	NA
Carbon monoxide	NES-AQ	10 mg/m^3	8-hour moving	6
Carbon monoxide	NAAQG	30 mg/m^3	1-hour	0
Nitrogen dioxide	NES-AQ	200 µg/m^3	1-hour	9
Nitrogen dioxide	NAAQG	100 µg/m^3	24-hour	0
Nitrogen dioxide	WHO Guideline	40 µg/m^3	Annual	NA

[3] WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide – global update 2005

3. Results

Summary statistics for air quality indicators measured during the 2014 year are presented in Table 3.1. Protocols for data capture and reporting are presented in Appendix 2.

Table 3.1: Air quality indicator summary statistics, 2014

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
PM_{10} 24-hour average µg/m^3						
Mean (annual)	13.1*	10.7	10.2	11.9	16.6*	10.3
Maximum	32	27	26	50	78	34
Median	12	10	10	9	12	9
Std deviation	4.3	4.4	4.5	8.2	13.6	5.2
25th percentile	10	8	7	7	8	7
75th percentile	15	13	13	14	20	13
95th percentile	20	19	19	29	45	20
99th percentile	26	24	22	42	69	27
No. > 50	0	0	0	0	13	0
Data capture %	88.8	99.2	99.2	99.5	89.3	99.2
$PM_{2.5}$ 24-hour average µg/m^3						
Mean (annual)				10.5	11.5	6.0
Maximum				59	67	37
Median				7	7	4
Std deviation				9.7	12.2	5.1
25th percentile				5	4	3
75th percentile				12	12	6
95th percentile				31	38	18
99th percentile				45	59	29
No. > 25				31	47	5
Data capture %				98.1	95.3	99.2
Carbon monoxide 8-hour moving average mg/m^3						
Mean (annual)	0.4		0.2	0.2		
Maximum	1.5		1.4	2.3		
Median	0.3		0.1	0.1		
Std deviation	0.22		0.19	0.29		
25th percentile	0.2		0.1	0.1		
75th percentile	0.5		0.2	0.2		
95th percentile	0.8		0.6	0.8		

* Less than 75% data capture for the summer period (December to February inclusive) may bias the mean upwards.

	Wellington central	Lower Hutt	Upper Hutt	Masterton West	Masterton East	Wainuiomata
99th percentile	1.1		1.0	1.5		
Data capture %	90.1		97.6	99.0		
Carbon monoxide 1-hour average mg/m3						
Mean (annual)	0.4		0.2	0.2		
Maximum	2.8		2.5	3.3		
Median	0.3		0.1	0.1		
Std deviation	0.28		0.23	0.34		
25th percentile	0.2		0.1	0.1		
75th percentile	0.5		0.2	0.2		
95th percentile	0.9		0.7	0.9		
99th percentile	1.4		1.2	1.9		
Data capture %	90.1		97.6	98.4		
Nitrogen dioxide 1-hour average µg/m3						
Mean (annual)	19.7		5.7	4.5		
Maximum	86.6		41.7	42.5		
Median	17.6		3.3	2.6		
Std deviation	12.81		6.33	5.48		
25th percentile	9.6		1.5	1.1		
75th percentile	28.0		7.2	5.5		
95th percentile	43.8		19.7	16.4		
99th percentile	54.5		29.8	27.1		
Data capture %	88.6		97.0	97.5		
Nitrogen dioxide 24-hour average µg/m3						
Mean (annual)	19.7		5.7	4.5		
Maximum	42.5		21.4	18.7		
Median	19.3		4.4	3.4		
Std deviation	8.02		4.07	3.41		
25th percentile	13.3		2.4	2.1		
75th percentile	25.4		8.7	5.8		
95th percentile	33.2		12.8	11.1		
99th percentile	38.5		16.5	14.7		
Data capture %	89.3		98.6	98.4		

3.1 PM_{10} exceedances

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 as 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 Masterton in the winter as a result of emissions from home fires). Table 4.1 shows the exceedance dates and concentrations measured at the two monitoring sites in Masterton. A total of 13 exceedances meant there were 12 breaches of the NES-AQ in the airshed.

Table 4.1: PM_{10} NES-AQ exceedance days recorded in Masterton, 2014

Date	Masterton (East) 24-hour average (µg/m^3)	Masterton (West) 24-hour average (µg/m^3)
17 May	53	< 50
18 May	55	< 50
27 May	57	< 50
28 May	69	≤ 50
6 June	53	< 50
13 June	78	< 50
14 June	55	< 50
15 June	60	< 50
20 June	70	< 50
23 June	54	< 50
4 July	67	< 50
7 July	54	< 50
10 August	72	< 50
TOTAL EXCEEDANCES	**13**	**0**

3.2 $PM_{2.5}$ 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 4.2 shows the dates when the concentration of $PM_{2.5}$ in Masterton exceeded the 24-hour WHO guideline value. In 2014, Masterton experienced 51 days in total that exceeded the WHO 24-hour guideline value based on combined monitoring results from Masterton West and Masterton East monitoring stations[4].

[4] Note an exceedance recorded at both stations on the same day is counted as a single exceedance.

Table 4.2: $PM_{2.5}$ days above WHO 24-hour guideline value in Masterton, 2014

Date	Masterton East 24-hour average (µg/m³)	Masterton West 24-hour average (µg/m³)
23 April	27	36
1 May	< 25	27
2 May	No data	29
3 May	39	29
10 May	29	< 25
11 May	37	29
12 May	28	< 25
13 May	28	32
17 May	47	31
18 May	53	43
19 May	40	38
20 May	33	≤ 25
27 May	49	40
28 May	No data	59
31 May	39	36
1 June	40	28
3 June	28	31
4 June	27	≤ 25
5 June	37	44
6 June	46	43
7 June	31	31
8 June	< 25	≤ 25
9 June	< 25	26
10 June	26	< 25
13 June	62	49
14 June	43	34
15 June	59	55
18 June	≤ 25	< 25
20 June	59	35
23 June	48	34
24 June	28	< 25
29 June	30	< 25
3 July	36	< 25
4 July	67	37

Date	Masterton East 24-hour average (µg/m^3)	Masterton West 24-hour average (µg/m^3)
7 July	48	36
18 July	30	≤ 25
24 July	34	< 25
25 July	29	< 25)
26 July	35	29
27 July	26	< 25
28 July	29	27
29 July	37	29
4 August	27	26
5 August	56	< 25
6 August	39	< 25)
7 August	30	< 25
10 August	62	46
11 August	32	< 25
18 August	30	< 25
19 August	30	< 25
31 August	34	26
1 September	36	< 25
21 September	27	< 25
TOTAL ABOVE GUIDELINE	**47**	**31**

Acknowledgements

The work of Darren Li in operating and maintaining monitoring equipment and stations is gratefully acknowledged.

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Appendix 1: Monitoring site metadata

Site Name	**Wellington central**		
Station	Corner V		
Hilltop site ID	215		
Location			
Address	Intersection Victoria and Vivian Street, Te Aro, Wellington		
Map reference	Easting	Northing	
NZTM	1748461	5427084	
NZMG	2658483	5997577	
WGS84	Lat: -41.294045	Long: 174.773121	
Site details			
Site type	Peak transport		
Airshed	Wellington City		
Altitude	19m		
Nearest Road	7m		
Nearest Tree	9-10m		
Site classification (MfE, 2009)	Traffic		
(AS/NZ 3580.1.1:2007)	Peak transport		

Parameters measured			
	Instrument	Start date	End date
PM_{10} ($\mu g/m^3$)	FH62	23/03/2004	28/11/2014
Carbon monoxide (ppm)	M300E	12/03/2004	28/11/2014
Nitrogen oxides (NO, NO_2, NOx) (ppb)	M200E	29/03/2005	28/11/2014
Meteorological	RH (%), Temperature (°C), Wind speed (m/s), Wind direction (degrees)	11/03/2004	28/11/2014
Mast height	4m		
Internal temperature	25°C		

Data acquisition	
Sampling rate	10 seconds
Logger average	10-minute
Logger	iQuest DS-4483
Telemetry	GPRS
Modem	iQuest ICE3
ICP	0001441727UN448

Monitoring notes		
Passive NO_2 in triplicate measured by NZTA	Start date	End date
	1/01/2009	28/11/2014

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	25/10/2001	
Mast height	10m		
Internal temperature	25°C		

Data acquisition	
Sampling rate	10 seconds
Logger average	10-minute
Logger	iQuest DS-4483
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	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		
Nearest Tree		
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, Temp, WS, WD, BP, solar radiation, soil moisture	1/01/2005	
Mast height	10m		
Internal temperature	25°C		

Data acquisition	
Sampling rate	10 seconds
Logger average	10-minute
Logger	iQuest DS-4483
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	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} (µg/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, Temp, WS, WD, solar radiation, rain	14/09/2005	
Mast height	10m		
Internal temperature	25°C		

Data acquisition			
Sampling rate	10 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483		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	Masterton West		
Station	Wairarapa College		
Hilltop site ID	2637		
Location			
Address	83 Cornwall 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)	FH62 (inlet 40°C)	18/06/2007	
$PM_{2.5}$ (µg/m^3)	SHARP 5030	28/01/2011	
PM_{10} (µg/m^3)	TEOM	9/10/2002	1/01/2011
PM_{10} (µg/m^3)	5014i	25/05/2012	2/12/2013
PM_{10} (µg/m^3)	High Volume Sampler	17/04/2003	30/03/2005
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	10 seconds		
Logger average	10-minute		
Logger	iQuest DS-4483		3/02/2014
	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	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			
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, WS, WD	11/05/2012	
Mast height	6m		
Internal temperature	25°C		

Data acquisition	
Sampling rate	10 seconds
Logger average	10-minute
Logger	iQuest DS-4483
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

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 solid particles and liquid droplets that are dispersed in air. PM_{10} is that portion of particulate matter with an equivalent aerodynamic cross section less than 10 microns. Particles of this size are easily inhaled into the respiratory system.

PM arises from human activities and from natural sources. Sources of PM_{10} 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 (WHO 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, $PM_{2.5}$) causes the most

harm to people's health because the smaller the particle the deeper it can penetrate into the lungs.

Data capture and reporting

All pollutants at GWRC's long-term air quality monitoring sites 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 (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 significant figure for reporting purposes in accordance with MfE (2009) recommendations.

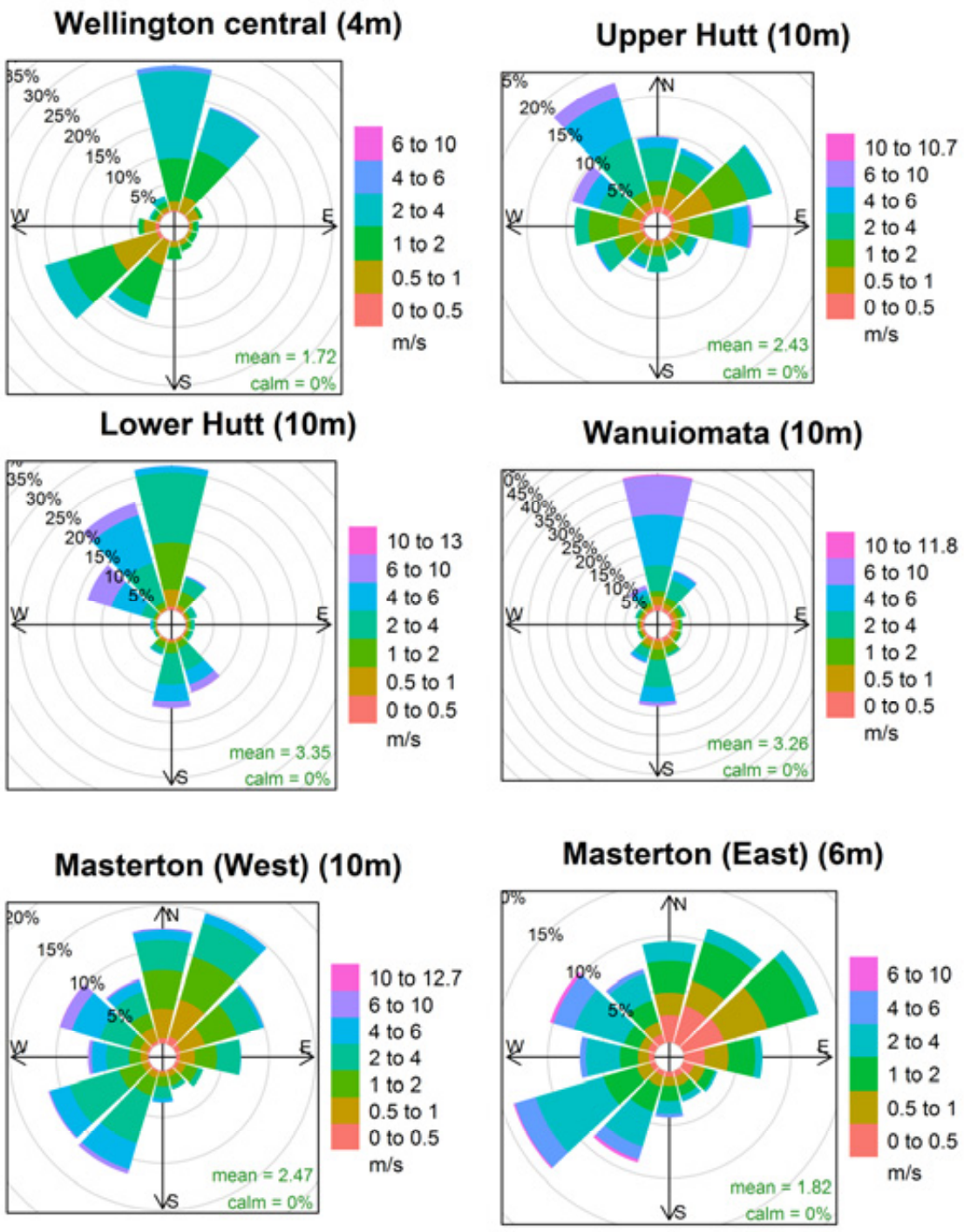
Measurement methods

Variable	Instrument	Method	Units
PM_{10}	Thermo Andersen series FH62 C14 beta attenuation monitor	Automated method equivalent to the United States Code of Federal Regulations (CFR)5 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-0609-1846 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	$\mu g/m^3$
$PM_{2.5}$	Thermo Andersen 5040i + 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	$\mu g/m^3$
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 $\mu g/m^3$ by multiplying by 2.05 (0^oC)

[5] 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.
[6] 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.

Appendix 3: Wind roses by monitoring site

A3.1: Wind roses showing wind speed and direction recorded at air quality monitoring stations during 2014 with mast height in brackets



The wind roses were created using R statistical software (R Core Team. 2015) using the 'openair' package (Carslaw & 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.