Yaldhurst Air Quality Monitoring

Summary Report: 22 December – 21 April 2018

Summary Report

19 June 2018

Prepared for
Environment Canterbury

by Paul Baynham

www.mote.io

Summary Report 22December 2017 - 21 April 2018

19 June 2018

Client: Environment Canterbury

Prepared by:

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Revision History

No.	Date	Author(s)	Reviewer(s)	Details
1	20 May 2018	**Paul Baynham** Senior Air Quality Specialist (Mote)	**Brett Wells** Managing Director (Mote) **Louise Wickham** Director & Senior Air Quality Specialist (EIL)	Draft report to client for comment
2	8 June 2018			Draft 2
3	14 June 2018			Draft 3
4	16 June 2018			Draft 4
5	18 June 2018			Draft 5
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Executive summary

In May 2017 Environment Canterbury invited tenders to develop an Air Quality Monitoring Programme in Yaldhurst around some quarries. Mote and Emission Impossible Ltd submitted a joint tender and were ultimately selected as the preferred partner. The purpose of the monitoring was to:

(i) **Health**: Determine if the levels of respirable crystalline silica (**RCS**) at residences in close proximity to the quarries in Yaldhurst exceed the annual ambient guideline for RCS; and

(ii) **Research**: Characterise the nature of particulate and RCS by measuring short-term (hourly) particulate levels in conjunction with (longer-term) RCS and measuring different size fractions of particulate at multiple locations.

Accordingly, ten ambient air quality monitoring sites were operated between 22 December 2018 – 21 April 2018 as follows:

- Six sites measured respirable crystalline silica (RCS). Sampling commenced on 19 January 2018 and continued through to 21 April 2018;[1]
- Six sites measured particulate matter less than 10 micrometres in diameter (**PM_{10}**) for the period 22 December 2017 – 21 April 2018;
- Three sites also measured particulate matter less than 2.5 micrometres in diameter (**$PM_{2.5}$**) for the period 22 December 2017 – 21 April 2018;
- One site measured meteorology for the period 22 December 2017 – 21 April 2018;
- Three additional sites measured PM_{10} at varying distances from the quarries (transect monitoring) for the period 9 February – 21 April 2018;[2] and
- An additional site measured RCS from 20 February – 21 April 2018.[3]

This report presents results for the first four months of monitoring from the date all PM_{10} monitors were successfully commissioned (22 December 2018).

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[1] Commencement of sampling was delayed due to late provision of RCS filters from the manufacturer.

[2] The deployment of the transect monitors involved placement on land occupied by the Christchurch Mens Prison. This required negotiation and discussion to ensure staff and prisoner safety which delayed the deployment until 9 February.

[3] The installation of an additional site was requested by Environment Canterbury in early February, Deployment was delayed until 20 February to ensure consistent data with other RCS monitors.

RCS Monitoring

To date, three months of monitoring RCS at six locations, and two months of monitoring RCS at one additional location (a total of 20 samples), has identified only two filters above the RCS detection limit (20 µg per filter).

RCS was detected twice at site 3 which is 50 metres to the south east of the quarries. The average RCS concentration at site 3 for the three-month period 19 January -21 April 2018 was 0.4 µg/m^3. The chronic reference exposure level for RCS is 3 µg/m^3 as an annual average.

RCS concentrations at all other locations were below detection limits.

Dust/ Particulate monitoring

Table E-1 presents maximum and average PM_{10} concentrations at the six main monitoring sites over the four months of monitoring.

There were 13 exceedances of the hourly suggested PM_{10} trigger threshold for dust nuisance at the five monitoring locations in Yaldhurst (17 exceedances including the transect monitoring locations).[4]

Table E-1 Maximum hourly, daily and average PM_{10} measured at six monitoring sites 22 Dec 17 – 21 Apr 18 (including background location, site 4 - shaded)*

Site	Distance from monitor to nearest quarry boundary (m)	PM_{10} Concentration (µg/m^3)		
		Maximum 1-hr	Maximum 24-hr	Average 4-month
Site 1	50	208	62	24
Site 2	190	183	58	23
Site 2 (BAM)*		-*	47	21
Site 3	50	284	63	27
Site 4	4,800	**99**	**57**	**19**
Site 4 (BAM)*		-*	**45**	**16**
Site 5	80	205	65	26
Site 6	160	147	56	21

*Beta attenuation monitor (reference method) is not accurate to 1-hour average

[4] Please note: There were 7 additional exceedances of the trigger threshold for dust nuisance which were measured outside of the reporting time period (22 December 2017 through to 21 April 2018).

Table E1 shows that for the monitoring period 22 December 2017 to 21 April 2018:

- Maximum hourly PM_{10} concentrations in Yaldhurst were significantly higher (147-284 µg/m^3) than those measured at the background site (99 µg/m^3).
- Maximum daily PM_{10} concentrations at site 2 in Yaldhurst were similar to maximum daily PM_{10} concentrations at the background location. Maximum daily PM_{10} concentrations at all other Yaldhurst sites (56-65 µg/m^3) were higher than background (45 µg/m^3).
- The 4-month PM_{10} concentrations at sites 2 and 6 in Yaldhurst (21-23 µg/m^3) were only slightly higher than that measured at the background location. The remainder of 4-month PM_{10} concentrations measured at Yaldhurst (sites 1, 3 and 5) were significantly higher (24-27 µg/m^3) than background (19 µg/m^3).

Beta attenuation monitors (**BAM**s) were installed at two locations (site 2, north rural/residential and site 4, background rural/residential). These instruments are called reference methods as they comply with Schedule 2 of the national environmental standards (**NES**) for air quality and permit direct comparison of results with the NES for PM_{10} (50 µg/m^3 as a 24-hour average). There were no exceedances of the NES for PM_{10} during the four months of monitoring at site 2 or site 4.

Nephelometers are not reference instruments and so elevated daily PM_{10} concentrations measured by nephelometers cannot be compared directly with the NES for PM_{10}.[5] However, nephelometers co-located with BAMs at site 2 and site 4 gave reasonable agreement with daily PM_{10} concentrations. Elevated daily PM_{10} concentrations were measured using nephelometers on nine days during the monitoring period. Of these, daily PM_{10} concentrations were elevated at all six monitoring sites (including background location) on two days (9th and 16th January 2018).

$PM_{2.5}$ levels were generally low with no recorded exceedances of the Ministry for the Environment reporting 24-hour guideline of 25 µg/m^3.

A comparison of $PM_{2.5}$ and PM_{10} data shows $PM_{2.5}$ to be a minor component of the PM_{10} concentrations measured in Yaldhurst (at sites 2 and 3) compared with background (site 4). The fine fraction $PM_{2.5}$ was 17% and 14% of PM_{10} measured at sites 2 and 3 respectively, but 24% at site 4. This suggests that the sources contributing to PM_{10} in Yaldhurst differ to those contributing to the PM_{10} measured at the background location.

A review of historical meteorological data from Christchurch Airport for the period of monitoring (22 December – 20 April) for the last ten years indicates there was an unusually high level of rainfall during the period of monitoring.

[5] Nephelometers are cheaper and more responsive than BAMs to short-term changes so more useful for measuring dust nuisance.

Glossary

Acronym	Name	Details
BAM	Beta attenuation monitor	Instrument that measures particulate matter concentration in air as a function of the attenuation of beta radiation, which is a function of mass. This is an accurate, reference method.
	Nephelometer	Instrument that measures particulate matter concentration in air as a function of light reflected into a detector. This method has excellent resolution (responds quickly to changes) but is not accurate for measuring coarse particles. It is not a reference method.
NES for PM_{10}	National environmental standard for PM_{10}	Ambient air quality standard set to provide a guaranteed level of health protection for all New Zealanders with a concentration limit of 50 micrograms per cubic metre (μg/m^3) as a 24-hour average with one permissible exceedance per year.
NESAQ	National Environmental Standards for Air Quality	Shortened reference to *Resource Management (National Environmental Standards for Air Quality) Regulations 2004*
NIOSH	National Institute for Occupational Safety and Health	The National Institute for Occupational Safety and Health (NIOSH) is the United States federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness.
OEHHA	Office of Environmental Health and Hazard Assessment	The Office of Environmental Health Hazard Assessment is a California (state) agency for the assessment of health risks posed by environmental contaminants. The Office is one of five state departments within the California Environmental Protection Agency.
$PM_{2.5}$	Fine particles	Particulate matter less than 2.5 micrometres in diameter is so small that it behaves like a gas, not a particle. $PM_{2.5}$ can reach the upper alveolar region of the lungs where inhaled gases can be absorbed by the blood. $PM_{2.5}$ is largely formed from gases but also may be emitted in primary form by combustion processes (WHO, 2006).

Acronym	Name	Details
$PM_{10-2.5}$	Coarse particles	Particulate matter between 2.5 and 10 micrometres in diameter is so small that it behaves like a gas, not a particle. $PM_{10-2.5}$ are inhalable particles that are sufficiently small to penetrate to the thoracic region. In urban areas, coarse particles typically contain re-suspended dust from roads and industrial activities, biological material such as pollen grains and bacterial fragments, crustal materials such as wind-blown dust from agricultural processes, uncovered soil, unpaved roads or mining operations and evaporated sea spray (WHO, 2006).
PM_{10}	PM_{10}	Particulate matter less than 10 micrometres in diameter includes, by definition, both fine and coarse particles.
	Reference method	Method listed in Schedule 2 of the NESAQ. A reference method is suitable for measuring and assessing PM_{10} against the ambient PM_{10} standard in the NESAQ.
REL	Reference exposure level	A (chronic) reference exposure level is an airborne level of a chemical at or below which no adverse health effects are anticipated in individuals indefinitely exposed to that level. Reference exposure levels are developed from the best available published scientific data, based solely on health considerations. (OEHHA, 2005). The chronic reference exposure level for RCS is 3 $\mu g/m^3$ as an annual average.
RCS	Respirable crystalline silica	Silica is silicon dioxide (SiO_2). Crystalline silica is the name for a group of naturally occurring minerals (quartz, cristobalite and tridymite) found in many types of rock. These minerals are polymorphs, i.e. they are all silica but have different crystalline structures. Respirable crystalline silica is the fraction that can enter the upper part of the lungs and is measured as particulate matter that is less than 4 micrometres in diameter (PM_4).
SEM	Scanning Electron Microscopy	A scanning electron microscope produces images of a sample by scanning the surface with a focused beam of electrons. This technique enables high resolution images below 1 nanometre.
	Suggested trigger threshold for dust nuisance	Suggested concentration of 150 $\mu g/m^3$ PM_{10} to protect against nuisance dust effects (Ministry for the Environment, 2016).

Acronym	Name	Details
TSP	Total suspended particulate	Particulate matter that remains suspended in the air; typically assumed to be less than 30 µm, but can be up to 100 µm, in diameter.
YAQM	Yaldhurst Air Quality Monitoring	The Yaldhurst Air Quality Monitoring programme was commissioned by Environment Canterbury, the Christchurch City Council and the Canterbury District Health Board (the partner agencies)

Contents

Contents continued

List of Figures

Contents continued

List of Figures

Contents continued

List of Figures

1.0 Background

On 15 May 2018, Environment Canterbury requested a report summarising the results of ambient air quality monitoring undertaken at Yaldhurst for the period from 22 December 2017 through to and including 21 April 2018.

This report summarises the information contained within Yaldhurst Air Quality Monitoring Reports 1, 2, 3 and 4 and includes all results of respirable crystalline silica monitoring performed to date.

The background and terms of reference of this monitoring project are detailed in the programme design recommendations report (Mote, 2018).[6]

1.1 Monitoring locations

To respect resident's privacy, this report will not disclose the exact locations of monitoring equipment on residents' private property. Their locations may be described as follows:

- **Site 1: East** - rural/residential location 50 metres to the east of the quarries. Site situated on private property in a paddock adjacent to a quarry. Two houses are situated on the same property with the nearest house being 120 metres from the monitor.
- **Site 2: North (east)** - rural/residential location 190 metres to the north of the quarries. Site situated on private property in a paddock north of the quarry. Two houses are situated on the same property with the nearest house being 15 metres from the monitor. The monitor is sheltered from the southwest by a large tree.
- **Site 3: South (east)** – rural location 50 metres in the prevailing wind direction to the south east of the quarries. Site is situated on farmland used by Christchurch Men's Prison. The nearest residential property is situated approximately 750 metres to the east.
- **Site 4: Background** - background rural location around 4.8 km from Yaldhurst. Site is situated on private property in a paddock. The property is currently used for cropping and grazing and there are two residential houses within 80 metres of the site, however, these are not presently occupied.
- **Site 5: South (west)** - rural location 80 metres to the south west of the quarries. Site is situated on farmland used by Christchurch Men's Prison. The nearest residential property is situated approximately 300 metres to the west.

[6] Mote & Emission Impossible Ltd, 2018. Yaldhurst Air Quality Monitoring Programme Design Recommendations. Prepared for Environment Canterbury. 12 Jan 2018.

- **Site 6: North (west)** - rural/residential location 160 metres to the north of the quarries. Site situated on private property in a paddock north of the quarry. The nearest house is situated approximately 40 metres to the southwest of the monitor.
- **Site 7**: **Transect 1** – rural location 250 metres south of quarries. Site is situated on farmland used by Christchurch Men's Prison.
- **Site 8: Transect 2** – rural location 500 metres south of quarries. Site is situated on farmland used by Christchurch Men's Prison.
- **Site 9: Transect 3** – rural location 650 metres south of quarries. Site is situated on farmland used by Christchurch Men's Prison.
- **Site 10**: **Background** – rural location 1.9 km south of Waimakariri River. Site situated on rural land in a paddock.

The sites general locations are in **Figure 1**.

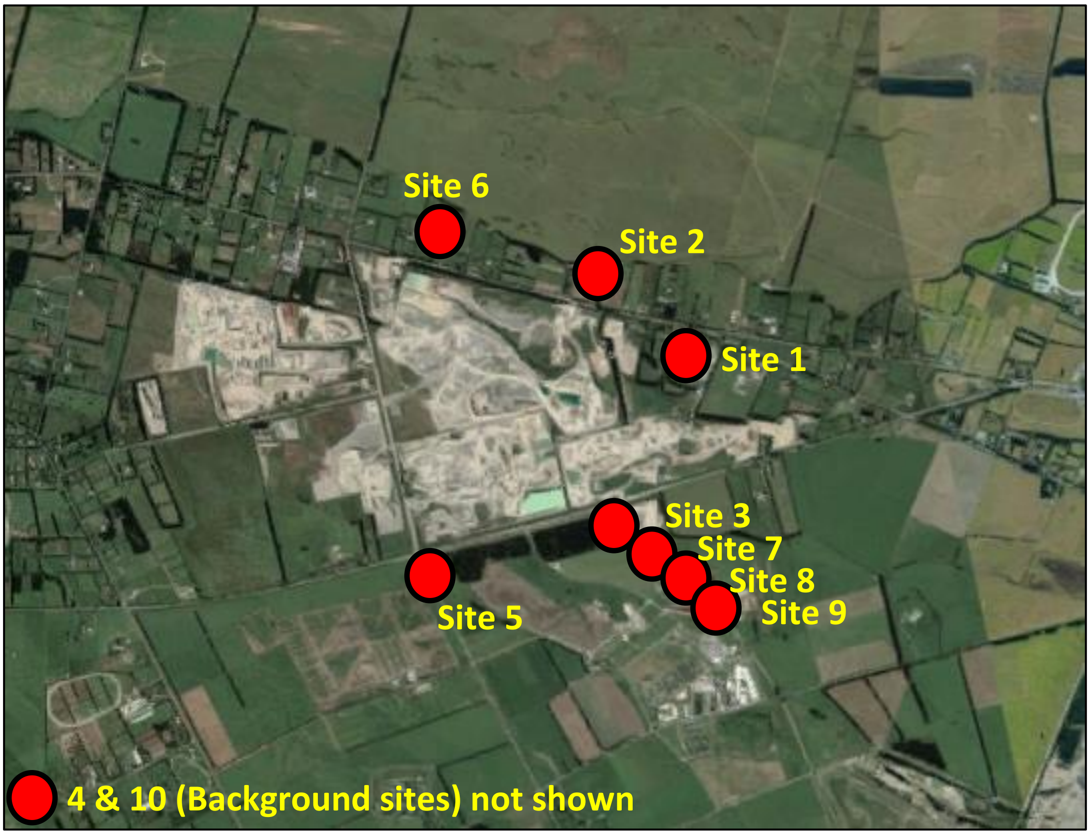

Figure 1 Indicative (only) locations of monitoring sites

Table 1, which follows, presents a summary of monitoring undertaken around the Yaldhurst quarries for the period 22 December 2017 through to 21 April 2018.

Table 1 Summary Yaldhurst Air Quality Monitoring: Dec 2017 - Apr 2018

Site	Location	Type	Monitoring*
1	East	Rural/residential	Nephelometer PM_{10} RCS
2	North (east)	Rural/residential	Nephelometer PM_{10} BAM PM_{10} Nephelometer $PM_{2.5}$ RCS Meteorology
3	South (east)	Rural	Nephelometer PM_{10} Nephelometer $PM_{2.5}$ RCS
4	Background	Rural	Nephelometer PM_{10} BAM PM_{10} Nephelometer $PM_{2.5}$ RCS
5	South (west)	Rural	Nephelometer PM_{10} RCS
6	North (west)	Rural/residential	Nephelometer PM_{10} RCS
7	Transect 1	Rural 250m south of quarries	Nephelometer PM_{10}
8	Transect 2	Rural 500m south of quarries	Nephelometer PM_{10}
9	Transect 3	Rural 650m south of quarries	Nephelometer PM_{10}
10	Background	Rural	RCS (Feb-Apr only)

*RCS monitoring commenced 19 Jan 2018

1.2 Monitoring methods

Nephelometer monitoring

An air quality nephelometer is an optical sensor that uses light scattering from particulate matter to provide a continuous real-time measurement of airborne particle mass. The light source is a visible laser diode and scattered light is measured in the near forward angle using focusing optics and a photo diode. The nephelometer has an on-board temperature sensor, which corrects for thermal drift, sheath air filter to keep the optics clean, automatic baseline drift correction and a fibre optic span system to provide a check of the optical components.

The near-forward nephelometers used in this study are more accurate that comparable side scattering nephelometers. However, as the near-forward scattering is less sensitive to particle size, they require a particle size inlet or sharp cut cyclone to provide a mechanical means of separating the size fraction prior to measurement. For this study, we deployed a PM_{10} sharp-cut cyclone co-located with each nephelometer. We also included a $PM_{2.5}$ sharp cut cyclone with an additional nephelometer at three sites (Sites 2, 3 and 4).

Our nephelometers take a reading once per second, we used a small single board computer to record these readings and calculate the average concentration each minute. The same single board computer uses a GPS to determine the local time very accurately – this way we time stamped the data. Every 10 minutes, we transmitted the previous data to our server using a cellular modem for direct upload to on our website.

We installed the nephelometers on poles and tripods at heights of between 1.5 and 2 metres above ground level. Excepting Site 2 and Site 4 (which were connected to mains power), the remainder of nephelometers were powered using a 12 volt battery which itself is charged using solar panels. To assist with smooth site operation and data interpretation, we mounted ultrasonic wind sensors on poles alongside the nephelometers.

The nephelometer utilises a heating control system based on relative humidity concentrations. When the relative humidity exceeds the set point (30% RH), the inlet heater switches on. This reduces the relative humidity down to below the set point at which point the heater switches off.

NB: Nephelometers are not reference instruments as they do not comply with Schedule 2 of the national environmental standards (**NES**) for air quality. This means we cannot directly compare PM_{10} data from nephelometers with the 24-hour average NES for PM_{10}. (For this reason, we have also co-located a Beta Attenuation Monitor (**BAM**) at Sites 2 and 4. PM_{10} data from a BAM can be directly compared with the NES for PM_{10}).

Figure 2, which follows, illustrates the types of nephelometers we deployed around the Yaldhurst quarries.

Figure 2 Typical nephelometer installations. The unit on the left is battery powered, while the unit on the right provides a close up of the instrument.

Beta Attenuation Monitoring

A Beta Attenuation Monitor or BAM is a widely used air monitoring technique employing the absorption of beta radiation by solid particles extracted from airflow. We used Thermo FH62 C14 beta attenuation monitors inside temperature-controlled enclosures. These are located at Site 2 (to the north of the quarries) and Site 4 (background site).

We operated the FH62 BAM in accordance with the *Good Practice Guide for Air Quality Monitoring and Data Management* (MfE, 2009) and in accordance with the standard method specified in the Resource Management (National Environmental Standards for Air Quality) Regulations 2004:

> *Australian/New Zealand Standard AS/NZS 3580.9.11:2008, Methods for sampling and analysis of ambient air—Determination of suspended particulate matter—PM_{10} beta attenuation monitors*

Due to the power requirements of both the instrument and the temperature-controlled enclosure, both sites operated using mains power.

Figure 3, which follows, shows a typical BAM installation.

Figure 3 An example of a temperature controlled BAM enclosure with the doors open to illustrate the BAM inside

Respirable Crystalline Silica (RCS)

In addition to the PM_{10} nephelometers, respirable crystalline silica monitors were deployed at sites 1 through 6 (Jan – Apr) and at site 10 (Feb – Apr). Each monitor consists of a pre-weighed PVC filter housed within a polycarbonate cassette. Air is sampled at a rate of 2.5 litres per minute through an aluminium cyclone. The cyclone removes particles larger than 4 µm in diameter. The air flow itself is measured using a flow sensor connected to a flow controller. This ensures that the flow through the cyclone is maintained at 2.5 litres per minute throughout the sampling period. The aluminium cyclone is heated by 10 degrees above the ambient air temperature to remove water droplets from the sample air.

The purpose of this sampling was to collect sufficient monthly respirable crystalline silica (RCS) samples to enable comparison with the annual guideline.

We also performed wind directional RCS monitoring at site 2 as follows:

- One RCS monitor sampled continuously;
- One RCS monitor sampled only when the wind direction was from the quarries; and
- One RCS monitor samples only when the wind was blowing in other directions (i.e. not from the quarries).

The purpose of this was to investigate the contribution, if any, of the quarries to RCS levels at site 2.

1.3 Data validation

We undertook data quality assurance and validation in accordance with good practice (MfE, 2009). In summary, this involves:

- Data review to ensure no drift or baseline shift
- Examination of check and calibration records
- Removing data collected during calibration and maintenance, including sufficient time for instrument stabilisation
- Removing negative values (except where data within system uncertainty)
- Removing spurious positive/negative spikes[7]

There will inevitably be differences between (raw, un-validated) data reported online and the data in this report. Some of these differences arise from data validation and some are structural as discussed below.

Data validation

The data validation process involves aligning datasets to account for missing or duplicated data to ensure the correct timestamp data is aligned. This is performed individually for each parameter from each instrument and then compiled into a validated spreadsheet. Basic parameter checks (temperature, pressure, flow etc.) are performed on each instrument at least once per month. Where differences between an instrument and reference equipment are observed, data will be adjusted back to the last time of the last good reading. Span and offset corrections may be applied after calibration or servicing. Normally this will apply to data after each calibration or service but may apply to smaller sections of data where instrumental data indicates an anomaly.

Table 2 presents the data capture and per cent valid data obtained at each site during the monitoring period 22 December - 21 April.

[7] NB: Occasionally, large negative spikes may occur due to instrumental error. These negative (and positive) spikes are reviewed during the data analysis process to evaluate whether they are real or spurious. Unless there is good evidence to remove a value, they are left in and a comment made in the metadata (MfE, 2009).

Table 2 Per cent valid monitoring data 22 December - 21 Apr 2018

Site	Monitoring	% Valid Data[1]	Comments
1	Nephelometer PM_{10}	99.5%	
	RCS	90%[8]	
2	Nephelometer PM_{10}	99.1%	
	BAM PM_{10}	96.2%	Daily calibration data removed
	Nephelometer $PM_{2.5}$	99.1%	
	Meteorology	99.1%	
	RCS	100%	
3	Nephelometer PM_{10}	98.6%	
	Nephelometer $PM_{2.5}$	100	
	RCS	100%	
4	Nephelometer PM_{10}	100%	
	BAM PM_{10}	97.3%	Daily calibration data removed
	Nephelometer $PM_{2.5}$	100%	
	RCS	100%	
5	Nephelometer PM_{10}	99.9%	
	RCS	100%	
6	Nephelometer PM_{10}	100%	
	RCS	100%	
7 (Transect 1)	Nephelometer PM_{10}	100%	
8 (Transect 2)	Nephelometer PM_{10}	100%	
9 (Transect 3)	Nephelometer PM_{10}	97.4%	
10	RCS	100%	Feb-Apr

[1] Calculated on hourly average data. RCS filtering commenced 9 February 2018

[8] The RCS filter at site one was found to have been tampered with resulting in a loss of data

Structural differences between online and reported data

Structural differences arise from differences in the way the data are reported. For example, **Figure 4** provides a screenshot of nephelometer PM_{10} data from Site 1 for the month of January 2018.

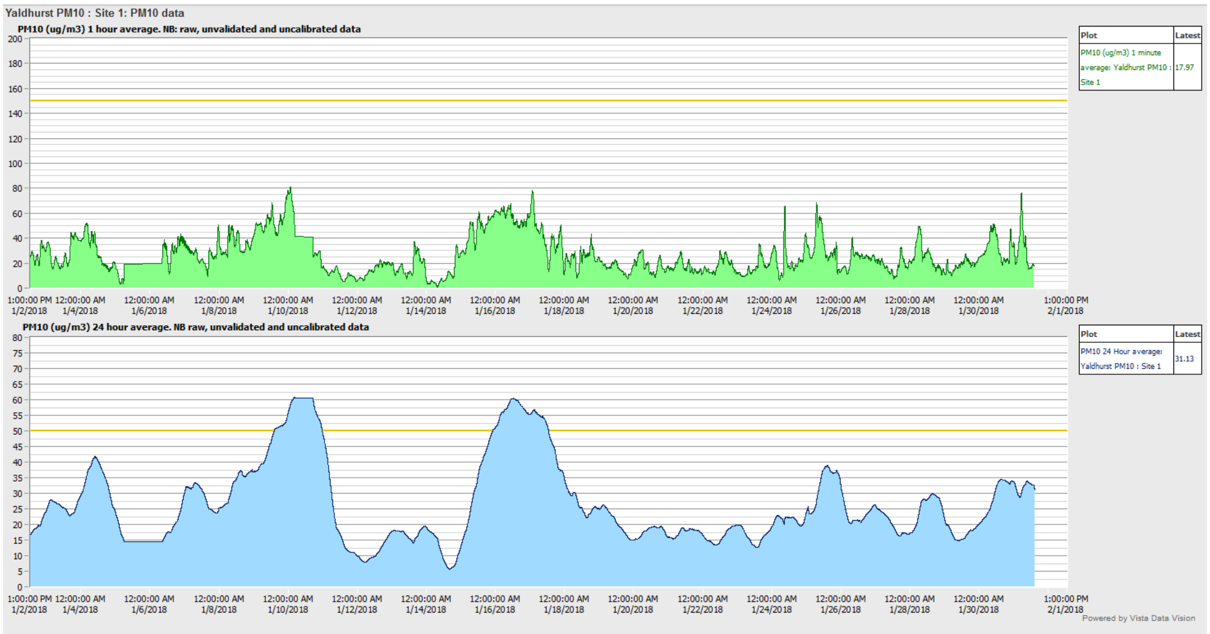

Figure 4 Screenshot of online nephelometer PM_{10} data for Site 1: East rural/residential 1:00 PM 2 Jan 2018 – 3:00 PM 31 Jan 2018

The top graph in **Figure 4** is hourly PM_{10}, and the hourly averages are updated each minute, hence the data have a spiky appearance.

Similarly, the daily PM_{10} averages in the bottom graph in **Figure 4** are updated every hour, every day. The rolling 24-hour average is thus a smooth line and looks very different to the daily PM_{10} bar charts for each site, which presents true daily averages for each day (i.e. the full 24-hours of each day commencing at midnight (12:01) continuing through the early hours of the morning, noon and finishing at midnight (12:00) that night).

Being raw, the online data also include measurements during calibration and maintenance as well as site outages that are removed during data validation.

1.4 Frequently Asked Questions

What is an exceedance?

When we measure a concentration on our instruments around Yaldhurst that is higher than assessment criteria, we refer to this as an “exceedance”.

The concentrations are measurements taken and averaged over the relevant time-period (i.e. one hour or 24 hour averages). Each of the nephelometers used in this study makes a reading every second, we average these readings to produce one minute concentrations. We then use these 1 minute concentrations to plot the 1 hour average and 24 hour average graphs (which can be seen on our website).

To calculate an average 1 hour concentration, we add each minute of data between the start of the hour and the end of the hour and divide this by the number of minutes of data (e.g. 60 minutes).

The ongoing monitoring data generate running or continual 1 hour average and 24 hour average plots. For reporting purposes, we calculate a separate 1 hour average for each hour of the day and then average these 1 hour averages for each 24 hour day (starting at one minute past midnight and finishing at midnight).

What is the suggested PM_{10} trigger threshold for dust nuisance?

In 2016, the Ministry for the Environment published a document titled "Good practice guide for assessing and managing dust" (MfE, 2016). This document includes a section on setting trigger levels for proactive on-site dust management and suggests a dust nuisance trigger level of 150 $\mu g/m^3$ as a 1-hour average.

NOTE: while we have adopted the Ministry's suggested trigger threshold of 150 $\mu g/m^3$ it is important to note that there are site specific factors which mean that an appropriate trigger level could be higher or lower (to indicate actual dust nuisance). For more information on this, please refer to the good practice guide for assessing and managing dust on the Ministry for the Environment website.

What is the national environmental standard for PM_{10}?

The national environmental standard (NES) for PM_{10} is 50 $\mu g/m^3$ as a 24-hour average with one permitted exceedance per year. A mandatory regulation under the Resource Management Act 1991, the (NES) for PM_{10} was set to provide a guaranteed level of health protection for all New Zealanders.

Why do the 24 hour PM_{10} graphs sometimes show values above the national environmental standard and why are these not reported as 'exceedances'?

The regulations relating to the PM_{10} national environmental standard mandate that only reference instruments may be used for direct comparison with this standard. We are operating two reference instruments (beta-attenuation monitors or BAM's) around Yaldhurst at site 2 and site 4.

The remainder of sites employ nephelometers to measure PM_{10}. While these instruments are very useful for identifying short term issues over minutes or hours, they are not as accurate as (more expensive) reference instruments for comparing against longer term standards such as the 24 hour national environmental standard for PM_{10}.

What is the reporting guideline for $PM_{2.5}$?

The reporting guideline for $PM_{2.5}$ is 25 $\mu g/m^3$ as a 24-hour average. It was included in the national ambient air quality guidelines published by the Ministry for the Environment (MfE, 2002) for assessing monitoring results and is numerically equivalent to the World Health Organisation global ambient air quality guideline for $PM_{2.5}$ (WHO, 2006).

What is the annual guideline for RCS?

The annual ambient guideline for RCS is the chronic reference exposure level for silica (crystalline, respirable) from the California Office of Environmental Health Hazard Assessment (OEHHA, 2005). A reference exposure level is the concentration level at or below which no adverse non-cancer health effects are anticipated for the specified exposure duration. This is 3 $\mu g/m^3$ as an annual average.

2.0 Results

In the first month we installed and commissioned particulate and meteorology monitoring instruments at sites 1-6. In the second month we deployed the RCS monitors (there were delays with provision of analytical filters from the manufacturer in the US) at sites 1-6 and the transect monitors at sites 7-9 to the south east of the quarries.

In the third month, at Environment Canterbury's request we installed and commissioned an additional background RCS monitor at site 10.

The following sections (2.1-2.7) discuss particulate and meteorology results for sites 1-9. These are results are tabulated in summary form in section 2.8.

Section 2.9 outlines the results of the RCS monitoring. Sections 2.10 and 2.11 discuss quarry operational data and complaints data received during the monitoring period.

Please note that all time averages are retrospective. Thus, we report data collected between 2:00 PM and 3:00 PM as an hourly average for 3:00 PM. Similarly, a 24-hour average for Monday 25 December is for the full 24-hours of Monday commencing at (1 minute after) midnight Sunday 24 December and finishing at midnight on Monday 25 December.

NB: As noted above in sections 1.2 and 1.4, we cannot compare nephelometer PM_{10} data directly with the NES for PM_{10}. This is because nephelometer PM_{10} data are indicative only (for indicating dust nuisance and investigating spatial and temporal resolution). However, we can (and do) compare PM_{10} data measured by the beta attenuation monitor (BAM) directly with the NES for PM_{10}. BAMs are deployed at site 2 (North) and site 4 (Background).

2.1 Site 1: East rural/residential particulate

PM_{10}

We installed and commissioned a nephelometer (PM_{10}) monitor at site 1 on 7 December 2017.

Figure 5 presents hourly PM_{10} and **Figure 6** presents daily PM_{10} for site 1 measured by the nephelometer between 22 December and 21 April 2018.

There were two exceedances of the 1-hour suggested dust nuisance trigger threshold (150 µg/m^3) during the monitoring period at Site 1 as summarised in **Table 3**, which follows.

NB: Nephelometers are not reference instruments. This means we cannot directly compare PM_{10} data from nephelometers in **Figure 6** with the NES for PM_{10}.

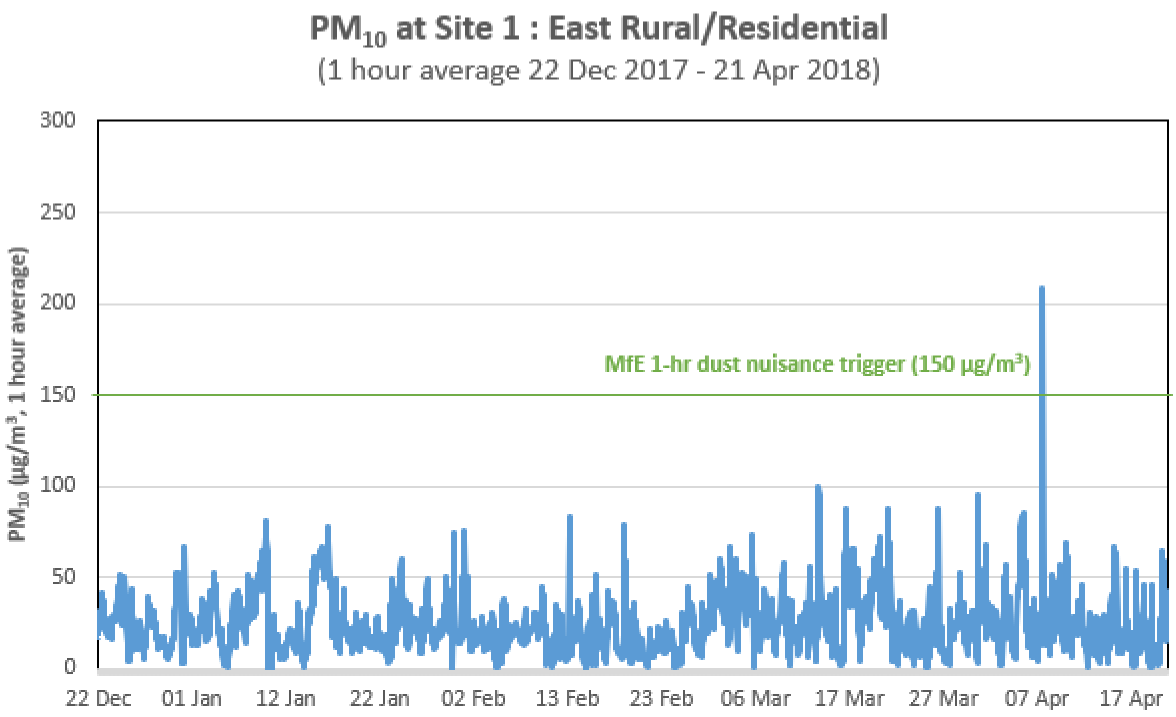

Figure 5 Hourly PM_{10} (nephelometer) at Site 1: East rural/residential for period 22 Dec 2017 - 21 Apr 2018

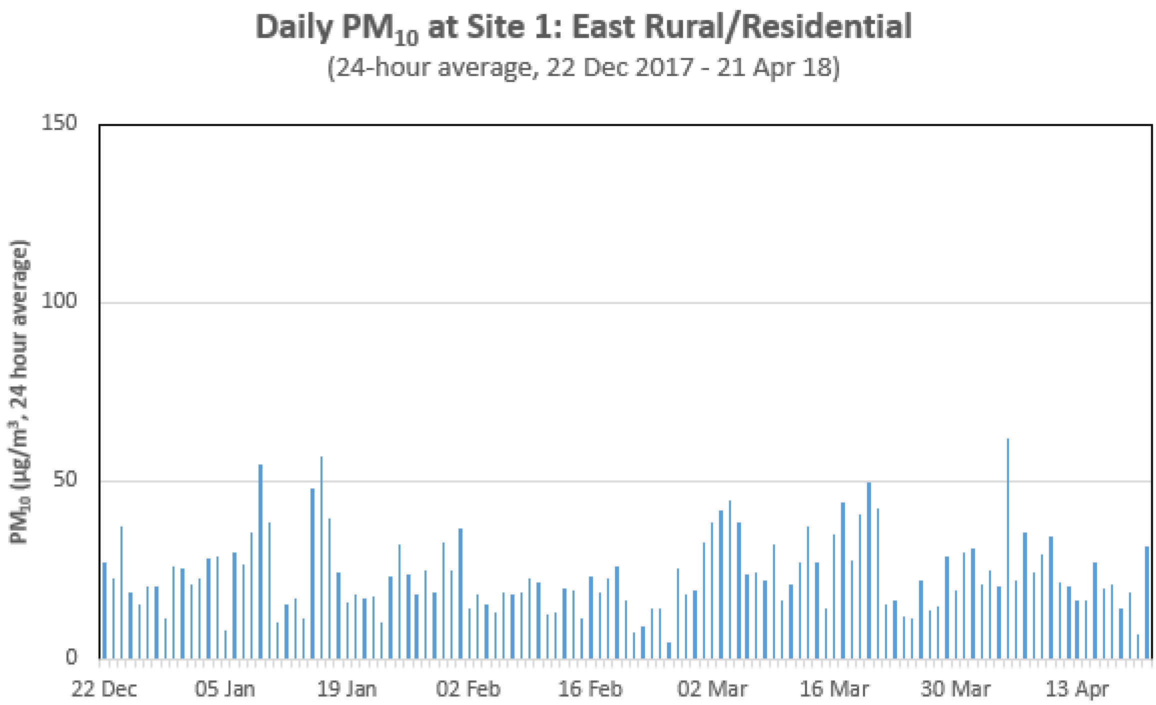

Figure 6 Daily PM_{10} (nephelometer) at Site 1: East rural/residential for period 22 Dec 2017 - 21 Apr 2018

Table 3 Summary of dust nuisance trigger level exceedances at Site 1 between 22 December 2017 and 21 April 2018

Date	Time[1]	1 hour PM_{10} concentration ($\mu g/m^3$)	Wind direction (°true)	Average 1 hour wind speed (km/hr)
07/04/2018	9:00pm – 10:00pm	208	Northerly	1.7
07/04/20018	8:00pm – 9:00pm	175	Northerly	1.4

Notes

[1] New Zealand standard time (NZST) – add one hour to get to New Zealand daylight savings time

2.2 Site 2: North (east) rural/residential particulate & meteorology

PM_{10} and $PM_{2.5}$

We installed and commissioned two nephelometer (PM_{10} and $PM_{2.5}$) monitors at site 2 on 15 December 2017 and these were fully operational from 16 December 2017.

We installed and commissioned a beta attenuation monitor (BAM) reference method PM_{10} monitor at Site 2 on 20 December 2017. This was fully operational from 22 December 2017.

Figure 7 presents hourly PM_{10} from the co-located nephelometer (blue) and BAM (pink) at site 2 for the period 22 December 2017 to 21 April 2018.

Elevated concentrations were observed between 2pm and 4pm on 8 March. An investigation revealed that there was a fire on a neighbouring property around this time and it is likely that the north-easterly winds transported the smoke to Site 2 resulting in elevated hourly concentrations of both PM_{10} and $PM_{2.5}$ during this period.

There was one exceedance of the 1-hour suggested dust nuisance trigger threshold (150 $\mu g/m^3$) during this monitoring period at site 2 as summarised in **Table 4**, which follows.

Figure 8 presents daily PM_{10} measured by the nephelometer and the BAM (reference method) between 22 December 2017 to 21 April 2018. There were no exceedances of the NES for PM_{10} measured by the BAM during this period at site 2.

Figure 9 presents daily PM_{10} measured by BAM as a function of daily PM_{10} measured by nephelometer for available validated (108) days of data at site 2. This correlation suggests the nephelometer is over-reading actual PM_{10} levels when compared with the reference method. This was not anticipated when designing the monitoring programme, i.e. we anticipated the nephelometer would under-read compared with the BAM.

Figure 10 presents monthly PM_{10} measured by BAM and monthly PM_{10} measured by nephelometer for four months of data at site 2. The longer time-average smooths the correlation between the two measurement methods and the data show good agreement.

Figure 11 presents hourly $PM_{2.5}$ measured by nephelometer at Site 2 for the period of operation (22 December 2017 - 21 April 2018). **Figure 12** presents hourly PM_{10} and hourly $PM_{2.5}$ measured by nephelometer at Site 2 for the period of operation.

Figure 13 presents daily $PM_{2.5}$ at Site 2 for this same period. There were no exceedances of the MfE reporting guideline for $PM_{2.5}$ (25 µg/m^3 as a 24-hour average).

Table 4 Summary of dust nuisance trigger level exceedances at Site 2 between 22 December 2017 and 21 April 2018.

Date	Time[1]	PM_{10} Concentration (µg/m^3, 1-hr ave)	Wind direction (°true)	Wind Speed (km/hr, 1-hr ave)	Comment
8/03/2018	2:00pm - 3:00pm	183	North-easterly	5.2	Fire on neighbouring property

Notes

[1] New Zealand standard time (NZST) – add one hour to get to New Zealand daylight savings time

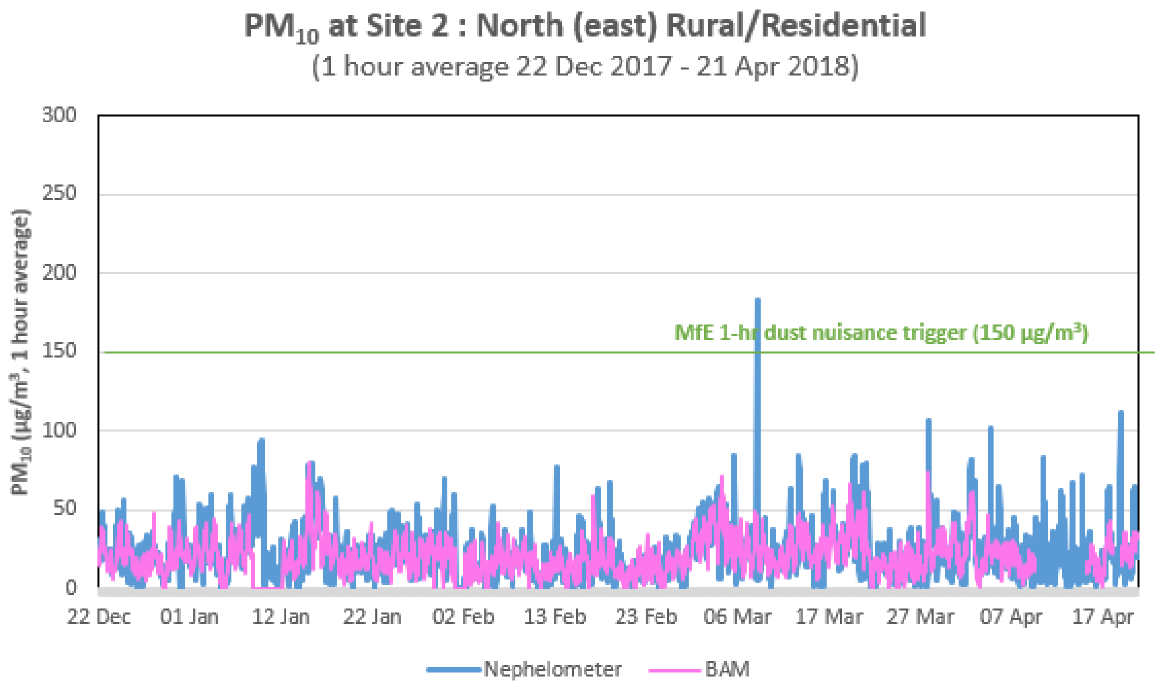

Figure 7 Hourly PM_{10} nephelometer (thick blue) and BAM (pink)* at Site 2: North (east) rural/residential for period 22 Dec - 21 Apr 2018

*Beta attenuation monitor (reference method) is not accurate to 1-hour average

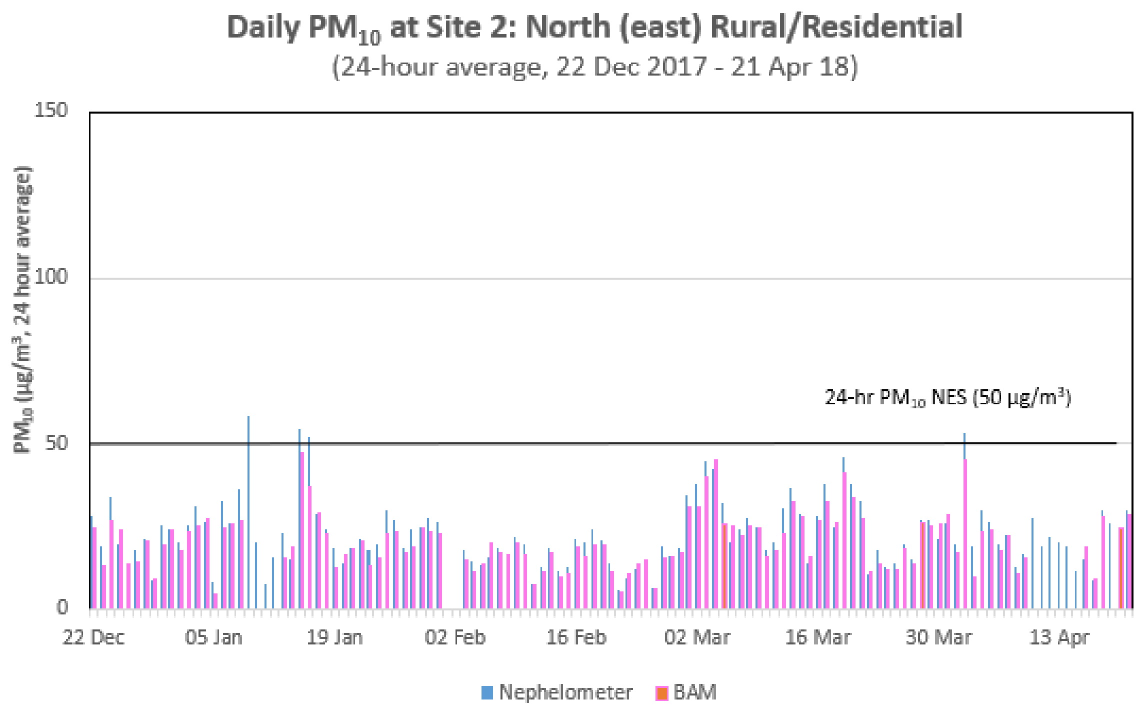

Figure 8 Daily PM_{10} nephelometer (blue) and BAM (pink) at Site 2: North (east) rural/residential for period 22 Dec - 21 Apr 2018

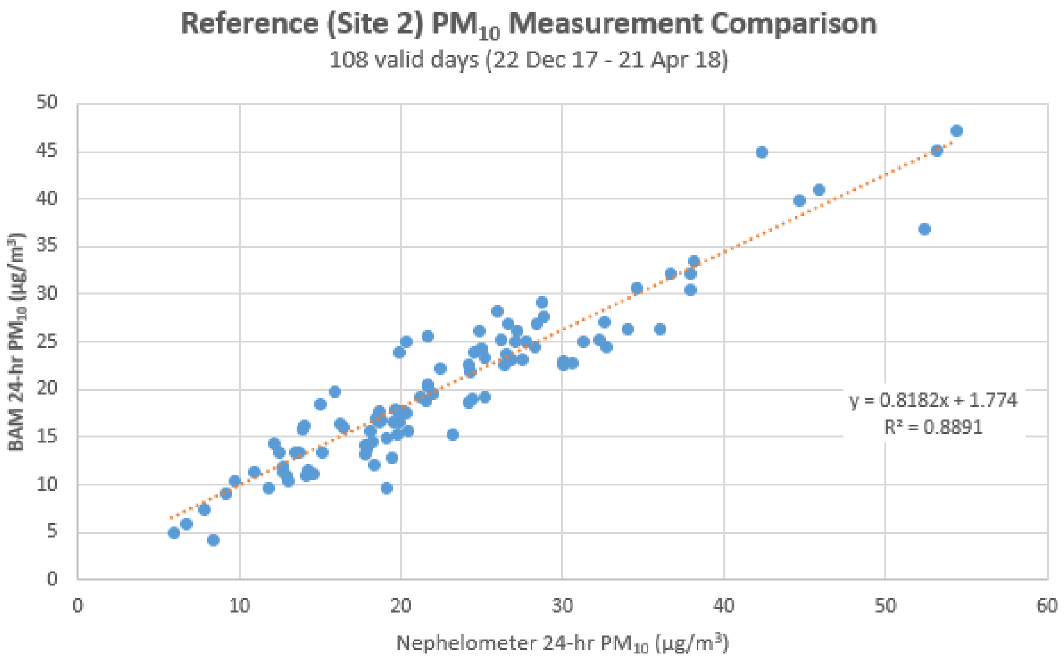

Figure 9 Daily PM_{10} measured by nephelometer as a function of daily PM_{10} measured by BAM at Site 2: North (east) Rural/Residential for (validated data) period 22 Dec 2017 - 21 Apr 2018.*

*NB: 3 days of BAM data were lost due to instrument damage following a power spike, 2 days were lost due to power outages and 7 days of data were lost when the enclosure temperature dropped below the 3 degree tolerance specified within the monitoring standard.

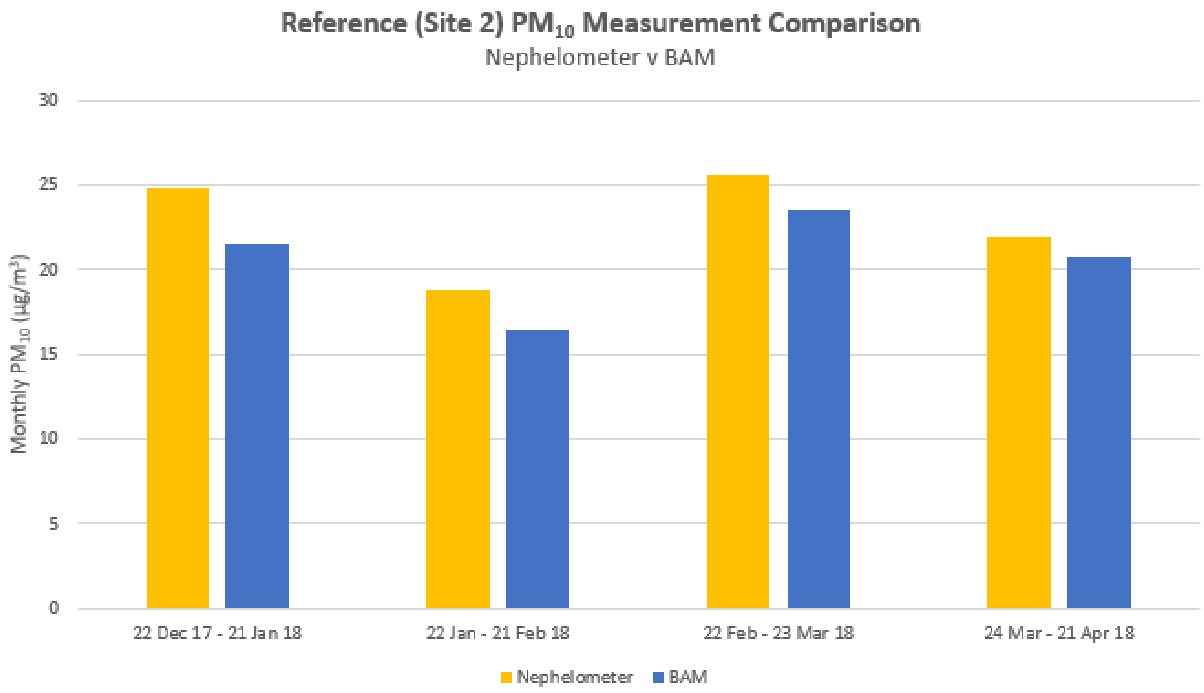

Figure 10 Comparison of PM_{10} concentration as measured by the nephelometer and beta attenuation monitor at Site 2: North (east) Rural/Residential for each reporting period

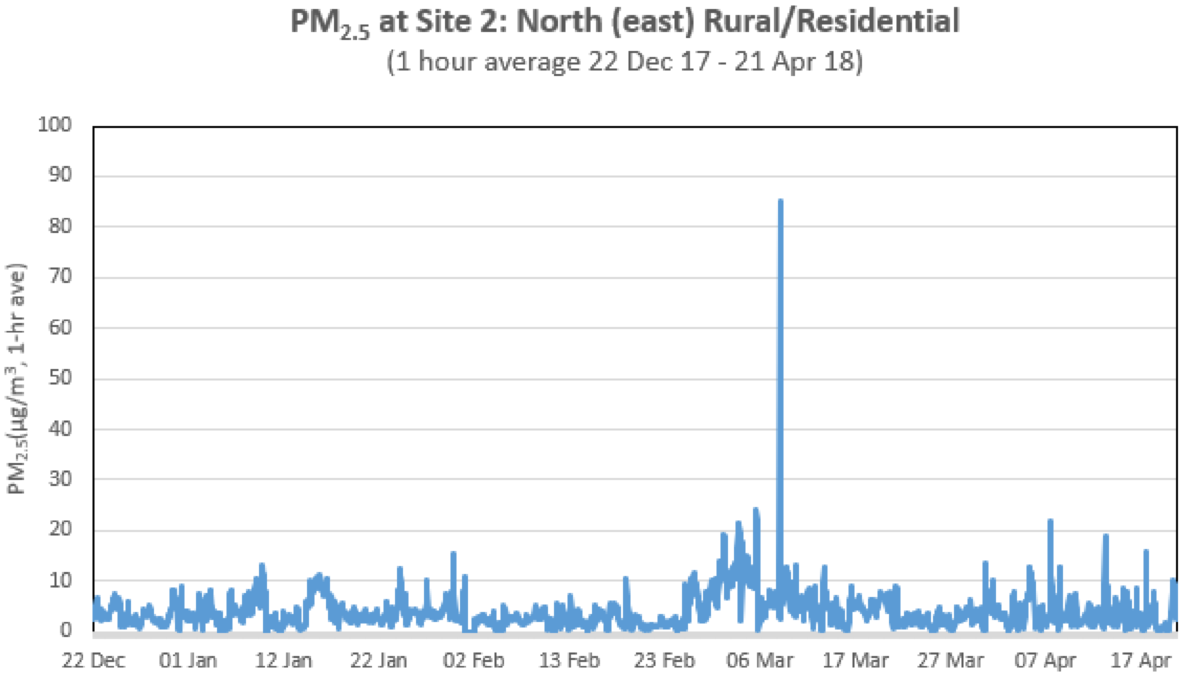

Figure 11 Hourly $PM_{2.5}$ measured by nephelometer at Site 2: North (east) Rural/Residential 22 Dec 2017 - 21 Apr 2018

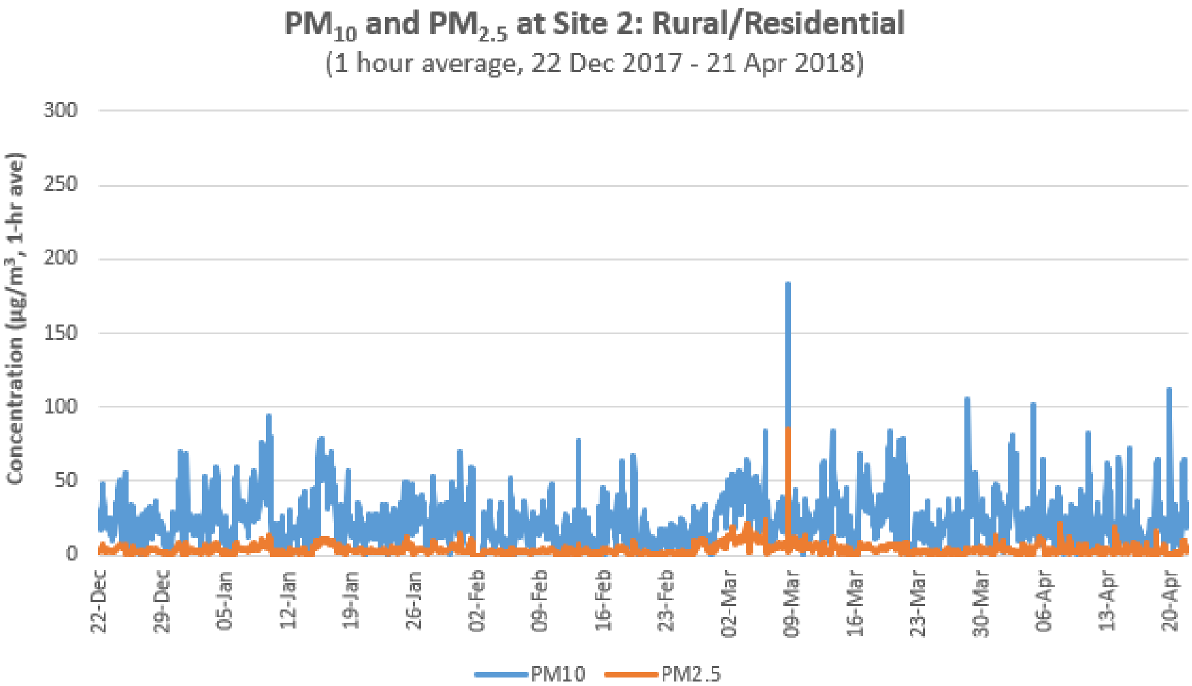

Figure 12 Hourly $PM_{2.5}$ and PM_{10} measured by nephelometer at Site 2: North (east) Rural/Residential 22 Dec 2017 - 21 Apr 2018

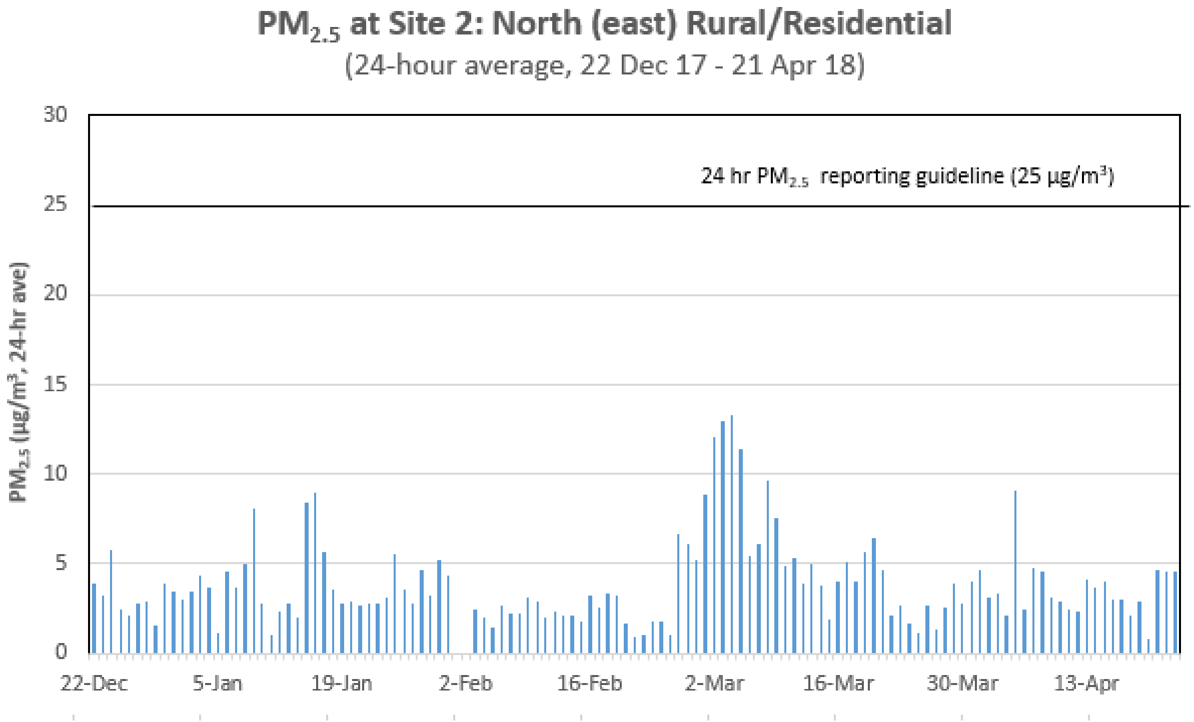

Figure 13 Daily $PM_{2.5}$ nephelometer at Site 2: North (east) Rural/Residential 22 Dec 2017 - 21 Apr 2018

Meteorology

We installed and commissioned a meteorological monitoring station at site 2 on 22 December 2018. This was fully operational from 22 December 2017.

There was 369.2 mm of rain recorded at Yaldhurst during the deployment period. However, this total excludes rainfall that occurred during a power outage (1 – 2 February). Based on available rainfall data from the Christchurch airport for this period, we estimate the actual total rainfall for the monitoring period is approximately 386 mm.

To assess how representative the rainfall measured at Yaldhurst was we compared the total rainfall measured in Yaldhurst over the monitoring period with the total rainfall measured at Christchurch airport (a nearby site) over the same period (22 December through to 21 April). This comparison is shown in **Table 5** below and reveals good agreement.

Table 5 also presents comparative rainfall data for the last 10 years as measured at Christchurch Airport. This shows that the total rainfall over the monitoring period was the highest quantity of rainfall received within the past 10 years (although there were at least two other years which received more than 300 mm of rain over the same period). The number of days which received rain were similar to the years with similarly elevated overall rainfall.

Table 5 Rainfall totals as measured at Yaldhurst Site 2 and Christchurch airport

Period	Site	Total rainfall	Days with rain
22 Dec 2017 – 21 Apr 2018	**Yaldhurst Site 2**	**386***	**33**
22 Dec 2017 – 21 Apr 2018	Christchurch Airport	**361.6**	**30**
22 Dec 2016 – 21 Apr 2017	Christchurch Airport	305	33
22 Dec 2015 – 21 Apr 2016	Christchurch Airport	195.2	20
22 Dec 2014 – 21 Apr 2015	Christchurch Airport	107.6	19
22 Dec 2013 – 21 Apr 2014	Christchurch Airport	331.4	29
22 Dec 2012 – 21 Apr 2013	Christchurch Airport	106	17
22 Dec 2011 – 21 Apr 2012	Christchurch Airport	175.6	22
22 Dec 2010 – 21 Apr 2011	Christchurch Airport	213	27
22 Dec 2009 – 21 Apr 2010	Christchurch Airport	97.6	21
22 Dec 2008– 21 Apr 2009	Christchurch Airport	154.2	22

*Includes estimated 17 mm rain during 1-2 February 2018 when power outage occurred at Site 2

Figure 14 presents wind direction and wind speed measured at Site 2 in Yaldhurst for the period 22 December 2017 - 21 April 2018.

Figure 15 displays the wind direction and wind speed measured at Kyle Street in Christchurch City for this same monitoring period.

Figure 16 displays the 10 yearly composite of wind speed and direction between 22 December and 21 April for each year at Kyle Street in Christchurch City.

The city data confirm the prevalence of the north-easterly winds during the monitoring period, however, the longer term composite plot also reveals a greater variety of wind directions than were observed during the 2017/18 monitoring term.

The Yaldhurst weather station shows slightly different wind patterns to the city site due to the lower height of the Yaldhurst mast (3 metres) and the presence of a tree to the southwest of the Yaldhurst station. Otherwise the sites reveal similar wind patterns, particularly the dominance of north-easterly winds during the monitoring period.

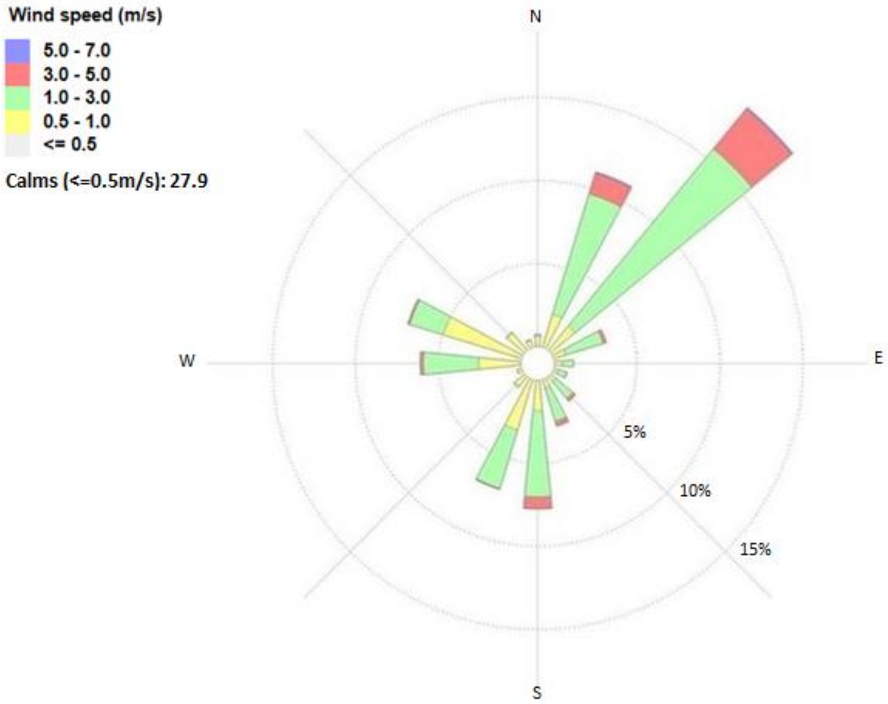

Figure 14 Wind direction and wind speed measured at Site 2: North (east) rural/residential for period 22 Dec - 21 Apr 2018

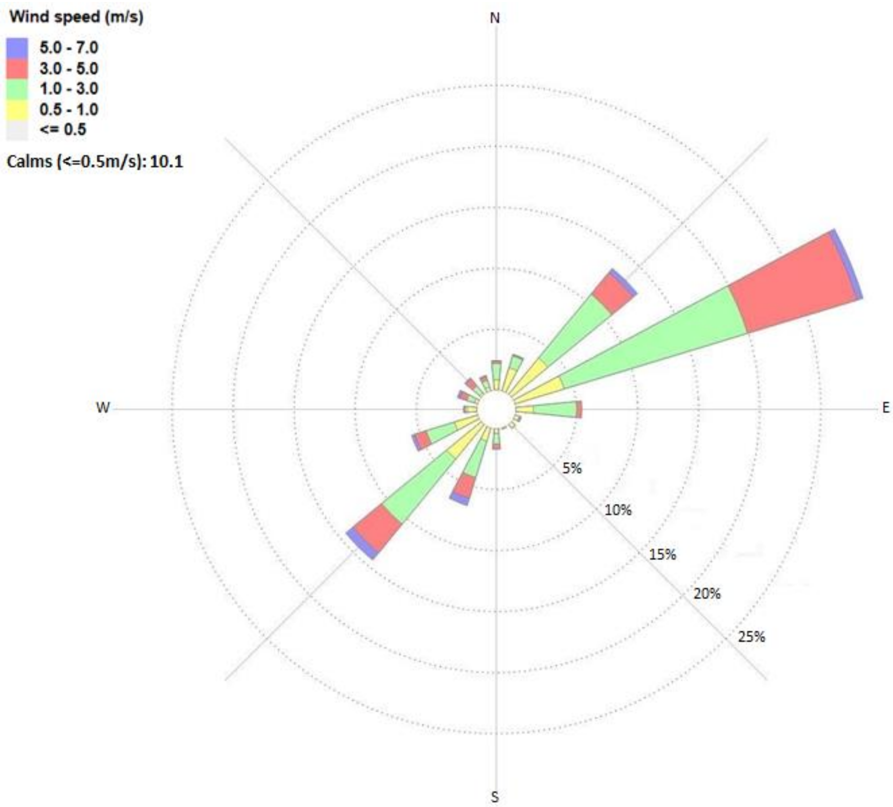

Figure 15 Wind direction and wind speed as measured at Kyle Street, Christchurch between 22 Dec 17 - 21 Apr 18

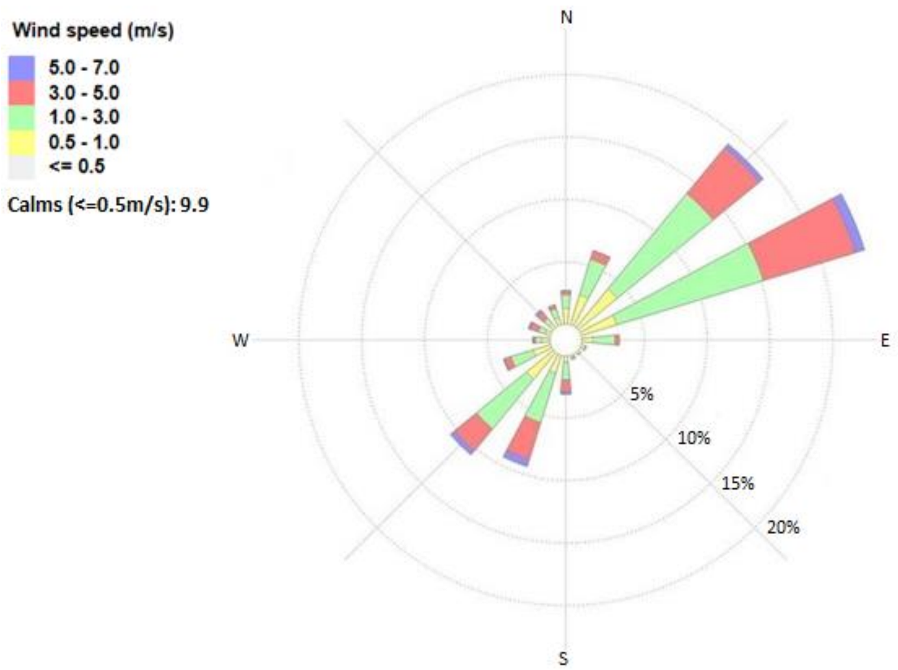

Figure 16 Ten year composite of wind direction and wind speed as measured at Kyle Street, Christchurch between 22 Dec - 21 Apr

2.3 Site 3: South (east) rural particulate

PM_{10} and $PM_{2.5}$

We installed and commissioned a PM_{10} nephelometer monitor at site 3 on 15 December and it was fully operational from 16 December 2017. We installed and commissioned a $PM_{2.5}$ nephelometer on 22 December and it was fully operational from 22 December 2017.

Figure 17 and **Figure 18** presents hourly and daily PM_{10} respectively for the monitoring period 22 December 2017 to 21 April 2018.

There were seven exceedances of the 1-hour suggested trigger threshold (150 µg/m^3) during this monitoring period at Site 3. These exceedances are summarised in **Table 6**, which follows

As noted above, nephelometers are not reference instruments. This means we cannot directly compare PM_{10} data from nephelometers in **Figure 18** with the NES for PM_{10}.

Figure 19 presents hourly $PM_{2.5}$ and **Figure 20** presents both hourly PM_{10} and $PM_{2.5}$.

Figure 21 presents the daily $PM_{2.5}$ measured at Site 3 for the monitoring period 22 February to 23 March 2018.

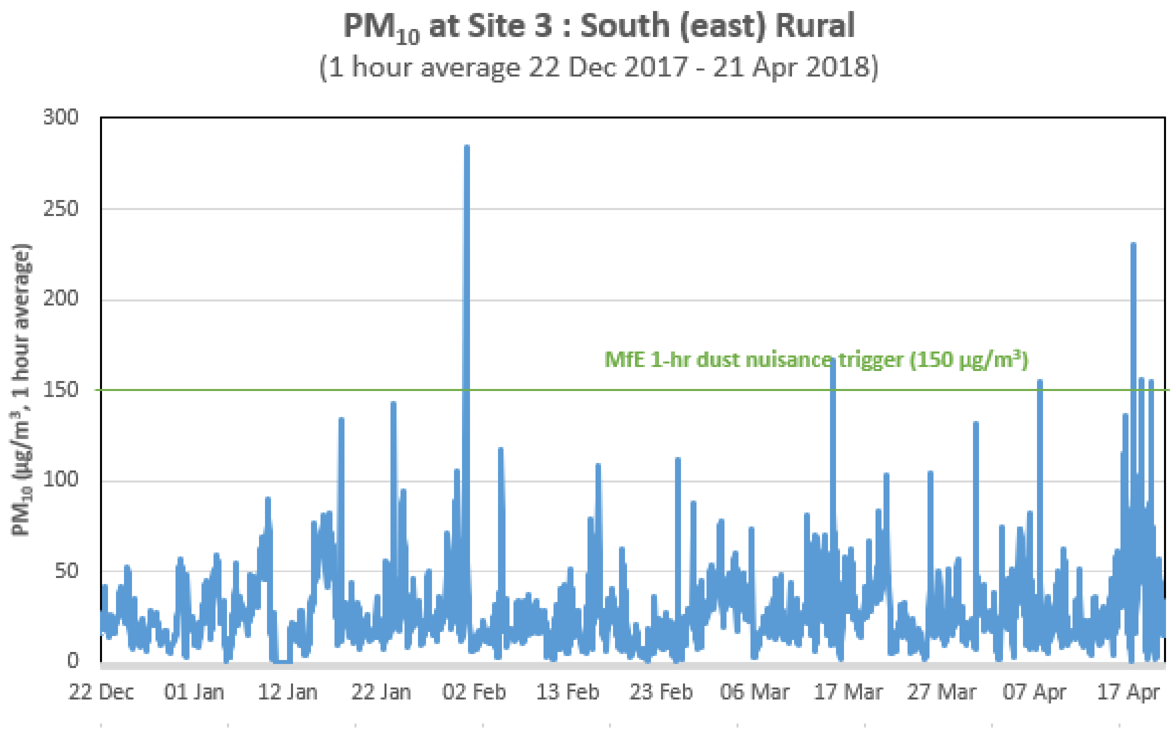

Figure 17 Hourly PM_{10} (nephelometer) at Site 3: South (east) Rural for period 22 Dec 17 - 21 Apr 18

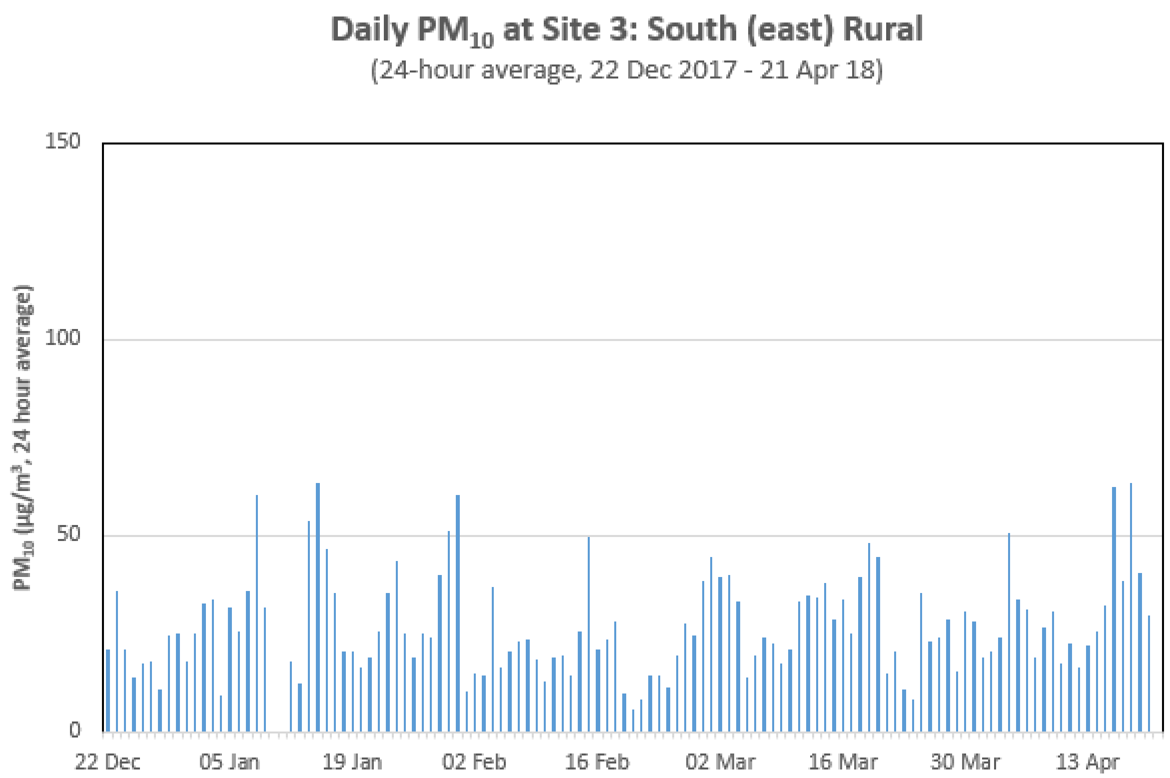

Figure 18 Daily PM_{10} (nephelometer) at Site 3: South (east) Rural for period 22 Dec 17 - 21 Apr 18

Table 6 Summary of dust nuisance trigger level exceedances (ordered from highest to lowest) at Site 3 between 22 December 2017 and 21 April 2018.

Date	Time[1]	1 hour PM_{10} concentration ($\mu g/m^3$)	Wind direction (°true)	Average 1 hour wind speed (km/hr)
01/02/2018	12:00pm - 1:00pm	284	North-westerly	19[2]
18/04/2018	9:00pm – 10:00pm	230	South-westerly	0.9
15/03/2018	7:00am-8:00am	167	Northerly (var)	2.8
19/04/2018	7:00am-8:00am	156	North-westerly	4.0
07/04/2018	8:00pm – 9:00pm	155	Light/variable	1.4
20/04/2018	11:00am – 12:00pm	154	Westerly	3.7
19/04/2018	6:00am-7:00am	153	North-westerly	2.8

Notes
[1] New Zealand standard time (NZST) – add one hour to get to New Zealand daylight savings time
[2] Wind speed based on incomplete data due to power outage during exceedance

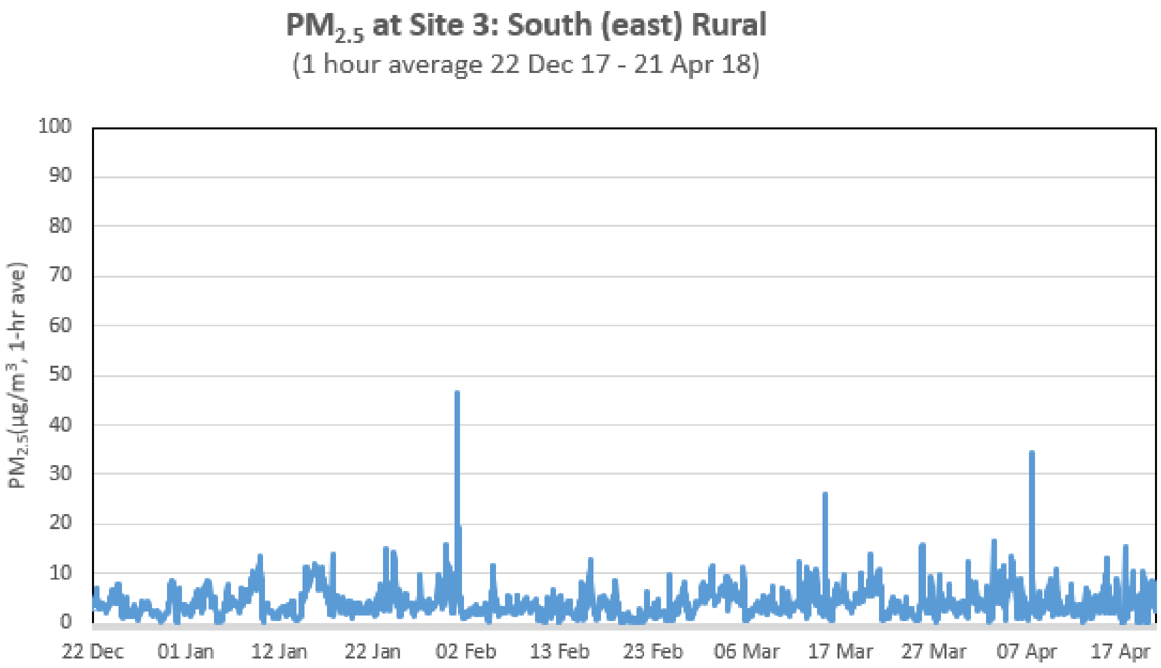

Figure 19 Hourly $PM_{2.5}$ (nephelometer) at Site 3: South (east) rural for period 22 Dec 17 - 21 Apr 18

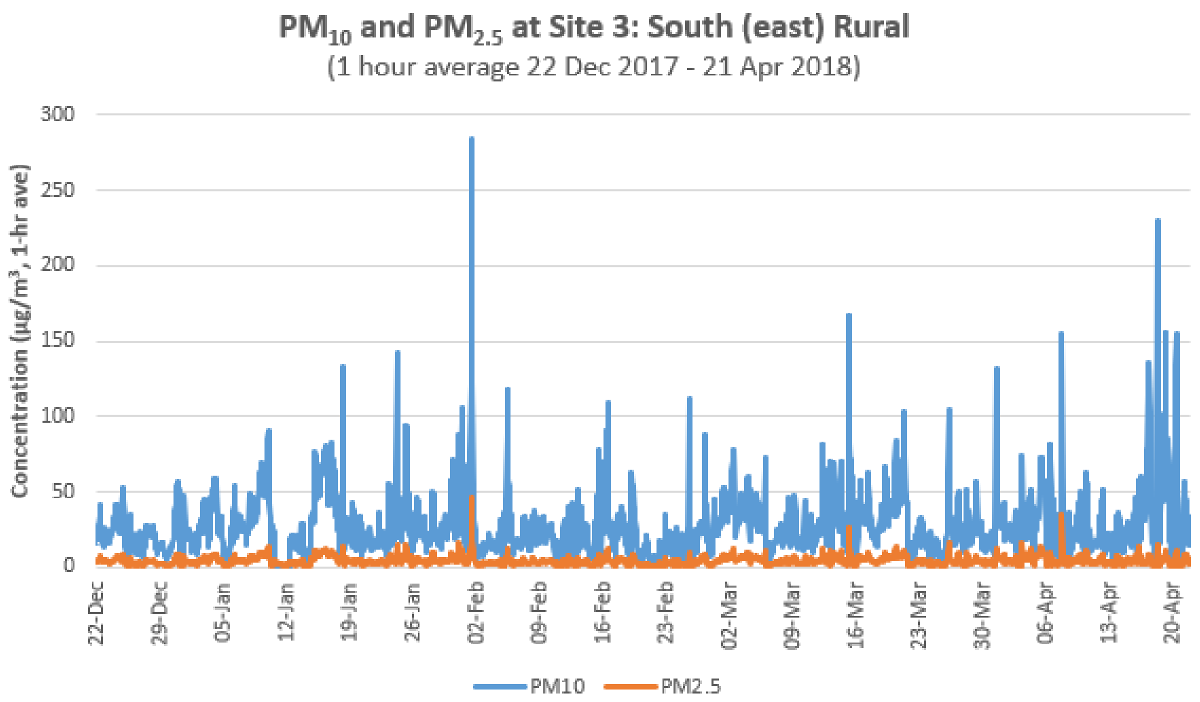

Figure 20 Hourly $PM_{2.5}$ and PM_{10} (nephelometer) at Site 2: South (east) rural 22 Dec 2017 - 21 Apr 2018

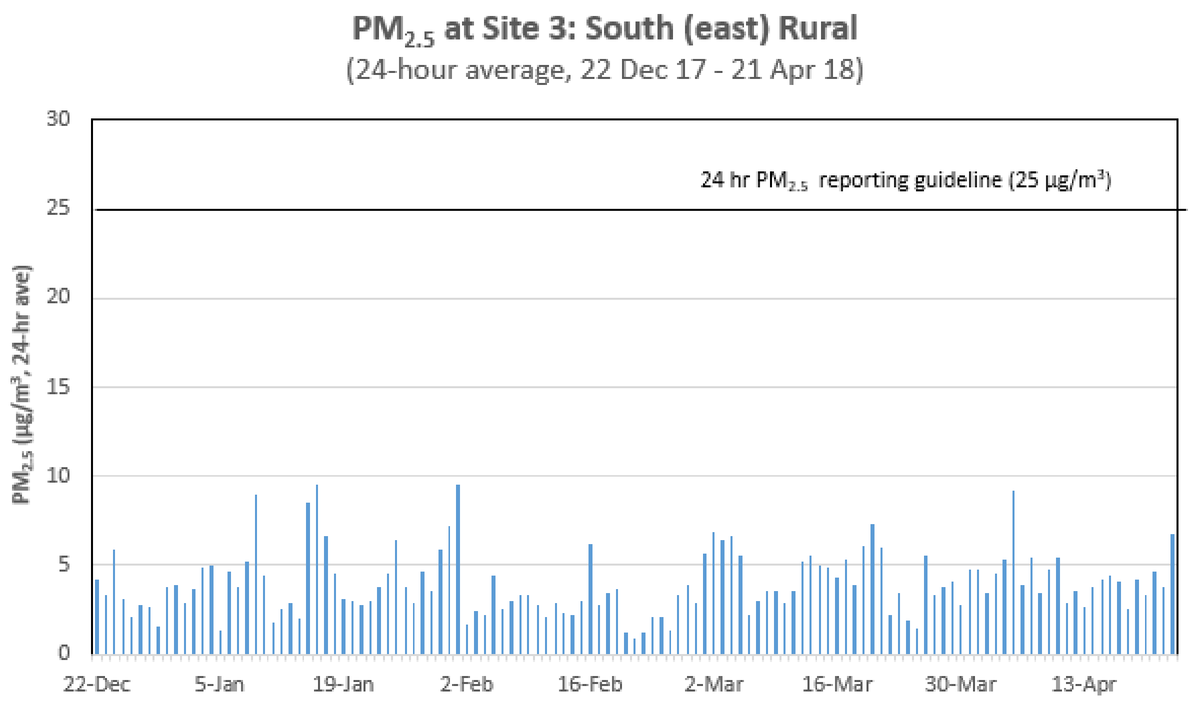

Figure 21 Daily $PM_{2.5}$ (nephelometer) at Site 3: South (east) Rural for period 22 Dec 17 - 21 Apr 18

2.4 Site 4: Background rural/residential particulate

PM_{10} and $PM_{2.5}$

We installed and commissioned a nephelometer (PM_{10}) monitor and BAM at site 4 on 14 December 2017. These were fully operational from 15 December 2017.

Figure 22 presents hourly PM_{10} from the nephelometer (blue) and BAM (pink) for the period 22 December 2017 to 21 April 2018. There were no exceedances of the 1-hour suggested dust nuisance trigger threshold (150 µg/m^3) during this monitoring period at site 4.

Figure 23 presents daily PM_{10} measured by the nephelometer and the BAM between 22 December 2017 and 21 April 2018. There were no exceedances of the NES for PM_{10} measured by the BAM during this period at Site 4.

Figure 24 presents PM_{10} measured by BAM as a function of PM_{10} measured by nephelometer for available validated (118) days of data at Site 4. This correlation suggests the nephelometer is over-reading actual PM_{10} levels when compared with the reference method.

Figure 25 presents monthly PM_{10} measured by BAM and monthly PM_{10} measured by nephelometer for four months of data at site 4. As with site 2, the longer time-average smooths the correlation between the two measurement methods and the data show good agreement.

Figure 26 presents hourly $PM_{2.5}$ measured by nephelometer at site 4 for the period 22 December 2017 to 21 April 2018.

Figure 27 presents both hourly $PM_{2.5}$ and PM_{10} as measured by nephelometer at site 4 and **Figure 28** presents daily $PM_{2.5}$ measured by nephelometer.

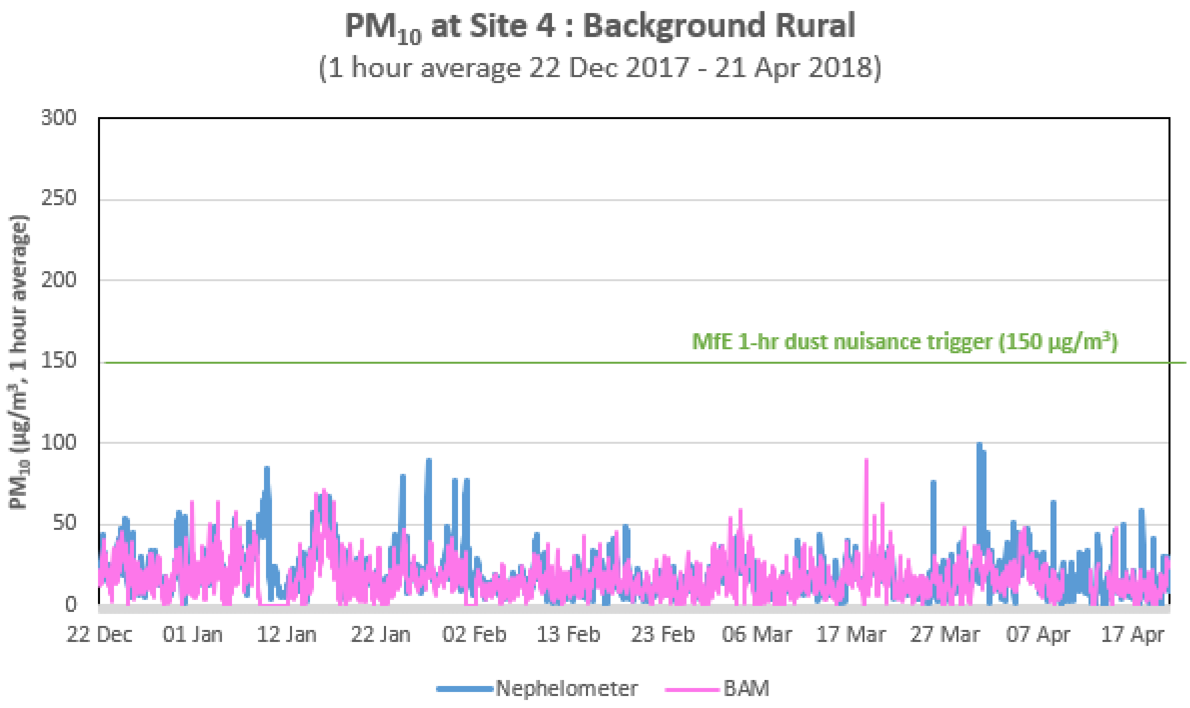

Figure 22 Hourly PM_{10} nephelometer (thick blue) and BAM (pink)* at Site 4: Background rural for period 22 Dec 2017 - 23 Apr 2018

*Beta attenuation monitor (reference method) is not accurate to 1-hour average

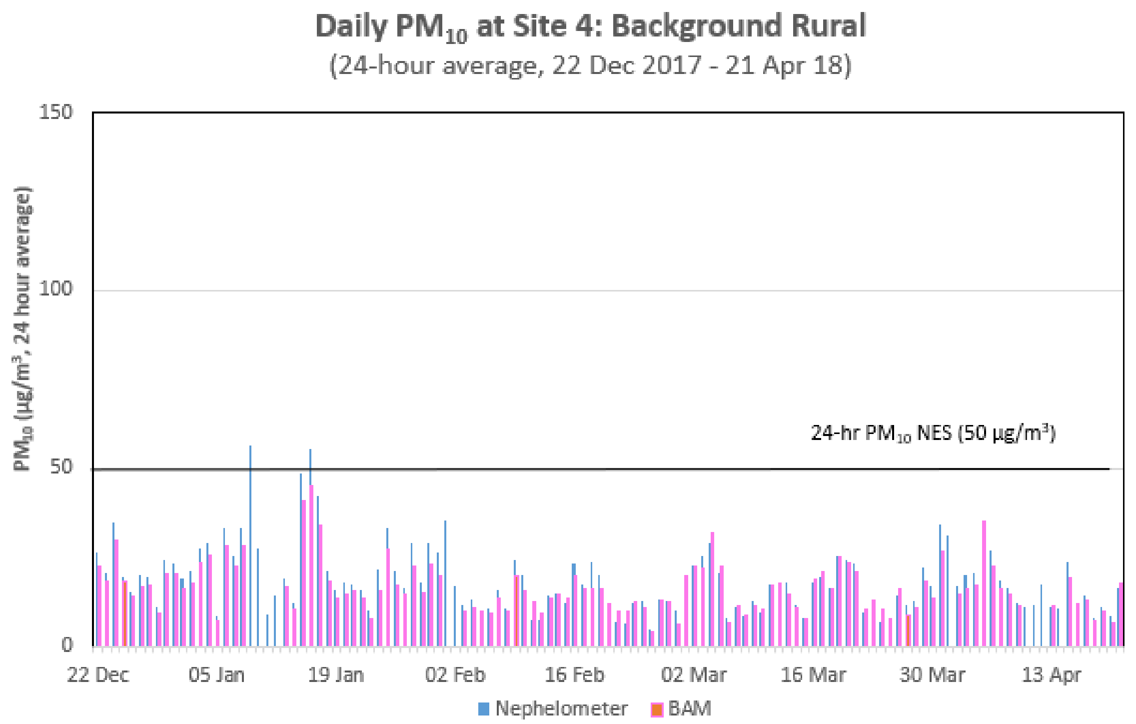

Figure 23 Daily PM_{10} nephelometer (blue) and BAM (pink) at Site 4: Background Rural for period 22 December 2017 - 21 April 2018

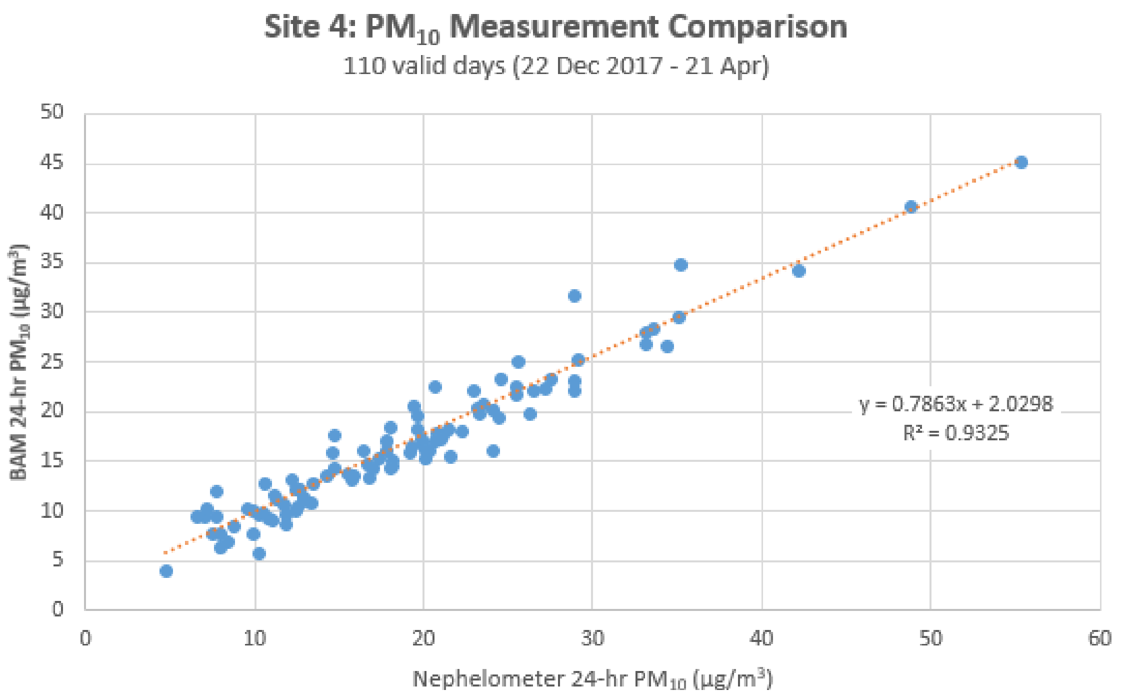

Figure 24 Daily PM_{10} measured by nephelometer as a function of daily PM_{10} measured by BAM at Site 4: Background Rural/Residential for (110 days of validated data) period 22 Dec 17 - 21 Apr 18 (3 days of BAM data were lost due to instrument damage following a power spike and 4 days due to the enclosure temperature dropping below the 3 degree tolerance)

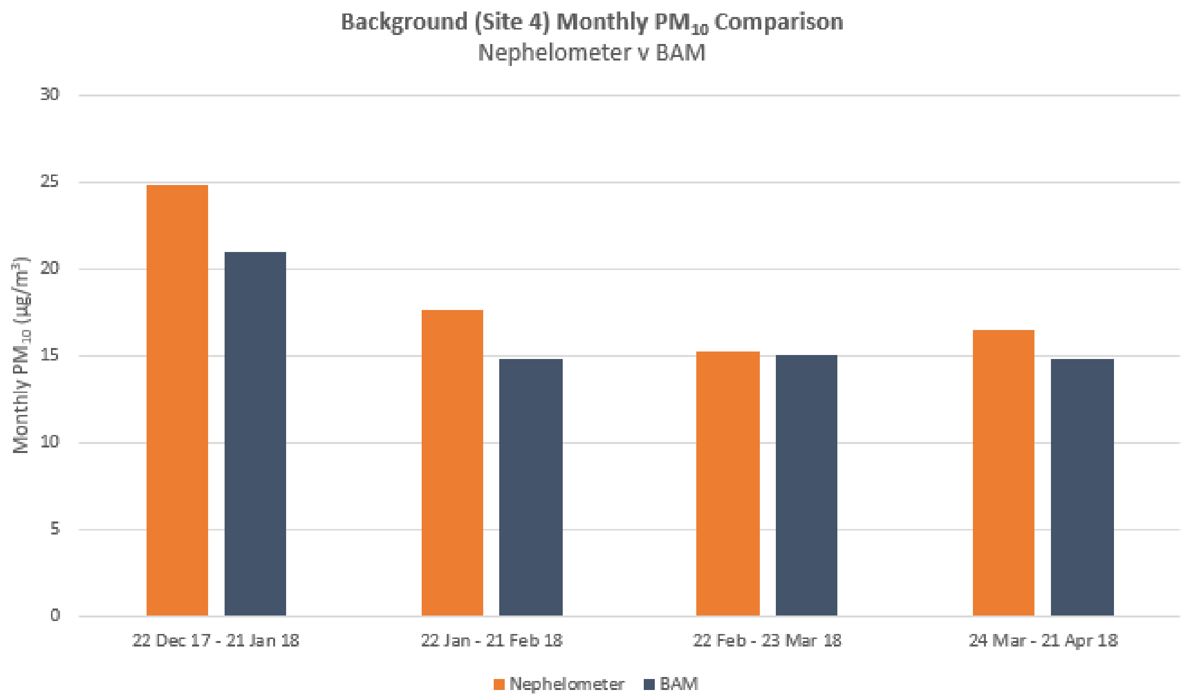

Figure 25 Comparison of PM_{10} concentration as measured by the nephelometer and beta attenuation monitor at Site 4: Background for each reporting period

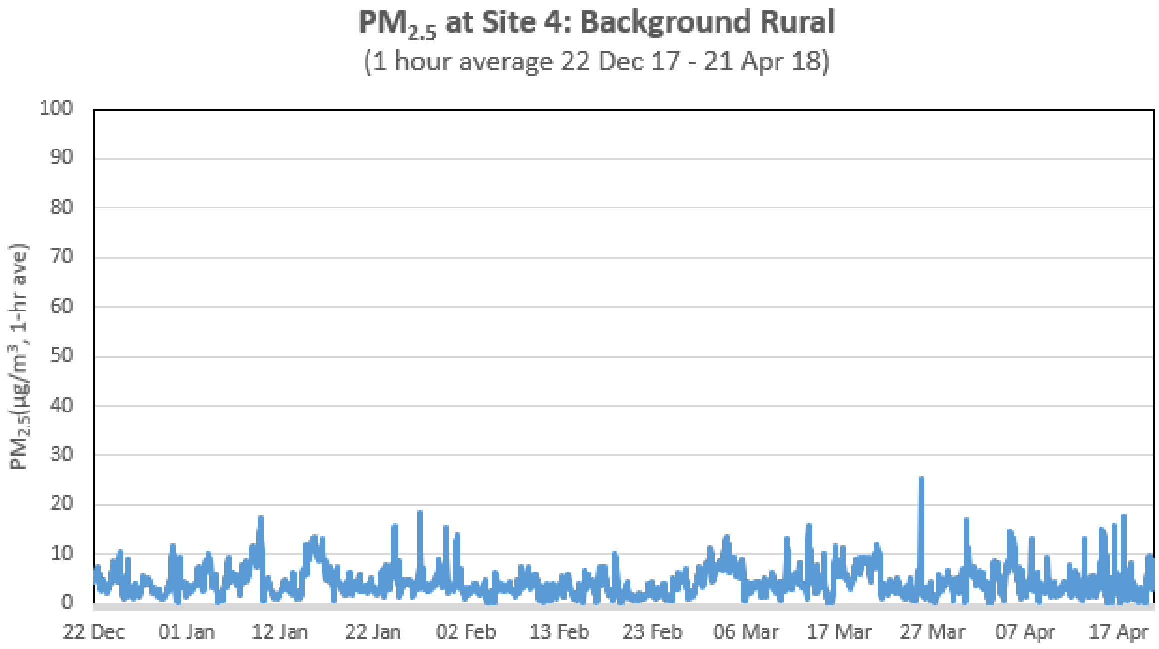

Figure 26 Hourly $PM_{2.5}$ (nephelometer) at Site 4: Background Rural/Residential for 22 Dec 17 - 23 Apr 18

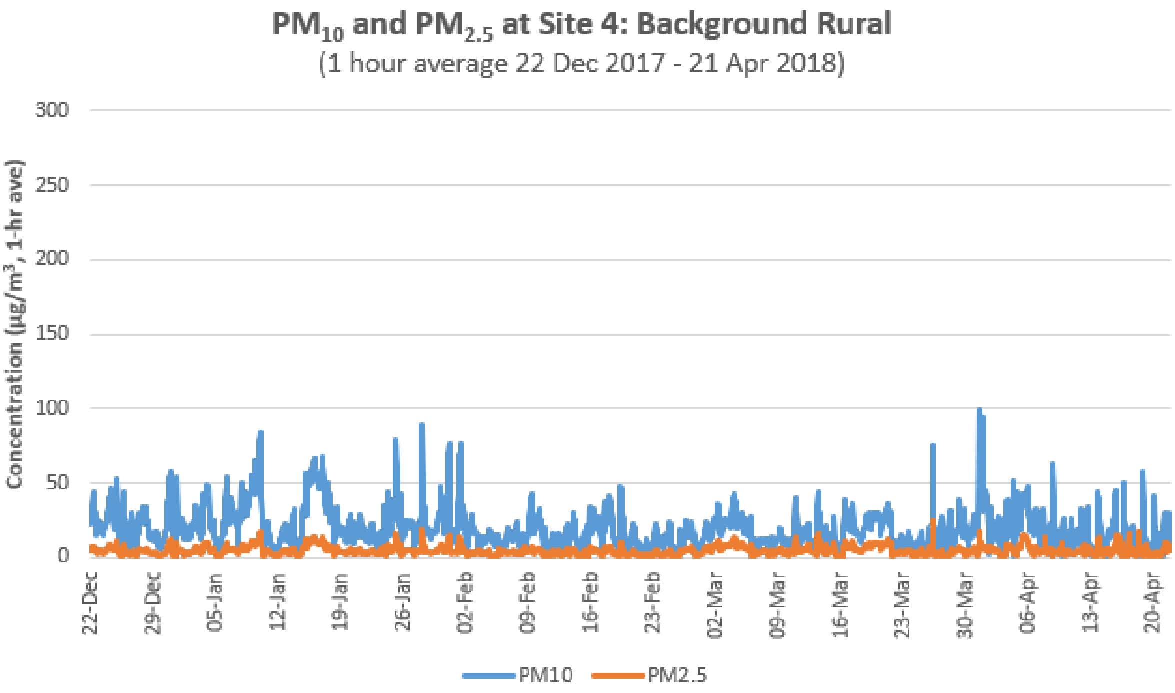

Figure 27 Hourly $PM_{2.5}$ and PM_{10} (nephelometer) at Site 4: Background rural/residential 22 Dec 2017 - 21 Apr 2018

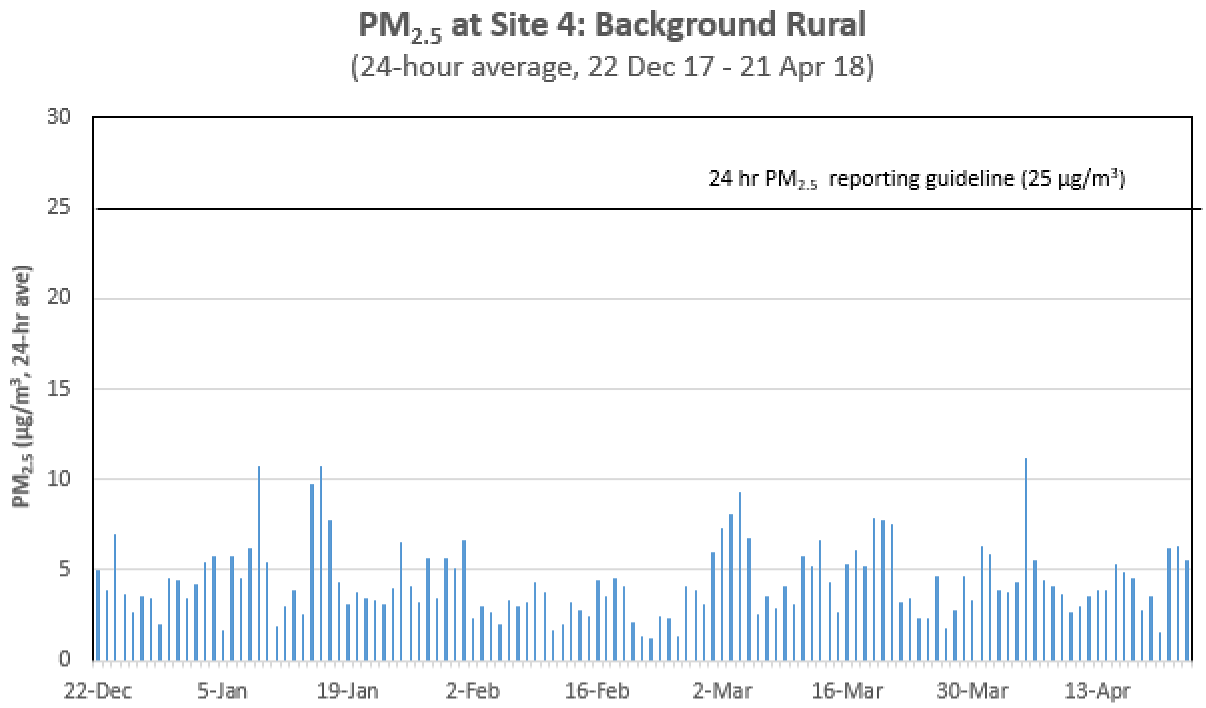

Figure 28 Daily $PM_{2.5}$ (nephelometer) at Site 4: Background Rural/Residential, 22 Dec 17 - 21 Apr 18

2.5 Site 5: South (west) rural particulate

We installed and commissioned a PM_{10} nephelometer monitor at site 5 on 15 December and it was fully operational from 16 December 2017.

Figure 29 presents hourly PM_{10} for the monitoring period 22 December 2017 – 21 April 2018. There were three exceedances of the 1-hour suggested dust nuisance trigger threshold (150 µg/m^3) during the monitoring period at site 5 as summarised in **Table 7**, which follows.

Figure 30 presents daily PM_{10} measured by the nephelometer between 22 December 2017 and 21 April 2018.

As noted above, nephelometers are not reference instruments. This means we cannot directly compare PM_{10} data from nephelometers in **Figure 30** with the NES for PM_{10}.

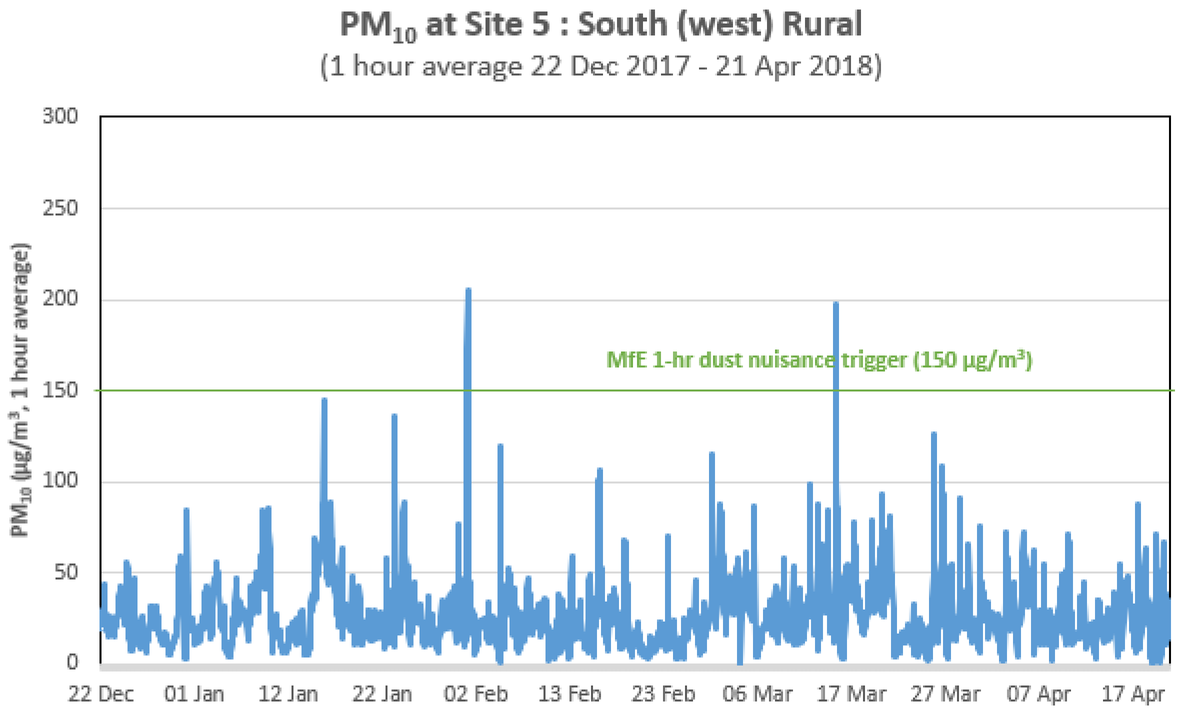

Figure 29 Hourly PM_{10} (nephelometer) at Site 5: South (west) rural for period 22 Dec - 21 Apr 2018

Table 7 Summary of dust nuisance trigger level exceedances at Site 5 (ordered highest to lowest) between 22 December 2017 and 21 April 2018.

Date	Time[1]	PM_{10} Concentration (µg/m³, 1-hr ave)	Wind direction (°true)	Wind speed (km/hr, 1-hr ave)	Comment
01/02/2018	12:00pm - 1:00pm	205[2]	North-westerly	19[3]	Strong winds
15/03/2018	7:00am – 8:00am	198	Variable	2.8	
01/02/2017	11:00am – 12:00pm	173	Northerly then northwesterly	16	Strong winds

Notes

[1] New Zealand standard time (NZST) – add one hour to get to New Zealand daylight savings time

[2] Wind data sourced from Christchurch airport for this period

[3] Wind speed based on incomplete data due to power outage during exceedance

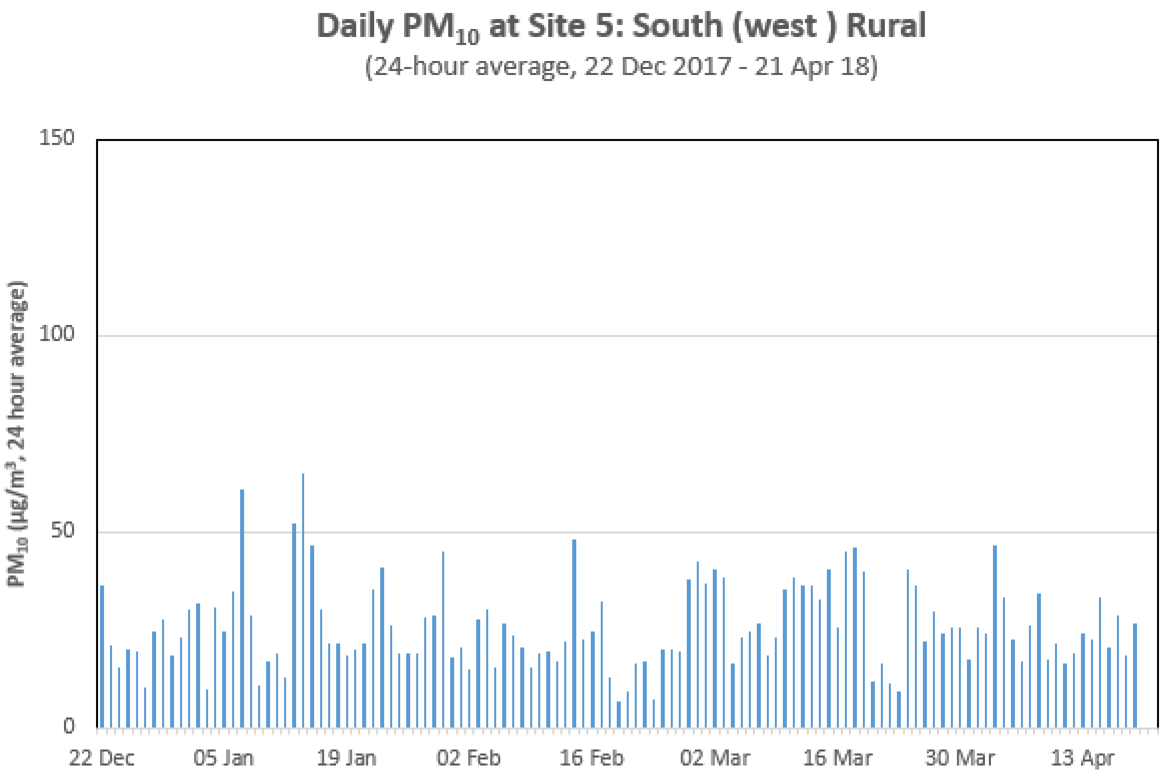

Figure 30 Daily PM_{10} (nephelometer) at Site 5: South (west) Rural for period 22 Dec 17 - 21 Apr 18

2.6 Site 6: North (west) rural/residential particulate

We installed and commissioned a PM_{10} nephelometer at site 6 on 22 December 2017. Due to communication problems, we shifted this site a small distance (<100 metres) in January 2018. This is not expected to make any significant impact on the monitoring results.

Figure 31 presents hourly PM_{10} for site 6. There were no exceedances of the suggested dust nuisance trigger threshold during the monitoring period 22 December 2017 to 21 April 2018. **Figure 32** presents daily PM_{10} measured by the nephelometer at site 6 for this period.

As noted above, nephelometers are not reference instruments. This means we cannot directly compare PM_{10} data from nephelometers in **Figure 32** with the NES for PM_{10}.

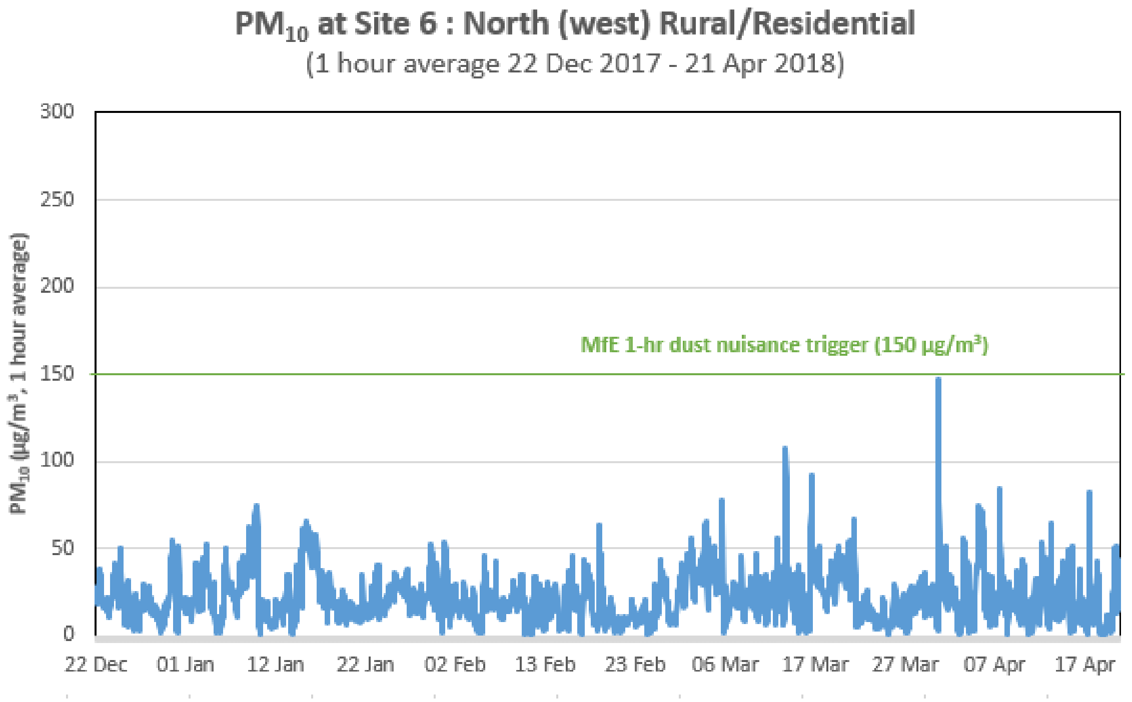

Figure 31 Hourly PM_{10} (nephelometer) at Site 6: North (west) Rural/Residential, 22 Dec 17 - 21 Apr 18

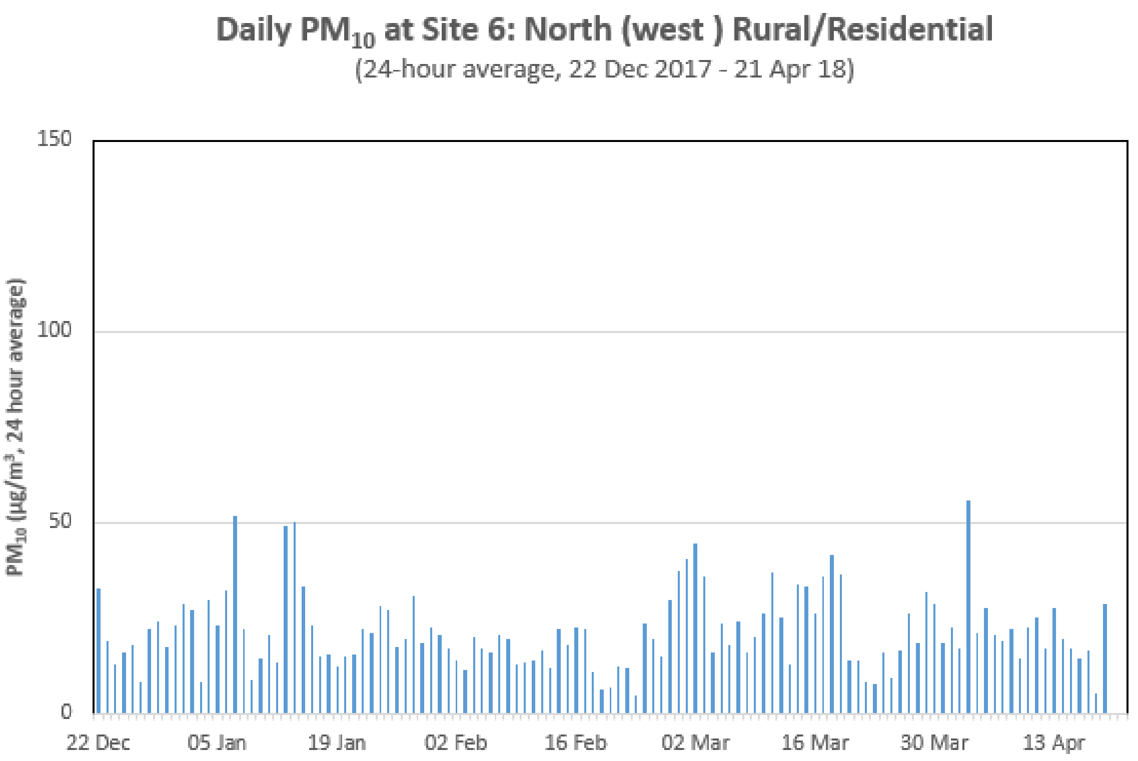

Figure 32 Daily PM_{10} (nephelometer) at Site 6: North (west) rural/residential, 22 Dec 17 – 21 Apr 18

2.7 Sites 7-9: Transect monitors particulate

Three PM_{10} nephelometers were deployed to the south-east of the site 3 monitor as shown in Table 8.

Table 8 Location and site details of transect monitors

Location	Installation date	Distance from quarries (metres)
Site 3	16 December 2017	50 m
Site 7 (Transect 1)	9 February 2018	250 m
Site 8 (Transect 2)	9 February 2018	500 m
Site 9 (Transect 3)	9 February 2018	650 m

A combined plot displaying the hourly average PM_{10} at each of the transect sites is shown below in **Figure 33**.

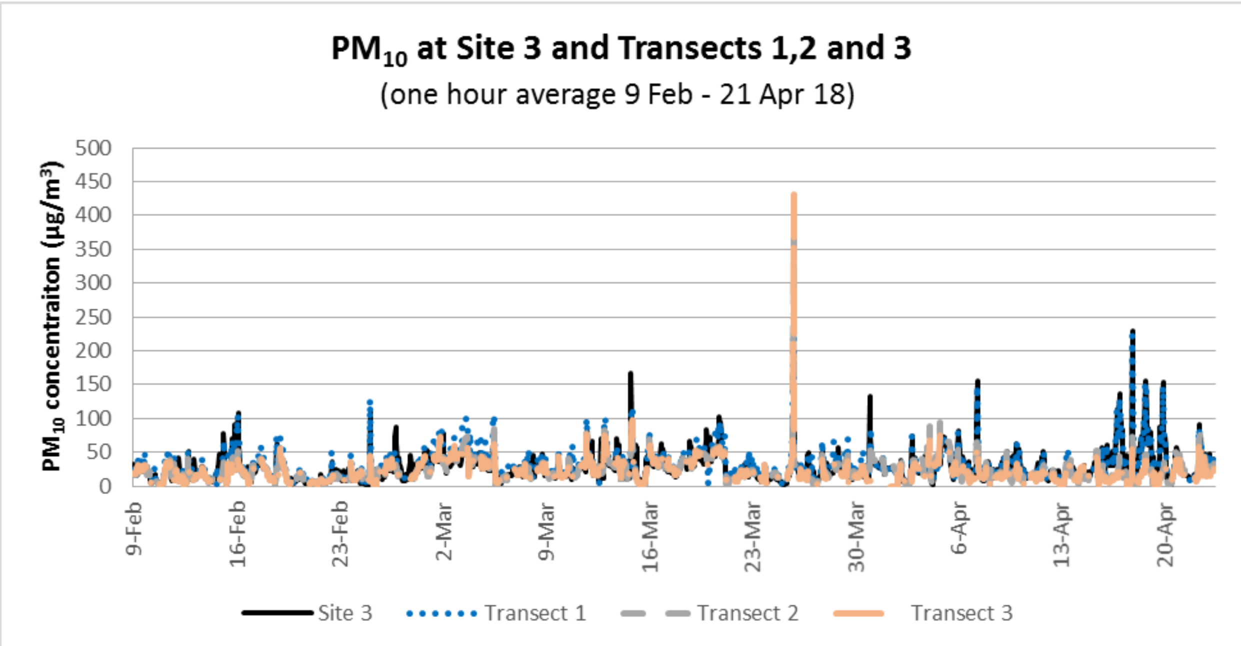

Figure 33 Hourly PM_{10} (nephelometer) at the transects south of the quarries, 9 Feb - 21 Apr 2018

There was one period of moderate north-westerly winds (peak speeds of 7.1 m/s or 25 kilometres per hour) and this occurred between 1 pm on 25 February and 1 am on 26 February. The peak wind gust of just over 7 metres per second coincided with an increase in PM_{10} concentrations downwind as shown in **Figure 33** below.

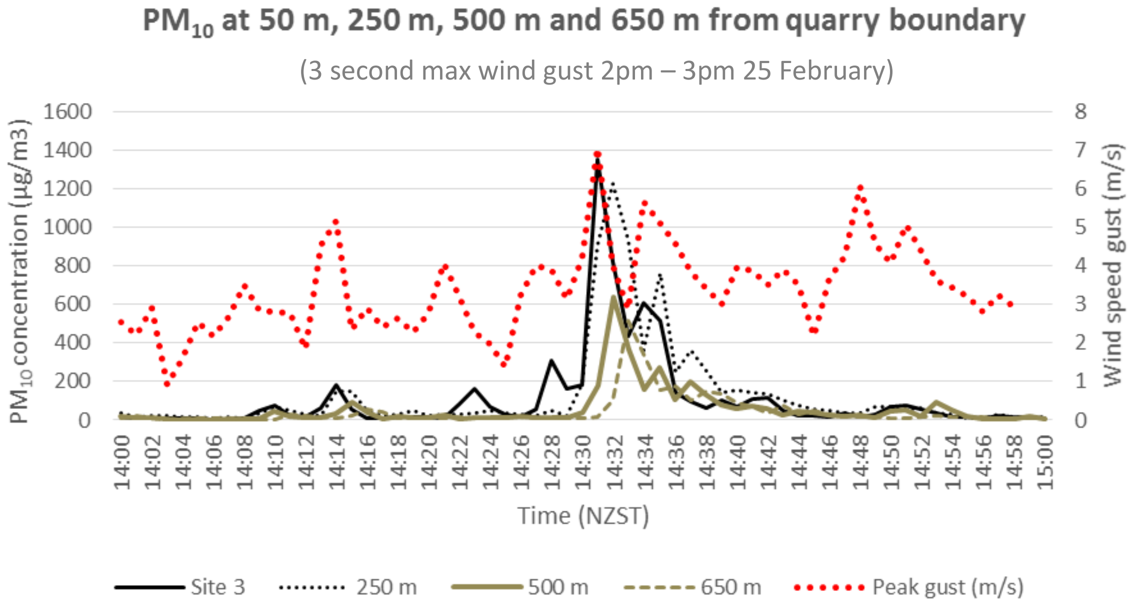

Figure 34 One minute average PM_{10} (nephelometer) and maximum wind speed at Site 3: South (east) rural and transect monitoring locations during moderate north west winds (2-3pm, 25 February 2018)

During this event, the peak (1-minute) concentration at site 3 (50 metres from the quarry boundary) reduced by approximately:[9]

- 9% at a distance of 250 metres;
- 54% at a distance of 500 metres; and
- 62% at a distance of 650 metres from the quarry boundary.

The increase in short-term PM_{10} coinciding with a north-westerly wind was over quickly and the 1-hour average at Site 3 (111 µg/m^3) did not exceed the suggested dust nuisance trigger level of 150 µg/m^3.

However, it is further apparent that this attenuation varies significantly with meteorology. For example, the exceedance of the dust nuisance trigger threshold measured at site 3 on 18 April 2018 occurred during very low wind speeds (less than 1 m/s). During this event, the peak (1-minute) concentration at site 3 (50 metres from the quarry boundary) reduced by approximately:

- 44% at a distance of 250 metres;
- 81% at a distance of 500 metres; and
- 83% at a distance of 650 metres from the quarry boundary.

[9] It should be noted that wind speed was recorded at a different site (Site 2). We have therefore, adjusted the wind speed times in **Figure 34** by approximately 2 minutes to account for the different location.

It should also be noted that attenuation further varies with the time average under consideration. For example, the reduction in 1-hour PM_{10} concentration during the above exceedance event during low wind speeds on 18 April at site 3 was:

- 3% at a distance of 250 metres; and
- 66% at a distance of 500 metres; and
- 72% at a distance of 650 metres from the quarry boundary.

The reduction in 1-hour average PM_{10} concentrations between site 3 and the transect monitoring locations is shown in **Figure 35** for the two exceedances of the suggested dust nuisance trigger threshold (150 µg/m^3) on 18 (9 pm) and 19 April (6 am).

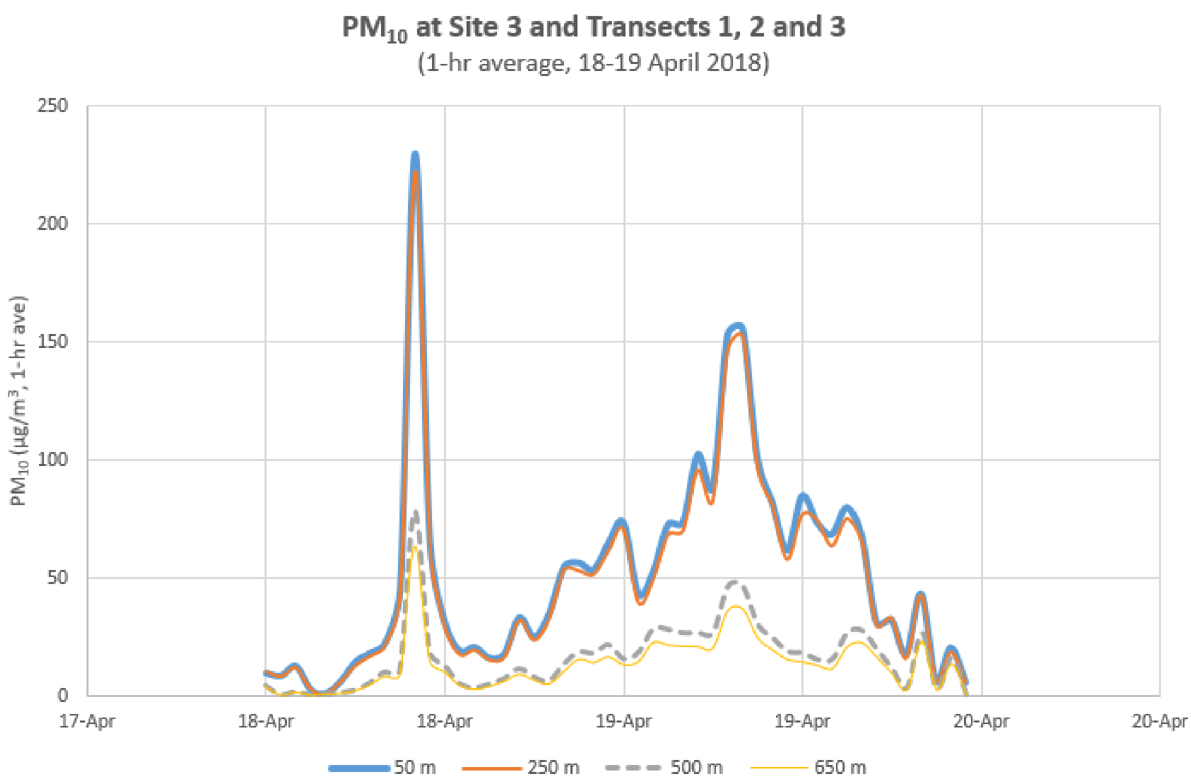

Figure 35 1-hour average PM_{10} concentrations at site 3 and transect monitoring locations, 18 - 19 April 18

2.8 Summary & discussion: particulate monitoring

Table 9, which follows, presents maximum short-term (hourly and daily) concentrations of PM_{10} measured using both nephelometers and reference (BAM) monitors at the five main Yaldhurst monitoring sites and one background location.

Table 10, which follows, displays the average PM_{10} concentrations measured by nephelometer at the five Yaldhurst monitoring sites and one background location during the study period.

Of the five main Yaldhurst monitoring sites[10], site 3 (south east) recorded the highest number of exceedances of the suggested 1-hour dust nuisance trigger threshold. Site 3 also recorded the highest four-month average (27 $\mu g/m^3$), while site 5 (south west) recorded the second highest four-month average (25 $\mu g/m^3$). These sites are both located less than 100 metres to the south of the quarries.

Four of the five Yaldhurst monitoring sites measured exceedances of the suggested 1-hour dust nuisance threshold concentration. The background location (site 4) and site 6 (north west) were the only sites which did not record any exceedance of the suggested dust nuisance trigger threshold.

The lowest four-month average PM_{10} of 19 $\mu g/m^3$ was recorded at the background site (site 4) and the highest (27 $\mu g/m^3$) at site 3 (south east).

It is interesting to note that although all six sites have similar average PM_{10} concentrations during December and January, the background site (site 4) displays a reduction relative to the Yaldhurst sites from February through to April.

Table 11 and **Table 12** present the distance each site is from the nearest quarry boundary, the amount of valid data and the events above selected concentration thresholds.

Table 13 presents the days of elevated PM_{10} concentrations as measured by nephelometer. Elevated daily PM_{10} concentrations were measured using nephelometers on nine days during the monitoring period. Of these, daily PM_{10} concentrations were elevated at all six monitoring sites (including background location) on two days (9th and 16th January 2018).

Overall, the monitoring shows that:

- Maximum hourly PM_{10} concentrations in Yaldhurst were significantly higher (147-284 $\mu g/m^3$) than those measured at the background site (99 $\mu g/m^3$).
- Maximum daily PM_{10} concentrations at site 2 in Yaldhurst were similar to maximum daily PM_{10} concentrations at the background location. Maximum daily PM_{10} concentrations at all other Yaldhurst sites (56-65 $\mu g/m^3$) were higher than background (45 $\mu g/m^3$).
- The 4-month PM_{10} concentrations at sites 2 and 6 in Yaldhurst (21-23 $\mu g/m^3$) were only slightly higher than that measured at the background location. The remainder of 4-month PM_{10} concentrations measured at Yaldhurst (sites 1, 3 and 5) were significantly higher (24-27 $\mu g/m^3$) than background (19 $\mu g/m^3$).

[10] i.e. excluding transect monitoring locations

Table 9 Maximum hourly and daily PM_{10} measured at five Yaldhurst monitoring sites and one background location (site 4, shaded) for monitoring period 22 Dec 17 – 21 Apr 18

Site	Distance from nearest quarry (m)	No. exceedances dust nuisance trigger threshold	Maximum 1-hr PM_{10} (µg/m^3)	Maximum 24-hr PM_{10} (µg/m^3)
Site 1	50	2	208	62
Site 2	190	1	183	58
Site 2 (BAM)*			-*	47
Site 3	50	7	284	63
Site 4	**4,800**	**0**	**99**	**57**
Site 4 (BAM)*			**-***	**45**
Site 5	80	3	205	65
Site 6	160	0	147	56

*Beta attenuation monitor (reference method) is not accurate to 1-hour average

Table 10 Average PM_{10} concentration measured at five Yaldhurst monitoring sites and one background location (site 4, shaded) for monitoring period 22 Dec 17 – 21 Apr 18

Site	**Average PM_{10} Concentration (µg/m^3) ***				
	22 Dec 17 – 21 Jan 18	22 Jan 18 – 21 Feb 18	22 Feb 18 – 23 Mar 18	24 Mar 18 – 21 Apr 18	**All 4 months**
Site 1	26	20	27	23	24
Site 2	25	19	26	22	23
Site 2 (BAM)*	22	16	24	21	21
Site 3	28	25	28	29	27
Site 4	**25**	**18**	**15**	**17**	**19**
Site 4 (BAM)*	**21**	**15**	**15**	**15**	**16**
Site 5	27	24	28	25	26
Site 6	23	18	24	20	21

*NB: Some BAM data was invalidated due to the enclosure temperature being outside the 3 degree control range.

Table 11 Summary Hourly (nephelometer) PM_{10} Results 22 Dec 2017 – 21 Apr 2018

Location	Distance to nearest quarry boundary	Number of hours of valid data	Percentage valid data	Maximum PM_{10} 1- hr average	95 Percentile PM_{10} 1- hr average	Standard deviation	Number of hours >100 µg/m³	Number of hours >150 µg/m³	Number of hours >200 µg/m³
	(m)		(%)	(µg/m³)	(µg/m³)	(µg/m³)			
Site 1	50	2,890	99.5	208	54	16	2	2	1
Site 2	190	2,879	99.1	183	55	16	5	1	0
Site 3	50	2,863	98.6	284	65	20	28	7	2
Site 4[a]	4,800	2,904	100	99	44	13	0	0	0
Site 5	80	2,901	99.9	205	58	18	15	3	1
Site 6	160	2,904	100	147	48	14	2	0	0
Site 7[b]	250	1,704	100	311	68	21	12	2	1
Site 8[c]	500	1,704	100	397	51	18	1	1	1
Site 9[d]	650	1,659	97.4	431	50	18	1	1	1

Notes

[a] Background monitoring location
[b] Transect 1
[c] Transect 2
[d] Transect 3

Table 12 Summary Daily (nephelometer and BAM) PM_{10} Results Dec 2017 – Apr 2018

Location*	Distance to nearest quarry boundary (m)	Number of days of valid data	Percentage valid data (%)	Maximum PM_{10} 24-hr average (µg/m³)	Number of days >50 µg/m³	Number of days >40 µg/m³	Number of days >30 µg/m³
Site 1	50	121	100	62	3	10	28
Site 2	190	119	98.3	58	4	7	21
Site 2 (BAM)		108	89.3	47	0	4	11
Site 3	50	119	99.3	63	8	16	42
Site 4	4,800	121	100	57	2	4	12
Site 4 (BAM)		110	90.9	45	0	2	5
Site 5	80	121	100	65	3	14	35
Site 6	160	121	100	56	3	7	19
Site 7[b]	250	71	100	64	7	14	30
Site 8[c]	500	71	100	61	1	7	16
Site 9[d]	650	68	95.8	49	0	7	15

Notes

*All nephelometers unless otherwise stated
[a] Background monitoring location, [b] Transect 1, [c] Transect 2, [d] Transect 3

Table 13 Days of elevated PM_{10} as a 24-hour average concentration, as measured by nephelometer during period 22 December 2017 – 21 April 2018

Date	PM_{10} Concentration (µg/m^3, 24-hour average)					
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
09-Jan-18	55	58	60	57	61	51
15-Jan-18	-	54	54	-	52	-
16-Jan-18	57	52	63	55	65	50
31-Jan-18	-	-	51	-	-	-
01-Feb-18	-	-	61	-	-	-
02-Apr-18	-	53	-	-	-	-
05-Apr-18	62	-	51	-	-	56
17-Apr-18	-	-	62	-	-	-
19-Apr-18	-	-	64	-	-	-

2.9 Respirable Crystalline Silica Monitoring

The results of the RCS monitoring are summarised in **Table 14**, which follows, and presented in full in **Appendix A**.

The purpose of the original monitoring programme was to collect 12 months of RCS data to enable comparison with a relevant annual ambient air quality guideline. We consider the chronic reference exposure level for silica (crystalline, respirable) from the California Office of Environmental Health Hazard Assessment (OEHHA, 2005) to be an appropriate guideline. This is 3 µg/m^3 as an annual average.

Only two results were detected above the RCS detection limit (20 µg/filter) – and both these samples were collected from site 3. The average of the three months monitoring at Site 3 indicates an average RCS concentration of 0.4 µg/m^3. All other monitoring sites were below detection limits during the monitoring period.

NB: It should be noted that the volume of air sampled is different for each period and at each site. This means that the resulting concentration limit will be slightly different for each site, as can be seen in **Table 14** below. Please also note that site 1 was subject to tampering in January 2018. RCS filters were thus exposed for different time periods at this site relative to others (no RCS was detected at site 1).

Table 14 RCS monitoring results for 22 Jan – 20 Apr 2018

Location	Date	Pre sample weight (g)	Post sample weight (g)	Mass (PM_4) (µg)	Air sampled (m^3)	RCS (µg)	RCS Concentration (µg/m^3)
Site 1	19-31 Jan	0.013673	0.014154	481	35.5	<20	<0.6
Site 1	9-20 Feb	0.012564	0.013238	674	57.0	<20	<0.4
Site 1	20 Feb - 20 Mar	0.011691	0.012581	890	83.5	<20	<0.2
Site 1	20 Mar - 20 Apr	0.011513	0.011773	260	97.8*	<20	<0.2
					Site 1 Average 19 Jan - 20 Apr 2018		**<0.3***
Site 2	19 Jan - 20 Feb	0.011214	0.012274	1060	92.8	<20	<0.2
Site 2	20 Feb - 20 Mar	0.012293	0.013466	1173	83.6	<20	<0.2
Site 2	20 Mar - 20 Apr	0.01211	0.012473	363	97.8*	<20	<0.2
					Site 2 Average 19 Jan - 20 Apr 2018		**<0.2**
Site 3	19 Jan - 20 Feb	0.010458	0.012374	1916	92.2	30	0.33
Site 3	20 Feb - 20 Mar	0.011066	0.01245	1384	83.7	<20	<0.2
Site 3	20 Mar - 20 Apr	0.011883	0.012547	664	97.8*	75	0.76
					Site 3 Average 19 Jan - 20 Apr 2018		**0.4**
Site 4	19 Jan - 20 Feb	0.011389	0.012468	1079	92.1	<20	<0.2
Site 4	20 Feb - 20 Mar	0.011488	0.012104	616	83.7	<20	<0.2
Site 4	20 Mar - 20 Apr	0.011795	0.011958	163	97.8*	<20	<0.2
					Site 4 Average 19 Jan - 20 Apr 2018		**<0.2**

Location	Date	Pre sample weight (g)	Post sample weight (g)	Mass (PM_4) (µg)	Air sampled (m^3)	RCS (µg)	RCS Concentration (µg/m^3)
Site 5	19 Jan - 20 Feb	0.012501	0.014311	1810	92.2	<20	<0.2
Site 5	20 Feb - 20 Mar	0.01606	0.01703	970	83.5	<20	<0.2
Site 5	20 Mar - 20 Apr	0.012019	0.012451	432	97.8*	<20	<0.2
					Site 5 Average 19 Jan - 20 Apr 2018		**<0.2**
Site 6	19 Jan - 20 Feb	0.012886	0.014078	1192	92.2	<20	<0.2
Site 6	20 Feb - 20 Mar	0.011234	0.012096	862	83.5	<20	<0.2
Site 6	20 Mar - 20 Apr	0.012068	0.012252	184	97.8*	<20	<0.2
					Site 6 Average 19 Jan - 20 Apr 2018		**<0.2**
Site 10	20 Feb - 20 Mar	0.01102	0.011765	745	83.6	<20	<0.2
Site 10	20 Mar - 20 Apr	0.011987	0.012245	258	97.8*	<20	<0.2
					Site 10 Average 19 Jan - 20 Apr 2018		**<0.2**

* A detailed review of the RCS data has identified that the proportion of particulate material collected on the filter (PM_4) has decreased relative to the PM_{10} measured by nephelometer. We suspect that the flow controllers on the RCS monitors are not moderating the flow sufficiently to correct for the drop in temperature during the onset of winter. Whilst this does not affect the accuracy of the RCS mass measured on the filter, it may be increasing the uncertainty of the calculated flow rate and the subsequent calculated RCS concentration. We reduced the temperature of the flow controllers in a controlled environment and measured the reduction in flow (as a result of reduced temperature). Based on this, we estimate the uncertainty of the three-month RCS concentration to be ±23%.

2.10 Quarry Operations

At our meeting with the quarries on 7 November 2017 we requested monitoring and operational data to inform the Yaldhurst monitoring programme. The quarry representatives responded positively to this request.

However, we have been unable to obtain operational data from the quarries to date.

2.11 Complaints data

Table 15 presents dust complaints registered with Environment Canterbury during the monitoring period that appeared to relate to this monitoring programme (only).

Table 15 Dust complaints received by Environment Canterbury 22 Dec 2017 -21 Apr 2018

Complaint Received Date	Incident Start Date	Incident Start Time	Description of Incident	No. Complaints	General Location Description
15 Jan 18	15 Jan 18	18:00	15/01/2017 6:05pm - [Dust Old West Coast Road and the Main West Coast Road, Yaldhurst] ... there is very visible dust in the air over our area Old West Coast Road and the Main West Coast Road. **2nd Incident Report** - 15/01/2018 6:00pm - ... a massive haze of dust...	2	Old West Coast Road and the Main West Coast Road, Yaldhurst, Christchurch
20/03/2018	16/03/2018	08:00	16/03/2018 - Excess dust from Winston's quarry on Friday March 16 after forecast southerly wind change duration of dust pollution 1 hr. This is not in compliance with consent restrictions.	1	Winston's quarry 233 Old West Coast Road
21/03/2018	20/03/2018	16:57	Email received 20/03/18 4:57pm: Massive dust cloud around fulton hogan/kbs quarries. Residents live near these quarries. **2nd Report** - [Dust - Miners Road/Fulton Hogan Quarry] - 21/03/2018 2:44pm - Caller reports seeing and breathing "intense amounts of dust" while driving down Miners Road [McLeans Island - Templeton] today at 11:30am near the Fulton Hogan Quarry (which is at 24 Miners Rd, Templeton).	2	Miners Road, Yaldhurst, Christchurch
8/04/2018	8/04/2018	15:30	Haze of dust from the Quarries sitting in suspension over our area, Old West Coast Rd, Yaldhurst, Christchurch .	1	Old West Coast Road, Yaldhurst
3/04/2018	3/04/2018	14:49	Lack of dust suppression at Road Metals Quarry on Main West Coast Road. A very strong Southerly wind has just come through (over 12 m/s) and I went to the back of our property (Old West Coast Road) to see if there was a water cart in operation to dampen down the Quarry. No water cart there at all	2	Old West Coast Road, Yaldhurst

3.0 Conclusions

Ten ambient air quality monitoring sites were operated between 22 December 2018 – 21 April 2018 as follows:

- Six sites measured respirable crystalline silica (RCS). Sampling commenced on 19 January 2018 and continued through to 21 April 2018;[11]
- Six sites measured particulate matter less than 10 micrometres in diameter (**PM_{10}**) for the period 22 December 2017 – 21 April 2018;
- Three sites also measured particulate matter less than 2.5 micrometres in diameter (**$PM_{2.5}$**) for the period 22 December 2017 – 21 April 2018;
- One site measured meteorology for the period 22 December 2017 – 21 April 2018;
- Three additional sites measured PM_{10} at varying distances from the quarries (transect monitoring) for the period 9 February – 21 April 2018;[12] and
- An additional site measured RCS from 20 February – 21 April 2018.[13]

This report presents results for the first four months of monitoring from the date all PM_{10} monitors were successfully commissioned (22 December 2018).

There were 13 exceedances of the suggested dust nuisance trigger threshold (150 µg/m^3 PM_{10} as a 1-hour average MfE, 2016) recorded at the five main monitoring sites in Yaldhurst during this monitoring period (17 including transect monitoring locations). There were no exceedances of the dust nuisance threshold at the background location.

There were no exceedances of the national environmental standard (**NES**) for PM_{10} recorded by the reference method monitors at two locations (site 2, North rural/residential and site 4, Background rural). Elevated daily PM_{10} concentrations were measured by non-reference method (nephelometer) on two days at all six monitoring sites (including background location). Elevated daily PM_{10} concentrations were also measured on seven days at the five main monitoring sites in Yaldhurst (but not the background location).

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[11] Commencement of sampling was delayed due to late provision of RCS filters from the manufacturer.

[12] The deployment of the transect monitors involved placement on land occupied by the Christchurch Mens Prison. This required negotiation and discussion to ensure staff and prisoner safety which delayed the deployment until 9 February.

[13] The installation of an additional site was requested by Environment Canterbury in early February, Deployment was delayed until 20 February to ensure consistent data with other RCS monitors.

A review of historical meteorological data from Christchurch Airport for the period of monitoring (22 December – 21 April) for the last ten years indicates there was an unusually high level of rainfall during the monitoring period.

Co-located monitoring for PM_{10} using non-reference (nephelometers) and reference method (beta attenuation monitors, **BAM**) at two monitoring locations (site 2 and site 4) has provided good correlations between the methods. The data to date suggest the nephelometers are over-reading actual PM_{10} levels when compared with the reference method. This was not anticipated when designing the monitoring programme, i.e. we anticipated the nephelometer would under-read compared with the BAM.

Co-located monitoring for $PM_{2.5}$ using nephelometers also appears to be providing realistic ambient data. $PM_{2.5}$ levels were generally low with no recorded exceedances of the Ministry for the Environment reporting 24-hour guideline of 25 µg/m^3.

A comparison of $PM_{2.5}$ and PM_{10} (nephelometer) data shows $PM_{2.5}$ to be a minor component of the PM_{10} concentrations measured in Yaldhurst (at sites 2 and 3) compared with background (site 4). The fine fraction $PM_{2.5}$ was 17% and 14% of PM_{10} measured at sites 2 and 3 respectively, but 24% at site 4. This suggests that the sources contributing to PM_{10} in Yaldhurst differ to those contributing to the PM_{10} measured at the background location.

Our review of the transect data suggests the elevated PM_{10} concentrations in Yaldhurst are associated with two different meteorological scenarios. The first scenario involves a sudden wind change, typically associated with an increase in wind speed. An example of this was the exceedance of the suggested trigger threshold for dust nuisance on 1 February 2018 at sites 3 and site 5 following a sudden wind change to a north-westerly wind.

The second scenario (and not anticipated when designing the monitoring programme) relates to much lighter wind speeds, often associated with variable wind directions. Examples of this were the exceedances of the suggested trigger threshold for dust nuisance on 18 and 19 April 2018 at site 3 when winds were very light (<1 metre per second, m/s).

Dust attenuation was measured at the transect locations downwind of the quarries (i.e. PM_{10} concentration reduced with distance). However, this varied considerably with meteorology and the time average being considered.

Three months of monitoring RCS at six locations, and two months of monitoring RCS at one additional location (a total of 20 samples), has identified only two filters above the RCS detection limit (20 µg per filter).

RCS was detected twice at site 3 which is 50 metres to the south east of the quarries. The average RCS concentration at site 3 for the three-month period 19 January -21 April 2018 was 0.4 µg/m^3. The chronic reference exposure level for RCS is 3 µg/m^3 as an annual average.

RCS concentrations at all other locations were below detection limits.

References

Ministry for the Environment (MfE), 2002. *Ambient Air Quality Guidelines: 2002 Update*. Wellington. May. Available at www.mfe.govt.nz

MfE, 2009. *Good Practice Guide for Air Quality Monitoring and Data Management 2009*. Wellington. April. Available at www.mfe.govt.nz

MfE, 2016. *Good Practice Guide for Assessing and Managing Dust*. Wellington. November. Available at www.mfe.govt.nz

World Health Organisation (WHO), (2006). *Air Quality Guidelines Global Update 2005*. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. WHO Regional Office for Europe. Copenhagen Ø. Denmark.

Appendix A RCS Analyses

Location	Sample ID	Start Date	End Date	Total Days	Pre sample weight	Post sample weight	Mass (PM_4)	Air sampled	RCS	RCS Conc
					(g)	(g)	(µg)	(m^3)	(µg)	(µg/m^3)
Site 1	197370-2	19/01/2018	31/01/2018	12	0.013673	0.014154	481	35.5	<20	<0.6
Site 1	197377-10	9/02/2018	20/02/2018	11	0.012564	0.013238	674	57.0	<20	<0.4
Site 1	198003	20/02/2018	20/03/2018	28	0.011691	0.012581	890	83.5	<20	<0.2
Site 1	198732	20/03/2018	20/04/2018	31	0.011513	0.011773	260	97.8	<20	<0.2
Site 1 Average 19 Jan - 20 Apr 2018										**<0.3**
Site 2	197372-4	19/01/2018	20/02/2018	32	0.011214	0.012274	1060	92.8	<20	<0.2
Site 2	198001	20/02/2018	20/03/2018	28	0.012293	0.013466	1173	83.6	<20	<0.2
Site 2	198735	20/03/2018	20/04/2018	31	0.01211	0.012473	363	97.8	<20	<0.2
Site 2 Average 19 Jan - 20 Apr 2018										**<0.2**
Site 2 Wind from quarries	197371-3	19/01/2018	20/02/2018	32	0.012933	0.013373	440	28.0	<20	<0.7
Site 2 Wind from quarries [a]	198000	20/02/2018	20/03/2018	28	0.01105	0.012161	1111	78.9	<20	<0.2
Site 2 Wind from quarries	198730	20/03/2018	20/04/2018	31	0.011981	0.012147	166	38.6	<20	<0.5
Site 2 Average 19 Jan - 20 Apr 2018, wind from quarry										**<0.5**
Site 2 Wind not from quarries	197373-5	19/01/2018	20/02/2018	32	0.012001	0.012655	654	64.8	<20	<0.3
Site 2 Wind not from quarries [b]	198002	20/02/2018	20/03/2018	28	0.012248	0.013195	947	77.4	<20	<0.2
Site 2 Wind not from quarries	198733	20/03/2018	20/04/2018	31	0.011872	0.012082	210	59.2	<20	<0.3
Site 2 Average 19 Jan - 20 Apr 2018, wind not from quarry										**<0.3**
Site 3	197369-1	19/01/2018	20/02/2018	32	0.010458	0.012374	1916	92.2	30	0.33
Site 3	197999	20/02/2018	20/03/2018	28	0.011066	0.01245	1384	83.7	<20	<0.2
Site 3	198731	20/03/2018	20/04/2018	31	0.011883	0.012547	664	97.8	75	0.76
Site 3 Average 19 Jan - 20 Apr 2018										**0.4**
Site 4	197376-8	19/01/2018	20/02/2018	32	0.011389	0.012468	1079	92.1	<20	<0.2
Site 4	198004	20/02/2018	20/03/2018	28	0.011488	0.012104	616	83.7	<20	<0.2
Site 4	198729	20/03/2018	20/04/2018	31	0.011795	0.011958	163	97.8	<20	<0.2
Site 4 Average 19 Jan - 20 Apr 2018										**<0.2**

Location	Sample ID	Start Date	End Date	Total Days	Pre sample weight (g)	Post sample weight (g)	Mass (PM_4) (µg)	Air sampled (m^3)	RCS (µg)	RCS Conc (µg/m^3)
Site 5	197375-9	19/01/2018	20/02/2018	32	0.012501	0.014311	1810	92.2	<20	<0.2
Site 5	198008	20/02/2018	20/03/2018	28	0.01606	0.01703	970	83.5	<20	<0.2
Site 5	198728	20/03/2018	20/04/2018	31	0.012019	0.012451	432	97.8	<20	<0.2
Site 5 Average 19 Jan - 20 Apr 2018										**<0.2**
Site 6	197374-7	19/01/2018	20/02/2018	32	0.012886	0.014078	1192	92.2	<20	<0.2
Site 6	198007	20/02/2018	20/03/2018	28	0.011234	0.012096	862	83.5	<20	<0.2
Site 6	198727	20/03/2018	20/04/2018	31	0.012068	0.012252	184	97.8	<20	<0.2
Site 6 Average 19 Jan - 20 Apr 2018										**<0.2**
Site 10	198006	20/02/2018	20/03/2018	28	0.01102	0.011765	745	83.6	<20	<0.2
Site 10	198734	20/03/2018	20/04/2018	31	0.011987	0.012245	258	97.8	<20	<0.2
Site 10 Average 19 Jan - 20 Apr 2018										**<0.2**

[a] Wind from quarries on dates 19 – 25 Feb, then wind from all wind directions for remainder of monitoring period

[b] Wind not from quarries on dates 19 – 25 Feb, then wind from all wind directions for remainder of monitoring period