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Prepared for:	Data and Information Committee
Report No.	SPS2107
Activity:	Governance Report
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Date:	10 March 2021

PURPOSE

[1] This annual report discusses the results of State of the Environment monitoring for air quality for the year 2020. Also included are a summary of Arrowtown PM_{10} spatial and temporal trends, an outline of the monitoring projects required to inform the future Regional Air Plan review, and an analysis of Otago's air quality data during the 2020 COVID-19 lockdown.

EXECUTIVE SUMMARY

[2] Otago has several towns – Alexandra, Arrowtown, Clyde, Cromwell and Milton, where air quality is considered degraded during winter. Under the Resource Management Act (RMA, 1991) and the National Environmental Standards for Air Quality (NESAQ, 2004, revised 2011) regional councils are required to monitor and improve air quality where necessary. The main pollutant of concern in Otago is particulate matter, a product of combustion, and in some Otago towns in excess of 90% of PM_{10} (particulate matter with a diameter of less than 10 microns) is produced by home heating emissions from solid fuel burners in winter (Environet, 2019). Long term exposure to PM_{10} and $PM_{2.5}$ (particulate matter with a diameter of less than 2.5 microns), contribute to the risks of developing, and exacerbating existing cardiovascular and respiratory conditions, which makes fine particulates a serious threat to human health (WHO, 2006).

[3] Otago Regional Council (ORC) has a State of the Environment (SOE) monitoring network to monitor PM_{10} and report exceedances of the NESAQ (50 µg/m³, 24-hour average). This network is currently being upgraded to include monitoring $PM_{2.5}$, in preparation for the NESAQ update incorporating limits for $PM_{2.5}$.

[4] During winter 2020 the NESAQ for PM_{10} was exceeded 80 times across six of the seven monitored towns in Otago. In the past, ORC has implemented a work programme (Air Quality Strategy (2018) to help Otago residents meet the Regional Air Plan rules in order to improve air quality in targeted towns. Analysis of long-term trends have shown that overall concentrations are decreasing in some airsheds, including Arrowtown, but significant decreases in emissions are still required to meet the NESAQ for PM_{10}.

[5] ORC air quality programmes include a Regional Air Plan review and the NESAQ update. These programmes are proposed for LTP planning years one to five.

RECOMMENDATION

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That the Council:

***Receives** this report*

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1) STATE OF THE ENVIRONMENT

[6] Otago has a network of seven air quality monitoring stations in the following locations: Alexandra, Arrowtown, Clyde, Cromwell, Central Dunedin, Milton and Mosgiel. All these sites monitor PM_{10}, and Central Dunedin also monitors $PM_{2.5}$. The $PM_{2.5}$ data will be analysed and presented in the next annual report.

[7] Under the RMA regional councils are required to monitor air quality and work towards meeting the standards of the NESAQ. The NESAQ is currently under review to include $PM_{2.5}$ standards, which are based on the current World Health Organisation recommended guidelines. The relevant standards and guidelines are given below (table 1).

[8] Table 1. Standards and guidelines for PM_{10} and $PM_{2.5}$.

Pollutant	Averaging Time	NESAQ Standard		NESAQ Guideline		WHO Guideline	
		Value (µg/m³)	Allowable exceedances	Value (µg/m³)	Allowable exceedances	Value (µg/m³)	Allowable exceedances
PM_{10}	24-hour	50	1 per year			50	NA
	Annual			20	NA	20	NA
$PM_{2.5}$	24-hour					25	3
	Annual					10	NA

[9] A summary of the key SOE monitoring indicators for 2020 are given below (Table 2).

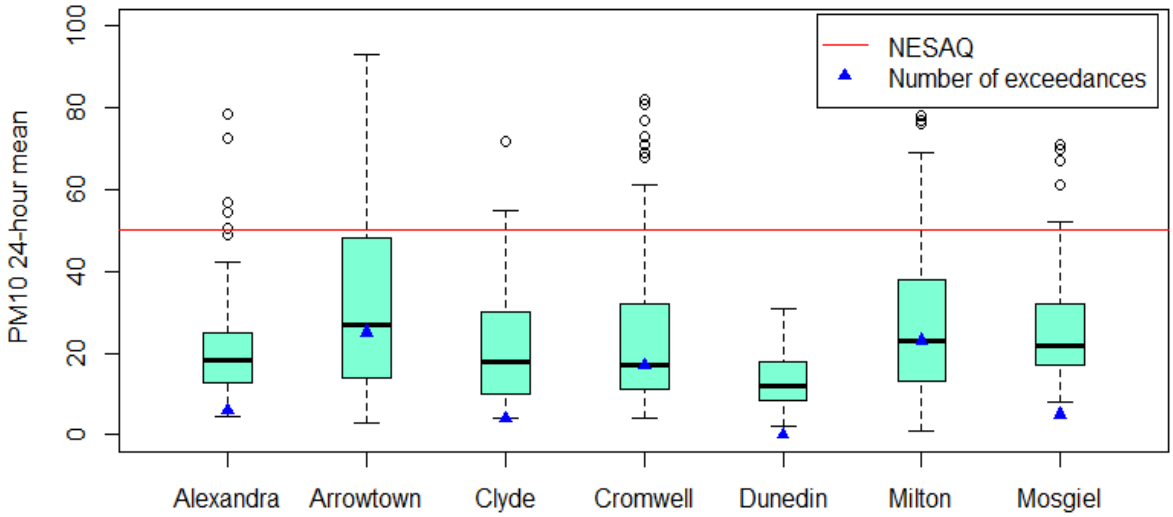
[10] Table 2. Key PM_{10} indicators for 2020 for Otago towns.

Site	Maximum daily concentration (µg/m³)	Winter Mean (µg/m³)	Average highest 10 days (µg/m³)	Number of exceedances (n)
Alexandra	79	21	54.2	6
Arrowtown	93	33	82.5	25
Clyde	72	23	51.4	4
Cromwell	82	29	72.0	17
Dunedin	40	13	29.3	0
Milton	96	32	74.8	23
Mosgiel	71	25	55.5	5

[11] With the exception of the Dunedin site, all sites exceeded the NESAQ limit for PM_{10} at least four times during 2020. Arrowtown and Milton had the highest number of exceedances, with 25 and 23 respectively, and both sites had the highest maximum concentrations with 93 µg/m³ and 96 µg/m³ respectively (table 1).

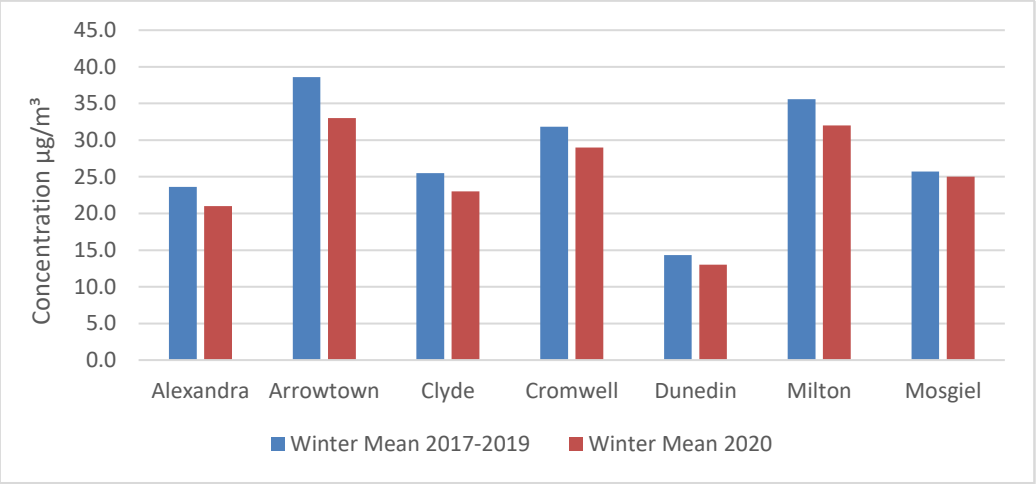
[12] Figure 1 below shows the wintertime (May-August inclusive) 24-hour average values of PM_{10} and the number of exceedances for each site. The exceedances of the NESAQ are shown to be mostly outliers at Alexandra, Clyde and Mosgiel (Figure 1).

[13] Figure 1. Winter PM_{10} daily concentrations and number of exceedances comparison. The box shows the median (horizontal bar) and interquartile range; whiskers are 1.5 times the interquartile range and more extreme (outlier) values are presented outside the whiskers. The NESAQ limit (red line) for PM_{10} is 50 µg/m³ (24-hour average).

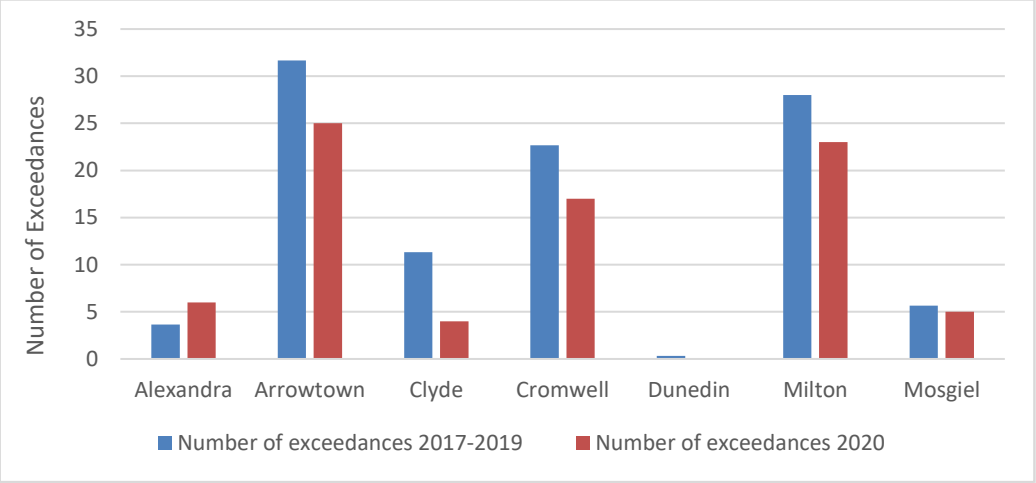


[14] When comparing data to previous years, the winter mean is a more appropriate indicator, as exceedances only occur in winter. Figures 2 and 3 below show how 2020 compares with the average of the previous three years. At all monitored sites, the mean winter concentrations have shown improvement. The least improvement has occurred in Dunedin and Mosgiel. For most sites the number of exceedances has shown improvement, except for Alexandra, which had six exceedances in 2020 compared to previous three year's average of four (Figure 3). Winter 2020 was one of the warmest on record, driven by warmer sea temperatures due to La Nina, and the prevalence of high pressures and north-easterlies causing sunny and warm conditions (NIWA, 2020).

[15] Figure 2. Mean winter PM_{10} concentrations comparison for Otago towns.



[16] Figure 3. Average annual number of PM_{10} exceedances (2017-2019) compared to exceedances in 2020 for Otago towns.

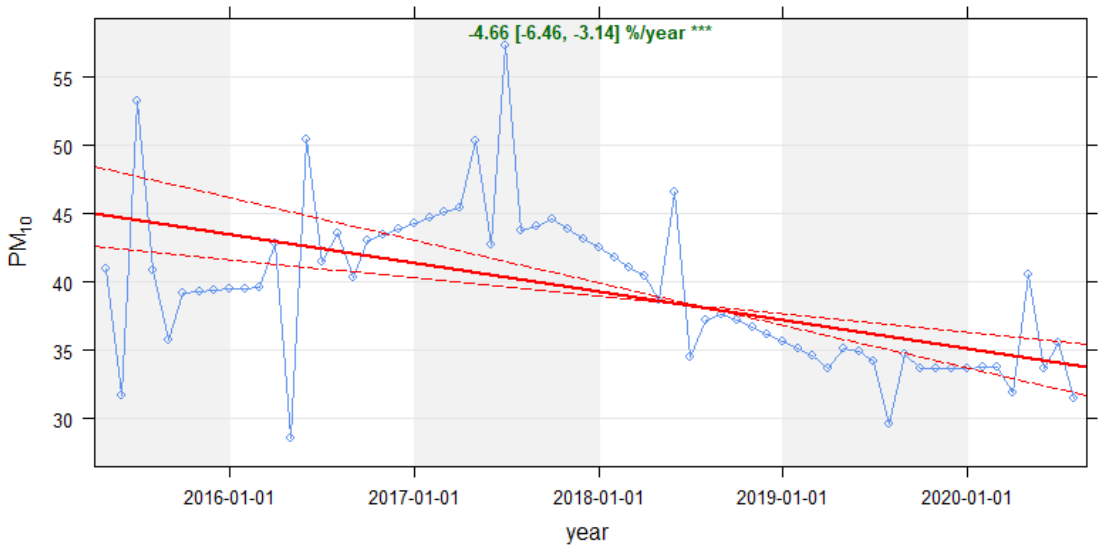


ARROWTOWN SPATIAL AND TEMPORAL TRENDS

[17] Arrowtown was the focus of a combined community engagement project undertaken by ORC, NIWA, Southern DHB and Cosy Homes Trust in 2019. The community response (feedback from Arrowtown Village Association, and the frequency of subsidy uptake in Arrowtown) to this work have shown that non-regulatory methods, such as education, help expand community understanding and enthusiasm for improving air quality (ORC 2020a).

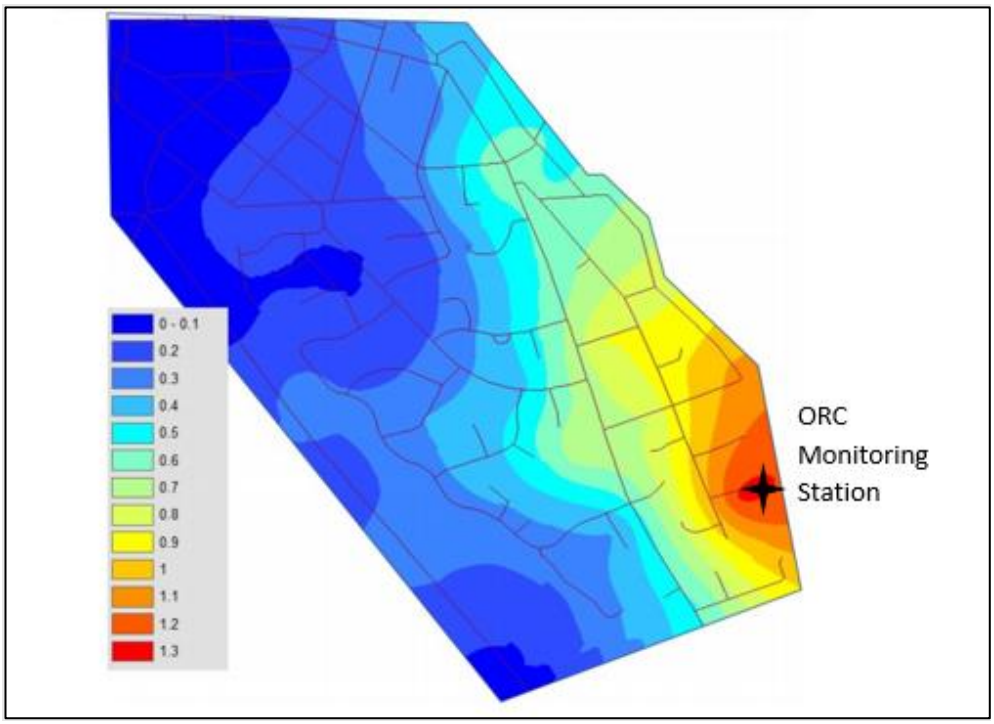
[18] Analysis of long-term trends have found that winter PM_{10} concentrations have decreased by 4% per year in Arrowtown between 2006 and 2014 (ORC, 2016), or 36% for the total period. In contrast winter-time emissions are estimated to have halved between 2006 and 2016, due to the replacement of older wood and coal burners to cleaner-burning or no-emission home heating (Wilton, 2016). This non-linear relationship between emissions and concentrations could be caused by a number of effects, however spatial variability, meteorological and topographical influences are some of the most likely. More recent analysis shows that the trend for winter concentrations is still decreasing by 4.7% per year (Figure 4), which equates to a 28% overall decrease between 2015 and 2020.

[19] Figure 4: Trend analysis for Arrowtown PM_{10} 2015 – 2020 (P<0.001). The blue line shows the de-seasonalised monthly averages, and the solid red line shows the trend, with dashed lines the 95% confidence of the slope.



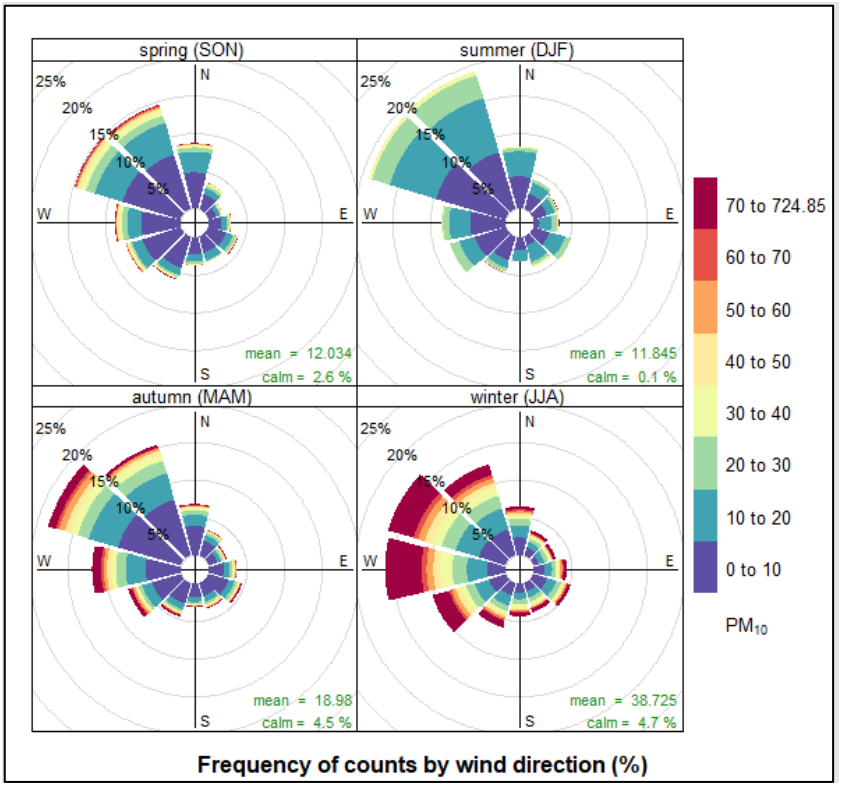
[20] Research conducted by NIWA in 2019, utilising a network of up to 47 low-cost sensors, concluded that $PM_{2.5}$ concentrations vary greatly across Arrowtown (Longley, 2020). NIWA indicate that these spatial differences are caused by the flow of smoke towards the eastern side of town, with the possibility of higher emissions from residences on the eastern side also contributing to the imbalance (Longley, 2020).

[21] Figure 5: Spatial variation in Arrowtown showing ratio of average $PM_{2.5}$ levels relative to the reference site, the ORC monitoring station. Source: Longley, 2020.



[22] Pollution roses for the ORC Arrowtown site indicate that the predominant wind directions are from the west to the northwest in all seasons. In winter the largest proportion of the highest PM_{10} concentrations come from the southwest to the north-west (Figure 6).

[23] Figure 6: Pollution roses by season for Arrowtown



[24] This work has helped increase awareness of air quality issues in Arrowtown and contributed to the continual replacement of inefficient wood burners. However, a large emissions reduction is required to improve air quality. The current target required for Arrowtown to meet the NESAQ for PM_{10} is 50 kg/day (ORC, 2017), and the latest emissions inventory estimated that the winter's daily average is 94 kg/day (Wilton, 2016). These targets will be reassessed with the onset of $PM_{2.5}$ monitoring and the new NESAQ limit.

[25] The 2016 emissions inventory also estimated that the number of burners non-compliant with Air Plan rules in Arrowtown to be around 260; the degree to which emissions would improve upon replacement of these burners depends on what they are replaced with, and user burn technique if replaced with ultra-low emission burners.

AIR PLAN REVIEW

[26] The Otago Regional Air Plan sets out the rules and policies for the different airsheds in Otago and is due to be updated in the near future. The proposed Long Term Plan will allow the investigation of the following, in order to obtain current air quality information for Otago's airsheds. The details of each issue are expanded upon below.

- Airshed categories

- Airshed boundaries
- Other pollutants

[27] The current NESAQ requires that all airsheds with the potential to exceed any of the standards must be monitored. Otago has 22 airsheds, and currently seven of these are monitored, with plans in place to expand to two new airsheds in Queenstown and Wanaka (Table 3). The 22 airsheds have been split into categories of Gazetted airshed (Gazette notice number 2005-go8236) and management areas named Air Zones, which are used in the Air Plan. This system of grouping airsheds together is unique to Otago, due to having more airsheds than other regions. Each group is represented by one permanently monitored site, except airshed 4, Queenstown, Wanaka, Hawea and Kingston. These sites were deemed unlikely to exceed the NESAQ at the time of gazetting. As there have been many changes to the urban areas in Otago since 2009, it would be beneficial to check that the airshed groups, and Air Zone groups are still relevant, and that the monitoring sites still represent the other airsheds in their groups. This would be undertaken using temporary monitoring of all airsheds that have neither recently or ever been monitored.

[28] Table 3: Current airsheds in Otago grouped by airshed and Air Zone number

Airshed Name	Airshed Number	Air Zone Number	Most recent year of monitoring
Alexandra	1	1	Current
Arrowtown*			Current
Clyde			Current
Cromwell			Current
Naseby		2	2007
Ranfurly			2008
Roxburgh			2007
Palmerston	2		2014
Mosgiel*			Current
South Dunedin			2009
Green Island			2002
Milton			Current
Balclutha	3		2018
North Dunedin			2007
Central Dunedin*			Current
Oamaru			2009
Port Chalmers			NA
Waikouaiti			NA
Hawea	4		NA
Kingston			NA
Queenstown			To be installed
Wanaka			To be installed
Middlemarch†	5	3	NA
Lawrence†			2012

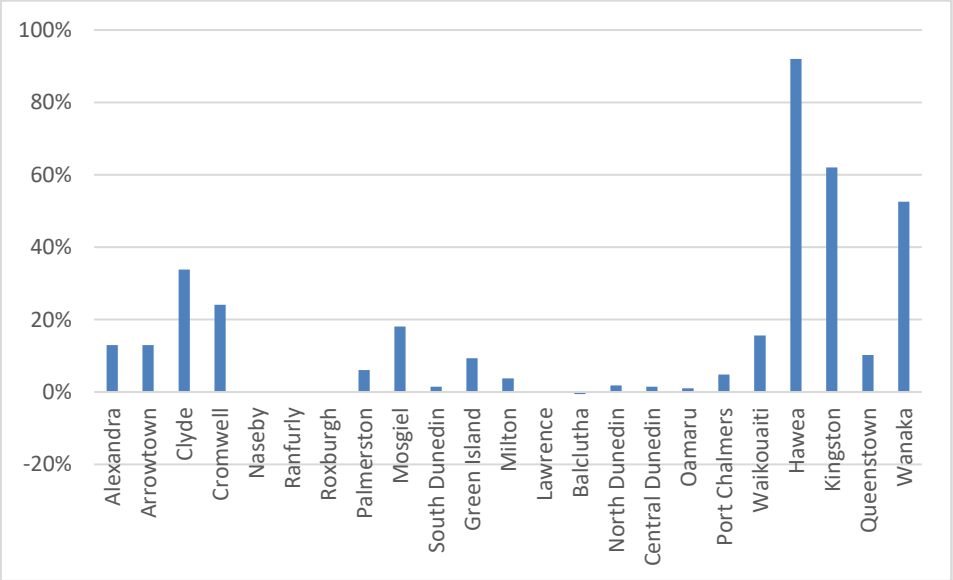
<Rest of Otago>			-
Total to be investigated in future			15

* Representative airshed site

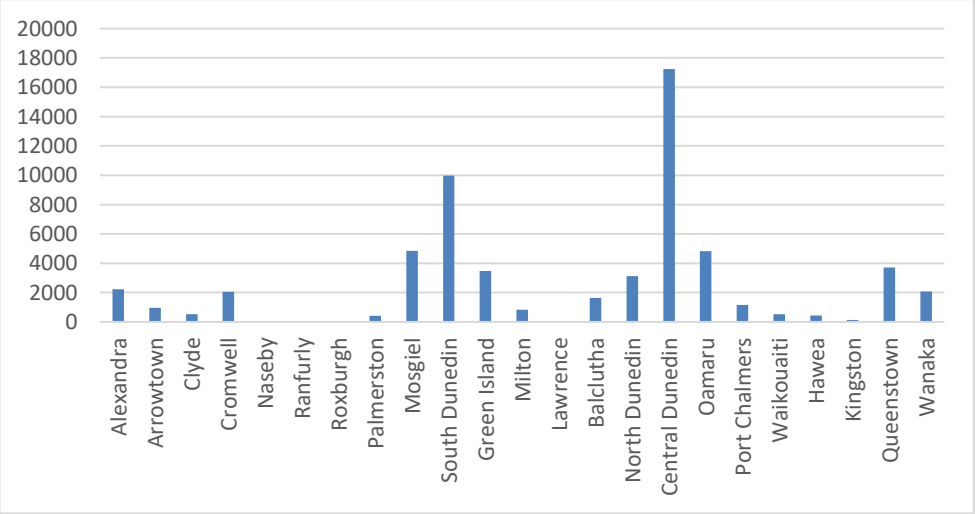
† Lawrence is due to become Airshed 2, Middlemarch is to be investigated.

[29] Some parts of Otago have been experiencing significant population growth and increased housing density. Figure 7 shows the percentage increase in households has changed significantly between 2006 and 2018. Hawea, Kingston and Wanaka have experienced the highest percentage of dwelling number increases within existing airshed boundaries (Figure 8).

[30] Figure 7: Number of household percentage change 2006-2018 within existing airshed boundaries



[31] Figure 8: Number of households in each airshed 2018



[32] Queenstown and Wanaka have experienced the most growth outside of their airshed boundaries with 46% and 69% respectively (Stats NZ, 2020). This is because they each have satellite suburbs growing outside of the central business districts, which didn't

exist when the airsheds were Gazetted. There are high winter concentrations of $PM_{2.5}$ in Albert Town, just outside of Wanaka (ORC 2020b). Any changes to airshed boundaries will be influenced by urban growth and district land use projections.

[33] There are five ambient air quality standards that regional councils are required to meet for the protection of human health, under the NESAQ. These are PM_{10}, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and ozone (O_3). Prior to the current Air Plan release, CO, NO_2 and SO_2 were monitored in various places in Otago; and were found unlikely to exceed any NESAQ standards. It is recommended that this work is repeated to establish up-to-date concentrations, and has been proposed for the next LTP.

[34] There are two other pollutants of interest in Otago – black carbon and benzo[a]pyrene. Both are products of combustion and strongly associated with wood burning. Black carbon is considered a significant climate change pollutant, which contributes to global and localised warming (Davy and Trompetter, 2018). Benzo[a]pyrene is a carcinogen that is often present in high levels where PM_{10} concentrations are high (Environet, 2003). Short term studies, for detecting these pollutants, would be beneficial in Otago.

COVID-19 AIR QUALITY DATASETS

[35] The Covid-19 lockdown in early 2020 provided an opportunity to examine the effect of reduced vehicular and industrial activity on air quality. Analysis was conducted on the 2020 data compared to historical data (2016-2019) for the four continuous monitoring sites – Alexandra, Arrowtown, Dunedin and Mosgiel.

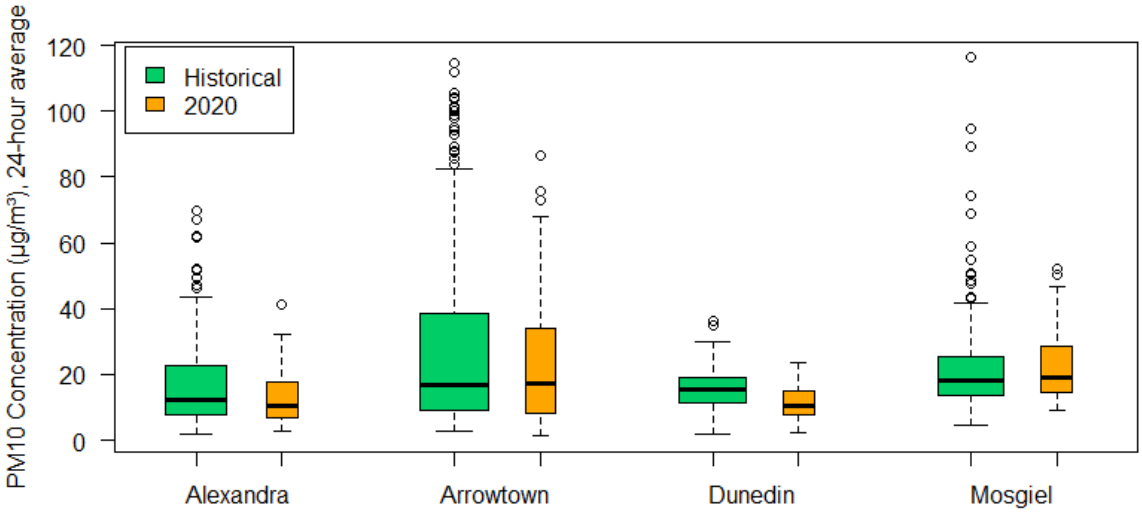
[36] Historical data used was "business as usual" data for a similar time of year, to allow for the seasonal impacts of meteorology on PM_{10} concentrations. Alert Level 4 corresponded with March and April, and Alert Levels 3 and 2 corresponded with April, May and June.

[37] When comparing the entire period of restrictions (27th March, start of Alert Level 4 to 7th June, end of Alert Level 2) with historical data both Alexandra and Dunedin show significantly lower PM_{10} concentrations (Table 4 and Figure 9).

[38] Table 4. Historical daily PM_{10} means compared to 2020 COVID-19 Alert Level data.

Site	Historical			2020			Difference		
	Mean	Std. dev	Data capture	Mean	Std. dev	Data capture	Concentration (µg/m³)	Concentration (%)	Significance to 95% confidence interval
Alexandra	16.2	11.7	77%	13.0	7.8	100%	-3.2	-20%	Significant
Arrowtown	26.8	24.2	95%	24.4	19.9	88%	-2.4	-9%	Not significant
Dunedin	14.6	6.0	89%	11.5	5.2	92%	-3.1	-21%	Significant
Mosgiel	21.5	11.9	82%	21.7	10.0	100%	0.3	1%	Not significant

[39] Figure 9. Historical daily PM_{10} compared to 2020 COVID-19 Alert Level data



[40] Further data analysis shows that Alexandra and Dunedin PM_{10} concentrations were lower during Alert Level 4 by 25% and 47% respectively, Alexandra PM_{10} was lower during Alert Levels 2 and 3 by 27%, and in contrast, Mosgiel PM_{10} was 27% higher during Alert Levels 2 and 3, than the same period for the previous years.

[41] International and New Zealand research has found that in most cases lockdowns have resulted in decreases of vehicle related emissions such as NO_2 and black carbon, with smaller reductions in particulate matter (Patel et al., 2019). The estimated contribution of vehicle emissions to PM_{10} was 42% in Alexandra in autumn (Wilton, 2017), so it is likely the reductions measured were due to the reduced amount of traffic and human activities. However, the traffic related emissions in Mosgiel (33% contribution to PM_{10} in autumn, Wilton, 2017) either didn't decrease or were compensated for by something else, with either natural or anthropogenic sources as possibilities.

[42] There were no significant changes in Arrowtown, however Level 4 restrictions took place prior to the beginning of wood-burning season. Arrowtown data suggests that there was not an increased amount of burning for home heating during any of the Alert Levels.

CONSIDERATIONS

[43] There are no considerations for the following:

- Policy
- Financial
- Significance and Engagement
- Legislative
- Risk

NEXT STEPS

[44] The next steps are:

- The monitoring network will continue upgrades and expansion during 2021.
- The proposed LTP includes programmes to inform the ORC Regional Air Plan review.

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APPENDIX

Exceedance Table 2020

Date	Site						
	Alexandra	**Arrowtown**	**Clyde**	**Cromwell**	**Dunedin**	**Milton**	**Mosgiel**
	PM_{10} µg/m³ (24-hour average)						
16-May			55	58			
17-May		52				52	
18-May						57	
19-May				58		57	
20-May		73		68		54	
21-May						69	
24-May						56	
29-May		54					
30-May		68				52	
31-May		76				59	
1-Jun		87				76	
2-Jun		55				95	
3-Jun						69	52
11-Jun						62	
13-Jun		76		69			
14-Jun		80		73		78	
15-Jun						77	
16-Jun	79		72			96	
19-Jun				61		61	
20-Jun		88		57			
21-Jun		69					
22-Jun		52					
23-Jun		57				51	70
24-Jun		87					67
27-Jun						63	
2-Jul				81			
3-Jul		57		71			
4-Jul	51			81			
5-Jul							61
10-Jul		82		77			
11-Jul		56		51			
13-Jul		55		55			
15-Jul		51					
16-Jul		56					
17-Jul		68				60	
18-Jul		93				54	
19-Jul		85				54	
20-Jul						64	71
27-Jul		59		82			
28-Jul		58		54		53	
1-Aug	55						
2-Aug	72						
3-Aug				55			
6-Aug	54						
16-Aug			54				
17-Aug			54				
18-Aug	57			52			
Total	**6**	**25**	**4**	**17**	**0**	**23**	**5**

ATTACHMENTS

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