9.1. Air quality activities 2023 update

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PURPOSE

[1] This report presents the results of two air quality projects undertaken during 2023: black carbon monitoring in Arrowtown and spatial PM_{10} monitoring in Alexandra.

EXECUTIVE SUMMARY

[2] Black carbon was monitored as a trial study at Arrowtown from March to October 2023. The instrument performed well, and the data was analysed in comparison to temperature and PM_{10} data.

[3] NIWA conducted a spatial study using 42 low-cost sensors within the Alexandra airshed to understand more about the variation in PM_{10} concentrations. It was found that the location of peak average concentrations is located to the northwest of the town, and those concentrations are approximately double the concentrations in other parts of town.

RECOMMENDATION

That the Council:

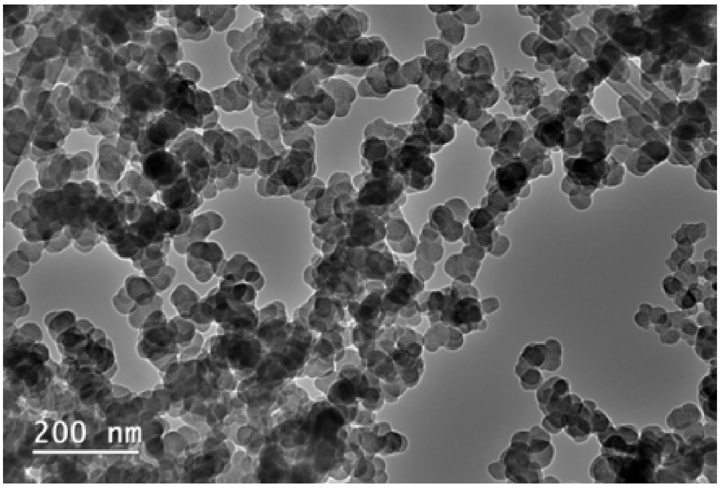
1) ***Notes** the two studies undertaken as part of the Air Quality programme.*

BLACK CARBON MONITORING AT ARROWTOWN

[4] Black carbon (BC) is a pollutant of emerging importance for both climate change and human health. BC is any light-absorbing chemical component of particulate matter (PM), and it comes from incomplete combustion. BC falls into the ultrafine size range of PM, generally between 10-30 nanometres for individual particles, to larger chains of 300-500 nm[1] (Figure 1), however the size, shape and composition of BC particles change as they age and react to other chemicals in the atmosphere.

[1] For comparison, the upper size limit of $PM_{2.5}$ is 2500 nm. BC particles are too small to be picked up by instruments that monitor PM_{10} and $PM_{2.5}$.

Figure 1 BC particle chains from biomass combustion. Source: Davy and Ancelet, 2015



[5] Because BC is black, it absorbs light and heat, contributing to warming the atmosphere. It is a short-lived pollutant, spending about one week in the atmosphere, however it is an important pollutant for radiative forcing[2] after CO_2 and methane. It can also impact cloud formation and increases ice and snow melt when it settles on these surfaces. New Zealand research shows that black carbon concentrations are likely to be highest in areas of either high traffic or high use of solid fuel burning for home heating (Davy and Trompetter, 2018).

[6] During winter 2023 ORC had the opportunity to monitor BC using a Magee Aethelometer AE33 on loan from Benchmark Monitoring. The AE33 is a continuous instrument which uses optical absorption to calculate the concentration of BC as the particles accumulate on the filter tape.

[7] The data shows a strong seasonal pattern, with higher concentrations during winter, which is similar to that of PM_{10} in Arrowtown, however on a much smaller scale (Figure 2). Figure 2 also shows the ambient temperature which has an inverse relationship to both pollutants. The daily pattern of BC indicates two periods of time during the day that BC is highest: at 08:00-09:00 and 19:00-21:00 (Figure 3), which is similar to the home heating pattern found in PM_{10} data. The data differs however as usually the PM_{10} evening peak is much higher than the morning peak. Overall, the BC data is similar in seasonal and daily patterns to PM. This is expected as they have the same source, home heating emissions.

[2] Radiative forcing refers to factors that alter the balance between the sun's incoming energy and the outgoing energy from the Earth's atmosphere. Climate pollutants can impact this balance as either cooling or warming forces and these can be added up to calculate total radiative forcing in Watts/m^2.

Figure 2 Black carbon, PM_{10} and ambient temperature for Arrowtown, 2023 (24-hour average)

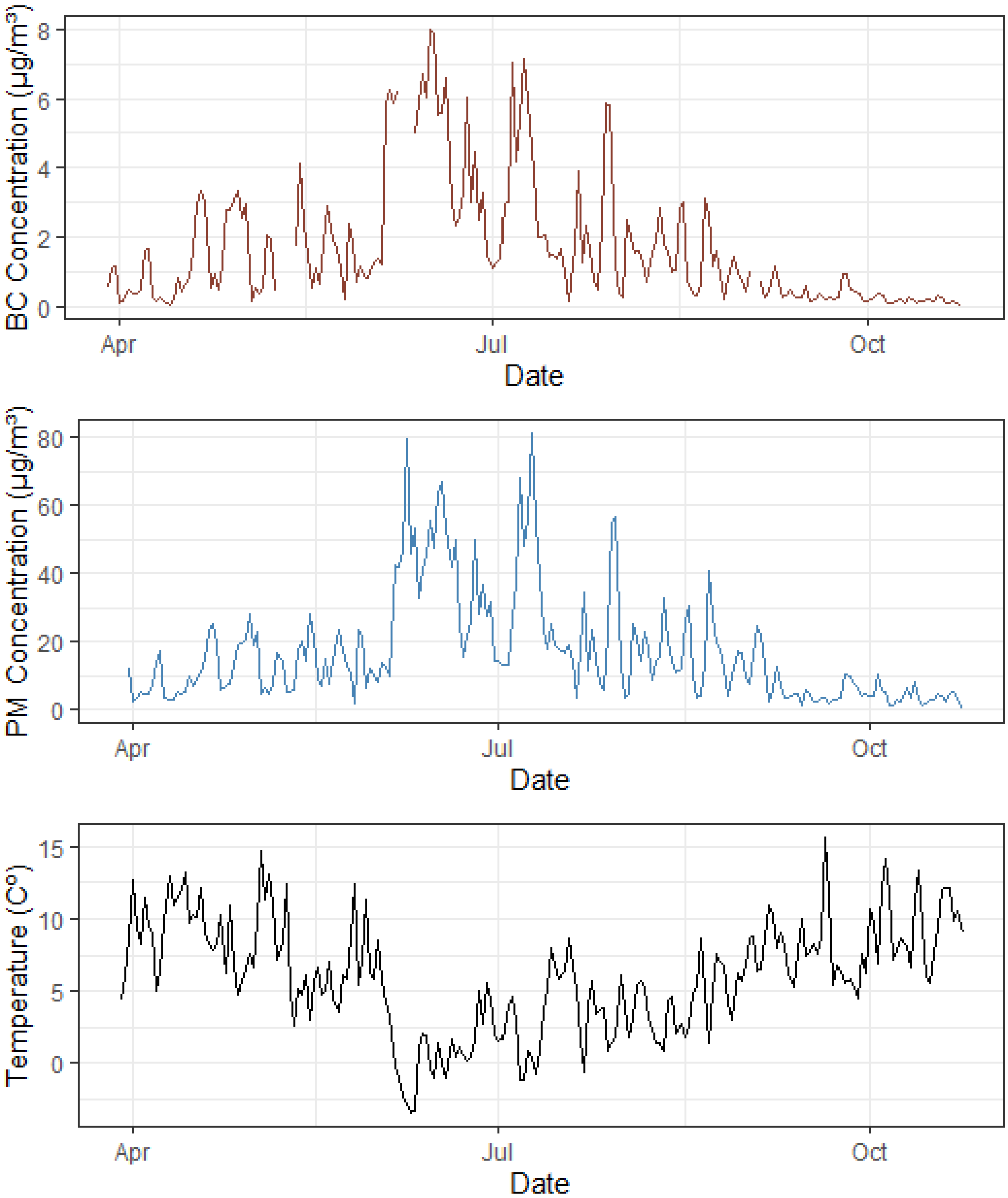
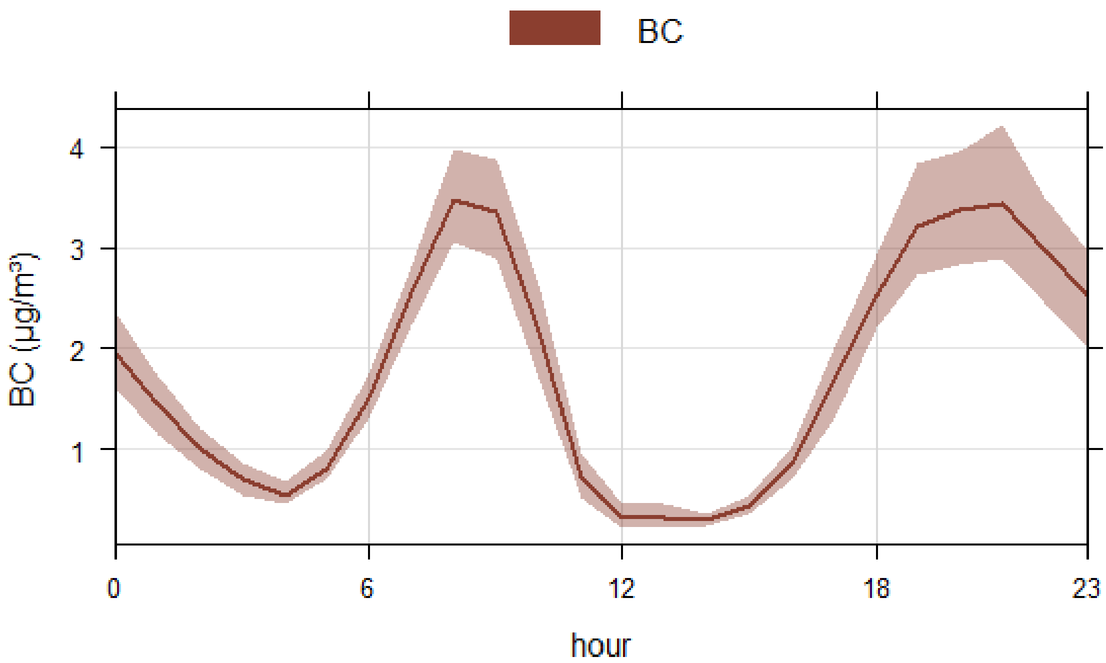


Figure 3 Diurnal mean of black carbon at Arrowtown (shading represents 95% confidence interval in the mean)



[8] Internationally aethalometers have many applications, including transport and shipping emissions, industrial monitoring, assessing urban policies such as low emission zones and home heating rules, and for climate change and/or atmospheric monitoring. On a national level, BC is currently being monitored by several other councils in New Zealand. It is monitored at sites that are influenced by domestic heating emissions or traffic exhaust, or both.

[9] In 2021 World Health Organization (WHO) produced a good practice statement recommending that regional authorities measure BC, undertake emissions inventories and source apportionment for BC, and take measures to reduce emissions, and where possible develop targets for BC concentrations (WHO, 2021).

PM_{10} SPATIAL MONITORING AT ALEXANDRA

[10] Stationary instruments monitor air quality at a single location within each airshed in ORC's SOE network. Depending on the size of the town, sources of pollution and the complexity of its terrain, the results may not be representative of the entire area. The National Environmental Standards for Air Quality (NESAQ) requires monitoring to be undertaken where the standards are likely to be breached by the greatest margin or the highest frequency.

[11] Methods to investigate spatial variability within airsheds have evolved recently to include networks of low-cost sensors. These sensors are not as accurate or reliable as

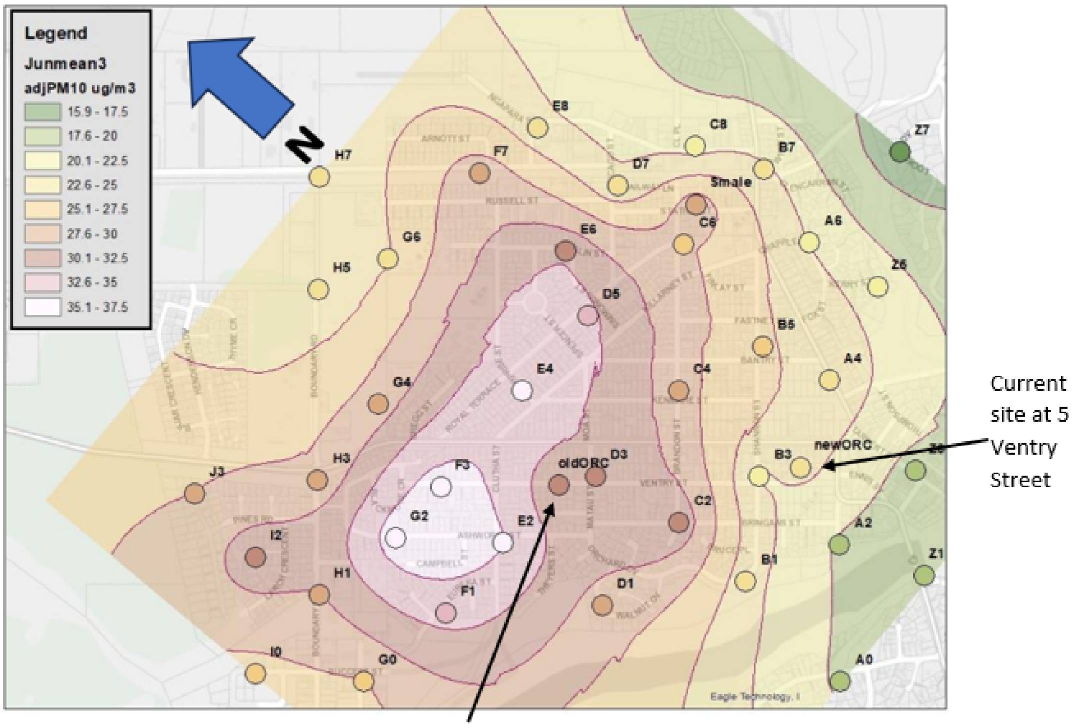
NESAQ compliant monitors[3], however because there are so many, they can provide an idea of where pollutants build up, and sometimes how they move around within an airshed. The meteorology of the Alexandra basin is very complex, and converging winds (Tate, 2011) are likely to cause zones of still air in which pollution can accumulate (Price, 2014).

[12] During June 2023, 42 low-cost sensors were in a dense network across Alexandra in order to understand the high-resolution spatial patterns of PM_{10} and assess how representative the ORC monitoring site is. The project was partially funded by ORC and ORC's Environmental Monitoring team assisted NIWA with the field work. NIWA's additional goals were to understand the optimal density of monitors required to understand air quality spatial variation and to find out more about how concentrations vary over space and time. As part of this work, NIWA were also able to determine the relationship between the current and previous Alexandra monitoring sites for June 2023. This was important because the change in locations meant they have different typical pollutant concentrations. This issue is discussed further in the 2017 Annual Air Quality report (ORC, 2017) and the SOE report of 2021 (ORC, 2021).

[13] This study identified the area of average peak PM_{10} concentrations in Alexandra, which is located to the northwest of the centre of town (Figure 4). This area on average, had double the concentrations than of the outskirts of town. The percentage difference between the previous and current SOE monitoring sites was calculated to be 23%, and a correction factor was produced. Unfortunately, as the concentrations in June did not get very high, especially compared to previous years' data, this correction factor may not be suitable for use in long term trend analyses. For any correction factor to work well it must incorporate a wide range of concentrations. However, this correction factor may be used for analyses of more recent data, within the concentration range that occurred during June 2023.

[3] Known as reference method instruments, these are a monitoring requirement under the NESAQ.

Figure 4 Spatial PM_{10} results for Alexandra, June 2023. Source: Longley, 2023

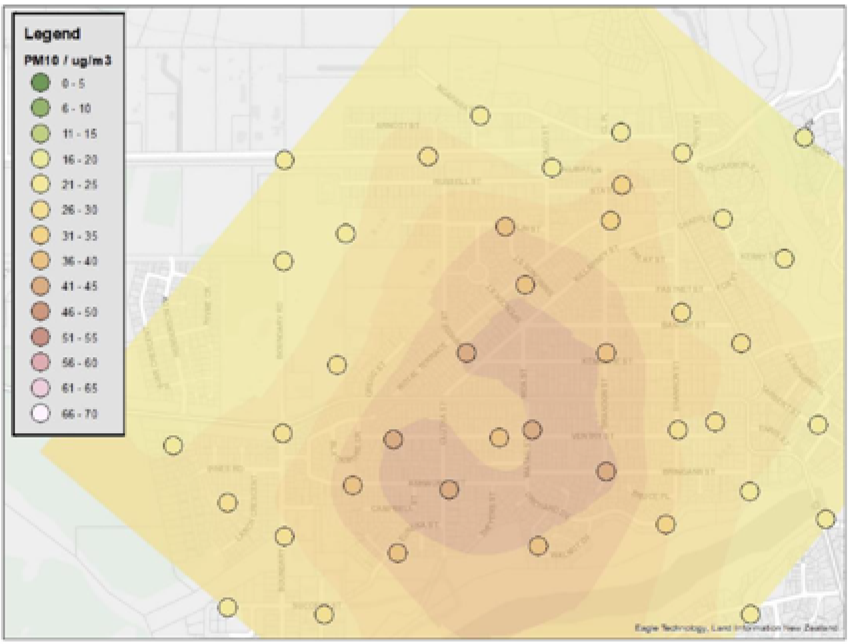


[14] Some examples of the high pollution days (as recorded at the SOE monitoring site) are highlighted in Figure 5. The area of highest concentrations was further to the southeast on 11 June, which is closer to the SOE monitoring site. This caused the third highest pollution night in June (38 µg/m³, 24-hour average) because of this proximity. In contrast on 19 June, the peak concentrations were up to 20 µg/m³ higher, but further to the northwest, and as such, a much lower concentration (29 µg/m³, 24-hour average) was recorded at the SOE site. This shows that as the area of peak concentrations moves around, it can greatly impact what is recorded at ORC's stationary monitoring site.

[15] Wind direction appears to have some influence on these concentrations. On average the dominant wind direction for June was the northeast (Figure 6). Some of the variations are displayed for the different days, such as the addition of the north-northeast direction on 11 June, which may have pushed the pollution further towards the south instead of the west. Overall, these wind speeds are very low, mostly below 1 m/s.

Figure 5 Examples of high pollution days in Alexandra, June 2023. Source: Longley, 2023

11 June 2023



19 June 2023

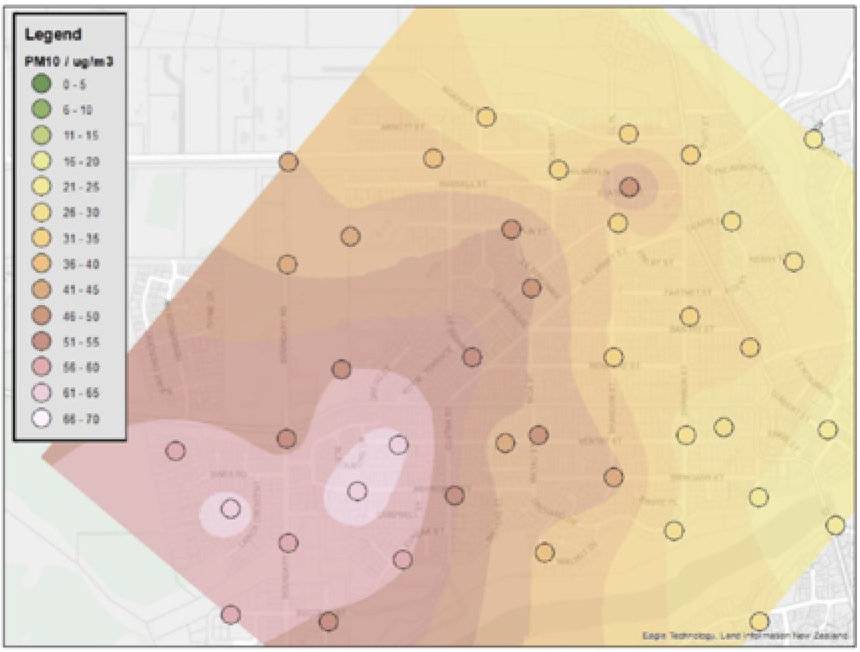
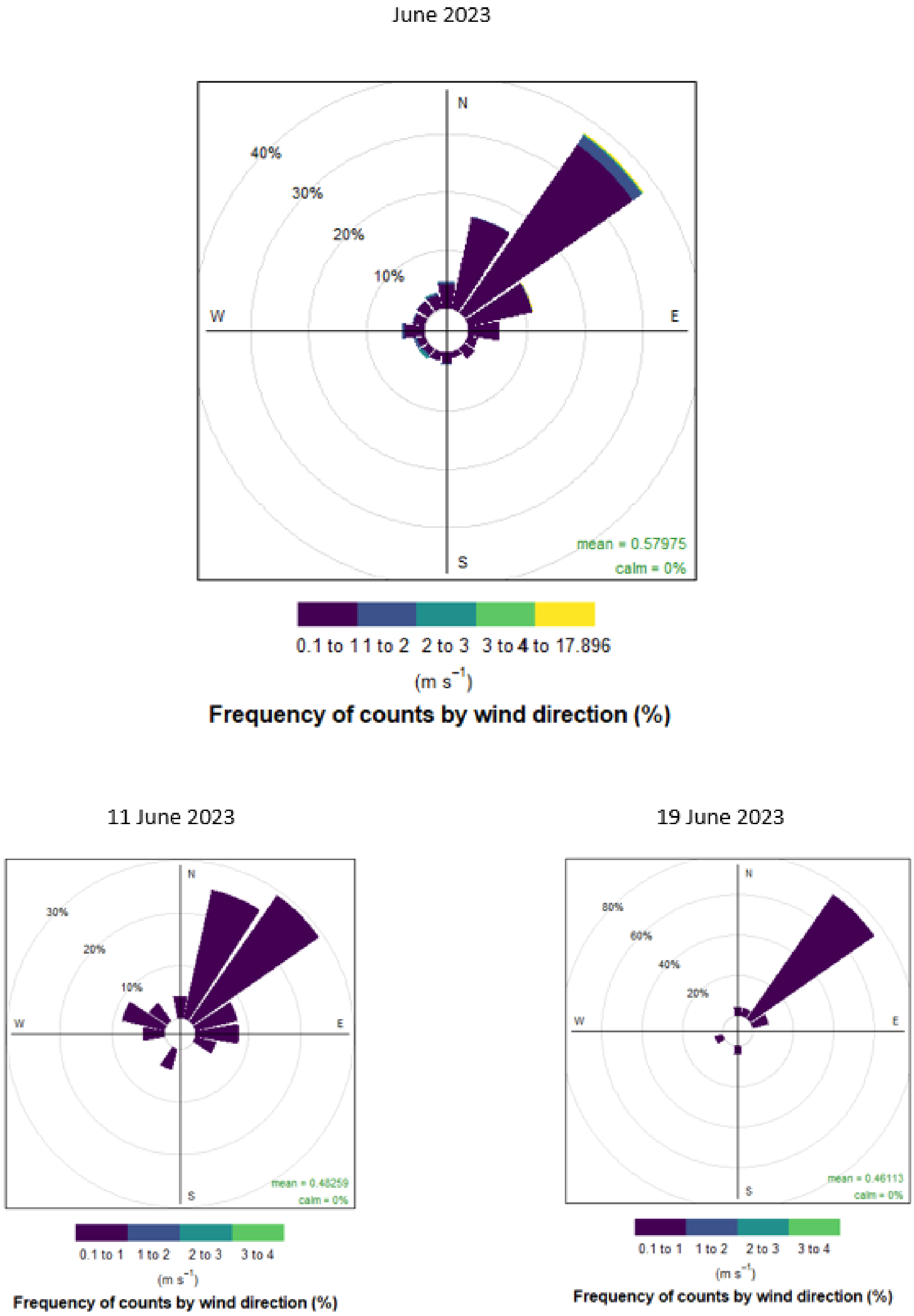


Figure 6 Wind roses for Alexandra, June 2023 (1-hour average)



[16] The requirement of the NESAQ to monitor in the area where standards are likely to be breached by the greatest margin or the highest frequency has not been possible in Alexandra since 2016 due to very low availability of suitable monitoring sites. Further

work to compare the previous and current Alexandra sites is recommended. Twelve months' worth of data that covers a wide range of concentrations is the minimum amount recommended for understanding this relationship.

CONSIDERATIONS

Strategic Framework and Policy Considerations

[17] The work outlined in this paper contributes to the following elements of ORC's Strategic Direction:
- Monitoring air quality in the region and investigate pollution sources.
- Provide best available information on Otago's air quality.

Financial Considerations

[18] Air quality work is a budgeted and planned activity.

Significance and Engagement

[19] N/A

Legislative and Risk Considerations

[20] N/A

Climate Change Considerations

[21] N/A

Communications Considerations

[22] N/A

NEXT STEPS

[23] Options for continuous monitoring of black carbon are currently in the draft LTP. Due to its relationship with PM, it would be beneficial for additional sites to monitor BC in Otago, and this would line up with World Health Organization recommendations.

[24] Further investigation (12 months+) is required to best understand the relationship between the previous and current Alexandra sites. This project needs consideration due to the lack of available sites at Alexandra, and possible monitoring instruments will need to be carefully considered.

ACKNOWLEDGEMENTS

ORC would like to thank Jason Potts and Matthew Anderson from Benchmark Monitoring for the loan and installation of the aethalometer, and for their technical support during the monitoring period. The author would also like to thank the ORC Environmental Monitoring team for looking after both the Arrowtown and Alexandra projects.

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ATTACHMENTS

1. NIWA Client Report 2023190 AK ORC Alexandra Air Quality 2023 FINAL [**9.1.1** - 34 pages]

Mapping of winter air quality in Alexandra

Prepared for Otago Regional Council

November 2023

Climate, Freshwater & Ocean Science

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Version 1.0	Draft version sent to client	30/08/2023
Version 1.1	Minor amendments	20/11/2023

Quality Assurance Statement		
	Reviewed by:	Guy Coulson, Principal Air Quality Scientist
	Formatting checked by:	Carole Evans
	Approved for release by:	Jonathan Moores, Regional Manager Auckland

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Executive summary

Otago Regional Council (ORC) is responsible for the management of air quality across the Otago region. Previous research by NIWA and others has shown how air quality can be highly variable in time and space within airsheds, especially smaller towns with prevalent use of winter wood-burning, such as Alexandra.

Determining spatial variation in air quality within towns is vital for understanding the representativeness (and hence fitness for purpose) of air monitoring sites. Better spatial information may also identify previously unknown localised air quality hot-spots, or intense emission sources.

Spatial and temporal variation in air quality, represented by particulate matter smaller than 10 microns (PM_{10}) was monitored in Alexandra, using 42 Clarity Node-S air monitors over the period 2nd June – 3rd July 2023. The monitors were deployed in an approximately uniform grid across the whole urban area of Alexandra (excepting Bridge Hill).

The data generated was used to create maps of daily average and whole campaign average PM_{10} levels across the town.

The data clearly show a large and consistent spatial variation in PM_{10} across Alexandra. Concentrations varied by an approximate factor of 2 with the highest concentrations being consistently found over a relatively small area between Ashworth Street and Simmonds Street, most frequently peaking around Table Top Park.

Current guidance states that air quality monitoring for regulatory purposes should be conducted at the most polluted location within an airshed. However, in advance of highly spatially detailed monitoring such as this (which has only very recently become feasible), it is very difficult to ascertain where such a location is, and how large an area can be considered to qualify.

This work has now revealed how localised the area of peak concentrations is in Alexandra and how the representativeness of any single monitoring site is highly sensitive to its precise location. This work clearly shows that the "new" monitoring site adopted by ORC for regulatory monitoring in 2017 reports concentrations around 23 % lower than the previous site, despite it being only 720 m away along the same road (Ventry Street). The current site is representative of median or average concentrations across the town, but both the current, and the previous site under-represent the maximum concentrations in the town, as required by current guidance.

As a consequence of the findings of this work we make the following recommendations to ORC:

- To comply with current regulatory guidance, we recommend that consider ORC re-locating their monitoring station again, closer to the "hot-spot" area identified in this work.
- We recommend that a "virtual" time series of PM_{10} be created both retrospectively and on an ongoing basis to estimate the concentrations at the previous ORC site to enable long-term analysis of trends. Compared to the precious ORC monitoring site, the new site has been reporting concentrations approximately 23 % lower. 24-hour PM10 concentrations from the new site could therefore be adjusted to create a "virtual" record for the previous site by multiplying concentrations by 1.295.

- Such spatial variation is also likely in most Otago towns, and we therefore recommend ilar monitoring assessment of other towns.
- We recommend ORC work with MfE and other regional councils to promote a review of regulatory guidance and requirements regarding air monitoring sites to better enable a consistent approach to site representativeness, trend analysis and compliance reporting. This could be informed by additional monitoring of the type demonstrated in this work.

1 Introduction

1.1 Background

Otago Regional Council (ORC) is responsible for the management of air quality across the Otago region. This includes a requirement to monitor air quality where non-compliance with National Environmental Standards is likely. Under the Otago Regional Air Plan towns with similar risk have been grouped into two Air Zones, with Air Zone 1 representing a higher risk. At present, monitoring of Air Zone 1 is conducted at four monitoring sites – one each in Arrowtown, Cromwell, Clyde and Alexandra.

Previous research by NIWA and others has shown how air quality can be highly variable in time and space within airsheds, especially smaller towns with prevalent use of winter wood-burning, such as the Air Zone 1 towns. This makes it quite difficult to assess the degree to which any given monitoring site meets the current guidance from MfE, that monitoring sites should be located at the persistently most polluted location within the airshed.

This was starkly illustrated when the ORC monitoring site for Alexandra was moved a mere 700 m in 2017. This led to an apparent sudden and permanent improvement in the air quality results, which are intended to represent the whole town. However, a period of overlap between the old and new stations, and subsequent unpublished research by NIWA, showed that the improvement could easily be explained by genuine differences in air quality between the two sites.

Determining spatial variation in air quality within towns is vital for understanding the representativeness (and hence fitness for purpose) of air monitoring sites, and this is especially so in smaller towns with large numbers of intense emission sources such as wood-burning domestic chimneys.

Spatial information can also be informative about the processes driving the formation of hot spots, such as whether prevalent airflows cause pollution to accumulate in particular areas, or whether some emission sources have more impact than others. This could indicate the potential for locally targeted mitigation options that may be more effective than airshed-wide approaches.

Finally, better spatial information may also identify previously unknown localised air quality hot-spots, or intense emission sources.

1.2 Scope

This project aims to deliver a clearer picture of how winter air quality (expressed in terms of PM_{10} and $PM_{2.5}$) varies in space across Alexandra, and how that spatial variation also varies in time. We understand that this information may be used to select a new regulatory monitoring site in Alexandra, and/or be used to better interpret the data from current or future sites.

To assist with the main aim, we also aimed to create an equation or mathematical formulation which expresses the relationship between $PM_{2.5}$ and PM_{10} values recorded at the former ORC monitoring site at 65 Ventry Street and the current site at 5 Ventry Street so that “virtual” datasets for the one site based on the other might be created.

2 Methods

2.1 Overview

Maps of wintertime air quality in Alexandra have been generated based on observational data captured using a network of PM_x monitors over the period 27th April – 3rd July 2023. This period is sub-divided into three phases depending on the number of active monitoring sites, as described in Table 2-1.

Table 2-1: The three observational periods making up the observational campaign upon which analysis is based.

Period name	Starts	Ends	#sites
Initial	27 April	4 May	11
Intermediate	4 May	2 June	30
Full	2 June	3 July	42

This report focusses on data from the "Full" period only as it is better placed to address the questions this report seeks to address.

Maps of air quality are provided for two different timeframes:

- Full-period average.
- Daily averages for each day of the campaign.

Maps of air quality are provided in two forms:

- Values at measurement points for each period.
- Interpolated maps over the study domain created by ordinary kriging (using ArcGIS Desktop 10.6).

Air quality is represented by concentrations of PM_{10}.

All maps are provided in Appendix A.

2.2 Observational methods

2.2.1 Instruments used

Original data for this study was collected using Clarity Node-S air quality monitors (www.clarity.io). These devices monitor particulate matter (PM) in a self-powered, FCC/CE certified, UV-resistant, and weatherproof package incorporating solar harvesting, internal battery, and global cellular communications.

Clarity monitors were installed on power poles and streetlight poles across Alexandra in as regular a grid pattern as was practically achievable. All monitors were installed at approximately 2.5 m height.

2.2.2 Instrument siting design

Our primary purpose was to produce high accuracy maps of PM_{10}. Previous research indicated that kriging of data derived from a regular grid of monitors is likely to be the best method of achieving this.

We therefore aimed to deploy monitors in a regular rectangular grid. 42 monitors were available for this project, allowing a grid of 6 x 7. However, deployment locations were limited to accessible streetlight poles and power poles, meaning that some intended locations were not viable. In addition, 2 monitors were dedicated to the current and previous ORC monitoring sites.

2.3 Data adjustment

2.3.1 PM_{10}

The Clarity monitor is not an approved method for regulatory purposes. It is based on a different sensor technology (optical scattering) from the method used in ORC's regulatory monitoring network (beta attenuation). To allow for our data and ORC regulatory data to be compared and combined, one Clarity monitor was placed at the ORC regulatory site in Alexandra for the full observational campaign. Figure 2-1 shows the relationship between hourly PM_{10} measured by the Clarity and the regulatory monitor. It can be seen that the Clarity over-estimates "regulatory" PM_{10} by an approximate factor of three. Based on this data a polynomial equation has been fitted and used to convert all Clarity PM_{10} data into regulatory-equivalent estimates of PM_{10}.

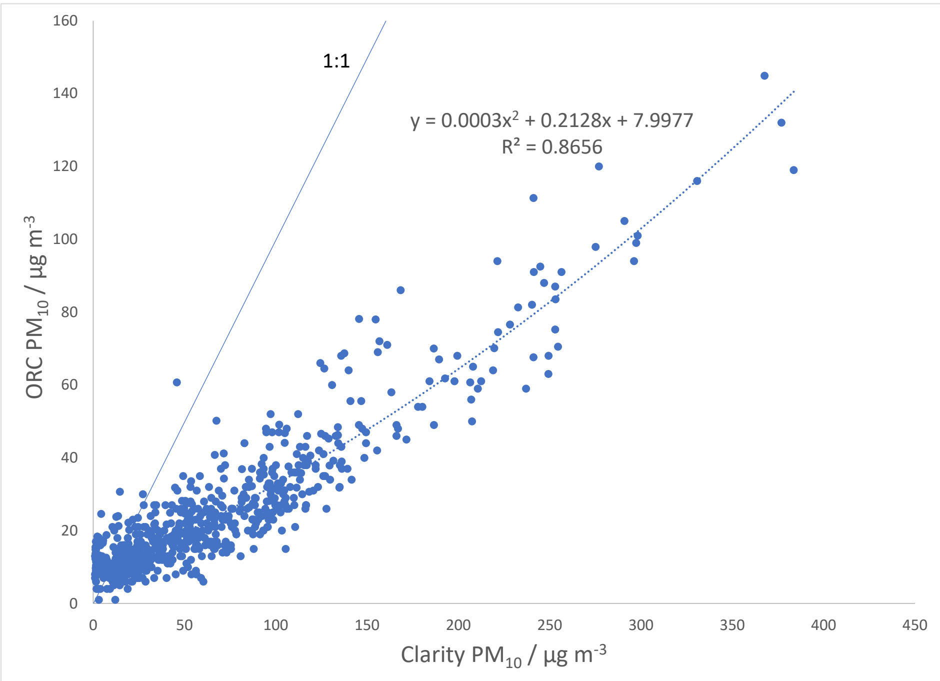


Figure 2-1: Relationship between hourly PM_{10} measured by ORC regulatory monitor and co-located Clarity monitor.

2.3.2 $PM_{2.5}$

Although $PM_{2.5}$ was measured by ORC at the Alexandra site during our campaign, a non-standard instrument (ES-642) was used. Therefore, we cannot apply an adjustment to $PM_{2.5}$ data as we have for PM_{10} data.

In our professional opinion there is considerable uncertainty in the way the Clarity monitors distinguish between $PM_{2.5}$ and PM_{10}. The interquartile range of the hourly ratio of PM_{10} to $PM_{2.5}$ reported by the Clarity monitors was 1.26 – 1.47 (i.e., $PM_{2.5}$ ranged from 68 – 79 % of PM_{10}). In our professional opinion the true percentage may be higher.

For these reasons, this report does not include $PM_{2.5}$ results.

3 Results

3.1 Long-term mean spatial variation

Figure 3-1 presents our map of average (adjusted) PM_{10} for the whole of the "full" campaign. Each site is given a "row & column" ID (e.g., D3). Maps for each 24-hour period (midnight to midnight) are provided in Appendix A.

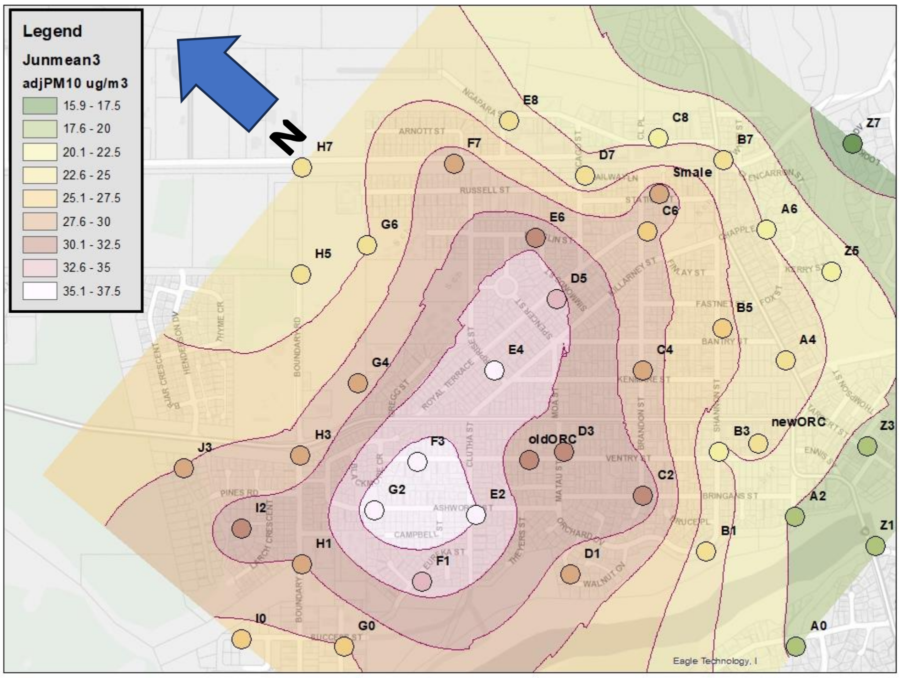


Figure 3-1: Mean adjusted PM_{10} for the period 2nd June (12:00) - 3rd July (12:00).

Figure 3-1 shows that month-average PM_{10} concentrations varied from 15.9 – 36.4 µg m^{-3}. The highest concentrations were recorded in the vicinity of Table Top Park and Ashworth Street (white zone in Figure 3-1), especially at site G2. The lowest concentrations were recorded at site Z7 on Lookout Drive (top right corner in Figure 3-1). The second lowest concentrations (19.2 – 19.7 µg m^{-3}) were all recorded close to the Clutha River (bottom right corner in Figure 3-1).

The median concentration across the grid was 24.5 µg m^{-3} and the mean concentration was 26.8 µg m^{-3}. Their similarity indicates very little skew in the concentration distribution, consistent with the gradual concentration gradients seen in Figure 3-1. This can also be seen in Figure 3-2 which plots each day's concentration distribution in space as a box and whisker plot. Figure 3-3 shows the same data but with days ordered in terms of median concentration. Figure 3-3shows that, broadly, going from less polluted days (left) towards more polluted (right) concentrations increase across the whole town, widening the concentration distribution in absolute terms. It also appears to show that, over the main campaign in June 2023, low, medium and high concentration days were roughly equally prevalent.

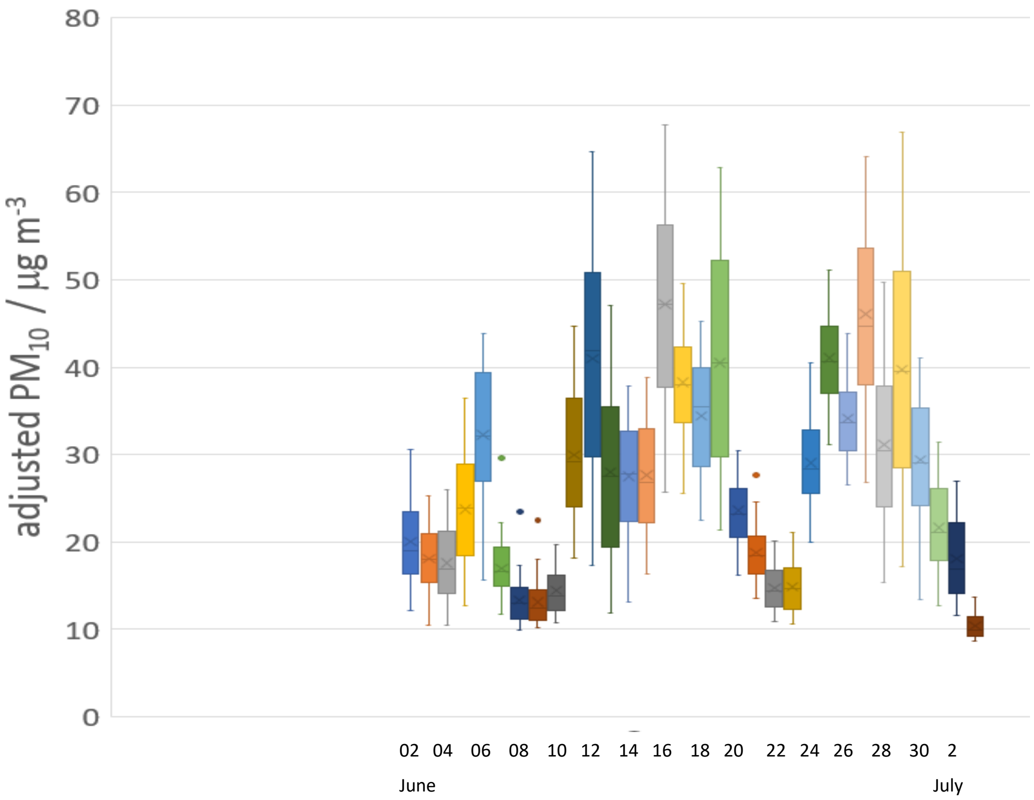


Figure 3-2: Distributions of 24-hour PM_{10} concentrations across the grid for each day.

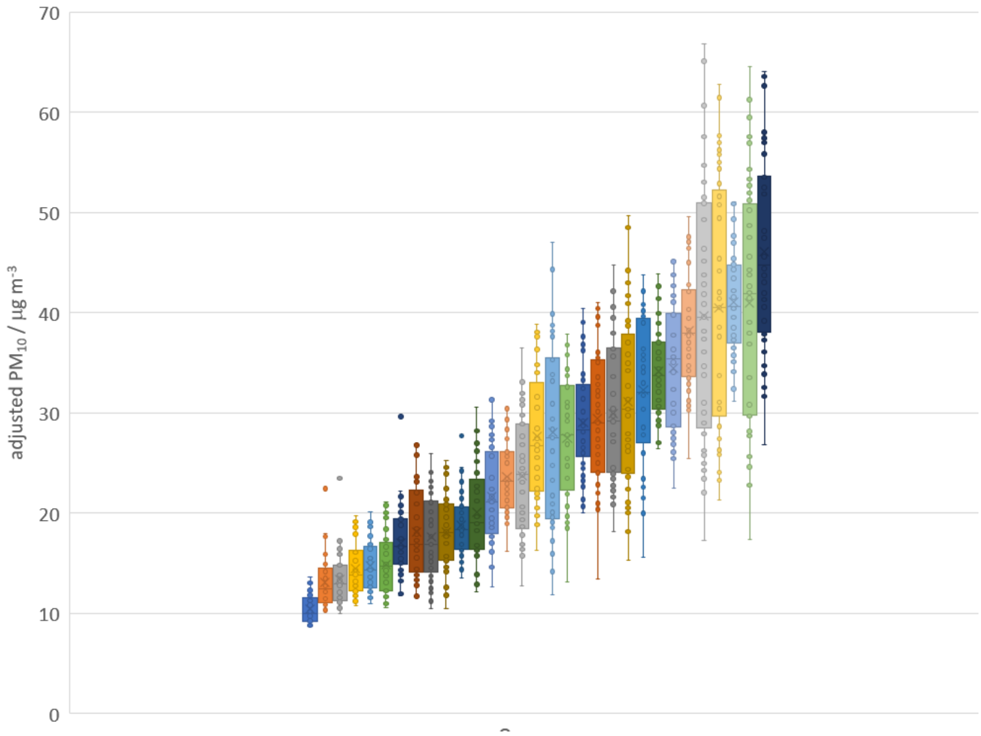


Figure 3-3: Distributions of 24-hour PM_{10} concentrations across the grid for each day. Days are ranked in terms of median concentration.

Figure 3-4 depicts the number of exceedances of the National Environmental Standard for PM_{10}, based on each individual monitor, including an interpolated prediction. The current ORC site recorded one exceedance during the full monitoring campaign (on 16th June). Our monitoring suggests that 3 exceedances would have been recorded using the previous monitoring site, and 6 if monitoring were conducted at the true hot spot.

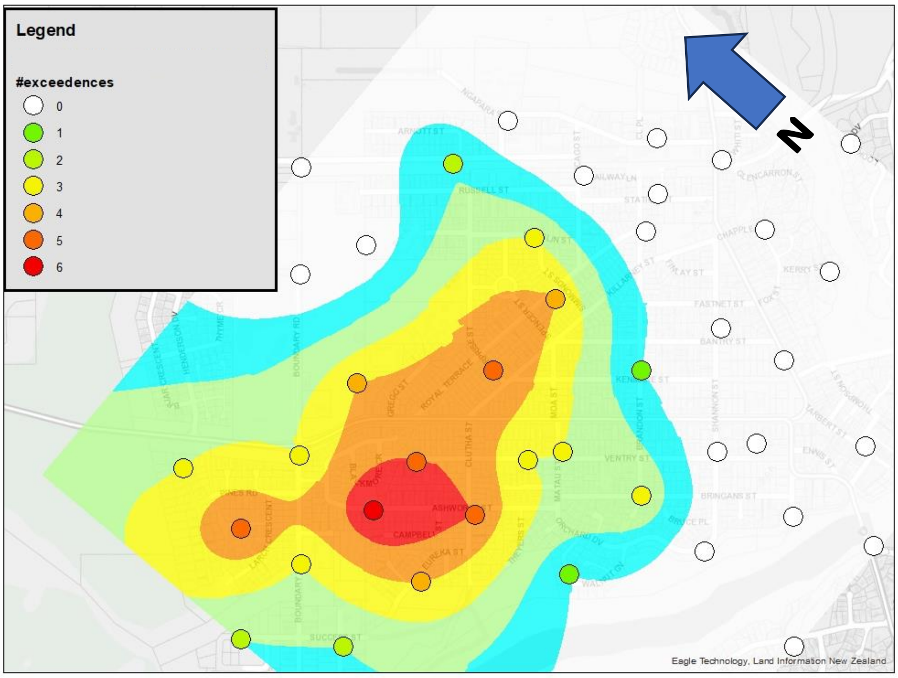


Figure 3-4: Predicted number of NES exceedances based on individual monitors for the period 3rd Jun - 2nd Jul 2023 inclusive.

3.2 Day-to-day variability in spatial variation

Comparing the map for each 24-hour period (Appendix A) it can be seen that the general spatial pattern changes little. The site reporting the maximum concentration in each 24 -hour period was always within a narrow area defined by the 32.5 $\mu g\ m^{-3}$ contour line in Figure 3-1, with only one exception. This was 15th June when the maximum concentrations lay approximately 500 m further south of the normal position, i.e., towards the SE end of Ashworth Street.

The lowest concentration was consistently recorded on Lookout Drive on every day. The second lowest concentration was usually recorded at one of the sites near the rivers, but was occasionally recorded to the eastern, northern or western periphery of the grid.

Figure 3-5 shows the relationship between 24-hour average concentrations measured at the peak site of G2 and site A0 on the grid's south-western edge near Poplar Grove in Bridge Hill – one of the sites recording systematically lower concentrations. This figure indicates that, as a rough guide, concentrations at the edge of the town grid were approximately half of the maximum concentrations recorded within the grid.

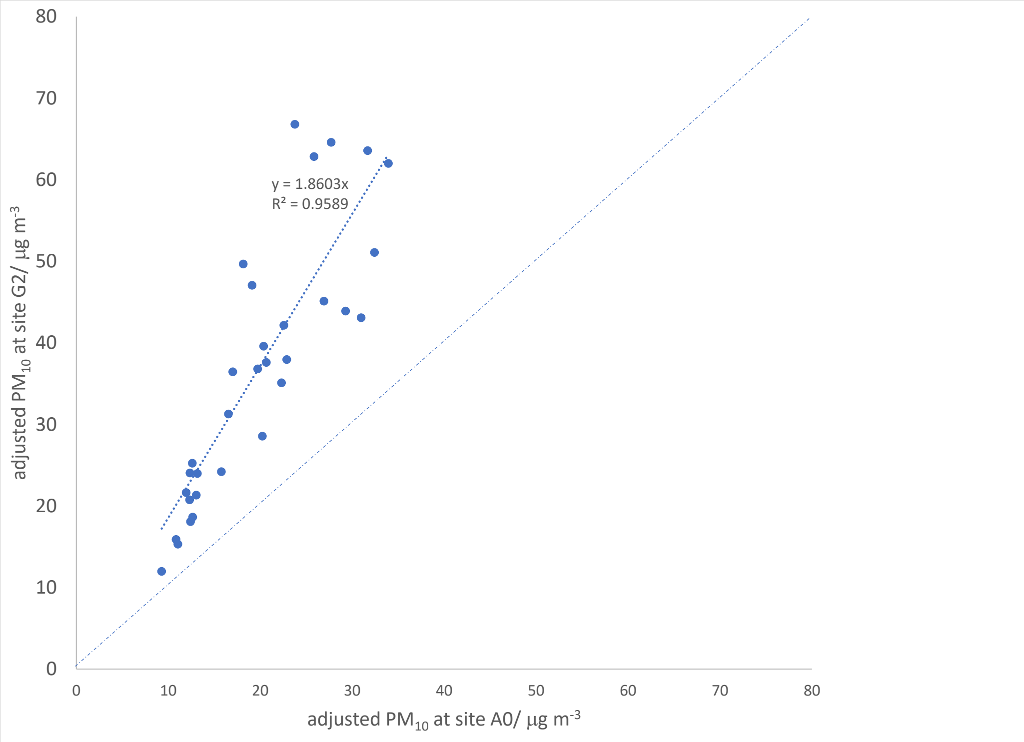


Figure 3-5: 24-hour average adjusted PM_{10} at the peak site (G2) and a peripheral site (A0).

3.3 What can we infer about air quality beyond the monitoring grid?

Figure 3-2 shows that the minimum adjusted PM_{10} concentration in our grid varied from 10 to 34 µg m^{-3} as a 24-hour average. Concentrations at site J3 varied from 12 to 57 µg m^{-3}, despite being at the far north-western edge of the town. These results strongly imply that elevated concentrations existed beyond the edge of our grid and beyond the urbanised area. This is consistent with observations made in 2022 in and outside Ashburton (currently unpublished). NIWA intend to look at this issue further in the future.

3.4 Relationship between current and previous ORC monitoring sites

Figure 3-6 shows that, compared to the precious ORC monitoring site, the new site has been reporting concentrations approximately 23 % lower. 24-hour PM_{10} concentrations from the new site could therefore be adjusted to create a "virtual" record for the previous site by multiplying concentrations by 1.295.

At the moment this relationship can only be verified for the period of monitoring, i.e., June 2023. However, we expect that this relationship is likely to hold for all seasons and all years. Outside of the winter period the concentrations generally get lower, which means the correction required is smaller and any errors in the correction becomes less critical. The correction factor is unlikely to change much over the year unless a very different emission source with a very different spatial pattern becomes significant, which we do not expect in Alexandra.

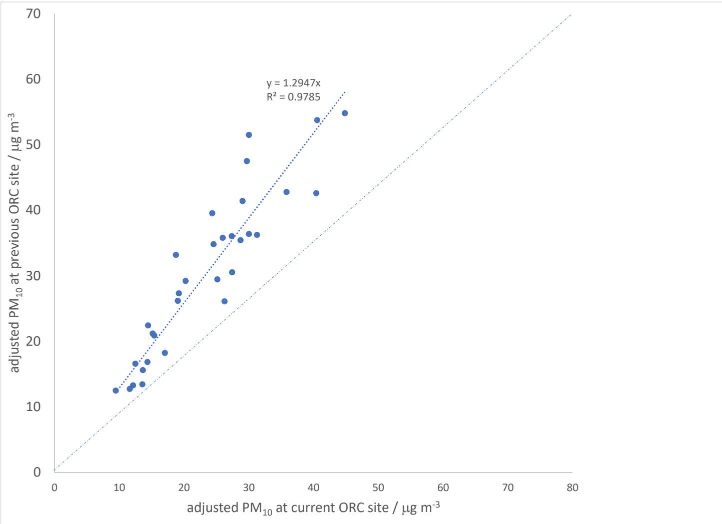


Figure 3-6: 24-hour average adjusted PM_{10} at the current and previous ORC monitoring sites.

3.5 Relationship between both current and previous ORC monitoring sites and town-wide median and maximum concentrations

Together, Figure 3-7 and Figure 3-8 show that the current ORC monitoring site reports concentrations very close to the town median, but that town maximum concentrations are approximately 63 % higher.

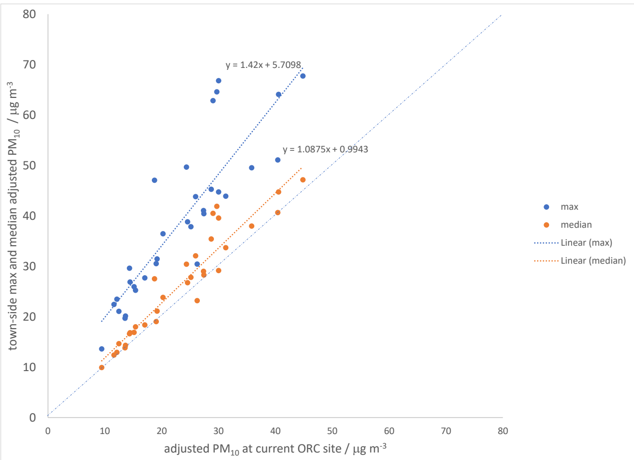


Figure 3-7: 24-hour average adjusted PM_{10} at the current ORC monitoring site and the town-wide median and maximum concentrations.

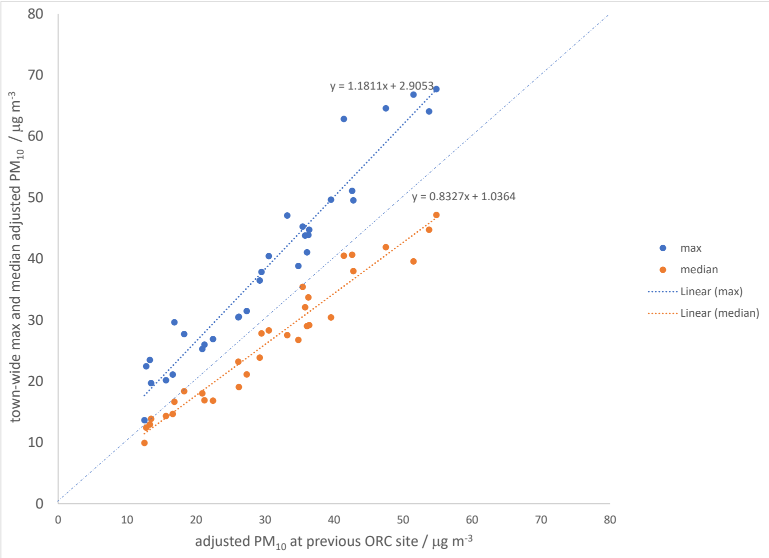


Figure 3-8: 24-hour average adjusted PM_{10} at the previous ORC monitoring site and the town-wide median and maximum concentrations.

3.6 Why is the hot spot where it is?

Explaining the spatial variation observed is beyond the scope of this report. However, this will be the subject of ongoing research by NIWA.

4 Conclusions and Recommendations

The monitoring conducted in this project clearly shows a large and consistent spatial variation in PM_{10} across Alexandra. Concentrations vary by an approximate factor of 2 with the highest concentrations being consistently found over a relatively small area between Ashworth Street and Simmonds Street, most frequently peaking around Table Top Park.

This spatial variation means that the representativeness of any single monitoring site is highly sensitive to its precise location. This work clearly shows that the "new" monitoring site adopted by ORC for regulatory monitoring in 2017 reports concentrations around 23 % lower than the previous site, despite it being only 720 m away along the same road (Ventry Street). The current site is fairly representative of median or average concentrations across the town, but both the current, and the previous site under-represent the maximum concentrations in the town.

Current guidance states that air quality monitoring for regulatory purposes should be conducted at the most polluted location within an airshed. However, in advance of highly spatially detailed monitoring such as this (which has only very recently become feasible), it is very difficult to ascertain where such a location is, and how large an area can be considered to qualify. This work has now revealed how localised this area is in Alexandra.

We make the following recommendations to ORC:

- To comply with current regulatory guidance, we recommend that ORC re-locate their monitoring station again closer to the "hot-spot" area identified in this work.
- We recommend that a "virtual" time series of PM_{10} be created both retrospectively and on an ongoing basis to estimate the concentrations at the previous ORC site to enable long-term analysis of trends. Compared to the precious ORC monitoring site, the new site has been reporting concentrations approximately 23 % lower. 24-hour PM10 concentrations from the new site could therefore be adjusted to create a "virtual" record for the previous site by multiplying concentrations by 1.295.
- Similar monitoring assessment of other towns should be considered.
- Work with MfE and other regional councils to promote a review of regulatory guidance and requirements regarding air monitoring sites to better enable a consistent approach to site representativeness, trend analysis and compliance reporting. This could be informed by additional monitoring of the type demonstrated in this work.

5 Acknowledgements

Permission to mount air quality monitors on power poles was provided by Aurora Energy.

Thanks to ORC for assistance with instrument deployment.

## Appendix A	Maps of observed and interpolated PM_{10}

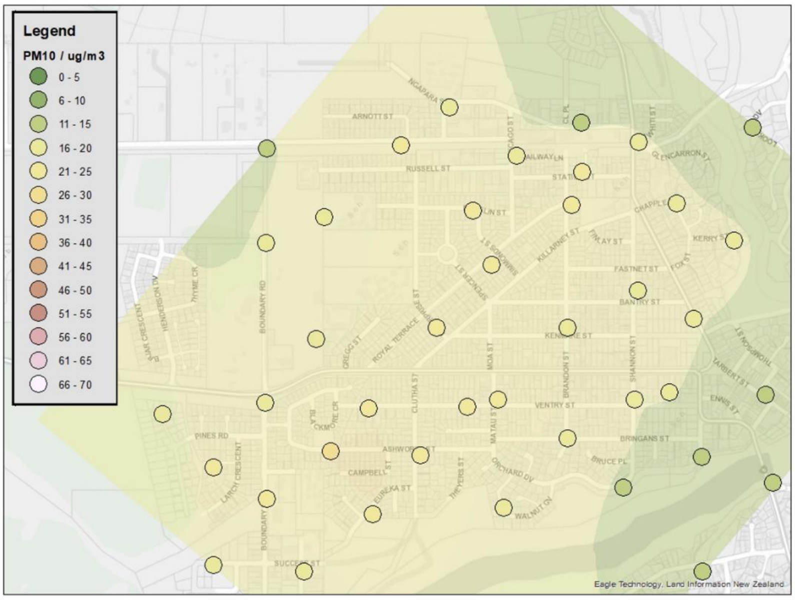


**Figure A-1:	3rd June 2023.**

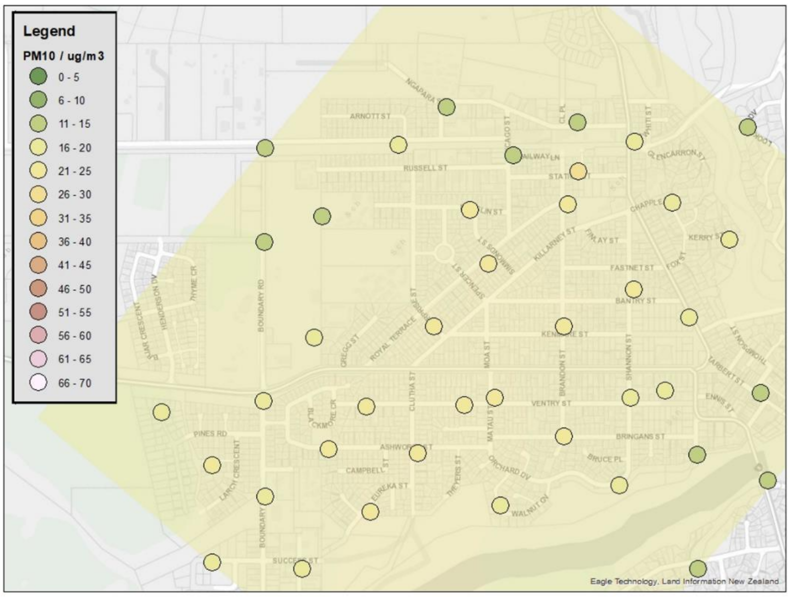


**Figure A-2:	4th June 2023.**

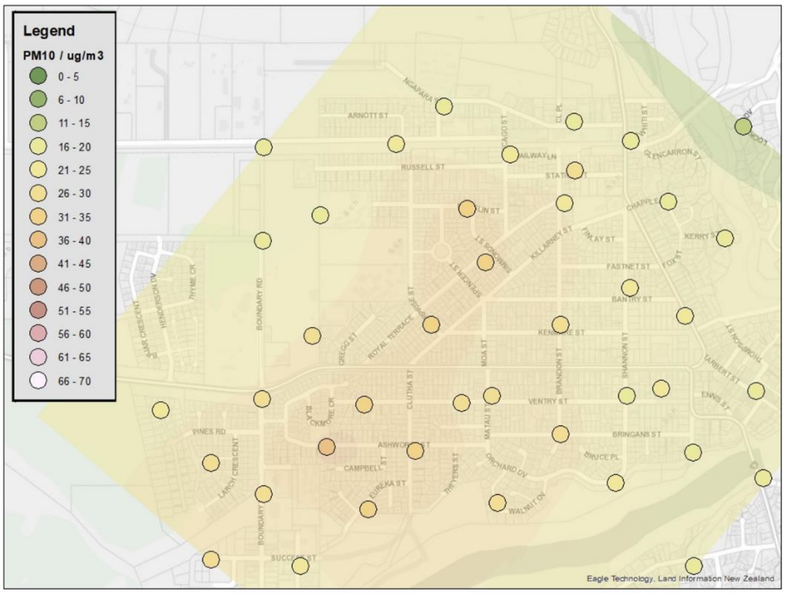


Figure A-3: 5th June 2023.

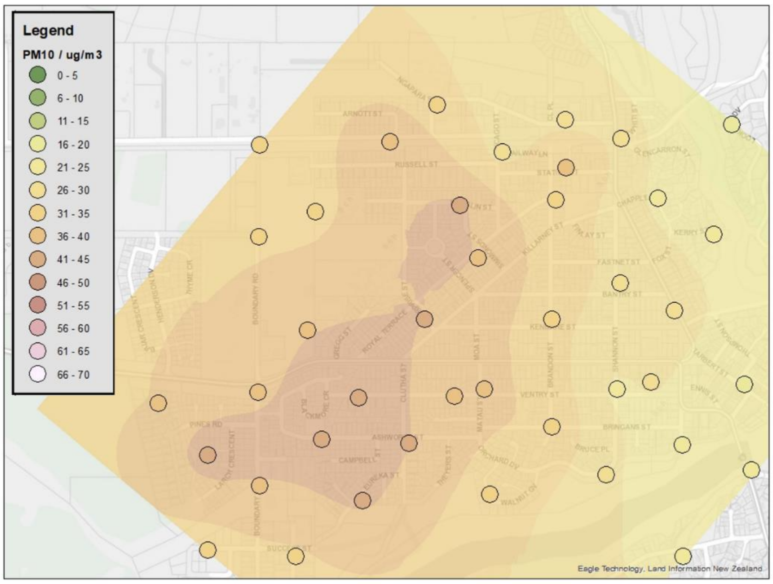


Figure A-4: 6th June 2023.

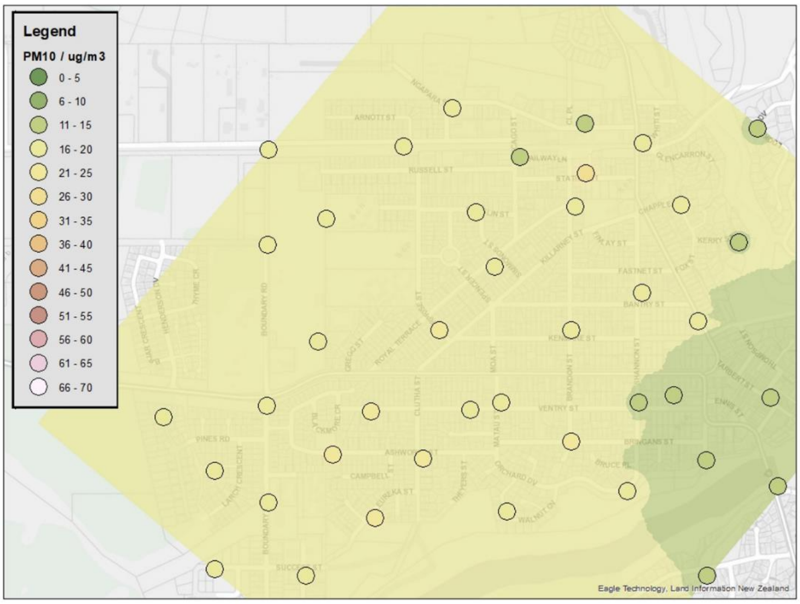


Figure A-5: 7th June 2023.

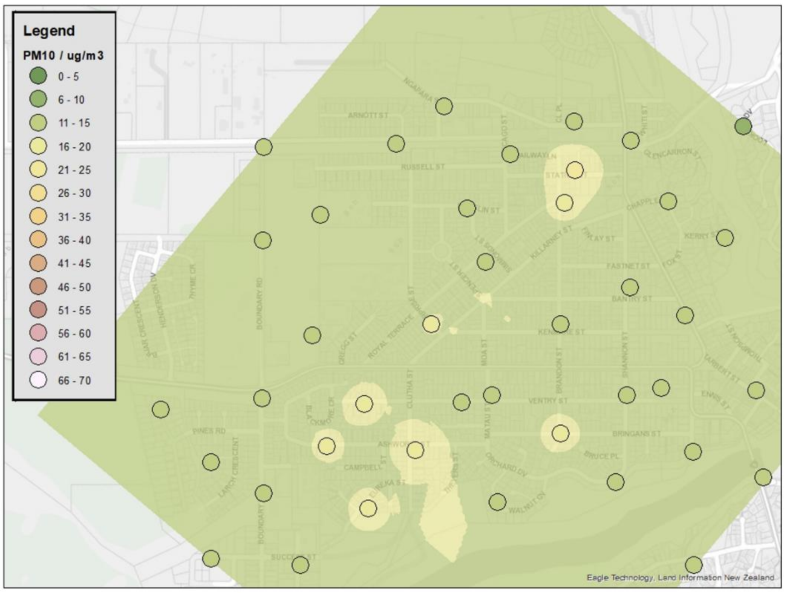


Figure A-6: 8th June 2023.

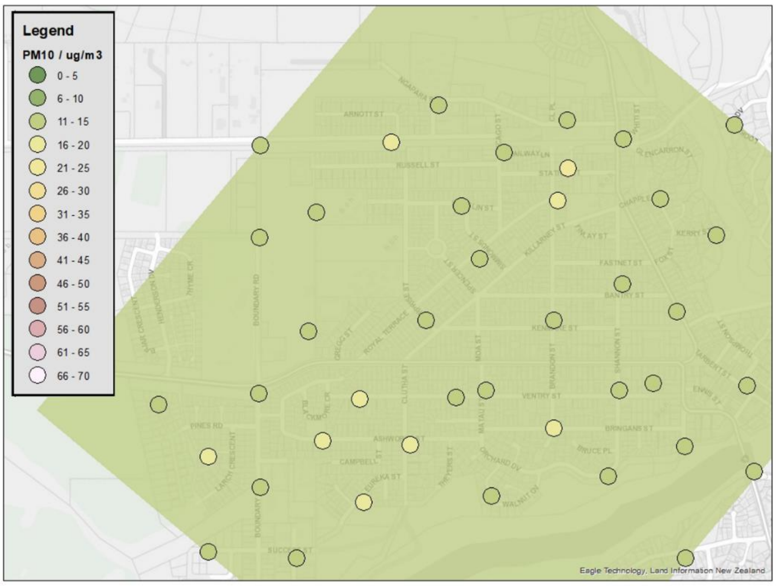


Figure A-7: 9th June 2023.

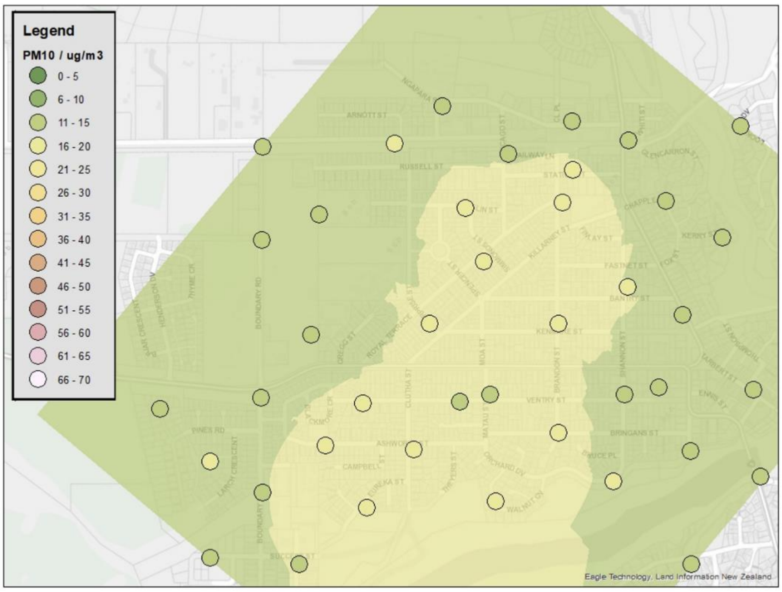


Figure A-8: 10th June 2023.

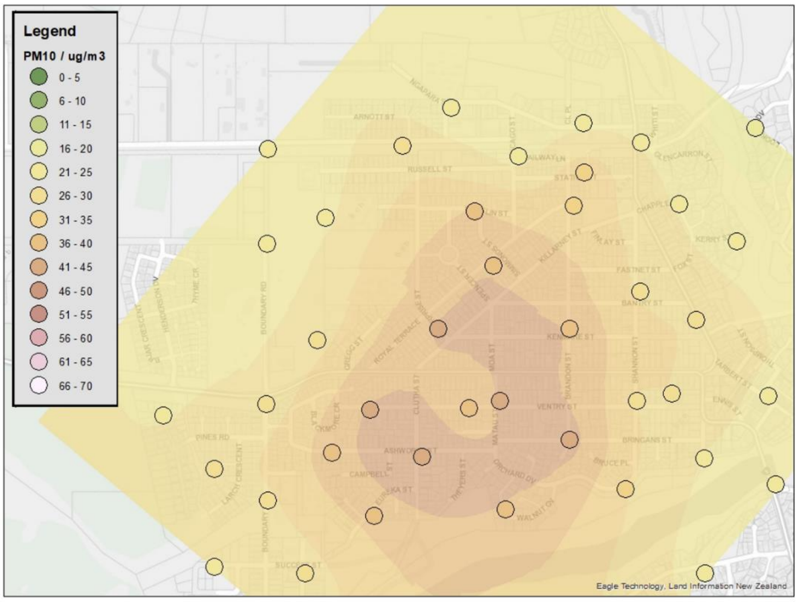


Figure A-9: 11th June 2023.

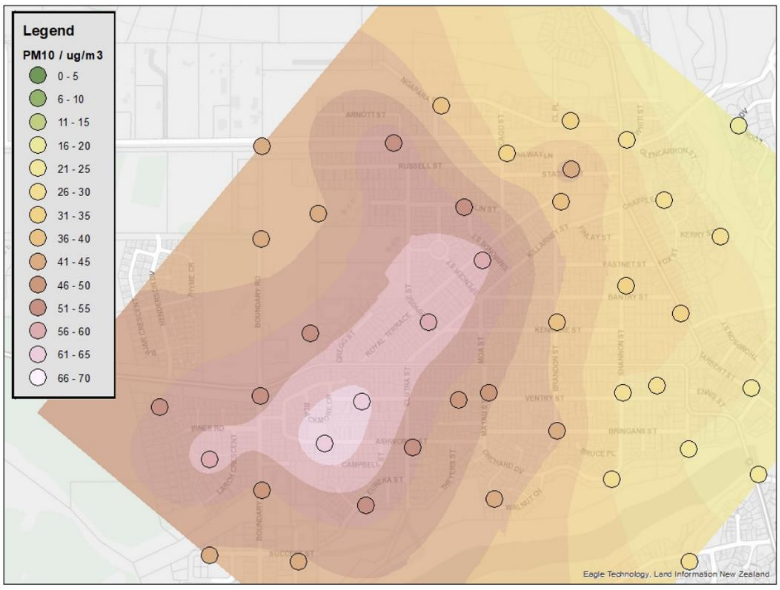


Figure A-10: 12th June 2023.

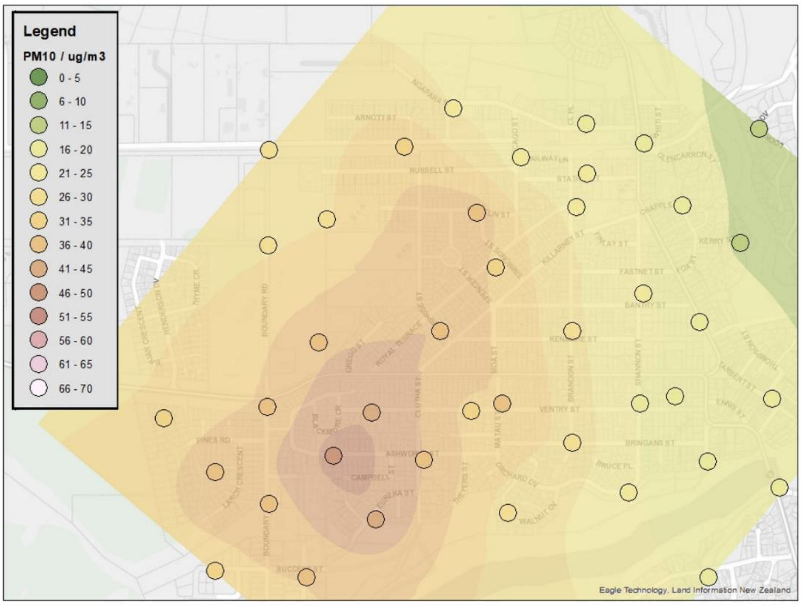


Figure A-11: 13th June 2023.

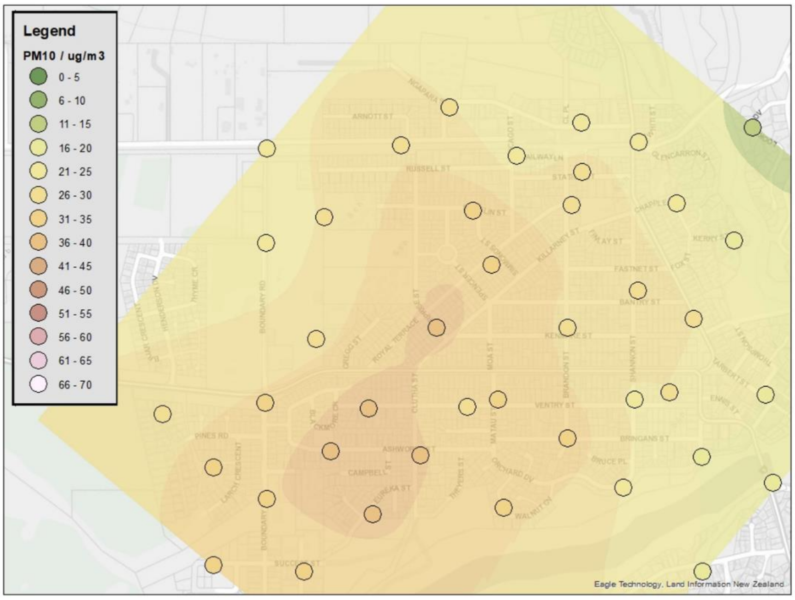


Figure A-12: 14th June 2023.

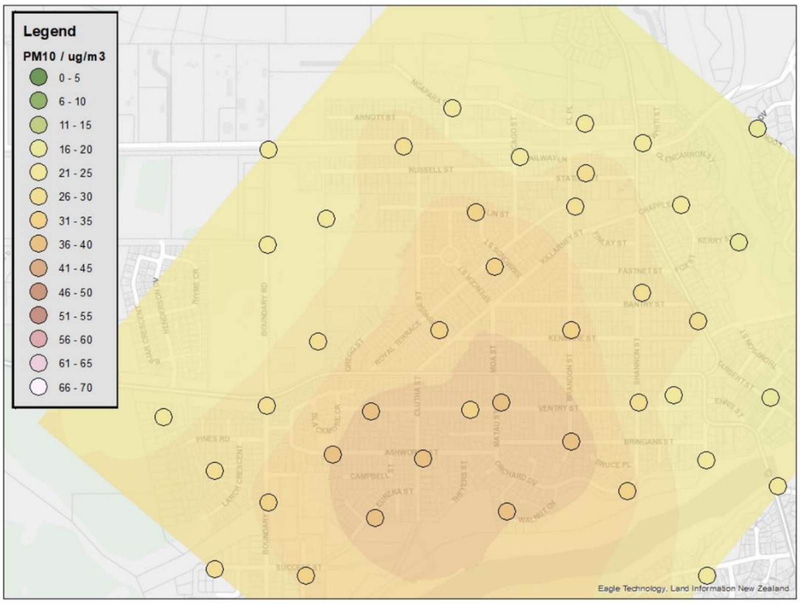


Figure A-13: 15th June 2023.

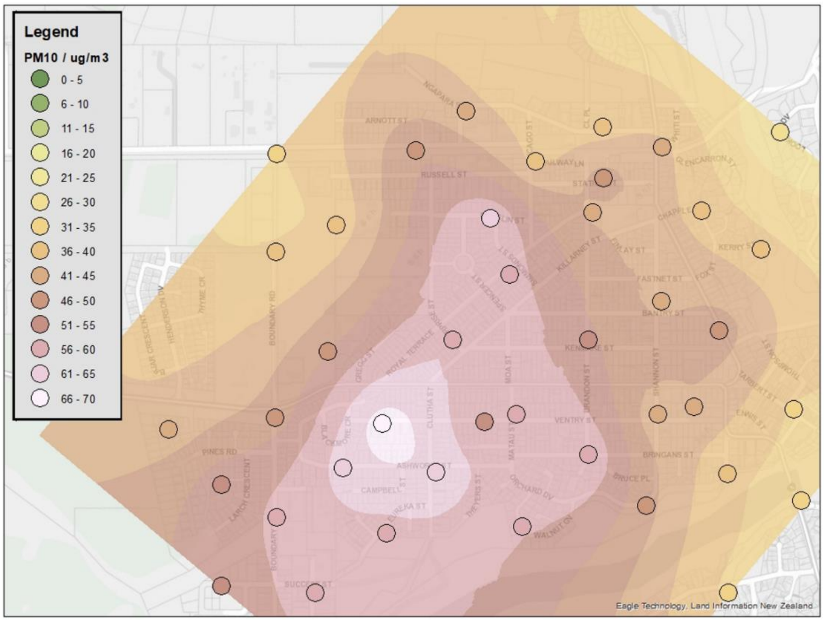
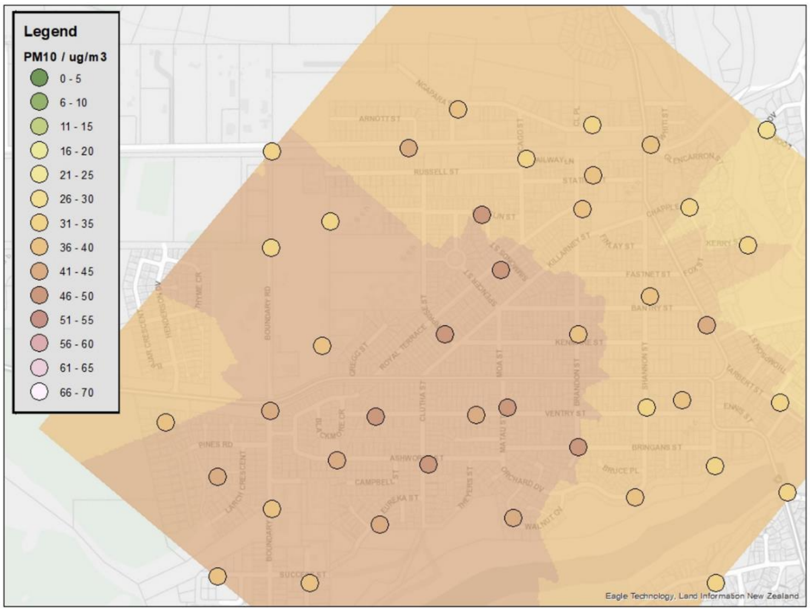


Figure A-14: 16th June 2023.



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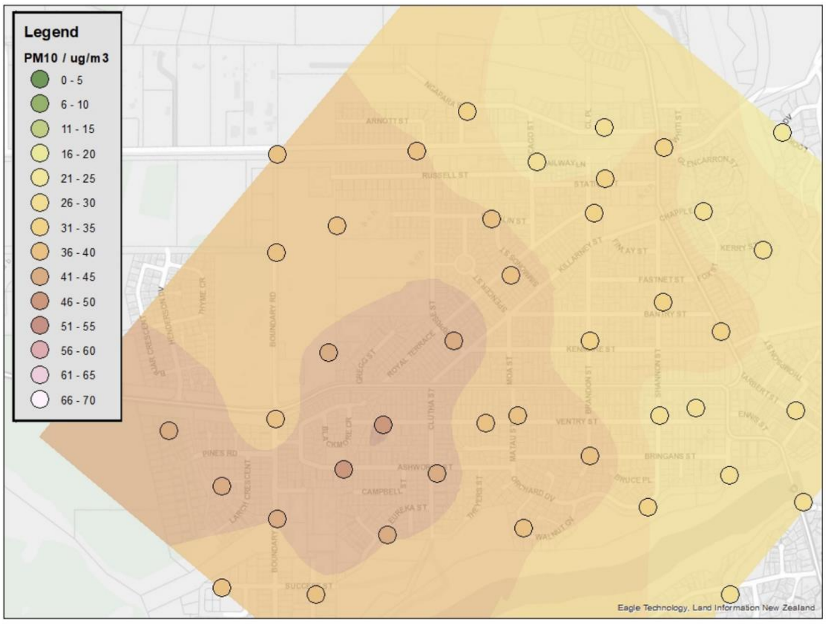

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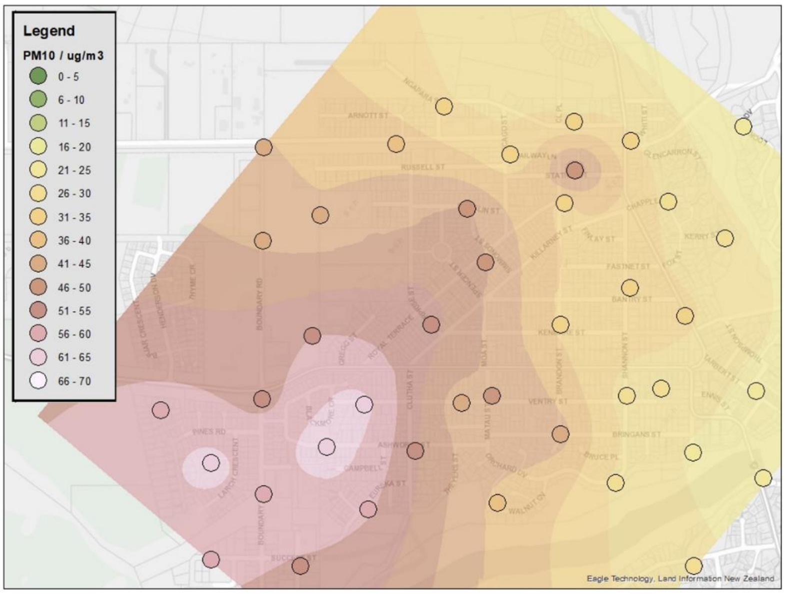
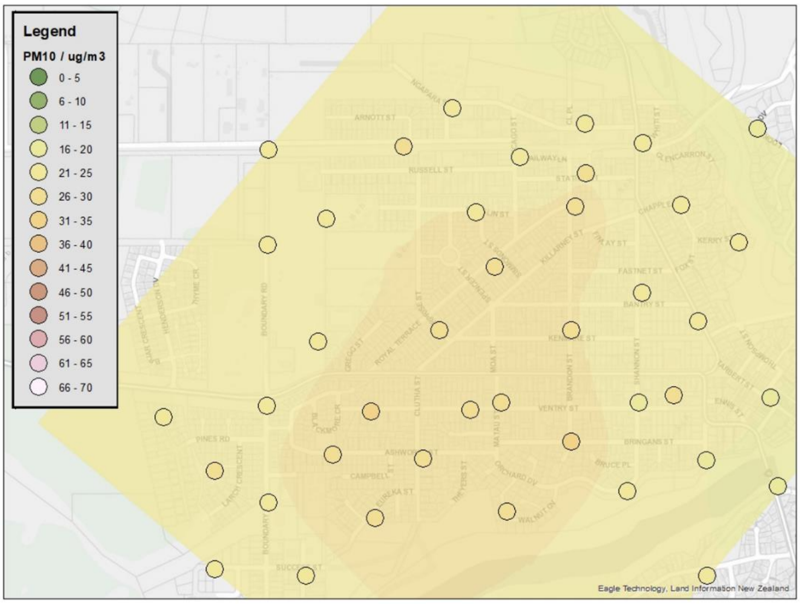


Figure A-17: 19th June 2023.



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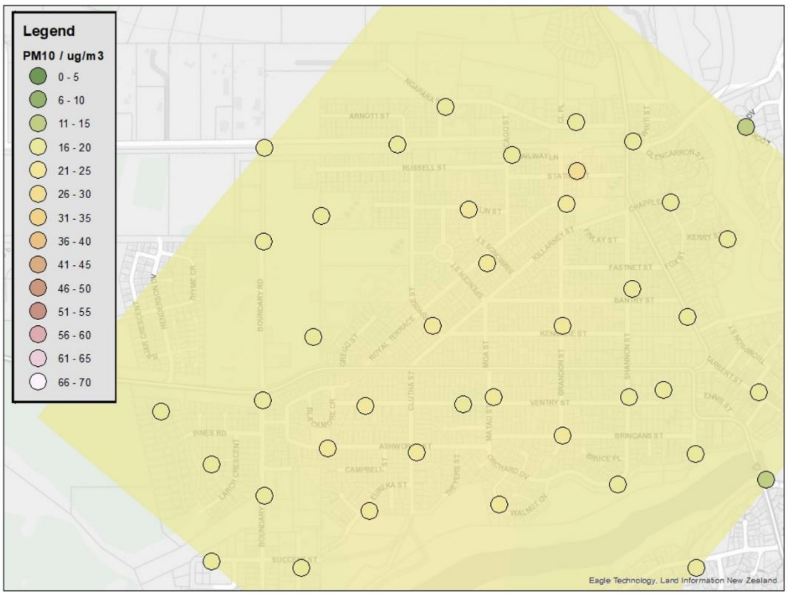

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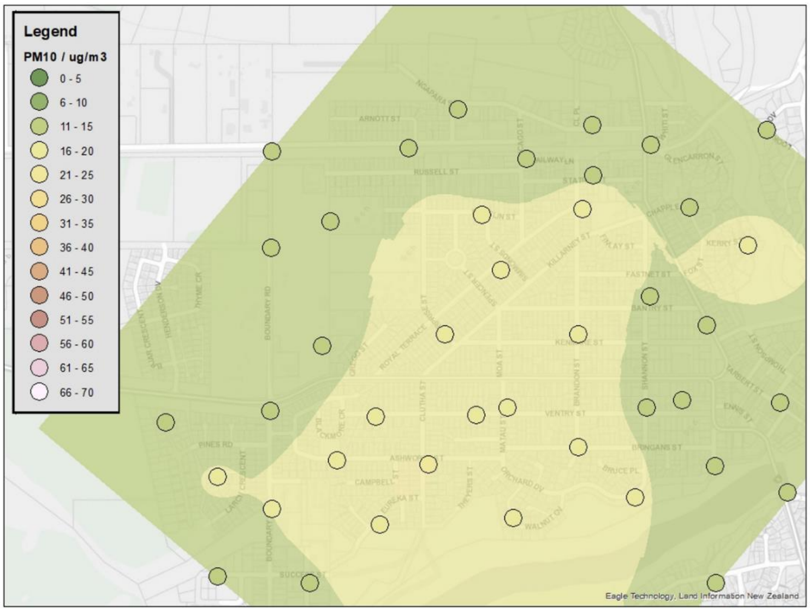


Figure A-20: 22nd June 2023.

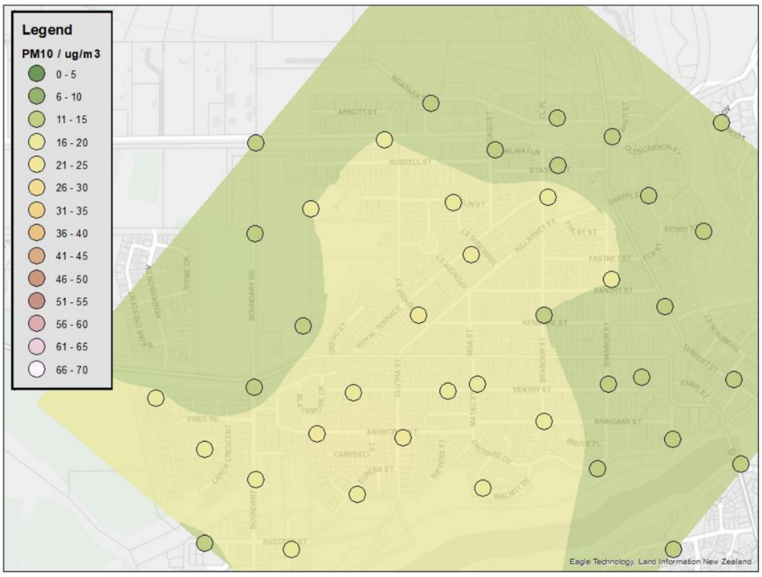
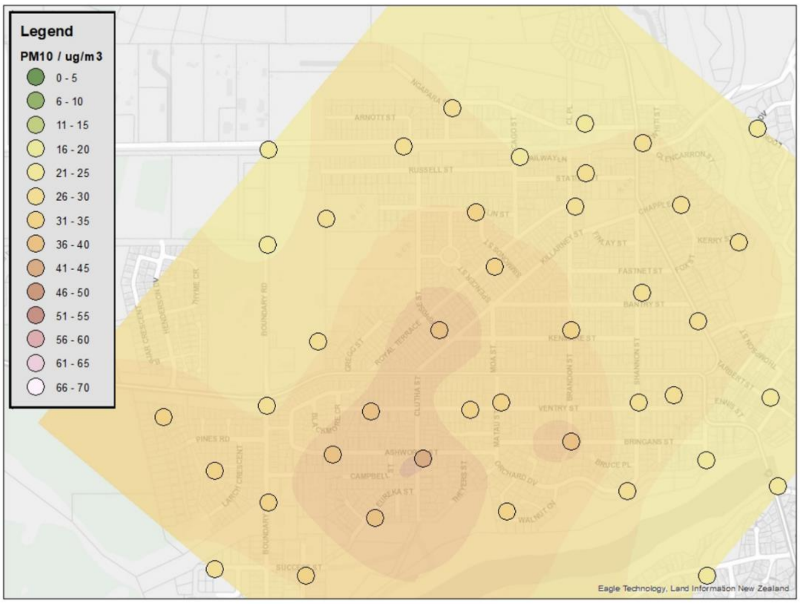


Figure A-21: 23rd June 2023.



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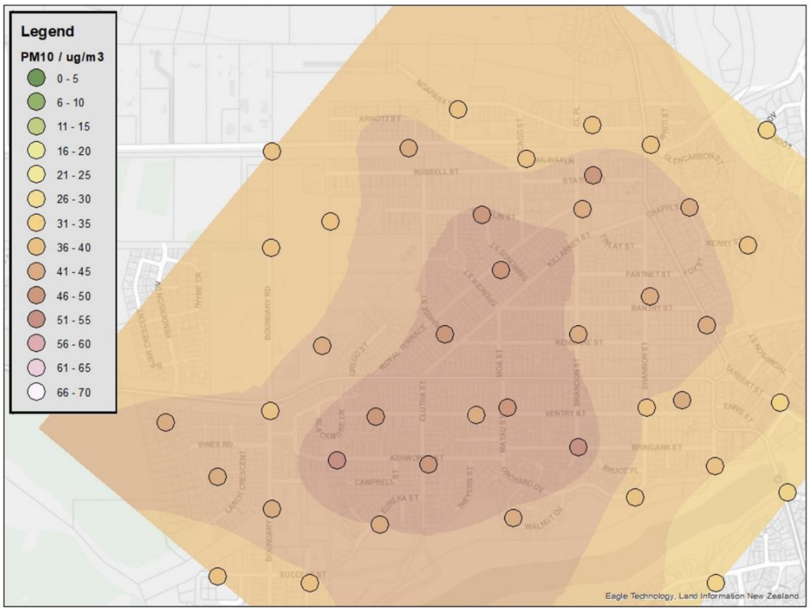

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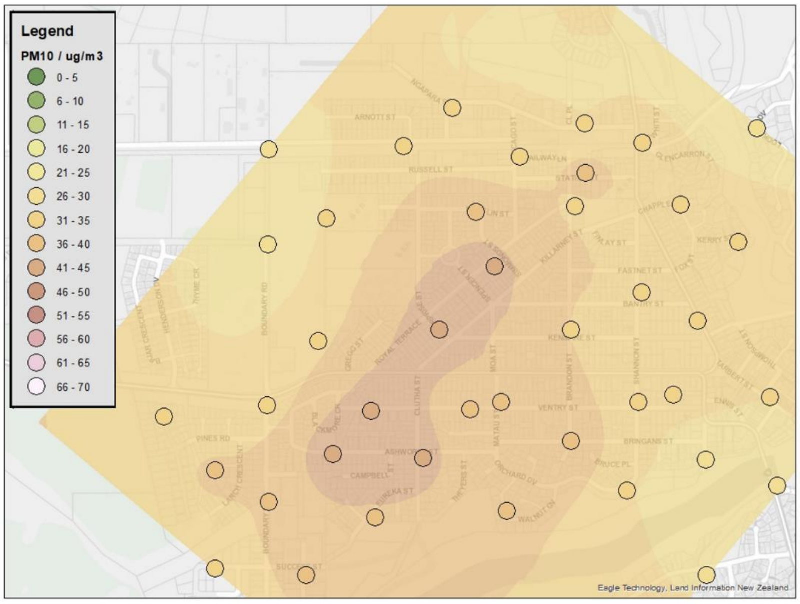

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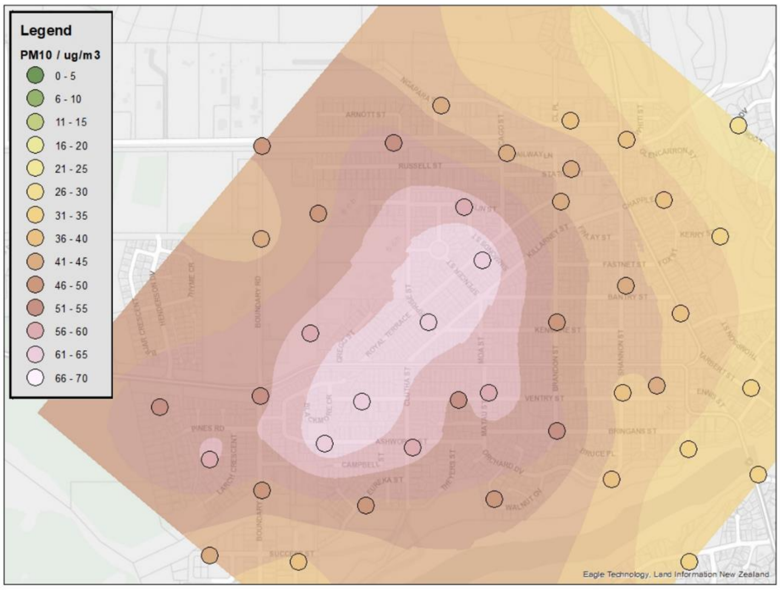

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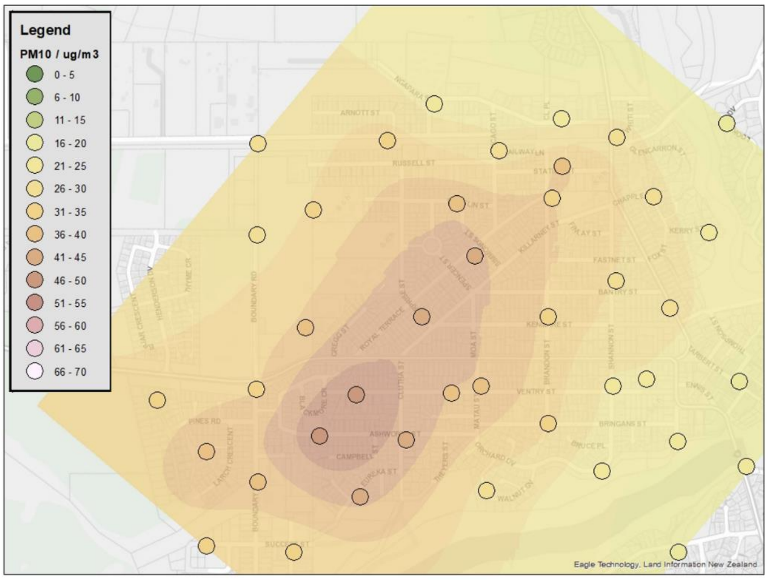

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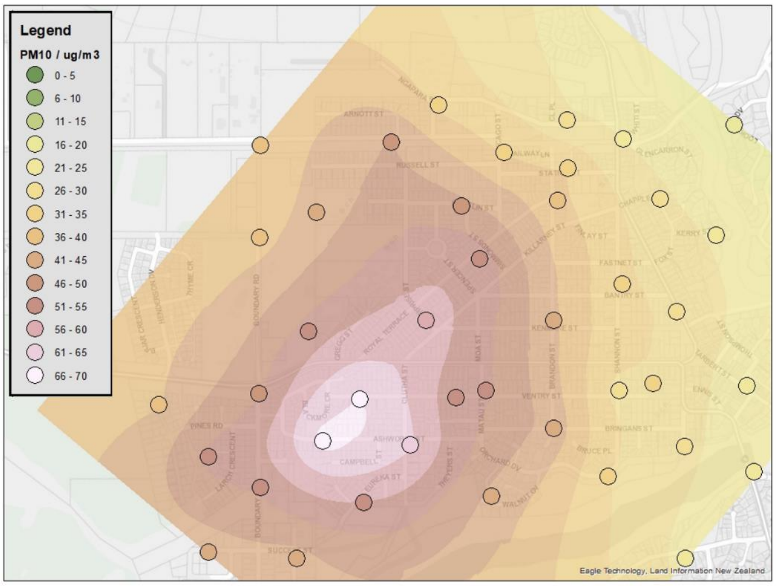

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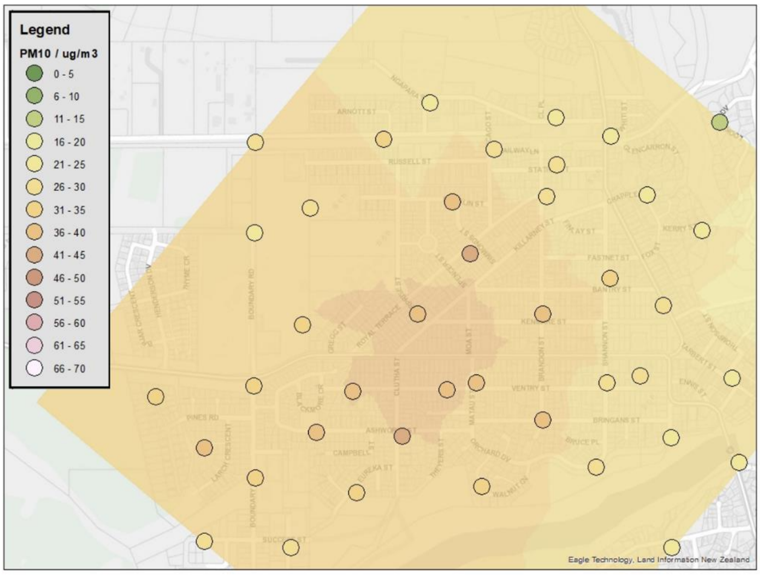

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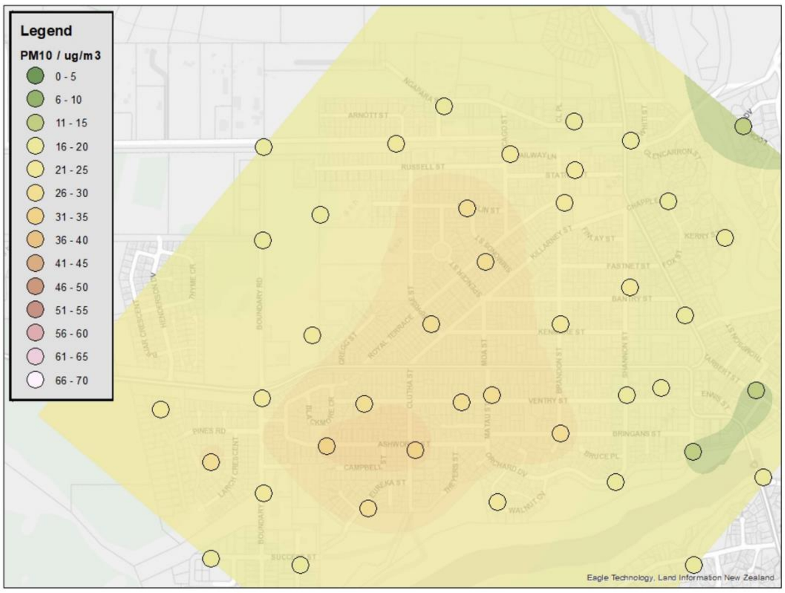

Figure A-29: 1st July 2023.

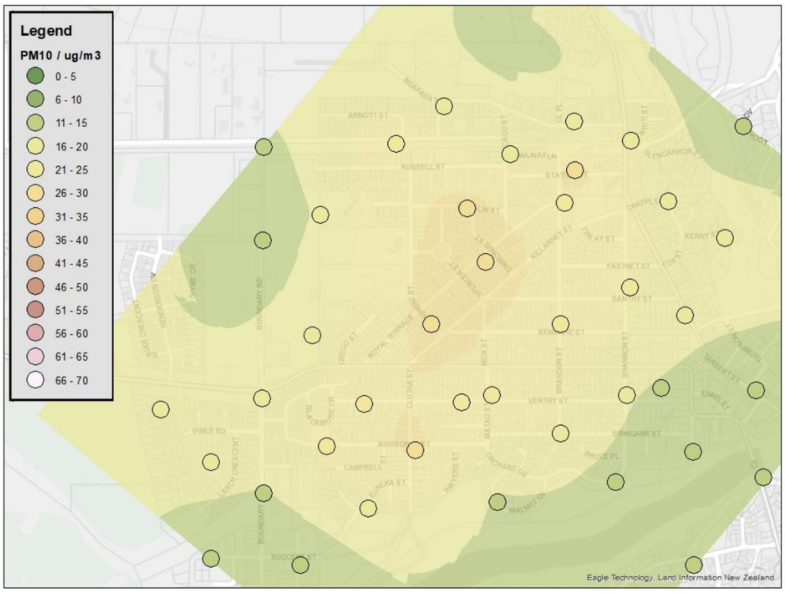

Figure A-30: 2nd July 2023.