Wakefield and Brightwater $PM_{2.5}$ monitoring network

May-September 2022

report for:

Tasman District Council

20 February 2023

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Acknowledgements

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Mote Limited would also like to thank the landowners/occupiers in Brightwater and Wakefield who kindly agreed to host an air quality monitoring during this monitoring campaign. Their assistance and patience during the installation and instrument removal is gratefully acknowledged.

Revision History

No.	Date	Author(s)	Reviewer(s)	Details
1	13 Sep 2022	**Paul Baynham**	**Dr. Brett Wells**	V1.0 Draft report completed
2	30 Dec 2022	**Paul Baynham**		V1.1 Revised draft sent to client
3	23 Jan 2023	**Paul Baynham**		V1.2 Incorporating feedback from client
4	20 Feb 2023	**Paul Baynham**		V1.3 Incorporating feedback from client

CONTENTS

1.0 EXECUTIVE SUMMARY

6 air quality monitors and 2 meteorological monitors were deployed around Wakefield and Brightwater between 26 May and 7 September 2022 as part of a high-resolution air quality monitoring network evaluating the effect and source of $PM_{2.5}$ concentrations in the Wakefield and Brightwater communities.

The investigation found that the winter air quality in the Brightwater/Wakefield area during the study period was excellent, good, or acceptable for between 68% and 100% of the time.

The lowest 24-hour average $PM_{2.5}$ concentrations were measured in southern Brightwater and southern Wakefield, while the highest 24-hour average $PM_{2.5}$ concentrations of 26 and 30 µg/m^3 were measured at Brightwater North and Wakefield North respectively. The peak concentrations at two of the six sites within the Brightwater and Wakefield communities exceeded the 2020 Ministry for the Environment's proposed 24-hour average National Environmental Standard for $PM_{2.5}$ of 25 µg/m^3. However, it should be noted that the 2020 proposed standard allows for up to 3 exceedances in any 12-month period. On this basis, the Wakefield north site, which experienced 4 days where the 24-hour average $PM_{2.5}$ concentration exceeded 25 µg/m^3, was the only site which would have exceeded the proposed guideline during the 2022 study period.

In 2021 the World Health Organisation (WHO) published the "WHO global air quality guidelines". These health-based guidelines take into consideration the scientific evidence which has accumulated since the previous guidelines were published in 2005. While traditionally, New Zealand air quality guidelines have maintained consistency with the WHO global air quality guidelines, it is unclear whether the Ministry for the Environment intends to do so on this occasion. Of relevance to this study is the recommended 24-hour $PM_{2.5}$ guideline of 15 µg/m^3 which allow for up to 3 exceedances per year. Based on the 2022 monitoring data, 4 of the 6 monitoring sites would not comply with the World Health Organisation 24-hour $PM_{2.5}$ guideline.

Wind speeds during the study remained relatively low and were typically south-westerly. Both meteorological monitoring stations displayed clear evidence of cold flow drainage under light winds which appeared to be the dominant dispersive mechanism at night. This dispersive mechanism would explain (in-part) the increasing $PM_{2.5}$ concentration from the south to the north in both the Brightwater and Wakefield communities.

2.0 PROJECT OUTLINE

Mote Limited were contacted by Tasman District Council in February 2022 regarding potential ambient air quality monitoring networks for the Brightwater and Wakefield communities. The objective of the study was to understand if there are air quality issues in Brightwater and/or Wakefield that may require ongoing monitoring and management.

The focus of the investigation was to assess the concentration of airborne particulate matter (the term of a mixture of solid particles and liquid droplets found in the air). The particulate size fraction of interest included particles with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$). The outputs of the study compared peak 24-hour average $PM_{2.5}$ concentrations with the proposed 2020 Ministry for the Environment Standard for $PM_{2.5}$ of 25 µg/m^3 (24-hour) and the 2021 World Health Guideline for $PM_{2.5}$ of 15 µg/m^3 (24-hour).

On 12 May 2022, 6 continuous particulate monitoring instruments and two meteorological monitors were co-located with a Partisol in Brightwater for a period of 12 days. This was to establish the relationship between the nephelometers and the National Environmental Standard compliant monitoring device (Thermo Scientific Partisol) operated by Tasman District Council. On 26 May 2022 five of the instruments were transferred to various locations in and around Brightwater and Wakefield with each community also receiving one ultrasonic meteorological anemometer.

The network was intended to be deployed for a three-month period to coincide with cooler winter weather when temperature inversions reduce the amount of atmospheric dispersion which can result in an increase in particulate concentrations.

2.1 Project location

Brightwater and Wakefield are small settlements in the Tasman District of New Zealand's South Island. They are situated 7.5 and 14 kilometres southwest of Richmond respectively. Brightwater has a population of approximately 2340 residents while Wakefield is home to 2680 residents[1].

Both communities are situated alongside the Wai-iti River on generally flat river valley terrain although both communities have elevated terrain to the northwest and southeast of their respective communities. The valley comprises the southwestern section of the Waimea River catchment but also drains several smaller tributaries into Tasman Bay.

A location map identifying the area can be seen in **Figure 1** over the page.

[1] 2018 New Zealand census

Brightwater and Wakefield study area location map

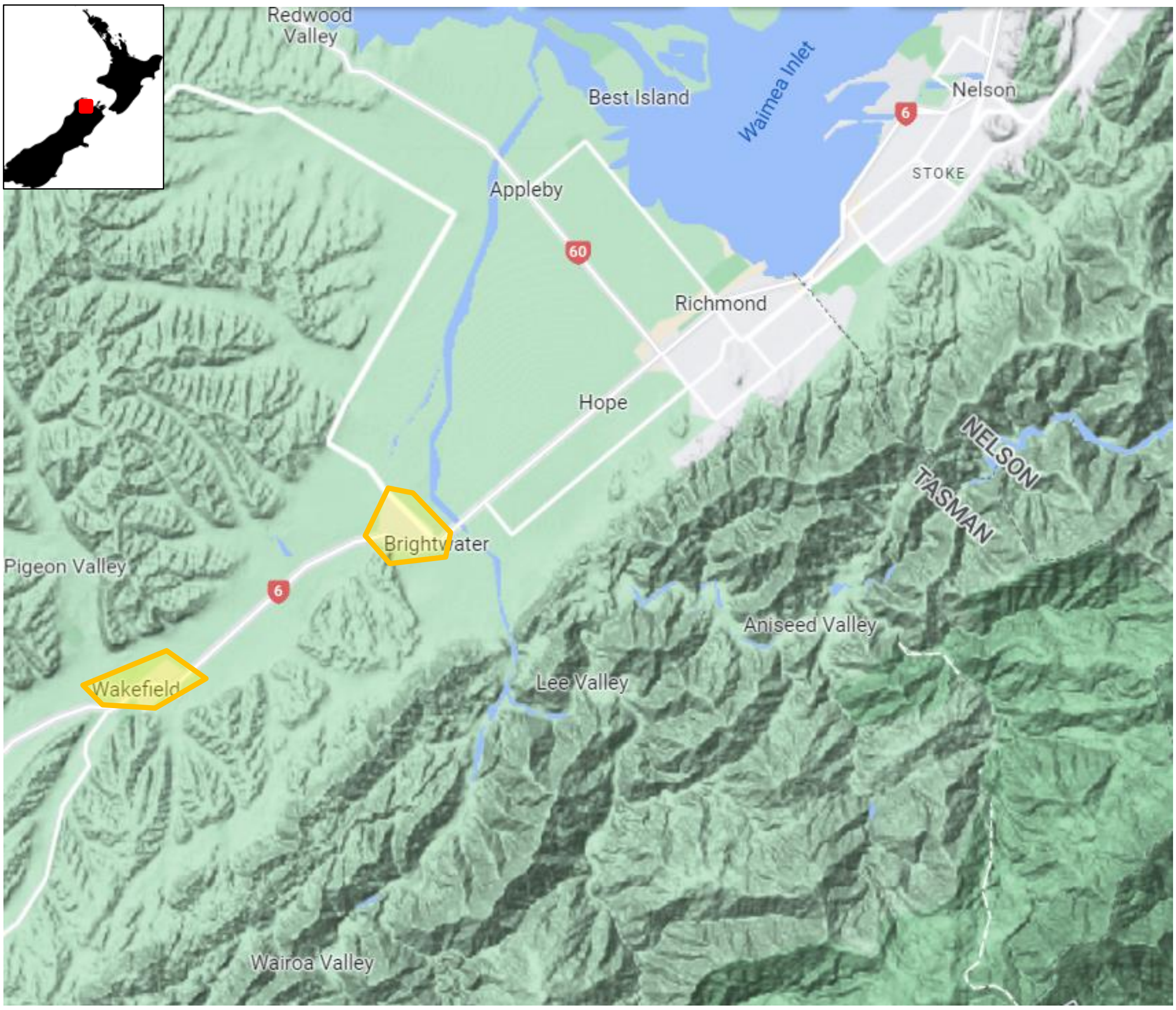


Figure 1: Location map of the study areas (highlighted yellow), Tasman District, New Zealand

Within each community, a total of three monitors were deployed. These monitors were positioned near the south, centre and northern sections of each community. In addition, a meteorological monitor was also deployed in each community to collect wind speed and direction data during the investigation.

The Brightwater and Wakefield communities have higher proportions of wood fires (42% and 49%) as shown in **Figure 2** below[2]

[2] Source 2018 New Zealand census.

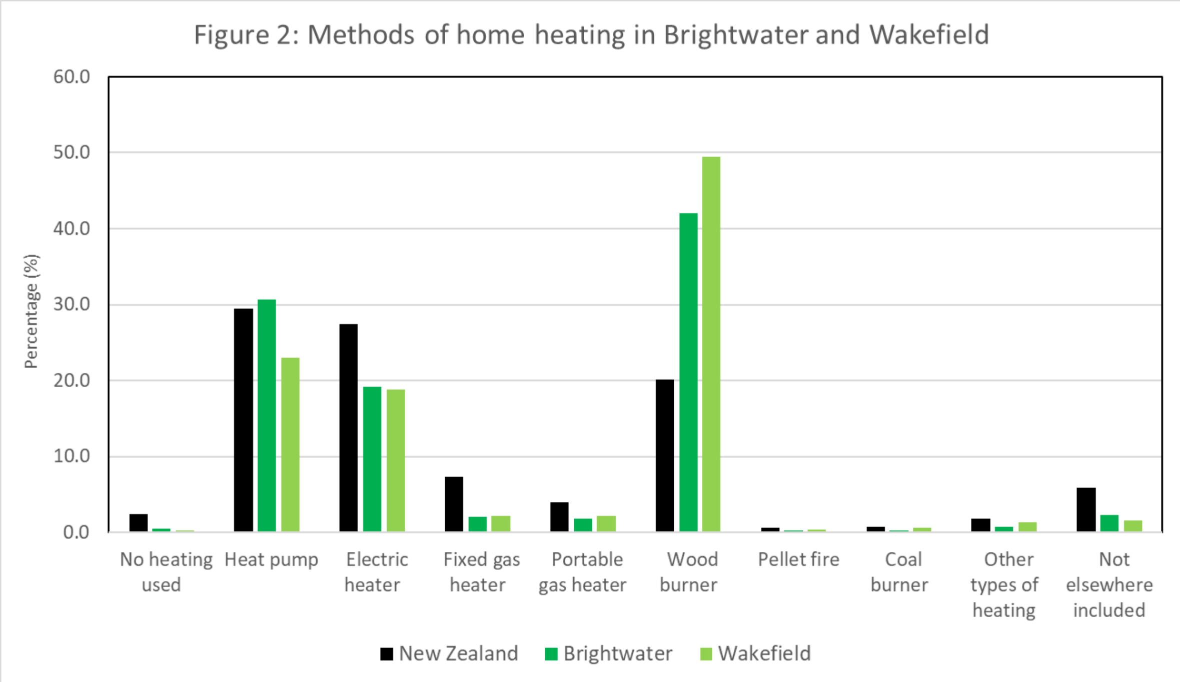


Figure 2: Graph displaying the proportion of different home heating methods in Brightwater and Wakefield compared with the New Zealand average based upon the 2018 Census data. Note that some households contain more than one heating type and/or multifuel burners.

2.2.1 Particle Instrument Selection

One primary instrument was selected - an optical nephelometers. The instrument is a Met One ES642 near-forward nephelometer which was coupled with a programmable modem.

The ES642 produces 1 second data which was collated to produce 1-minute averaged data. The ES642 unit contains an inlet heater which was controlled using a set point of 35% relative humidity. Sample flow rates of 2 litres per minute were calibrated using a DryCal defender immediately following installation of the instrumentation. The flow rates were confirmed at the conclusion of the project and were all found to be within 5% of the original flow rates.

Temperature, pressure, and relative humidity sensors were also calibrated using Vaisala HMT330 and HM70 meters following installation to ensure accurate flow measurement.

The instruments store data locally if cellular transmission is disrupted. When cellular connectivity is restored, then data transmission will recommence with older data transmitted first.

Figure 3: Photograph of the ES642 units co-located alongside the TDC Partisol in Brightwater.

All instruments were co-located at Brightwater alongside the TDC partisol for an initial 12-day period. The purpose of this co-location was firstly, to ensure that the optical nephelometers are producing consistent data prior to their respective field deployment locations (degree of precision). The second purpose is to enable the optical concentration data to be corrected to gravimetric equivalent (degree of accuracy).

Following the 12-day co-location, the data from each of the units was adjusted using a linear correction factor to ensure consistent measurements during the monitoring campaign and to verify that the instrumental concentrations were comparable during the initial 12-day deployment. This was performed by calculating an average concentration during the co-location and comparing this with combined average value of all instruments over the same period.

The gain on each instrument was then adjusted and the instrumental data checked to verify that the values where within +/-2 μg/m^3. A comparison of the instruments confirmed that the 24-hour average values were within tolerable thresholds.

Standard practice is to replace any instruments which fail to meet this requirement, however following gain adjustments, all optical nephelometers met the required degree of precision (24-hour average +/-2 μg/m^3).

Figure 4 displays the corrected instrumental concentrations for each of the monitors used during the deployment.

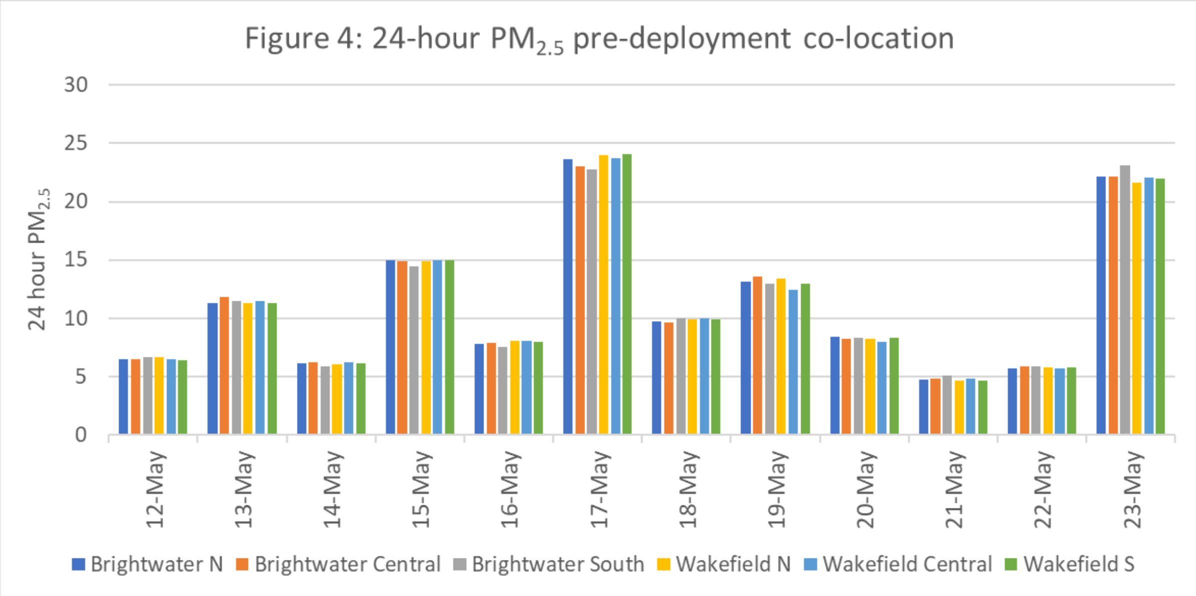


Figure 4: comparison of 24-hour average concentrations for the 6 $PM_{2.5}$ instruments co-located in Brightwater (12 May – 23 May).

The second part of the co-location process involves applying a linear correction factor to correct the optical concentrations to gravimetric equivalent. This is normally achieved by either sampling the optical particles onto a filter (e.g. MetOne ESampler), calculating the optical correction factor and applying linearly across the sampling period or as in this case, using filter based results from a co-located instrument.

The correction factor recognises that two different instrumental techniques are used by the instruments (Gravimetric vs Optical). Essentially, the optical devices measure the number of particles during a given period of time and then convert this to a concentration by making an assumption around particle density(ρ). Investigations in other parts of New Zealand have established that $PM_{2.5}$ particle density assumptions can vary ($0.8>\rho>2.2$) between sites.

As the particle size decreases, there is generally better agreement between optical nephelometers and gravimetric instruments. There are several reasons, for this, however if one considers the formulae to calculate the volume of a sphere:

$$V = \frac{4}{3}\pi r^3$$

It is apparent that the cubic radius has a significant effect on particle volume. Therefore, it follows that as the particle size decreases, the particle volume and the effect of particle density becomes less significant.

2.2.2 Meteorological Instrument Selection

Two meteorological sensors were deployed, one in Brightwater North and the second in Wakefield South. Both sensors consisted of Gill Windsonic 60 ultrasonic wind speed and direction sensors which were mounted on poles which extended 900mm above the ES642 inlet height. The devices were aligned to true north during installation. The instruments were factory calibrated prior to deployment with the reported accuracy of the wind speed and wind direction being +/- 2% and +/-2º respectively.

The ultrasonic anemometers collect data at 1 second intervals (u & v vectors). The meridional and zonal components are then converted to 1 minute average data using vector averaging. The 1-minute average data has the same timestamp as the associated ES642 data to enable direct comparison.

2.3 Site Selection

The Tasman District Council identified their preferred locations during the pre-planning phase of the deployment in conjunction with Mote limited. All instruments were mains powered with RCD trip devices installed in the event of any electrical earth fault developing.

All instruments were generally positioned between 2 and 3 metres above ground level where possible and associated wind speed and direction monitors were positioned approximately 1 metre above the nephelometers.

A location map depicting the location of the instruments is shown in **Figure 5**.

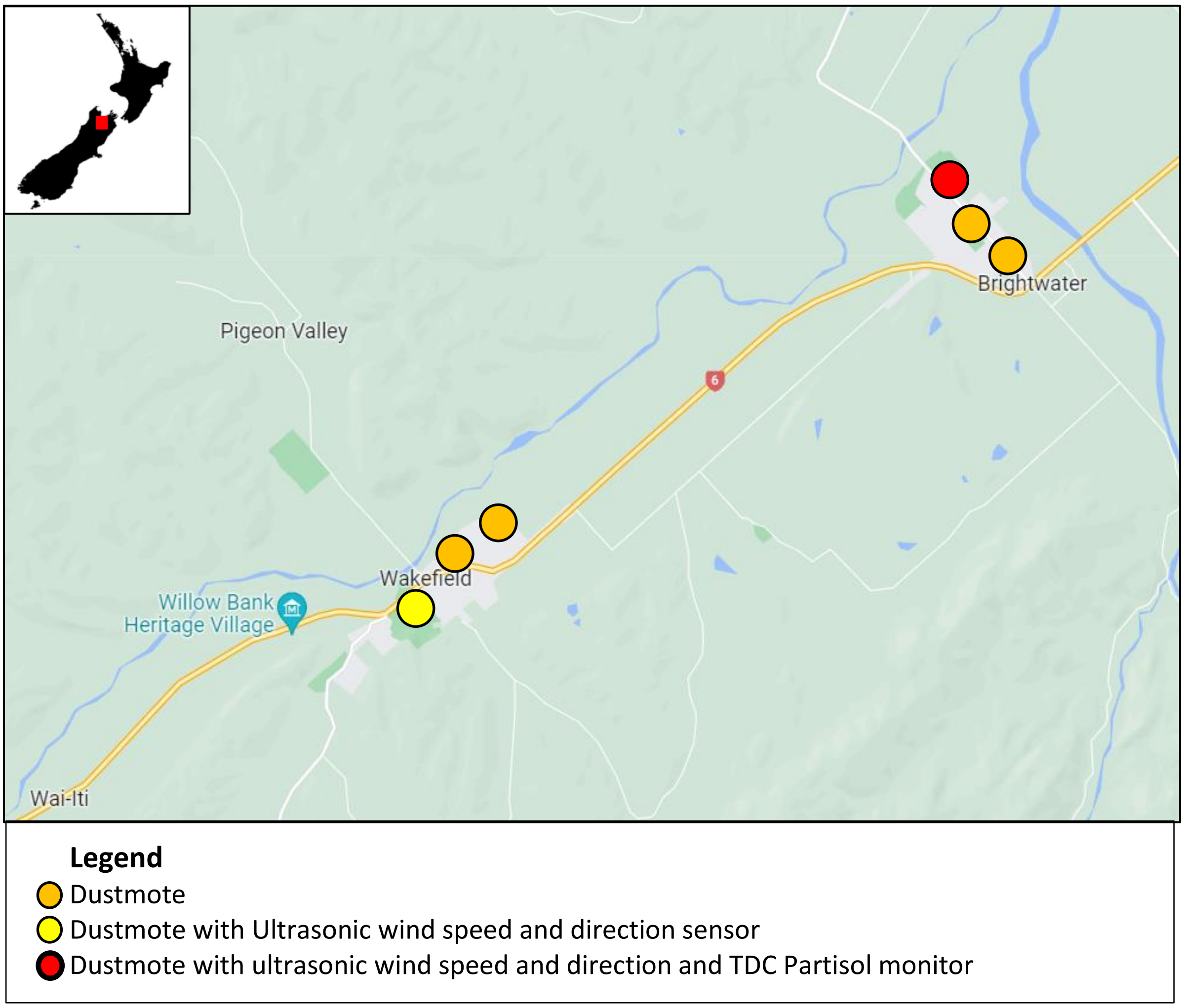


Figure 5: Location map of monitors in the Brightwater and Wakefield areas during the monitoring network deployment.

3.0 RESULTS

Landowners/occupiers who provided approval to house the instrument were given a food voucher for a local supermarket upon the initial installation along with a second food voucher when the instrument was removed.

These vouchers were provided to compensate the landowners and occupiers for the inconvenience of having an instrument on their property and also in recognition of the small amount of electricity consumed by the device while it was operational.

3.1 Data capture rate

On 26 May, the 6 Dustmotes and two meteorological instruments were installed at their designated monitoring locations in Brightwater and Wakefield. These devices operated continuously until 7 September when the units were removed and co-located with the Partisol in Brightwater where the devices operated for another 6 days until their decommissioning on 14 September.

The overall data capture rate for the investigation was 96.9%. Intermittent power issues that were experienced at the Brightwater South site resulted in some data loss and a significant storm event on 18 August also resulted in some power outages. Total data capture rates are shown in **Table 1** below.

Table 1: Instrument deployment details and data capture rate

Instrument	Target hours[1]	Actual hours[1]	Data capture rate (%)	Comment
Brightwater North	3022	2944	97.4	Power outage from 29 Jul through to 1 Aug
Brightwater Central	3022	2996	99.1	
Brightwater South	3022	2654	87.8	Intermittent power outage
Wakefield North	3022	2994	99.1	
Wakefield Central	3022	2994	99.1	
Wakefield South	3022	2978	98.5	

[1] Number of hours between 11 May and 14 September 2022

[2] Total hours of data collected

Yellow refers to units which experienced data loss during the study period

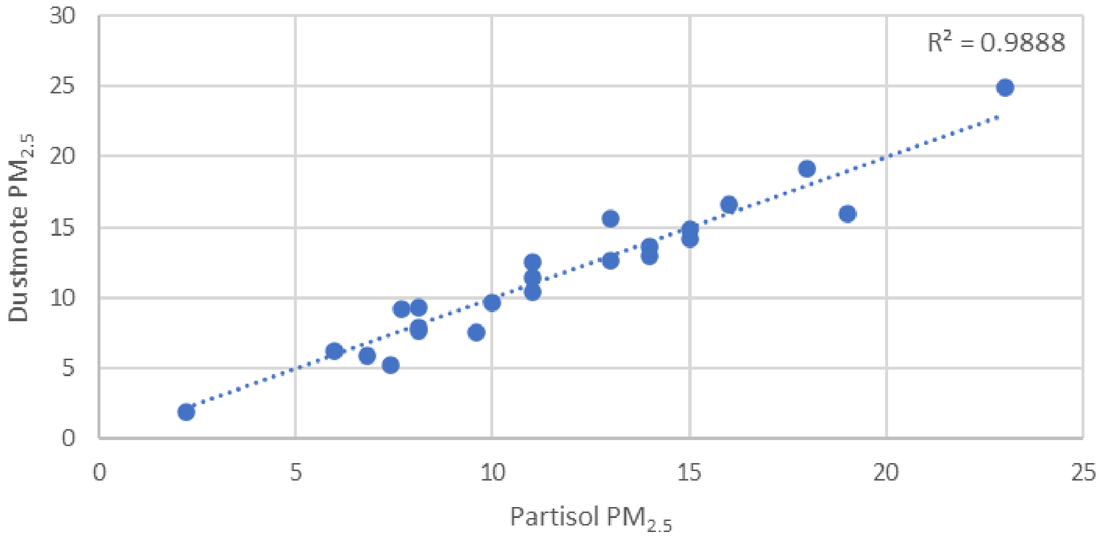
A validated spreadsheet containing the 1 minute and 24-hour average data from Brightwater and Wakefield accompanies this report. The spreadsheet is named **Brightwater_Wakefield_Data_V1.1.xlsx.**

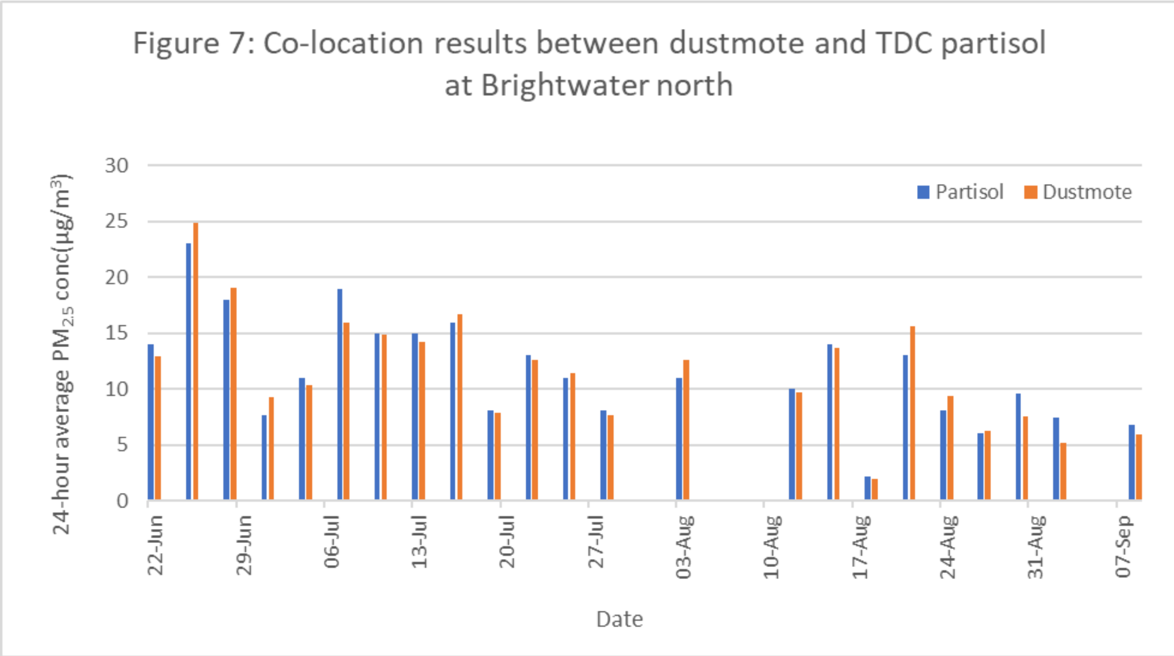
3.1.1 Brightwater north co-location results

A TDC partisol was co-located with the Brightwater North dustmote and a comparison of the data revealed good agreement between the two instruments. The Pearson correlation co-efficient which assesses the degree of agreement between two linear variables indicates an r^2 of 0.99. Figure 6A below depicts the comparison between the Partisol and Brightwater Dustmotes between 22 June and 8 September 2022. This plot displays the strength of the relationship between the instruments for the duration of the study. Figure 6B below displays a time series plot comparing the results from both instruments over the same period. This plot confirms that the variation between the instruments remained reasonably consistent throughout the duration of the study.

A comparison of the average $PM_{2.5}$ concentration between the Partisol and the Brightwater North dustmote revealed average concentrations of 13.56 and 13.61 µg/m^3 respectively. The similarity between these two values demonstrates that the relationship between the two types of instruments is acceptable given the different techniques (gravimetric vs nephelometric) methods used to quantify particle concentration.

Figure 6: 24-hour average $PM_{2.5}$ comparison
Dustmote vs Partisol





Figures 6 and 7: Co-location monitoring results between the Dustmote and Partisol at Brightwater North.

At the conclusion of a deployment, all instruments were again co-located back at the Brightwater site for a period of 6 days to evaluate whether the initial adjustments made to the instruments remained valid (+/- 2 µg/m³).

The TDC partisol was generally operated on a 1 day in 3 scheduled meaning that one 24-hour averaged sample was collected every three days.

This post-location analysis confirmed that the 24-hour equivalent concentrations remained within +/-2 µg/m³ at the conclusion of the study.

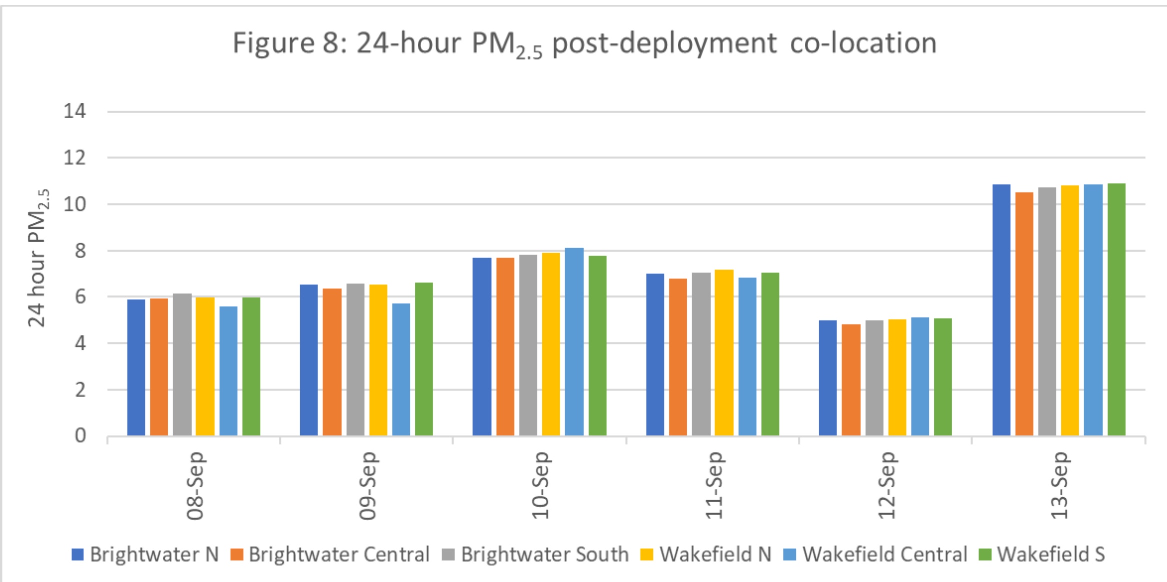
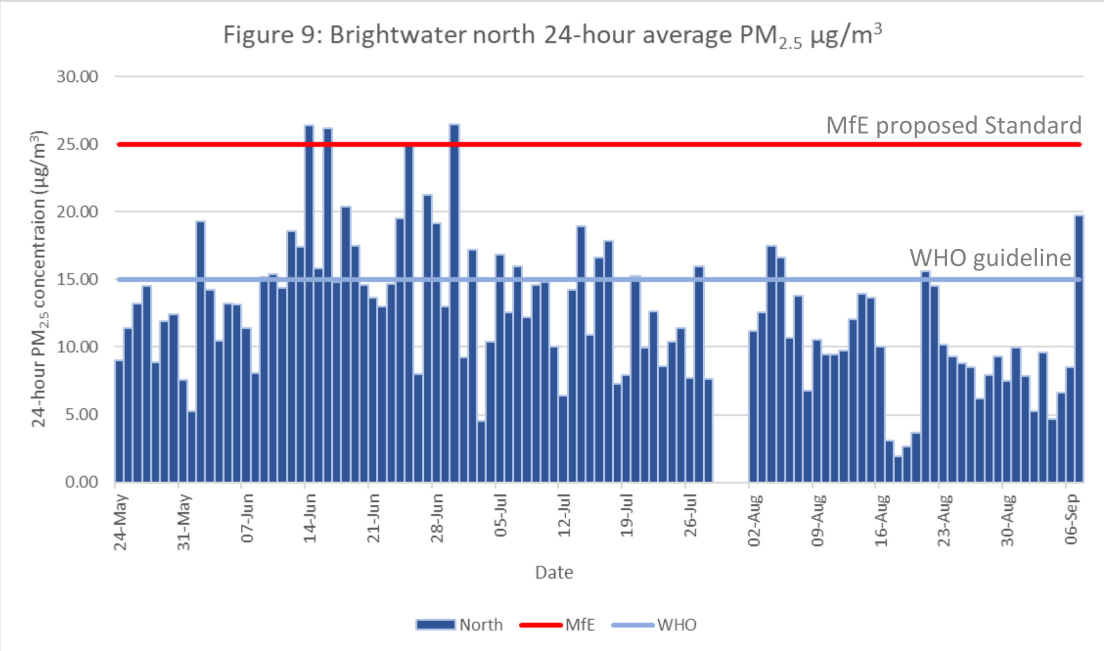
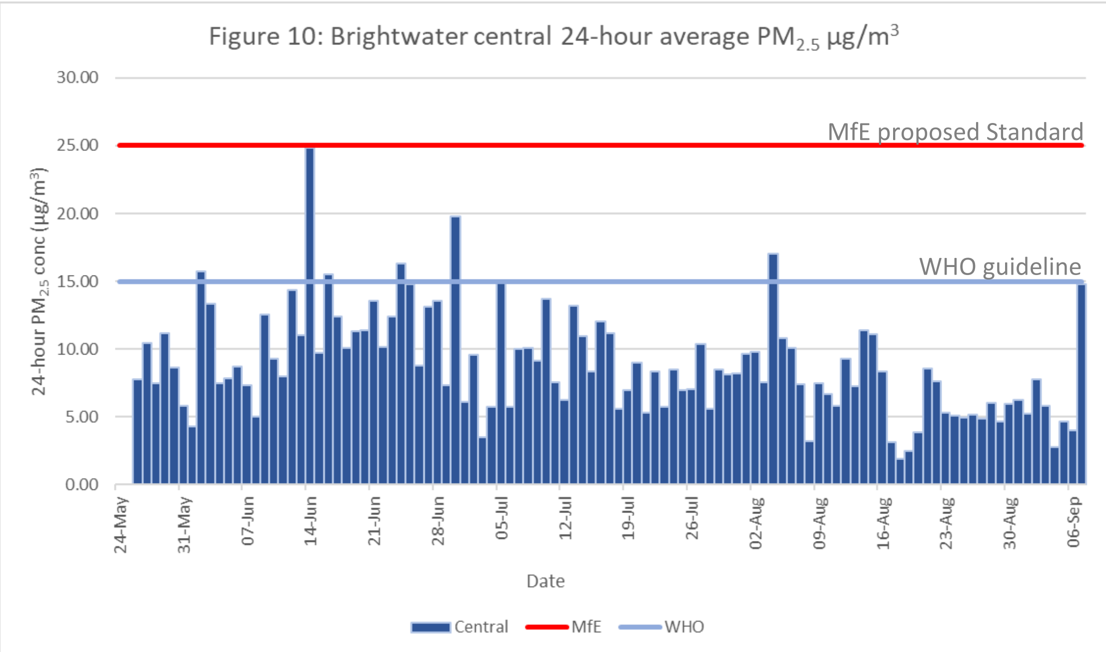


Figure 8: Comparative plot of deployed instruments post-deployment

3.2 $PM_{2.5}$ results

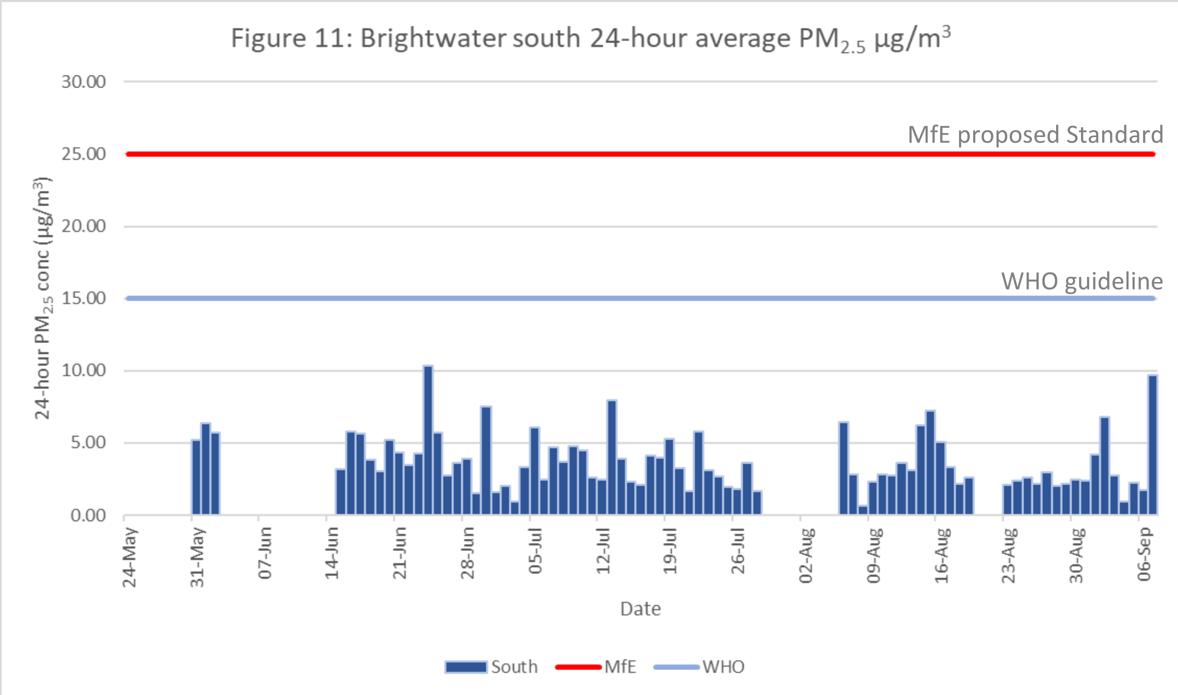
The following series of graphs reveal the daily maximum 24-hour $PM_{2.5}$ concentration for each of the monitoring stations. Comparisons are made against the proposed 2020 National Environmental Standard for $PM_{2.5}$ of 25µg/m3 (24-hour)[3], and the more recent 2021 World Health Organisation guideline of 15µg/m3 (24-hour).

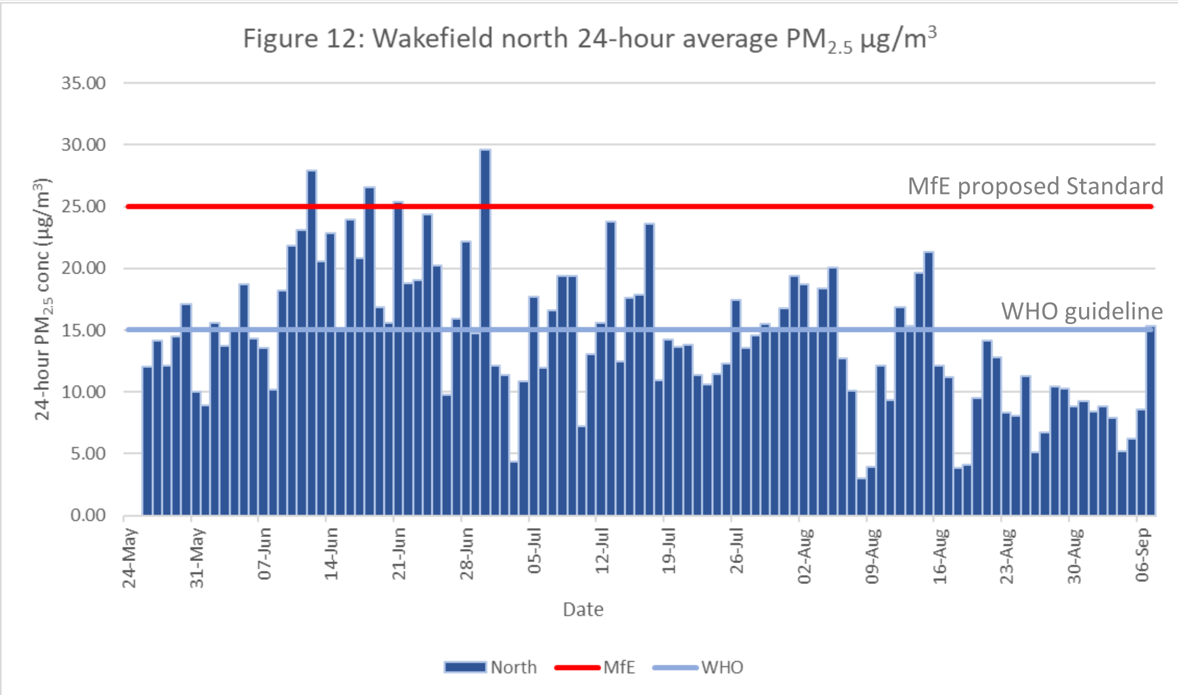




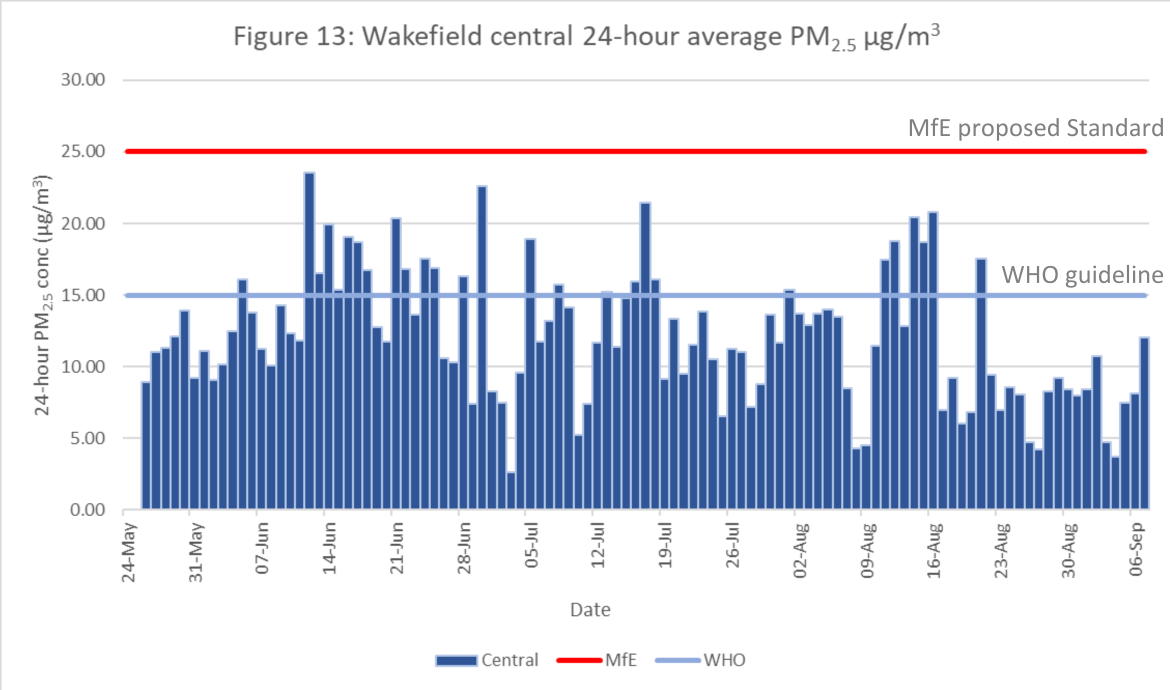
Figures 9 & 10. Plots of 24-hour average $PM_{2.5}$ concentration for each instrument. Note periods where less than 75% of the valid data was present have been left blank. The red line indicates the proposed 24-hour National Environmental Standard for $PM_{2.5}$ (25 µg/m³) while the blue line indicates the World Health Organisation 2021 guideline (15 µg/m³).

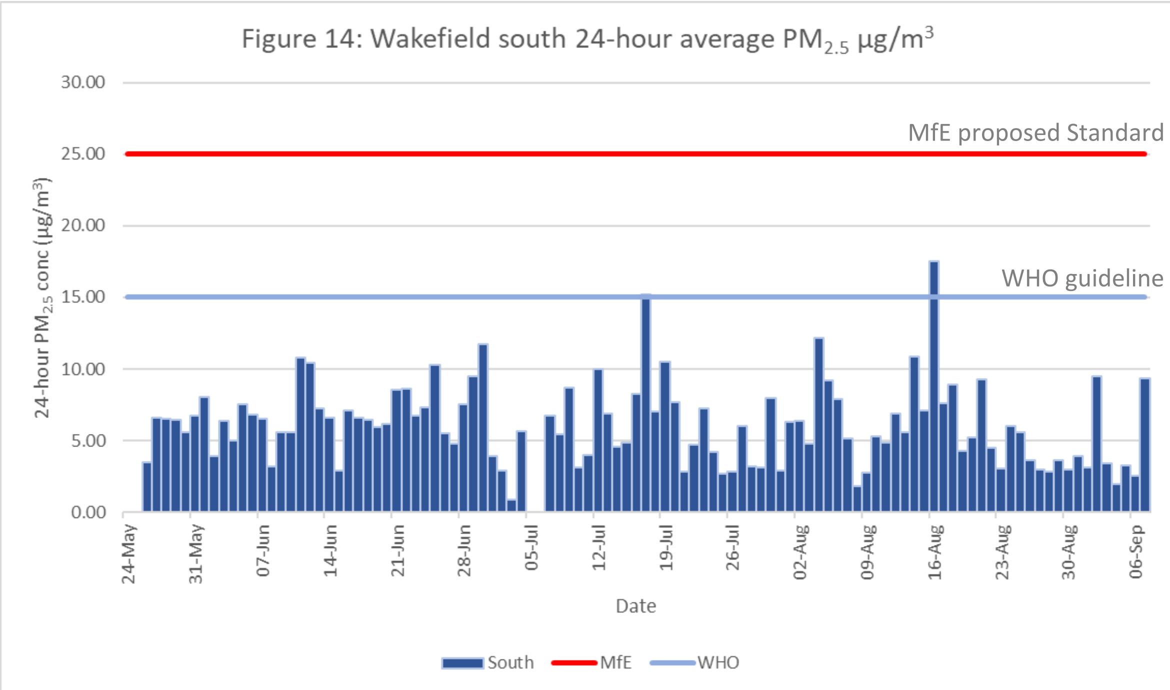
[3] Ministry for the Environment. 2020. Proposed amendments to the National Environmental Standards for Air Quality: particulate matter and mercury emissions – consultation document. Wellington: Ministry for the Environment.





Figures 11 & 12: Plot of 24-hour average $PM_{2.5}$ concentration for each instrument. Note periods where less than 75% of the valid data was present have been left blank. The red line indicates the proposed 24-hour National Environmental Standard for $PM_{2.5}$ (25 µg/m3) while the blue line indicates the World Health Organisation 2021 guideline (15 µg/m^3).





Figures 13 & 14: Plot of 24-hour average $PM_{2.5}$ concentration for each instrument. Note periods where less than 75% of the valid data was present have been left blank. The red line indicates the proposed 24-hour National Environmental Standard for $PM_{2.5}$ (25 µg/m3) while the blue line indicates the World Health Organisation 2021 guideline (15 µg/m^3).

The lowest 24-hour average $PM_{2.5}$ concentrations were measured in southern Brightwater and southern Wakefield, while the highest 24-hour average $PM_{2.5}$ concentrations of 26 and 30 µg/m^3 were measured at Brightwater North and Wakefield North respectively.

The peak concentrations at two of the six sites within the Brightwater and Wakefield communities exceeded the 2020 Ministry for the Environment's proposed 24-hour average

National Environmental Standard for $PM_{2.5}$ of 25 µg/m^3. However, it should be noted that the proposed standard allows for up to 3 exceedances in any 12-month period. On this basis, the Wakefield north site which experienced 4 days where the 24-hour average $PM_{2.5}$ concentration exceeded 25 µg/m^3 was the only site which would have breached the proposed guideline during the 2022 study period.

In 2021 the World Health Organisation published the "WHO global air quality guidelines". These health-based guidelines take into consideration the scientific evidence which has accumulated since the previous guidelines were published in 2005.

While traditionally, New Zealand air quality guidelines have maintained consistency with the WHO global air quality guidelines, it is unclear whether the Ministry for the Environment intends to do so on this occasion.

Of relevance to this study is the recommended WHO 24-hour $PM_{2.5}$ guideline of 15 µg/m^3 which allow for 3-4 exceedances per year. For the purposes of this report, the lower threshold of 3 exceedances has been applied as a comparison. Based on the 2022 monitoring data, 4 of the 6 monitoring sites would not comply with the World Health Organisation 24-hour $PM_{2.5}$ guideline.

Table 2: List of World Health Organisation exceedances per site during 2022

Location	Number of days where 24-hour average $PM_{2.5}$ is greater than 15 µg/m^3	Allowable number of exceedances per year	Number of days where $PM_{2.5}$ breaches WHO guideline	Total number of days monitored at each site (26 May – 7 Sep)
Brightwater north	27	3	24	101
Brightwater central	7	3	4	105
Brightwater south	0	3	0	77
Wakefield north	45	3	42	105
Wakefield central	27	3	24	105
Wakefield south	2	3	0	103

Figures 15a and 15b below depicts the proportion of time each site spent in each air quality category during the study period.

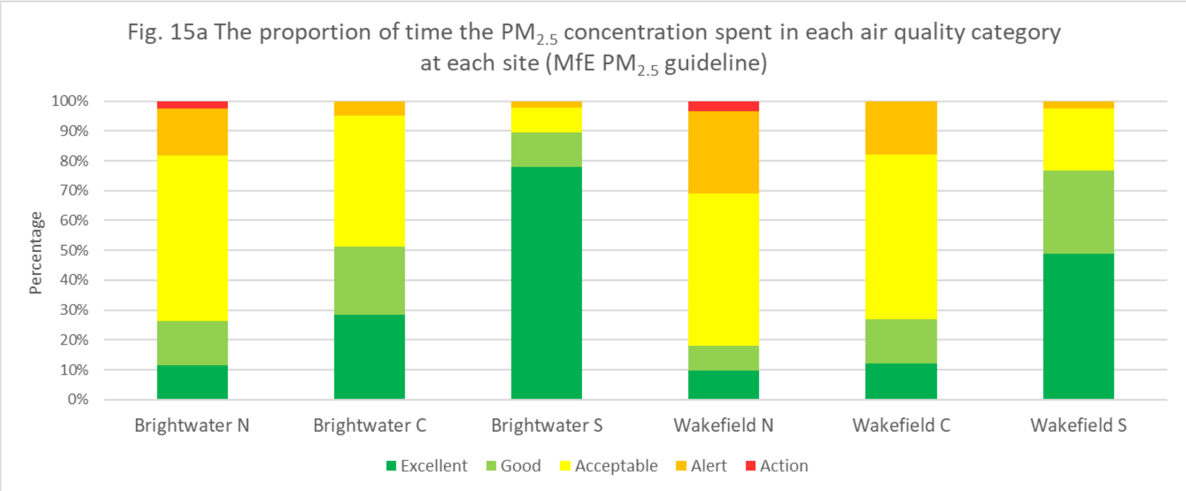


Figure 15a: The proportion of time each site spent in each air quality category for the proposed 2020 MfE $PM_{2.5}$ Standard (MfE Environmental Performance Indicator (EPI) programme air quality indicators (2002).

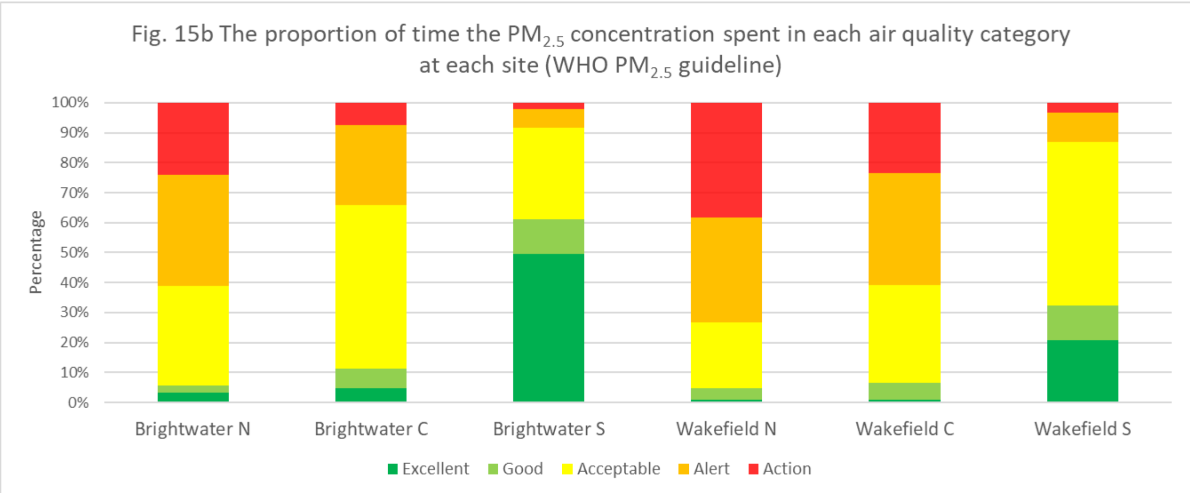


Figure 15b: The proportion of time each site spent in each air quality category for the World Health Organisation $PM_{2.5}$ guideline.

Figure 15a confirms that the air pollution exceeded the draft 2020 Ministry for the Environment $PM_{2.5}$ standard of 25 μg/m^3 at Brightwater north on 3 days and at Wakefield north on 4 days during the 2022 winter. However, the draft standard presently allows for up to three exceedances[4] in any 12-month period. When this is taken into consideration only Wakefield north would actually breach the draft standard.

Figure 15b follows similar logic to Figure 15a but instead uses the 2021 World Health Organisation $PM_{2.5}$ guideline of 15 μg/m^3. The WHO guideline allows 3-4 days in any 12-month period to exceed the standard without resulting in a breach. If the WHO guideline is

[4] Days where the 24-hour $PM_{2.5}$ average exceeds the MfE draft $PM_{2.5}$ standard of 25 μg/m^3

applied to the data collected during the 2022 winter, we find that only Brightwater south and Wakefield south would comply with the WHO guideline for $PM_{2.5}$.

Traditionally, the Ministry for the Environment have adopted the World Health Organisation guidelines as the basis for ambient air quality guidelines and standards in New Zealand. It is currently unclear whether the Ministry for the Environment intends to amend the current air quality standards to bring them into line with the WHO air quality guidelines.

Table 3 below displays the co-efficient of variation between each of the sites for the period between 24 May through to 7 September 2022. The values provided are based on the 24-hour average data and provide an indication of the degree of similarity between sites during the investigation.

Table 3: Co-efficient of variation between each of the 7 sites

	Brightwater north	Brightwater central	Brightwater south	Wakefield north	Wakefield central	Wakefield south
Brightwater north		0.96	0.82	0.93	0.89	0.80
Brightwater central	0.96		0.88	0.92	0.90	0.81
Brightwater south	0.82	0.88		0.83	0.85	0.82
Wakefield north	0.93	0.92	0.83		0.95	0.85
Wakefield central	0.89	0.90	0.85	0.95		0.90
Wakefield south	0.80	0.81	0.82	0.85	0.90	

The coefficient of variation describes the extent to which one site agrees with another or put another way the proportion of variation at one site (dependant) that can be explained by the variation at another (independent) site.

A value of "1" means that two sites completely agree with each other while a value of "0" means that two sites behave completely independently.

The values have been shaded with darker colouration indicating a stronger relationship than a lighter colouration to assist with visual interpretation of the data. Green shading has been used to highlight variation in the Brightwater and Wakefield communities.

In an air quality context, these tables can be used to identify whether parts of an airshed or even different airsheds behave in the same way and whether one or more monitoring sites could be representative of the entire airshed or even other airsheds in the region.

By examining the strength of the relationship between instruments and also the change in relationships between sites, it is possible to deduce information about the sources of particulate impacting a given location.

If, for example we were exploring whether open burning was the primary source of the particulate then it follows that we might expect to observe the following:

- Open burning typically commences during the day

- Particulate emissions tend to be higher during the day when compared with domestic home heating where emission are typically higher in the morning and evening.
- Open burning generally has a local effect. That means that if open burning was occurring on a frequent basis, then there would be a poor relationship (<0.5) between monitors in Brightwater and those in Wakefield.
- With open burning there is often a strong relationship between wind speed and direction and very high particulate concentration whereas emissions from domestic home heating tend to become more evident during very light winds and cool/cold weather.

Conversely if domestic home heating was the primary source of particulate then we might expect to observe the following:

- Unlike open burning, there is usually a moderate relationship between air temperature and 24-hour average particulate concentrations.
- There will be reasonably high levels of agreement (>0.7) between monitoring sites even some distance from one another provided the primary emission source consists of domestic home heating.
- Domestic fires typically exhibit more minute-to-minute variation in particulate concentration than open burning. This is often a function of distance to the source – so adding fuel to a domestic fire may result in a short-term increase in emissions which is characterised by short duration spikes in the one minute data recorded by the nearby monitor. Open burning tends to occur some distance from residential dwellings and so changes in particulate concentrations tend to occur more gradually under consistent meteorological conditions.

Table 2 confirms that that a moderate relationship exists between many of the sites and when consideration is given to previous observations suggests:

1. That the emission sources are linked. Given the geographic spread of the monitoring stations, this suggests that most of the variation at the monitoring sites probably relates to home heating rather than that of other sources.

2. There is a reasonable agreement both within Brightwater and Wakefield as well as between Brightwater and Wakefield suggesting that similar sources of $PM_{2.5}$ are contributing to air quality in each community.

3. A review of the hourly emission data on elevated pollution days confirms that emissions typically begin increasing above background in the evening (6pm) and typically peak between 11:00pm and 2:00am in the morning then decrease in the hours prior to sunrise. This emission profile is consistent with emissions from domestic home heating.

4. Tasman District Council analysis of the air quality data from the Richmond airshed has previously identified a double overnight peak resulting from the onshore/offshore sea breeze and transport of resulting emissions. A review of the data from the Brightwater and Wakefield investigation reveals that this “double peak” occurs very rarely during the 2022 winter and is more

commonly associated with an increase in wind speed which in turn increases dispersion rather than the change in wind direction observed in the Richmond airshed. Generally, under winter inversion conditions, the wind direction is typically SSW until the wind speed drops below 1 metre per second at which time the wind direction becomes more variable.

5. If we examine emissions within each community, we can see that there is a general gradient increasing the $PM_{2.5}$ from the south to the north of each community during periods of elevated $PM_{2.5}$ concentration. A review of the meteorological data during these events confirms light variable winds generally from the south/southwest which is consistent with katabatic cold flow drainage.

3.3 Effect of meteorology

Two meteorological instruments were deployed in each of the study areas. Ultrasonic meteorological sensors were selected to monitor wind speed and direction. This type of sensor is much more sensitive at lower wind speed than traditional cup and vane anemometers and recorded wind speed and direction at 1 second intervals during the study. This one second data was converted to 1 minute (vector) averaged wind speed and direction to enable comparison with the one-minute data collected by the $PM_{2.5}$ nephelometers.

Windrose plots for each of the meteorological monitoring stations are shown in Figures 16 and 17.

Figure 16: Brightwater north

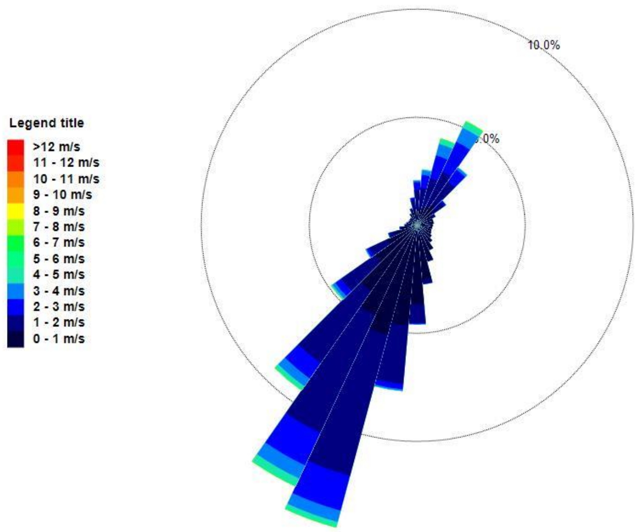
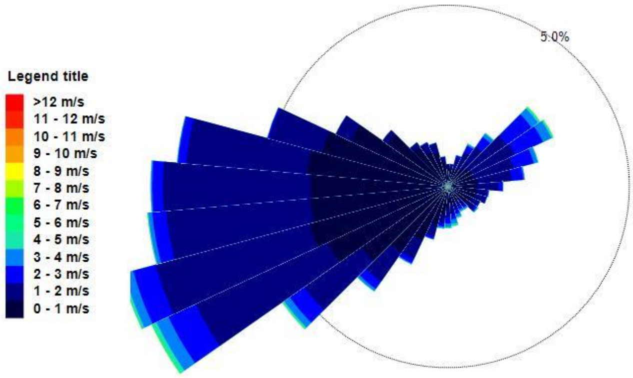


Figure 17: Wakefield south

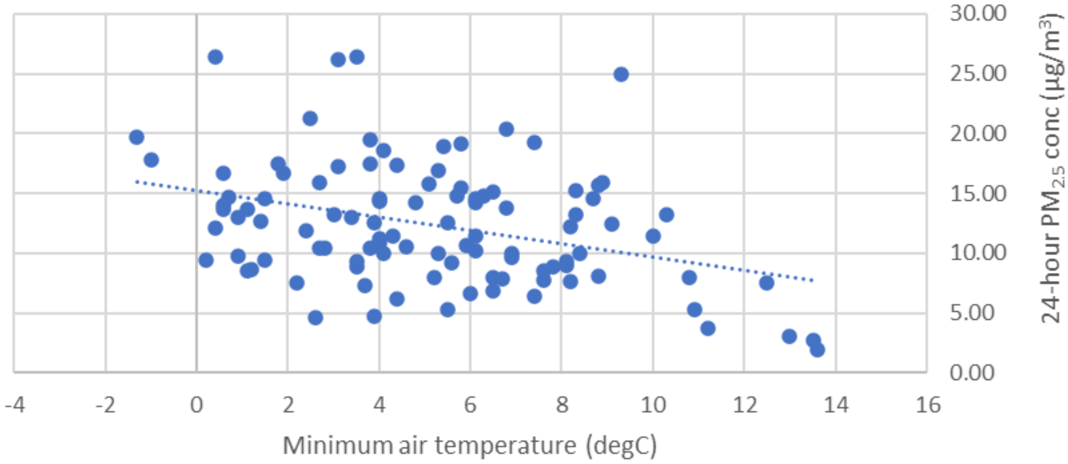


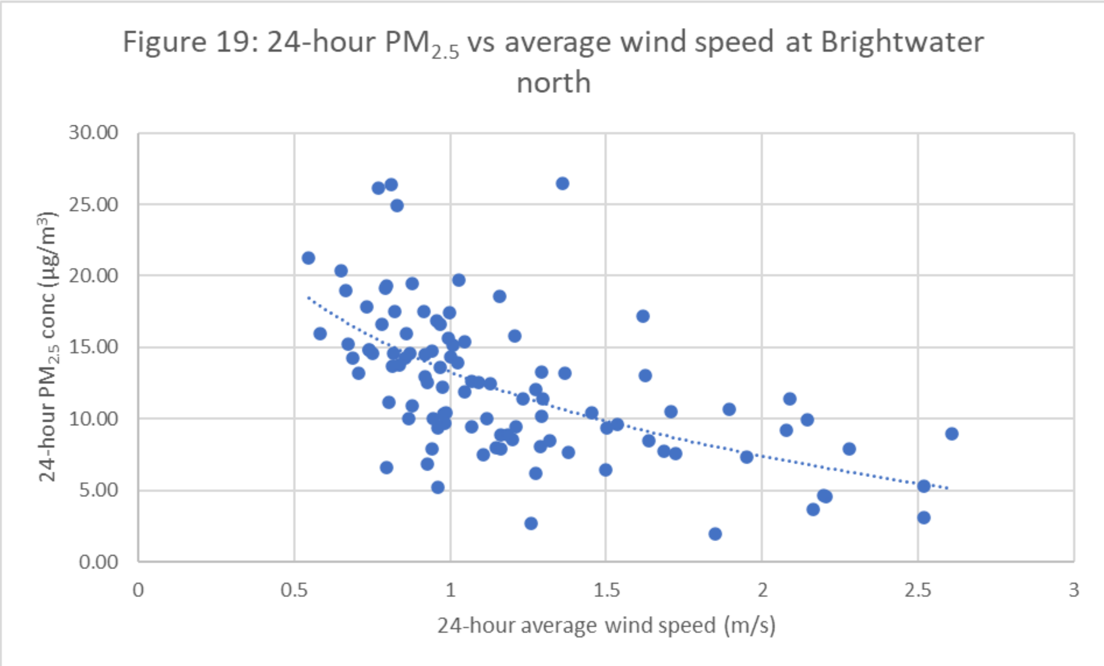
Figures 16 & 17: Windrose plots at Brightwater and Wakefield for the period from 25 May through to 7 September 2022.

The windrose plots confirm that both Brightwater and Wakefield were dominated by relatively low winds speeds during the study period. The variation in wind direction at different monitoring points in the study area suggests that the low wind speeds are strongly influenced by topography within the study area.

A comparison of average 24-hour $PM_{2.5}$ concentration with minimum air temperature and average wind speed at Brightwater north reveals a weak relationship as shown in **Figures 18** and **19** below.

Figure 18: 24-hour $PM_{2.5}$ vs minimum air temperature at Brightwater north





Figures 18 and 19: Plot of 24-hour average $PM_{2.5}$ concentration against minimum air temperature and average wind speed at Brightwater north.

Despite the weak relationship in the two figures above, the plots demonstrate that the 24-hour average $PM_{2.5}$ concentration complies with both the MfE proposed $PM_{2.5}$ standard and the WHO guideline when the minimum air temperature remains above 10 degrees Celsius or when the 24-hour average wind speed is greater than 1.6 metres per second.

The time series plot shown in **Figure 20** depicts the hourly PM2.5 concentration during a period of elevated $PM_{2.5}$ concentrations in both Brightwater and Wakefield. On the evening of Thursday 30 June 2022 when the highest $PM_{2.5}$ concentrations were recorded at Brightwater north and Wakefield north, the weather was characterised by low wind speeds and low air temperatures.

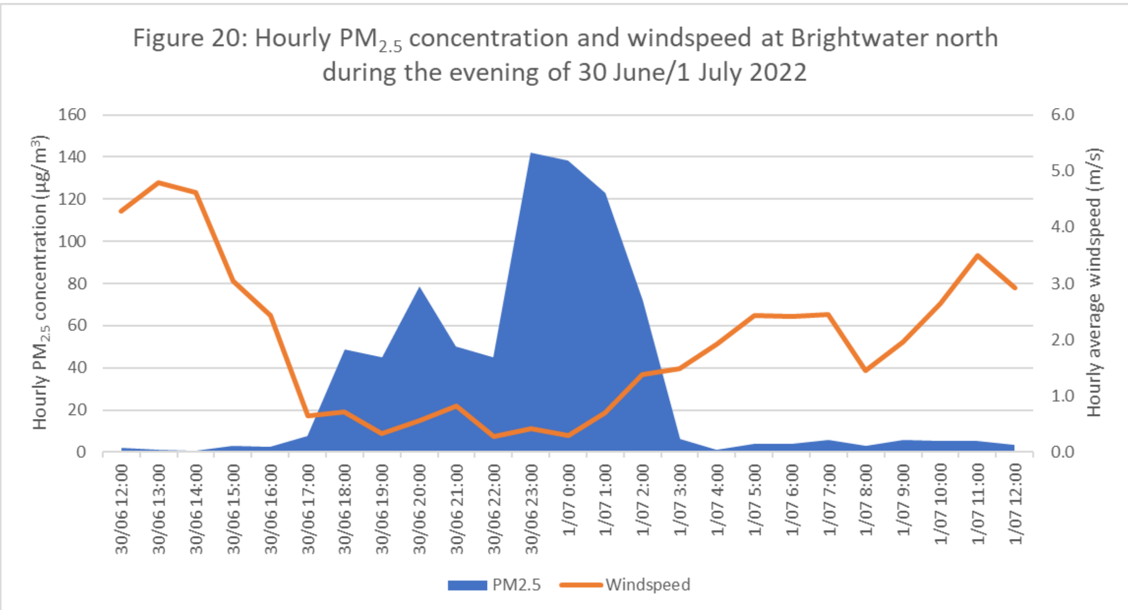


Figure 20: Plot of hourly $PM_{2.5}$ alongside the hourly average wind speed on 30 June/1 July 2022.

Peak $PM_{2.5}$ concentrations from domestic fires are typically observed in the early evening when families return home and light their fires. Emissions usually increase following this period until around midnight when most families retire and the emissions from domestic home fires slowly decrease.

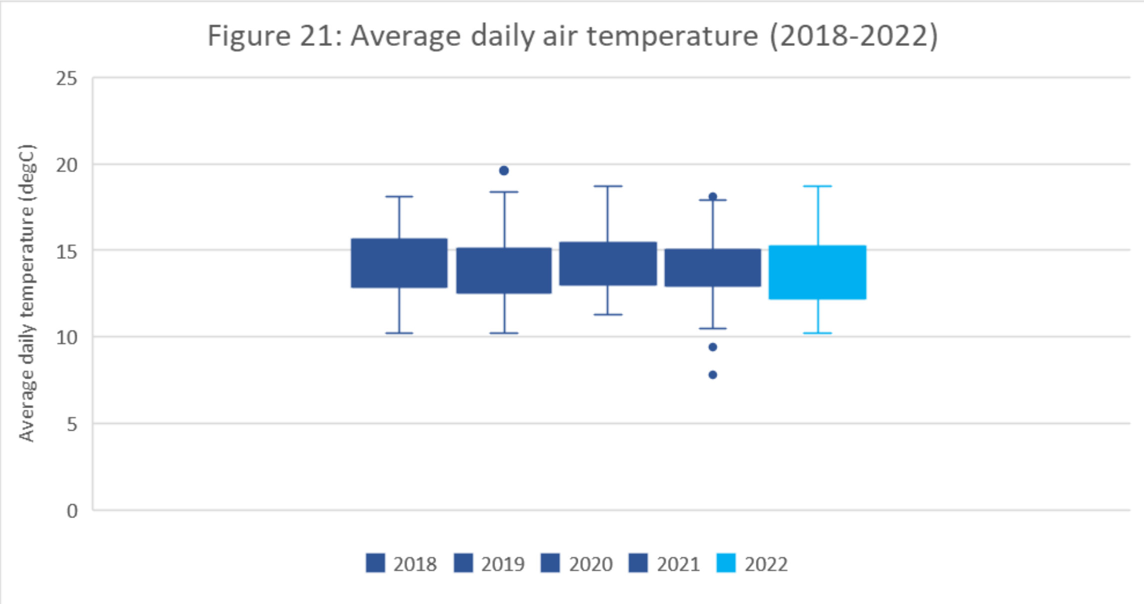


Figure 21: Comparison of the average daily air temperature during the study period (26 May – 7 September) with the same period in previous years (Richmond electronic weather station)

Figure 21 reveals that the average air temperature was similar to that of previous years

Despite some very heavy rainfall events during 2022, the frequency of wet days is broadly similar to that of the previous 4 years (see Appendix A for data analysis). Furthermore, given that daily air temperatures were similar to previous years, it is likely that the data collected during the 2022 monitoring investigation is broadly representative of typical emissions in the Brightwater and Wakefield communities.

4.0 CONCLUSION

Mote Limited deployed a network of 6 continuous nephelometers and 2 continuous meteorological instruments in Brightwater and Wakefield during the winter of 2022.

The data capture rate for the field deployed instruments between 26 May to 7 September 2021 was 96%, despite a significant storm event which passed through the area on 18 August 2022. Pre and post deployment collocation data confirmed all instruments were comparable (+/- 2 µg/m^3). The instruments also displayed reasonable agreement with TDC's National Environmental Standard compliant equipment operated in Brightwater.

Maximum 24-hour $PM_{2.5}$ concentrations of between 10 and 30 µg/m^3 were measured at each of the 6 instruments located in the Brightwater and Wakefield communities during the study period. The proposed 2020 Ministry for the Environment $PM_{2.5}$ standard of 25 µg/m^3 allows for three exceedances per year. On this basis while both the Brightwater North and Wakefield north sites both exceeded the limit of 25 µg/m^3 only the Wakefield North site breached the proposed standard as there were four days when the average 24-hour $PM_{2.5}$ concentration exceeded the 25 µg/m^3 limit. However, it should be noted that one of these days the concentration was 25.4 µg/m^3 which is only marginally higher than the proposed standard.

In comparison to the 2021 World Health Organisation (WHO) 24-hour global guideline for $PM_{2.5}$ of 15 µg/m^3 which also allows for 3-4 exceedances per year, four of the 6 monitoring sites would breach the guideline (using a threshold of 3 exceedances) as follows: Brightwater north (24 days), Brightwater central (4 days), Wakefield north (42 days) and Wakefield central (24 days).
Two monitoring locations, one in Brightwater south and one in Wakefield south complied with the WHO 2021 guideline during this 2022 winter monitoring investigation.

Wind speeds during the study remained relatively low and were typically south/south-westerly, although nearby topographical features appeared to have had some effect on both wind direction and wind speed. Most sites displayed clear evidence of cold flow drainage under light winds which appeared to be the dominant dispersive mechanism at night. It is likely that this dispersive mechanism resulted in the southern sections of both Brightwater and Wakefield to exhibit better air quality than the monitoring stations to the north.

5.0 REFERENCES

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APPENDIX A: Review of rainfall on $PM_{2.5}$ concentrations

A review of rainfall data was undertaken to investigate any association with the $PM_{2.5}$ concentrations recorded during this study. The association between rain and PM tends to be relatively weak compared to other meteorological variables.

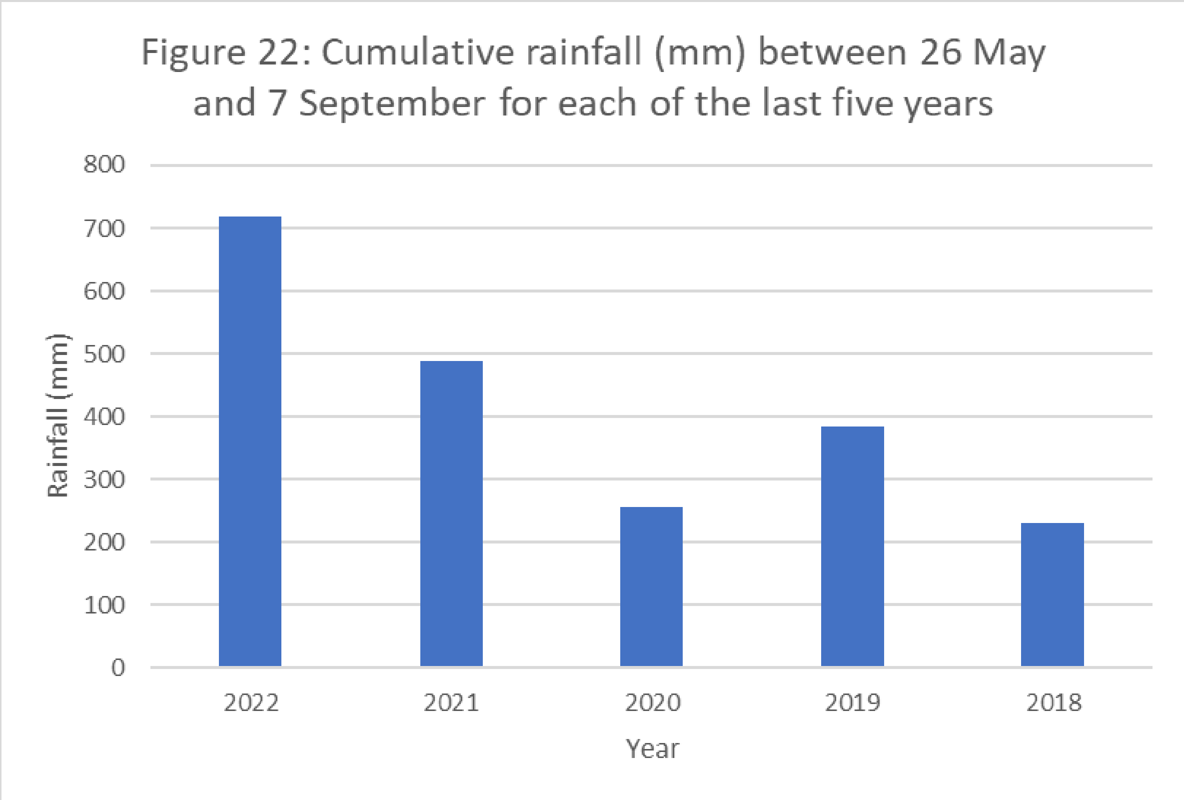

Figure 22: Comparison of the cumulative rainfall during the study period (26 May – 7 September) with the same period in previous years (Richmond electronic weather station)

Figure 22 reveals that the total rainfall during the 2022 study period was significantly higher than that of previous years. To investigate this further, a comparative plot of the average 24-hour cumulative rainfall against the average 24-hour $PM_{2.5}$ concentration which is shown over the page in **Figure 23**.

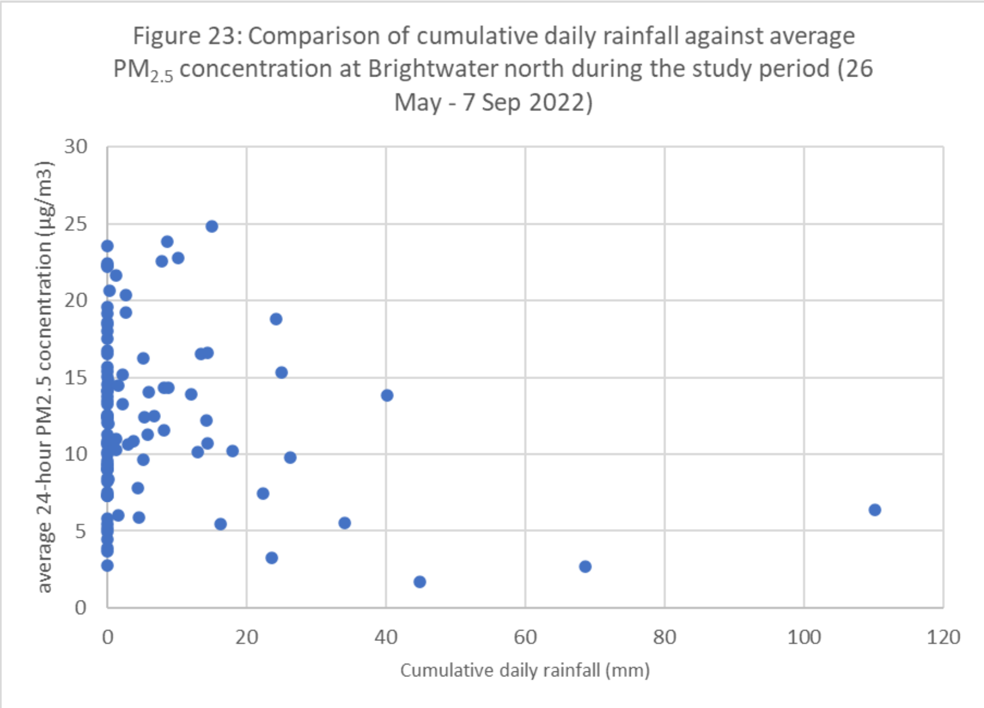

Figure 23: Comparison of the average 24-hour $PM_{2.5}$ concentration at Brightwater north against cumulative rainfall during the study period (26 May – 7 September). Note daily rainfall quantities are calculated at 9:00am each morning. The 24-hour average $PM_{2.5}$ concentration has also been recalculated for a 9:01-09:00 am period for consistency. (Richmond electronic weather station)

Figure 23 reveals that there is a weak inverse relationship between cumulative daily rainfall and peak $PM_{2.5}$ concentration. That is the more rainfall that occurs in any 24-hour period, the lower the maximum concentration 24-hour average of $PM_{2.5}$. The likely reason for this is that the weather patterns which bring heavier rainfall during this period are commonly associated with elevated wind speeds. These winds increase the dispersion of air pollutants thereby reducing the potential for ground level accumulation of $PM_{2.5}$.

On this basis, a better assessment of the effect of rainfall on average 24-hour $PM_{2.5}$ concentration suppression would be the number of days during the study period when the total average daily rainfall volume exceeded 30mm.

Figure 24 over the page displays the number of days between 26 May and 7 September for each of the past 5 years where the daily volume of rainfall reached or exceeded 30mm.

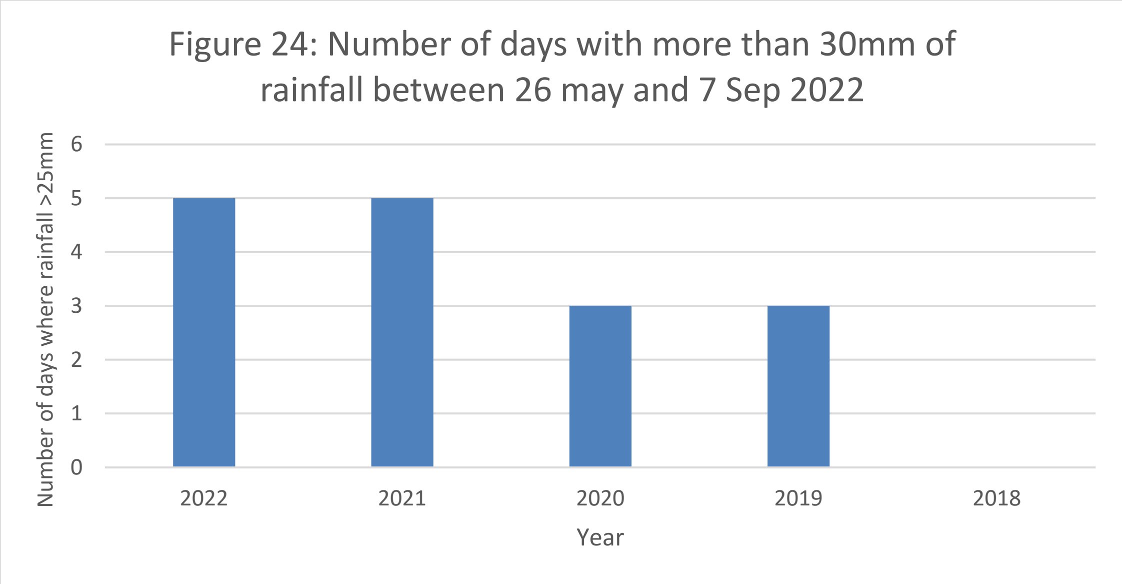

Figure 24: Comparison of the number of days during the study period (26 May – 7 September) which received more than 30mm of rainfall. (Richmond electronic weather station)

Figure 24 reveals that the number of days receiving more than 30 mm of rainfall in any 24-hour period was the same as 2021 and only slightly higher than in 2020 and 2019. 2018 appears to have had no days which received more than 30mm of rainfall.