MOTE
MEASUREMENT | NETWORKS

Westport $PM_{2.5}$ monitoring network

June-September 2022

Draft report for:

West Coast Regional Council

25 November 2022

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Acknowledgements

Mote Limited would like to thank WCRC staff Horrox for their assistance with identifying potential monitoring locations and assistance with resolving operational challenges during the operation of the air quality monitoring network.

Mote limited would also like to thank the residents and businesses in Westport 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	25 Nov 2021	**Paul Baynham**	**Brett Wells**	V1 Draft report reviewed
2	28 Nov 2021	**Paul Baynham**	**Paul Baynham**	V1.2 Revised draft
3	07 Dec 2022	**Paul Baynham**	**WCRC**	V1.3 Spelling and typographical corrections

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1.0 EXECUTIVE SUMMARY

15 air quality monitors were deployed in Westport between 31 May and 8 September 2022 as part of a high resolution air quality monitoring network. The purpose of the network was to measure the concentration of particulate matter across Westport and determine what the variation in concentration was across the town

The bulk of the instruments were operational as of 31 May and the study concluded on 8 September. There were several strong storm events during the monitoring period which included gusts up to 120 km/hr. These events resulted in damage to some instrumentation which needed to be repaired and reinstated. Despite these setbacks, the overall data capture rate for the network was acceptable at 95.8%.

The results of the monitoring identified a peak 24 hour $PM_{2.5}$ concentration of 55 µg/m^3 and found that 11 of the 15 monitors recorded peak $PM_{2.5}$ concentrations at or above the proposed draft 24 hour standard of 25 µg/m^3.

The study found that while there was day to day variation in particulate concentrations, overall concentrations of particulate matter were consistent throughout central Westport. Higher concentrations were measured near the centre of town while concentrations decreased towards the town boundary.

2.0 PROJECT OUTLINE

Mote were contacted by WCRC in January 2022 with the intention to install and operate a 15 node network in Westport for three months during the 2022 winter.

The focus of the investigation was to deploy a series of high resolution, real-time air quality monitors throughout the Westport township to determine the spatial variation in particulate concentrations across Westport. The network was intended to be deployed for a three month period intended to coincide with cold winter weather when emissions from home heating were expected to peak.

2.1 Project location

Westport is a small town situated on the West Coast of the South Island and is home to a population of 4290 residents.

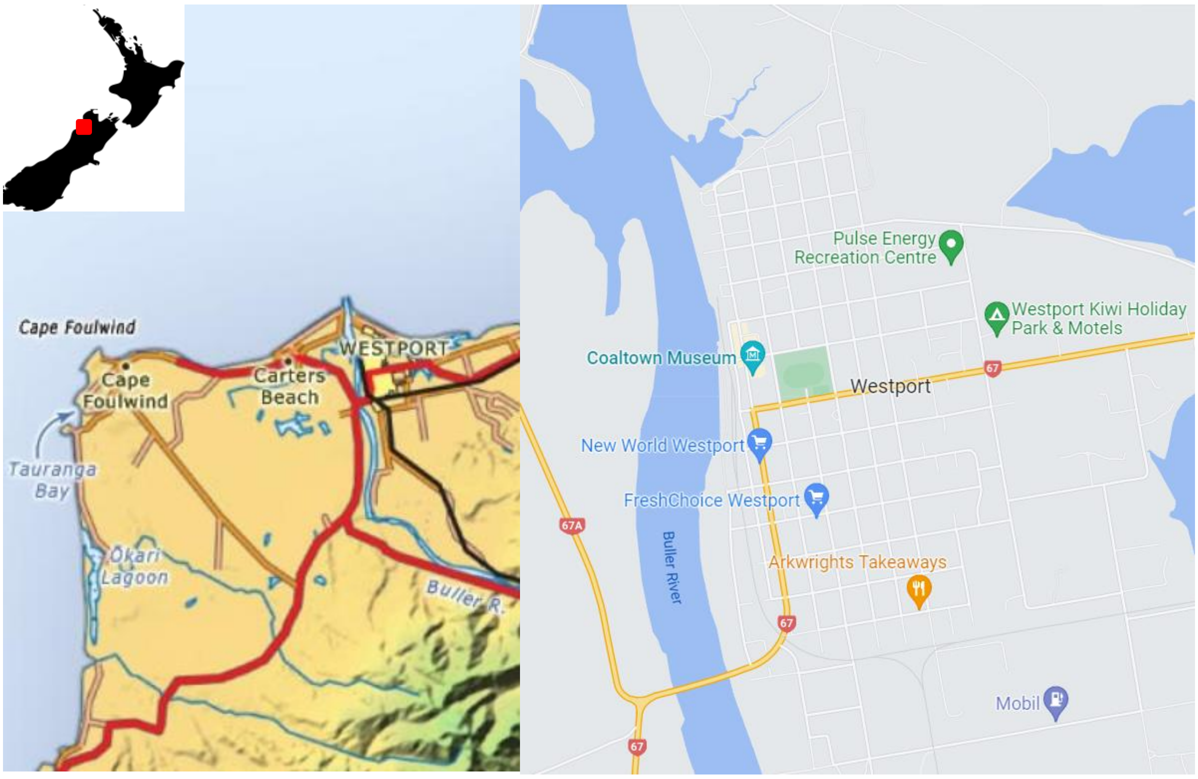


Figure 1: Location map of Westport, West Coast, New Zealand (https://teara.govt.nz/en/map/20961/Westport)

2.2 Instrument Selection

The instrumentation consists of a solar powered monitor referred to as a minimote.

This unit consists of modified dual SDS011 side-scattering nephelometer units with heated inlets. Flow rates for each device were set following installation and were nominally 0.6 litres per minute (+/- 0.05 litres per minute). Flow rates were also checked following the deployment and confirmed to be within 5% of the initial flow rate for each instrument.

Both nephelometers produce 1 second data that are averaged using a programmable modem to produce one minute average data. The minimotes use GPS to ensure the accuracy of timestamped data is within 0.1 seconds.

The collated data is transmitted via a privately provisioned cellular network to a secure web-based server every 15 minutes. The minimote is powered using a monocrystalline solar panel which uses a small MPPT solar charge controller specifically designed to operate at the voltages required for the LiPo battery storage.

Both sets of instruments store data locally in the event that cellular transmission is disrupted. If cellular connectivity is restored, then data transmission will recommence with older data transmitted first.

The instruments were placed in a light smoke chamber and then co-located for a seven day period prior to installation to verify that the instrumental concentrations were comparable (within +/-2% over a range of 1-500 µg/m^3. At the conclusion of the study, this process was repeated and all instruments were found to comply with the +/-2% average concentration criteria.

Figure 3: Photograph of a minimote mounted beneath a solar panel on a pole in Westport.

2.3 Site Selection

The West Coast Regional Council (WCRC) provided a list of locations and attempts were made to position instruments as close to these sites as possible. It should be noted that to minimise health and safety risks, solar powered devices were mounted between 2.5 and 3 metres above ground level.

Locations where powered instruments were installed involved contacting the landowner in advance and obtaining their prior agreement. All landowners/occupiers 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.

There were a number of disruptions to the instrumental monitoring programme. The first of these occurred on 1 June when a local resident on Bentham Street objected to the monitor being installed on the Street near his home. Following some consultation, the device was removed and a new, alternative location was found following discussions with a nearby resident. This process took time to complete and approximately 21 days of data was lost at this location. Another monitor on Fonblanque Street had the solar panel removed which resulted in the loss of approximately 8 days of data from that site until a replacement panel was installed.

The Westport community also experienced two significant storm events during the monitoring programme. The first of these took place on 12 June and included gusts of up to 120 kilometres per hour. Four monitors were damaged during this event and another four were damaged approximately one month later when a second storm event passed through the region on 12/13 July. In most cases, the units were either repaired or replaced within several days of these storm events occurring, however a total of 10 days of data was lost during each event due to instrumental damage.

A location map depicting the location of the instruments and their designation code is shown below in Figure 4 below. The location of the powered instruments is approximate. Units MM13 and MM14 were repositioned higher on 17 July to minimise the risk of water ingress into the instrument power supply.

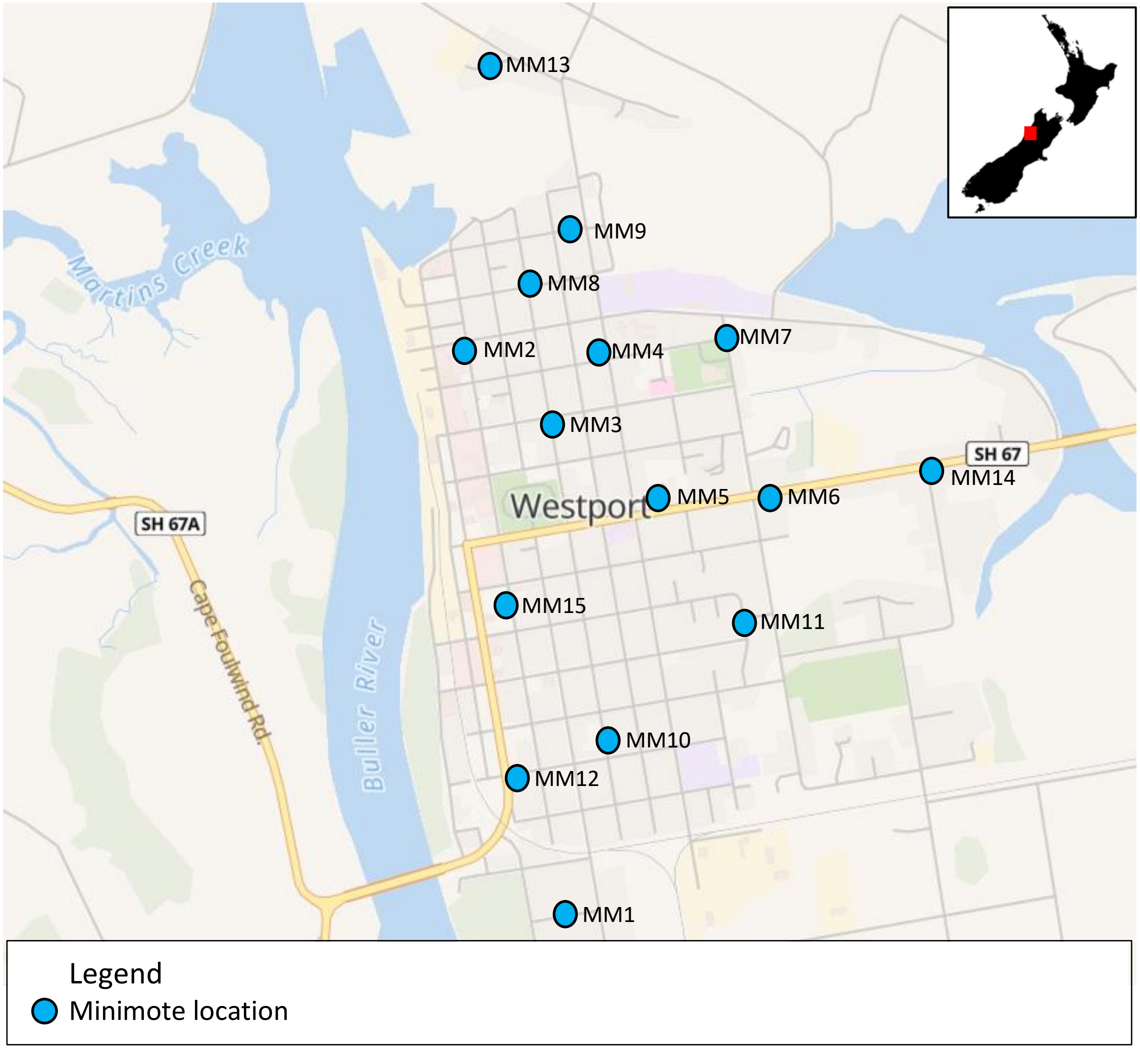


Figure 4: Device location map for Westport, June – September 2022

3.0 RESULTS

3.1 Data capture rate

In mid May 2022, the first three units were installed to test cellular connectivity in preparation for the remaining deployment. On 30 May 2022 all remaining units were deployed bringing the total number of operating units to 15.

These units operating from 31 May through until decommissioned on 9 September representing approximately 101 days of operation.

Unfortunately, two strong wind events on 12 June and 12/13 July respectively damaged a number of the instruments. On both occasions, damaged instruments were repaired or replaced and the network was operational again usually within 2-3 days of the event occurring.

As mentioned previously, one instrument was relocated following discussions with a local resident. The relocation site was approximately 70 metres from the original location.

Two additional units had their solar panels stolen and each lost several days of data before repairs could be made.

With the exception of these events, the remaining devices functioned well and the total data capture rate for the period from 31 May through to 8 September was 95%.

Table 1: Instrument deployment details and data capture rate

Instrument	Type	Start date	End date	No. days	Data capture rate (%)	Comment
MM1	Minimote solar	31 May	9 Sep	101	100	
MM2	Minimote solar	31 May	9 Sep	96	95	Storm damage
MM3	Minimote solar	31 May	9 Sep	101	100	
MM4	Minimote solar	31 May	9 Sep	98	97	
MM5	Minimote solar	31 May	9 Sep	100	99	
MM6	Minimote solar	31 May	9 Sep	93	92	Storm damage
MM7	Minimote solar	31 May	9 Sep	100	99	
MM8	Minimote solar	31 May	9 Sep	92	91	Storm damage
MM9	Minimote solar	31 May	9 Sep	84	83	Storm damage
MM10	Minimote solar	31 May	9 Sep	76	75	Relocation
MM11	Minimote solar	31 May	9 Sep	99	98	Solar panel theft
MM12	Minimote solar	31 May	9 Sep	98	97	
MM13	Minimote solar	31 May	9 Sep	98	97	
MM14	Minimote solar	31 May	9 Sep	98	97	
MM15	Minimote solar	31 May	9 Sep	101	100	

A spreadsheet containing the hourly and 24 hour average $PM_{2.5}$ data from Westport is available. The spreadsheet is named **Westport_Data_V1.2.xlsx.**

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.

Figure 5. MM1 : 24-hour $PM_{2.5}$ concentration

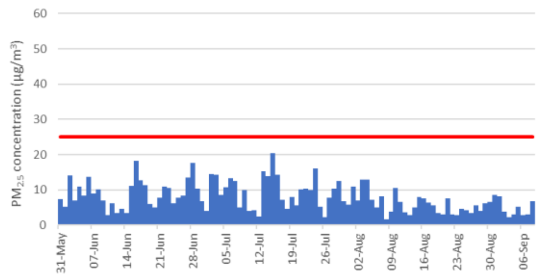


Figure 6. MM2 : 24-hr $PM_{2.5}$ concentration

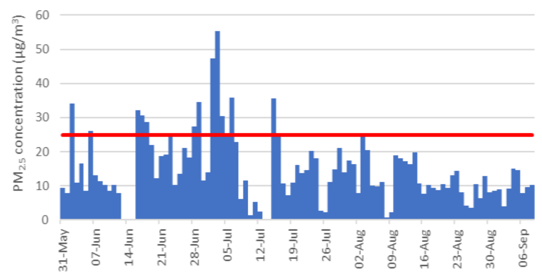


Figure 7. MM3 : 24-hr $PM_{2.5}$ concentration

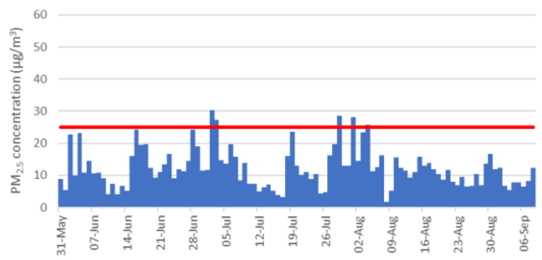


Figure 8. MM4 : 24-hr $PM_{2.5}$ concentration

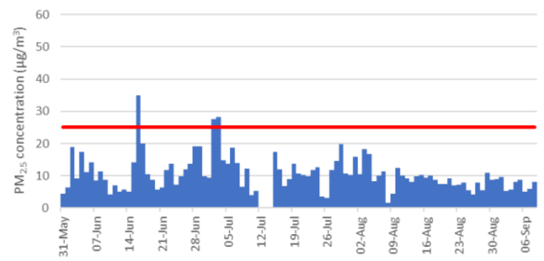


Figure 9. MM5 : 24-hr $PM_{2.5}$ concentration

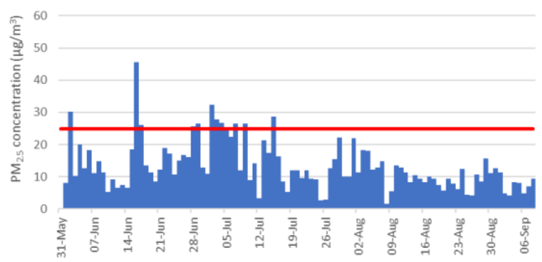


Figure 10. MM6 : 24-hr $PM_{2.5}$ concentration

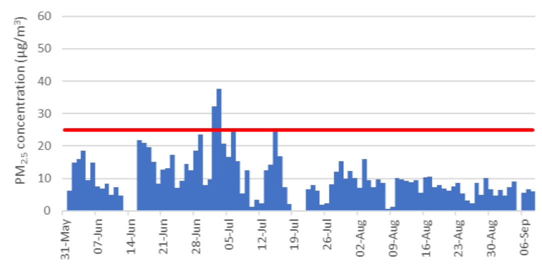


Figure 11. MM7 : 24-hr $PM_{2.5}$ concentration

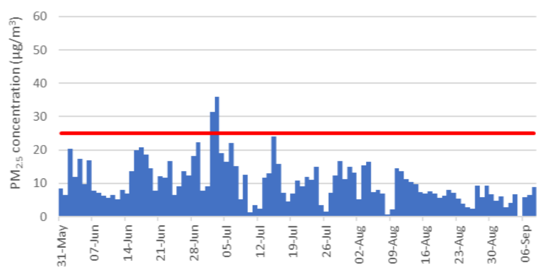


Figure 12. MM8 : 24-hr $PM_{2.5}$ concentration

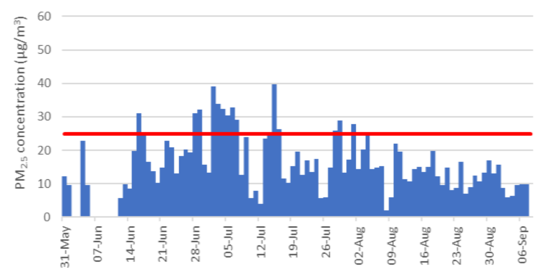


Figure 13. MM9 : 24-hr $PM_{2.5}$ concentration

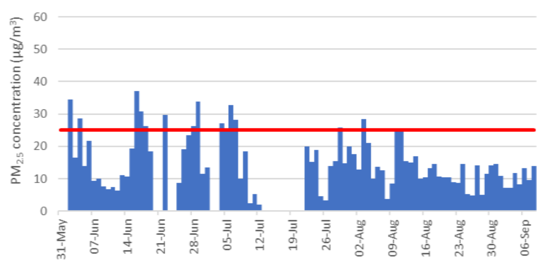
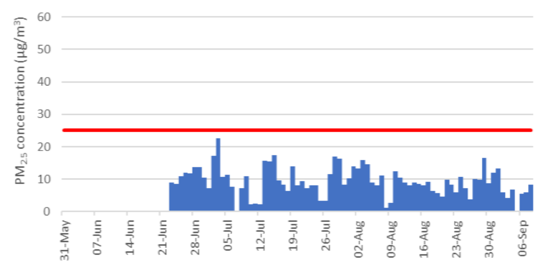
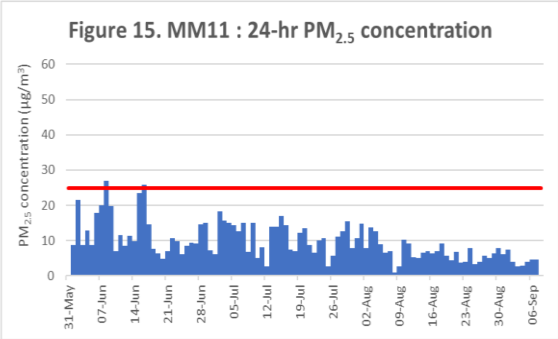
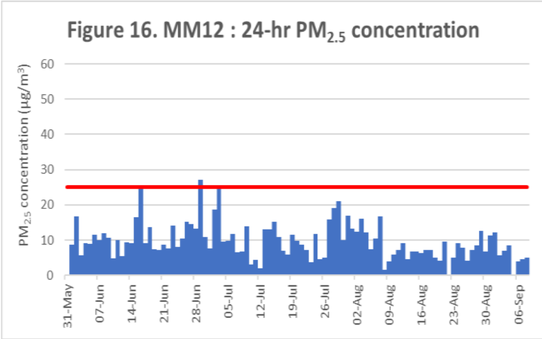
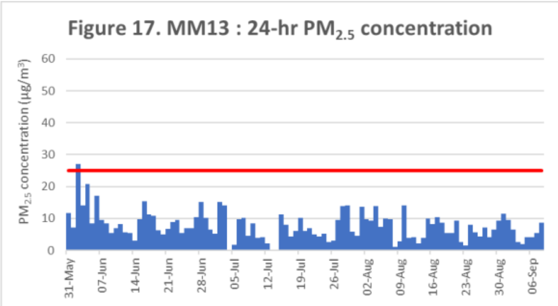


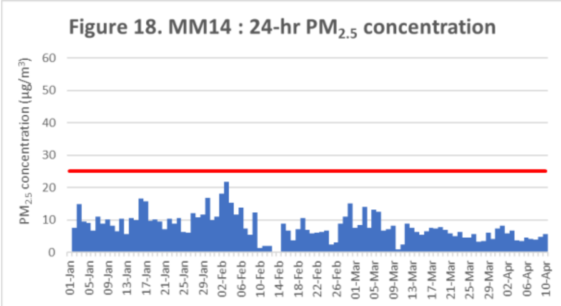
Figure 14. MM10 : 24-hr $PM_{2.5}$ concentration

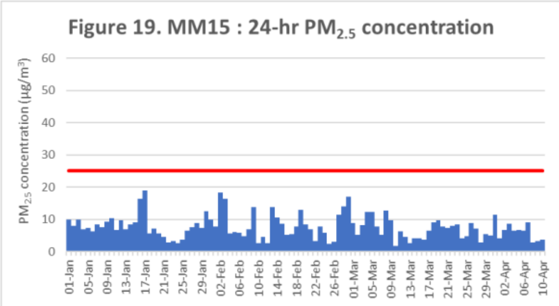












Figures 5 through 19. Plots of 24 hour average $PM_{2.5}$ concentration for each instrument. Note periods where less than 75% of the valid data was present have been left blank.

Interestingly, the 8 sites which recorded the highest average daily $PM_{2.5}$ concentration all occurred at sites either on or north of Brougham Street (SH67). Only two of the 5 sites sites south of Brougham Street (MM11 and MM12) exceeded the proposed 24 hour average for $PM_{2.5}$ of 25 µg/m^3 and the peak 24-hour concentration at these two sites (27 and 27.2 µg/m^3 only just breached the proposed guideline. In general, the residential area to the south of Brougham Road largely complied with the proposed 24-hour $PM_{2.5}$ guideline during the 2022 winter monitoring campaign.

While it is possible that this may be due to cold flow katabatic air coming down the Buller River which could transport emissions from the south of Westport to the north, this does not appear to be supported by the monitoring data. For example, if we examine Figure 18 which displays emissions from all sites on the 3rd and 4th of July – a period of elevated $PM_{2.5}$ concentrations across Westport. We can see that the elevated concentrations generally occurred at the same time at all sites with elevated concentrations between 5pm and 1am the following morning. If katabatic transport was the dominant dispersion mechanism, it is likely that "downwind" sites would display a lag or tail of elevated concentrations while "upwind" sites would display improved air quality during the same period.

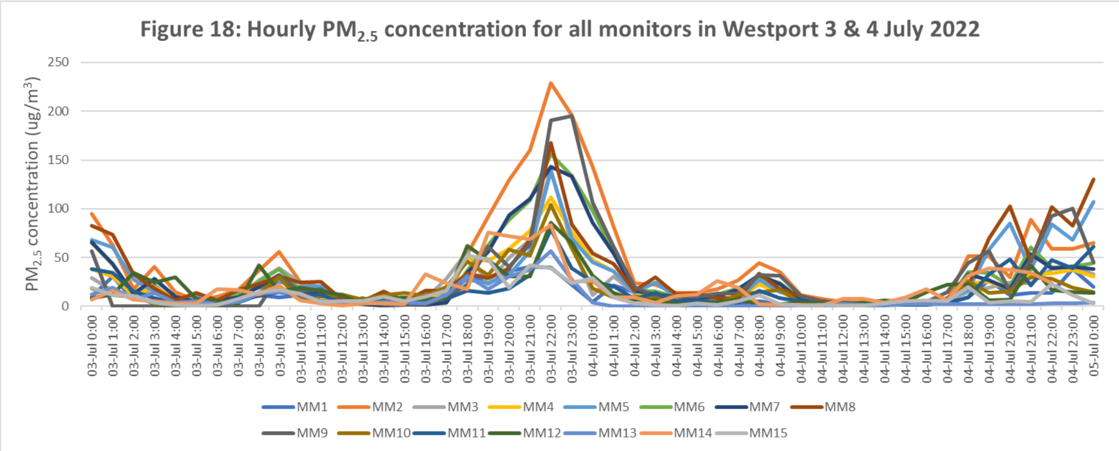


Figure 18. Plot of hourly concentration of all sites in Westport between midnight 3 July to midnight 5 July 2022.

Figure 18 confirms that the emission profile is consistent with a community that utilises wood and coal fuel for domestic home heating during the winter. Figure 18 also suggests that the higher $PM_{2.5}$ emissions observed to the north of Brougham Street simply reflect the fact that more fuel was burnt in this part of Westport compared with parts of Westport to the South.

Table 2 below displays the maximum 24 hour $PM_{2.5}$ concentration measured at each instrument during the study. Most of the instruments recorded similar elevated $PM_{2.5}$ concentrations during one of three dates during the study period being 8 June, 15/16 June or 02/03 July.

Table 2: Peak and average $PM_{2.5}$ concentration measured at each site

Instrument	Peak $PM_{2.5}$ concentration	Date measured	Average $PM_{2.5}$ concentration[1]
MM1	20.3	15-Jul	7.8
MM2	55.3	03-Jul	15.0
MM3	30.4	02-Jul	12.2
MM4	35.0	16-Jun	10.6
MM5	45.6	16-Jun	13.3
MM6	37.7	03-Jul	10.4
MM7	35.9	03-Jul	10.3
MM8	39.7	15-Jul	16.4
MM9	37.0	16-Jun	16.2
MM10	22.5	03-Jul	9.5
MM11	27.0	08-Jun	9.7
MM12	27.2	29-Jun	9.8
MM13	27.1	02-Jun	7.9
MM14	21.8	03-Jul	8.1
MM15	19.0	16-Jun	7.5

Figure 19 below displays the combined 24-hour average of all sites on each date during the study period.

[1] Covers the period from 31 May through to 8 September 2022

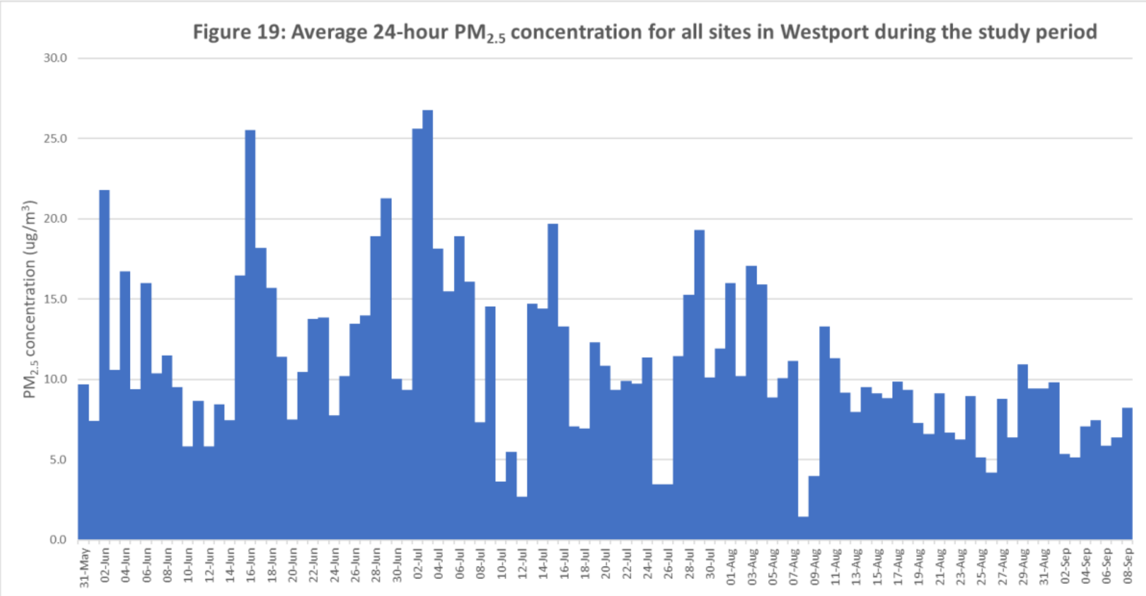


Figure 19: Combined 24-hour average of all sites for each day during the study period.

While the combined average of all sites for the entire study period was 10.9 µg/m^3, Figure 19 confirms that there were three days (16 June and 02/03 July) where the combined average air quality for Westport exceeded the proposed 24 hour guideline of 25 µg/m^3.

In 2021, the World Health Organisation published a revised set of global guidelines[2]. This revised set of global guidelines recommends a 24-hour $PM_{2.5}$ guideline value of 15 µg/m^3 as a 99th percentile of the annual 24-hour average concentrations – effectively meaning that 3 or 4 exceedances a year would still enable a community to meet the guideline. Based on the "average" data for Westport in Figure 19, approximately 21 days exceeded the 24 hour average guideline of 15 µg/m^3 suggesting that Westport does not currently meet the WHO $PM_{2.5}$ 24-hour guideline.

Table 3 below displays the co-efficient of variation between each of the sites for the period between 31 May through to 8 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 15 sites in Westport

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1		0.87	0.84	0.93	0.93	0.86	0.89	0.94	0.91	0.89	0.89	0.87	0.87	0.87	0.79
2	0.87		0.82	0.92	0.89	0.96	0.98	0.91	0.95	0.82	0.81	0.83	0.76	0.90	0.72
3	0.84	0.82		0.93	0.86	0.83	0.85	0.87	0.91	0.88	0.81	0.87	0.88	0.92	0.82
4	0.93	0.92	0.93		0.96	0.92	0.93	0.94	0.94	0.94	0.88	0.92	0.86	0.93	0.86
5	0.93	0.89	0.86	0.96		0.90	0.91	0.95	0.92	0.91	0.89	0.88	0.85	0.90	0.81
6	0.86	0.96	0.83	0.92	0.90		0.97	0.92	0.95	0.84	0.81	0.85	0.78	0.91	0.76
7	0.89	0.98	0.85	0.93	0.91	0.97		0.93	0.97	0.86	0.82	0.86	0.80	0.91	0.74
8	0.94	0.91	0.87	0.94	0.95	0.92	0.93		0.95	0.91	0.94	0.88	0.88	0.92	0.80
9	0.91	0.95	0.91	0.94	0.92	0.95	0.97	0.95		0.87	0.82	0.83	0.83	0.90	0.74
10	0.89	0.82	0.88	0.94	0.91	0.84	0.86	0.91	0.87		0.92	0.93	0.91	0.92	0.90
11	0.89	0.81	0.81	0.88	0.89	0.81	0.82	0.94	0.82	0.92		0.86	0.83	0.89	0.83
12	0.87	0.83	0.87	0.92	0.88	0.85	0.86	0.88	0.83	0.93	0.86		0.82	0.93	0.90
13	0.87	0.76	0.88	0.86	0.85	0.78	0.80	0.88	0.83	0.91	0.83	0.82		0.86	0.80
14	0.87	0.90	0.92	0.93	0.90	0.91	0.91	0.92	0.90	0.92	0.89	0.93	0.86		0.88
15	0.79	0.72	0.82	0.86	0.81	0.76	0.74	0.80	0.74	0.90	0.83	0.90	0.80	0.88	

[2] https://apps.who.int/iris/bitstream/handle/10665/345329/9789240034228-eng.pdf?sequence=1&isAllowed=y

Table 3 confirms the earlier observation that many of the sites are strongly correlated – particularly in the northern part of Westport suggesting that meteorological conditions are reasonably homogenous during inversion conditions.

The following interpolation plots (**Figures 21-24**) have been included as indicative plots which provide a visual aid to distinguish $PM_{2.5}$ concentrations between sampling locations. There is insufficient data to definitely demonstrate a linear reduction in concentration from one node to the next and the interpolation used in these images does not account for convective turbulence of objects and structures or topography.

The assumption of linear reduction is unlikely to hold over short timeframes of seconds to minutes due to the variable nature of emissions from nearby sources and the limited dispersion under specific meteorological conditions. As the sample period increases (hours to days), the nature of dispersion begins to approximate a more probabilistic nature and while linear reductions between sample nodes cannot be assumed, it is not unreasonable to expect that the average gradation will follow patterns similar to the interpolation shown in the images below.

Figure 20 displays the maximum 24 hour $PM_{2.5}$ concentration recorded at each site during the study period. As such the image is a composite of the maximum concentration observed throughout the study rather than that of a single day. These peak concentrations have been mapped across Westport to produce a contour map depicting the variation of peak $PM_{2.5}$ concentration across Westport.

Figure 21 displays the peak concentrations that occurred on 3 July 2022 – the day the highest average daily $PM_{2.5}$ concentration was measured in Westport. The image confirms that the section of Westport north of Brougham Street exhibits higher $PM_{2.5}$ concentrations that areas to the South.

The last contour plot – **Figure 22** is the average $PM_{2.5}$ concentration measured at each site for the period between 31 May – 8 September 2022. This useful plot demonstrates that although there may be differences on individual days, overall concentrations are broadly consistent throughout the central Westport area.

It should be noted that the apparent truncation of the contours (particularly evident on the left hand side of the map) is a result of the interpolation and reflects the fact that one of the monitors (MM2) which recorded higher concentrations was situated near the boundary of the interpolation polygon. In future, placing a monitor to the west of this site would resolve this issue.

Figure 20: maximum 24 hour $PM_{2.5}$ concentration measured at each site during the study period (21 May to 8 September 2022).

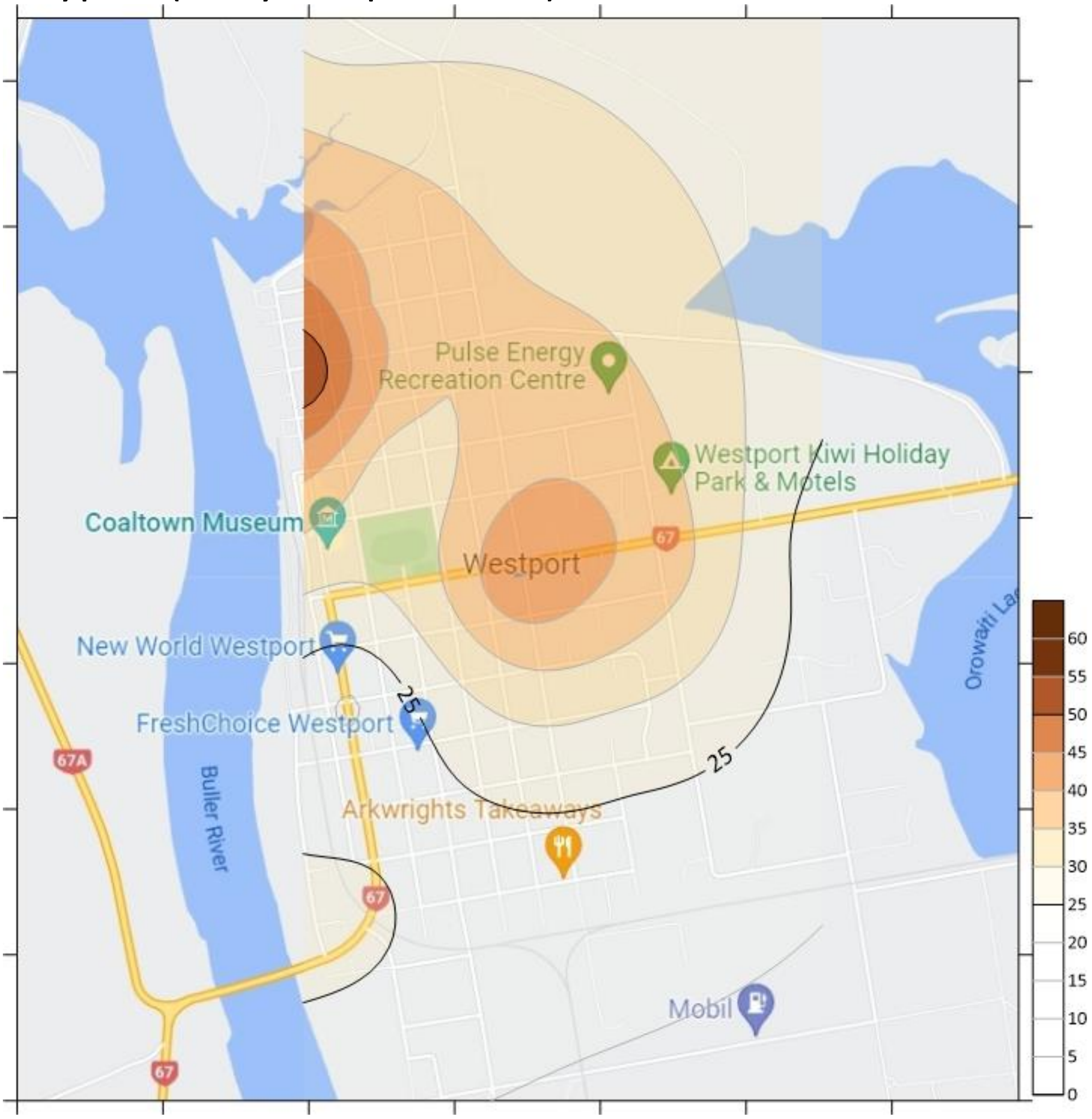


Figure 21: peak 24 hour average $PM_{2.5}$ concentrations measured at each site on 3 July 2022.

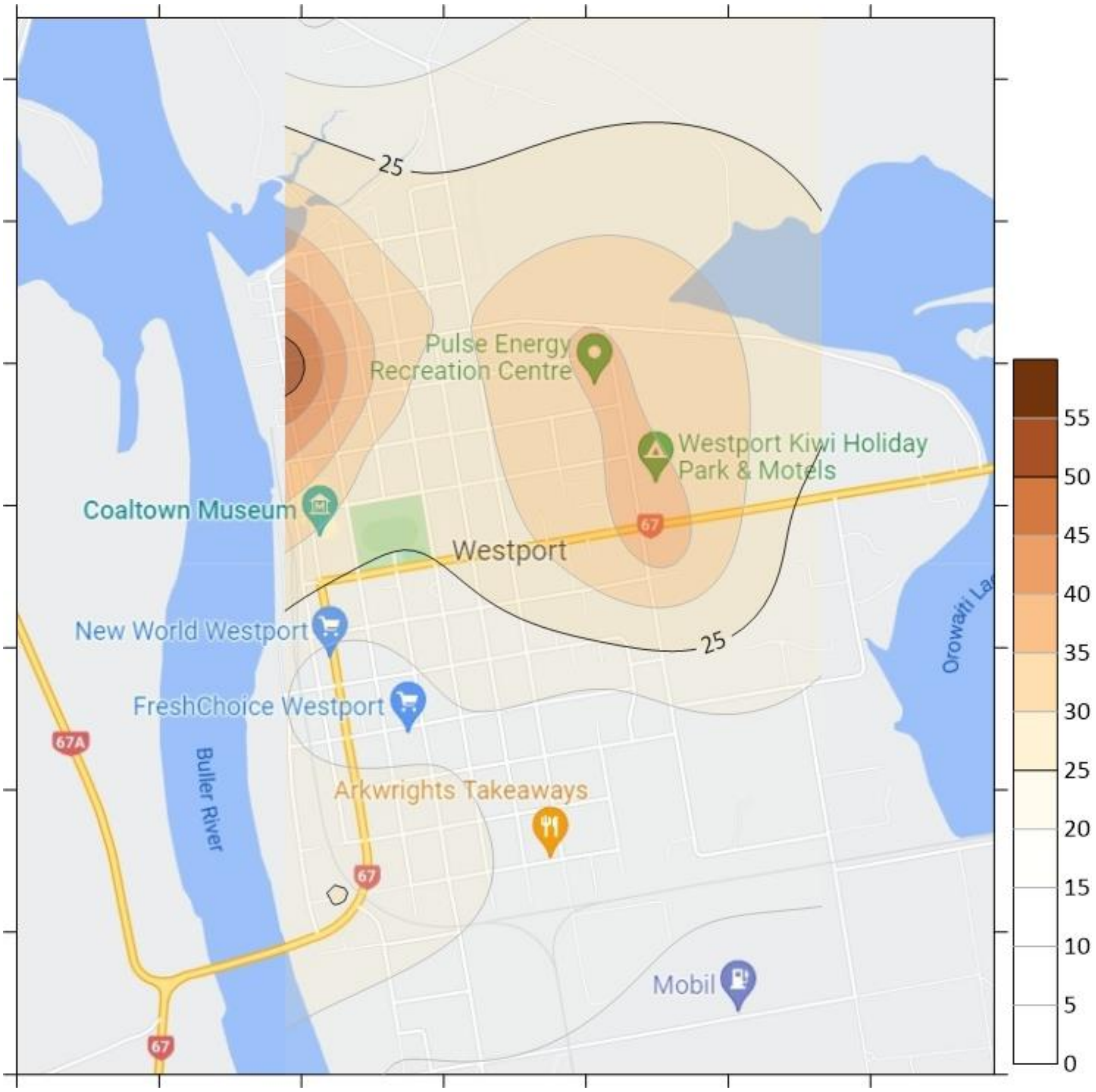
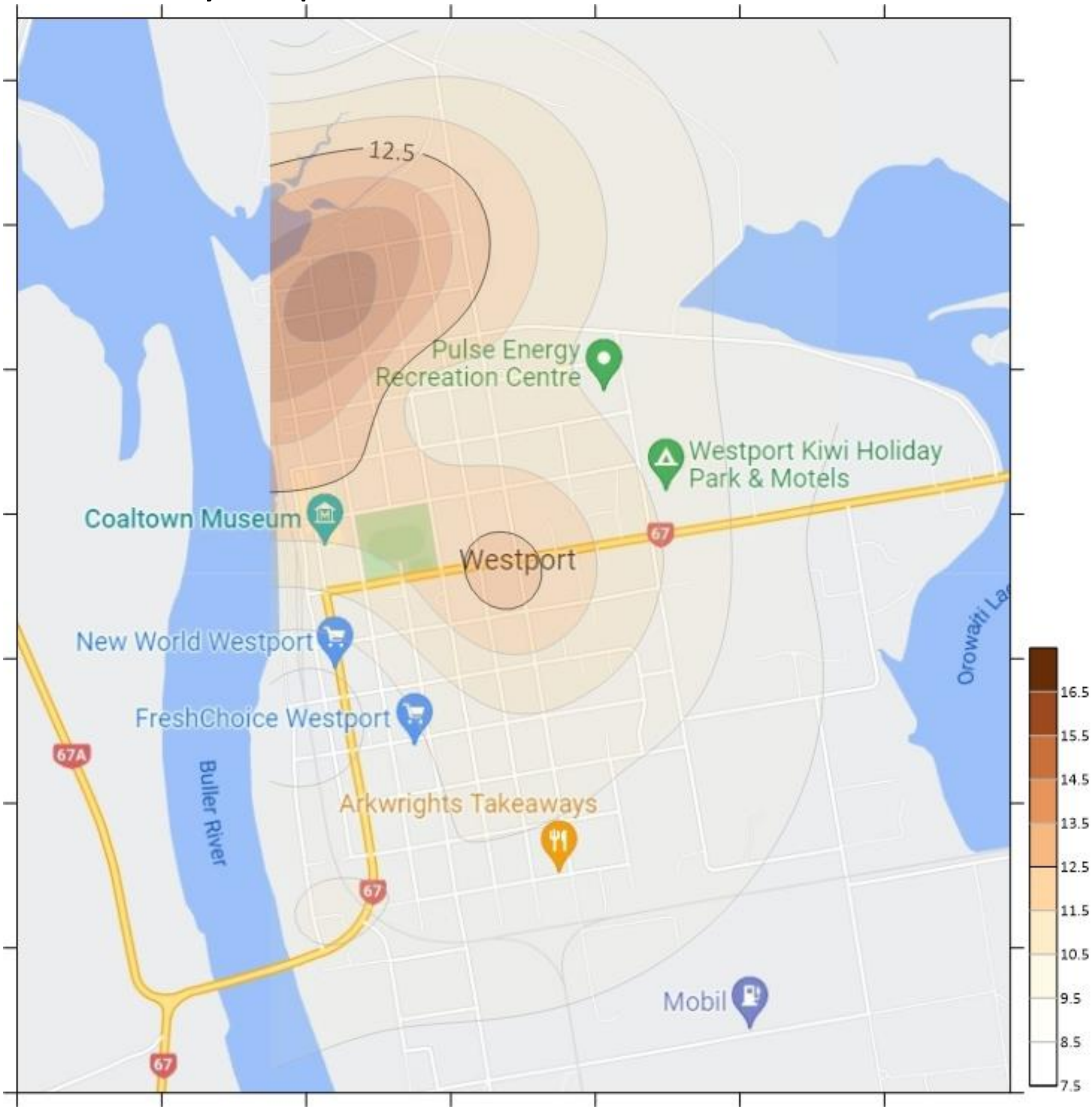


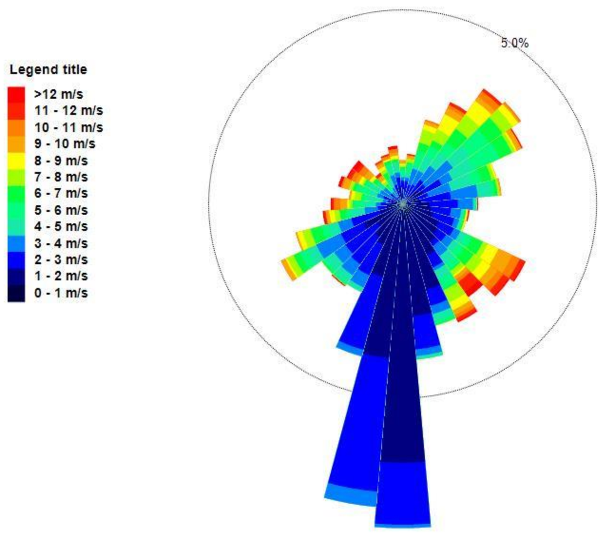
Figure 22: The average $PM_{2.5}$ concentration measured at each site for the period between 31 May – 8 September 2022



3.4 Meteorological conditions

Figure 27 below is a windrose covering the study period (31 May – 8 September 2022). The windrose illustrates that winds from a southerly direction dominated during the study. However very strong winds (>12 m/s) from northwest, northeast and southeast also occurred.

Westport windrose 31 May through to 8 September 2022



Meteorological conditions during the 2022 study period can be compared to previous years in Table 4 below.

A comparison of meteorological conditions during the 2022 study period (31 May – 8 September) reveals that the 2022 period was slightly windier than previous years. How ever the air temperature was similar to that of previous years (not unusually warm or cold) suggesting that the study period was generally representative of a typical winter in Westport.

Table 4: Comparison of meteorological conditions during the 2022 study period with previous years.

Year	Average wind speed (m/s)	Average air temperature (degC)
2022	3.8	10.0
2021	3.2	10.6
2020	2.9	10.3
2019	2.8	9.1
2018	2.8	10.2

4.0 RECOMMENDATIONS

Following on from the investigation into the ambient air quality in Westport, this report makes the following recommendations:

1. It is recommended that consideration be given to communicating with adjacent residents prior to installing future air quality monitors to ensure that they understand the purpose of the equipment and are comfortable with the monitoring instrumentation.

2. In addition to point (1) above, it is also recommended that consideration be given to placing a notice in the local paper (where available) advising of the purpose of the monitoring instrumentation and the limited deployment.

3. Although this study focused on monitoring for $PM_{2.5}$, based on the available data, it is likely that the average 24-hour PM_{10} concentration may, at times, reach or exceed the relevant National Environmental Standard for this pollutant. On that basis, consideration should be given to monitoring for this pollutant in accordance with regulation 15 of the National Environmental Standards for Air Quality Regulations 2004

4. Consider the implications of the 2021 World Health Organisation air quality guidelines – in particular the recommendation to limit the 24 hour average $PM_{2.5}$ concentration to 15 micrograms per cubic metre.

5. Consider repeating an ambient $PM_{2.5}$ monitoring network assessment in Westport within the next 10 years to verify that the findings in this report remain relevant. Alternatively, the reassessment could be linked to population growth or housing in Westport.

5.0 CONCLUSION

Mote limited deployed a network of 15 monitors throughout Westport between 31 May and 8 September 2022. Despite two major storms in the region which damaged a number of units, the overall data capture rate for the network was acceptable at 95%.

A maximum 24 hour $PM_{2.5}$ concentration of 55 micrograms per cubic metre was measured on 3 July at one locality and 11 of the 15 monitoring locations registered 24 hour averages above the proposed draft 24 hour PM2.5 standard of 25 micrograms per cubic metre.

The results demonstrated that the northern portion of Westport situated north of Brougham Street seems to exhibit higher levels of $PM_{2.5}$ than the portion of Westport south of Brougham Street. The higher concencentrations of $PM_{2.5}$ do not seem to be the result of katabatic cold flow drainage and are more likely to be due to either a greater number of operating domestic fires in this part of Westport and/or higher mass emissions from the domestic fires which are present.

6.0 REFERENCES

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