Ramsey County, Minnesota

Air Quality Monitoring

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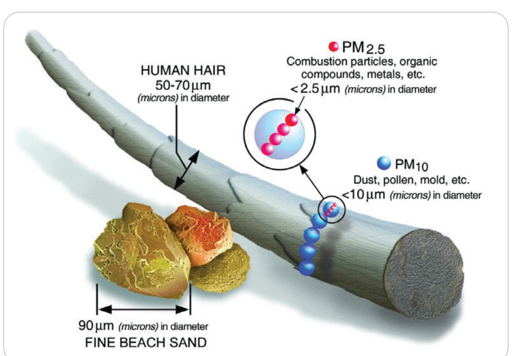
In addition to mapping heat, project members in Ramsey County aimed to better understand the distribution of air pollution across the City using light-weight particulate matter sensors in both a combined mobile data collection (for a spatially-rich snapshot) and stationary data collection campaign (to observe temporal patterns). During the Heat Watch campaign, volunteers attached their AirBeam sensor alongside the CAPA heat sensor to collect mobile readings of a harmful pollutant class known as Particulate Matter ($PM_{2.5}$). The sensors were then installed for a 23 day stationary phase outdoors at fire stations and several other locations across the southern portion of Ramsey County. The resulting maps and statistical summaries from the Mobile Campaign and Stationary Campaign are presented in this report.

AirBeam Air Quality Sensor

What is $PM_{2.5}$?

Particulate matter (PM) are tiny air particles that can be made of many different chemicals and are often produced through combustion processes of automobiles, construction equipment, industrial plants, and wildfires. PM particles smaller than 2.5 micrometers in diameter, known as $PM_{2.5}$, can be especially harmful to human health when breathed in elevated concentrations. By attempting to map these concentrations, we can better understand who is more or less exposed to $PM_{2.5}$, and to what degree.



US AQI Level	PM2.5 (µg/m³)	Description
Good	0-12.0	Air quality is satisfactory, and air pollution poses little or no risk.
Moderate	12.1-35.4	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Unhealthy for Sensitive Groups	35.5-55.4	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Unhealthy	55.5-150.4	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Very Unhealthy	150.5-250.4	Health alert: The risk of health effects is increased for everyone.
Hazardous	250.5+	Health warning of emergency conditions: everyone is more likely to be affected.

Ranges of $PM_{2.5}$ sizes (left); $PM_{2.5}$ concentration levels (right), Source: EPA
$PM_{2.5}$ concentration levels and health recommendations based on 24-hour means

Mapping $PM_{2.5}$

While the concentration and distribution of $PM_{2.5}$ across urban environments can vary with weather patterns day-to-day or even hour-by-hour, many sources of chronic pollution, such as industrial districts and high-traffic roadways, remain in relatively the same location and continue to emit pollution over time (in varying amounts). With mobile traverses we are able to gather a large amount of spatial information about these pollutants. The stationary data that follows provides a look at daily levels of air quality across several specific locations of interest.

Mobile Traverse Analysis

Air Quality Monitoring

With the mobile mapping air quality campaign we aimed to gather $PM_{2.5}$ traverse point data for three time periods (Morning, Afternoon, Evening) on July 27th, 2024. The AirBeam Sensors were installed alongside CAPA Heat Watch sensors on volunteer's vehicles and collected data simultaneously with heat and humidity data. In this analysis we average the traverse point measurements into 100m² hexagons in order to show the relative distribution of $PM_{2.5}$ at a readable scale. The range of $PM_{2.5}$ values for each time period is visualized from blue to purple to highlight differences between lower and higher values of $PM_{2.5}$ within each respective period. The maps are accompanied by summary statistics that describe the traverse point measurements and hexagon averages, as well as a histogram of the hexagon values and notes section.

Morning Air Quality Traverses

The following maps describe $PM_{2.5}$ data collected by mobile traverse on July 27th, 2024.

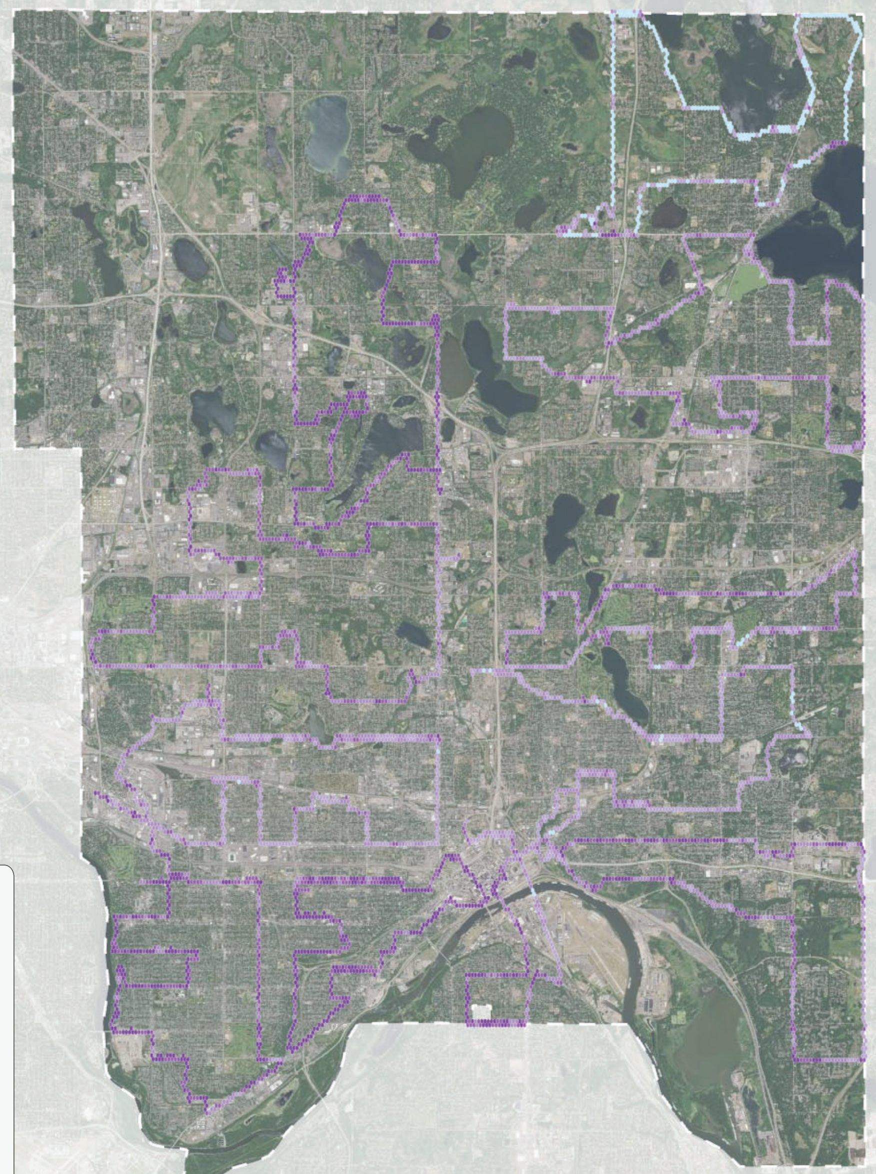
24.7
µg/m³

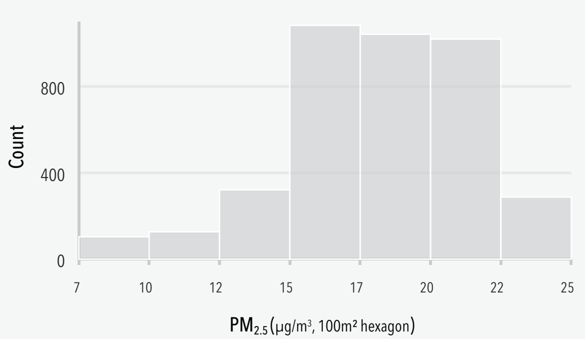
7.0
µg/m³

Summary Statistics		
	Traverse	Hex
Min	6.0	7.0
Mean	18.0	17.8
Median	18.0	18.0
Max	25.0	24.7
Count	30,940	4,215

Ramsey County mapping boundary

Mean $PM_{2.5}$
Resolution: 100m²



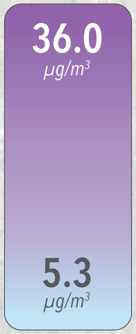


Notes

The map shows the distribution of $PM_{2.5}$ only in areas that were traversed by vehicles during the mobile campaign. Elevated levels of $PM_{2.5}$ are indicated in darker purple, which appear to concentrate towards in pockets throughout the city in the central, northern, southwestern, and a small portion of the southeastern part of the study area in Ramsey County.

Afternoon Air Quality Traverses

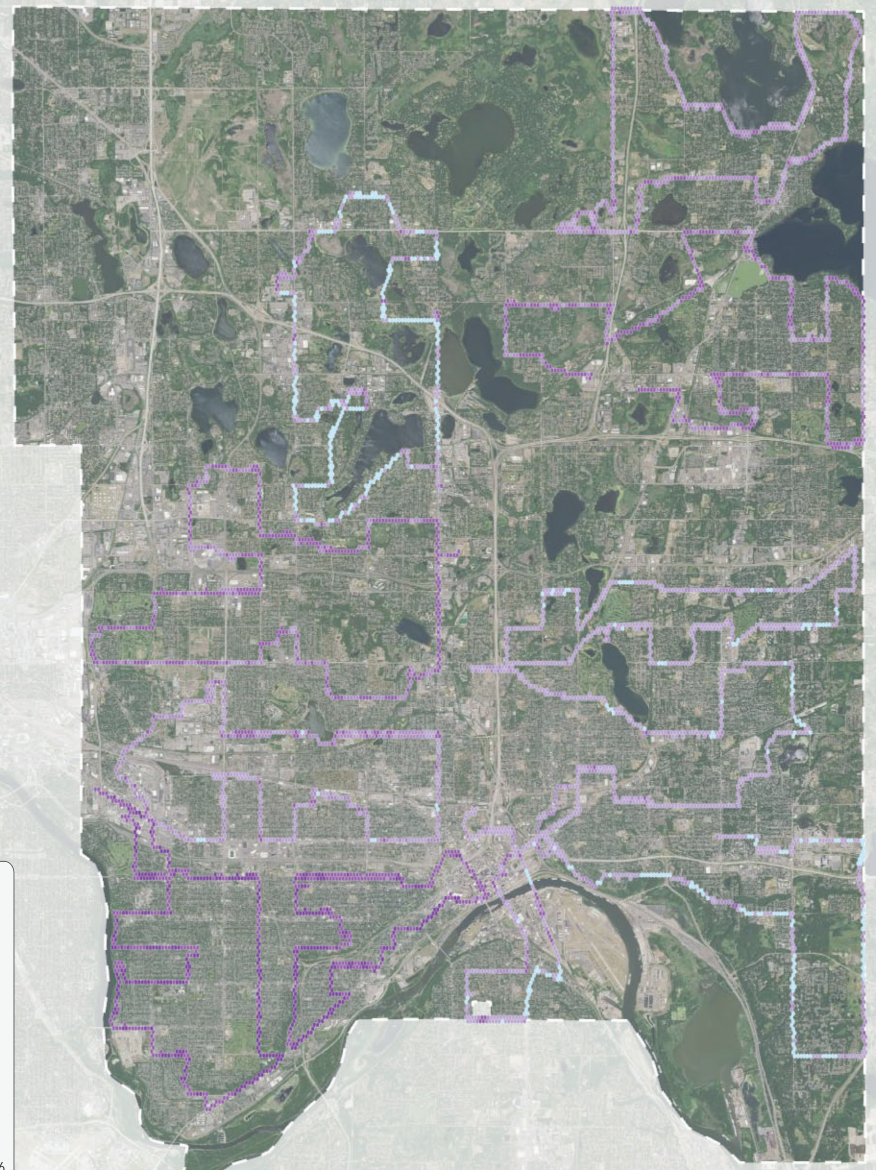
The following maps describe $PM_{2.5}$ data collected by mobile traverse on July 27th, 2024.

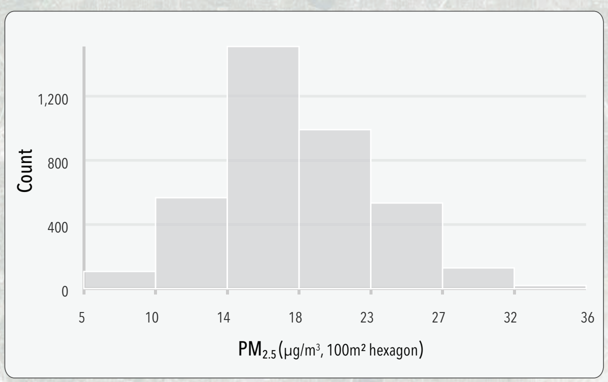


Summary Statistics	Traverse	Hex
Min	5.0	5.3
Mean	19.0	18.3
Median	18.0	17.7
Max	39.0	36.0
Count	31,258	4,190

Ramsey County mapping boundary

Mean $PM_{2.5}$ Resolution: 100m²





Notes

$PM_{2.5}$ levels in the afternoon are higher than the morning. The highest concentrations of $PM_{2.5}$ appear in the southwestern part of the map.

Evening Air Quality Traverses

The following maps describe $PM_{2.5}$ data collected by mobile traverse on July 27th, 2024.

HEAT WATCH

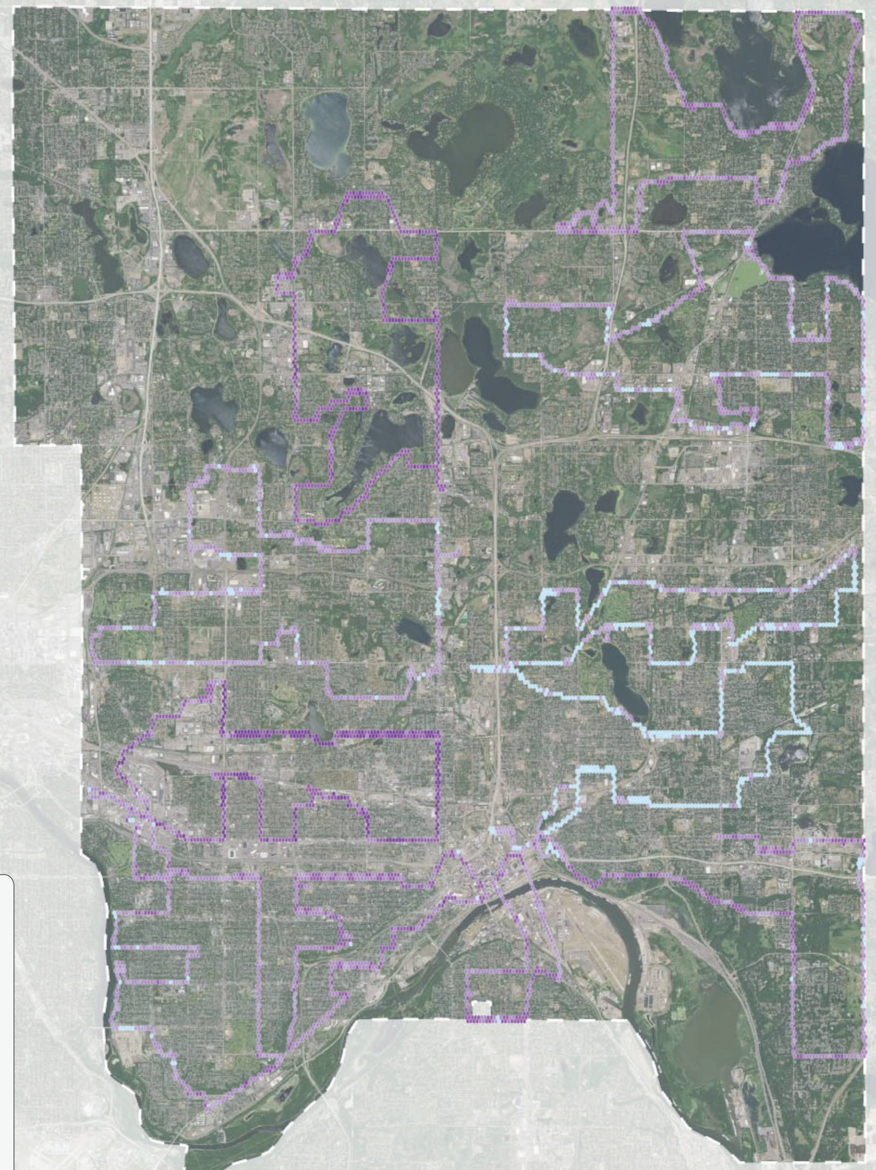
48.3 µg/m³

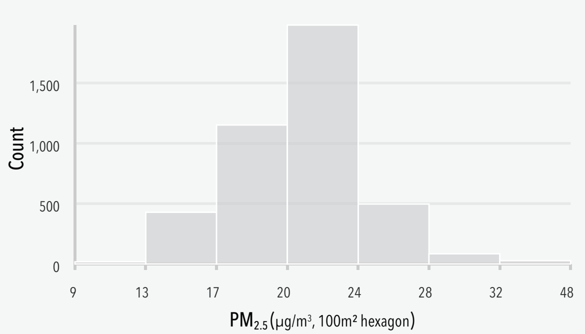
8.8 µg/m³

Summary Statistics		
	Traverse	Hex
Min	8.0	8.8
Mean	21.0	21.2
Median	22.0	21.4
Max	52.0	48.3
Count	31,279	4,194

Ramsey County mapping boundary

Mean $PM_{2.5}$ Resolution: 100m²





Notes

Evening $PM_{2.5}$ levels are similar in range to the afternoon and indicate higher median and mean values overall than the afternoon and morning. The highest values can be found in the southwestern portion of the city, which is a consistent pattern across morning, afternoon, and evening traverses.

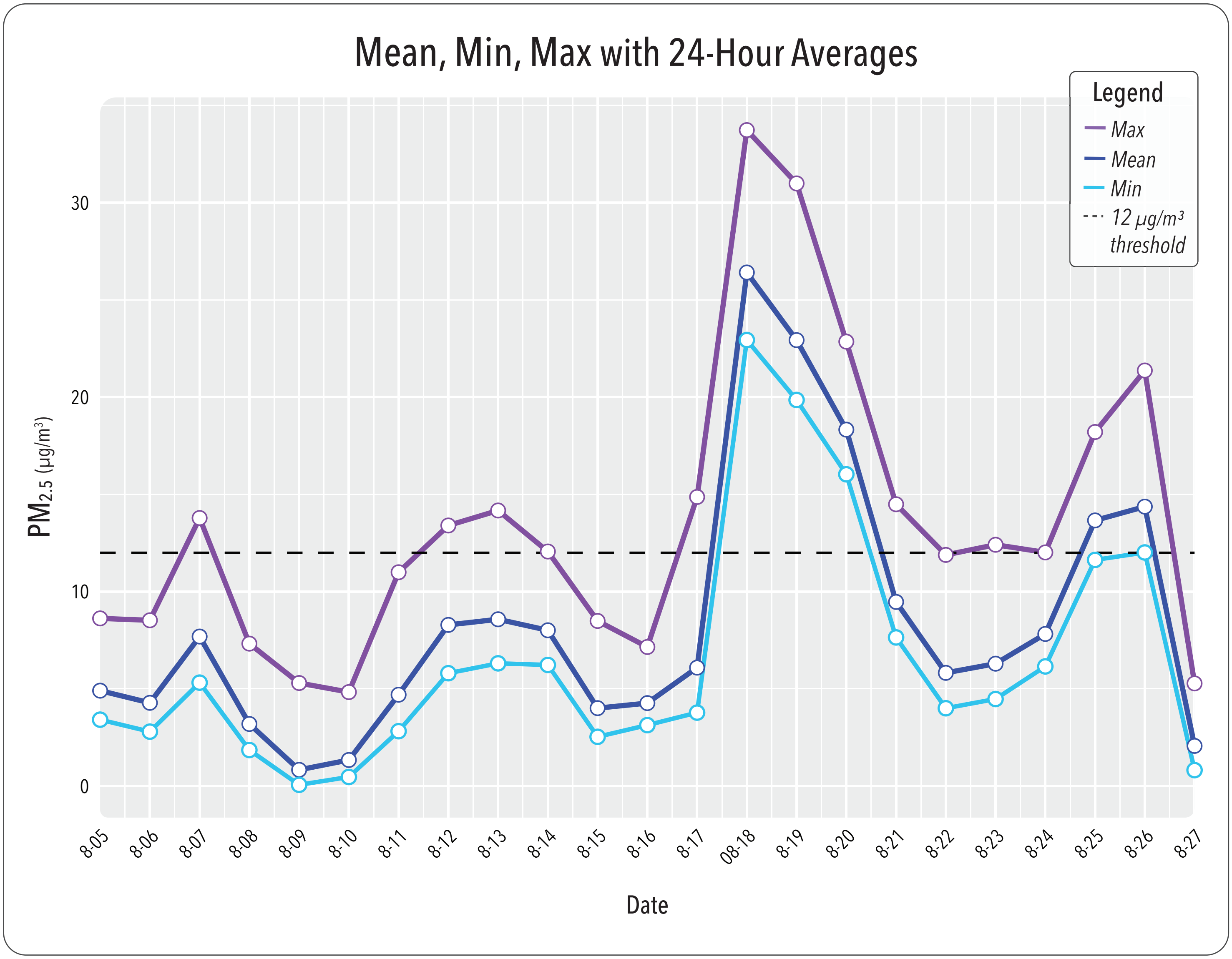
Stationary Analysis

Air Quality Monitoring

With the stationary mapping campaign we aimed to gather a geographically-diverse picture of trends in $PM_{2.5}$ distribution over a 23 day period between August 5th and August 27th, 2024. The 16 AirBeam sensors were installed at Saint Paul Fire Department stations and facilities spread across the southern portion of Ramsey County, as well as at the Frogtown Green Farm and Park. In this analysis we summarize the data gathered (focusing on the 23 days when all 16 sensors were operating), examine trends by sensors, determine which locations reached elevated pollution levels (i.e. averaged >12 μg/m³ over a 24 hour period), and compare the AirBeams' data with a nearby EPA reference sensor's data. The air quality monitoring station is owned and operated by the Indiana Department of Environmental Management (IDEM). We highlight the threshold of 12 μg/m³ throughout the report as the EPA advises that air quality poses a risk for some people, particularly those who are unusually sensitive to air pollution, when $PM_{2.5}$ concentrations are between 12.1 to 35.4 μg/m³ on average for 24 hours.

Stationary Air Quality Summary

The summary below describes $PM_{2.5}$ data collected by stationary sensors from 8/5/24 - 8/27/24



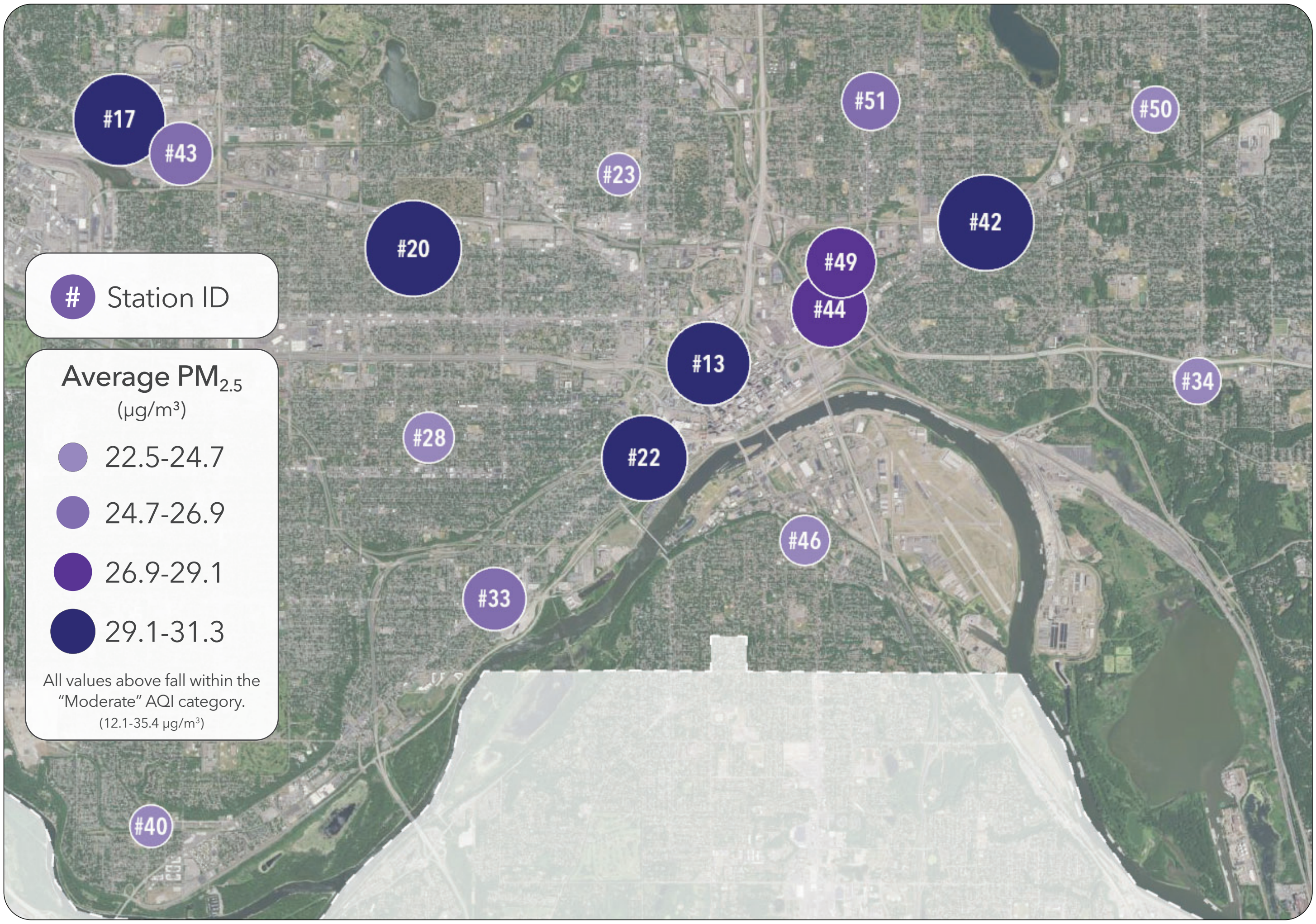
In this trend-over-time plot, we see the minimum, maximum, and average hourly $PM_{2.5}$ measurements per day at each sensor over the 23 day period. Overall, average hourly measurements were the highest on August 18th, and lowest on August 9th. On the following page we examine the spatial distribution of $PM_{2.5}$ on this peak day.

The AirBeam sensors collected measurements of $PM_{2.5}$ in one-minute intervals during their stationary installment. Since exposure periods to air pollution are typically assessed in hours and days, we averaged all of the one-minute measurements into one-hour statistics, referred to as "Hourly Averages", and averaged the one-hour summaries from each day into 24-hour statistics, referred to as "24-hour Averages" or "Daily Averages". A summary table of the raw one-minute measurements is also provided in the Appendix.

Peak Day Sensor Averages

Average $PM_{2.5}$ on 8/18/24

Displayed here are the average $PM_{2.5}$ concentrations of each sensor from the day with the highest average recorded measurements from the study period, August 18th.



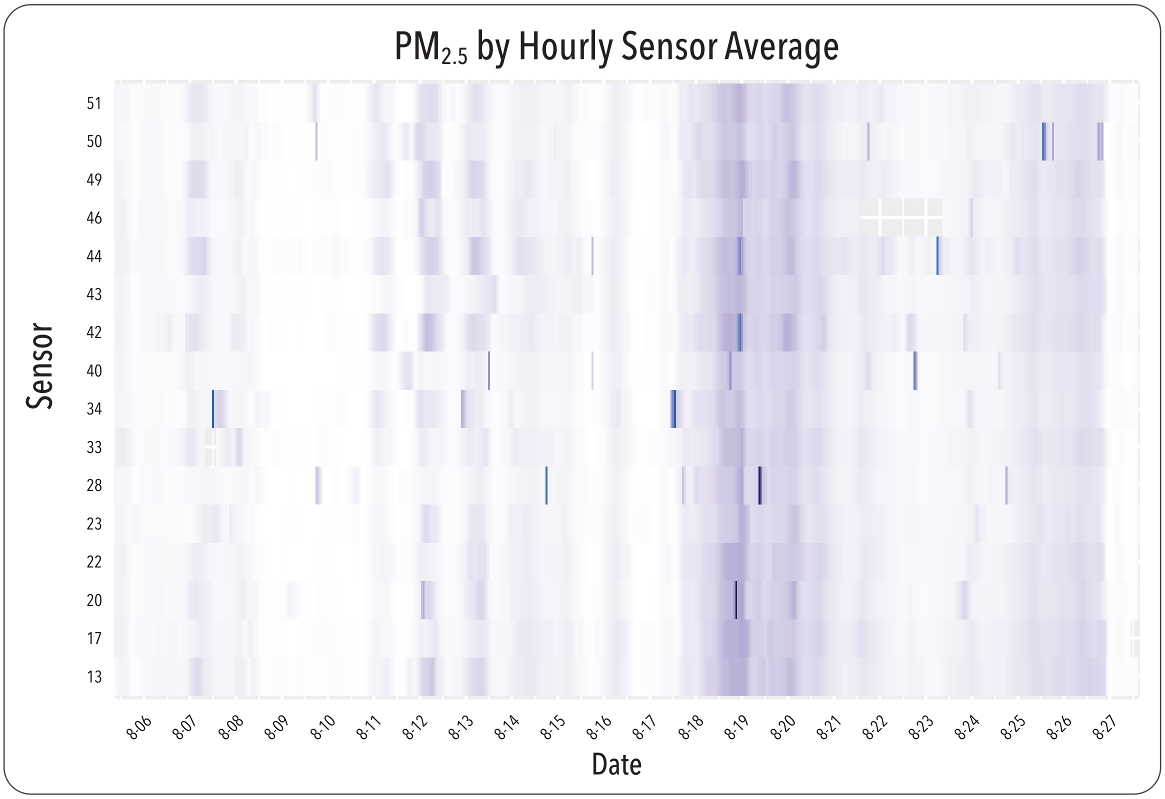
Color scheme here not comparable to color scheme in mobile traverse maps

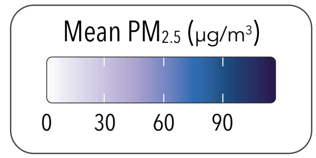
Sensors #20 (31.3 μg/m³) and #42 (31.2 μg/m³) measure the highest on average on August 18th.

Individual Sensor Summary

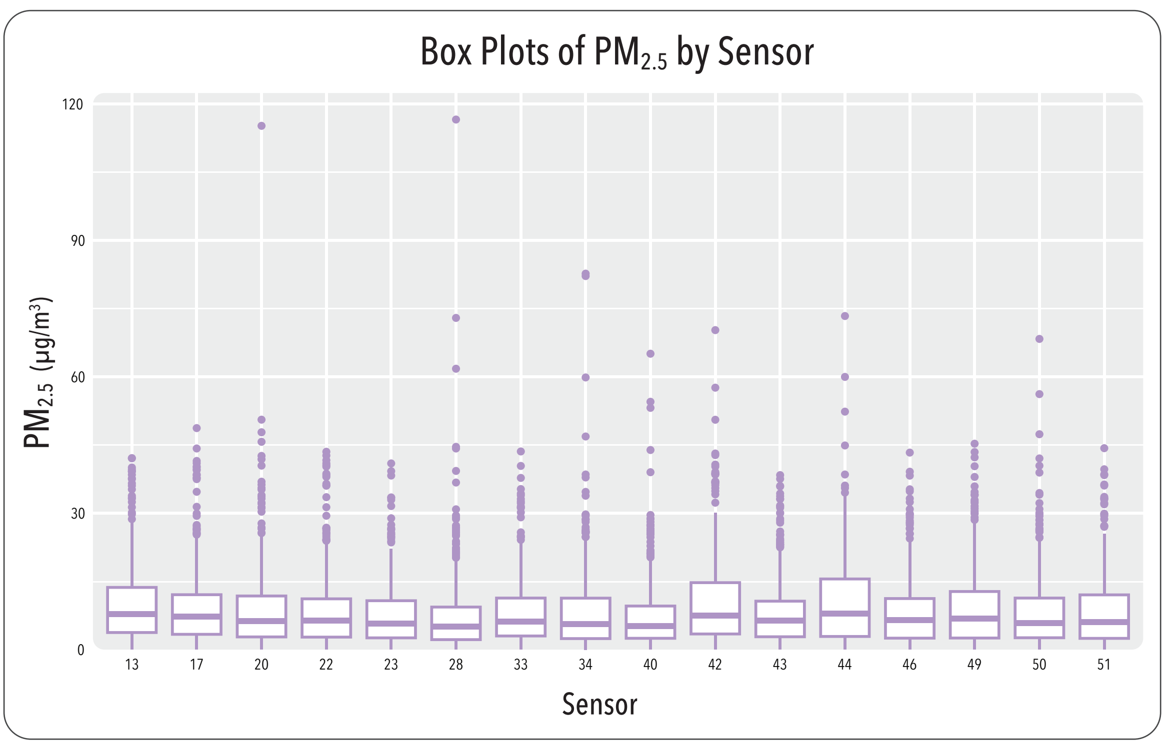
The below describes $PM_{2.5}$ data collected by stationary sensors from 8/5/24 - 8/27/24

Measuring the highest in $PM_{2.5}$ concentration over the 23 day period was AirBeam #17, installed at a fire station in the Langford Park Area, with an average $PM_{2.5}$ reading of 9.2 μg/m^3. The second highest reading sensor was AirBeam #44 located at a fire station just over 5 miles east of AirBeam #17 in the Railroad Island neighborhood with an average of 9.0 μg/m^3.





The graph here displays $PM_{2.5}$ levels over the 23 day period.

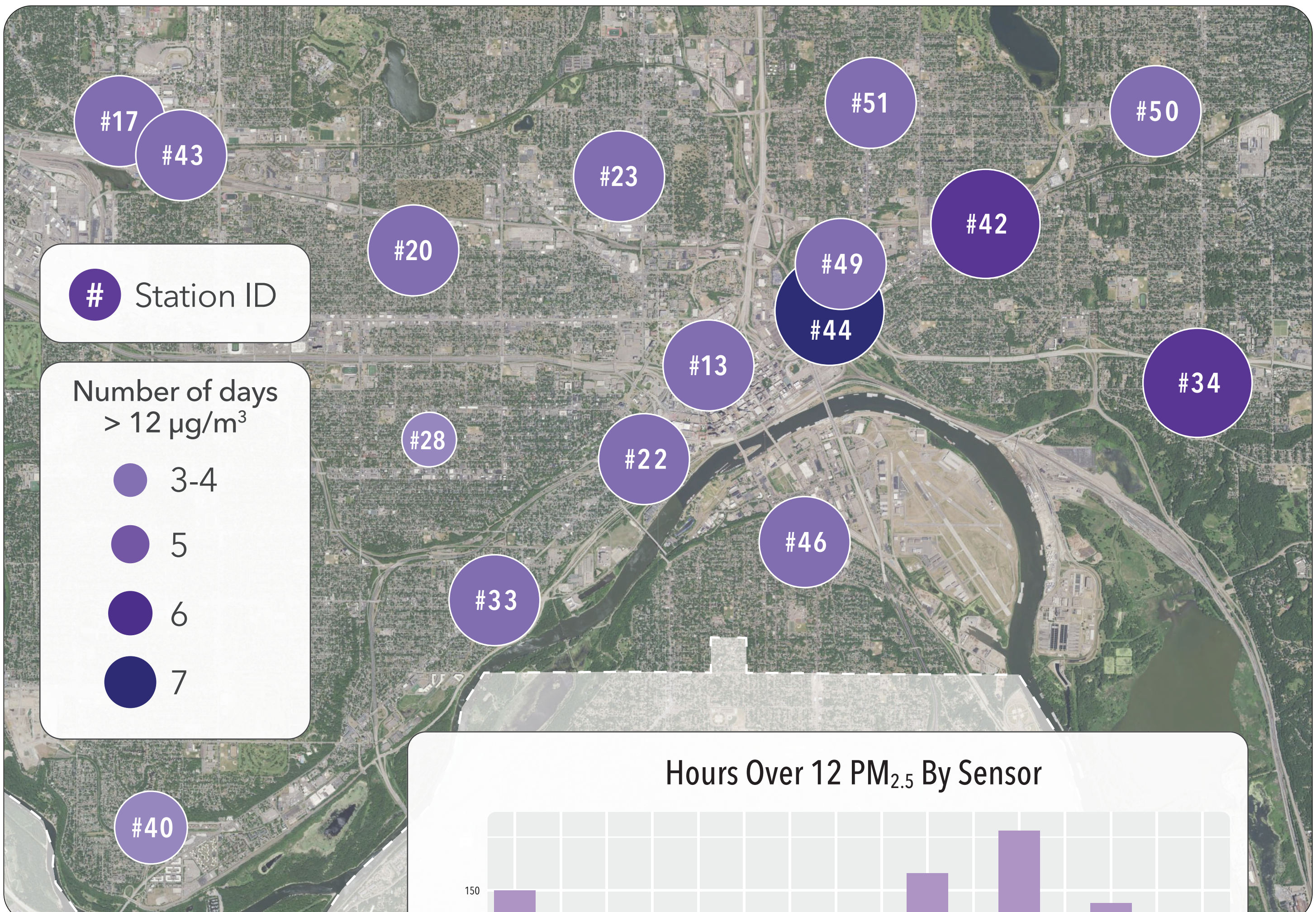


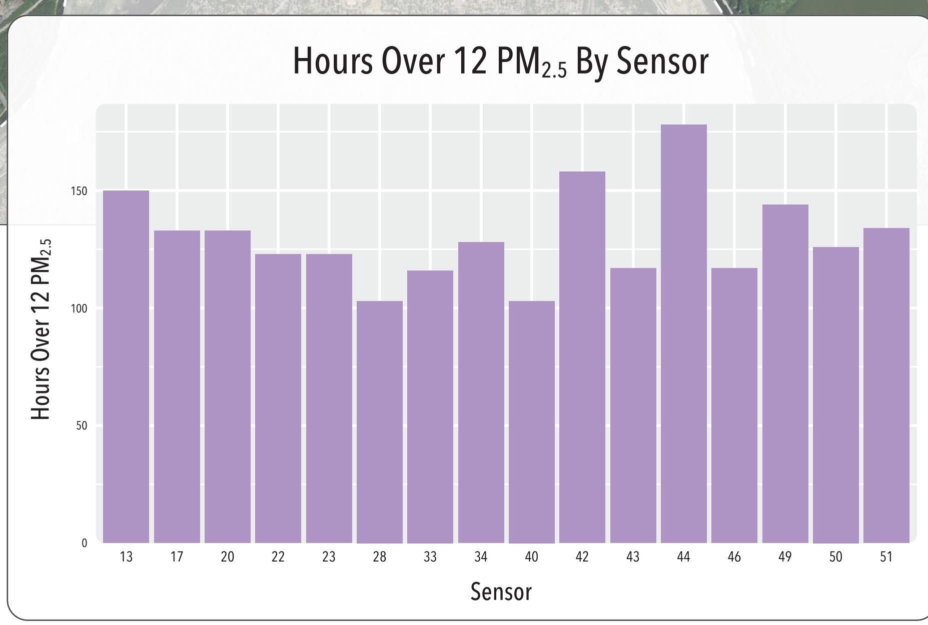
Box and whisker plots show for each sensor the median measurement across the 23 day period (middle horizontal bar) and interquartile range (lower bar to upper bar), with values outside of this range depicted as points along the whiskers.

Elevated 24-Hour Averages

Number of Days with Average $PM_{2.5}$ over 12 µg/m^3

According to the EPA, when $PM_{2.5}$ measurements reach a 24-hour average between 12-35 µg/m^3, there may be some risk to people who are unusually sensitive to air pollution. We present the number of days and hours that each sensor measured over 12 µg/m³ in the map and graph, respectively, below. AirBeam #44 had a daily average over 12 µg/m³ for 7 days of the study period, with a total of 178 hours above 12 µg/m³. AirBeams #34 and 42 had a daily average over 12 µg/m³ for 6 days of the study period, with a total of 128 and 158 hours above 12 µg/m³ respectively. At these levels, unusually sensitive people should consider making outdoor activities shorter and less intense or wearing an N-95 HEPA filter air mask while outdoors.

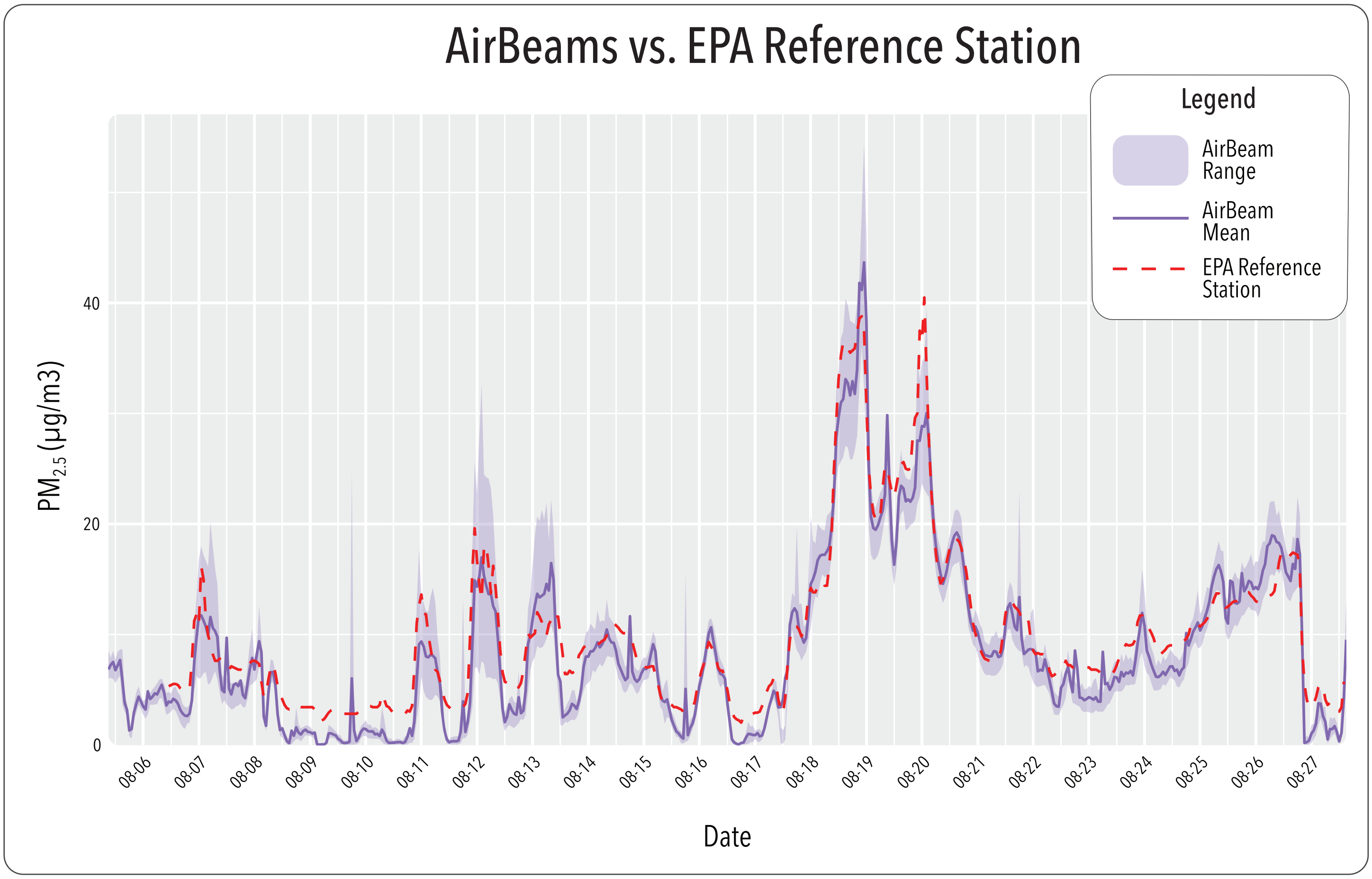




Co-Location Assessment

PM$_{2.5}$ 8/5/24 - 8/27/24

Co-location is a method of comparing low-cost sensors with EPA reference stations to assess their performance. We were unable to directly co-locate any of the AirBeam sensors with a reference station in Ramsey County, though Airbeam #34 was just 0.8 miles away from the EPA reference monitor at St. Paul-Harding High School. Below we plotted the range and mean measured across all 16 AirBeams in Ramsey County against the EPA reference station.



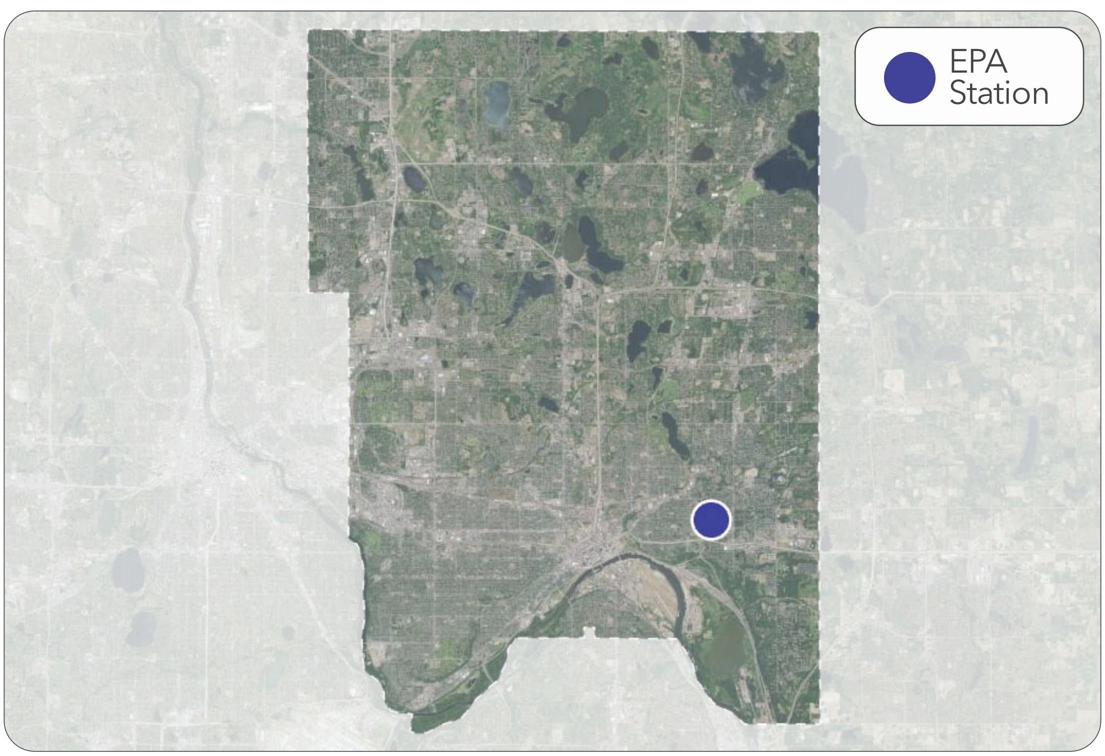
Overall the AirBeams and reference station indicated a close relationship over the 23 day period. The AirBeam range indicates variation in PM$_{2.5}$ across Ramsey County that is not captured by the single reference station. There are several important deifferences to note between the reference station and the AirBeams, including different design and casing, functional differences such as response time and measurement increment, and processing methods like filters for noise and outlier removal.

Conclusion

In this study we explored the capabilities of low-cost air quality monitoring across Ramsey County to provide valuable and accurate information across a 23 day period in August, 2024. As evidenced by the mobile traverses, on relatively low air pollution days concentrations of particulate matter still vary across the area by location and time of day. On-road mobile monitoring reached locations outside of established EPA reference station areas, highlighting areas experiencing elevated concentrations of particulate matter that may not have otherwise been detected.

During the stationary monitoring period we saw temporal fluctuations in $PM_{2.5}$ concentrations at select sites across the region and through analysis derived several key findings:

1. Certain locations consistently saw higher levels compared to others, contributing to disparate levels of exposure by location;
2. The AirBeams and EPA reference station at St. Paul Harding High School tracked closely in $PM_{2.5}$ measurements; and,
3. Given the evidence of spatial variability in $PM_{2.5}$ concentrations across the area, some gaps exist in the long-term air quality monitoring network across Ramsey County. Improving monitoring coverage across Ramsey County could improve the ability of planners to sufficiently strategize long-term adaptation actions as well as short-term response activities during poor air quality events.



EPA regulatory station that monitors $PM_{2.5}$

Conclusion

Given these findings we recommend increasing the presence of long-term stationary monitoring networks across Ramsey County, specifically in areas that indicated higher levels of $PM_{2.5}$ concentrations in the mobile study as well as the peak-day and 24-hour mean exposure maps from the stationary study. Combining these insights along with population vulnerability data (provided by tools such as the U.S. Climate Vulnerability Index) can help to identify areas facing the highest risk of impacts from degraded air quality and most in-need of long-term monitoring.

Low-cost sensors can provide a well-tested and integrative solution for long-term monitoring (AQ - SPEC). The widespread platform PurpleAir, which employs the same sensing technology in its products as AirBeam (along with additional redundancy for improved accuracy) provides a publicly accessible mapping dashboard for installed monitors. Data flows from such networks can be used for a variety of purposes, such as better informing regional forecasting models like those provided by IQ Air, and providing more granular insight to planners and public health officials. Including additional pollutants such as carbon monoxide (CO), nitrogen dioxide (NO_2), carbon dioxide (CO_2) and volatile organic compounds (VOCs) could also be achieved with relatively low-cost devices in future studies.

Findings and recommendations in this study comprise a direction for improved monitoring, a key element for managing and addressing the health risk that particulate matter poses in Ramsey County. Collaborative studies that span governance structures are key for raising public awareness and a valuable touch point for continued efforts in co-creating mitigation and adaptation solution strategies, and guiding further research. Studies such as these need also to be integrated with existing work by local researchers for a robust understanding of the effects of other pollutants and patterns with particulate matter. We hope that this study provides a stepping stone in such directions.

Thank you to all participants of the mobile and stationary monitoring campaign, including mobile data collection teams as well as hosts of the stationary sensors across Ramsey County.

Appendix
Air Quality Monitoring

Sensor Summary Statistics

PM$_{2.5}$ Summary Statistics of One-Minute Measurements

Sensor ID	Mean (µg/m³)	Min (µg/m³)	Max (µg/m³)	SD (µg/m³)	Median (µg/m³)	Mode (µg/m³)
13	8.8	0.0	249.0	8.6	7.0	1.0
17	9.2	0.0	136.0	8.2	7.0	5.0
20	7.9	0.0	402.0	11.7	5.0	1.0
22	7.2	0.0	63.0	7.2	5.0	0.0
23	6.9	0.0	147.0	7.9	5.0	0.0
28	6.4	0.0	525.0	11.9	4.0	0.0
33	8.0	0.0	161.0	7.6	6.0	1.0
34	7.1	0.0	353.0	10.1	5.0	0.0
40	6.3	0.0	606.0	10.8	5.0	0.0
42	8.8	0.0	369.0	10.1	6.0	1.0
43	7.4	0.0	387.0	7.3	6.0	1.0
44	9.0	0.0	363.0	10.7	6.0	1.0
46	7.0	0.0	422.0	8.2	5.0	0.0
49	8.0	0.0	95.0	9.0	6.0	1.0
50	7.8	0.0	510.0	12.9	5.0	6.0
51	7.9	0.0	216.0	7.9	6.0	0.0