

Data Center Air Quality Analysis

Virginia DEQ, Office of Air Quality Monitoring

Loudoun County Study Area

June 12, 2026

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1 Introduction

Virginia DEQ's Office of Air Quality Monitoring (AQM) is currently operating 7 APEX/Kunak AIR Pro sensors in Loudoun County, north of Dulles International Airport in the vicinity of Sterling and Ashburn.

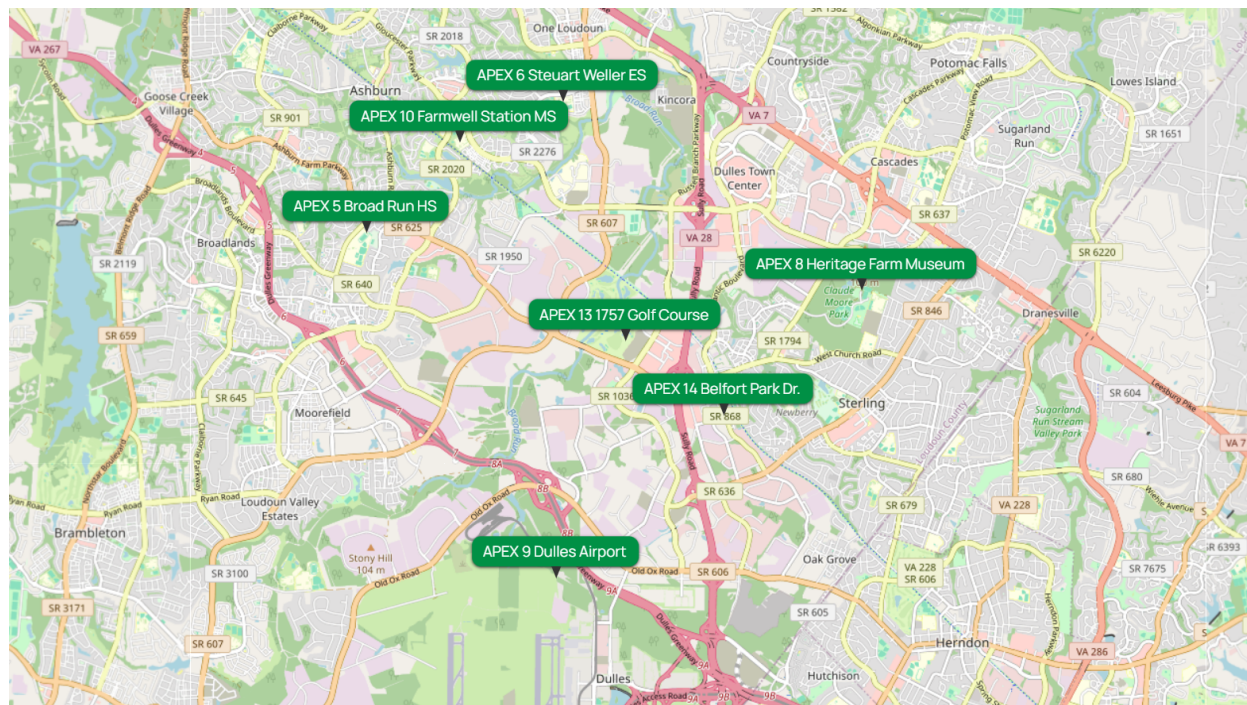


Figure 1: Study area with the APEX/Kunak sensors highlighted in green. Dulles Airport is visible in the bottom (South) of the map.

These sensors were placed to monitor ambient air quality in “Data Center Alley”, an area with a high density of data centers in Loudoun County. Five of these sensors were installed on Wednesday, Feb 25, 2026, and were transmitting data later that day.¹ These were the sensors at Newberry Condo Association (Newberry Condo Assoc.), Broad Run High School (Broad Run HS), Dulles Airport, the Heritage Farm Museum, and Stuart Weller Elementary School (Steuart Weller ES). Due to the stabilization period, this report only uses data post-stabilization period, or from March 3, 2026, to the morning of June 12, 2026.

An additional two APEX/Kunak sensors, which had been operating in Prince William County were moved to Loudoun County on April 8, 2026. The two new APEX/Kunak sensors were installed at the 1757 Golf Course and Farmwell Station Middle School (Farmwell Station MS). These two sites only have data starting from April 8, 2026.

¹Kunak states that there is a stabilization period after installation, which may last up to 5 days. Only post-stabilization period data is analyzed in this report.

On the morning of Thursday May 14, 2026, the APEX/Kunak 14 Sensor at Newberry Condo Assoc. was moved to Belfort Park Drive (Belfort Park Dr.). Therefore, the data collection for the Newberry Condo Assoc. site ends on May 14, 2026, and the data collection for Belfort Park Dr. starts on May 14, 2026.

Phase 1b - Loudoun County Sensor Deployment

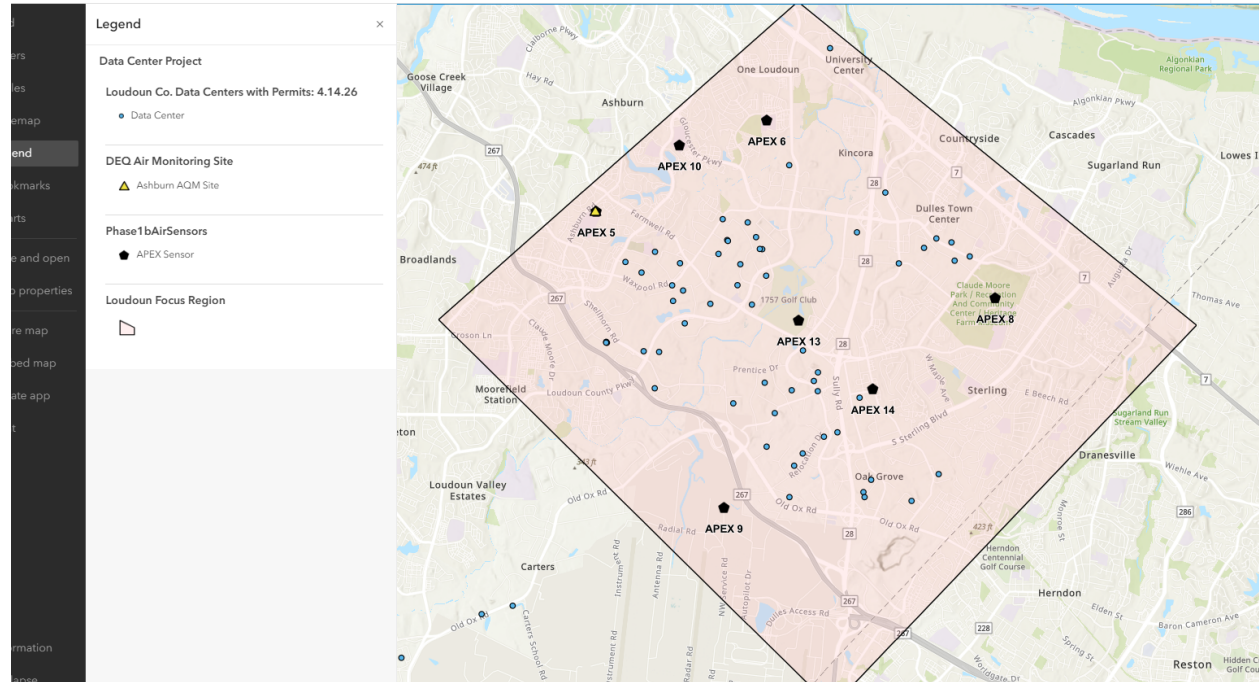


Figure 2: Study area highlighted, with permitted (blue circles) data centers mapped along with the local VADEQ air monitoring site (yellow triangle, Broad Run HS) and APEX/Kunak sensor positions (black pentagons).

The pollutants that are being measured are [carbon monoxide \(\$CO\$ \)](#), [nitrogen dioxide \(\$NO_2\$ \)](#), and particulate matter less than 2.5 microns in size ([\$PM_{2.5}\$](#)).

These sensors are capable of collecting pollutant concentration data and establishing pollutant concentration trends, but they are not regulatory instruments as specified in the Code of Federal Regulations (CFR). They cannot be used in determining attainment or non-attainment of the National Ambient Air Quality Standards ([NAAQS](#)). Only [Federal Reference/Equivalent Method designated monitors](#) can.

The APEX Broad Run HS sensor is collocated (located at the same site) as Virginia DEQ's Broad Run HS regulatory monitoring site. The Broad Run HS regulatory monitoring site and the APEX/Kunak sensors both measure NO_2 and $PM_{2.5}$ so a direct statistical comparison between these two instruments can be performed for these two pollutants.

For the APEX/Kunak CO sensors, the closest general ambient air regulatory monitoring site to the APEX/Kunak CO sensors is in Arlington County. Virginia DEQ's Arlington regulatory monitoring site is located outside of the "Data Center Alley" study area.

There is a closer *CO* regulatory monitoring site in Fairfax County, but it is focused on near-highway and near-road emissions and would not be representative for general ambient air quality.

All dates & times presented below are in U.S. Eastern Standard Time (U.S. EST, UTC - 5:00).

2 CO Hourly Concentrations: Loudoun County Sensor Data

The current National Ambient Air Quality Standards (NAAQS) for *CO* are set at two levels, corresponding to two different averaging times:

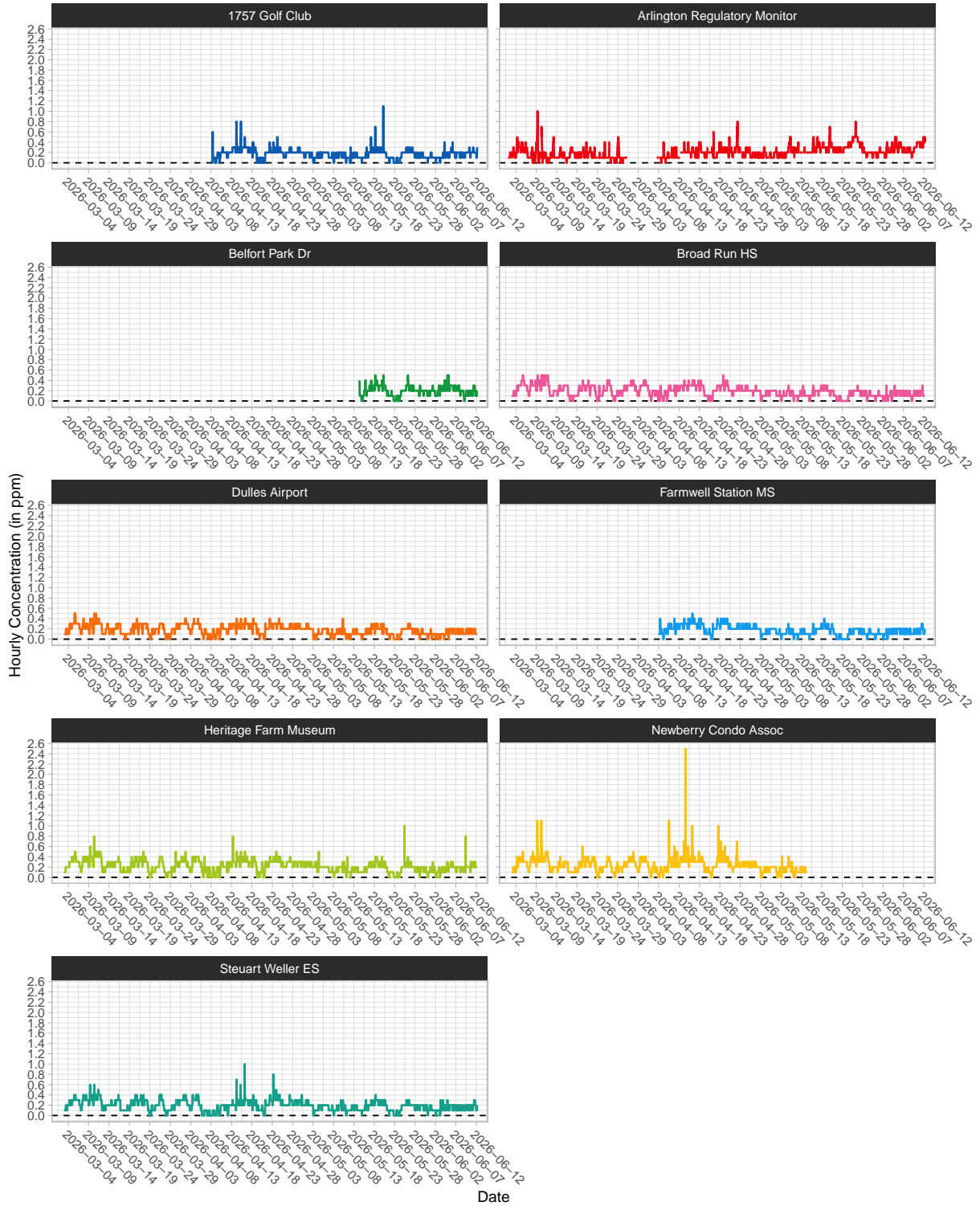
1. No 8-hour rolling concentration average may exceed 9 parts per million (ppm) more than once per year.
2. No 1-hour concentration average may exceed 35 parts per million (ppm) more than once per year.

The APEX/Kunak Air sensors measure *CO* in parts per billion (ppb), where 1000 ppb = 1 ppm. For ease of comparison, we have converted sensor ppb values into ppm to compare with our regulatory monitor values (which record in ppm, the unit that the *CO* NAAQS are assessed in). The closest comparable *CO* monitoring site to the APEX/Kunak sensors is Virginia DEQ's Aurora Hills monitoring site, in Arlington County, Virginia. [According to the EPA](#), the largest sources of *CO* pollution are vehicles and other machinery that burn fossil fuels. As *CO* concentrations in Virginia have historically been well below the NAAQS levels (and very low in general), and because *CO* sources correlate with more traffic/higher population densities, the Virginia DEQ ambient air regulatory monitor for Northern Virginia is in Arlington County. This is why the Loudoun County regulatory air monitoring site (Broad Run HS) does not have a regulatory *CO* monitor.

The APEX/Kunak sensors at the 1757 Golf Course and Farmwell Station MS were installed on April 8, 2026; therefore, these sites only have data beginning April 8, 2026. The sensor at Belfort Park Dr. was installed on May 14, 2026, and data collection for that sensor begins on that day. Data collection for Newberry Condo Assoc. ended on May 14, 2026.

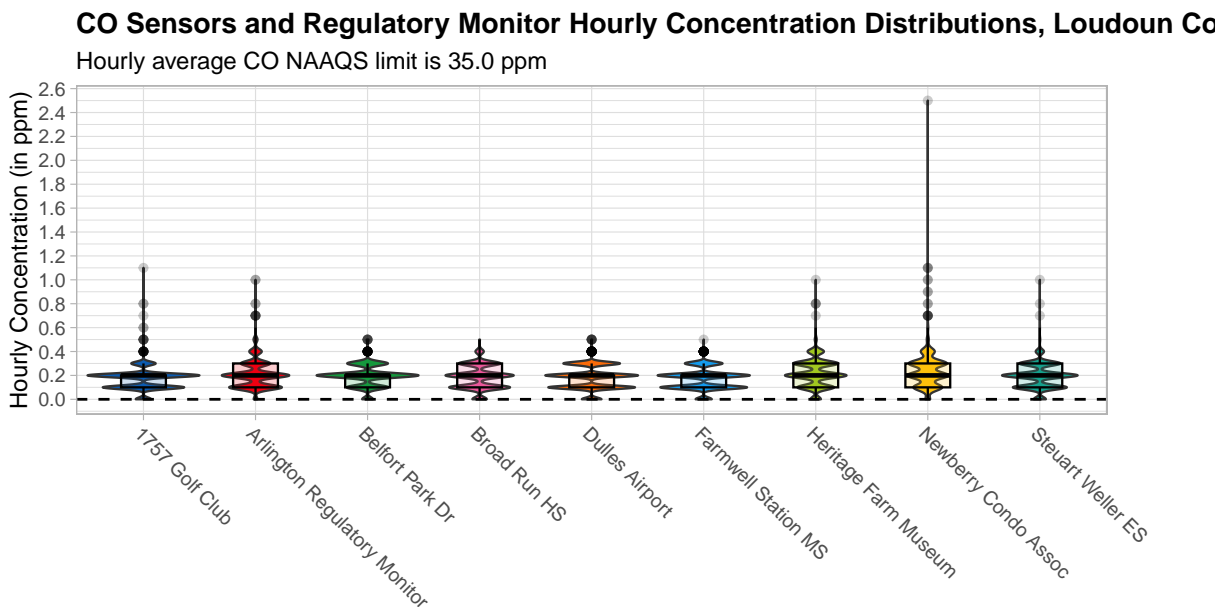
CO Hourly Average Concentrations, Loudoun County

Hourly average CO NAAQS limit is 35.0 ppm



As the graph above illustrates, *CO* concentrations from the sensors in Loudoun County are in the same general range as *CO* concentrations at the Arlington County regulatory

monitoring site, at around 0 - 1.1 ppm, with a few spikes up to 3.0 ppm.² The concentrations are well below the hourly NAAQS limit for *CO* (35.0 ppm). Because the hourly concentrations are consistently below 1 ppm, all 8-hour average concentrations are also well below the associated NAAQS limit of 9.0 ppm.



As the above [violin plot](#) (which plots a box plot over the statistical distribution of values across each site) illustrates, *CO* concentrations from the sensors in Loudoun County have relatively similar distributions and medians, in the 0.2 - 0.3 ppm range. A full table of statistical values from each sensor and the regulatory monitor can be found below. The 98th percentile values are extremely low across the region, all lying at or below 0.5 ppm.

Table 1: CO Hourly Concentrations Statistical Summary, Loudoun County (in ppm)

Site	mean	standard_deviation	median	percentile_98
1757 Golf Club	0.1	0.0	0.2	0.3
Arlington Regulatory Monitor	0.2	0.1	0.2	0.5
Belfort Park Dr	0.1	0.0	0.2	0.4
Broad Run HS	0.1	0.1	0.2	0.4
Dulles Airport	0.1	0.0	0.2	0.3
Farmwell Station MS	0.1	0.0	0.2	0.4
Heritage Farm Museum	0.2	0.1	0.2	0.4
Newberry Condo Assoc	0.2	0.1	0.2	0.5
Stuart Weller ES	0.1	0.1	0.2	0.4

²Due to data quality and instrumentation issues, data between March 31, 2026, and April 7, 2026, were voided at the Arlington regulatory *CO* monitor.

3 NO₂ Hourly Concentrations: Loudoun County Sensor and Regulatory Monitor Data

The current National Ambient Air Quality Standards (NAAQS) for NO_2 are set at two levels, corresponding to two different averaging times:

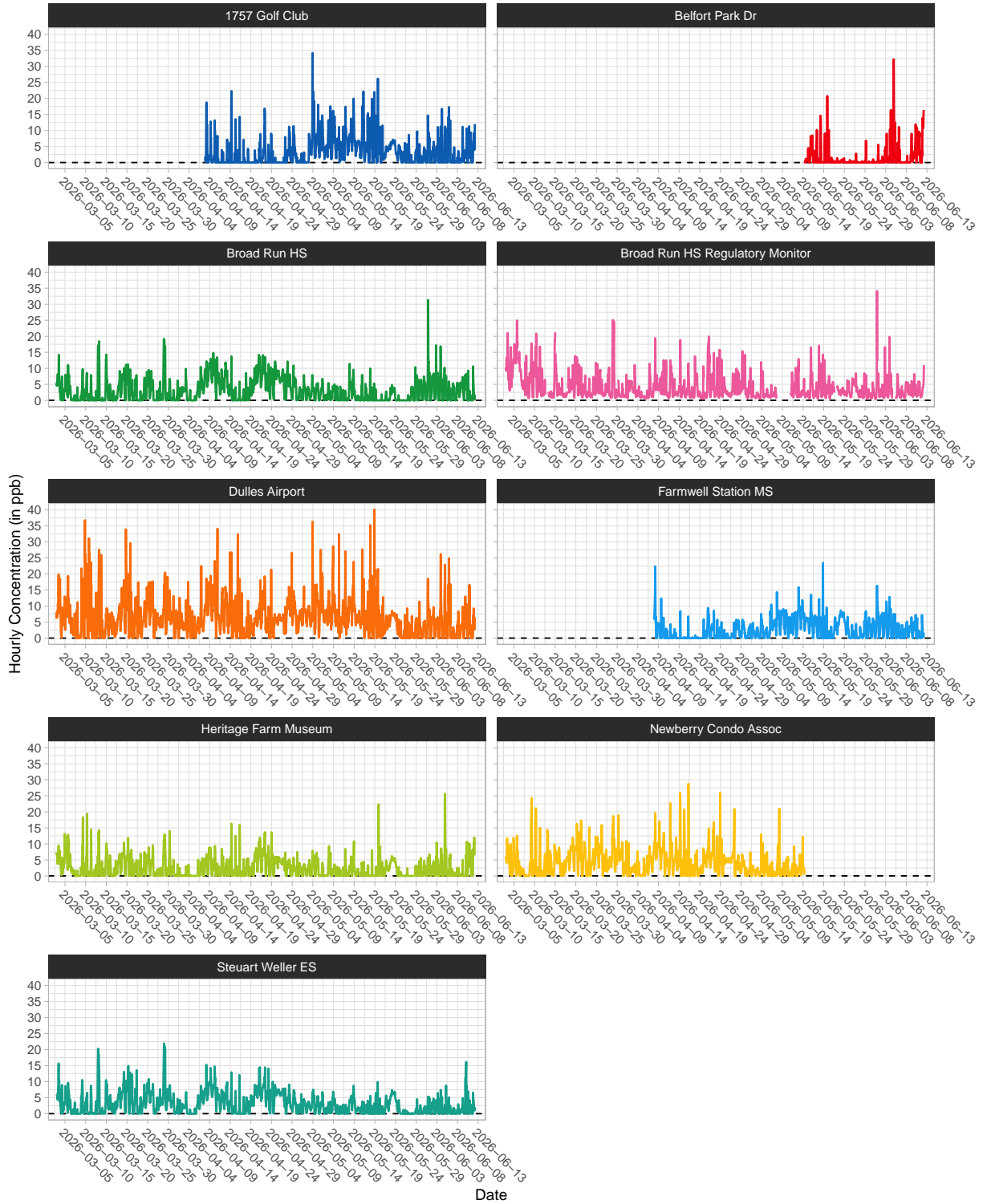
1. The 98th percentile of 1-hour daily maximum concentrations of NO_2 may not exceed 100 parts per billion (ppb), when averaged over 3 years.
2. The yearly average of 1-hour NO_2 concentrations may not exceed 53 parts per billion (ppb).

The APEX/Kunak Air sensors measure NO_2 in parts per billion (ppb); Virginia DEQ's regulatory NO_2 analyzers also measure NO_2 in ppb. The closest NO_2 regulatory monitoring site is at Broad Run HS in Loudoun County, where a regulatory NO_2 monitor and an APEX/Kunak sensor (APEX Broad Run HS) are collocated.

The APEX/Kunak sensors at the 1757 Golf Course and Farmwell Station MS were installed on April 8, 2026; therefore, these sites only have data beginning April 8, 2026. The sensor at Belfort Park Dr. was installed on May 14, 2026, and data collection for that sensor begins on that day. Data collection for Newberry Condo Assoc. ended on May 14, 2026.

NO2 Hourly Average Concentrations Loudoun County

Hourly 98th-percentile NO2 NAAQS limit is 100 ppb



The above time-series graph shows a moderate amount of agreement between sensors, with the highest NO_2 values on average measured at the Dulles Airport, the Broad

Run HS regulatory, and Newberry Condo Assoc. NO_2 sites. Due to data quality and instrumentation issues, data between May 8, 2026, and May 10, 2026, were voided at the Ashburn regulatory NO_2 monitor. The full statistical analysis can be seen in the violin plot and the statistical summary table below:

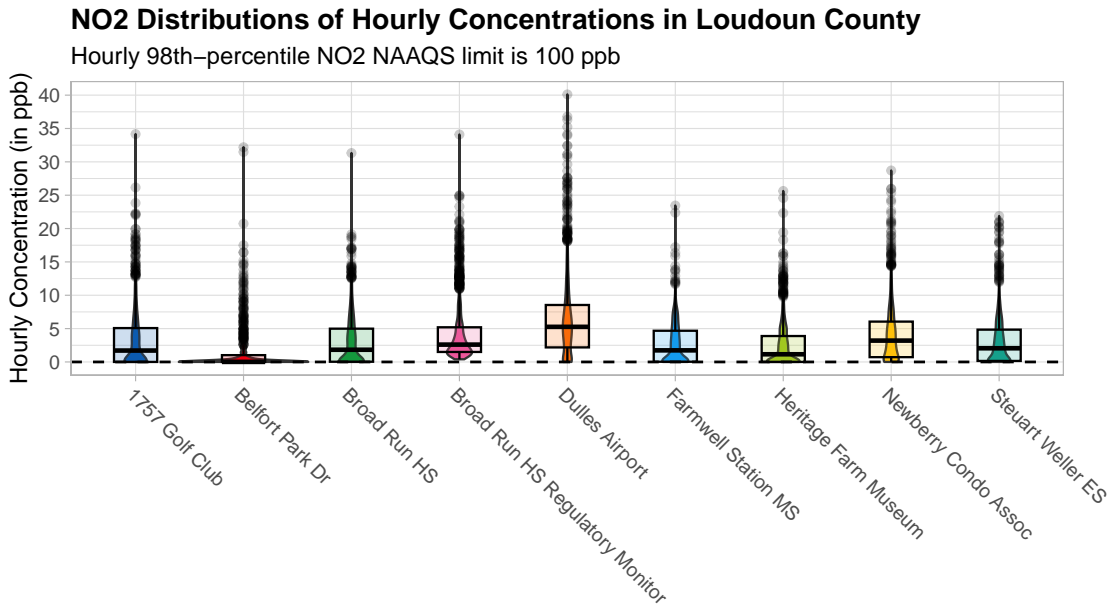


Table 2: NO2 Hourly Concentrations Statistical Summary, Loudoun County (in ppb)

Site	mean	standard_deviation	median	percentile_98
1757 Golf Club	3.3	4.2	1.7	15.8
Belfort Park Dr	1.6	3.5	0.0	12.6
Broad Run HS	3.0	3.5	1.8	12.1
Broad Run HS Regulatory Monitor	4.0	3.8	2.6	16.0
Dulles Airport	6.1	5.4	5.3	20.4
Farmwell Station MS	2.7	3.0	1.7	9.5
Heritage Farm Museum	2.3	3.0	1.1	10.6
Newberry Condo Assoc	4.1	4.1	3.2	15.8
Steuart Weller ES	3.0	3.3	2.0	11.5

Mean values across all sites are below 10 ppb, with the highest at Dulles Airport, followed by Newberry Condo Assoc. and the Broad Run HS regulatory monitor. The hourly 98th percentile values are low (in the 9 - 25 ppb range), compared with the NAAQS Hourly 98th percentile limit of 100 ppb.

3.1 Collocation Statistics: Broad Run HS NO2

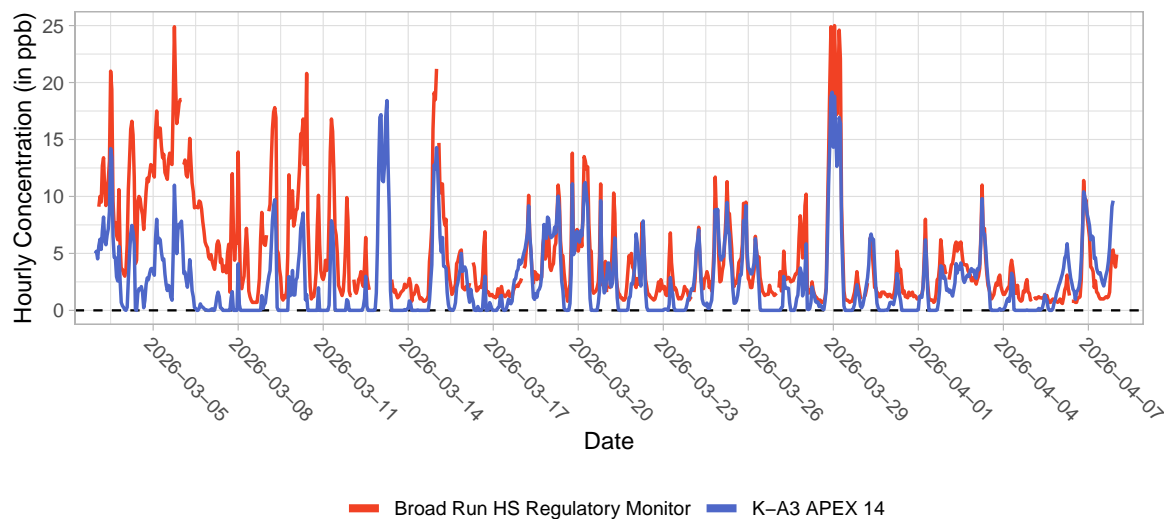
Because the Broad Run HS NO_2 regulatory monitor and the APEX/Kunak sensor at Broad Run HS are collocated, a deeper statistical analysis can be performed to compare the accuracy and correlation between the two analyzers. In order to get a sense of the general quality of the APEX/Kunak sensors, two sensors were rotated through to be collocated at Broad Run HS.

1. From March 3, 2026 - April 8, 2026, the APEX 14 sensor was collocated at Broad Run HS.
2. From April 8, 2026 - present, the APEX 5 sensor was collocated at Broad Run HS.

The data from each sensor was separated out and is presented below. First, the time-series graphs are compared to get a general view of agreement. In an ideal, perfect scenario the sensor data and the regulatory monitor data would lie completely on top of each other since they are measuring the same pollutant at the same place and time. Because no measurement system is truly perfect, and as the APEX/Kunak sensor relies on an entirely different NO_2 measurement method, there are some differences between the concentrations measured between the two analyzers, with the Broad Run HS regulatory monitor generally measuring higher concentrations compared to both sensors.

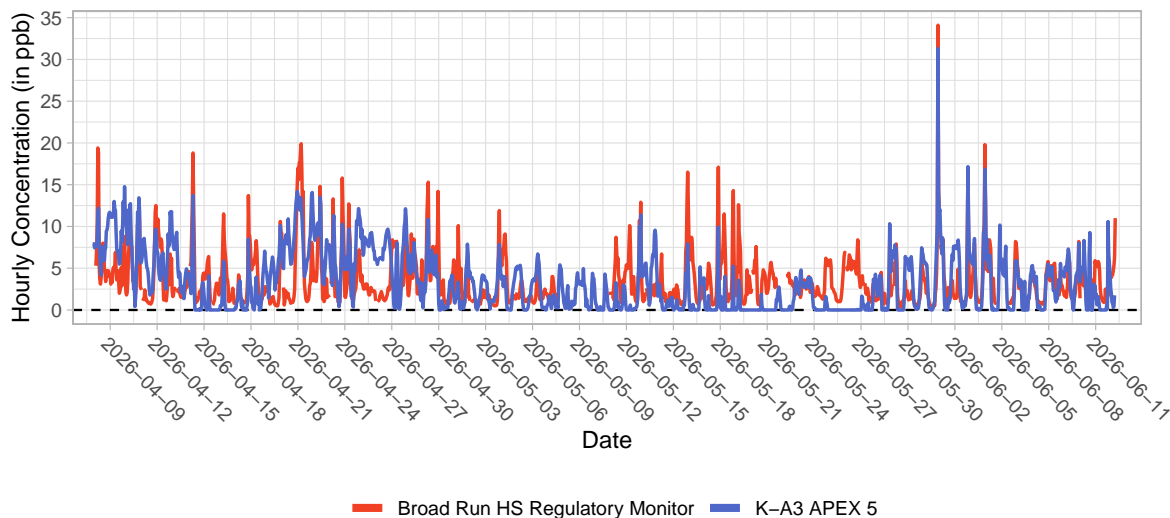
NO2 Hourly Avg Concentrations at Collocated Broad Run HS Site, APEX 14

Hourly 98th-percentile NO2 NAAQS limit is 100 ppb



NO₂ Hourly Avg Concentrations at Collocated Broad Run HS Site, APEX 5

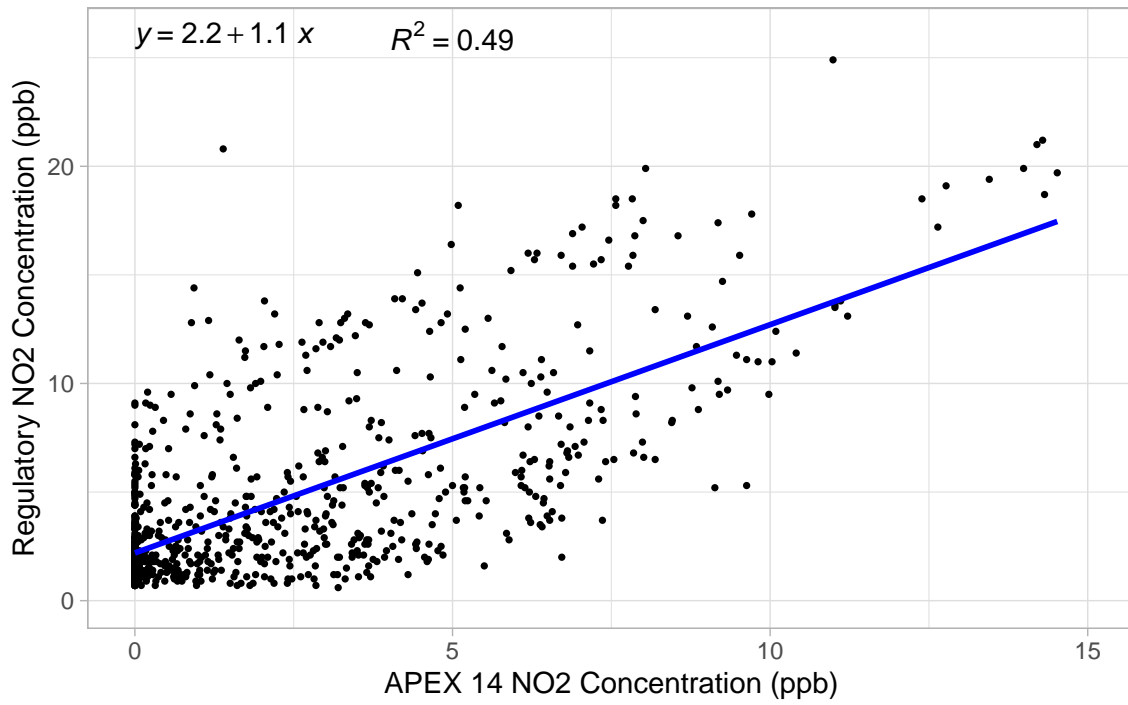
Hourly 98th-percentile NO₂ NAAQS limit is 100 ppb



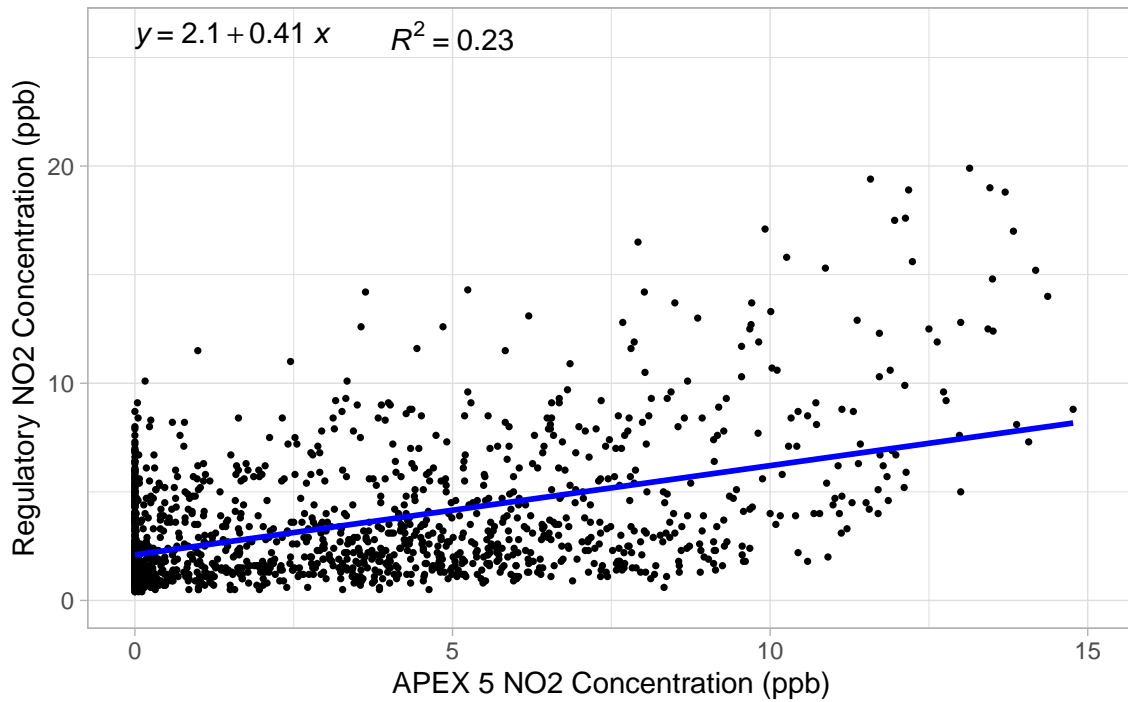
A [scatter plot](#) can also be used to compare concentrations measured by the APEX sensors with those from the Broad Run HS regulatory NO_2 monitor. In this plot, the APEX sensor readings are placed on the x axis and the regulatory monitor readings on the y axis. This allows for a visual assessment of how closely the two instruments agree. If the measurements matched perfectly, all points would fall along a single straight line.

The scatter plots below show that the APEX 5 sensor does not align closely with the Broad Run HS regulatory (T500u) monitor. This is reflected in the relatively low R^2 value, which indicates a weaker correlation and a poorer fit of the linear trend line. The best-fit line is shown in blue. In comparison, the APEX 14 sensor displays a stronger relationship with the regulatory monitor, as indicated by its higher R^2 value. APEX 5 has now had a longer time period correlated with the Broad Run HS regulatory monitor compared to APEX 14. Despite this time difference, APEX 5's R^2 value remains low. This could be attributed to difficulty in sensor accuracy when reading lower NO_2 concentrations.

Broad Run HS: NO2 APEX 14 Sensor vs Regulatory Monitor



Broad Run HS: NO2 APEX 5 Sensor vs Regulatory Monitor



4 PM2.5 Hourly Concentrations: Loudoun County Sensor and Regulatory Monitor Data

The current National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ are set at two levels, corresponding to two different averaging times:

1. The yearly mean of 24-hr (daily) average $PM_{2.5}$ concentrations may not exceed 9.0 micrograms per cubic meter ($\mu g/m^3$), when averaged over 3 years.
2. The 98th percentile of 24-hr (daily) average $PM_{2.5}$ concentrations may not exceed 35.0 micrograms per cubic meter ($\mu g/m^3$), when averaged over 3 years.

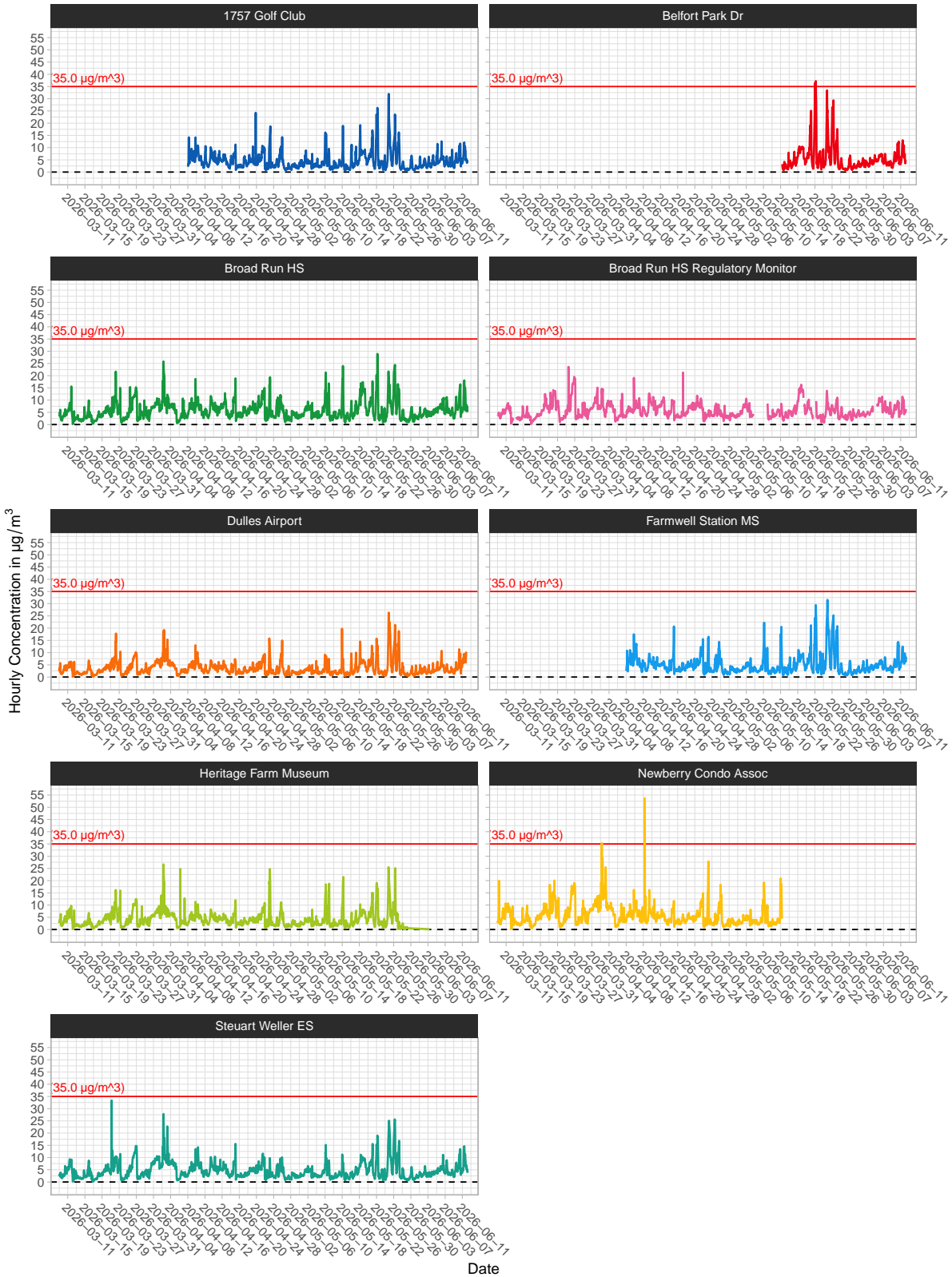
The APEX/Kunak Air sensors and Virginia DEQ's regulatory $PM_{2.5}$ monitors both measure $PM_{2.5}$ in micrograms per cubic meter ($\mu g/m^3$). The closest $PM_{2.5}$ regulatory monitoring site is at Broad Run HS in Loudoun County, which has a collocated regulatory $PM_{2.5}$ monitor and an APEX/Kunak sensor.³

The APEX/Kunak sensors at the 1757 Golf Course and Farmwell Station MS were installed on April 8, 2026; therefore, these sites only have data beginning April 8, 2026. The sensor at Belfort Park Dr. was installed on May 14, 2026, and data collection for that sensor begins on that day. Data collection for Newberry Condo Assoc. ended on May 14, 2026.

³Due to high humidity and data quality issues with the Kunak/APEX sensors, the first week of $PM_{2.5}$ sensor collected data (March 3, 2026 - March 8, 2026) was voided and is not included in this analysis.

PM2.5 Hourly Average Concentrations in Loudoun County

24-hr Avg 98th-percentile PM2.5 NAAQS limit is 35.0 $\mu\text{g}/\text{m}^3$



Hourly concentrations greater than $35.0 \mu\text{g}/\text{m}^3$ do not represent exceedances of the $PM_{2.5}$ NAAQS, as NAAQS compliance is determined with the 98th percentiles of daily (24-hr) $PM_{2.5}$ averages.

Besides some localized and short-term spikes, the $PM_{2.5}$ data agrees very well between all the sensors and the Broad Run HS regulatory monitor. Due to data quality and instrumentation issues, data between May 7, 2026, and May 10, 2026, were voided at the Ashburn regulatory $PM_{2.5}$ monitor. $PM_{2.5}$ data from the Heritage Farm sensor stops after May 30, 2026, due to air flow failure in the particle sensor. This issue is ongoing, but the instrumentation team at Air Quality Monitoring plan to address it during the next site visit. Further statistical analysis can be seen below in the violin chart and the summary statistics table:

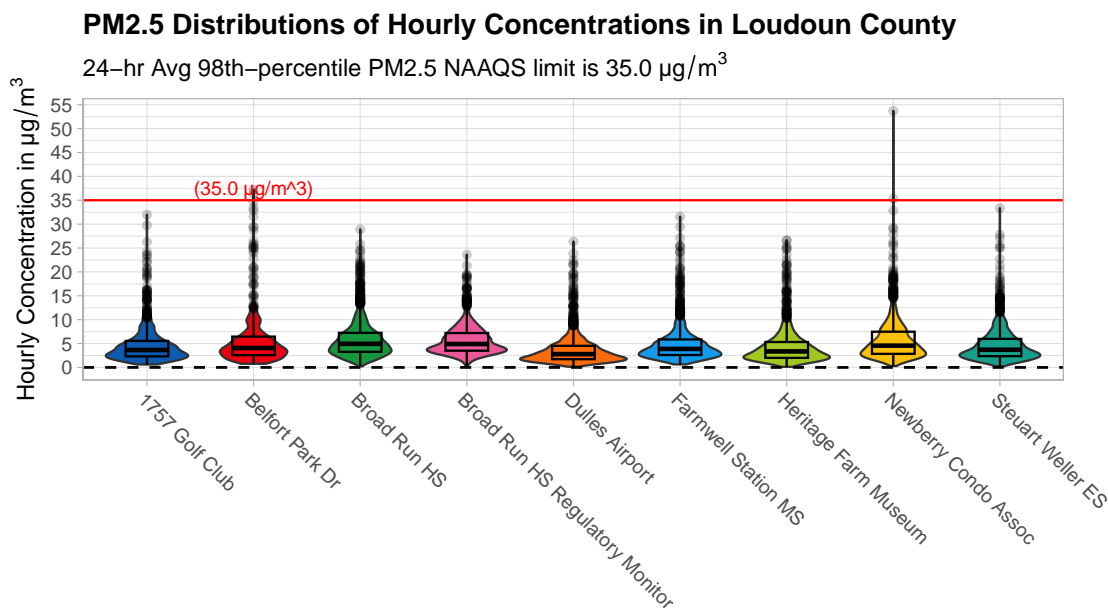


Table 3: PM_{2.5} Hourly Concentrations Statistical Summary

Site	mean	standard_deviation	median	percentile_98
1757 Golf Club	4.5	3.5	3.6	15.2
Belfort Park Dr	5.6	5.2	4.1	25.0
Broad Run HS	5.8	3.7	4.9	16.7
Broad Run HS Regulatory Monitor	5.7	3.0	4.9	14.0
Dulles Airport	3.6	2.9	2.8	12.6
Farmwell Station MS	4.9	3.7	3.9	17.2
Heritage Farm Museum	4.2	3.4	3.4	15.6
Newberry Condo Assoc	5.7	4.3	4.6	18.1
Steuart Weller ES	4.6	3.2	3.7	13.8

The mean and median $PM_{2.5}$ concentrations for each site are all below $9.0 \mu g/m^3$. The Broad Run HS sensor measured the highest concentration out of the group, followed by the Broad Run HS regulatory monitor and Newberry Condo Assoc. sensor. All sensors' 98th percentile values, except Belfort Park Dr., were below $20 \mu g/m^3$. The 98th percentile value for Belfort Park Dr. was still below $35 \mu g/m^3$.

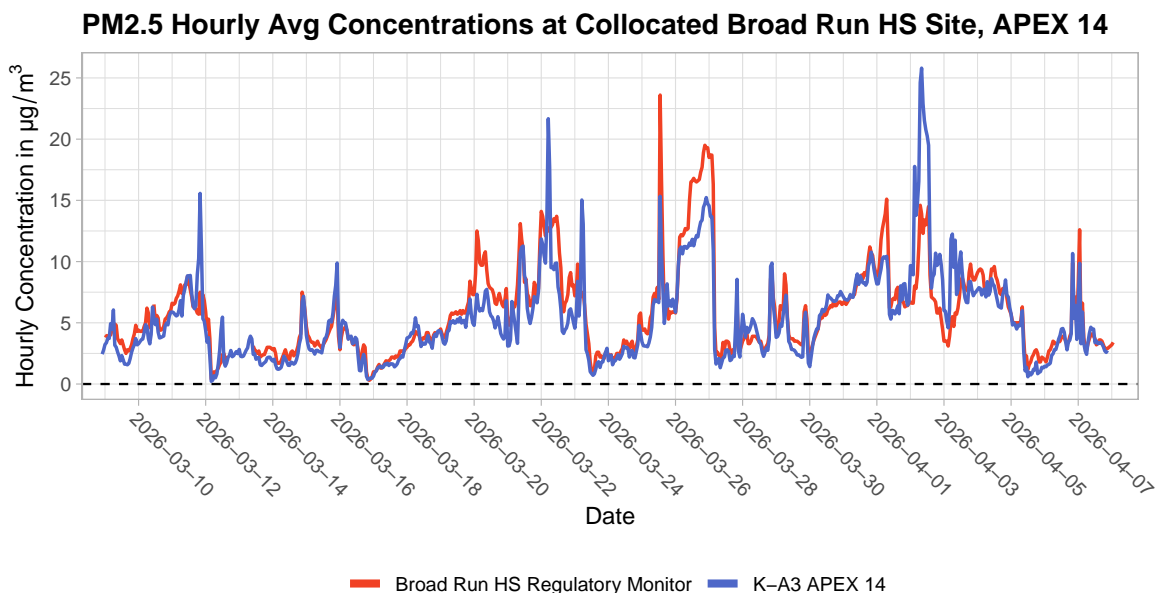
4.1 Collocation Statistics: Broad Run HS $PM_{2.5}$

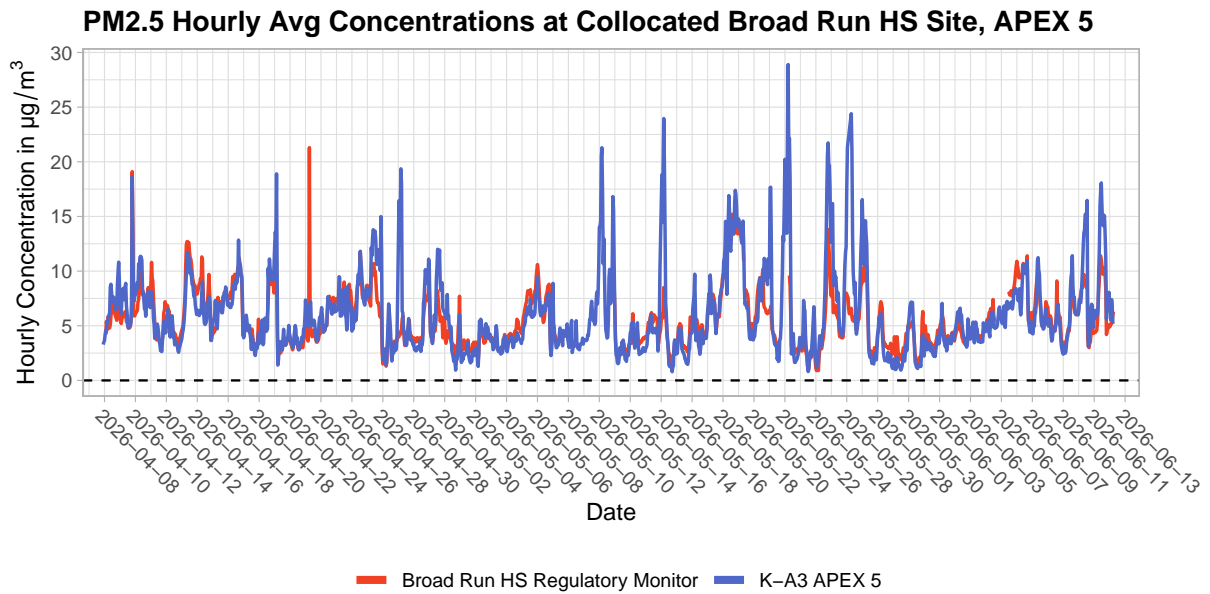
As with the NO_2 data, the APEX 14 sensor was collocated with the Broad Run HS $PM_{2.5}$ regulatory monitor for a period of time before being swapped with the APEX 5 sensor - which is currently collocated with the Broad Run HS $PM_{2.5}$ regulatory monitor.

The time-periods of collocation were the same for $PM_{2.5}$ as they were for NO_2 :

1. From March 3, 2026 - April 8, 2026, the APEX 14 sensor was collocated at Broad Run HS.
2. From April 8, 2026 - present, the APEX 5 sensor was collocated at Broad Run HS.

Again, we can compare the time-series to get a general view of agreement. In the graphs below, the readings from the APEX sensors and the regulatory $PM_{2.5}$ monitor were overlaid on each other. AS we can see in the graphs, the sensor data and the regulatory monitor are close, with the regulatory monitor reading slightly higher except for a few spikes in the sensor data.

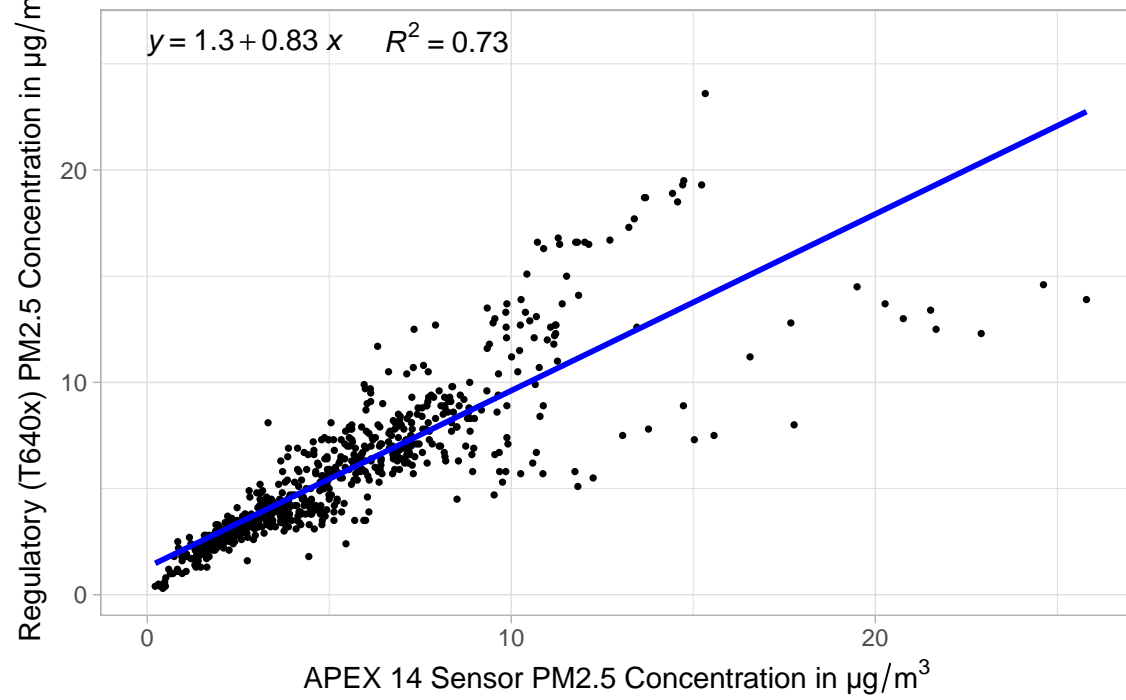




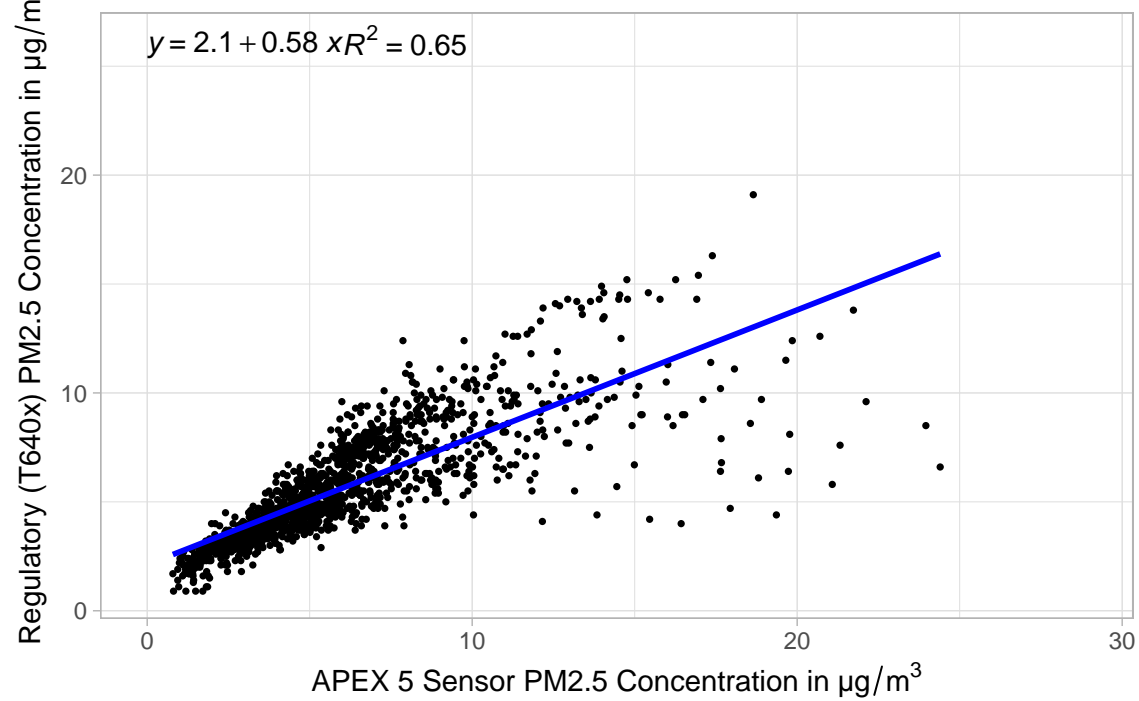
As with the NO_2 data, scatter plots were created for the APEX 5 and APEX 14 sensors. Both scatter plots show that data from the APEX $PM_{2.5}$ sensors do not perfectly match the data from the Broad Run HS regulatory (T640x) monitor, although the $PM_{2.5}$ data from the sensors are more accurate compared to the NO_2 sensor data.

Notably, the R^2 values for the $PM_{2.5}$ data are much higher for both collocated APEX/Kunak sensors, indicating stronger correlations with the $PM_{2.5}$ data between the APEX/Kunak sensors and the DEQ Broad Run HS regulatory monitor. At higher concentration values for $PM_{2.5}$, differences between the sensor and regulatory monitor widen, as reflected in the scatter plots below.

APEX 14 Sensor vs Regulatory Monitor PM2.5 Concentration



APEX 5 Sensor vs Regulatory Monitor PM2.5 Concentration



5 PM_{2.5} 24-hour (daily) Concentrations: Loudoun County Sensor and Regulatory Monitor Data

As the *PM*_{2.5} NAAQS are given in terms of the 24-hour (daily) concentrations, the daily 24-hr average data is presented below, in a time-series and a distribution (violin plot) format.

The current National Ambient Air Quality Standards (NAAQS) for *PM*_{2.5} are set at two levels, corresponding to two different averaging times:

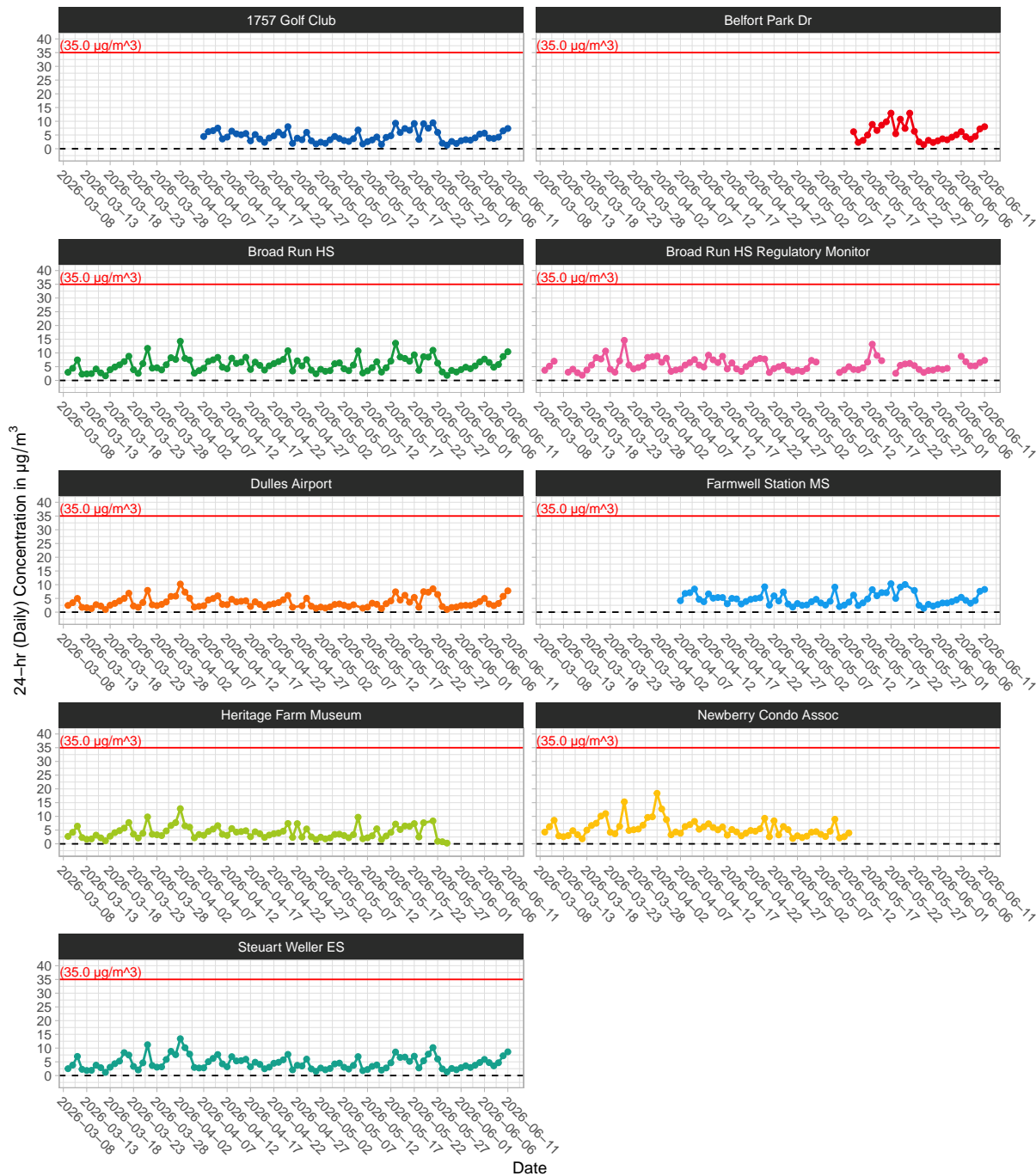
1. The yearly mean of 24-hr (daily) average *PM*_{2.5} concentrations may not exceed 9.0 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), when averaged over 3 years.
2. The 98th percentile of 24-hr (daily) average *PM*_{2.5} concentrations may not exceed 35.0 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), when averaged over 3 years.

At least 18 out of 24 hours are required to make a valid 24-hour (daily) *PM*_{2.5} average. Since this report was produced the morning of June 12, 2026, daily *PM*_{2.5} average data only goes until June 11, 2026.

The APEX/Kunak sensors at the 1757 Golf Course and Farmwell Station MS were installed on April 8, 2026; therefore, these sites only have data beginning April 8, 2026. The sensor at Belfort Park Dr. was installed on May 14, 2026, and data collection for that sensor begins on that day. Data collection for Newberry Condo Assoc. ended on May 14, 2026.

PM2.5 24-hr (Daily) Average Concentrations in Loudoun County

24-hr Avg 98th-percentile PM2.5 NAAQS limit is $35.0 \mu\text{g}/\text{m}^3$



Daily concentrations across all sensor sites and the Broad Run HS Regulatory monitor lie well below the $35.0 \mu\text{g}/\text{m}^3$ limit for $PM_{2.5}$.

The violin plot below shows the distributions and median of all sensor data, as well as the Broad Run HS regulatory monitor data. The full statistical analysis for the 24-hour (Daily)

$PM_{2.5}$ concentrations are presented in a table below the violin plot.

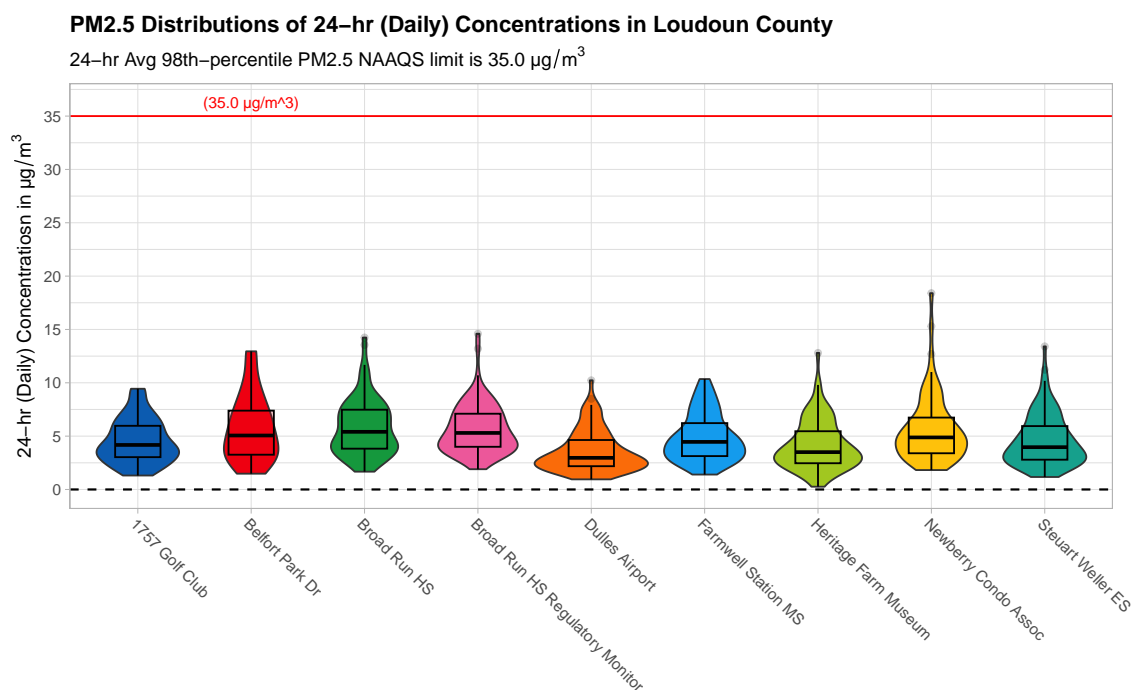


Table 4: PM_{2.5} 24-Hour (Daily) Concentrations Statistical Summary

Site	mean	standard_deviation	median	percentile_98
1757 Golf Club	4.6	2.1	4.2	9.3
Belfort Park Dr	5.8	3.1	5.1	12.9
Broad Run HS	5.8	2.6	5.4	11.9
Broad Run HS Regulatory Monitor	5.7	2.3	5.3	11.5
Dulles Airport	3.6	1.9	3.0	8.0
Farmwell Station MS	4.9	2.2	4.5	9.8
Heritage Farm Museum	4.2	2.3	3.5	9.7
Newberry Condo Assoc	5.7	3.1	4.9	14.5
Stuart Weller ES	4.6	2.4	4.0	10.3

As the above table and violin plot illustrates, the 98th percentile concentrations of the daily $PM_{2.5}$ averages are well below the 24-hr 98th percentile $PM_{2.5}$ NAAQS limit of 35.0 $\mu\text{g}/\text{m}^3$. Additionally, the mean values are also well below the daily (24-hr) yearly average $PM_{2.5}$ NAAQS limit of 9.0 $\mu\text{g}/\text{m}^3$.

6 Wind Speed and Direction

Below is a wind rose from Dulles International Airport, directly South/Southwest of AQM's study area.



Windrose Plot for [IAD] WASHINGTON/DULLES
 Obs Between: 03 Mar 2026 01:52 AM - 12 Jun 2026 06:52 AM America/New_York
 ↳ constraints: 12 AM-6 AM

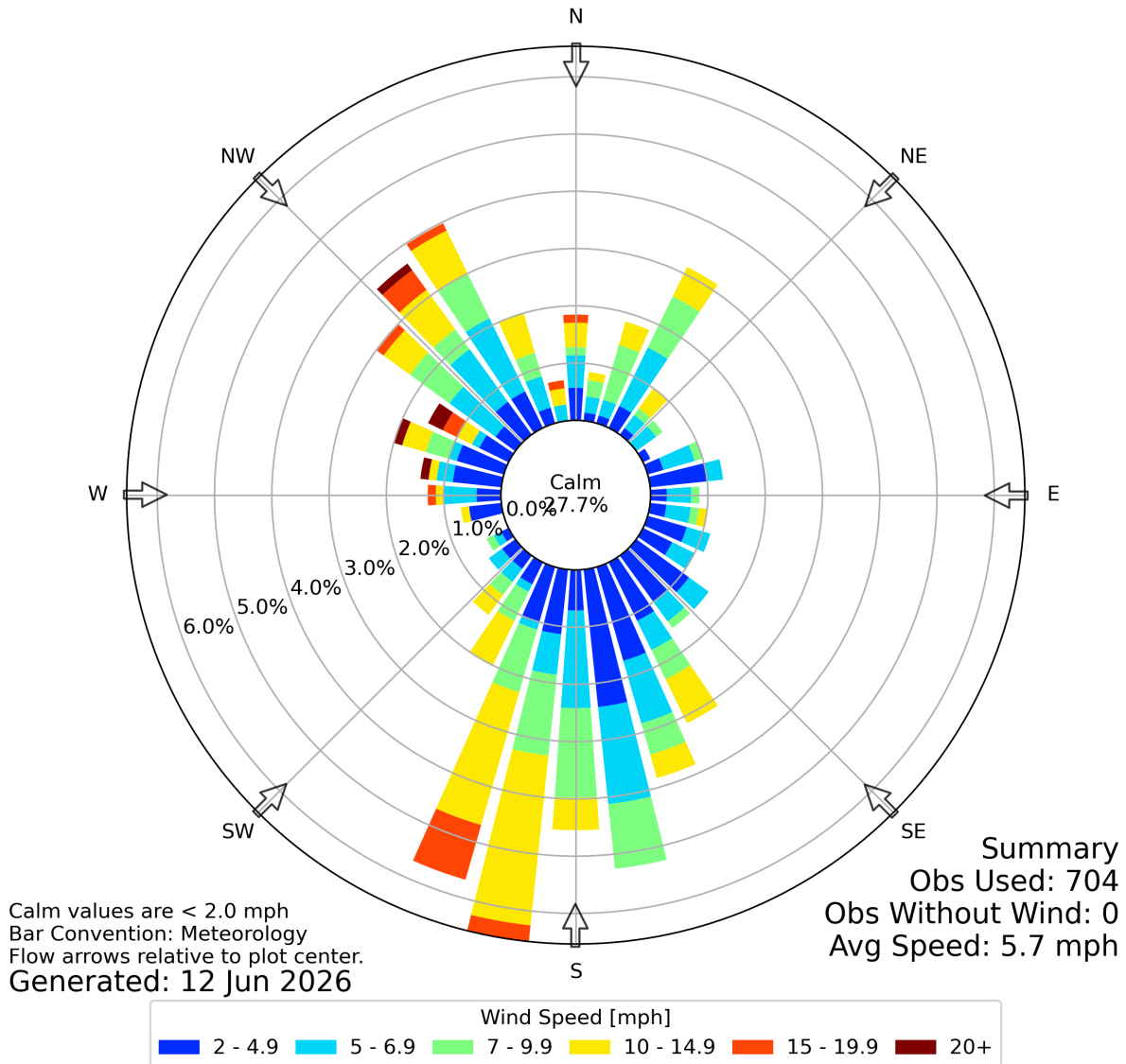


Figure 3: Wind Rose from Dulles Airport.

Wind speeds and directions during the study period show most winds came from either the South-Southwest or Northwest direction. This suggests that AQM's Broad Run HS and Dulles sites are good upwind sites with regard to Loudoun County's "Data Center Alley."