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Air Quality Monitoring Report:

Juneau, Alaska

Floyd Dryden Middle School

2010-2015 Data Summary

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Table of Contents

List of Tables

Appendix C: Site Photos and Information

List of Figures

Appendix A: PM2.5

Appendix B: PM_{10}

Appendix C: Site Photos and Information

Executive Summary

The Alaska Department of Environmental Conservation (DEC) has been mandated by the legislature to evaluate, assess, and mediate environmental issues that may affect the health and welfare of residents within the state. To further these objectives, the Air Quality Division of DEC established a statewide air monitoring network. The network currently consists of sites in Juneau, Anchorage, Fairbanks, and the Matanuska-Susitna Valley. This report provides information about air monitoring in Juneau, Alaska from 2010 through 2015.

DEC has been monitoring particulate matter (PM) in Juneau since the mid-1980s. DEC's Air Quality efforts in Juneau were started in part due to public concerns about wood smoke in the winter and road dust throughout the year. Wood smoke is a well-known contributor to elevated $PM_{2.5}$ concentrations (particulate matter less than or equal to 2.5 micrometers in diameter), while road dust primarily contributes to elevated PM_{10} concentrations (particulate matter less than or equal to 10 micrometers in diameter). The City and Borough of Juneau paved most roads as well as instituted aggressive wood smoke controls during the 1990's which reduced PM levels below State[1] and National Ambient Air Quality Standards (NAAQS)[2]. Juneau is currently in compliance for both the $PM_{2.5}$ and PM_{10} NAAQS.

The NAAQS for $PM_{2.5}$ is an annual mean (averaged over 3 years) of 12 µg/m^3 and a 24-hour average of 35 µg/m^3. In Juneau, $PM_{2.5}$ has been monitored since 1999. Data from 2010 to 2015 shows that over the 6 year period, the average $PM_{2.5}$ 24-hour value was 7.0 µg/m^3. The largest 24-hour average over this period was a value of 46.9 µg/m^3 recorded in 2014. The $PM_{2.5}$ winter average (October 1st through April 30th) over this period was 9.0 µg/m^3 with highs of approximately 38 µg/m^3. The $PM_{2.5}$ summer average (May 1st through September 30th) over this period was 5.1 µg/m^3 with highs of 18.8 µg/m^3.

The NAAQS for PM_{10} is a 24-hour average of 150 µg/m^3. At Juneau's Mendenhall Valley monitoring site, PM_{10} highs dropped from approximately 80 µg/m^3 to 30 µg/m^3 between the early 1990s and the late 2000s. Over the last six years (2010 to 2015), the average 24-hour PM_{10} value is 9 µg/m^3. The maximum 24-hour average concentration recorded over this period was 44 µg/m^3 in 2014.

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[1] Department of Environmental Conservation, 18 AAC 50 Air Quality Control (State of Alaska: 2016),
dec.alaska.gov/commish/regulations/pdfs/18 AAC 50.pdf

[2] US Environmental Protection Agency, *NAAQS Table* (2016),
epa.gov/criteria-air-pollutants/naaqs-table

Introduction

The Alaska State Legislature has mandated the Alaska Department of Environmental Conservation (DEC) to assess, evaluate, and mediate environmental issues that may affect the health and welfare of residents within the state (Title 46 of the Alaska Statutes)[3]. A statewide air monitoring network has been established by the DEC Division of Air Quality. DEC's network is currently comprised of sites in Juneau, Anchorage, Fairbanks, and the Mat-Su Valley as well as additional special purpose or temporary sites. This report provides information about air monitoring in Juneau, specifically the Floyd Dryden Middle School monitoring site located in the Mendenhall Valley.

A great deal of effort is invested initially to select a monitoring location for which the collected data will represent a larger geographic area of pollutant exposure. In Juneau, this means that data collected at the Mendenhall Valley monitoring site are generally considered to represent air quality conditions at other locations throughout the Mendenhall Valley. This does not necessarily mean that these concentrations are homogeneous throughout the valley, but that similar daily concentrations are expected to occur at other locations at differing time periods when compared with levels measured at the site. Air quality conditions at other Juneau locations outside of the Mendenhall Valley are believed to generally have better air quality than inside of the valley.

Short-term exposure is an air quality issue of concern in Alaska. Short-term meteorological conditions can result in air pollutants being trapped in a specific area or transported to an area in a relatively concentrated form. Consequently, the probability of observing pollutant concentrations that exceed health standards is more likely for short-term averaging periods than for standards established for annual average exposures. Since the worst-case, short-term conditions are irregular events, a monitoring project may need to span several months, or even years, in order to succeed in assessing the maximum pollution levels.

Air Quality Standards

The Clean Air Act (CAA) authorizes the EPA to set air quality standards to protect the health and welfare of the public and the environment. The law requires the EPA to periodically review and update the standards to ensure that health and environmental protection are adequately based on the scientific justifications. The EPA sets National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO), lead (Pb), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2). The EPA set primary standards for public health, including higher risk populations, and secondary standards for public welfare and environmental protection. The State of Alaska's Ambient Air Quality Standards match the national standards. At Floyd Dryden, the EPA requires that DEC monitor PM_{10}, and $PM_{2.5}$. Table 1 shows the primary and secondary NAAQS for particulate matter.

[3] State of Alaska, *Title 46.03.010. Water, Air, Energy, and Environmental Conservation* (Alaska Statutes: 2015), legis.state.ak.us/basis/statutes.asp#46

Table 1: Primary and Secondary NAAQS for particulate matter[4].

Pollutant	Primary/ Secondary	Standard	Averaging Time	Compliance Criteria
PM_{10}	P & S	150 µg/m^3	24-hours	Not to be exceeded more than once per year on average over 3 years.
$PM_{2.5}$	P & S	35 µg/m^3	24-hours	98th percentile, averaged over 3 years.
	P	12 µg/m^3	1 year	Annual mean, averaged over 3 years.
	S	15 µg/m^3	1 year	Annual mean, averaged over 3 years.

Each criteria pollutant is associated with a set of detrimental health effects including, but not limited to, irritation of the respiratory system, tightness in the chest, headache and fatigue, increased chance of respiratory infection, cardio vascular disease, cancer, and the aggravation of asthma. The elderly, children, and people with chronic respiratory illnesses or asthma are especially sensitive to air pollutants.

To determine compliance with the PM_{10} NAAQS, the maximum concentration recorded may not exceed the standard of 150 µg/m^3 more than once per year averaged over the past three consecutive years.

To determine compliance with the $PM_{2.5}$ NAAQS, the EPA employs a statistic called the design value. This method of determining if a region is in attainment or non-attainment with the NAAQS allows for multiple exceedances per year, as long as the distribution of sampled values is such that the design value is less than the NAAQS.

- An area complies with the 24-hour NAAQS if the design value is equal to or falls below 35 µg/m^3. The design value is an average of the 98th percentile values of the past three consecutive years. The 98th percentile value is the 24-hour concentration at which 98 percent of the data fall below.
- An area complies with the annual $PM_{2.5}$ NAAQS if the 3-year average of weighted annual means is less than 12 µg/m^3. Design values change from year to year depending on meteorological conditions and pollutant levels. This method makes compliance with the NAAQS less sensitive to extreme conditions that may not be typical of the local area.

The natural events policy allowed data exclusion for qualifying events. In 2007, EPA replaced the natural events policy with the exceptional events policy. This allows data arising from exceptional events to be excluded when determining compliance with the NAAQS. Exceptional events are events such as a wildfire or dust storm that the State can adequately demonstrate are of natural origin and could not be reasonably prevented or controlled.

If an area is unable to meet the air quality standards, the EPA may designate it as a non-attainment area under the Clean Air Act. This designation triggers a five-year window during which the state must gather additional data, submit a State Implementation Plan to the EPA

[4] US Environmental Protection Agency, *40 CFR part 50: National Primary and Secondary Air Quality Standards* (2012). ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr50_main_02.tpl

which includes control measures and describes a pathway for how the State will meet the standard at the end of that time. The EPA can levy sanctions against a designated non-attainment area and the State as a whole that may result in loss of federal highway funding and of economic development opportunities if state and local agencies do not make sufficient progress on mitigation of violations of the NAAQS.

Public Health

The earth's atmosphere is a complex mix of gases, vapors, and particles. Particles in the atmosphere are a mixture of solids and liquids. They can be nuclei around which vapors condense, can stick together and form larger particles, and may react chemically with other substances in the atmosphere to form different compounds. If particles suspended in the air get large enough, they fall to the ground. Those particles that remain suspended in the air are referred to as particulates.

Particulates can be classified by their chemical attributes but are commonly classified by their physical attributes. Different sized particles behave differently in the atmosphere and have different human health and environmental effects. Therefore, scientists find it useful to classify particulates according to size. The size definition most useful is one that directly relates to how particulates behave in air and the two properties that most influence behavior are shape and density.

For particulate matter, particle size is directly related to the potential adverse health effects. Different sized particles behave differently in the atmosphere and have different human health and environmental effects. Therefore, particulates are classified by aerodynamic diameter. Scientists have developed the term "aerodynamic diameter" that unites both shape and density in a single dimension. The aerodynamic diameter is the diameter of a spherical particle having a density of one gram per cubic centimeter (g/cm^3) and the same terminal settling velocity in the air as the particle of interest. A solid sphere, a hollow sphere, and an irregular shaped particle having different densities and different shapes can have the same aerodynamic diameter. Conversely, visually similar particles can have different aerodynamic diameters.

The smaller the particle, the greater the potential effect, as it can penetrate further into the respiratory system. PM_{10} is defined as a particle with an aerodynamic diameter of less than or equal to 10 µm. $PM_{2.5}$ is defined as a particle with an aerodynamic diameter of less than or equal to 2.5 µm. The body can naturally eliminate larger particles, thus they do not penetrate deeply into the respiratory tract.

PM_{10} often consists of common crustal materials such as dust from roads as well as volcanic ash, whereas $PM_{2.5}$ generally comes from combustion processes like industrial stack emissions, motor vehicles, wood smoke from forest fires or home heating, and chemical processes that emit gases containing sulfur dioxide and other volatile organic compounds. $PM_{2.5}$ also forms when pollutant gases combine in the atmosphere. Natural sources of suspended particulates include volcanic ash, glacial silt, windblown dust from unpaved roads and non-vegetated land, and ash from forest and grass fires. These natural sources contribute both fine and coarse particles to ambient air. Anthropogenic sources include industrial processes, mining, vehicles, and home heating.

$PM_{2.5}$ particles can lodge in the very small air sacs of the lungs, the alveoli. These particulates slow the transfer of oxygen and carbon dioxide and cause the heart to work harder to achieve the same rate of transfer. This effect is most noticeable in children, the elderly, and people with respiratory diseases such as bronchitis, asthma, emphysema, or heart problems. However, particulate inhalation affects all people and adverse effects may appear after repeated low concentration exposures or exposure to extremely high concentrations. $PM_{2.5}$ particulates may contain carcinogens and other harmful substances.

Floyd Dryden Middle School Monitoring

Background

The City and Borough of Juneau is located in Southeast Alaska and encompasses 2,702 square miles of land[5]. Juneau has a mild, maritime climate with average winter temperatures ranging from 25°F to 35°F and summer temperatures ranging from 44°F to 65°F. Annual precipitation varies throughout the region with 92 inches in downtown Juneau and 54 inches at the airport ten miles to the west. Snowfall averages 101 inches at the airport. The population at the 2010 census[6] was 31,275.

Historical Monitoring

DEC established several monitoring sites in the Lemon Creek and Mendenhall Valleys in the 1980s. These sites were established to determine whether the concentration of airborne pollutants in the valleys have the potential to impair the health of local residents. Periodic winter inversions[7], coupled with pollution-emitting activities, have resulted in noticeable ground based pollution. Citizen complaints have primarily centered on woodstove smoke and road dust. These particular pollutants are trapped within a specific locale of origin or transported to neighboring areas depending upon the localized meteorology.

In response to a variety of public concerns over degradation of air quality in Juneau during the early 1980s, DEC established several monitoring sites in the Mendenhall Valley. These sites were established to determine whether the concentration of airborne pollutants in these glacier valleys could be impairing the health of local residents. The Mendenhall Valley is located northwest of Juneau and is separated from the Lemon Creek Valley by Heintzelman Ridge, a 1000 plus meter ridgeline, oriented north to south. The valley is susceptible to wintertime inversions which trap locally polluted air, particularly during cold-weather events combined with minimal winds. Current efforts are focused on the long-term monitoring site

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[5] United States Census Bureau, *QuickFacts: Juneau City and Borough, Alaska* (U.S. Department of Commerce: 2015) census.gov/quickfacts/table/POP060210/0236400

[6] United States Census Bureau, *Juneau City and Borough, Alaska:* 2010 Census Interactive Population Search (2010) census.gov/2010census/popmap/ipmtext.php

[7] Winter Inversions are formed when normal atmospheric conditions (where air temperatures get cooler with increasing altitude) become inverted. Calm winds and cold temperatures can cause situations where the ground layer of air is colder than the air above it. This cold layer of air becomes pinned near the ground by the warmer layer of air above. During an inversion, particulate matter is trapped in the cold layer near the ground, resulting in poor air quality.

established at Floyd Dryden Middle School in the Mendenhall Valley. With the exception of forest fire smoke from Northwest Canada or Interior Alaska, pollution sources outside the valley are not expected to impact the monitoring site at Floyd Dryden Middle School. Sources of particulate matter within the Mendenhall Valley include: residential heating wood smoke; automobile exhaust; dust from ball fields, playgrounds, construction/land clearing sites; dust from vehicular tracking; and smoke from open burns.

EPA designated the Mendenhall Valley area of Juneau, Alaska as a moderate non-attainment area for the PM_{10} NAAQS equivalent, upon enactment of the federal Clean Air Act Amendments of 1990 (56 FR 56694, November 6, 1991). The non-attainment classification was based on violations of the 24-hour standard that occurred throughout the 1980s. Juneau is currently in limited maintenance status for PM_{10} and Floyd Dryden Middle School is in compliance for PM_{10}. The EPA fully approved Alaska's moderate PM_{10} non-attainment area plan as a State Implementation Plan (SIP) revision for the Mendenhall Valley PM_{10} non-attainment area in 1994 (Federal Register: March 24, 1994). Juneau has had no measured violation of EPA's PM_{10} standard since 1993. DEC has produced a Limited Maintenance Plan (LMP) for the Mendenhall Valley area of Juneau. The LMP provides contingency plans should Juneau ever experience a PM_{10} problem in the future and allows for Juneau to be designated as attainment for PM_{10}.

Monitoring Requirements

Juneau's Mendenhall Valley was designated non-attainment for PM_{10} on November 15, 1990. The two primary sources of PM_{10} required the community to develop two separate action plans to minimize exceedance of the standard. The first was to start paving roads to minimize the impact of fugitive dust and the second was to issue alert notices for people to curtail use of their woodstoves to reduce the impact from smoke. The EPA removed Juneau from their national list of nonattainment areas in February 2009[8] due to a successful effort by the City and Borough of Juneau and DEC to reduce road dust and limit wood smoke emissions.

Site Description

Currently, there is only one particulate monitoring site in Juneau which is operated by DEC staff. The site is located on top of Floyd Dryden Middle School east of the Mendenhall Loop Road between Tongass and Valley Streets in the Mendenhall Valley in Juneau, Alaska. Appendix A includes images of the site (Figures A-1 and A-2) and a table of site samplers (Table A-1).

The samplers are installed on a platform on the roof of Floyd Dryden Middle School, approximately 10 meters east of the doorway to the roof and 6 meters (19 feet) above ground level. There is a furnace flue approximately 20 meters (64 feet) to the east of the sample platform. There is also a nearby dryer vent exiting the building's north wall on the ground level below the current sampler location. The school has a penthouse which is approximately 4 meters above the roof and 6 meters (19 feet) to the south of the sample platform.

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[8] Alaska Department of Environmental Conservation, *Press Release Oct. 08, 2009: New data shows Juneau meets federal air quality standards* (2009), http://dec.alaska.gov/air/anpms/doc-anpms/Juneau_pm2-5_final.pdf.

The Floyd Dryden site is approximately 65 meters east of Mendenhall Loop Road which is the access road to the site. The roads and parking lot are paved and, in the winter, sanded for traction. The sample platform is sited on the north side of the school away from the parking lot.

A row of trees approximately 25 meters (80 feet), at the closest point, skirts the northern exposure of the site. The trees are approximately 15 meters (48 feet) tall, and come nearest to the monitoring site to the north at a distance of 25 meters. Airflow is generally uninterrupted with the exception of the trees to the north-northeast. These trees are not considered to be a barrier because most elevated PM concentrations occur during winter inversions and/or during times when the wind is less than 5 mph. Under these conditions the particulate concentrations are thought to have near homogeneous dispersion.

RESULTS

This report summarizes data collected at the Floyd Dryden Middle School from January 2010 through December 2015. The discussion that follows provides a summary statistical analysis and a brief discussion of the data. Yearly 24-hour average graphs and additional information can be found in Appendices B and C.

$PM_{2.5}$ Summary

$PM_{2.5}$ Compliance with NAAQS

DEC began sampling for $PM_{2.5}$ in 1999. Between 1999 and 2015 the maximum 24-hour concentration did not exceed 50 µg/m^3. In December 2006 the 24-hour PM10 NAAQS was lowered by the EPA from 65 µg/m^3 to 35 µg/m^3. Under the old standard there were no exceedances for $PM_{2.5}$. $PM_{2.5}$ jumped from maximums of around 30 µg/m^3 from prior to 2005 to over 40 µg/m^3 after 2005 and an average yearly maximum of 38 µg/m^3 between 2010 and 2015.

Under the 24-hour standard of 35 µg/m^3, there were 6 exceedances between 2010 and 2015. In 2010, there was an exceedance of 40.0 µg/m^3 on December 26th. Additionally, the $PM_{2.5}$ value recorded on December 12th was a borderline exceedance of 35.3 µg/m^3, but due to rounding did not actually exceed the standard. There were no exceedances of the NAAQS in 2011. The maximum value for 2011 was 29.7 µg/m^3 on January 10th. In 2012, there was a recorded exceedance of 42.0 µg/m^3 on December 25th. In 2013, there were 2 exceedances of 38.0 µg/m^3 on December 3rd and 35.7 µg/m^3 on December 8th. December 4th and 5th, 2014 recorded 2 exceedances of 46.9 µg/m^3 and 45.0 µg/m^3. There were no $PM_{2.5}$ exceedances recorded in 2015. The $PM_{2.5}$ maximum value was 31.4 µg/m^3, recorded on December 11th. Exceedances are highlighted red, underlined and in bold in Table 2 below.

At its inception in 1997, the $PM_{2.5}$ federal standard for the annual mean was set at 15 µg/m^3. In 2012, this was lowered to 12 µg/m^3. The $PM_{2.5}$ annual means for 1999 through 2015 were well below the $PM_{2.5}$ standard and in the single digits. Yearly annual means are listed in Table 2.

Table 2: $PM_{2.5}$ Means Media, and Maxima for Floyd Dryden 2010-2015

	24-hr NAAQS	Annual Mean	98th Percentile Values	1st Max	2nd Max
2010	35	8.7	27.3	**40.0**	**35.3**
2011	35	7.1	24.5	29.7	28.8
2012	35	6.4	23.6	**42.0**	31.6
2013	35	6.0	25.0	**38.1**	**35.7**
2014	35	7.5	28.1	**46.9**	**45.0**
2015	35	6.6	20.9	31.4	28.0

indicate numbers exceeding the $PM_{2.5}$ standard of 35 µg/m³

24-Hour and Annual Design Values for $PM_{2.5}$

The annual $PM_{2.5}$ design values are summarized in Table 3 below. Annual design values are calculated using the annual mean averaged with the two previous annual means. From 2010-2015, all the annual design values fall between 6.0 – 8.7 µg/m³, falling well below the NAAQS standard of 12 µg/m³.

The 24-hour average design value is a measure of compliance with the NAAQS. The 24-hour design value is the integer calculated by averaging the 98th percentile of the three consecutive years leading up to and including the year of the design value. The values are summarized below in Table 3. The 24-hour design values for 2010-2015 are all below the 35 µg/m³ criteria.

Table 3: $PM_{2.5}$ Annual Design Values and 24-hr Design Values for Floyd Dryden 2010-2015. Values in µg/m³.

	Annual mean	Annual NAAQS	Annual Design Value	98th Percentile Values	24-hr NAAQS	24-hr Design Value
2010	8.7	12	7.6*	27.3	35	30
2011	7.1	12	7.6*	24.5	35	28
2012	6.4	12	7.4	23.6	35	28
2013	6.0	12	6.5	25.0	35	28
2014	7.5	12	6.6	28.1	35	30
2015	6.6	12	6.7	20.9	35	29

*2009 only had 3 valid quarters of data.

Seasonal Trends for $PM_{2.5}$

As a general trend for Juneau, $PM_{2.5}$ shows a significant elevation in winter when wood heating is common and a minimum in summer. This is similar to the PM_{10} data discussed above. Unlike elevated PM_{10} levels which are mostly due to fugitive dust, elevated $PM_{2.5}$ levels are mostly due to smoke from wood burning and wildfires, vehicle exhaust, and industrial emissions. In the winter the Mendenhall Valley occasionally develops very stable air masses that tend to lead to inversion conditions lasting usually 2 to 5 days. These dry stable air masses trap smoke, vehicle exhaust, and power plant emissions. Generally during the summer months, a combination of reduced wood smoke from home heating and precipitation keeps the $PM_{2.5}$ concentration in the air to a minimum. Vertical mixing is more common. However during wildfire season, (May through August) spikes in $PM_{2.5}$ mirror the smoke from local slash burning and/or distant wildfires. Figure 1 shows 24-hr averages for $PM_{2.5}$ over 2010 to 2015. An individual annual graph for 2015 $PM_{2.5}$ data is shown in Figure 2 below. A complete set of individual annual graphs (2010 to 2015) is attached in Appendix B.

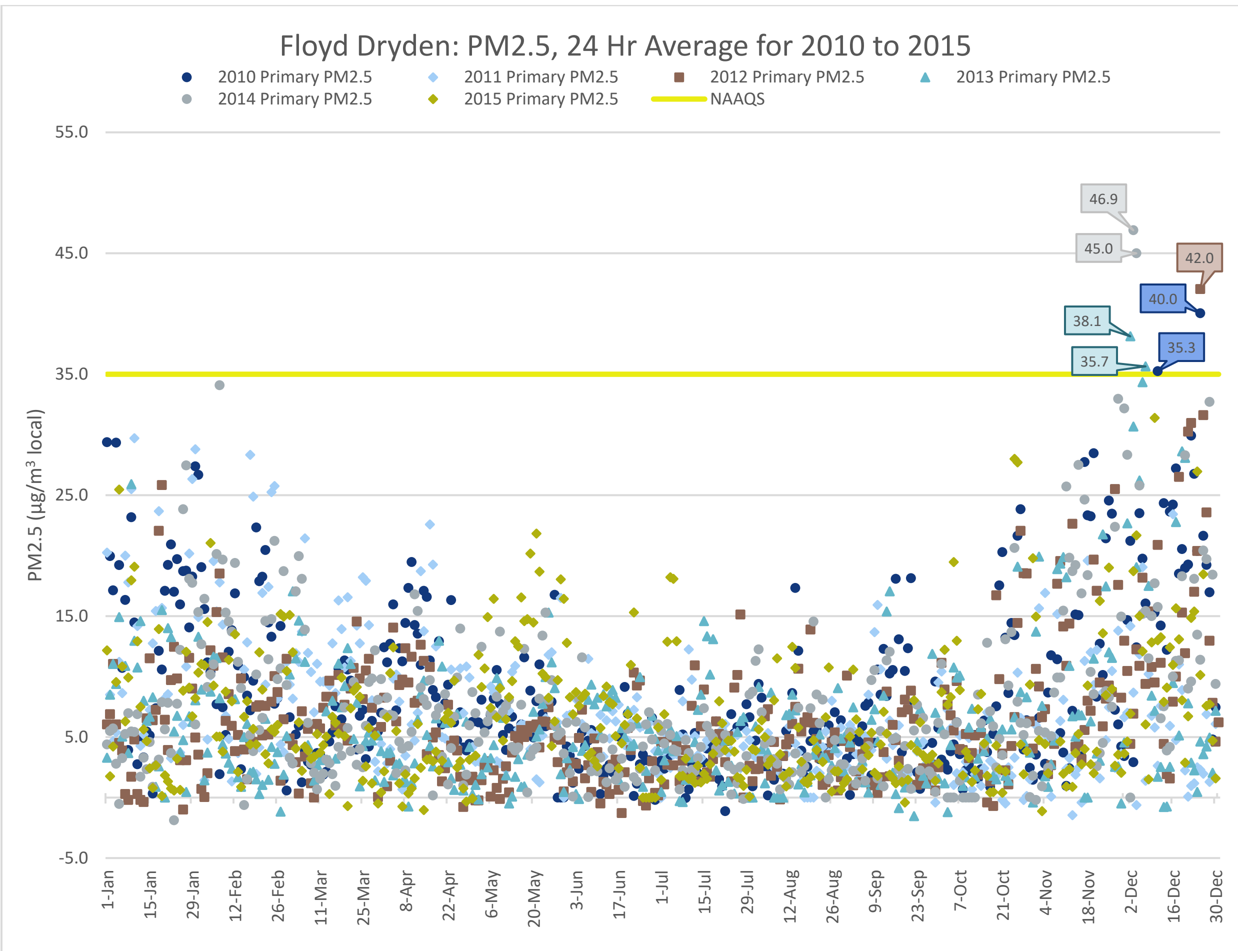

Figure 1: 24-hour averages for $PM_{2.5}$ over 2010 to 2015, Floyd Dryden. The yellow line is the NAAQS of 35 µg/m^3.

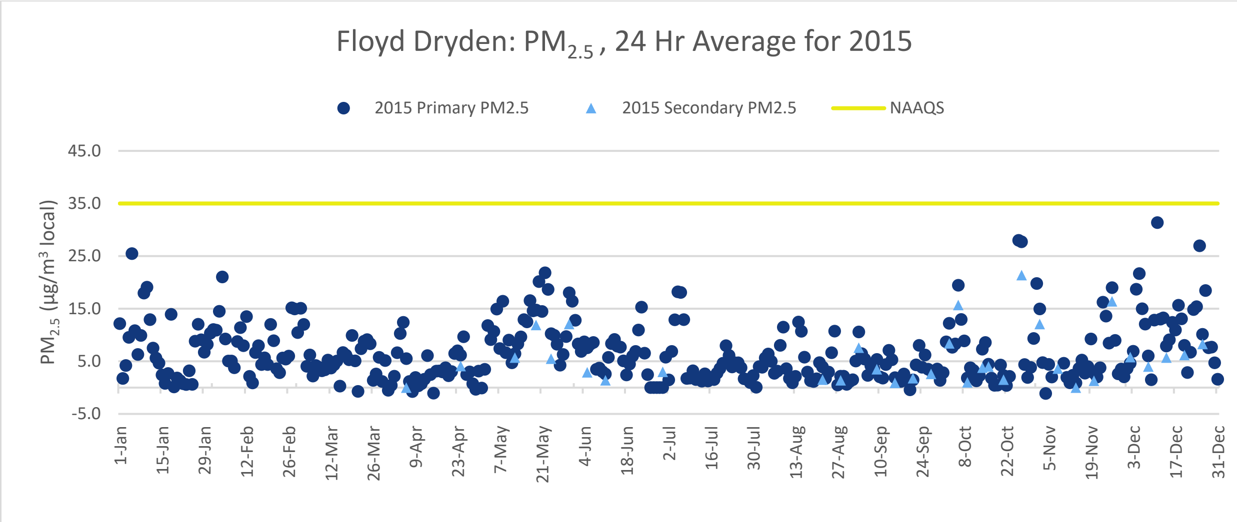

Figure 2: 24-hour average of $PM_{2.5}$ in 2015, Floyd Dryden. Maximum value: 31.4 µg/m^3. The yellow line is the NAAQS of 35 µg/m^3. The correlation between primary and secondary samples ≥ 3 µg/m^3 was 0.93 (19 pairs of samples).

Comparison of $PM_{2.5}$ FRM and Continuous Methods

The EPA designated the Met One BAM 1020 as a Class III Federal Equivalence Method (FEM) in 2008. To qualify as an FEM the instrument needs to meet performance criteria when compared to the FRM[9]. The performance criteria for Class III FEM approval for monitors must meet the key statistical metrics for multiplicative bias, the slope, between 0.9 and 1.1, and an additive bias, the intercept, between -2.00 and 2.00[10].

Using data from 2009 to 2011, the correlation between the Juneau $PM_{2.}$ FRM and FEM monitors was calculated. Results from the linear regression analysis were well within EPA requirements (See Figure 3) and, as a result, operation of the $PM_{2.5}$ FRM manual sampler was discontinued April 1, 2011. The FRM monitor was reinstated in Juneau on April 22nd 2015 to fulfill the EPA's collocated site requirements. Data points from 2015 were insufficient to again calculate the correlation between $PM_{2.5}$ FRM and FEM, however, results are expected to be similar to the 2009 to 2011 correlation.

[9] US Environmental Protection Agency, *40 CFR part 58.11e*: Ambient Air Quality Surveillance (2016), ecfr.gov/cgi-bin/text-idx?SID=f9aa9392842dc6d1a5656b682f14976d&mc=true&node=pt40.6.58&rgn=div5

[10] US Environmental Protection Agency, *40 CFR part 53 Subpart C Figure C-2* (2007), ecfr.gov/cgi-bin/text-idx?SID=f9aa9392842dc6d1a5656b682f14976d&mc=true&node=ap40.6.53_135.7&rgn=div9

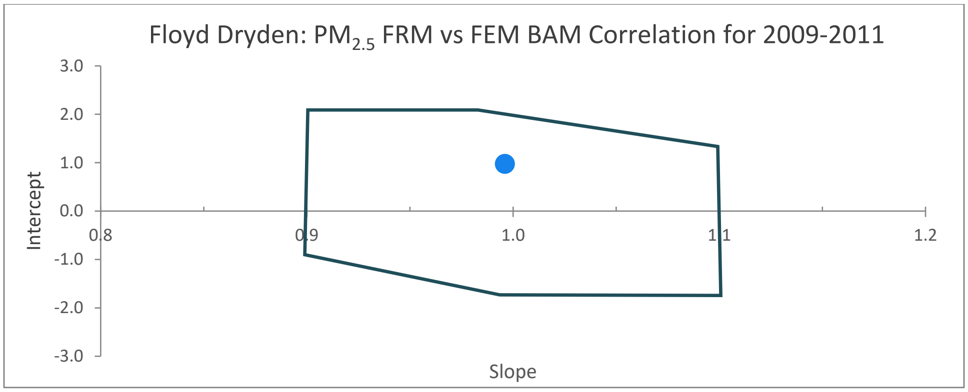

Figure 3: Floyd Dryden $PM_{2.5}$ FRM vs FEM BAM Correlation for 2009 to 2011.
Correlation slope = 0.996, intercept = 0.977.

PM_{10} Summary

PM_{10} Compliance with NAAQS

There is currently no NAAQS for a PM_{10} annual mean, however, PM_{10} annual means were all under the $PM_{2.5}$ NAAQS of 12 µg/m^3. The 24-hour NAAQS for PM_{10} is set at 150 µg/m^3, not to be exceeded more than once per year on average over three years[11]. When PM_{10} is not sampled for daily (as is the case at Floyd Dryden), an adjustment is made to correct for the possible effect of incomplete data and to estimate the number of exceedances not recorded in a calendar year (see Equation 1)[12]. This calculation is made quarterly to avoid a possible seasonal imbalance. Floyd Dryden has not exceeded the NAAQS limit since 1993. The highest value since was recorded in 1995 at 86 µg/m^3 (approximately 57% of the standard). Between 2010 and 2015, the highest recorded value was 44 µg/m^3 recorded in 2014.

Equation 1: $\left\{e_q = \left[(v_q)\left(\frac{N_q}{n_q}\right)\right]\right\}$, where;

e_q = the estimated number of exceedances for calendar quarter q;
v_q = the observed number of exceedances for calendar quarter q;
N_q = the number of days in calendar quarter q;
N_q = the number of days in calendar quarter q;
q = the index for calendar quarter, q = 1, 2, 3, or 4

Means, median, and maxima for PM_{10} are summarized in Table 5. The annual median is lower than the mean because the means incorporate the highest values whereas the medians just count the higher values. Since the statistical population of concentrations is not normally distributed, the higher values have a disproportionate effect on the value of the mean. In essence, the populations are skewed to the left or there is a tail of high values that does not

[11] US Environmental Protection Agency, *40 CFR part 50: National Primary and Secondary Air Quality Standards* (2012). ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr50_main_02.tpl

[12] US Environmental Protection Agency, *40 CFR part 50 Appendix K: Interpretation of the National Ambient Air Quality Standards for Particulate Matter* (2012). ecfr.gov/cgi-bin/text-idx?SID=b609ff6c40f2cadf713dcc1b7c0bd44c&mc=true&node=ap40.2.50_119.k&rgn=div9

make a normal distribution of values. Although the annual maxima are considerably higher than the means or medians, they do not exceed the NAAQS for PM_{10} (150 µg/m^3).

Table 3: PM_{10} Means, Media, and Maxima for Floyd Dryden 2010-2015. Values given in µg/m^3.

	24-hour NAAQS	1st Quarter Mean	2nd Quarter Mean	3rd Quarter Mean	4th Quarter Mean	Annual Mean	Annual Median	98th Percentile Values	1st Max	2nd Max
2010	150	11	10	8	9	9	8	27	28	27
2011	150	10	8	5	9	8	6	25	26	25
2012	150	9	5	6	8	7	6	23	28	20
2013	150	9	7	7	12	9	6	31	36	28
2014	150	15	9	7	10	10	7	40	44	36
2015	150	8	9	5	10	9	6	31	36	23

Seasonal Trends for PM_{10}

In general, PM_{10} increases in the winter due to fugitive dust from road sanding, and decreases during the summer. As the ground freezes in the fall before it snows, dust is blown off nearby unpaved roads. A similar process occurs in the spring when roads are sanded for traction and uncovered by melting. Thus, as more and more roads have been paved in Juneau, the overall dust, measured as PM_{10}, should have decreased throughout the years of monitoring from 1993 to 2015. In fact, the data show that winter PM_{10} did decrease with time. Winter highs in the 1990s were around 70-80 µg/m^3 and have progressively dropped to less than 40 µg/m^3 in the 2000s and 2010s. The wintertime trend from the beginning of monitoring has generally trended downward to lower PM_{10} values. Summer PM_{10} values show a lesser rate of decrease to average highs of approximately 19 µg/m^3 and a daily average of 5 µg/m^3 when looking at data from 2010 to 2015.

All PM_{10} data and graphs for each individual year are included in Appendix C. A graph of 24-hour averages from 2010 to 2015 is shown in Figure 4, and a typical yearly graph for PM_{10} is presented in Figure 5 below. Higher values are measured in the winter and lower values in the summer. This seasonal difference is attributed to increased road sanding in the winter. Frequent rain in the summer prevents dust from rising and so the PM_{10} values remain at a minimum.

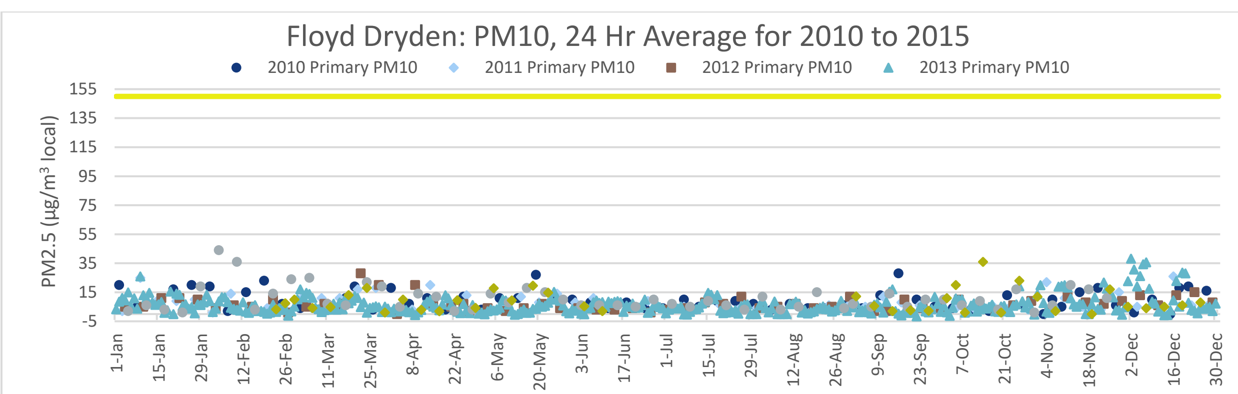

Figure 4: 24-hour averages for PM_{10} over 2010 to 2015, Floyd Dryden. The yellow line is the NAAQS of 150 µg/m^3.

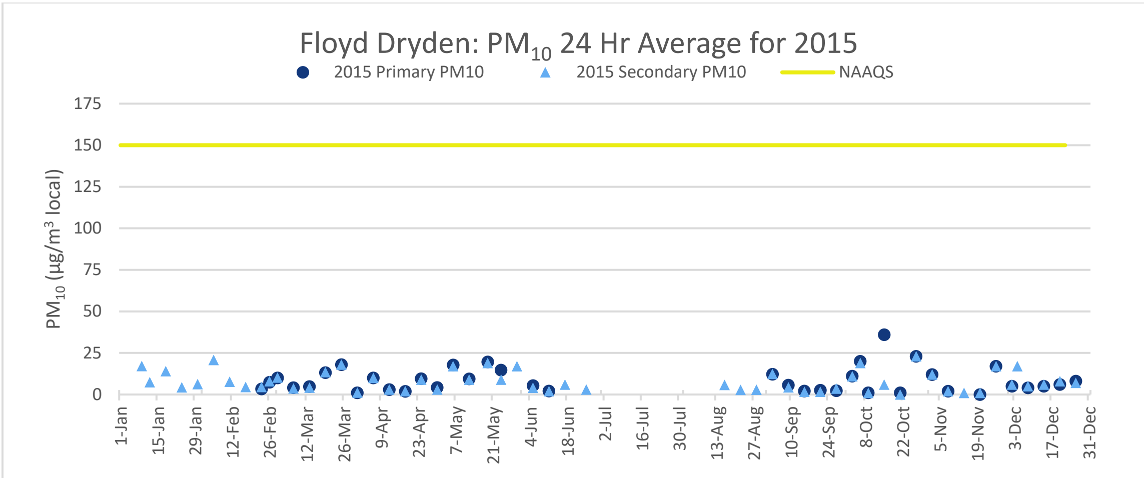

Figure 5: 24-hour average of PM_{10} in 2015, Floyd Dryden. Maximum value: 36 µg/m^3. The yellow line is the NAAQS of 150 µg/m^3. The correlation between primary and secondary samples ≥ 3 µg/m^3 was 0.41 (28 samples).

CONCLUSIONS

DEC monitors $PM_{2.5}$ at the Mendenhall Valley Monitoring Station (Floyd Dryden) to show attainment of the NAAQS. At Floyd Dryden $PM_{2.5}$ concentrations are generally below the NAAQS. Juneau is not designated as non-attainment for $PM_{2.5}$, however, occasional exceedances do occur in the winter months. To limit exceedances, the City and Borough of Juneau enforces wood burning bans on days where exceedances are more likely to occur. These include days when the weather forecast shows inversion conditions and when $PM_{2.5}$ concentrations reach a threshold level of 30 µg/m^3 and are expected to remain over 30 µg/m^3 for 24-hours if the burn ban is not put in place[13]. During a burn ban, the City and Borough of Juneau requires all wood burning (aside from wood pellet stoves) to cease until the ban is lifted. Fines are imposed by the city for those that fail to comply.

DEC is required by the EPA to monitor PM_{10} at the Mendenhall Monitoring Site for the second 10 years of its Limited Maintenance plan. The NAAQS 24-hour primary standard for PM_{10} has not been exceeded at the monitoring site since November 1993. The drop in PM_{10} levels after 1993 is largely attributed to the City and Borough of Juneau's effort to pave many of the streets in the Mendenhall Valley throughout the 1990s. As a requirement by the EPA after the Mendenhall Valley's non-attainment designation, the State of Alaska worked with the City and Borough of Juneau to produce a Limited Maintenance Plan[14] for the Mendenhall Valley.

[13] City and Borough of Juneau Division of Lands and Resources, *Air Quality-Open Burning (2016),* juneau.org/lands/woodsmoke.php

[14] Department of Environmental Conservation, *Juneau's Mendenhall Valley Proposed PM10 Limited Maintenance Plan (2009)*, dec.alaska.gov/air/anpms/SIP/SIPDocs/cbjPM10LMP09doc/CBJ PM10 LMP FINAL FEB 20 2009.pdf

Appendix A: Site Photos and Information

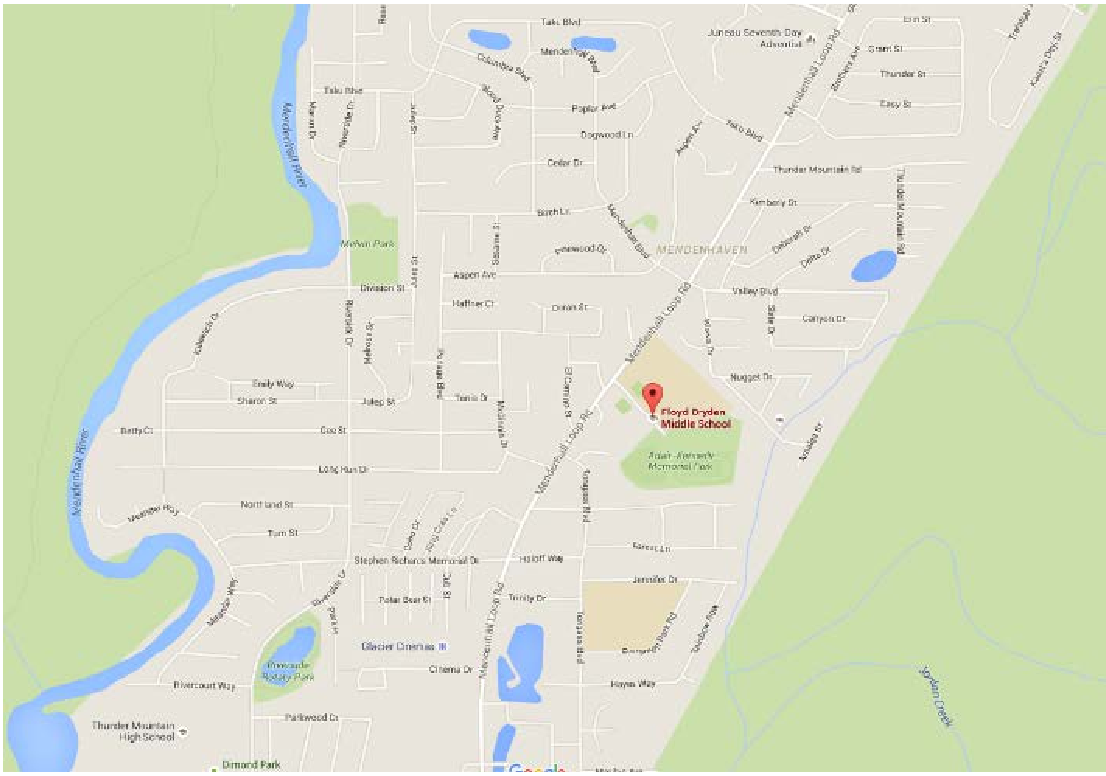

Figure A-1: Map and satellite view of Floyd Dryden Middle School (Google Maps ©2016). Site Coordinates, 58º 23’30” N., -134 º33’30” W., and 45 meters (143 feet) above sea level.

Figure A-2: View looking southeast towards the Floyd Dryden monitoring site on the roof of the school

Table A-1: List of samplers at the Floyd Dryden monitoring site.

Pollutant	Sampler	Manufacturer	Information
$PM_{2.5}$	Partisol 2000	Thermo Scientific	On April 1, 2008 the sampling schedule changed from 1-in-3 day to a 1-in-6 day schedule. The FRM Partisol was designated the PM2.5 primary monitor up until October 21, 2009.
$PM_{2.5}$	Beta Attenuation Monitor (BAM)	Met One Instruments	A single Beta Attenuation Monitor continuous monitor installed to provide information in real time for evaluating the Air Quality Index was designated as the PM2.5 primary monitor on October 21, 2009.
PM_{10}	Partisol 2000	Thermo Scientific	1 monitor installed on site as the secondary PM_{10} source.
PM_{10}	Partisol 2000i	Thermo Scientific	1 monitor installed on site as the primary PM_{10} source.

Appendix B: $PM_{2.5}$ Annual 24-Hour Averages

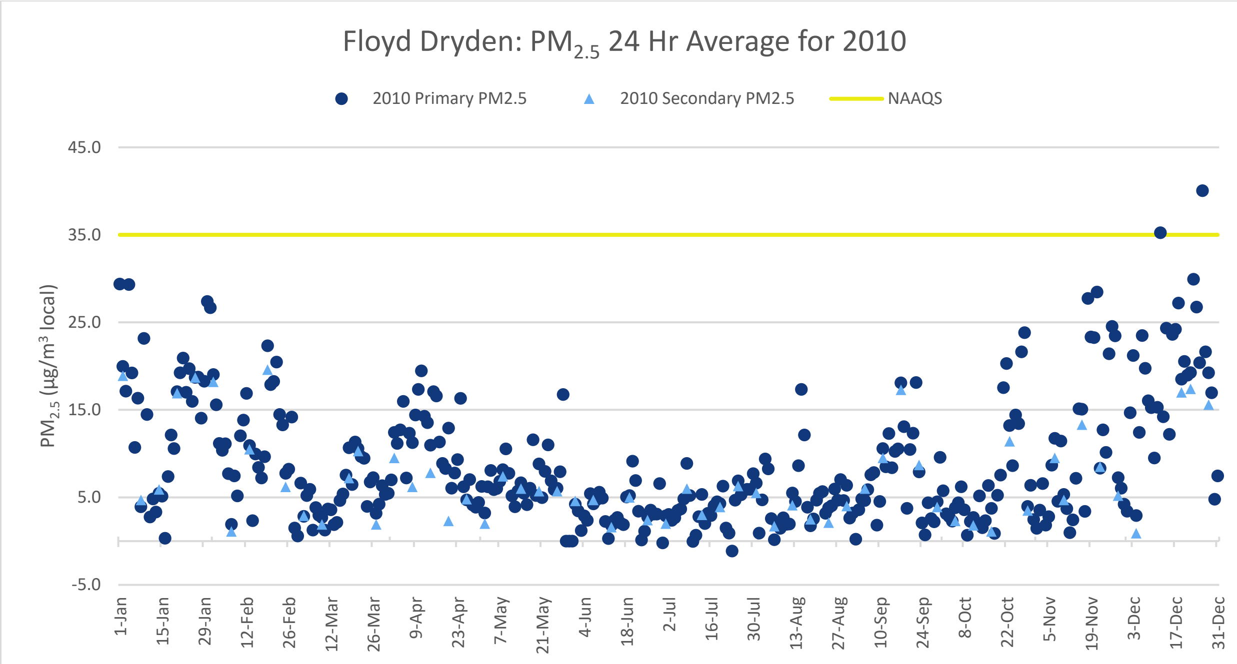

Figure B-1: 24-hour average of $PM_{2.5}$ in 2010, Floyd Dryden. Maximum value: 40.0 µg/m³. The yellow line is the NAAQS of 35 µg/m³. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m³ = 0.93 (43 samples).

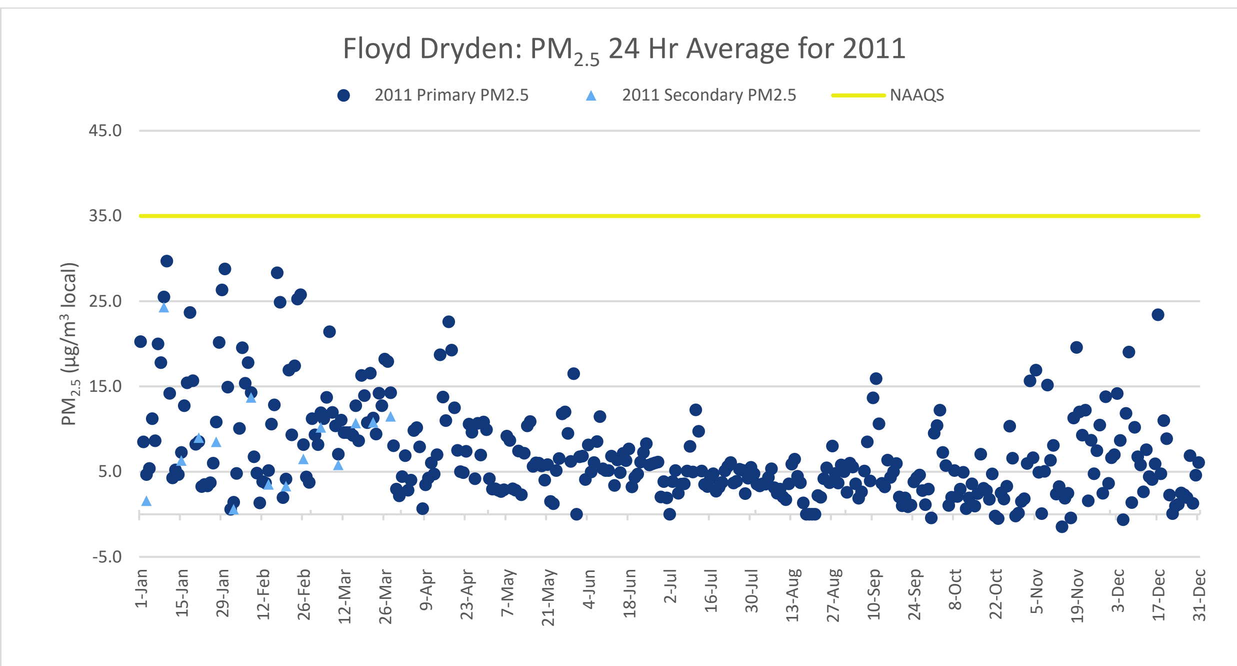

Figure B-2: 24-hour average of $PM_{2.5}$ in 2011, Floyd Dryden. Maximum value: 29.7 µg/m³. The yellow line is the NAAQS of 35 µg/m³. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m³ = 0.93 (12 samples).

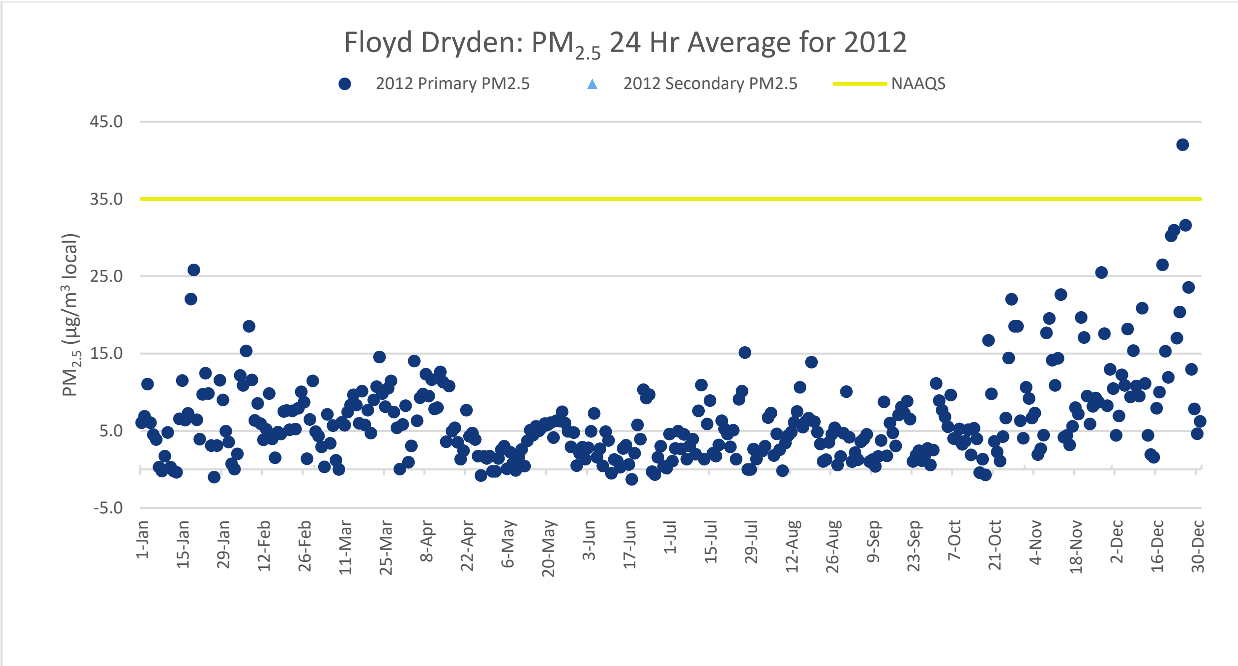

Figure B-3: 24-hour average of $PM_{2.5}$ in 2012, Floyd Dryden. Maximum value: 42.0 µg/m^3. The yellow line is the NAAQS of 35 µg/m^3.

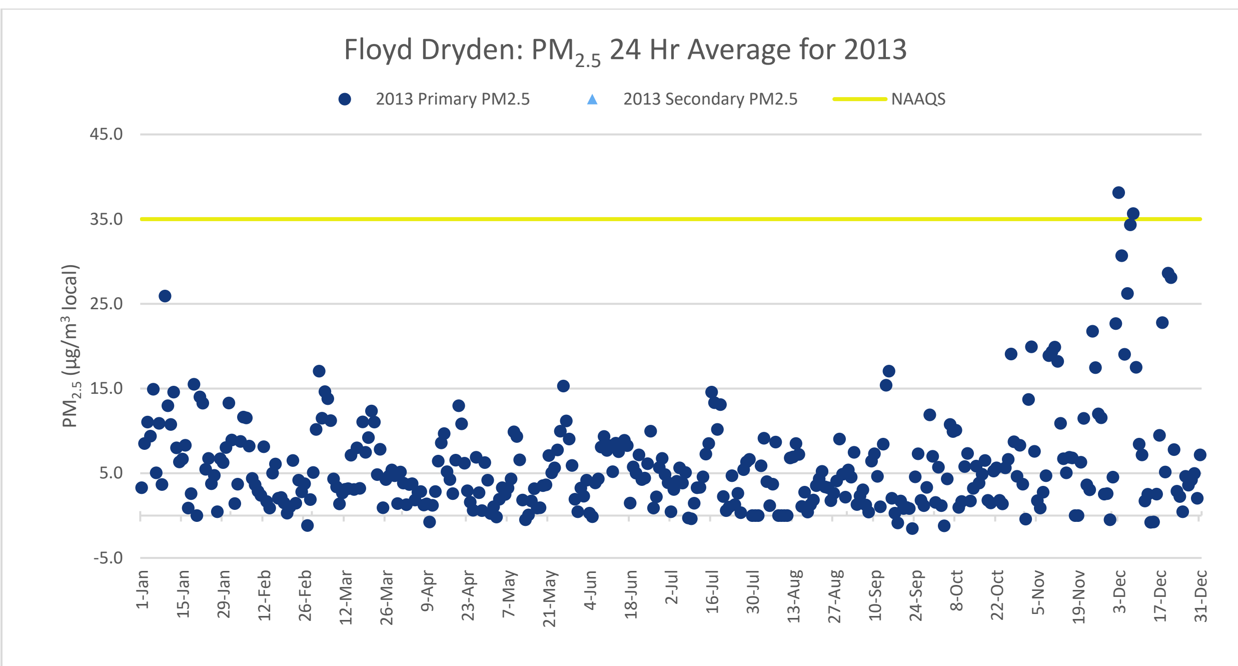

Figure B-4: 24-hour average of $PM_{2.5}$ in 2013, Floyd Dryden. Maximum value: 38.1 µg/m^3. The yellow line is the NAAQS of 35 µg/m^3.

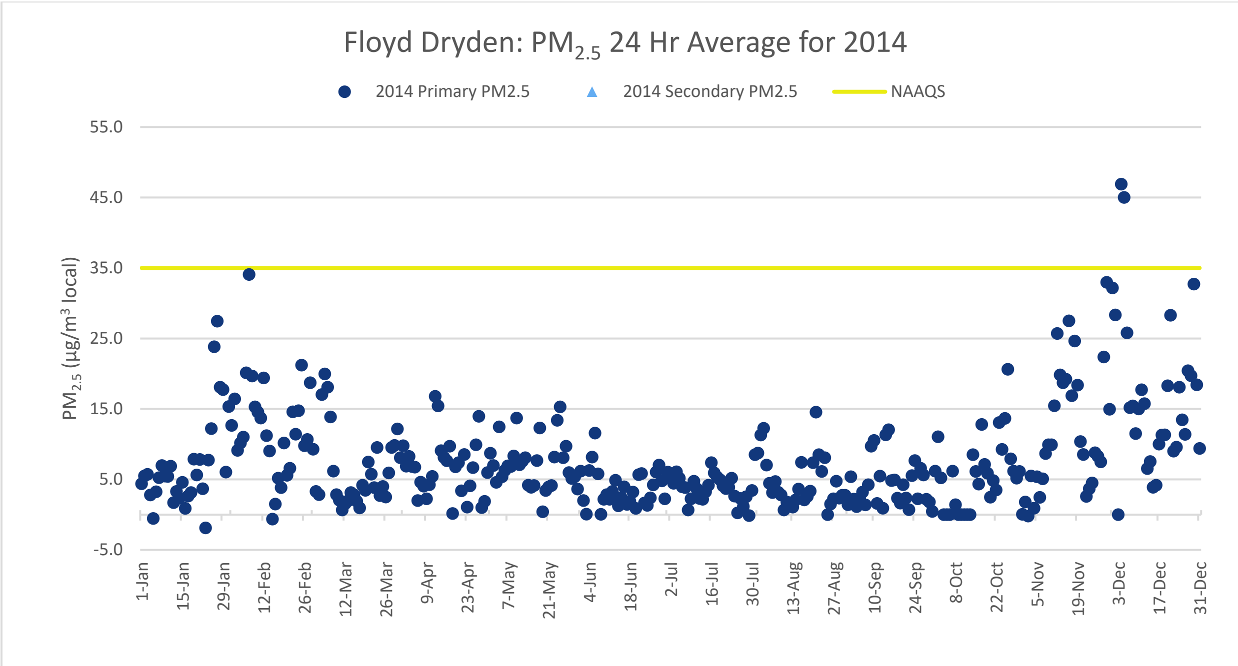

Figure B-5: 24-hour average of $PM_{2.5}$ in 2014, Floyd Dryden. Maximum value: 46.9 µg/m^3. The yellow line is the NAAQS of 35 µg/m^3.

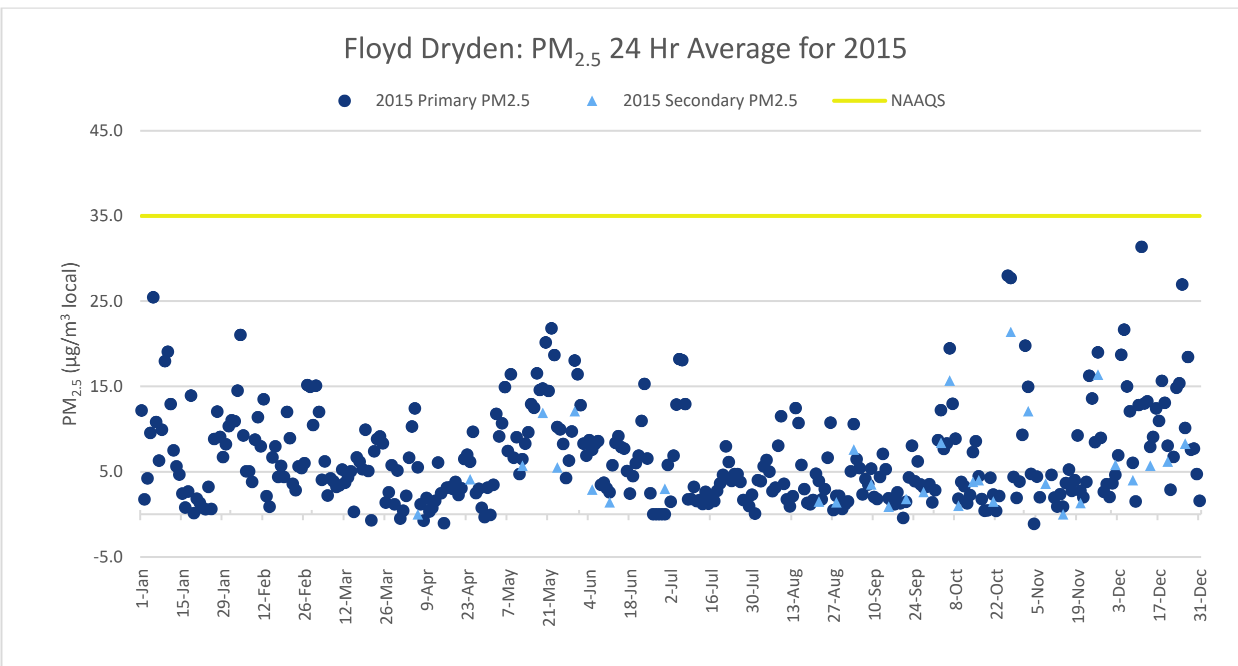

Figure B-6: 24-hour average of $PM_{2.5}$ in 2015, Floyd Dryden. Maximum value: 31.4 µg/m^3. The yellow line is the NAAQS of 35 µg/m^3. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m^3 = 0.93 (19 samples).

Appendix C: PM_{10} Annual 24-hour Averages

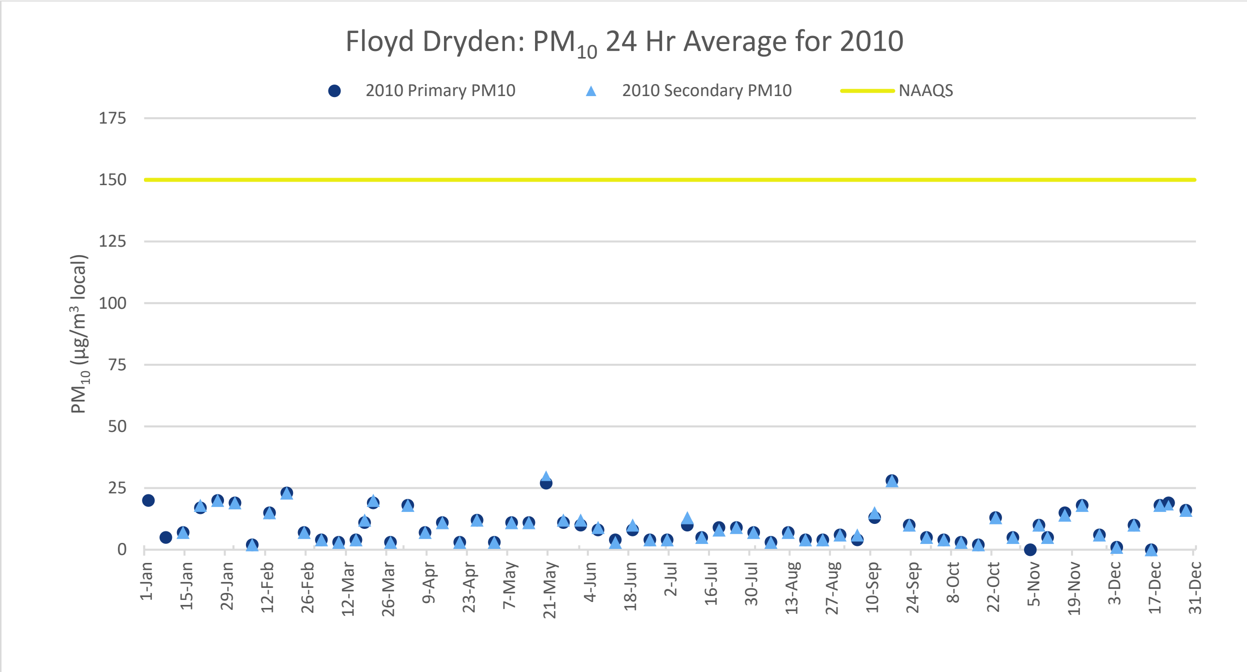

Figure C-1: 24-hour average of PM_{10} in 2010, Floyd Dryden. Maximum value: 28 µg/m^3. The yellow line is the NAAQS of 150 µg/m^3. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m^3 = 0.98 (57 samples).

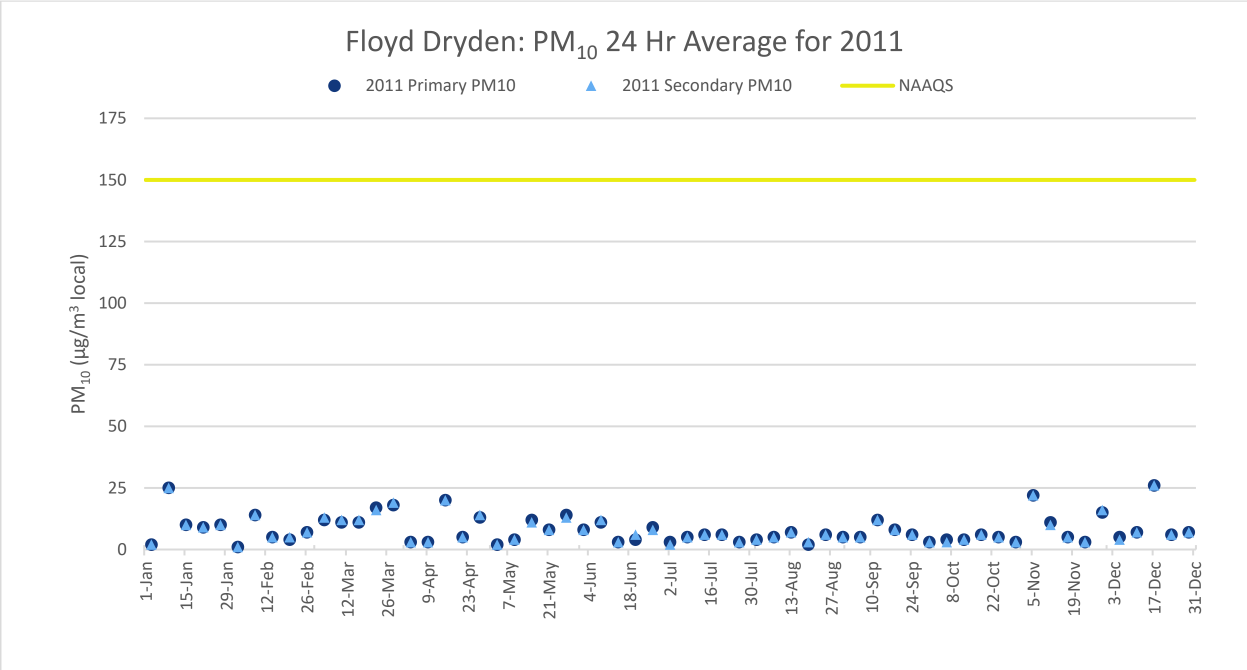

Figure C-2: 24-hour average of PM_{10} in 2011, Floyd Dryden. Maximum value: 26 µg/m^3. The yellow line is the NAAQS of 150 µg/m^3. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m^3 = 0.99 (56 samples).

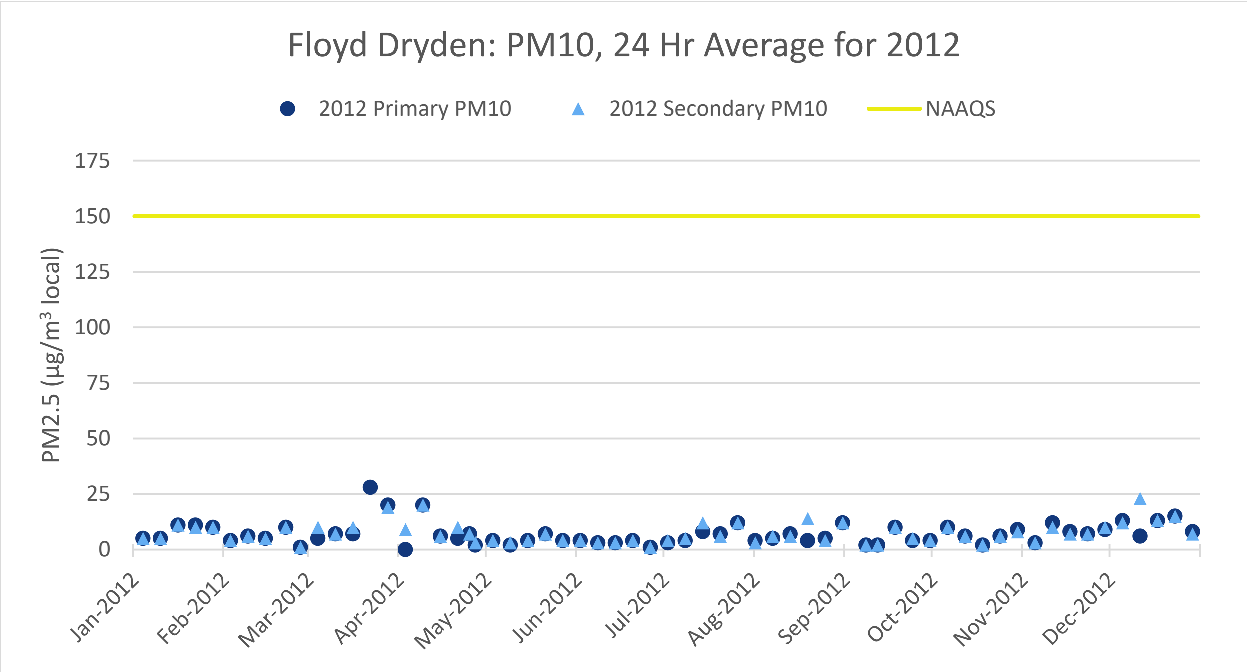

Figure C-3: 24-hour average of PM_{10} in 2012, Floyd Dryden. Maximum value: 28 µg/m³. The yellow line is the NAAQS of 150 µg/m³. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m³ = 0.58 (53 samples).

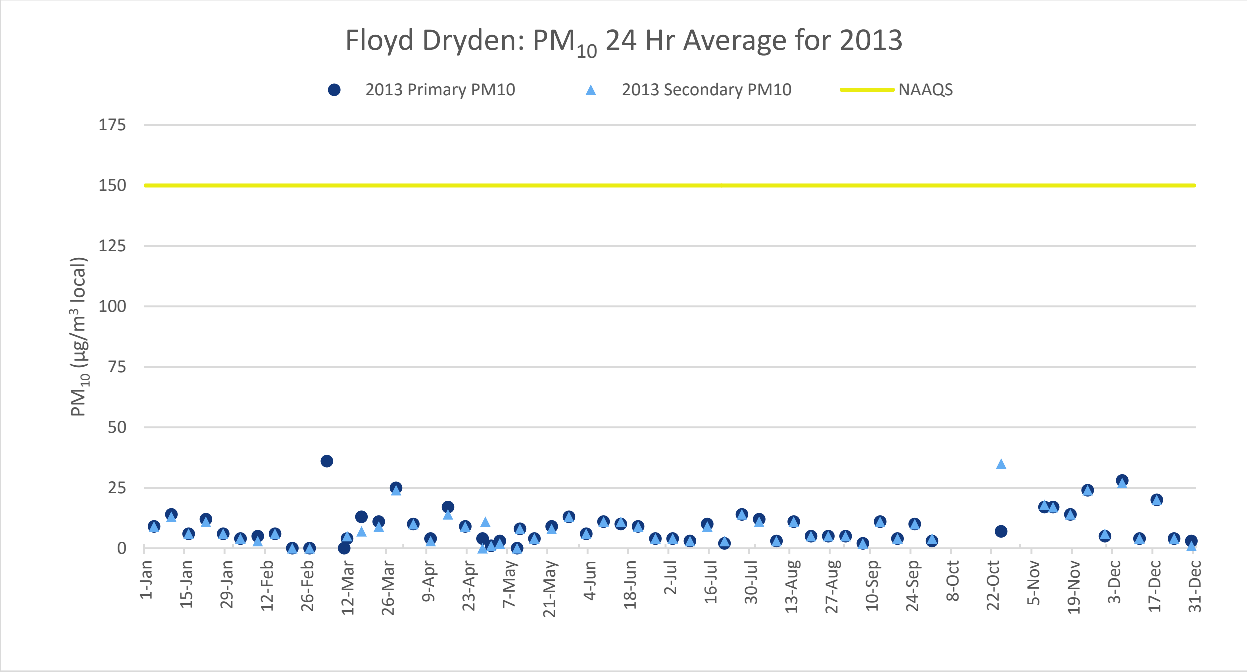

Figure C-4: 24-hour average of PM_{10} in 2013, Floyd Dryden. Maximum value: 36 µg/m³. The yellow line is the NAAQS of 150 µg/m³. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m³ = 0.63 (49 samples).

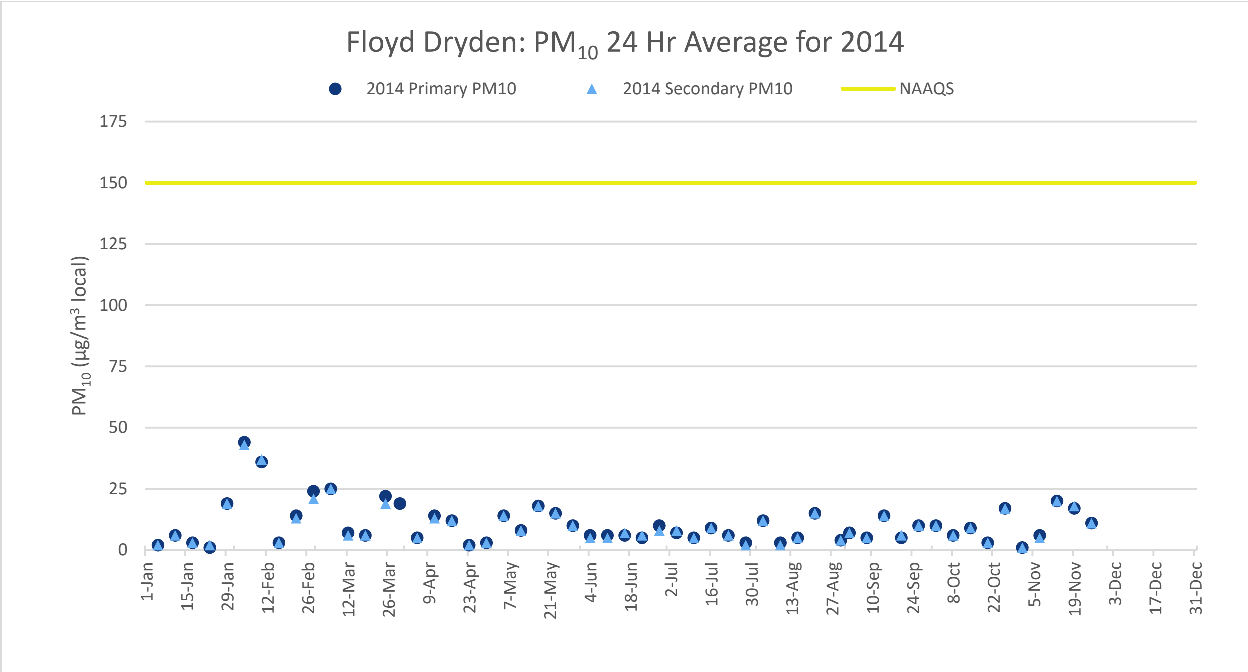

Figure C-5: 24-hour average of PM_{10} in 2014, Floyd Dryden. Maximum value: 44 µg/m^3. The yellow line is the NAAQS of 150 µg/m^3. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m^3 = 0.99 (48 samples).

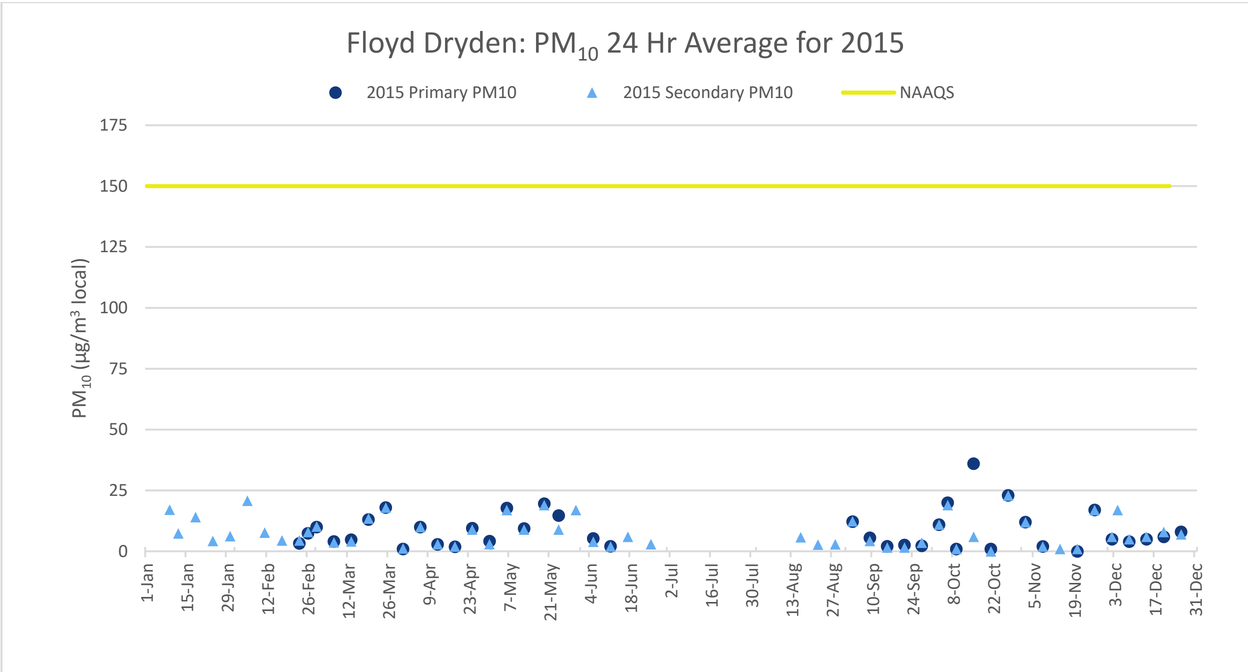

Figure C-6: 24-hour average of PM_{10} in 2015, Floyd Dryden. Maximum value: 36 µg/m^3. The yellow line is the NAAQS of 150 µg/m^3. The correlation (r^2) between primary and secondary samles ≥ 3 µg/m^3 = 0.41 (28 samples).